REGIONAL OFFICE
RAJASTHAN STATE POLLUTION CONTROL BOARD
18,Near Pannadhaya Circle,Azad Nagar,Bhilwara
Phone : 01482-241159; Email ID:-rorpcb.bhilwara@gmail.com

No. RPCB/RO/BHL/NGT(2019)/L-4/ 25 **Dated :** 05/04/2021

Urgent/NGT Matter(O.A. No. 288/2019)
Date of Next Hearing-07.05.2021.

(Through Post/Email)

To,
The Registrar,
National Green Tribunal,
Principal Bench, New Delhi
(Email:-judicial-ngt@gov.in)

Subject:-.Regarding Compliance of directions passed by Hon'ble N.G.T.,Principal Bench,New Delhi in O.A. No. 288/2019, titled as Shri Balkrishan Vyas V/s State of Raj & Others.

Ref:- 1. Hon'ble N.G.T.,Principal Bench,New Delhi's order sheet dated 12.10.2020.
2. Office of the District Collector,Bhilwara's letter no. Nyay/2020/22742,dated 25.03.21

Sir,

Apropos above, in compliance of directions passed by Hon'ble N.G.T.,Principal Bench,New Delhi, it is submitted that :-

1. Hon'ble N.G.T.,Principal Bench, New Delhi has passed directions in O.A. No. 288/2019, titled as Shri Balkrishan Vyas V/s State of Raj & Others vide order sheet dated 12.10.2020 , interalia reproduced as follows:-
   Accordingly, we grant time for submitting final report by 31.01.2021 by e-mail at judicial-ngt@gov.in preferably in the form of searchable PDF/ OCR Support PDF and not in the form of Image PDF.
2. In compliance of above stated directions, Combined scanned copy of above reports alongwith office of the District Collector ,Bhilwara as received vide letter no. 22742 dated 25.03.2021 is enclosed as Annexure-E.
3. Searchable PDF copies /soft copy of of reports asreceived from esteemed institutions detailed and enclosed as :-
   I. Consolidated executive summary submitted by Dr. Brijesh K.Yadav,Assosiate Professor ,Dept. of Hydrology ,IIT Roorkee (U.K.),Dr. Harsh Kumar Verma, Sr. Principal Sci. & Head of the section, Mining Science Research group,CSIR-Regional Research Centre CIMFR,Bilaspur (C.G.) and Prof. S.K.Singh , Sr. Principal Sci. & Head of the section, PPC group , CSIR-CBRI, Roorkee (U.K.)- (Enclosed herewith as **Annexure-A.)**
   II. Report on Hydro-Geological Study of Pur Village Area, Bhilwara, Rajasthan by Dr. B.K. Yadav and Team,Indian Institute of Technology Roorkee(U.K.)- (Enclosed herewith as **Annexure-B.)**
   III. Report on Scientific Studies on Blast Induced Ground Vibration & Air Overpressure and Investigation on its Damage Potential vis-à-vis Housing Structures in Pur Village, Bhilwara, Rajasthan by Central Institute of mining & fuel research (Council of Scientific and Industrial Research, New Delhi, Govt. of India) Regional Research Centre, Bilaspur (CG) 495001 (Enclosed herewith as **Annexure-C.)**

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IV. Report on Studies to investigate the Reasons for Cracks Development in Buildings of Pur Village, Bhilwara, Rajasthan by_CSIR-Central Building Research Institute Roorkee – 247667 Uttarakhand. (Enclosed herewith as **Annexure-D)**

Submitted for kind perusal.

Encl: As above.

Yours Sincerely,

(Mahaveer Mehta)
Regional Officer,
RSPCB,Bhilwara

Copy to followings for information:

1. District Collector, Bhilwara in compliance your office letter no. 22742 dated 25.03.2021.
2. SDM and Nodal Officer (OA 288/2019),Bhilwara,
3. In charge Legal Cell , RSPCB, Jaipur.

Regional Officer,
RSPCB,Bhilwara

Scientific study to ascertain the Causes and Effects of Development of Cracks in Buildings in and around Pur village, Bhilwara

Executive Summary

- District Magistrate and Collector, Bhilwara vide its letter no: Jud/l9/26230 dated 22.07.2019 requested a few esteemed institutions to carry out the scientific study and find out causes and effects of development of cracks in buildings/ structures/ roads/ drains in and around Pur village, Bhilwara, Rajasthan being an interdisciplinary problem. The district administration had also requested to suggest the mitigation measures and action plan to district administration/ state government.

- Accordingly, a joint site visit by the representatives of CSIR-Central Institute of Mining and Fuel Research (CIMFR), Dhanbad, CSIR-Central Building Research Institute (CBRI), Roorkee, Uttrakhand and Indian Institute of Technology (IIT) Roorkee, Roorkee was carried out during 18-20 August 2019 to Pur village, Bhilwara. Subsequently a meeting in the office of the District Magistrate, Bhilwara District, Rajasthan was conducted for undertaking scientific studies to evaluate the possible causes of the crack in the buildings of Pur village, Bhilwara. In addition, the scope of works has been independently submitted by individual institutions to District Administration by CSIR-Central Institute of Mining and Fuel Research (CIMFR), Dhanbad, CSIR-Central Building Research Institute (CBRI), Roorkee, Uttrakhand and IIT Roorkee, Roorkee based mutually agreed terms and conditions by all the stake holders.

- District Magistrate and Collector, Bhilwara vide letter no: Jud/l9/26667 dated 09.10.2019 requested CSIR-CIMFR Dhanbad *to evaluate the impact of the blast induced ground vibration*. Similarly, CSIR-CBRI, Roorkee was requested vide letter No. Jud/l9/26668 dated 09.10.2019 *to carryout scientific study to investigate the reasons of cracks development in buildings of Pur Village, Bhilwara*. Also, IIT Roorkee was requested vide letter no: Jud/l9/26669 dated 09.10.2019 *to carryout hydro-geological study of Pur Village Area, Bhilwara, Rajasthan.*

- The detailed study reports carried out by CSIR-Central Institute of Mining and Fuel Research (CIMFR), Dhanbad, CSIR-Central Building Research Institute (CBRI), Roorkee, Uttrakhand

and Indian Institute of Technology (IIT) Roorkee, Roorkee were submitted individually. However, brief of studies comprising all the studies were summarized as under:

CSIR-CIMFR, Dhanbad

- CSIR-CIMFR Dhanbad team have conducted altogether 15 experimental blast rounds at Dhedwas Iron Ore mine in different phases for the field investigations. The parameters of the experimental blast round were decided after reviewing the data of mine blasting operations carried out during April 2018 to Dec 2019.

- Experimental blasts have been conducted with different combination and range of parameters. Small as well as large blasts both in terms of number of holes and total explosive quantity were conducted both in overburden as well as in bottom benches.

- In experimental study, the blasts holes depths were varied from 3.5 m to 12.0m, total charge varied from 3.06 ton to as high as 10.06 tons, no of holes varied from 39 holes to 195 holes. Although, average maximum charge per delay in day to day mine blasting operation was 100 kg, experimental blast rounds upto 190 kg have been conducted to create a severe condition and to evaluate the impact of vibration. The range of experimental blast design parameter covered entire range of day-to-day blasting practices of Dhedwas iron ore mine, Bhilwara.

- Comprehensive vibration monitoring was carried out during blasting study. The complete exercise was carried out in presence of representatives from Pur village. Altogether vibration was monitored at 56 different locations. Monitoring locations were chosen considering size of blast, mine location the distance of the presence of any domestic structures. The monitoring locations include domestic houses and other prominent structures of the Pur village such as Temple and Mosques and community hospital. In all the cases, measurements were carried out in the direction with an intention to record maximum vibration as well as air overpressure intensity. Simultaneous vibration monitoring both in close-field as well as far-field using four set of four channel monitoring system was carried out. All these instruments are four-channel seismographs provided with one tri-axial transducer for monitoring of vibration (in mm/s or inch/s) and one-channel for monitoring of air overpressure/noise in dB (L) or Pa. The instrument records vibrations in three orthogonal directions [i.e. Longitudinal (L), Vertical (V)

and Transverse (T)] and peak frequency of vibration in individual directions as well as compute the peak vector sum of vibrations. The instruments also permit full wave recording at any instant of time for a preset duration. Sensors are having an articulation of spikes for proper coupling with the ground for more precise reading of particle velocity.

- Observed vibration data were analysis and a site specific mathematical relationship has been established correlating the maximum explosives weight per delay (Q_{max} in kg), distance of vibration measuring transducers from the blasting face (D in m) and recorded peak particle velocity (V in mm/s) using square root scaled distance at 95% confidence interval. The equation which shows attenuation characteristics of the blast induced ground vibration were further analysed in details to understand the damaging effect of vibration on domestic houses of Pur village with different blast design parameters.

- It is observed that the blast induced ground vibration and air overpressure beyond a distance of 500 m from the blasting site remained less than 2.00 mm/s (with frequency ranging from 2.0 Hz to 30 Hz) and 115 dB(L) against recommended safe values of 5.0 mm/s and 134 dB(L) respectively. Analysis of propagation characteristics of the vibration reveals that ground vibration beyond a distance of 1.5 km decayed to less than 1.0 mm/s in majority of the cases. In most of the housing structure beyond 2.0 km from the blast site, equipment did not record any vibration and the values were not noticeable by human body. Therefore, it is concluded that observed blast induced ground vibration values are safe and well within the permissible limit as per the recommendations of Directorate General of Mine Safety (DGMS).

- Based on the findings of the study it is concluded that impact of blast induced ground vibration and air overpressure in causing the damage to the housing structures of Pur village, approx., 2.5 km away is practically not possible. Cracks in the houses may be accounted to hydrogeological set-up of Pur village and its interaction with the weak non-engineered foundation of the houses.

- It is however, recommended that an expert agency may be engaged to supervise blasting operations at Dhedhwas iron ore mine. Vibration monitoring shall be carried out by such expert agency in close co-ordination with representative of Pur village.

CSIR-CBRI, Roorkee

- CSIR-CBRI, Roorkee has carried out survey of buildings stocks to assess the type of damages in the buildings and other structures. About 80 houses were randomly selected for crack monitoring by installing demec point. In addition, four bore holes were drilled in different locations in the Pur village of varying depths from 12m to 20 m. The different site locations were selected to know the sub-surface lithology of the surrounding region of the Pur Village, Bhilwara and also the central part of the Pur village.

- The Pur village is situated on schist, a high-grade metamorphic rock with vertical foliation. The bore log study found that the soil thickness overlying the rocks in the periphery of the village is very less, around 3m. However, in the inner region of the village, the fragmented rock, sand mixed with pebbles/boulders of rocks were found overlying the schist rocks. The overburden thickness of these loose rock fragments and soil above the bed rocks was found varying from 8m to 14m.

- The bedrock below the soil layer at a depth of 8m to 14m is weathered schist having low strength with vertical foliation. This may undergo dilation if saturated with water because of dominating mica minerals having swelling property. Although, the sandy soil was having adequate engineering properties.

- There is a thick heterogeneous soil layer comprises of sand and pebbles/boulders in the central part of the village where cracks are developed in the clusters of houses. There could be a possibility of washing out of fines due to water seepage in this soil layer or subjected to any kind of dynamic loading creating some void spaces. This may cause settlement of buildings resulting in appearance of cracks.

- It is inferred from the geotechnical investigations that the cracks are appeared in the buildings, which are situated on the considerably thick heterogeneous soil in the central part of the Pur village. The buildings situated at the village periphery having less overburden are less damaged than the buildings in the central part of the village where the loose soil mixed with rock fragments has a thickness varying from 8m to 14m.

- The damages were observed mainly in non-engineered and old constructed buildings. The crack pattern in the buildings clearly indicate towards differential settlements in foundation. The damages were observed in the form of diagonal cracks, separation of the walls, separations of floors with wall. The roofs made of stone slab placed over steel/ wooden girders were also found damaged.

- The damages in buildings were found mild to severe depending on the construction types and foundation systems. During study, it was found that damages due to cracks were mainly in stone masonry structures(non-engineered type buildings).

- The majority of reinforced concrete framed structure buildings and properly constructed masonry buildings were found with only minor cracks on surface of plaster.

- The cracks were monitored for about 8 months and found gradually progressing at several locations. It is also due to progressive nature of differential settlements.

- Therefore, it is advised that dismantling and reconstruction or repair and rehabilitation of buildings were taken up after considering all factors with due consultative meetings with affected residents. The excessively damaged buildings need to be vacated and affected people may be relocated to other locations.

- Proper categorization of the damages are therefore, important for post damage rehabilitation or reconstruction program for Pur village. It is advised to retrofit and strengthen the building foundations before retrofitting to buildings.

Indian Institute of Technology (IIT) Roorkee

- IIT Roorkee carried out comprehensive site surveys followed by a series of field experiments conducted during 07-11 November 2019 and 28 January to 01 February 2020, to know the hydro-geological behaviour of the study area.

- Initial field observation around the village indicates that the in-situ rock exposures have been significantly affected as a result of growing inhabitations and only partially eroded/isolated remnants of hillocks are found. Examination of one partially eroded hillock near '*Baoli Naka*' revealed fragile exposures of grey black mica-schists with dip of 75-80 degrees in the N-130

degrees direction, implying strike of N40-220 degrees. The spot examination of the geological formations in the Sukhadia stadium indicated presence of isolated outcrops of schistose quartzites within the alluvial expanse. The quartzites displayed dips of 80-85 degree towards southeast and a strike of N50-230 degree. The quartzites also showed clear evidence of displacement as manifested by presence of slicken sides with visible silicification on the steep rock face(s).

- The project area contains gneiss and schist (Bhilwara Super group); gneiss, schist, phyllite, slate and limestone (Aravalli Supergroup); sandstone, shale and limestone (Vindhyan Super group); and alluvium as the major water bearing formations. The aquifers are localized within the weathered, fractured and jointed hard rock zones.

- A total of 19 geophysical surveys were conducted in and around the village using 06 vertical electrical soundings (VES), 11 electrical resistivity tomography (ERT) surveys, and 02 Surface nuclear magnetic resonance (SNMR) surveys using ground magnetic resonance (GMR).

- Findings of VES surveys conducted around the village show that the area contains thin top soil/alluvium of thickness varying between 1-5 m. The top layer of sand is underlain by weathered hard rock (schistose quartzite) having thickness ranging from 2-7 m, with its maximum value at *Sukhadia stadium*. Besides, the top veneer is directly comprised of weathered hard rock at *Jindal Mata Mandir* as seen from the high resistivity of the topmost layer. The above interpretation is corroborated by the presence of isolated outcrops (schistose quartzite) dotting the area. The rocks in these outcrops show steep dips towards SE, with presence of slicken sides at *Sukhadia stadium*, pointing to the incidence of displacement of rocks in the geological past. The weathered schist/quartzite is indicated to be underlain by hard/compact Schist/quartzite at depths varying between 5 m below the surface at *Pathwari* site and 9.5 m below ground level at *Sukhadia stadium* site.

- The top soil depth in central part of the village is found thicker than the other sites situated at the village periphery particularly towards the mining industry. A sudden drop in resistivity along the survey line observed from 2-D ERT inversion near *Bada (Teli) Mandir* shows a presence of vertical fracture/anomaly which continued throughout the depth. Furthermore, a saturated soil or soft material zones are visible in the ERT images at couple of places in the

subsurface of this site. A substantial variation in subsurface formation is also observed vertically and horizontally at other locations.

- A significant variation in water content and hydraulic conductivity observed with depth of GMR surveys indicates towards the sudden change in subsurface strata. These types of subsurface anomalies are prone for differential land settlement.
- The evidences relating to proneness to displacement within hard rocks strengthen the possibility of generation of new cracks and fractures in the area. In general, the village geology of its top subsurface is found significantly heterogeneous in nature. It contains varying thickness of sand mixed with gravels underlain by weathered/hard schist at random places making it vulnerable under the possible vibrations, surface overburden or other (sub)surface modifications.
- Possible water seepage from leaky drainage network seems further aggravating the observed differential land settlement and associated cracks. Extreme rainfall event of 1023 mm observed in 2019 monsoon period appears contributing land settlement. The isotopic analysis indicates that properties of seepage water and groundwater are found close, and hence, the high groundwater table in the surrounding area of the school seems to be main cause of seepage and waterlogging.

Report on

Hydro-Geological Study of Pur Village Area, Bhilwara, Rajasthan



by

Dr. B.K. Yadav and Dr. P. K. Sharma
(Associate Professors)
Dr. D. C. Singhal
(Retired Professor)

Indian Institute of Technology Roorkee

Submitted to

District Magistrate
Bhilwara, Rajasthan
India

[January 18, 2020]

1. Introduction

A survey team comprised of Prof. Brijesh Kumar Yadav (Department of Hydrology), Prof. Pramod Kumar Sharma (Department of Civil Engineering), and Dr. Dinesh Chand Singhal (Retired Prof. Department of Hydrology), Mr. Manik Goel (Research Scholar), Mr. Shubham Tiwari (Research Scholar), Mr. Uttam Singh (Senior Research Scholar), Shri Raj Kumar (Senior Laboratory Technician), and Shri Ashok Kumar (Laboratory Technician) from IIT Roorkee visited the Pur village, Bhilwara, and its nearby areas along with the required instruments during 07 Nov to 11 November 2019 for conducting the field study. Mrs. Tina Dabi, SDM Bhilwara, along with her team from the DM office Bhilwara, joined the team during the field survey. All geological and hydrological data collected in this first field visit were analyzed in the laboratories of IIT Roorkee. A total of 06 one-dimensional Vertical Electrical Soundings (VES), 08 two-dimensional Electrical Resistivity Tomography (ERT) were conducted along with 02 surface nuclear magnetic resonance (SNMR) survey using ground magnetic resonance (GMR) equipment during this first field work. The results are assessed to find the existing hydro-geological conditions of the area for possible causes of the cracks in the village buildings. After assessing the results, it was observed that some additional locations in the target area were required to be covered for improving the findings of the first field work. Keeping this in mind, a second field visit was planned for collecting more data from eleven locations in the target area during 28 Jan to 01 Feb 2020. A total of three 2-D ERT soundings, two aquifer pumping tests, and thirteen water samples (surface and groundwater) from seven different locations were collected during the second field visit.

2. Scope of the study

The following scope of the study was mutually agreed after conducting a reconnaissance survey by the principal investigator.

a) Conducting in-depth Hydrogeological survey of the area within 2 km radius from center of the Pur village using a series of field experiments.
b) Development of a lithofacies map of subsurface zone of the study area using a series of geophysical investigation techniques. About 10-15 multidimensional electrical resistivity soundings will be performed based on availability of suitable sounding locations in and around the Pur village.

c) Aquifer characterization at different depths using appropriate pumping and recovery tests along with Ground magnetic resonance (GMR) equipment. Existing tube-wells and open well of the site will be used for conducting the pumping and recovery tests.
d) Estimating groundwater flow regime of the area based on field survey and other observed data of groundwater resources. Coordinates of all monitoring points to be taken and marked along with the existing groundwater flow pattern.
e) Chemical analysis of water supplied to the village and groundwater samples using existing hand-pumps/tube-well and groundwater outflow location observed in the village school. This is required to investigate interaction between water supply network of the village and existing groundwater resources of the site.
f) Preparation of general guidelines for effective measures of the existing problem.

3. Study Area

Bhilwara district in Rajasthan is famous for its mineral resources and textile industries. It is situated between latitude North 25.0167^0 to 25.967^0 and longitude East 74.01^0 to 75.467^0, covering a geographical area of 10,455 sq. Km. It is divided into 7 sub-divisions: Bhilwara, Shahpura, Gangapur, Gulabpura, Asind, Mandalgarh, and Jahajpur that are further divided into 12 tehsils having a total population of about 24.1 lakh as per the census of 2011. It is bounded from the north, east, south, and west by Ajmer, Bundi, Chittorgarh, and Rajsmand districts, respectively. Bhilwara district comprises of fairly open plains in the north and southeast with a few hillocks and undulating plains/hills in the south and northeastern part. Most of the district area drains to Banas river except the eastern part that drains to the Chambal river. Geologically, Bhilwara Super Group occupies a major part of the district. The area comprises of the Vindhyan group in the south-eastern part, the Gogunda group in the north-western part, and the Kumbhalgarh group in the southwestern part. The average groundwater table in the district varies from 3 to 23 m and 1 to 16 m bgl during pre- and post- monsoon seasons, respectively (CGWB Report, 2013).

The study revolves around the Pur village and the Jindal Saw Ltd. of Bhilwara District. The study area is located towards southwest of Bhilwara town, between the latitude $26^0$18'-$26^0$20' N and longitude 74°31' – 74°33' E having an area of about 24 sq. Km. The map of the target area along with grid range marked by selected locations used for geophysical surveying during the first field work is shown in figure 1. The relative location of Pur village settlement and Dhedwas Iron Ore Mine is also shown in figure 2.

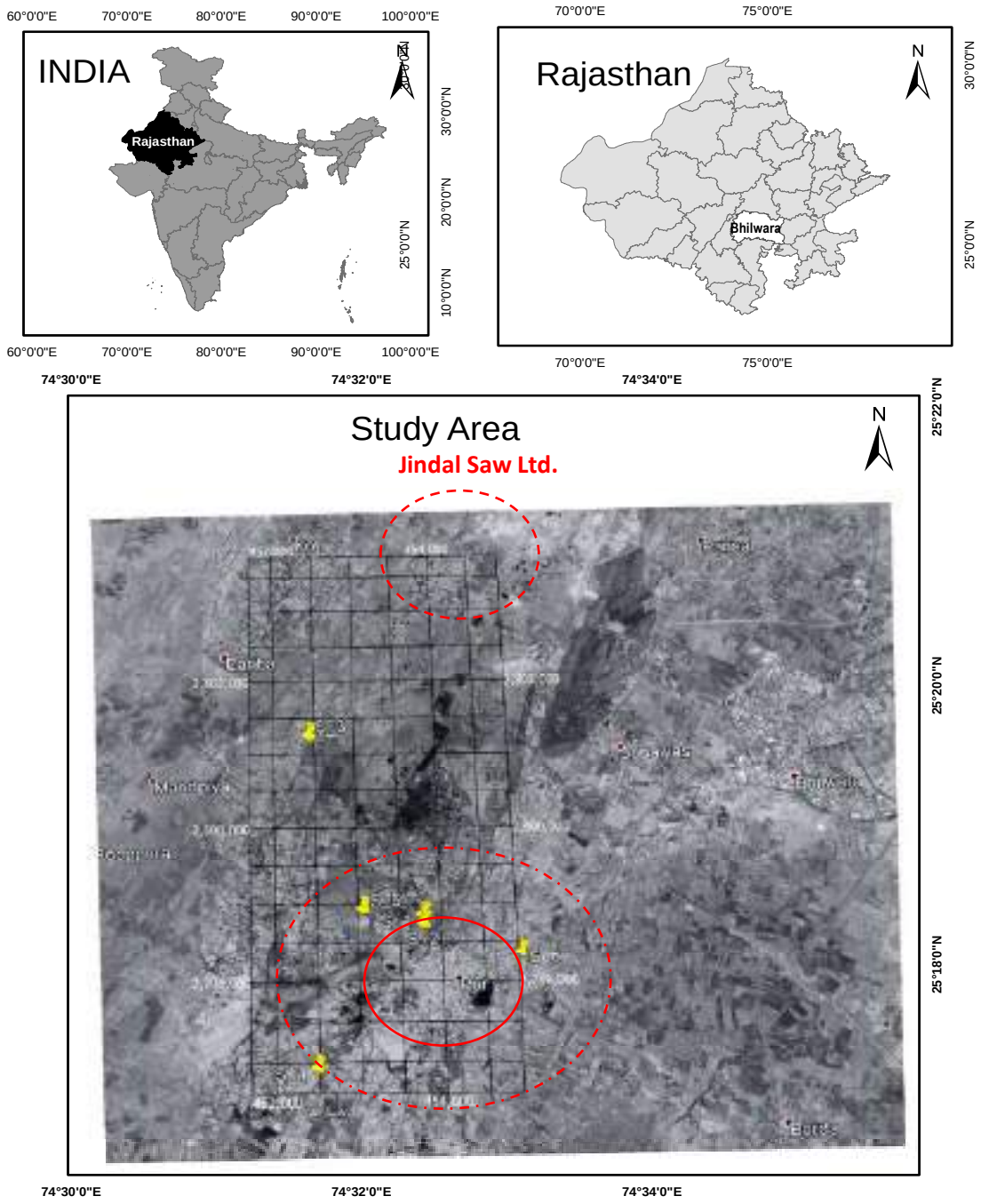


Figure 1: Figure showing the extent (grid) and location of the study area with marking for VES survey sites covered during the first field visit of the Pur village and it surrounding area.

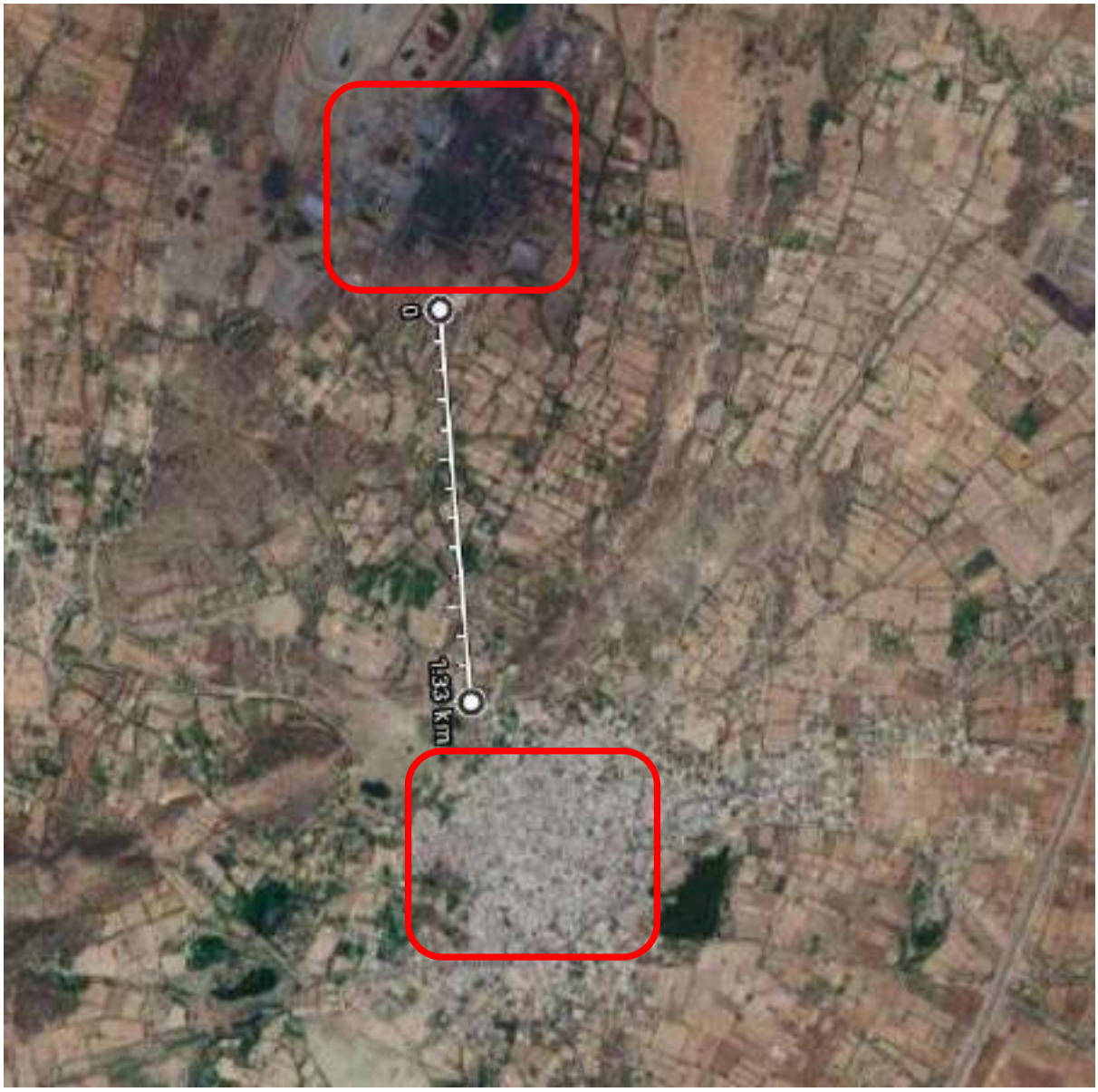


Figure 2: Map showing relative location of Jindal Saw Ltd Iron Ore Mine and Pur Village

The Digital Elevation Model (DEM) of the Bhilwara District showing the anomaly in surface elevation along with mark for the initial survey sites is shown in figure 3.

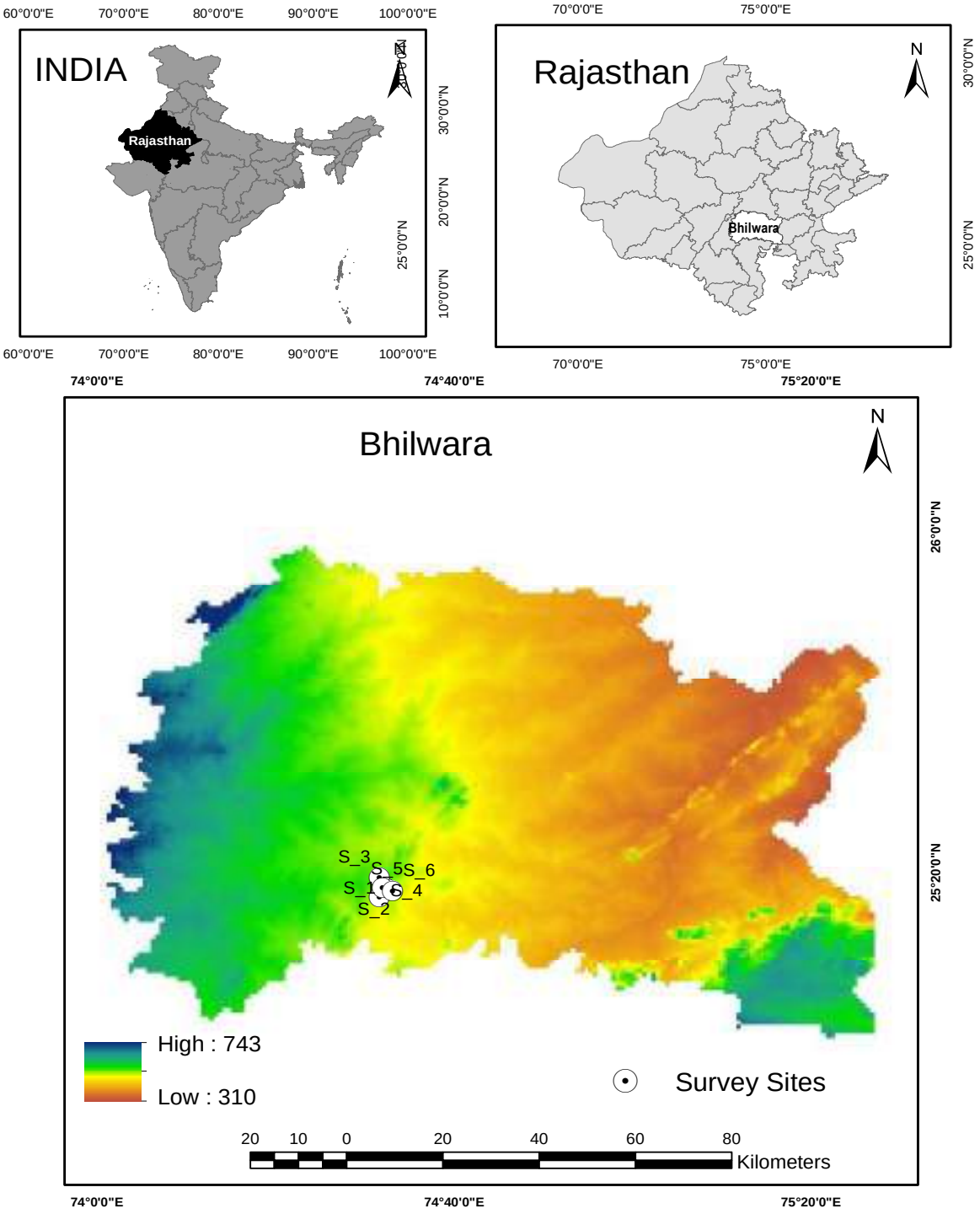


Figure 3: Digital elevation map (DEM) of the Bhilwara District showing surface elevation in meters with mark for survey sites.



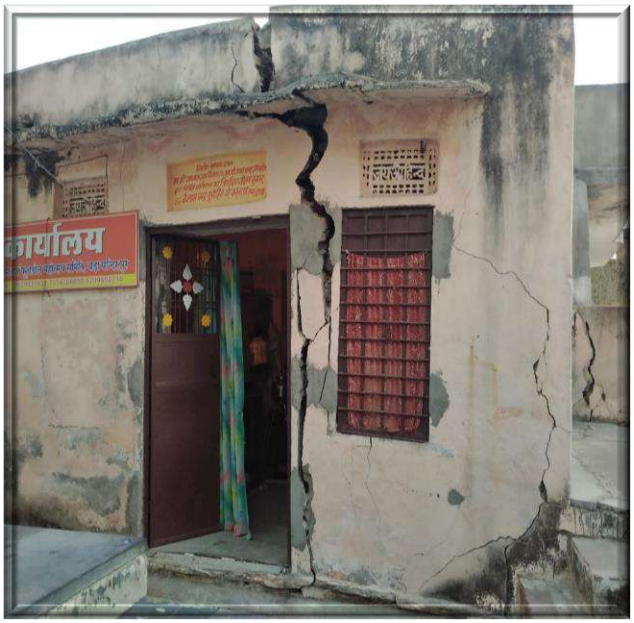
(a): Cracks along the joints of the domestic structures



(b): Cracks across the roads in Pur village



(c): Cracks across the wall of housing structure



(d): Cracks across the wall of a house widening from bottom to up



(e): Cracks along column in Laxminarayan Temple

Figure 4 a-e: Cracks developed in housing structures, roads and other structures of Pur settlement

3.1 Hydro-geological Setup

The project area contains gneiss and schist (Bhilwara Super group); gneiss, schist, phyllite, slate and limestone (Aravalli Supergroup); sandstone, shale and limestone (Vindhyan Supergroup) and alluvium as major water bearing formations. The aquifers are localized within the weathered, fractured and jointed hard rock areas zones. The geomorphological map of the area is shown in figure 5. Weathered gneiss forms upper part of the bedrock in the central part. Weathered gneiss with schist occupies most of the northern part under thin cover of alluvium. In schists, phyllites and slates, weathered zone extends to greater depth than in granites and gneisses. Muscovite schist often grades into gneiss. These have well-developed foliation and irregular joints and are intruded by granite, pegmatite and quartz veins. The contact between these intrusives and schists provides good channel for ground water circulation. These formations are intercalated with dolomitic limestone, quartzite and basic intrusive. Dolomitic limestone is grey to light brown and compact at the surface. It forms aquifer in intercalations with slates and phyllites in areas around Bagota, Laxmipura, Rampura, Amargarh, Dolpura, Kishangarh, Bakli, Bhajgarh, west of Banakhera, Mal Ka

Khera, northeast of Mohanpura, Ladpura and Ratiya Khera. Quartzites are generally intercalated with phyllites and slates which are brown coloured, hard and jointed.

Lithologs of eight boreholes derived from coring in the mining area merely 2-3 km towards north-northwest of Pur village have revealed that the subsurface geological formations in Pur area are mainly composed of garnetiferous, quartz-biotite, kyanite schist along with banded magnetite quartzite rocks and calc- gneisses with disseminations of pyrite, pyrrhotite and specks of sphalerite and chalcopyrite. The depth of these boreholes varied between 147 m and 307 m bgl and these are distributed on different parts of Tiranga hills, the main mining area of the Jindal Saw Ltd.

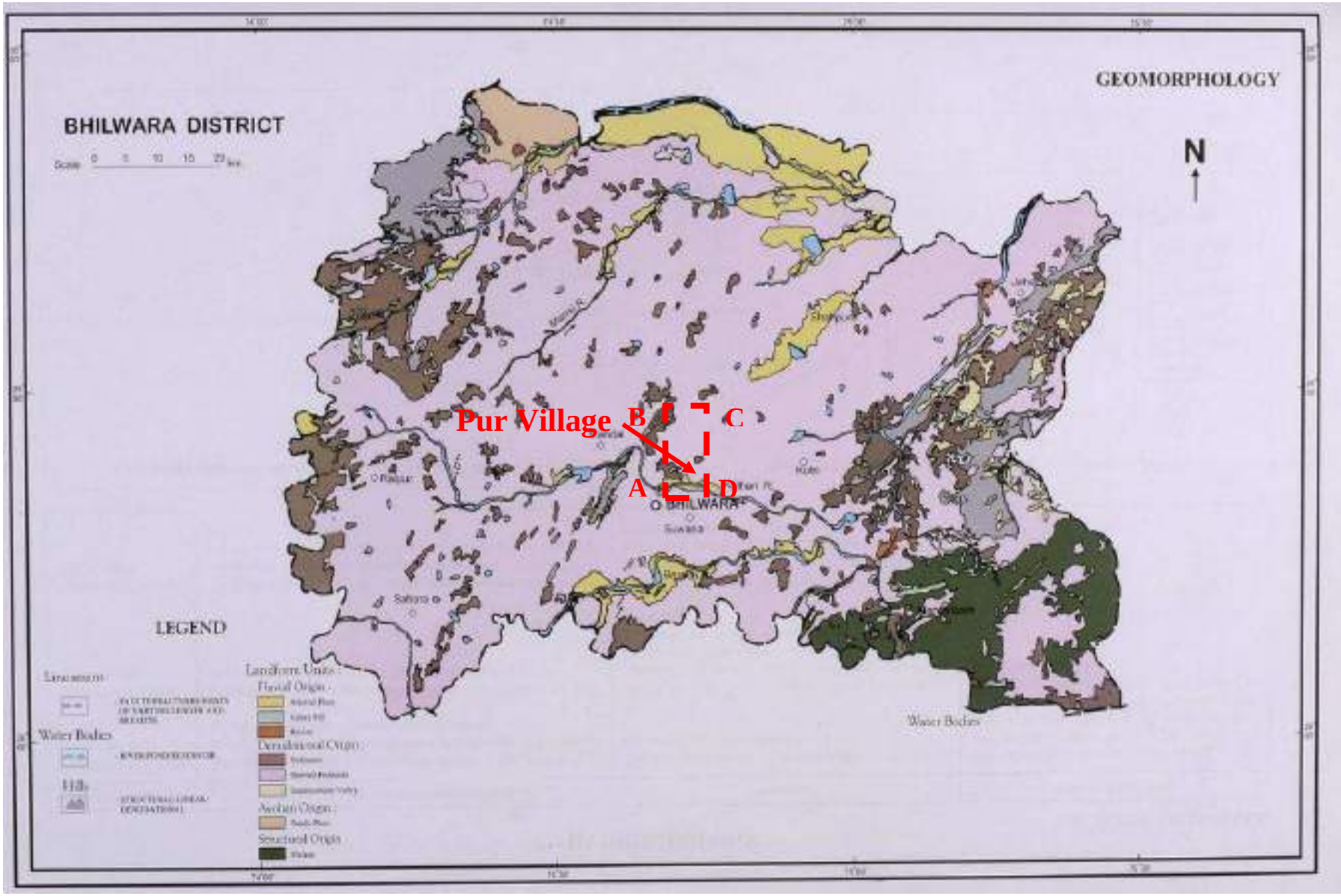


Figure 5: Geological map of the Bhilwara District, with marking of the target area (adopted from Indianwaterportal.org)

Geological Features Observed during the current Field Survey

It was observed that the in-situ rock exposures are significantly affected as a result of growing inhabitations in the area. Due to such incursions, only partially eroded and isolated remnants of hillocks are now found in the study area. Besides, many of the hillocks have virtually disappeared in the vastly expanding village. During our visit to the Laxmi (Teli) Mandir, prolific cracks and fissures were clearly observed in transverse, vertical-horizontal directions. As such, examination of one partially eroded hillock near 'Baoli Naka' revealed fragile exposures of grey black mica-schists with dip of 75-80 deg in the N-130 deg direction, implying strike of N40-220 deg, which also seems to be slightly disturbed in nature. The dip direction also seemed to be vaguely towards an adjoining pond. Further, in a nearby open lined dug well of Sh Radhey Shyam S/o Baloji, situated in the vicinity of the Mata 'mandir', the static water level was reported to hover around 20 feet bgl with the total well depth being approximately 60 feet. The well had a centrifugal pump and reportedly got empty within 3-4 hours of pumping which was reported to recover in 6-7 hours. An area of around 2 bigha farm is irrigated by the slight brackish groundwater pumped from the well. The spot examination of the geological formations at Sukhadia stadium, situated on the periphery of Pur indicated presence of isolated outcrops of schistose quartzites within the alluvial expanse. The quartzites displayed dips of 80-85 degree towards southeast and a strike of N50-230 degree. The quartzites also showed clear evidence of displacement due to faulting in the geological past as manifested by presence of slicken sides with visible silicification on the steep rock face(s).

3.2 Meteorological Information

The climate of Bhilwara is characterized by hot and dry climate receiving precipitation mostly in the form of southwest monsoon during July-September. The average annual rainfall of the area is 635.1 mm and the average monthly rainfall for the last decade is listed in table 1. Drought analysis based on agriculture index indicates that the area is prone to mild and normal types of droughts. Occurrence of severe and very severe types of droughts is very rare. The average air temperature of the area is 25.47^0 C. January is the coldest month with mean max and min temperatures of 22.2^0C and 7.3^0C respectively. Temperature in summer month of June reaches up to 46^0C. The humidity is highest in August with mean daily relative humidity at 80%. The annual potential evapotranspiration in the district is 1495 mm with average pressure of 1007.5 mb. A high rainfall of amount more than 1023 mm observed in 2019 was accompanied by aggravation of building cracks as reported by the villagers.

Table 1: The monthly rainfall average in mm from year 2010 to 2019 for the Bhilwara District

	January	February	March	April	May	June	July	August	September	October	November	December	Total
2020	7.7	12.27	2.2	21.6	33.34	15.04	240.58	376.1	150.01	14.13	0	0	872.97
2019	8.5	13.54	2.42	23.8	36.8	16.6	265.54	415.12	165.6	15.6	0	0	1023.52
2018	6.39	12.83	8.69	8.63	12	27.62	112.37	153.5	78.73	5.4	16.1	1.5	443.76
2017	23.27	2.32	8.42	13.74	5.37	21.6	64.65	83.7	66.08	0	1.22	15.49	305.86
2016	2.72	8.69	14.28	3.73	1.52	35.25	174.11	56.47	10.64	0	0	0.24	307.65
2015	4.25	13.83	51.15	13.98	1.38	21.44	126.11	100.57	52.26	1.1	2.01	4.32	392.4
2014	8.81	23.24	12.64	2.73	13.28	10.4	47.74	71.38	35.34	2.01	0	7.6	235.17
2013	13.83	31.9	7.64	4.78	2.67	98.61	179.29	129.95	16.15	7.96	0.49	2.41	495.68
2012	2.98	3.77	3	18.82	3.66	3.07	116.05	207.7	129.21	0.19	0.05	3.87	492.37
2011	3.45	13.12	2.01	16.69	26.55	64.81	162.39	232.82	76.55	5.07	0	0.47	603.93
2010	7.56	26.37	0.96	0.67	5.21	1.87	191.52	145.08	222.75	7.75	0.81	9.44	619.99

4.0 Field Test Results

Three main equipment setups comprising 1) Sounding Terrameter for 1-D VES, 2) Earth resistivity meter for 2-D ERT and 3) Surface nuclear magnetic resonance (SNMR) field study conducted by Ground magnetic resonance (GMR) instrument were used for this study along with the dip-meter, water quality probe and other relevant accessories. Six locations were selected for performing VES, ERT, and SNMR surveys during the first field visit based on the topography and area availability. Three more locations were selected for ERT during the second field visit. The locations and elevation above msl of sites are listed in table 2 and marked in figure 4. A total of 17 resistivity (6 VES and 11 ERT) soundings and 2 SNMR surveys were conducted during the whole field visits. In-situ water quality analysis was conducted at 4 different locations during the first visit while 9 water samples were collected during the second field visit for analysis of isotopic and other physio-chemical water quality parameters. It is to be noted that most of the soundings were performed at the periphery of the Pur village facing towards the mining site with the aim to map the existing hydrogeological profile of the severely affected area.

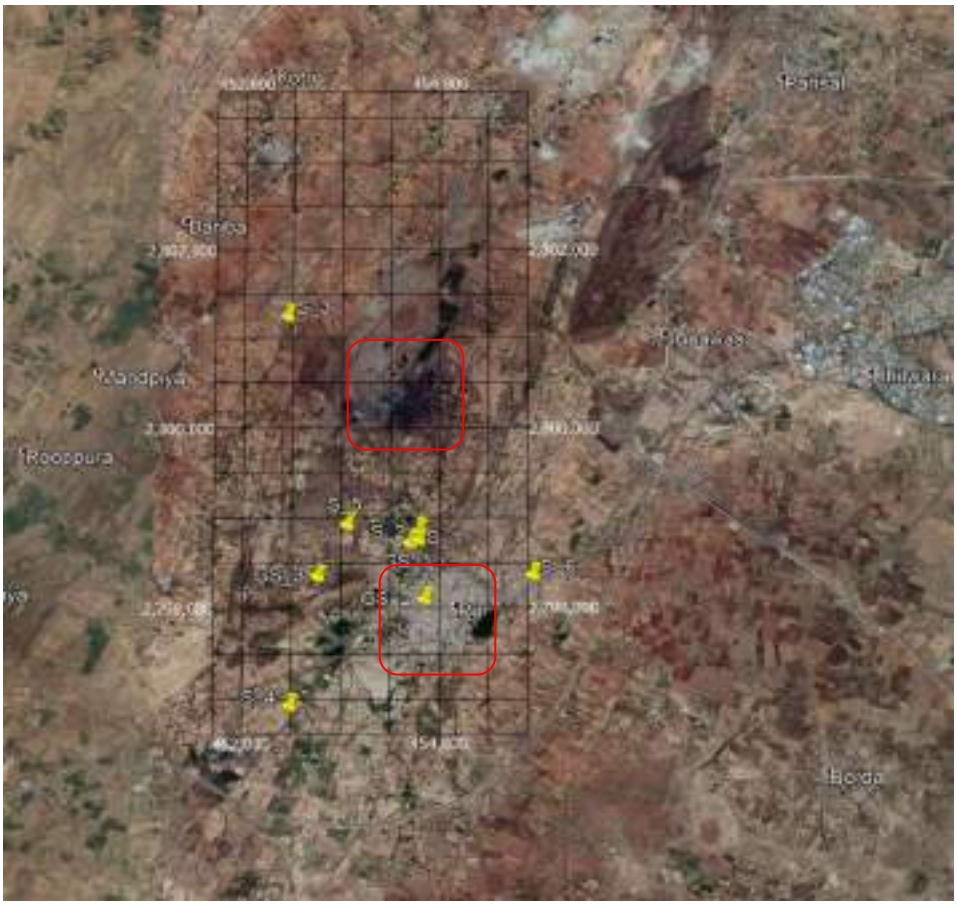


Figure 6: Locations of all survey sites used for resistivity and tomography surveys.

Table 2: Location of survey sites with their spatial coordinates in WGS 1984 coordinates system.

Site Code	Location	Latitude	Longitude	Elevation (m)	Performed Sounding			
					VES	SNMR	ERT	Total
S_1	Pathwari	25.301319	74.540528	455	1 (VES_1)	0	1	2
S_2	Ghati Ke Hanuman	25.303355	74.540543	454	0	1	1	2
S_3	Jindal Mata Mandir	25.325926	74.527081	456	1(VES_5)	0	1	2
S_4	Moldi Ke Shyam	25.2869106	74.52765	438	1(Ves-6)	1	1	3
S_5	Sukhadia Stadium	25.30495	74.53331666	448	2(VES_3 and VES_4)	1	4	7
S_6	Gyas Mata Colony	25.2998833	74.5520166	448	1(VES_2)		0	1
GS_1	Near Old Masjid	25.30305	74.53965	452	0	0	1	1
GS_2	Infront of Bada Mandir	25.297467	74.541183	457	0	0	1	1
GS_3	Ghata rani temple	25.2997167	74.53035	459	0	0	1	1

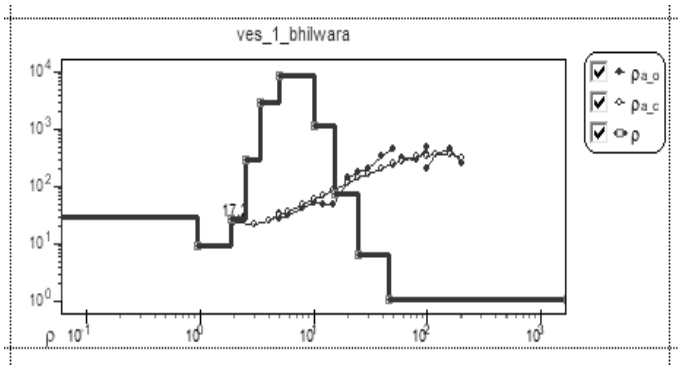
4.1 VES Survey using Terrameter

The ABEM SAS 300B terrameter shown in figure 5 was used for performing the one-dimensional vertical electrical soundings (VES) at sites denoted as S_1, S_3, S_4, S_5 and S_6. It is necessary to mention here that at the site S_5, two VES (one parallel and another perpendicular to the Strike direction, NE-SW, of the area) were conducted for better assessment of subsurface. The VES works on the principle of measuring resistivity anomaly in the subsurface. It gives the one dimensional geological characterization of the area in term of apparent electrical resistivity along the survey line.

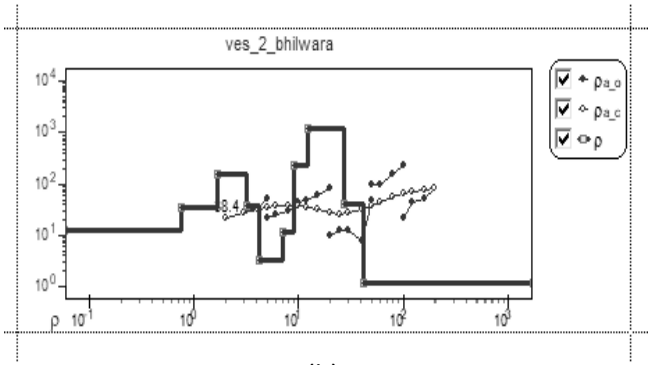


Figure 7: Terrameter installed in the field along with connecting cables and other supportive accessories.

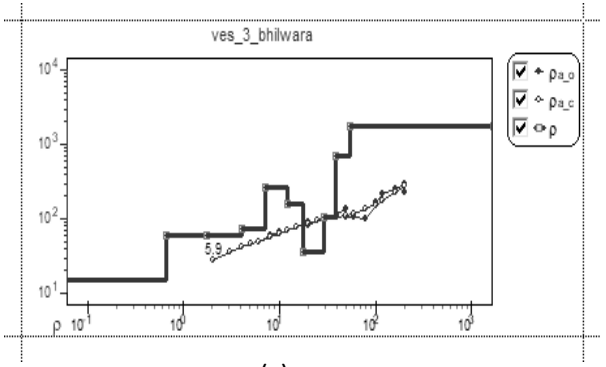
Soundings are carried out using Schlumberger configuration with maximum current electrode spacing (AB) of 400 m to delineate the subsurface. The field data (Apparent resistivity and half current electrode separation, AB/2, along with the spatial coordinates of VES locations are interpreted using Master Curves and also by using a geophysical exploration software (Zondip 1D). The resistivity data is analyzed and depth to resistivity models are prepared using forward modelling followed by inverse modeling for more accurate results. The plots of field apparent resistivity versus AB/2 on log-log graph are given in figure 8 (a-f). The results of the interpretation of the field data in terms of layer thicknesses and true resistivity are shown in figure 9 (a-f). Along with the software interpretation, all the VES performed in the field are also interpreted manually. A perusal of the interpreted results indicates that each VES location is comprised of 2-5 layers and showing possibility of cracks, fissures, and fractures in the subsurface. In general, the top layer in the Project area of the Pur village is found to be composed of schist and quartzite rock, often overlain by a top layer of alluvial soil mixed with gravel and clay. The thickness of the soil layer is more in village central and is negligible towards the village periphery towards the mining zone.



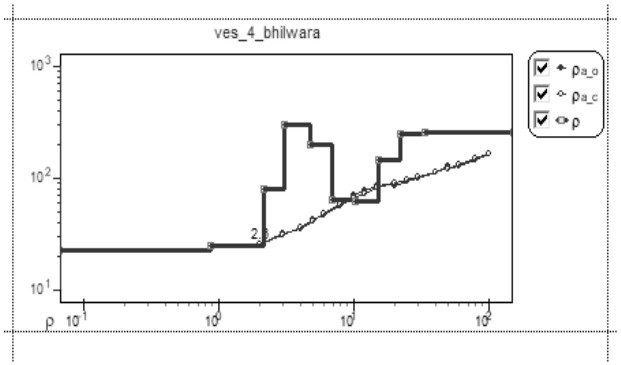
(a)



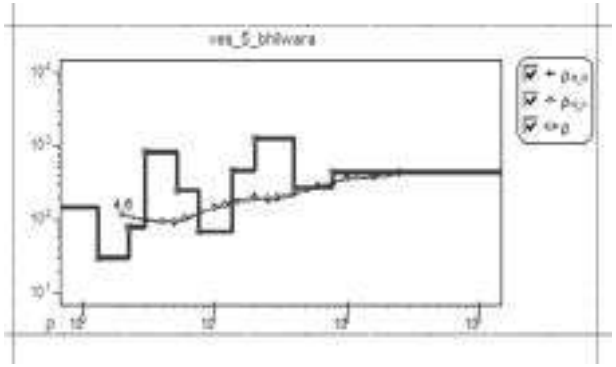
(b)



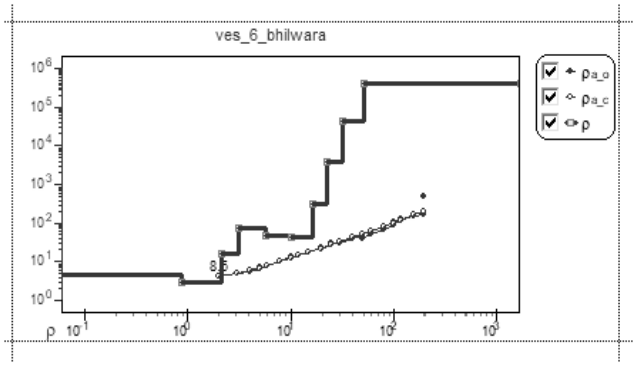
(c)



(d)



(e)



(f)

Figure 8. Field resistivity curves plotted by the Zondip 1D for the site: (a) S_1, (b) S_6. (c) S_5 parallel to dip, (d) S_5 perpendicular to strike direction, (e) S_3, and (f) S_4.

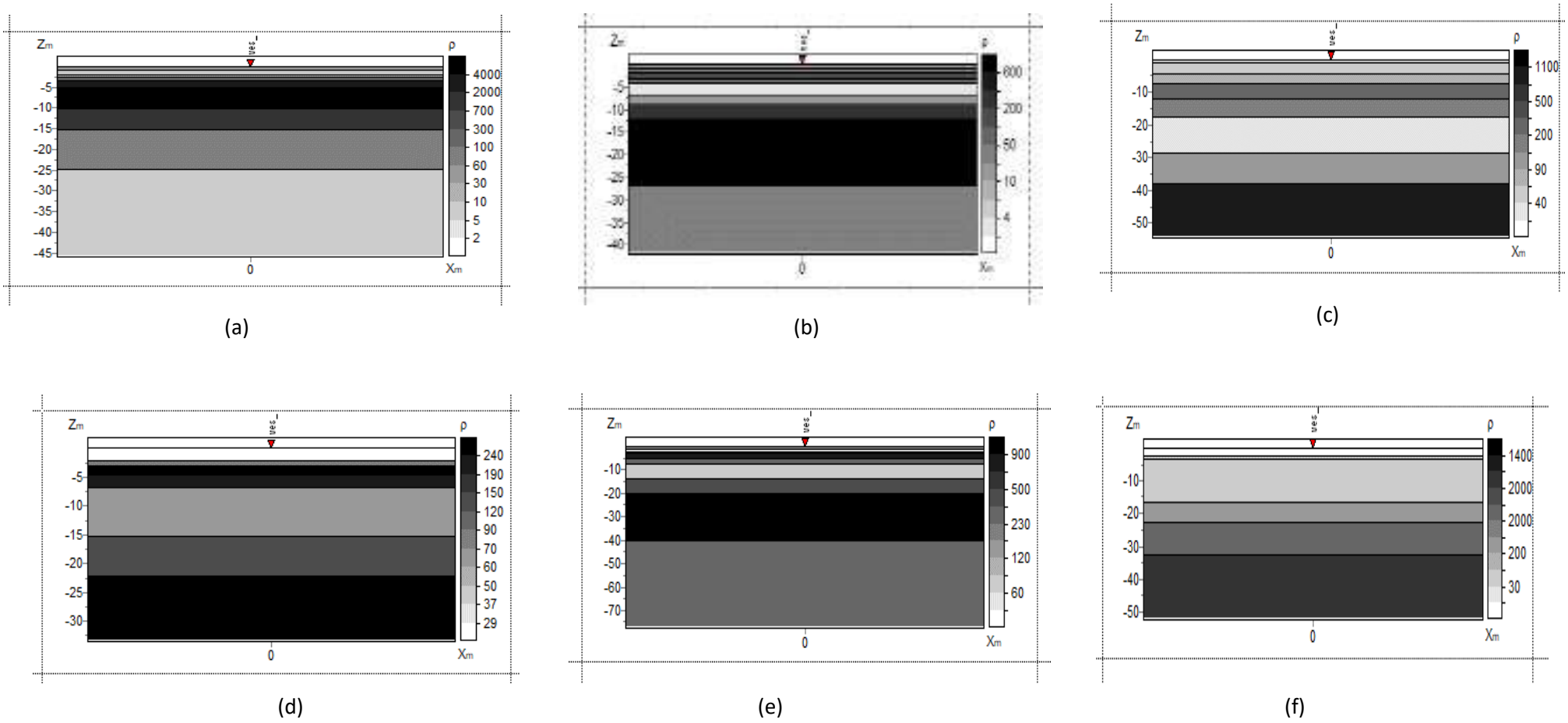
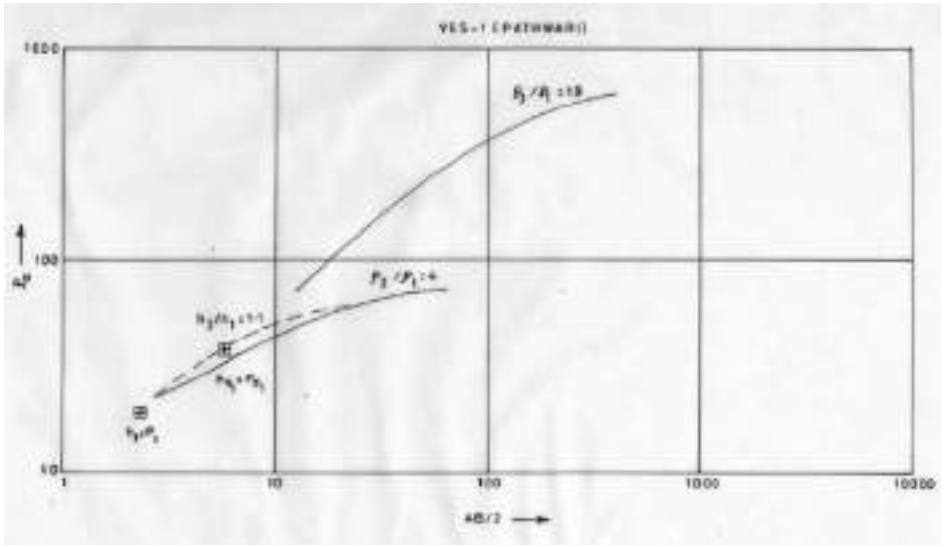
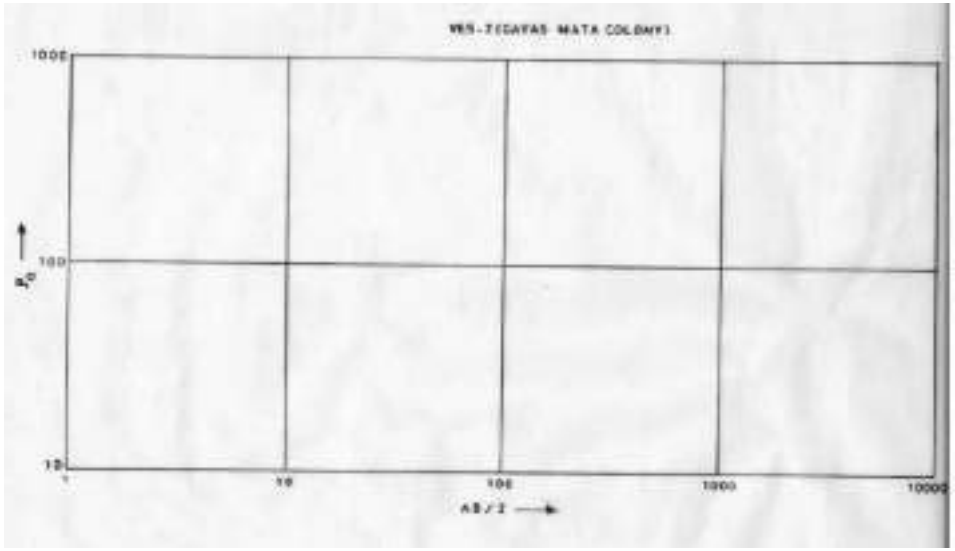


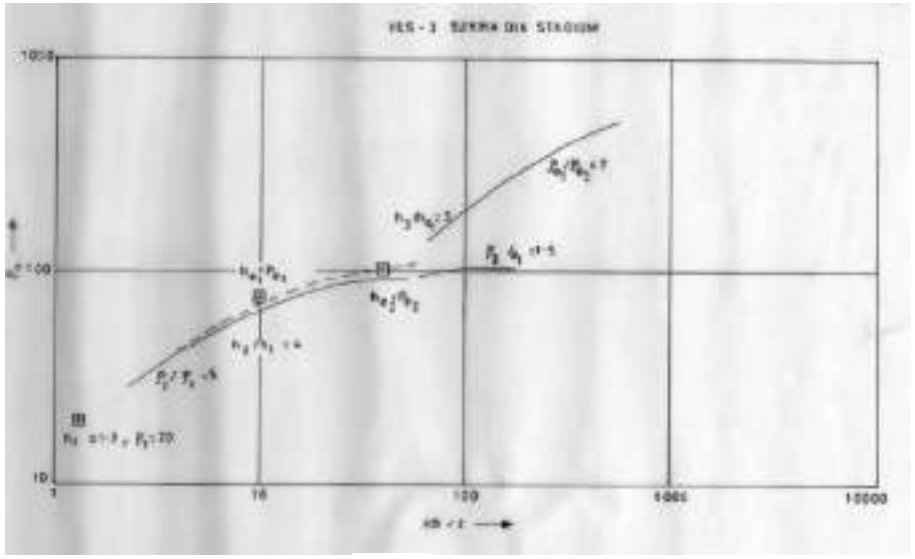
Figure 9: Depth-Resistivity models for the VES sites: (a) S_1, (b) S_6. (c) S_5 parallel to dip, (d) S_5 perpendicular to strike direction, (e) S_3, and (f) S_4. The depth (Z_m) is shown in meters and resistivity (ρ) is in Ohm-meters (Ω-m).


VES-1 (PATHWARI)
1000
100
10
1
10
100
1000
10000
AB/2

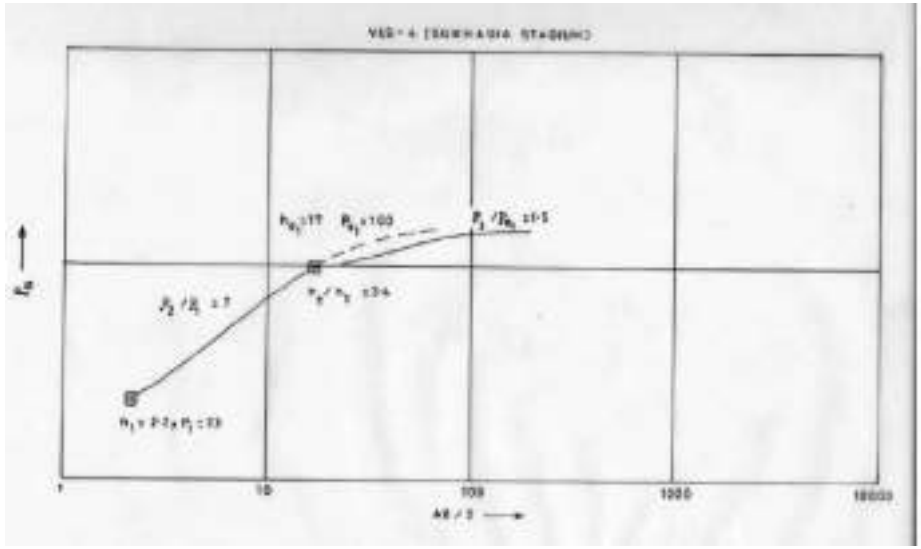
(a)


VES-7(GAYAS MATA COLONY)
1000
100
10
1
10
100
1000
10000
AB/2

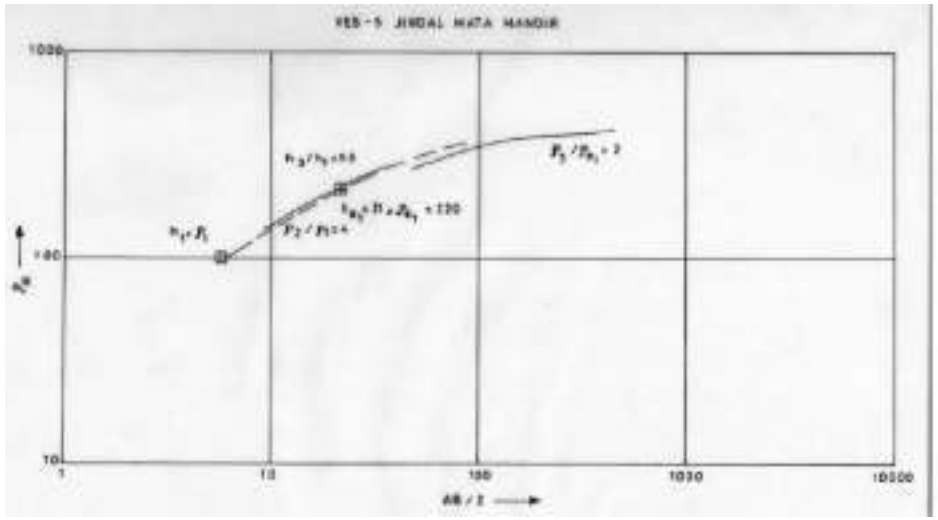
(b)


VES-3
1000
100
10
1
10
100
1000
10000

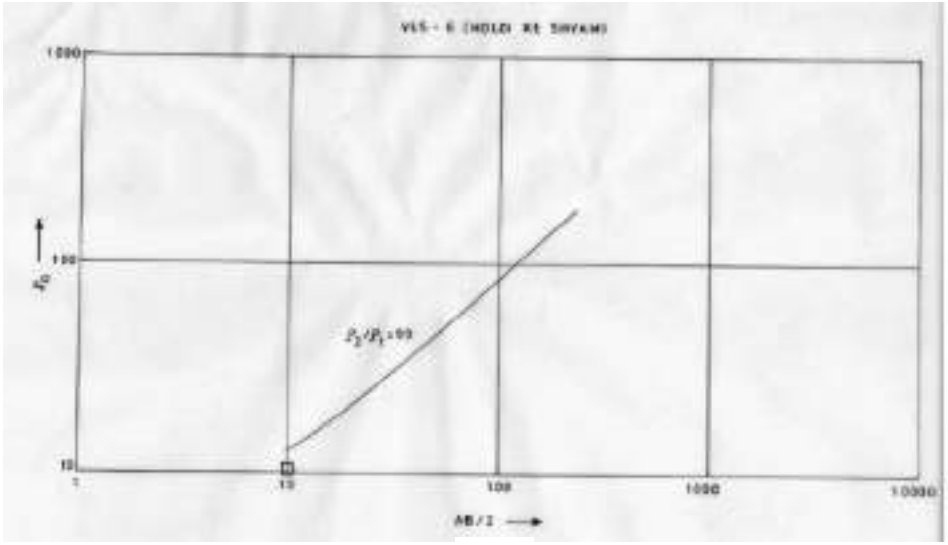
(c)


1
10
100
1000
10000
AB/2

(d)



(e)



(f)

Figure 10: Smoothened Field data curves matched over the master curve manually for the sites: (a) S_1 (VES_1), (b) S_6 (VES_2) (c) S_5 parallel to dip (VES_3) not relevant, (d) S_5 perpendicular to dip direction (VES_4) considered relevant, (e) S_3 (VES_5), and (f) S_4 (VES_6).

The data of plotted apparent resistivity curves are shown in Figures 10a-f. A visual analysis of these plots indicates that the curves display A-A (double ascending) pattern in general, whereas the plots recorded in Sukhadia stadium (VES 3 and VES 4) displayed K-A type of resistivity curves. However, the sounding VES-2 recorded at Gyas Mata colony (Figure 8b) displayed lot of scatter of plotted points, and thus could not be interpreted. The plotted graphs of apparent resistivity versus AB/2 were interpreted by partial curve matching techniques, using Master curves given by Orellana and Mooney (1966). Table 3 shows the data of true resistivities and layer thicknesses derived from the partial curve matching for all the soundings. Attempts made to interpret the field resistivity data using Zondip 1-D software were found comparatively inconsistent, mainly due to anisotropic nature of geological formation(s) in the area. Yet, the field resistivity data interpreted by inverse modeling are also presented in Figure 8.

A perusal of the table 4 generally indicates presence of a thin top soil/alluvium, having resistivity of 2 to 20 ohm-m, of thickness varying between 1m to 5 m. The top soil/alluvium is underlain by weathered rock, garnetiferous schistose quartzite, having resistivity in the range of 76 to 161 ohm-m and thickness ranging from 2 m to 7 m, with its maximum value at Sukhadia stadium observed in VES-4. Data of VES-3 is not relevant as its alignment is normal to rock strike. However, at VES-5 location nearby to Jindal Mata Mandir, the top veneer is directly comprised of weathered hard rock as seen from the higher resistivity of 100 ohm-m. The above interpretation is corroborated by the presence of isolated outcrops of schistose quartzite dotting the area. The rocks in some outcrops show steep dips towards SE, with presence of slicken sides in Sukhadia stadium, at sites VES-3 and VES-4, pointing to the incidence of displacement of rocks in the geological past. The weathered schist/quartzite is indicated to be underlain by hard/compact Schist/quartzite having resistivity of 440-9900 ohm-m at depths varying between 5 m below the surface at Pathwari and 9 m bgl at Sukhadia stadium.

It is to be noted that results from graphical interpretation are almost in line with the Zondip 1-D except for the site S_6 (Gyas Mata Colony). Hence, the results of VES performed in these sites are validated itself, indicating greater accuracy. The apparent resistivity points from the site S_6 (Figure 8b) are very scattered and almost invisible; so their manual interpretation in term of field curve could not be done. Depth-resistivity curves are further decoded in probable lithologs listed in table 4 (a-f) using the secondary data collected from the field and

available literature on subsurface lithology as revealed from coring data of eight bore wells in the Tiranga hill area.

Table 4: Subsurface characterization by depth-resistivity models prepared for VES at:

(a) Site S_1: Pathwari (VES_1)

Thickness Interval (m)	Resistivity(ohm-m)	Probable Lithologs
0 - 2.3	19	Silty Clay
2.3 - 4.8	76	phyllite
4.8 - (++)	684	Schistose Quartzite

(b) Site S_6: Gyas Mata Colony (VES_2)

Thickness Interval (m)	Resistivity (Ohm-m)	Probable Lithologs
0-12	12.65	Clayey sand
12-27	1185	Hard phyllite
27-(++)	40.236	Weathered phyllite

(c) Site S_5: Sukhadia Stadium Parallel to Rock DIP (VES_3), not considered relevant

Thickness Interval (m)	Resistivity (Ohm-m)	Probable Lithologs
0 - 1.3	20	Surface Soils (Clayey)
1.3 – 36.5	100	Weathered phyllite/ Schistose Rock
36.5 - indefinite	700	Hard Quartzite rock

(d) Site S_5: Sukhadia Stadium Parallel to Strike (VES_4)

Thickness Interval (m)	Resistivity (Ohm-m)	Probable Lithologs
0 – 2.2	19	Surface Soil (Clayey)
2.2 – 9.7	161	Garnetiferous Schist
9.7 - indefinite	500	Schistose Quartzite rock

(e) Site S_3: Jindal Mata Mandir (VES_5)

Thickness Interval (m)	Resistivity (Ohm-m)	Probable Lithologs
0 – 5.5	100	Weathered Schistose Rock
5.5 – indefinite	400 – 440	Hard Quartzite (Schistose)

(f) Site S_4: Moldi Ke Shyam (VES_6)

Thickness Interval (m)	Resistivity (Ohm-m)	Probable Lithologs
0 – 10	10	Clayey Soil
10 – indefinite	990	Hard Quartzite (Schistose)

The table 4 is prepared considering the results from Zondip 1-D and graphical interpretations in combination with lithology of cored bore wells drilled in the past in Tiranga hill area. Whole area is found to be composed of garnetiferous schist and quartzite schist whether weathered, hard, or in saturated state. Hard quartzite (metamorphic rock) is found at a depth of 5m approximately at site S_1. Out of the two VES (3 and 4) performed at Survey site S_5, the VES-3 performed parallel to the dip seems to be lesslogical and inaccurate when compared to the VES-4 performed parallel to the Strike.

4.2 Electrical resistivity tomography (ERT)

The earth resistivity meter shown in figure 11 is a 4-point light 10W high precision instrument for determination of soil resistivity. The electrical resistivity allows determination of the water content in the soil and of the types of soils and rock. It is suitable for groundwater prospecting, mining, and other environmental investigations (Stummer et al., 2004). The phase shift between output current and voltage provides information about the induced polarization (IP). The accuracy of the instrument is about 0.1 % with a resolution of max. 100 nV. From the current I, the voltage U and a geometric configuration factor the specific electrical resistivity rho (Ohm-m) is calculated. The receiver of the instrument is highly selective and only records voltages at the set frequency. However, noise at the measurement frequency degrades the quality of the measurement and should be suppressed. Major reasons for noise may include Mains (electric) interferences, magnetic interferences, wind, rain, and mechanical instability of the electrodes. The ERT is performed over sites S_1, S_2, S_3, S_4, S_5, GS_1, GS_2, and GS_3 in this study.



Figure 11: Earth Resistivity meter installed in the field

The resistivity values obtained by resistivity meter are interpolated in lithological formations using Palacky (1988). The 2-D inverse resistivity model and subsurface characterization for different sites are as follows:

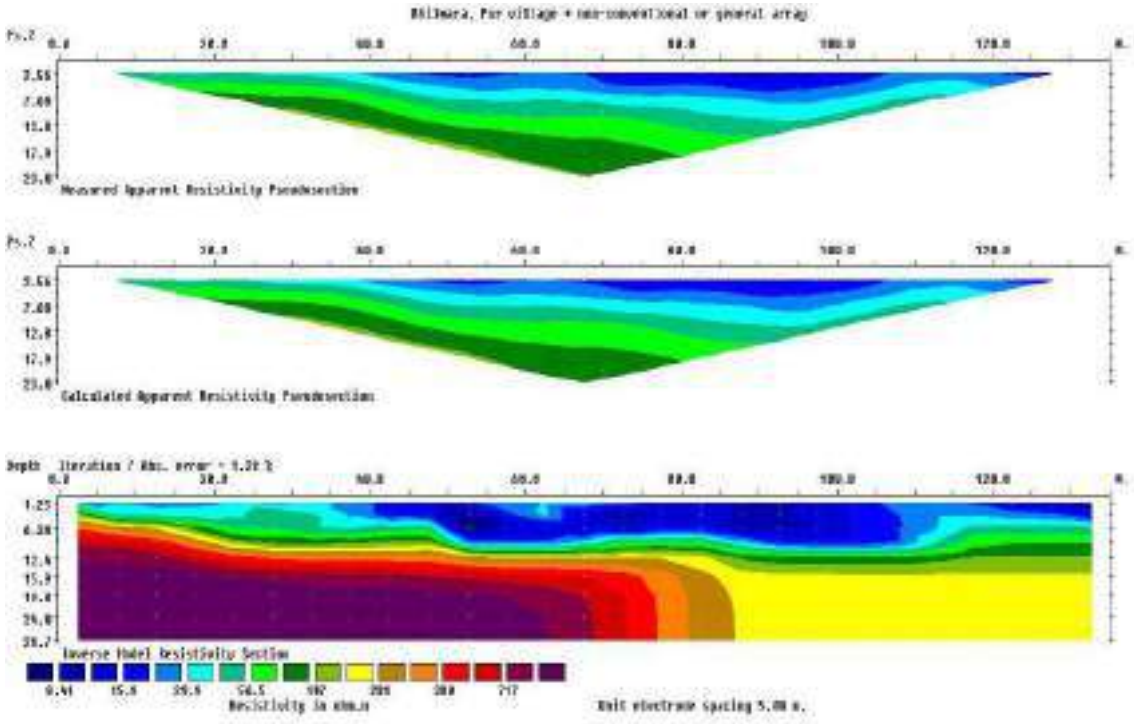


Figure 12: 2D resistivity inverse model by Wenner method at S_1 (Pathwari).

Table 4: Subsurface characterization by ERT at S_1 (Pathwari)

Depth of Investigation (meter)	ERT test	
	Resistivity (Ohm-m)	**Probable lithologs**
0-4	8.74-42.8	Sandy Soil
4-12	42.8-463	Sand and clay/Sandstone
12-22	463-1024	Garnetiferous Quartzite/Schist
22-26	463-2266	Quartzite

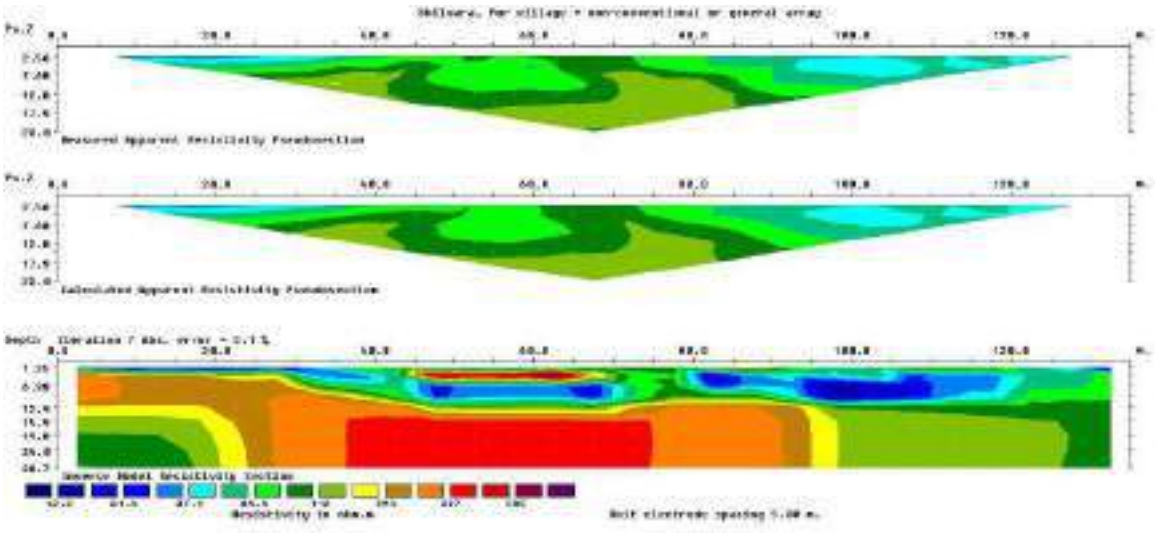


Figure 13: 2D resistivity inverse model result at site S_2 (Ghati Ke Hanuman).

Table 5: Subsurface characterization by electrical resistivity tomography (ERT) at S_2 (Ghati ke Hanuman)

Depth of Investigation (meter)	ERT test	
	Resistivity (Ohm-m)	**Probable lithologs**
0-7	11.5-472	Hard clayey soil
7-26.2	137-877	Schistose Quartzite/gneiss with possible water in fractures

Site S_3 (Jindal Mata Mandir)

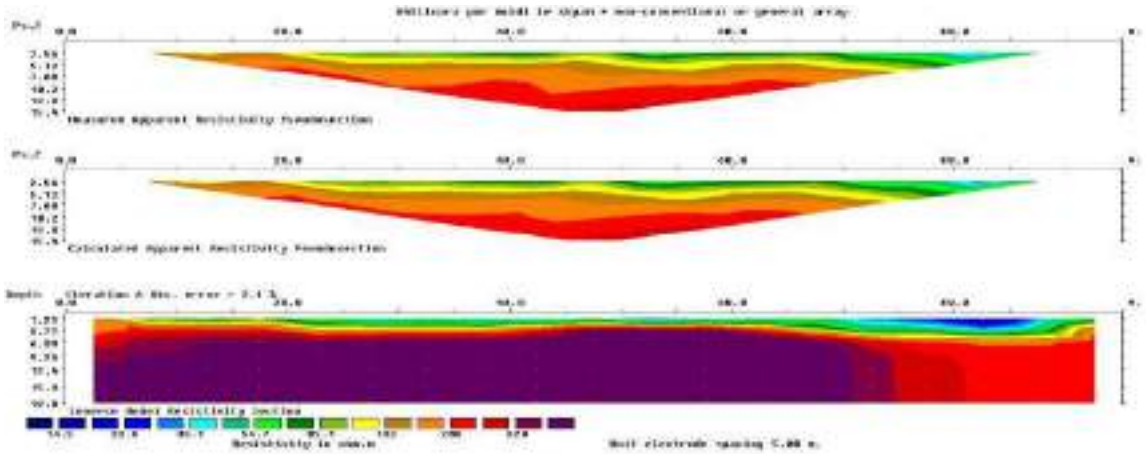


Figure 14: 2D resistivity inverse model by Wenner method at S_3.

Table 6: 2D resistivity inverse model by Wenner method at east direction of S_3.

Depth of Investigation (meter)	ERT test	
	Resistivity (Ohm-m)	**Probable litho log**
0-4	15.7-202	Topsoil and Schistose
7-32	202-308	Schist

Site S_4 (Moldi Ke Shyam)

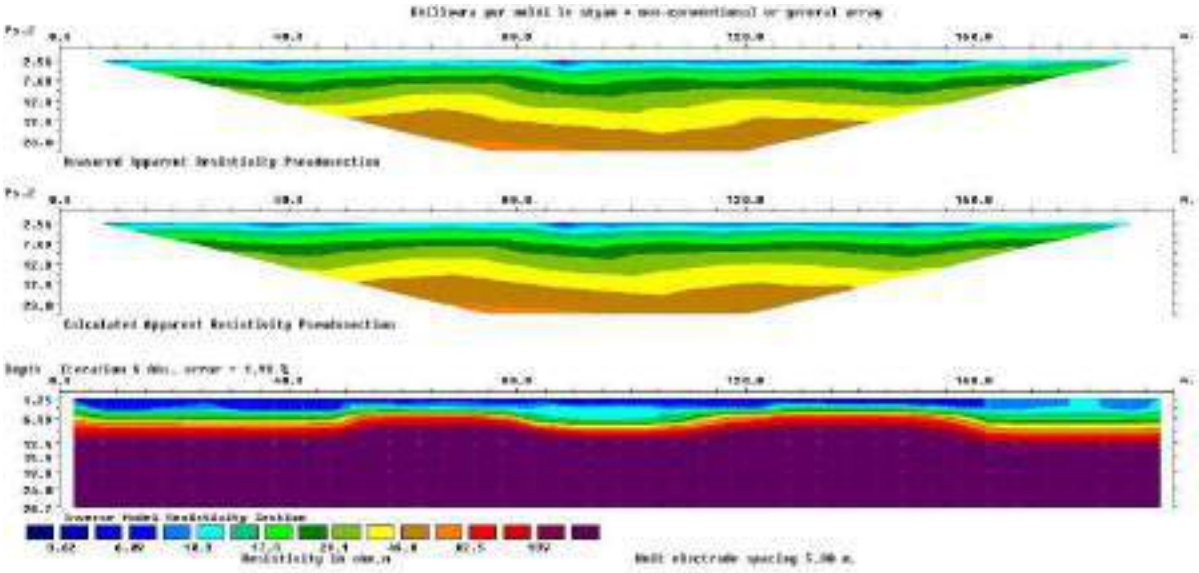


Figure 15: 2D resistivity inverse model by Wenner method at S_4.

Table 7: 2D resistivity inverse model by Wenner method at east direction of S_4

Depth of Investigation (meter)	ERT test	
	Resistivity (Ohm-m)	**Probable litho log**
0-7	3.53-38.3	Clayey soil
7-32	38.3-229	Schistose rock

Site S_5: Sukhadia Stadium

At this site, the survey was conducted in east, west, north and south direction up to 100-meter length on earth surface.

East

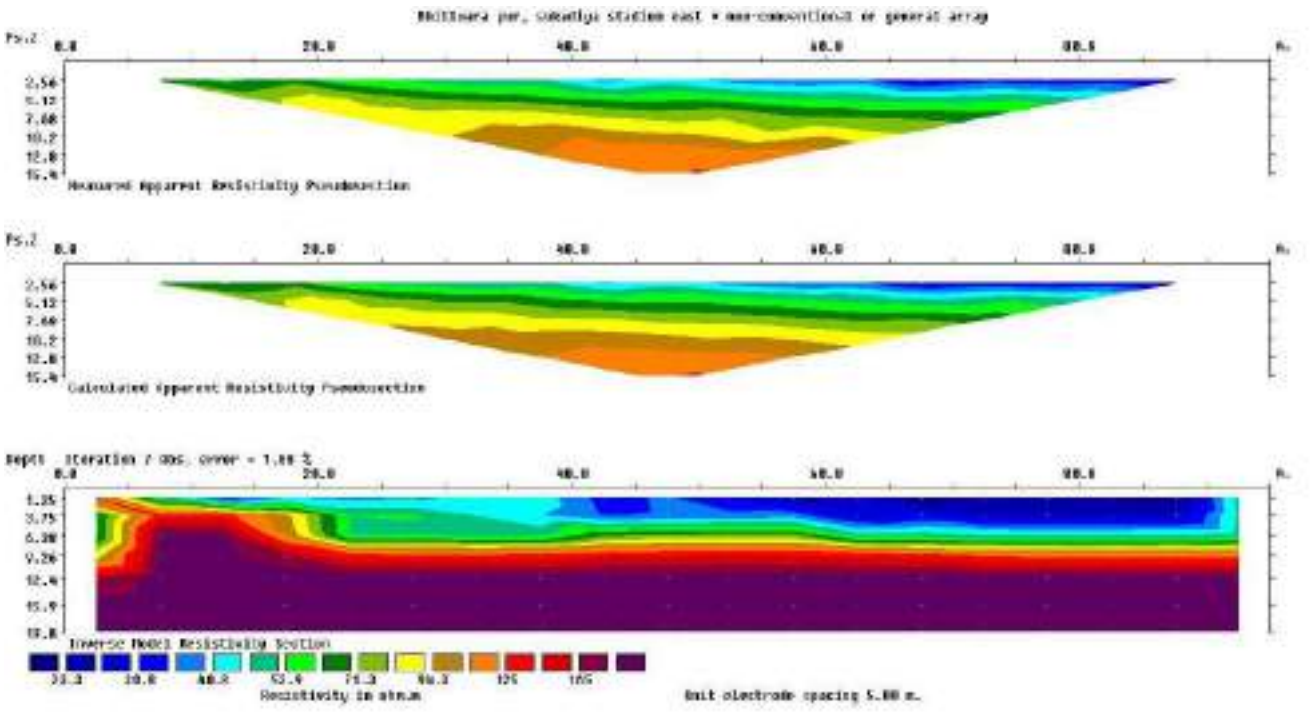


Figure 16: 2D resistivity model by Wenner method at east direction of Sukadiya stadium.

Table 8: Subsurface characterization by electrical resistivity tomography at east direction of Sukadiya stadium

Depth of Investigation (meter)	ERT test	
	Resistivity (Ohm-m)	**Probable lithologs**
0-3	23.2-76.5	Clayey soil, highly weathered schist
3-10	76.5-114	Weathered sandstone/ schist
10-17.3	114-375	Schist

West

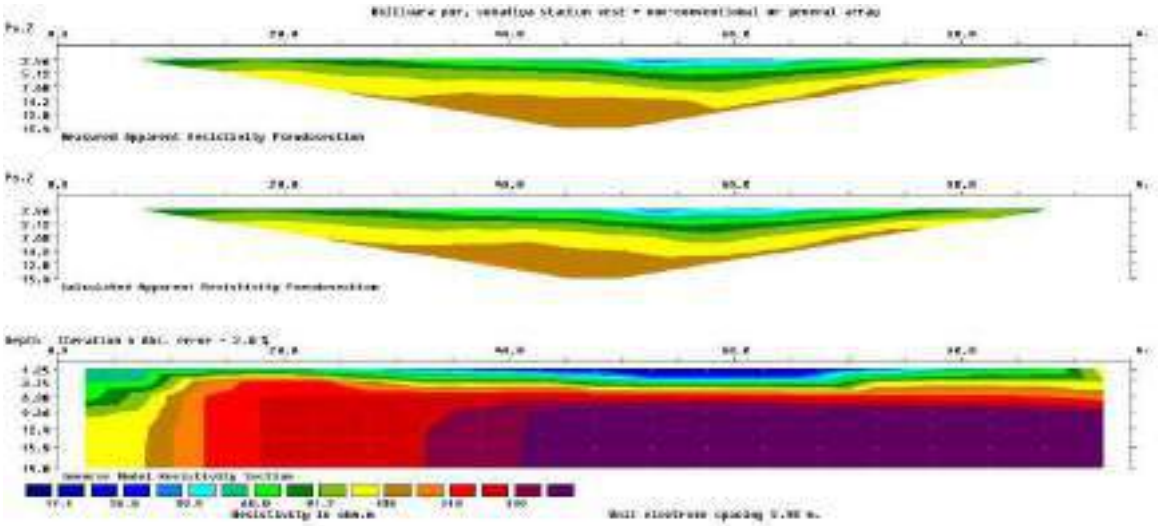


Figure 17: 2D resistivity model by Wenner method at West direction of Sukadiya stadium

Table 9: 2D resistivity inverse model by Wenner method at West direction of Sukadiya stadium

Depth of Investigation (meter)	ERT test	
	Resistivity (Ohm-m)	**Probable litho log**
0-3	16.7-215	Clayey soil
3-10	129-357	Partially saturated Schist
10-17.3	215-595	Schist

North

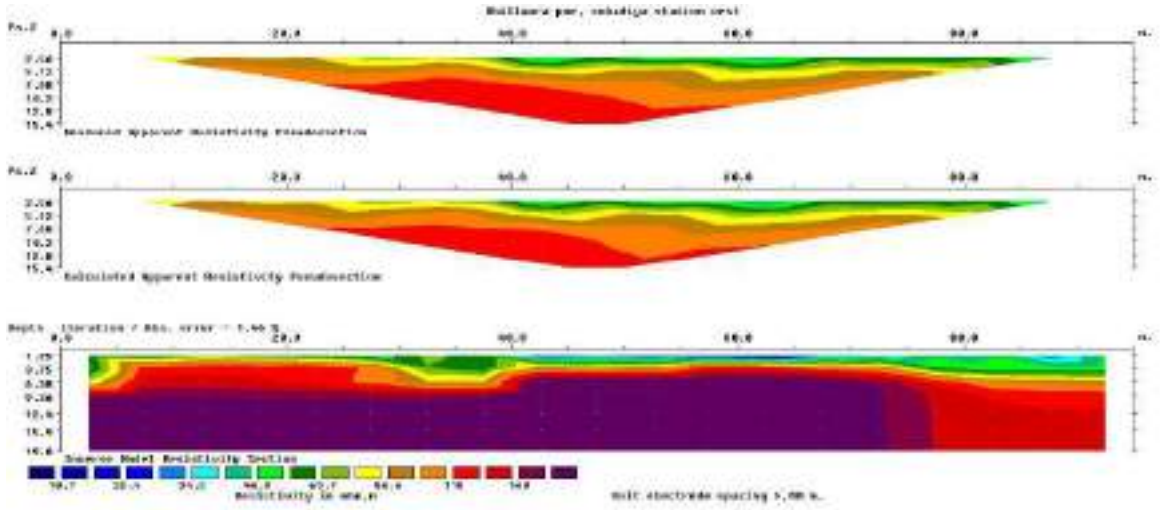


Figure 18: 2D resistivity model by Wenner method at north direction of Sukadiya stadium

Table 10: 2D resistivity inverse model by Wenner method at north direction of Sukadiya stadium

Depth of Investigation (meter)	ERT test	
	Resistivity (Ohm-m)	**Probable litho log**
0-3	10.4-86.7	Clayey soil, Sandstone (weathered)
3-17.3	86.7-161	Schist

South

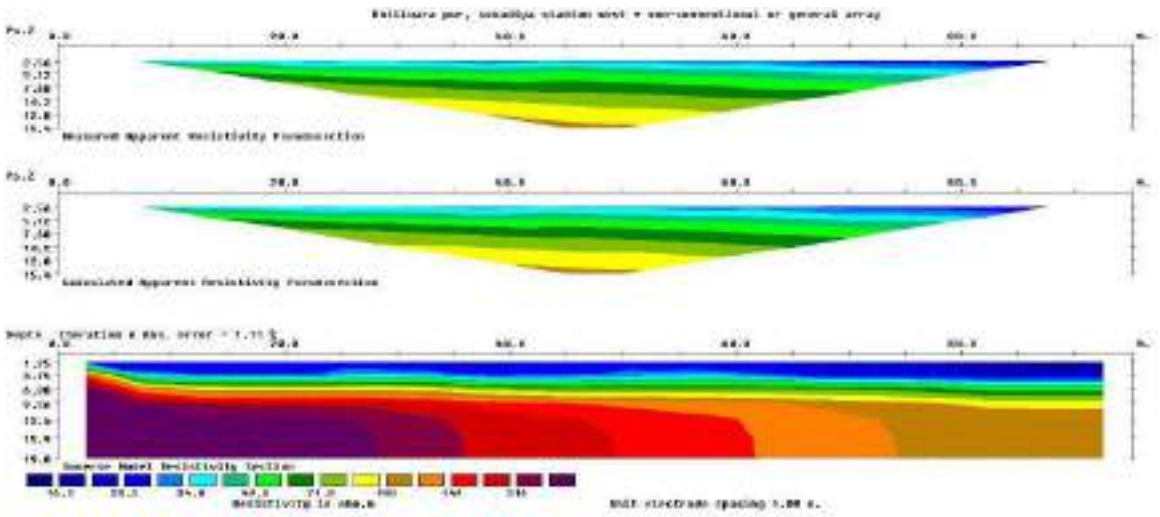


Figure 19: 2D resistivity model by Wenner method at south direction of Sukadiya stadium

Table 11: 2D resistivity inverse model by Wenner method at south direction of Sukadiya stadium

Depth of Investigation (meter)	ERT test	
	Resistivity (Ohm-m)	**Probable litho log**
0-3	15.8-90.4	Clayey soil
3-17.3	90.4-335	Schistose rock

Site GS_1: Near Old Masjid

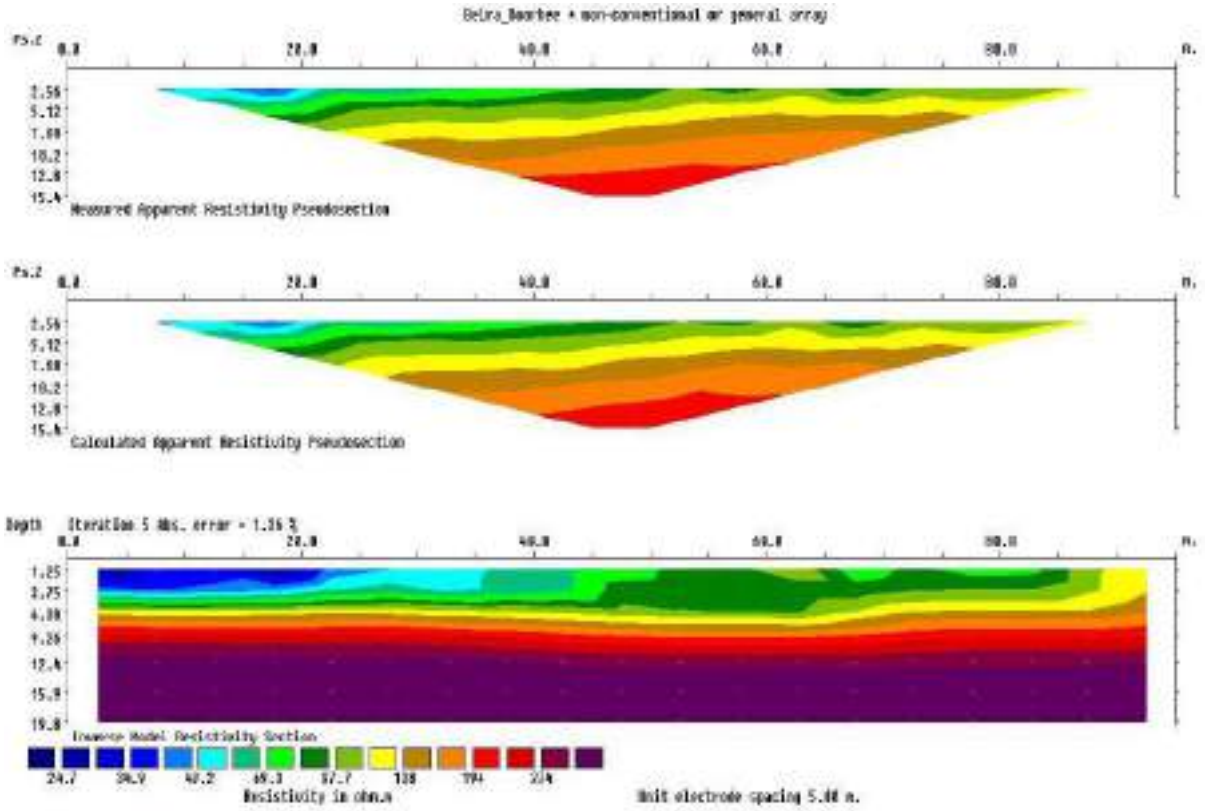


Figure 20: 2D resistivity inverse model by Wenner method near old masjid beside the pond

Table 12: Subsurface characterization by electrical resistivity tomography (ERT) at site GS_1

Depth of Investigation (meter)	ERT test	
	Avg. Resistivity (Ohm-m)	**Probable litho log**
0-5	95	Top Soil
5-10	194	Schistose rock
10-25	274	Weathered Schist

Site GS_2: Near Bada Mandir

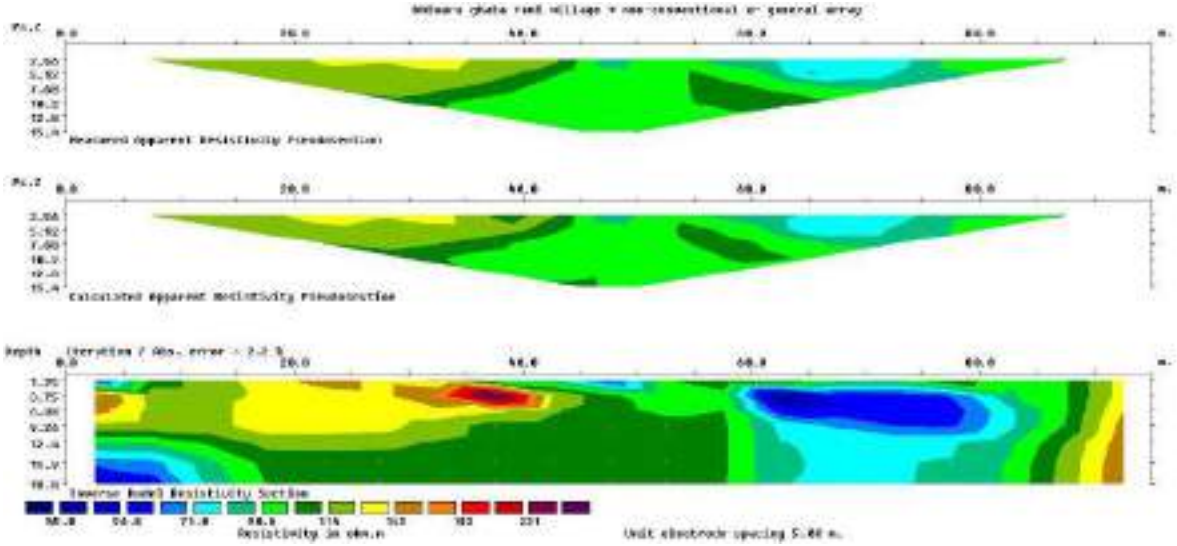


Figure 21: 2D resistivity inverse model by Wenner method near Bada Mandir

Table 13: Subsurface characterization by electrical resistivity tomography (ERT) at site GS_2

Depth of Investigation (meter)	ERT test	
	Avg. Resistivity (Ohm-m)	**Probable litho log**
0-5	50	Top Soil
5-10	85	Fractured Schistose
10-15	228	Weathered schist
15-20	243	Weathered schist

Site GS_3: Near Ghata Rani Temple

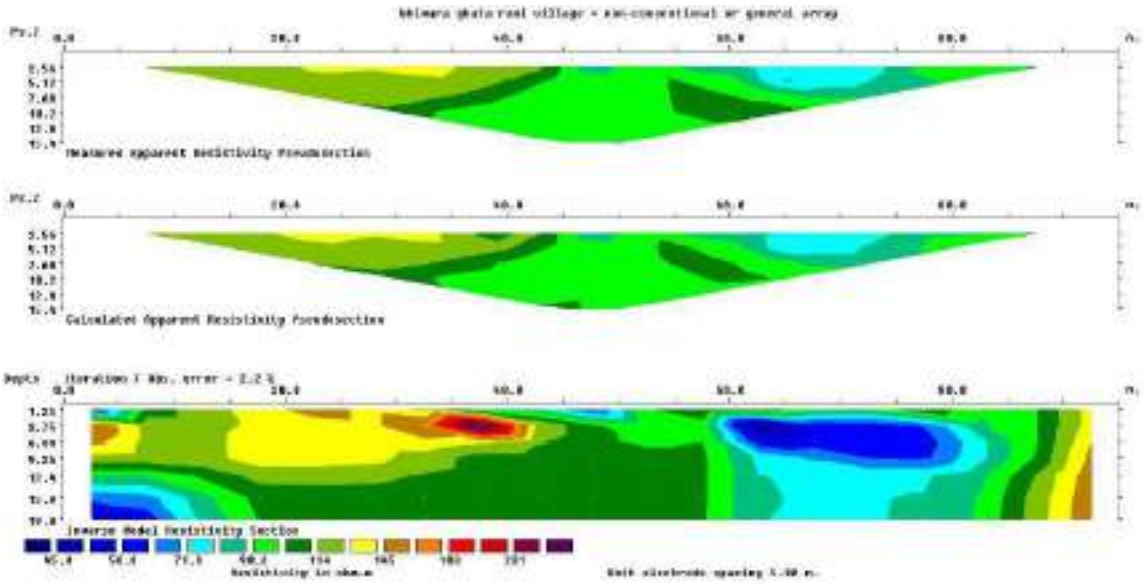


Figure 22: 2D resistivity inverse model by Wenner method near Bada Mandir.

Table 14: Subsurface characterization by ERT at site GS_2

Depth of Investigation (meter)	ERT test	
	Avg. Resistivity (Ohm-m)	**Probable litho log**
0-5	126	Weathered phyllite
5-10	125	Weathered schist
10-20	104	Grey Phyllite

The findings of both 1-D vertical electrical soundings and 2-D electrical resistivity tomography give heterogeneous pattern of subsurface. It was observed from the 2D ERT inversion that a sandstone/soil present between 60m to 80m below 10m from the ground surface of the survey line at site S_1 as a sudden drop in resistivity from 717 Ohm-m to 201 Ohm-m is observed. A similar type of pattern was observed at S_3 site. A sudden drop in resistivity along the survey line can be observed from ERT inversion at GS_2 at 60m from the starting point. There is a high possibility of vertical fracture/anomaly here as resistivity value drops from 114 Ohm-m to 90 Ohm-m which continues throughout the depth. The similar pattern is observed between 80m-100m from the starting point showing vertical foliation in the underlying rock. Furthermore, a saturated soil seems to be present between

60-80 m away from the starting point throughout the subsurface depth. A similar type of soft material zone is also observed at 15-20 m depth below the weathered schist at the starting point of the ERT survey. A significant variation in subsurface formation is thus observed vertically and horizontally within the 100 m of the survey length in the problematic area. These types of subsurface anomalies are making the lithology of the Pur village vulnerable for differential land settlement.

Three-Dimensional modelling of Subsurface

The existing geological picture of the study area obtained by performing various VES and ERT can be understood by a professional hydro-geologist but may not be easy to conclude by others. In order to clearly explain the current geological scenario in the area, results of both these tests are clubbed together and 3-dimensional solid model, strip log diagrams, and fence diagrams are developed using ROCKWARE modelling software. The grid network used as base for 3-D lithological modelling is shown in figure 21. The problematic area i.e., in and around Pur village is situated near to edge AD of the grid whereas mining site is located near the BC edge of this grid.

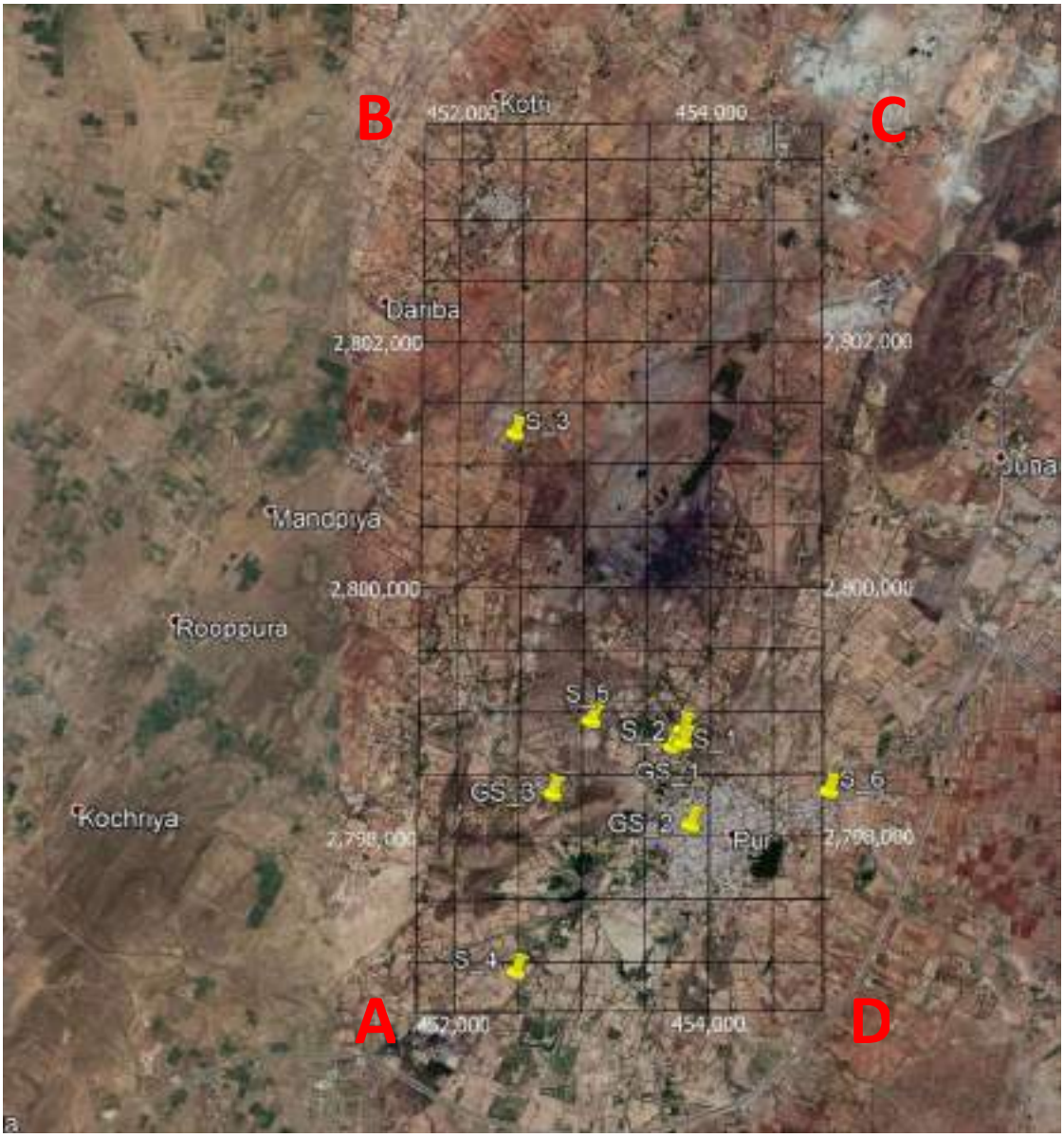


Figure 23: Google map of study area with marking for testing sites and grid ABCD used in lithological modelling.

A three dimensional geological model of the study area is shown in figure 24. This model gives the overall picture of the existing subsurface conditions in the area. As single view side of this complex model seems insufficient to deliver the whole information, the strip log diagram for these welllogs is shown in figures 23 and 24 with the South-East and South-West face forward.

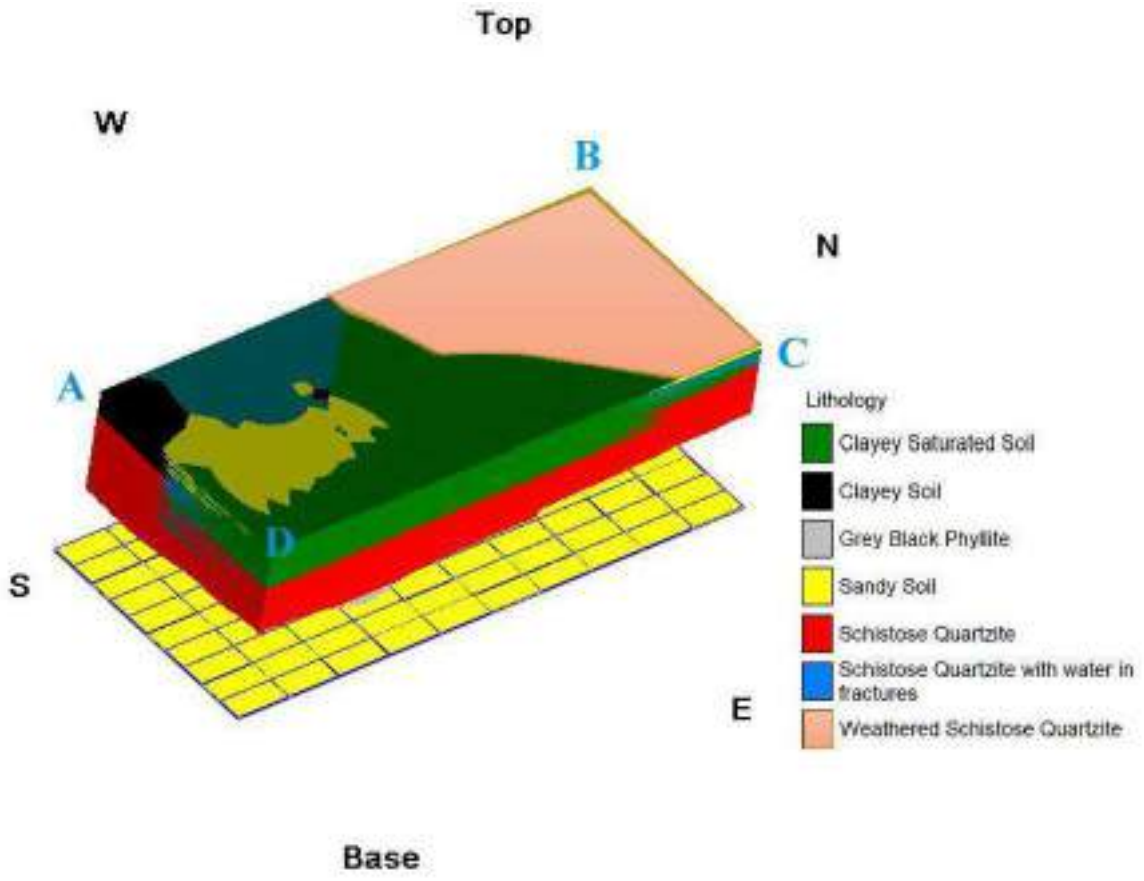


Figure 24: Three dimensional solid geological model of the study area with direction and grid marking for better understanding.

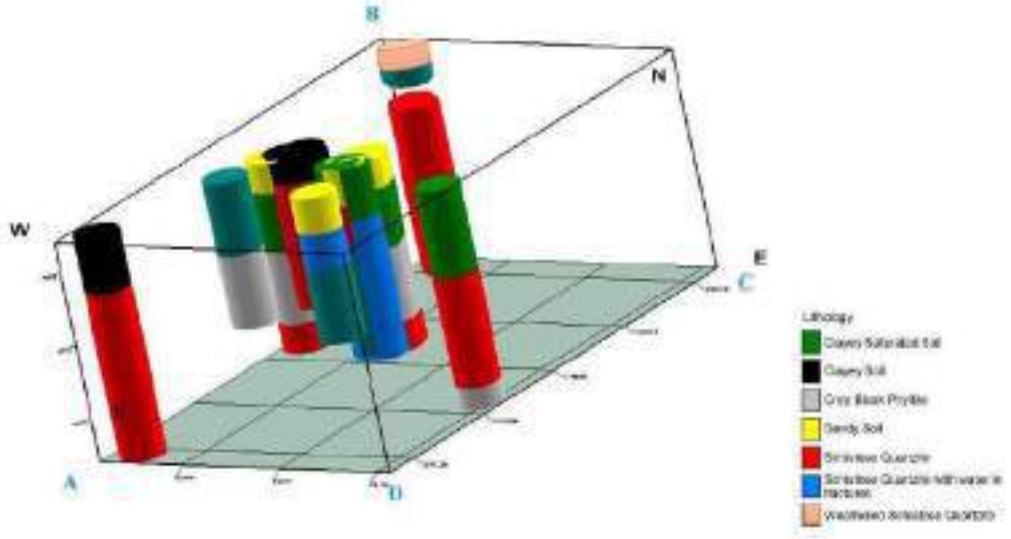


Figure 25: Three-D strip log model of the study area with South-East face forward.

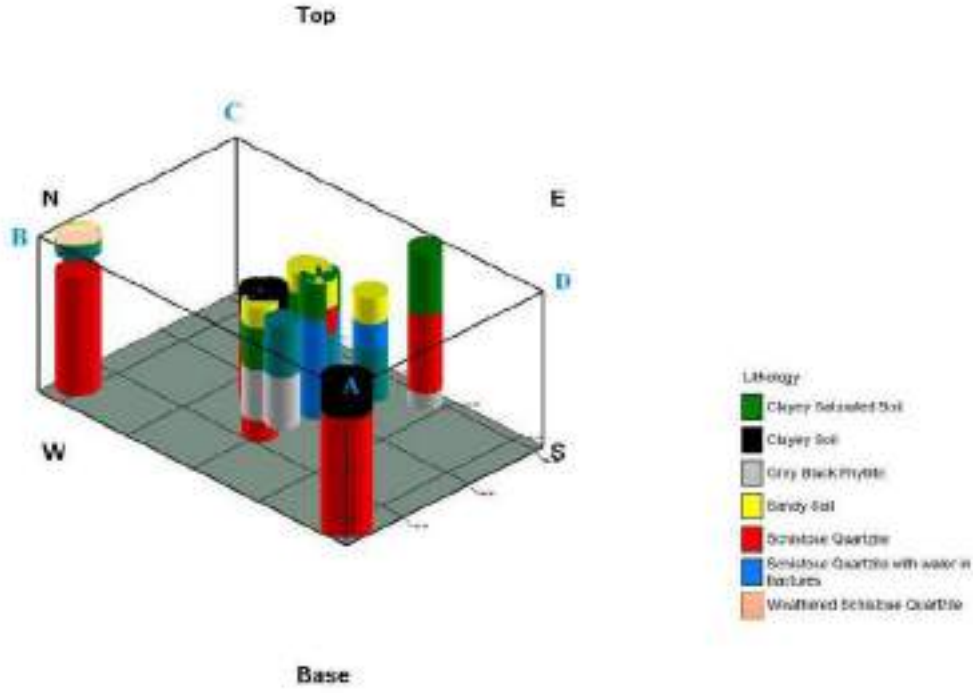
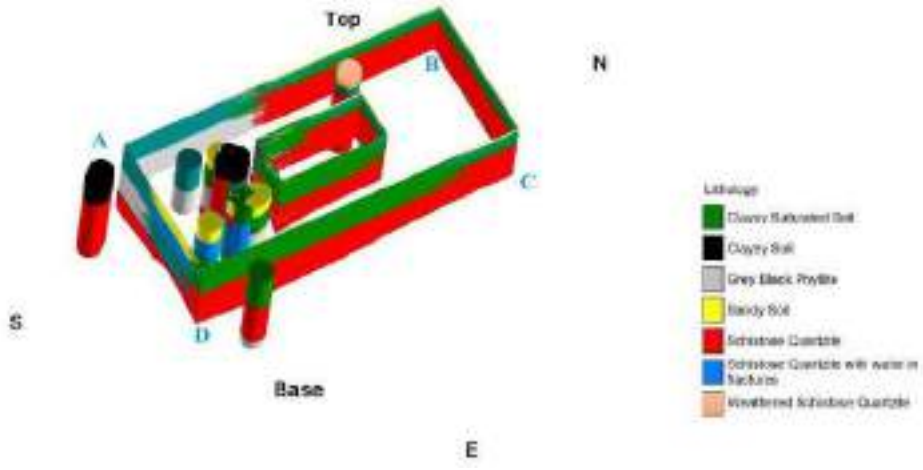


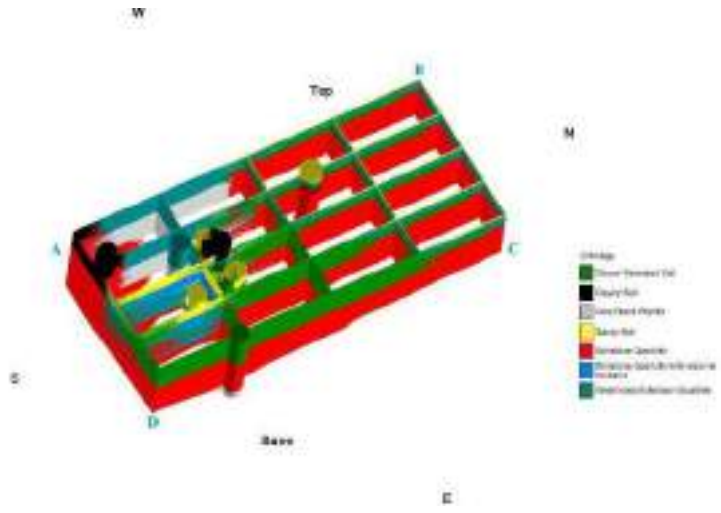
Figure 26: Three-D strip log model of the study area with South-West face forward.

Apart from solid 3-D model and strip log diagrams, fence diagram is useful to depict the geological condition more clearly. The fence diagram refers to three or more geologic

sections showing the relationship of wells to subsurface formations. The scales diminish with distance from the foreground to give a proper perspective of the whole area. Similar in some respect to a block diagram, fence diagram has the advantage of transparency, which is not possible in a block diagram. The fence diagrams for the study area are shown in figure 27 (a) and (b).



(a) Fence consisting of Collinear Rectangles



(b) Fence consisting of Collinear Grids

Figure 27: Three dimensional geological fence diagrams of the study area for different fence geometry

4.3 Surface nuclear magnetic resonance (SNMR) Survey using GMR

SNMR study was conducted by GMR system directly which detects the presence of soil water utilizing a phenomenon known as proton nuclear magnetic resonance (NMR). Proton NMR observed when proton spins associated with hydrogen atoms in groundwater are subjected to perturbation in the background magnetic field. In the static magnetic field, the proton spins preferentially align in the same direction as the field and so form a small magnetic moment. The SNMR system provides unambiguous detection of soil water because the measured signal is generated by hydrogen present in in soil water. By measuring the NMR properties of the subsurface, GMR provides quantitative images of moisture content along with estimation of hydro-geologic parameters, including specific yield and permeability (Vista Clara, 2009). The field setup of SNMR is shown in figure 28 which directs non-invasive imaging of subsurface to depths of approximately 100 m. Quantitative assessment of water content with its mobile/immobile water c

ontents is performed along with vadose zone characterization using this technique (Behroozmand et al., 2015). Factors like electric and magnetic interferences can affect the accuracy of the SNMR survey.



Figure 28: Field setup of SNMR survey using GMR

The sites S_2, S_4, and S_5 are initially selected for performing the SNMR survey. Data of SNMR survey at site S_2 cannot be able to conclude due to presence of high electromagnetic noise and residential area. Figures 29 and 30 show the variation of water content, hydraulic conductivity and soil strata at different depths below the surface of the soil at site S_4 and S_5.

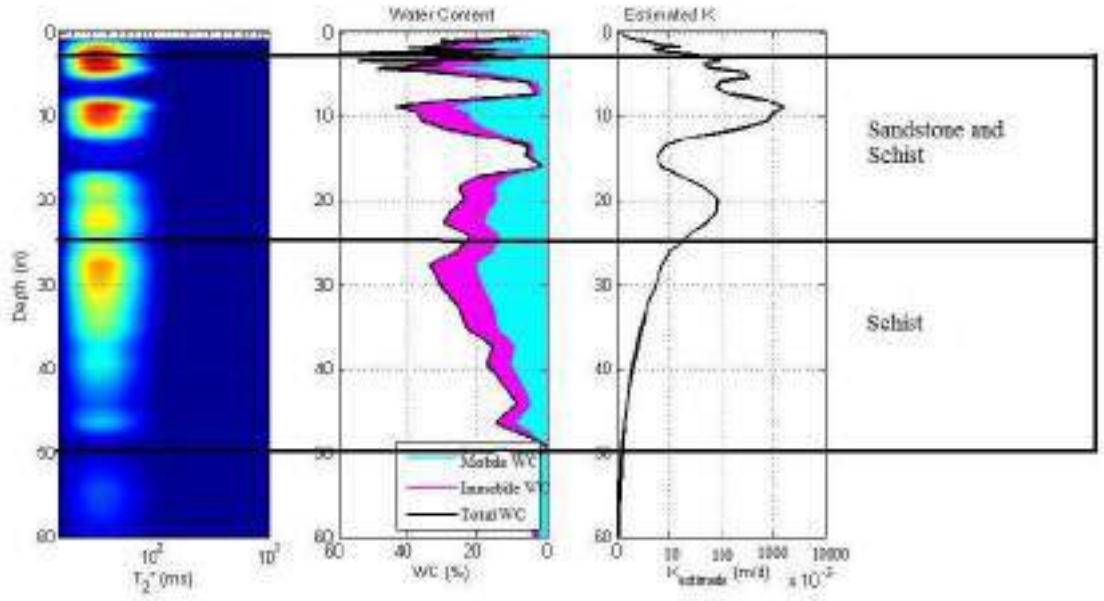


Figure 29. Distribution of water content, hydraulic conductivity and soil strata at site of Sukhadia stadium at Pur-Village

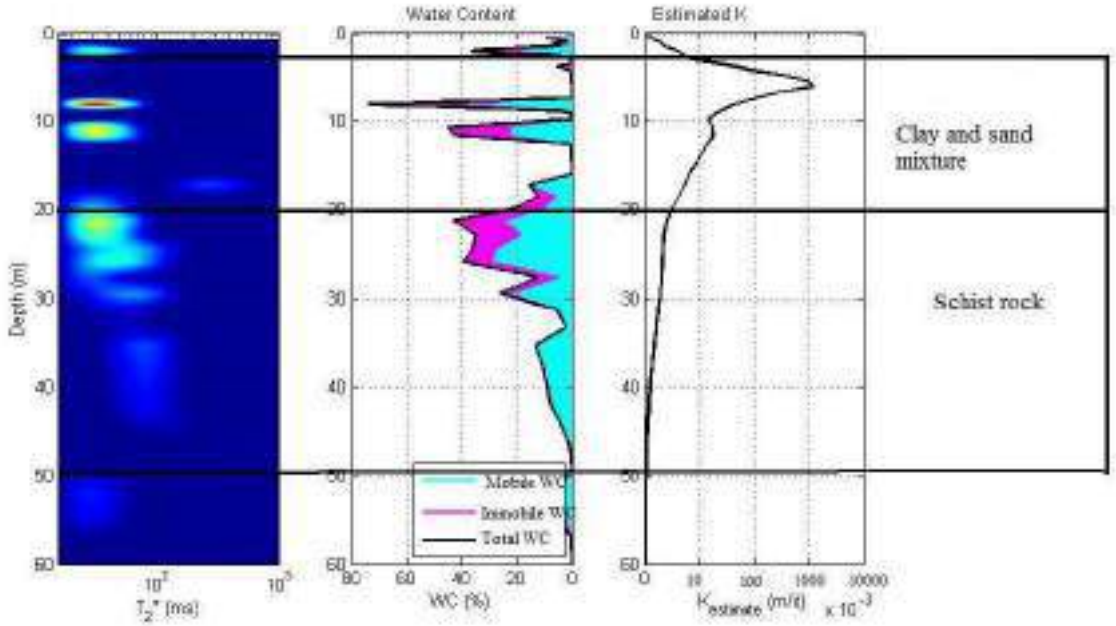


Figure 30. Distribution of water content, hydraulic conductivity and soil strata at site of Moldyka Shyam at Pur-Village

These results show that the soil moisture content is varying significantly from ground surface to subsurface even though there was no recent rainfall or irrigation event at those sites. This shows the presence of vertical heterogeneity in subsurface in form of different stratigraphic

layers observed with depth. Sharp change in moisture content particularly no observation of immobile water content at some depths shows the presence of cracks and fracture in subsurface. Variation in hydraulic conductivity of the strata fortifies the heterogeneous nature of the variably saturated zone. Negligible values of K at deeper locations at both the sites show the presence of hard rock.

4.4 Aquifer Tests

Aquifer test (pump test) is a field experiment performed in controlled condition for estimation of hydraulic properties of the aquifer system such as storativity (S) and transmissivity (T). It is often followed by recovery test for the validation of parameters obtained during the pumping time. Depending on the geology of the concerned area and available resources, aquifer test are performed either constant head or constant discharge type. The data collected in field test is then analyzed either using Theis, Cooper-Jacob, Neuman or any other suitable methods. The relationship between drawdown (s) and time (t) from start of pumping are used in these methods with well function W(u) defined as

$$s = \frac{Q}{4\Pi T} W(u)$$

The auxiliary parameter is defined as $u = \frac{r^2 S}{4Tt}$, where t is the time from start of pumping and r is the radial distance from the pumping well. Plot of drawdown (s) versus time since pumping starts (t), known as data curve is matched with the Theis type curve for obtaining the s and $r^2/4t$ values for a corresponding well function value. Then the value of S and T can be calculated from the well function. After pumping has stopped, value of residual drawdown (s') is also measured in the observation well. A plot of residual drawdown s' versus the logarithm of t/t ' is then plotted to obtain a best fit line. The slope of the line ($\Delta s'$ per log cycle of $\frac{t}{t'}$) given as

$$\Delta s' = \frac{2.303Q}{4\Pi T}$$

The results of recovery test are used to validate the pumping test results. In this study, two pump test at different sites (table 15 and figure 31) both followed by recovery tests are

performed in the study area for determining aquifer parameters, Storativity (S) and Transmissivity (T). The detail of test at both places is described below.



Figure 31: Images of well test locations

Table 15: Location of pumping well test sites

S.No.	Location Name	Latitude	Longitude	Type of Control Well
1	Banshi Mali ka kuwa **(WT_1)**	25.3038833	74.54033	Open Well
2	Mukesh Mali ka kuwa **(WT_2)**	25.3129166	74.53845	Bore Well

Test at Banshi Mali ka Kuwa: The test was performed on 31/01/2020 using an existing dug well of diameter 5m as control well and an existing bore well of diameter 0.1016m as observation well. Both the wells are situated in an unconfined aquifer of approximate thickness 25-30 m, extending from 8 to 35m bgl. Pump test with a constant discharge of 48.9645 m^3/day was performed for a period of 90 minutes followed by a recovery test for 20 minutes. The plot of time vs. drawdown data of monitoring well obtained from the pumping test is shown in figure 28. This data Curve is then matched with the Theis type curve with the

help of software AQTESOLV 4.5. Transmissivity (T) and Specific yield (S) of the aquifer system is calculated and were found as 35.46 m^2/day and 3% respectively. A plot of residual drawdown s′ vs. log (t/t′) is plotted (figure 33) and slope of best fit straight line is used for this calculation.

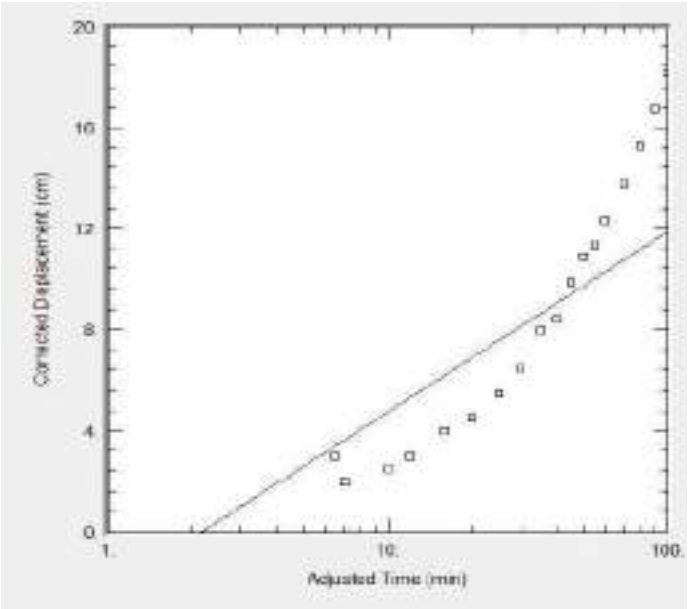


Figure 32: Data curve obtained after plotting the corrected drawdown recorded in the observation well against adjusted time since pumping start.

These values of T and S obtained are in good agreement with the study carried out by CGWB in 2013. Further the obtained hydraulic conductivity (K) of the aquifer is nearby to the unity which is also observed using the SNMR survey at nearby locations.

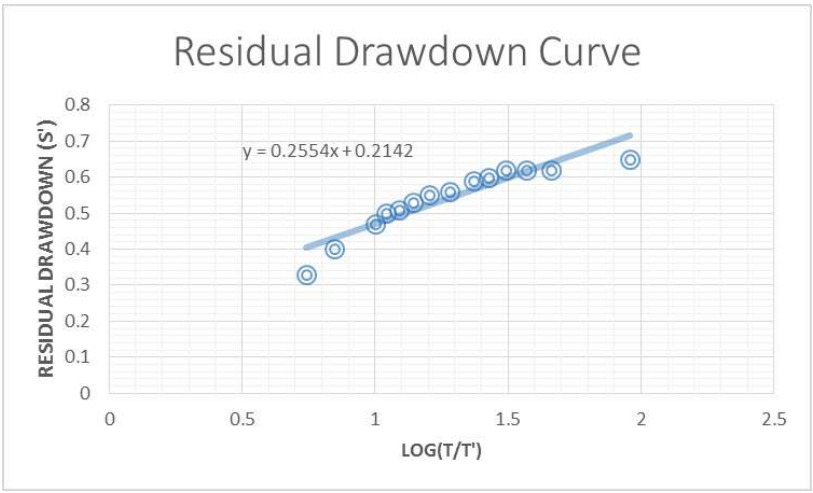


Figure 33: Recovery test plot of the observation well obtained after plotting the residual drawdown per log cycle of time.

Test at Sh. Mukesh Mali ka Kuwa: The test was performed on 31/01/2020 using two existing bore wells each of diameter 0.33 m as control well and observation well. Pump test with a constant discharge of 26.4835 m^3/day were performed for a period of 100 minutes followed by recovery test for 30 minutes. But the observed drawdown obtained from this test cannot be concluded to yield meaningful value of the aquifer parameters. This disturbance seems due to operating of one or more nearby wells either before or during the pump test without the knowledge of the investigators at the site.

4.5 Water Quality Parameters

A general water quality analysis for the study area is performed for assessment of chemical composition of its surface and groundwater. A total of 9 sampling points scattered in the entire area are selected for the analysis of various physio-chemical water quality parameters. The location, site code along with the source of water sample is mentioned in the table 16 and marked in figure 34. The direct and random samplings of groundwater from the wells of each site are used to collect the samples. Sample from Q_1, Q_2, Q_3, and Q_4 are analyzed in-situ using multi-meter sensors for temperature, total dissolved solids (TDS), resistivity, conductivity, salinity, pressure, and absolute conductivity as listed in table 17.

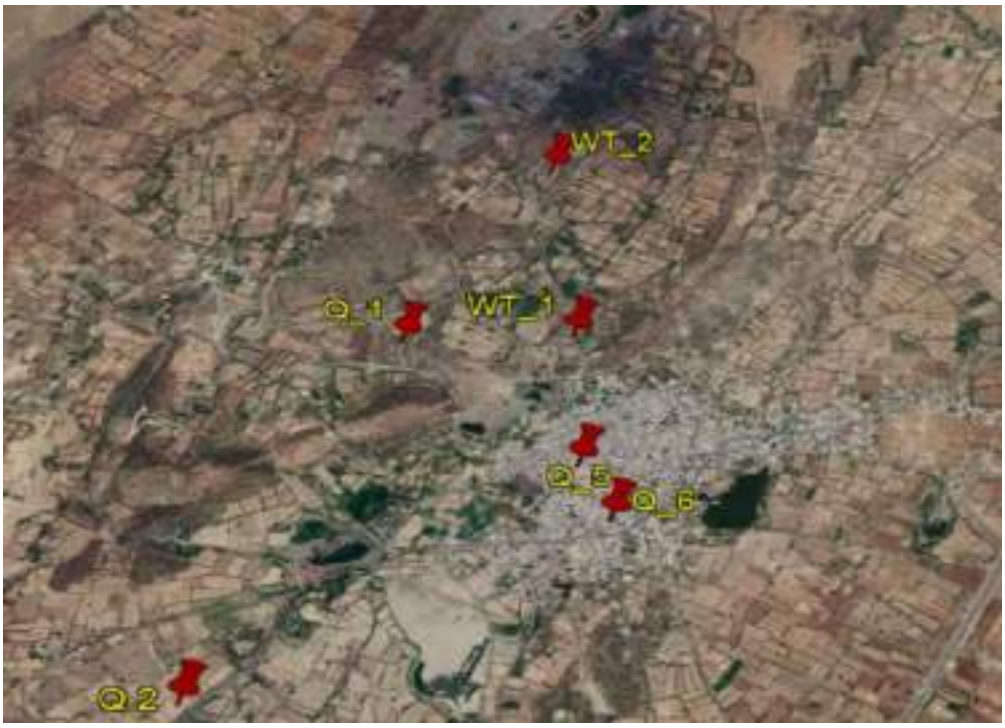


Figure 34: Location of sampling site for Water quality analysis.

Table 16: Location of water sample collection sites along with their respective site codes used in this study.

Site Code	*Sample Location*	*Latitude*	*Longitude*	*Source of Water*
Q_1	Shukhadia Stadium	25.30356	74.53331666	Hand Pump
Q_2	Bhramano Ka Kua	25.2869166	74.5276333	Open Well
Q_3	Ghati Ke Hanuman	25.303355	74.540543	Open Well
Q_4	Pumping Site	25.30395	74.5405433	Tube Well
Q_5	Bada Mandir	25.029755	74.5411833	Hand Pump
Q_6	School	25.29505	74.542683	Seepage water
Q_7	School	25.29505	74.542683	Water Supply
Q_8	School	25.29505	74.542683	Drain Water
Q_9	School	25.29505	74.542683	Handpump

Apart from the in-situ analysis, samples from the site Q_5, Q_6, Q_7, Q_8, and Q_9 are analyzed in the lab of Department of Hydrology, IIT Roorkee using the Atomic Adsorption Spectroscopy (AAS) and ICP-MS. Concentration of heavy metals and trace elements like Lithium, Sodium, Magnesium, Aluminum, Potassium, Calcium, Chromium, Manganese, Iron, Cobalt, Nickel, Copper, Zinc, Cadmium, and Lead are measured and are listed in table 18. The concentration of Na, K, Mg, Cd and Pb in water samples were estimated through Atomic Emission Spectroscopy. The study samples were diluted appropriately before undertaking the experiment. Calibration curves were plotted using various concentration of these elements along with the blank solution before the analysis. In general, groundwater of the area is found safe except the little high salinity at some locations.

Table 17: The in-situ measured values of the temperature, total dissolved solids (TDS), resistivity, conductivity, salinity, and absolute conductivity of collected groundwater samples in the study area.

Site Code	Temperature (^{0}C)	Conductivity (µS/cm)	Abs. Conductivity (µS/cm)	Resistivity(µΩ-cm)	TDS (ppm)	Salinity (PSU)
Q_1	29.6	1036	1126	963	519	0.51
Q_2	23.74	643	629	1553	322	0.31
Q_3	27.28	1178	1236	840	598	0.59
Q_4	26.9	1564	1617	644	774	0.77

Table 18: The concentration (in ppb) of the Lithium, Sodium, Magnesium, Aluminum, Potassium, Calcium, Chromium, Manganese, Iron, Cobalt, Nickel, Copper, Zinc, Cadmium, and Lead of collected water samples in the study area.

Site Code	Li	Na	Mg	Al	K	Ca	Cr	Mn	Fe	Co	Ni	Cu	Zn	Cd	Pb
Q_5	5.34	22653.39	2269.72	16.85	79672.61	4238.609	0.303	0.169	0	0.023	0.235	0.328	25.82	0.282	ND
Q_6	3.36	26204.02	1550.619	11.357	104548.06	1639.082	1.518	ND	0	0.041	0.142	1.922	8.003	0.09	0.021
Q_7	0.25	2373.903	1223.062	28.774	1398.69	4279.941	ND	4.415	0	0.388	0.29	4.014	205.784	0.717	2.841
Q_8	2.34	26840.59	4359.73	11.197	57642.56	12221.14	0.333	ND	0	0.043	0.346	1.216	9.064	0.734	ND
Q_9	3.98	44323.83	8933.544	5.671	95448.49	10091.815	0.043	6.969	0	0.138	0.445	0.792	96.545	0.185	ND

ND: not detected

4.6 Groundwater Flow Pattern

The groundwater table levels of various locations distributed throughout the study area are observed during the field visits. The observed heads are collected from both open wells and tube wells. The groundwater table is then interpolated by inverse distance weightage (IDW) technique to prepare the overall distribution of groundwater table throughout the area, as shown in figures 35 a-b.

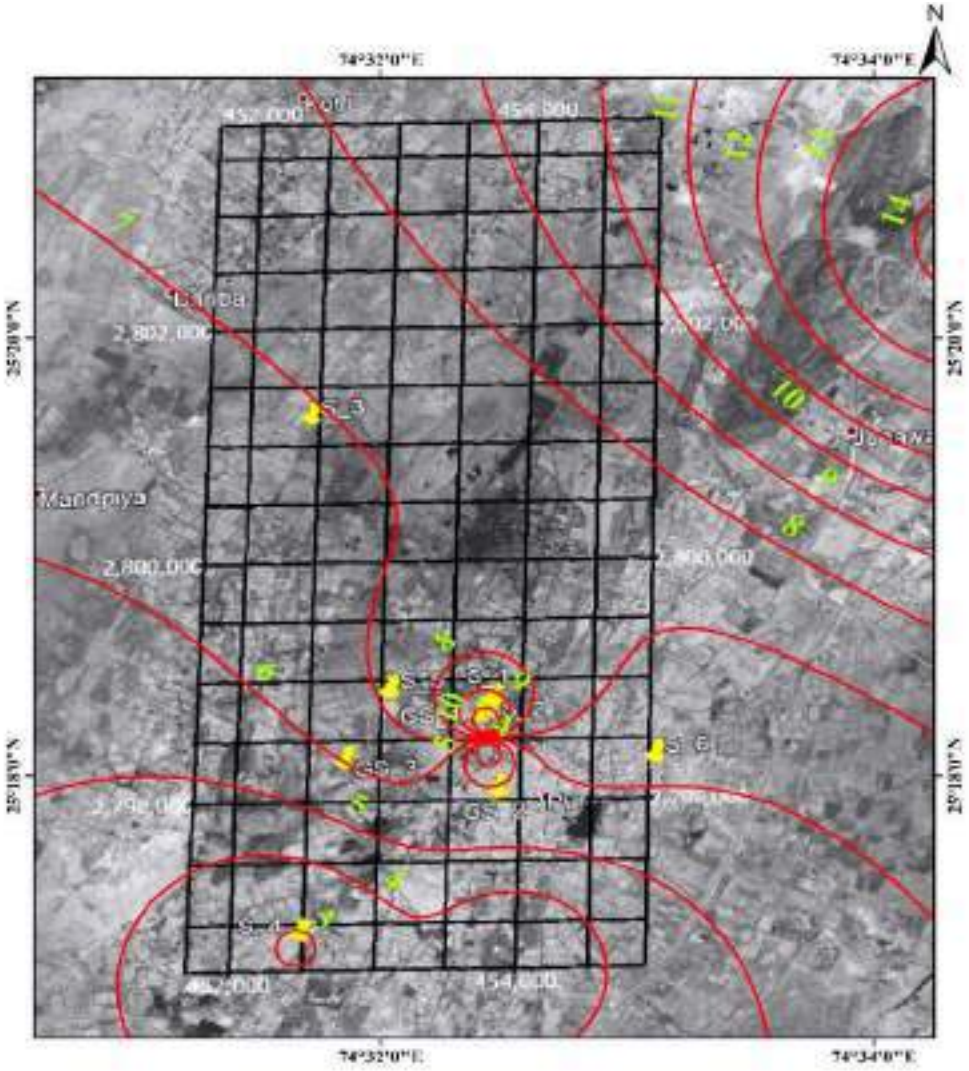


Figure 35 a: Variation of Groundwater table (Hydraulic head) in and around the study area with grid mark ABCD for better understanding.

As groundwater flows from a higher hydraulic head to lower, general groundwater flow direction is found to be from Southwest to Northeast direction i.e., from village to Jindal Industries. Groundwater flow below the Pur settlement could be established due to non-availability of the reliable groundwater level data.

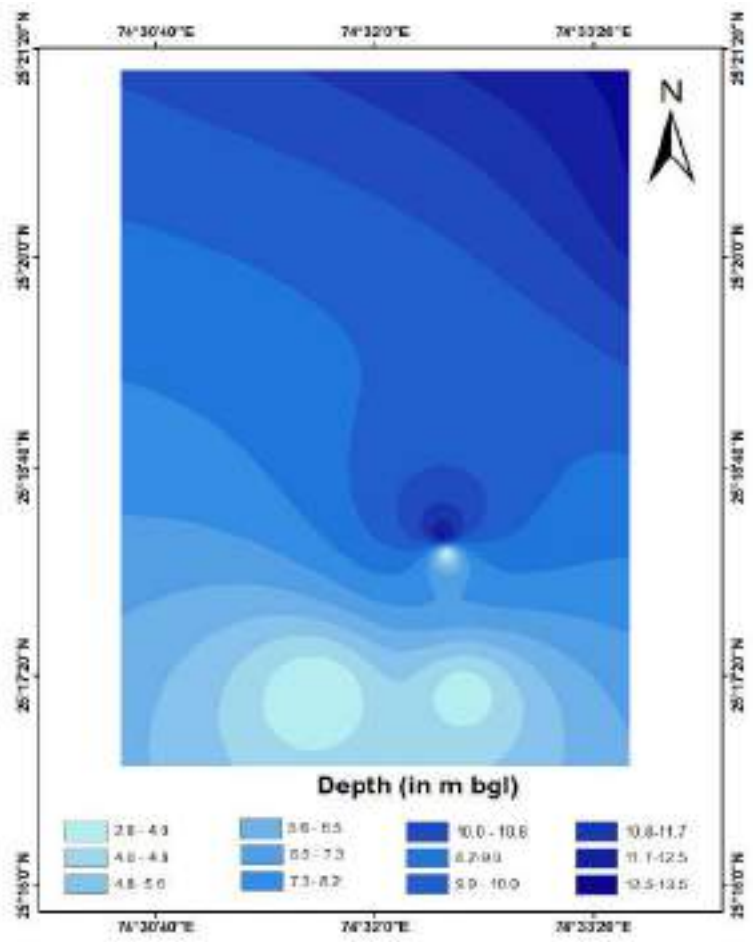


Figure 35B) Variation of Groundwater table (Hydraulic head) in and around the study area with grid mark ABCD for better understanding

4.7 Isotopic Analysis

Isotopes are the element having same atomic number with different molecular masses. Water (H_2O) is composed of two hydrogen and one oxygen atom. Oxygen has three stable isotopes, ^{16}O, ^{17}O, and ^{18}O whereas hydrogen has two stable isotopes, ^{1}H (Portion or P) and ^{2}H (deuterium or D), and one radioactive isotope, ^{3}H (Tritium or T). The oxygen and hydrogen combine in various forms to make water, thus making their isotopic composition a powerful tracer of the hydrosphere. Water resources develop unique isotopic compositions that can be indicative of their source or the processes that formed them. Isotopic composition differs for sea water, polar ice, atmospheric water vapor, and meteoric water. There are nine possible isotopic configurations for water, which are distinguished by their mass numbers as well as their characteristics. However, because of the low abundance of the heavier isotopes, almost all water molecules are of three isotopic combinations. Table 19 indicates the characteristics of three isotopic combination of water found generally.

Table 19: Characteristics of Water molecules with different isotopic combination

Properties	$^{1}H_2{}^{16}O$	$^{2}H_2{}^{16}O$	$^{1}H_2{}^{18}O$
Density @ 20°C	0.997	1.1051	1.1106
Boiling Point	100.0	101.42	100.14
Temperatory Density Max	3.98	11.24	4.30

Oxygen and hydrogen isotopic ratios are measured using gas source isotope ratio mass spectrometry (IRMS). Oxygen and hydrogen compositions are reported as delta values. Delta values (δ) are commonly used in light stable isotope geochemistry to express isotopic composition in terms of per mil (‰) deviation from a standard. Stable isotope ratios of deuterium/hydrogen ($^{2}H/^{1}H$) and $^{18}O/^{16}O$ of water are conventionally expressed as a per mil (‰) deviation from Standard Mean Ocean Water (SMOW) or VSMOW (Vienna SMOW). In carbonates, the isotopic composition of oxygen is sometimes compared instead to PDB, a standard based on the Peedee formation, a carbonate rock found in South Carolina.

Isotopic study is carried out in this study on four water samples collected from Rajkiya Uchh Madhaymik Vidhayalaya Pur (school in Pur village), which has a problem of water logging from the ground surface. As per the School authority, this water logging issue has started in July 2018. The isotope analysis is conducted to identify the source of this seepage water in the school premise. Measure of the ratio of stable isotopes oxygen-18 and oxygen-16, $\delta^{18}O$ and deuterium D are measured for the groundwater samples collected from a nearby hand pump, Drains (flowing outside from school), Government supply water, and seepage water from the school. Table 20 shows the location, source, isotope analysis results, EC and pH of collected water samples. The results from this analysis indicate that properties of seepage water and groundwater are found closer, and hence, a high groundwater table in this area is the main cause of waterlogging.

Table 20: **Result of Isotope analysis along with code, source, and isotopic analysis along with In-situ measured Electrical Conductivity and pH.**

S. No.	Code	Location	Source	δD	δO18	EC (mS/cm)	pH
1	BW4	N 25-degree 17.703 m E 074-degree 32.561 m (School)	Seepage	-16.43	-1.54	2.4	9.22
2	BW5		Water supply from chambal	-45.28	-6.11	0.32	8
3	BW6		Drain water from school	-33.17	-4.15	2.06	7.15
4	BW7		Hand pump	-22.69	-2.47	4.37	7.55

Summary and conclusion

Based on the comprehensive site surveys followed by a series of field experiments conducted during 07-11 November 2019 and 28 January to 01 February 2020, the findings of this study are concluded in this section. Preliminary observations based on the field survey and secondary data gathered from different sources of the project site are mentioned first. The results of various field experiments and laboratory analysis in context of the existing building cracks are concluded next followed by the recommended guidelines to mitigate the problem.

Preliminary observations

Initial field observation around the Pur village indicates that the in-situ rock exposures have been significantly affected as a result of growing inhabitations in the area. Due to such incursions, only partially eroded and isolated remnants of hillocks are found in the study area. Besides, many of the hillocks have virtually disappeared in the vastly expanding village. During the visit to the Laxmi temple (*Teli mandir*), prolific cracks and fissures were clearly visible in transverse and vertical-horizontal directions. As such, examination of one partially eroded hillock near '*Baoli Naka*' revealed fragile exposures of grey black mica-schists with dip of 75-80 degrees in the N-130 degrees direction, implying strike of N40-220 degrees, which also seems to be slightly disturbed in nature. The dip direction also seemed to be vaguely towards the adjoining pond. The spot examination of the geological formations in the Sukhadia stadium, situated on the periphery of Pur village indicated presence of isolated outcrops of schistose quartzites within the alluvial expanse. The quartzites displayed dips of 80-85 degree towards southeast and a strike of N50-230 degree. The quartzites also showed clear evidence of displacement due to faulting in the geological past as manifested by presence of slicken sides with visible silicification on the steep rock face(s). The project area contains gneiss and schist (Bhilwara Super group); gneiss, schist, phyllite, slate and limestone (Aravalli Supergroup); sandstone, shale and limestone (Vindhyan Super group); and alluvium as the major water bearing formations. The aquifers are localized within the weathered, fractured and jointed hard rock zones.

Observations from field experiments

A total of 19 geophysical surveys were conducted around the village using 06 vertical electrical soundings (VES), 11 electrical resistivity tomography (ERT) surveys, and 02 Surface nuclear magnetic resonance (SNMR) surveys using ground magnetic resonance

(GMR). Findings of these VES surveys show that the study area contains thin top soil/alluvium of thickness varying between 1-5 m. The top layer of sand is underlain by weathered hard rock (schistose quartzite) having thickness ranging from 2-7 m, with its maximum value at *Sukhadia stadium*. Besides, the top veneer is directly comprised of weathered hard rock at *Jindal Mata Mandir* as seen from the high resistivity of the topmost layer. The above interpretation is corroborated by the presence of isolated outcrops (schistose quartzite) dotting the area. The rocks in these outcrops show steep dips towards SE, with presence of slicken sides at *Sukhadia stadium*, pointing to the incidence of displacement of rocks in the geological past. The weathered schist/quartzite is indicated to be underlain by hard/compact Schist/quartzite at depths varying between 5 m below the surface at *Pathwari* site and 9.5 m below ground level at *Sukhadia stadium* site.

The findings of 2-D electrical resistivity tomography are matching well with the 1-D VES results and showing the similar lithological pattern at the common sites around the Pur village. Further, it was observed from the 2D ERT inversion that a sandstone/soil is present below 10m from the ground surface between 60m to 80m of the survey at site S_1 (*Pathwari*) as a sudden drop in resistivity from 717 Ohm-m to 201 Ohm-m was observed. A similar type of pattern was observed at S_3 (*Jindal Mata Mandir*) site. It is to be noted that the top soil depth at GS-2 site present nearby to *Bada Mandir* in the problematic area is found more as compared to the other sites situated at the village periphery towards the mining industry. A sudden drop in resistivity along the survey line was also observed from ERT inversion at GS_2 around 60m from the starting point. This shows a presence of vertical fracture/anomaly as resistivity value was found to drop from 114 Ohm-m to 90 Ohm-m which continued throughout the depth. The similar pattern was observed between 80m-100m from the starting point showing vertical foliation in the underlying rock. Furthermore, a saturated soil seems to be present between 60-80 m away from the starting point throughout the subsurface depth. A similar type of soft material zone is also observed at 15-20 m depth below the weathered schist at the starting point of the ERT survey. A significant variation in subsurface formation is thus observed vertically and horizontally within the survey length in the problematic area.

A significant variation in water content and hydraulic conductivity observed with depth of SNMR survey performed at two sites further indicates towards the existence of soil strata heterogeneity. ERT at *Ghati ke Hanuman* area revealed that the area is having heterogeneous geology both laterally and in vertical direction. Fractured schistose quartzite/gneiss possibly filled water in fractures upto a depth of about 27 m was observed at this site. ERTs near *Old*

masjid and near *Bada mandir* area revealed that the geology is composed of schistose quartzite some in solid and remaining in weathered form. Sudden drops in resistivity along/vertical to the survey lines were observed from ERT surveys in and around the Pur village. This shows a high possibility of vertical and lateral fracture/anomaly existence in the top subsurface. Furthermore, saturated soil zones are also observed at some random depths along the survey lines below the weathered schist. These types of subsurface anomalies are prone for differential land settlement. The average water quality parameters are found to be within safe limits for potable water (BIS) except observing slightly brackish water at some locations.

A perusal of the interpreted results from these hydro-geophysical surveys shows that the top subsurface of 40 m at the target area is comprised of 2-4 different geological layers and is indicating presence of fractures/anomalies. The evidences relating to proneness to displacement within hard rocks strengthen the possibility of generation of new cracks and fractures in the area. In general, the village geology of its top subsurface is found significantly heterogeneous in nature. It contains varying thickness of sand mixed with gravels underlain by weathered/hard schist at random places making it susceptible under the possible vibrations, surface overburden or other (sub)surface modifications. Likely water seepage taking place from leaky drainage network seems further aggravating the differential land settlement. Extreme rainfall event of 1023 mm observed in 2019 monsoon period appears contributing in land settlement. The isotopic analysis indicates that properties of seepage water and groundwater are found close, and hence, the high groundwater table in the surrounding area of the school seems causing seepage and waterlogging.

Recommendations

Based on the hydrogeological survey of the Pur village site, the following guidelines are proposed for tackling the existing problem of building cracks.

- The top subsurface of the village area is heterogeneous with patches of weathered/hard rocks and soil, particularly in the central part of the village, and seems sensitive in the context of differential land settlement. Increased water content, any forms of vibrations, surface overburden, and any other (sub)surface modifications would trigger the existing problem and must be avoided in future.
- The observed signature mapping of surface and groundwater show that the village area is lacking the proper surface and subsurface drainage facility. The existing surface drainage

network needs maintenance for checking household water effluent seepage to the underlying subsurface formations. Proper drainage of runoff water generated during the rainfall storms is also required to avoid its recharge in the village area.

- The study reveals that some areas of the village settlement are having localized high groundwater table resulting in the problem of groundwater seepage and waterlogging. The *Rajkiya Uchh Madhaymik Vidhayalaya Pur* (school in Pur village), is currently facing a problem of water leakage from the ground surface. It is proposed to build a subsurface drainage ditch at the up-gradient side to collect and remove the drainage water to tackle the existing waterlogging issue in the school premise.

- Groundwater quality of the study area is found safe except it's slight brackish nature at some places. The executive summary of this investigation is prepared altogether with CIMFR and CBRI teams and is also attached herewith.

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PROJECT NO.
SSP/R/421/19-20

Report
on

Scientific Studies on Blast Induced Ground Vibration & Air Overpressure and Investigation on its Damage Potential vis-à-vis Housing Structures in Pur Village, Bhilwara, Rajasthan



Submitted to

Office of District Collector and District Magistrate,
Bhilawara, Rajasthan State Govt.

By

CENTRAL INSTITUTE OF MINING & FUEL RESEARCH
(Council of Scientific and Industrial Research, New Delhi, Govt. of India)
Regional Research Centre, Bilaspur (CG) 495001
Telefax: +91-7752-271582, www.cimfr.nic.in

CSIR-CIMFR

JANUARY 2021

Report
On

Scientific Studies on Blast Induced Ground Vibration and Air overpressure and Investigation on its Damage Potential vis-à-vis Housing Structures in Pur Village, Bhilwara Distt., Rajasthan

Project No.: SSP/R/421/19-20

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Signature of the Project Proponents

15.01.2021.

(Harsh Kr. Verma)
Sr. Pr. Scientist & Project Leader
CSIR-CIMFR Research Centre Bilaspur

15/01/2021

(S P Singh)
Scientist-in-Charge
CSIR-CIMFR Research Centre Bilaspur

CSIR-CIMFR Authorized Signatures

15/01/2021

(P.K. Mishra)
Sr. Principal Scientist & HOS,
Project Monitoring & Evaluation

18/01/2021

(R. V. K. Singh)
Chief Scientist & HOS
Business Development & Industrial Liaison

CENTRAL INSTITUTE OF MINING & FUEL RESEARCH, DHANBAD

(COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH)

REPORT ON

Scientific Studies on Blast Induced Ground Vibration and Air overpressure and Investigation on its Damage Potential vis-à-vis Housing Structures in Pur Village, Bhilwara Distt., Rajasthan

CSIR-CIMFR PROJECT NO.: SSP/R/421/19-20

BY

INVESTIGATING TEAM

Dr. H. K. Verma,	***Sr. Pr. Scientist & Project Leader***
Dr. P B Chaudhary	***Sr. Pr. Scientist***
Mr. M K Meena	***Technical Officer***
Dr. R. D. Dwivedi	***Sr. Pr. Scientist***
Mr. Anil Swarup	***Sr. Pr. Scientist***
Dr. J K Mohnot	***Chief Scientist***
Dr. R. K. Goel	***Retd. Chief Scientist***
Dr. P. K. Singh	***Director***

Executive Summary

District Magistrate and Collector, Bhilwara vid their Letter no Ref: Jud/l9/26667 dated 09.10.2019 requested CSIR-CIMFR Dhanbad to evaluate the impact of the blast induced ground vibration. A team of scientist and technical officers of CSIR-Central Institute of Mining and Fuel Research, Dhanbad and Regional Research Centres at Bilaspur, Roorkee and Nagpur carried out a detailed investigation in the mine site as well as houses in the Pur village in three rounds of field investigations.

CIMFR team have conducted altogether 15 experimental blast rounds at Dhedwas Iron Ore mine in different phases of field investigations. The parameters of the experimental blast round were decided after review of the data of mine blasting operations carried out during April 2018 to Dec 2019. It may be noted that experimental blasts have been conducted with different combination and range of parameters. Small as well as large blasts both in terms of number of holes and total explosive quantity in blasts rounds were conducted both in overburden as well as in bottom benches. In experimental blasts holes depth varied from 3.5 m to 12.0m, total charge varied from 3.06 ton to as high as 10.06 tons, no of holes varied from 39 holes to 195 holes. Although, average maximum charge per delay in day to day mine blasting operation is 100 kg, experimental blast rounds upto 190 kg have been conducted to create a sever condition and to evaluate the impact of vibration. The range of experimental blast design parameter covered entire range of day to day blasting practices of Dhedwas iron ore mine, Bhilwara.

Comprehensive vibration monitoring was carried out during blasting experiment. The complete exercise was carried out in presence of representatives from Pur village. Altogether vibration was monitored at 56 different locations. Monitoring locations were chosen considering size of blast, mine location the distance of the presence of any domestic structures. The monitoring locations include domestic houses and other prominent structures of the Pur village such as Temple and Mosques and community hospital. In all the cases, measurements were carried out in the direction with an intention to record maximum vibration as well as air overpressure intensity. Simultaneous vibration monitoring both in close-field as well as far-field using four set of four channel monitoring system was carried out. All these instruments are four-channel seismographs provided with one tri-axial transducer for monitoring of vibration (in mm/s or inch/s) and one-channel for monitoring of air overpressure/noise in dB (L) or Pa. The

instrument records vibrations in three orthogonal directions [i.e. Longitudinal (L), Vertical (V) and Transverse (T)] and peak frequency of vibration in individual directions as well as compute the peak vector sum of vibrations. The instruments also permit full wave recording at any instant of time for a preset duration. Sensors are having an articulation of spikes for proper coupling with the ground for more precise reading of particle velocity.

Observed vibration data were analysis and a site specific mathematical relationship has been established correlating the maximum explosives weight per delay (Q_{max} in kg), distance of vibration measuring transducers from the blasting face (D in m) and recorded peak particle velocity (V in mm/s) using square root scaled distance at 95% confidence interval. The equation which shows attenuation characteristics of the blast induced ground vibration were further analysed in details to understand the damaging effect of vibration on domestic houses of Pur village with different blast design parameters.

It is observed that the blast induced ground vibration and air overpressure beyond a distance of 500 m from the blasting site remained less than 2.00 mm/s (with frequency ranging from 2.0 Hz to 30 Hz) and 115 dB(L) against recommended safe values of 5.0 mm/s and 134 dB(L) respectively. Analysis of propagation characteristics of the vibration reveals that ground vibration beyond a distance of 1.5 km decayed to less than 1.0 mm/s in majority of the cases. In most of the housing structure beyond 2.0 km from the blast site, equipment did not record any vibration and the values were not noticeable by human body. Therefore, it is concluded that observed blast induced ground vibration values are safe and well within the permissible limit as per the recommendations of Directorate General of Mine Safety (DGMS). Based on the findings of the study it is concluded that impact of blast induced ground vibration and air overpressure in causing damage to the housing structures of Pur village, approx., 2.5 km away is practically not possible. This is further corroborated by the facts that the houses which are between Dhedwas iron mine and Pur village does not have cracks and are not damaged. Cracks in the houses may be accounted to hydrogeological set-up of Pur village and its interaction with the weak non-engineered foundation of the houses.

It is however, recommended that an expert agency may be engaged to supervise blasting operations at Dhedhwas iron ore mine. Vibration monitoring shall be carried out by such expert agency in close co-ordination with representative of Pur village.

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Report on

Scientific Studies on Blast Induced Ground Vibration & Air overpressure and Investigation on its Damage Potential vis-à-vis Housing Structures in Pur Village, Bhilwara District, Rajasthan

1.0 INTRODUCTION

Pur is a village located in Bhilwara District of Rajasthan. Geographically, it is situated at 25°27°50'N & 74°03°75°50'E & 410 m above the Mean Sea Level (MSL). Population of Pur village is approximately 250000 and there are roughly 4500 housing structures. Many of the houses/structures/roads/drains in and around the village have developed cracks and major structural damage rendering structures non-habitable.

It is pertinent to mention here that there is a low grade iron ore (Magnetite) reserve near Pur village. This reserve is allotted to Dhedwas Iron Ore and Associated Mineral Mine of M/s Jindal Saw Limited (JSL) for commercial exploitation. M/s JSL is carrying out mining activities. The rock containing iron ore is broken down in small pieces by drill and blasting method. The fragmented rock material is further processed to prepare iron pallets for use in steel industry. Villagers have made complaints to District Magistrate that the blasting operation in the Dhedwas Iron Ore mine is the primary cause of the cracks in the domestic houses. The mine is approx.. 2.5 km away from the village. A location map showing relative position of the Dhedwas Iron Ore mine and Pur village is presented in Figure 1.

A high level committee meeting chaired by Chief secretary, Govt of Rajasthan was held on 5th July 2019 at Jaipur and it was decided to carry out a comprehensive scientific study to identify and characterize the root causes of cracks in the housing structures of Pur village by engaging expert institutions. It was decided in this meeting that three institutes namely IIT Roorkee, CSIR-Central Building Research Institute (CBRI), Roorkee and CSIR-Central Institute of Mining and Fuel Research (CIMFR), Dhanbad be engaged for scientific investigations. IIT Roorkee was entrusted to carry out investigation of crack by evaluating hydro-geological and sub-surface investigation. CBRI Roorkee was advised to look into the contribution of building foundation and geotechnical part.

Similarly, District Magistrate and Collector, Bhilwara vid their Letter no Ref: Jud/l9/26667 dated 09.10.2019 requested CSIR-CIMFR Dhanbad to evaluate the impact of the blast induced ground vibration.

CSIR-CIMFR Team have carried out scientific study by conducting field trials in the Dhedwas Iron Ore mine by conducting blasting experiments by varying various blast design parameters and investigation of blast Induced ground vibration & air overpressure (AOP) in and around houses and mine near Pur Village. This report is record of the investigations carried out by CSIR-CIMFR Team at Pur village. This report includes details of the blasting field trials in the mine, monitoring of the blast induced ground vibration, analysis of the data, and final recommendations and concussions as an outcome of the scientific investigation.



Fig. 1: Map showing relative location of Dhedwas Iron Ore Mine and Pur Village

2.0 STATEMENT OF THE PROBLEM

CSIR-CIMFR team initially made survey of the damage in the housing structures of Pur village. Various domestic houses were surveyed and the team have taken observation on cracks, their characteristics, location, width etc. Photographs of the cracks in the domestic houses and temple of Pur village are presented in Fig(s) 2 to 10.

Initially CSIR-CIMFR Team carried out a detailed survey of the house to evaluate the problem of the cracks in the housing structures along with district administration team. During survey of the cracks in the housing structures, it was informed by the local authorities that there are more than 350 buildings in which cracks developed. These cracks were present in the double storey as well as single storey buildings. Cracks were present almost in every location of the house such as outer wall, inner wall and floor in the houses, celling and floor level. Crack in walls were vertical to sub-vertical cracks. It was also noticed that this crack prone area is situated at higher elevation compare to other locality of the Pur village. The elevation of the village varies from 410m to 435m above MSL. It is important to mention here that the mine is approx. 2.5 km from the village. Most of the houses having cracks are at certain elevated location of the village. Some of houses closer to mine does not have cracks. Further, as per IMD data, no seismic activity has taken place during period of July, 2018 to January, 2019. It is surprising to note that > 350 buildings have suffered such kind of damage without any seismic event.

During interaction with the villagers, they have an apprehension that the crack were developed due to blasting activities carried out at Dhedwas Iron Ore mine. Team of Scientists of CSIR-Central Institute of Mining and Fuel Research was entrusted to carry out scientific investigation to evaluate the damage potential of the blasting vibration and contribution of the blasting vibration in development of the crack in the housing structures of the village.

CSIR-CIMFR Team conducted three round of the field visits to Pur village and mine site as part of this investigation. During these field visits, a comprehensive investigation was carried out by conducting experimental blast in stages in mine site and concurrently vibration monitoring were carried out at more than 50 different locations around mine and Pur village.



Fig 2: Cracks along column in Laxminarayan Temple



Fig 3: Cracks in the corners of the Laxminarayan Temple

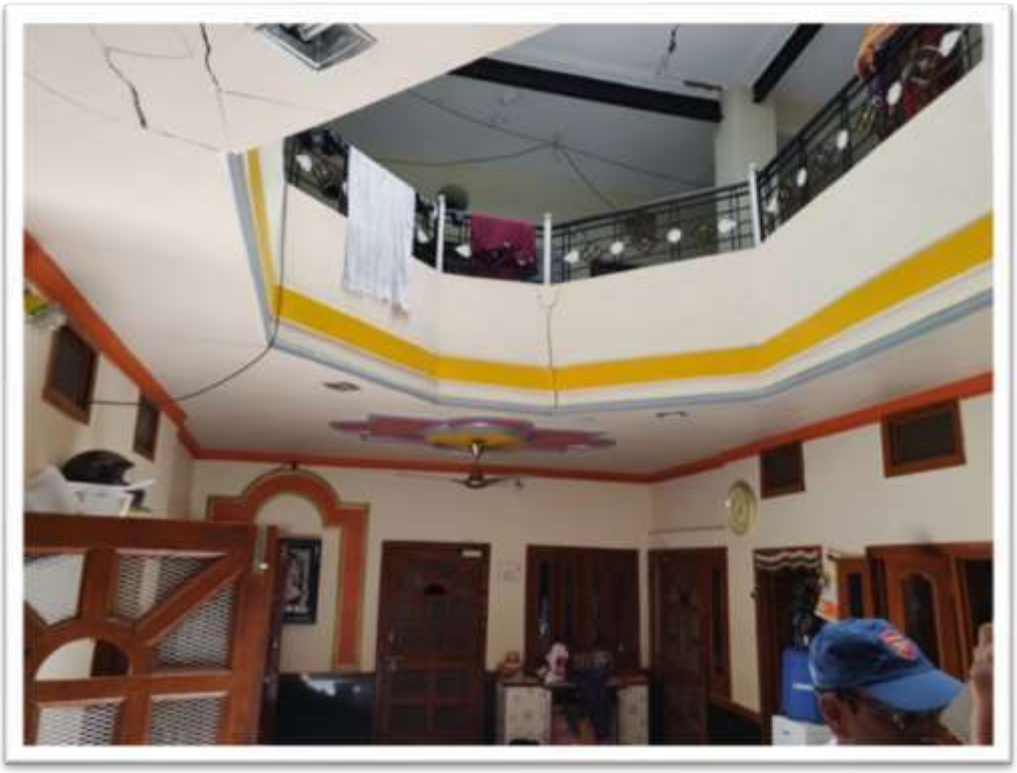


Fig. 4: Cracks in the housing structure at middle level



Fig 5: Cracks along the joints of the domestic structures



Fig 6: Cracks along the joints of the domestic structures



Fig 7: Widening of Separation joint along two joints indicating settlement of the foundation



Fig 8: Cracks across the beam and column of housing structure



Fig 9: Cracks in the floor level of housing structures



Fig 10: Cracks in the floor level of housing structures

3.0 OBJECTIVES OF THE STUDY

In light of above discussion as presented in the preceding section 2.0: Statement of the Problem, following objectives of the studies were mutually identified in consultation all stake holders including representative of the Pur village.

a. CSIR-CIMFR Team will jointly conduct study with CBRI Roorkee and IIT Roorkee to investigate impact of blast induced ground vibration and air overpressure, directly or indirectly as cause of cracks in the housing structures of Pur village, Bhilwara District.

b. CIMFR Team will carry out comprehensive blast vibration and air overpressure study using multiple seismographs at Pur village and records blast vibration and air overpressure induced by the blasting operation in the Iron Ore mine of M/s Jindal Saw Ltd., Dhedwas, Bhilwara.

c. Simultaneous blast vibration and air overpressure monitoring at different distance will be carried out in different phases of field investigations to evaluate the impact of various blast design parameters on the intensity of the blast induced ground vibration and air overpressure. Efforts will be made to record and analyse all possible combination of the blast design parameters which represent the blasting operations conducted by the Iron Ore mines of M/s Jindal Saw Ltd., (JSL) Dhedwas, Bhilwara

d. CSIR-CIMFR Team will carry out measurement of blast induced vibrations and air overpressure at different structures, both foundation and ceiling level depending on the site requirement with due consideration to vulnerability and proximity of the critical structures. Following parameters of blast induced vibration will be measured and calculated on during field investigations:

   i. Ground vibration in terms of peak particle velocity (mm/s)
   ii. Ground acceleration in term of "g"
   iii. Displacement (mm)
   iv. Vibration frequency, Hz.
   v. Air Overpressure/ Noise in term of dB (L)
   vi. Peak Vector Sum, mm/s

e. Analysis of the blast induced ground vibration and air overpressure to derive precisely attenuation characteristics and its damage potential in light of various national and other international standards.

f. CSIR–CIMFR will submit a technical report to District Administration incorporating details of the field investigations, analysis of the observed vibration and air overpressure data along with conclusion and recommendations.

4.0 REVIEW OF BLASTING PRACTICES IN DHEDWAS IRON ORE MINE

Before commencement of the field investigation, CIMFR team collected all previous blasting related data pertaining to period from April 2018 to Dec 2019. It was reported that the cracks were observed during this period only. The period CSIR-CIMFR Team also reviewed blasting practices of the iron ore mine by collecting all the blasting data since April 2018 to Dec 2019. Cracks in the housing structures of Pur village were reported to have developed during this period only. The review of the blasting operation were done in light of the permission granted by Directorate General of Mines

Safety (DGMS) vide letter No. AJR/DMS/Perm-164(1-B)(a)/20183 dated 04.10.2018 (copy enclosed as Annexure-III). DGMS has recommended following parameters for deep hole controlled blasting at Tiranga Block of Dhedwas Iron Mine based on scientific studies

Bench Height (m)	Drill Hole Dia (mm)	Max. No of Holes in a Round	Pattern of Holes(m)		
			Depth (m)	Spacing (m)	Burden (m)
8 - 10	115	200	9 - 10	3.0 - 3.5	2.5 - 3.0

DGMS has given permission of 10 mm/s as safe vibration limit at dwellings/structures falling within 300 m of the place of blasting and not belonging to the management. In addition to above, DGMS have recommended safe limit of vibration to be 5 mm/s for Tiranga Block, 10 mm/s for Dhulkhera Block (with frequency 8-25 Hz for both the blocks and 15 mm/s for Sura block having frequency greater than 25 Hz. The detailed recommendation of DGMS is appended in Annexure-III,

M/s Jindal Saw Ltd., Bhilwara submitted all the blasting related data for the period April 2018 to Dec 2019. Review of the blasting operation performed in the past at Dhedwas mine reveals that blasting practices in the mine have holes depth ranging from 6.0 m to 10.0 m. Few blasts with 12.0 m depth have also been taken in the past. Site mixed emulsion explosive with cast booster is used for blasting operation. The total charges in blasting round as per usual practice are mostly in the range of 8 tons-10 tons. No of holes in blasting round are in the range of 100 – 150 holes having dia. 115 mm. The blasting practices were found to be in accordance with the DGMS permission in majority of the cases.

While conducting the blasting experiment as a part of this scientific investigation, parameters of previous blasting practices were also included. Efforts were made to create severe blasting experimental conditions and monitor impact of such blasting on the vibration attenuation characteristics and resulting damage potential of the blast induced ground vibration on domestic structures.

5.0 GEOLOGY OF THE PROJECT AREA

Predominant geological formation includes rock types belonging to Bhilwara Super Group, Aravallis and Vindhyan Super group. The depth of soil varies from 5 to 10 m, and in some areas rock outcrops are seen above the ground. Predominant soil found in the area are Clay loam or medium black (in northeastern hilly areas), loam (predominant soil type) and, sand and sandy loam (near the banks of rivers/streams). The origin of landform is fluvial (alluvial) along River Kothari, dunudational (buried pediment) in most places, and structural hills in the northeastern outskirts of the city.

The topography of the area is characterized as rugged in North- Eastern and South- Western part and the remaining part is nearly peneplain. The maximum elevation is 529 m above msl towards the North- Western direction of the Pur village and the minimum elevation is 410 m above msl near the Government Senior Secondary school, Pur. Kothari River with several nallas forms the main drainage of the area. Drainage pattern in the area is dendritic. Small water bodies are present.

Pur village is located on the southern edge of Aravali hills. This area comes under the Potla Formation of the Mangalwar Group. Its basement is basically consisting of Granite gneiss-amphibole gneiss and garnetiferous mica schist trending NE-SW moderate to high dip towards NW Bhilwara super group.

As per the seismic zoning map of India, Pur Village, Bhilwara District falls under the Zone II, which is the lowest earthquake risk zone in India. This zone is termed as “low damage risk zone.

Bhilwara is located near the right bank of River Kothari, a tributary of River Banas, an important river of Rajasthan. River Kothari originates in the eastern slopes of the Aravali ranges in Rajsamand District. The river flows through Rajsamand and Bhilwara Districts for about 51 km in a hilly region, and 100 km through plains, before joining the Banas near Nandrai village in Bhilwara District. The other tributaries of Banas in Bhilwara District are Bedach and Khari. River is rain-fed and is a seasonal flowing river. River carries good flow during normal and above normal rainfall years. Meja Baandh (Meja Dam) constructed across Khari River, about 20 km northwest of Bhilwara is an important source of water for irrigation, industrial and drinking purposes.

Major water bearing formations are gneiss and schist (Bhilwara Supergroup); gneiss, schist, phyllite, slate and limestone (Aravalli Supergroup); sandstone, shale and limestone (Vindhyan Supergroup) and alluvium. Ground water occurs under unconfined to semi-confined condition.

Weathered zone below the water table acts as a good storage. The joints, fissures and other plains of structural weakness as well as their extent, size, opening and inter connection control occurrence & movement of ground water. Phyllites and schists are predominating in Bhilwara City and these formations are intercalated with dolomitic limestone, quartzite and basic intrusive.

6.0 FIELD INVESTIGATIONS

Before commencement of the field investigations, a team was constituted in co-ordination with the district officials which have representative from villagers to ensure transparency and witnessing of the experimental blasts. Two persons from the Pur villager were nominated by the district official to represent the villagers and they were made part of all the experimental blasting study in all the field visits. Fig 10 shows Photographs of Dhedwas Iron Ore mine working in different benches. Photograph of CSIR-CIMFR team along with representatives of Pur village is presented in Fig. 12.



Fig 11: Photograph showing Dhedwas Iron Ore mine near Pur Village



Fig. 12: CSIR-CIMFR team along with representatives of Pur Village at Dhedwas Iron Ore mine during field experiment in the mine.

CSIR-CIMFR Team also reviewed blasting practices of the iron ore mine by collecting all the blasting data since April 2018 to Dec 2019. Most of the cracks were reported to have developed during this period only. The parameters of the experimental blast were decided to represent the day to day blasting operations of iron ore mine. The experimental blast design parameters were chosen to represent day to day blasting operation with an endeavor to constitute severe condition so that the maximum damage potential of the blast vibration may be evaluated and its impact of the surrounding housing structure of the Pur village be quantified.

During field experiment comprehensive vibration and air overpressure monitoring was also carried out. The monitoring locations were chosen in close consultation with the all the stake holders including representative from the Pur village. The objective of the team was to conduct the experimental blasts and monitor the blast induced ground vibration and air over pressure at different locations in Pur village and to analyse its adverse impact on domestic houses/structures in Pur village.

6.1 Details of Experimental Blasts

CSIR- CIMFR Team conducted altogether 15 experimental blast rounds in two different phases of field investigation at the Dhedwas Iron ore mine of M/s Jindal Saw Ltd., Bhilwara. First phase of experimental blasts and monitoring was carried out during 01.02.2020 to 06.02.2020 and second phase of the investigations was carried out in during 03.03.2020 to 06.03.2020. The parameters of the experimental blast round were decided after review of the data of mine blasting operations carried out during April 2018 to Dec 2019. The parameters of the experimental blast round are presented in Table 1.

Experimental blasts were conducted in both overburden (upper benches) and iron ore benches (lower benches) of JSL mine. Bulk explosive were used for charging the blast holes along with cast booster of 100g as primer charge. Bottom hole initiation is done using Down-The-Hole Shock tube/NONEL initiation system. The blast holes having depth more than 10m were double decked with solid decking. Two shock tubes were used with deck separating two explosive decks in one blast hole. Shock tube with lower delay time of 450ms was used in bottom and of 500ms was kept in top deck. Trunk line connection was done by using Shock tube/NONEL of varying length and different delay for providing delay between holes and rows in a blast round.

Detailed data of blasting experiment data are presented in Table 1 which include detailed parameters of experimental blasts such as date of blast, number of holes, average hole depth, Total and maximum chare per delay, average burden and spacing used in experiment blast rounds. Different steps involved in charging and firing of the blast holes during experimental blast at mine site are presented in Fig(s) 13(A to F) for a detailed illustration. Locations of various experimental blasts in mine are presented in Fig 14.

It may be noted that experimental blasts have been conducted with different combination and range of parameters. Small as well as large blasts both in terms of number of holes and total explosive quantity in blasts rounds were conducted both in overburden as well as in bottom benches. In experimental blasts holes depth varied from 3.5 m to 12.0m, total charge varied from 3.06 ton to as high as 10.06 tons, no of holes varied from 39 holes to 195 holes. The range of experimental blast design parameter covered the day to day blasting practices of Dhedwas iron ore mine, Bhilwara.



13(A): 10 Ton Capacity Site Mix Emulsion (SME) Truck



13(B): Measuring of Explosive Density at Site before loading into blast holes



13(C): Double decked loaded blast holes



13(D): Stemming in loaded blast holes



13(E): Use of TLD for surface connection of blast holes



13(F): View of charged blast holes

Fig. 13: Photographs of different steps involved during experimental blast conducted at Dhedwas Iron ore Mine

Table 1: Details of the parameters experimental blasts conducted by CSIR-CIMFR Team at Dhedwas Iron Ore Mine, Bhilwara

Sr. No	Date	No of Holes	Hole Depth	Average Burden (m)	Average Spacing (m)	Average Stemming (m)	Max. Charge Per Delay (Kg)	Total Charge (kg)	Blast Location (RL) (m)	Blast Location (Bench No)
1	1.02.2020	90	4.0 - 12	4	4	2.8 - 9.4	60	9450	478	BENCH-1
2	1.02.2020	166	3.5 - 11	3.5	4	2.8 - 7.02	190	8430	470	BENCH-1
3	3.02.2020	195	3.5 - 6.0	3.5	4	2.8 – 4.0	50	8800	471	BENCH-1
4	4.02.2020	88	6.0 - 11.8	4	4	2.04- 9.1	60	9660	474	BENCH-1
5	5.02.2020	88	7.0 - 12	4	4	2.4 - 4.3	60	9320	474	BENCH-1
6	5.02.2020	116	7.0 - 12	3	4	2.4 - 9.2	60	6380	458	BENCH-3
7	6.02.2020	86	7.0 - 12	4	4	2.4 - 9.3	60	8720	472	BENCH-1
8	6.02.2020	114	7.0 - 12	4	4	2.8 - 4.0	60	9500	480	BENCH-1
9	3.03.2020	76	4.0 - 6.0	3	4	2.8 - 4.0	85	3065	425	BENCH-5
10	3.03.2020	119	5.0 - 10	4	4	3.4 - 6.5	90	10365	465	BENCH-2
11	4.03.2020	39	6.0 - 9.0	4	4	4.0 - 6.0	80	2800	432	BENCH-5
12	4.03.2020	134	4.0 - 10	4	4	2.8 - 6.5	90	9790	465	BENCH-2
13	5.03.2020	161	4.0 - 9.5	4	4	2.8 - 6.2	85	10080	459	BENCH-3
14	6.03.2020	75	4.0 - 6.0	4	4	2.8 - 4.0	55	4100	445	BENCH-4
15	6.03.2020	180	4.0 - 8.0	3	4	2.8-5.0	100	9400	437	BENCH-5



Fig. 14: Location of Experimental Blasts Conducted at Dhedwas Iron Ore Mine of M/s JSL Mine, Bhilwara

6.2 Monitoring of Blast Induced Ground Vibration and AOP

During two rounds of the field investigations altogether 15 experimental blast have been carried out incorporating vide range of blast design parameters which represent the day to day blasting

operation at Dhedwas iron ore mine of M/s JSL, Bhilwara. Blast vibration and air overpressure monitoring have been carried out at more than 60 locations such as housing structures, temples, mosque in and around Pur village during experimental blasts. In each phase of field investigations, four set of engineering seismographs of Instantel Canada Make have been used. All these instruments are four-channel seismographs provided with one tri-axial transducer for monitoring of vibration (in mm/s or inch/s) and one-channel for monitoring of air overpressure/noise in dB (L) or Pa. The instrument records vibrations in three orthogonal directions [i.e. Longitudinal (L), Vertical (V) and Transverse (T)] and peak frequency of vibration in individual directions as well as compute the peak vector sum of vibrations. The instruments permit full wave recording at any instant of time for a preset duration. Sensors are having an articulation of spikes for proper coupling with the ground for more precise reading of particle velocity. One such seismographs namely MiniMate Blaster is viewed in **Figure-15**.



Figure 15: View of MiniMate Seismograph along with external geophone and microphone

One of the most critical aspects of ground vibration monitoring is the mounting (placement) of transducers in the field. Good coupling refers to the transducer that maintains proper contact with the ground. Poor coupling can cause slippage or toppling of the transducer resulting in distorted, often higher vibration levels. Most recommendations agree that the best coupling can be

achieved by burying the transducer when the measurement surface consists of soil and by bolting or quick setting cement (plaster of paris) when the measurement on surface consists of rock or concrete. Burial is desirable for particle acceleration exceeding 0.2 g but it is essential if it is greater than 1.0 g (Dowding, 1996; Stagg and Engler, 1980; ISEE, 2005, ISRM, 1991). Coupling of sensors is illustrated in Fig 16.



Fig 16: Photograph illustrating sensor coupling using Plaster of Paris during vibration monitoring

In this study, coupling of the transducers were carried out using burial techniques in soil and plaster of paris (POP) in case of hard rock surface (**Figure-16**). During most of the blasting experiments simultaneous monitoring at different housing structure and ground surface using velocity meter were carried out.

During all these blasting experiments, monitoring of vibration and air overpressure/ noise in more than 50 locations were carried out using different types of engineering seismographs. Monitoring locations were chosen considering size of blast, mine location the distance of the presence of any domestic structures. In all the cases, measurements were carried out in the

direction with an intention to record maximum vibration as well as air overpressure intensity. The geophone trigger level for all the seismographs were fixed at 0.5mm/s. This indicates that the vibration value of ≥0.5mm/s will be recorded in instrument. The consolidated plan showing different vibration monitoring locations are presented in Figure 17.

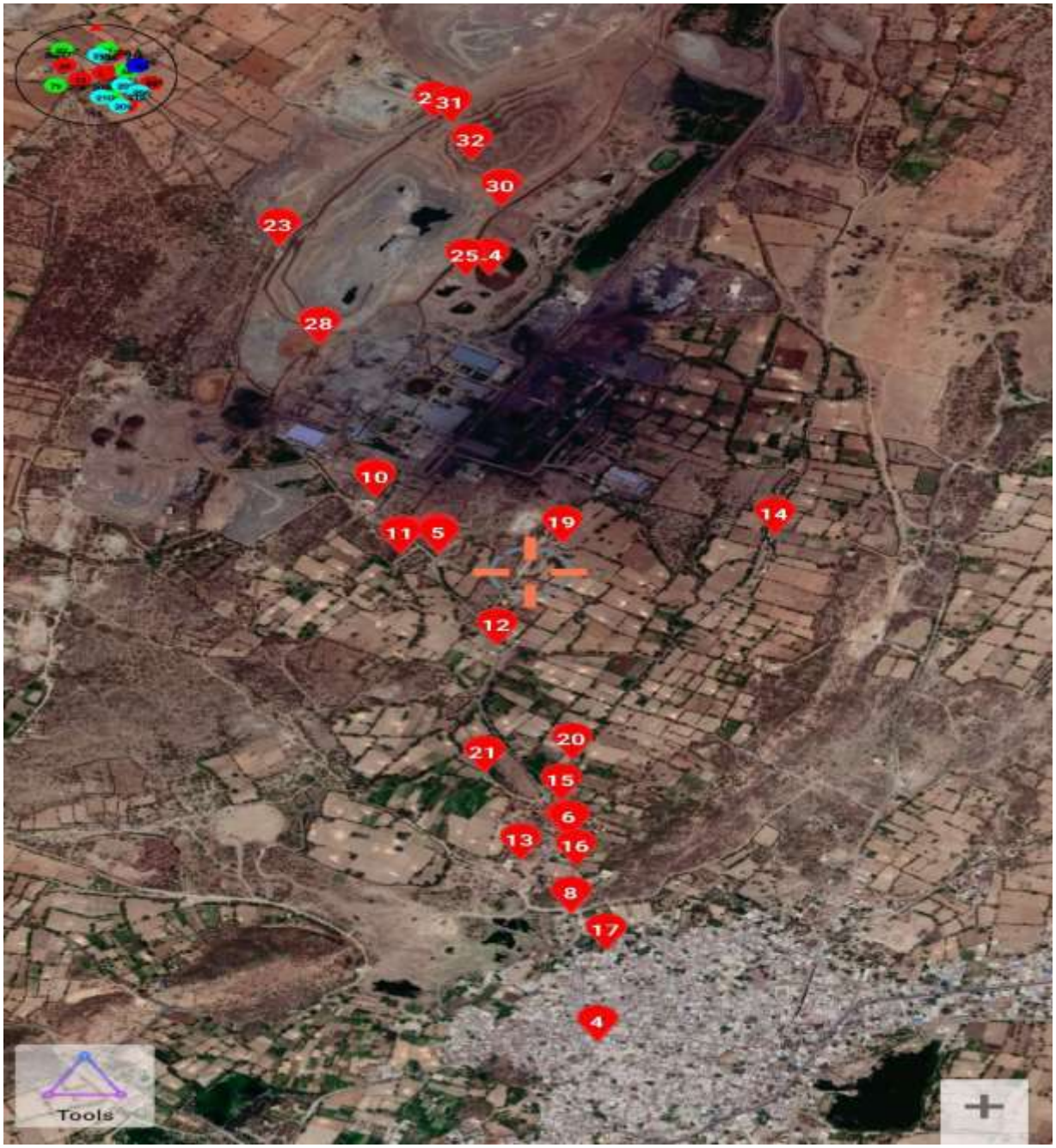


Fig. 17: Location of blast induced ground vibration & AOP monitors in Mine and Pur Village, Bhilwara

It is important to mention here that during initial rounds field investigation in the month of Feb 2020, far-field monitoring was carried out. Most of the houses of the monitoring was in the village houses of Pur Village. In second phase of investigation, close field monitoring of the vibration was carried out. Therefore, in second phase experimental investigations, majority of the minoring locations were intermediate location between mines and Pur village and few monitoring locations within the mine premises. This is required for developing mathematical model of blast vibration propagation characteristics precisely. Photographs of the vibration and air overpressure monitoring locations during experimental investigations are presented in Figure 18 (A-P).



A. Near mine Gate 1, Jindal plant,Tiranaga Mata Temple, Pur Village



B. Guru-Kripa Restaurant, Roadside, Pur Village





C. Roof top, Sunarogi Temple, Pur Village



D. House near Kali Babadi, Pur Village



E. House in Mundar road, Pur Village



F. Miththu Ji Mali Farm House, along Pur Road



G. Laxminath Bada Madir

H . JSL Electric Grid, M/s JSL Mine





I. Mine site office, in M/s JSL Mine

J. JSL Weigh bridge no.2, in M/s JSL Mine



K. Mill Tailing Road, NE in M/s JSL Mine



L. Dump yard road in M/s JSL mine



M. Sunarogi Temple, Pur Village



N. Eidgaah Masjid, Pur Village



O. Rajshree Kirana & Bhojnalay, Pur village



P. Hanuman Temple, Pur Village

Fig. 18 (A-P): Various vibration monitoring location completed by CSIR-CIMFR Team during two phases of field investigations in Pur Village

7.0 ANALYSIS OF THE DATA

7.1 Observed Vibration and AOP Data

CSIR-CIMFR Team conducted 15 rounds of the blasting experiment with different permutation and combination of the blasting parameters. The parameters of the blasting experiments are presented in Table 1. The values of observed peak particle velocity, frequency, air overpressure (AOP), monitoring location, distance of the monitoring are given in Table 2.

7.2 Attenuation Characteristics of Vibration and Air Overpressure

When an explosive is detonated in a blast hole, large amount of energy is generated and it transmits along the ground. Part of this energy is utilized for breaking and throwing the rock for fragmentation and a major portion of the vibration is transmitted through the surrounding medium in the form of shock waves which is called blast-induced ground vibration. Ground vibration is measured in terms of peak particle velocity (PPV) in mm/s. Poor blast design results in higher intensity of the vibration and it may inflicts damage to the nearby structures. Therefore, it is important to design blast in a scientific manner and control the intensity of vibration. Vibrations attenuate with distance (D) of the point of interest (here monitoring station) from the blast site and have a relationship with the maximum charge per delay (Q_{max}). Vibration is generally measured in terms of peak particle velocity in three orthogonal directions. A vector sum of individual measurement is called Peak Vector Sum (V_{max}). The relationship yields two site parameters (K & β) which can be used to calculate the permissible Q_{max}. The relationship between V_{max}, distance (D) and Maximum Charge per Delay, Q_{max} is expressed as given by Eq. 1.

$$V_{ppv} = K\left(\frac{D}{\sqrt{Q_{max}}}\right)^{-\beta} \qquad \text{Eq. 1}$$

Equation 1 gives a fair idea about the maximum charge per delay that can be used to achieve a prescribed level of vibrations for safe blasting in the area. Statistical analysis of ground vibrations and air overpressure data have been carried out to develop mathematical model of attenuation characteristics of vibration An site specific empirical relationship has been established correlating the maximum explosives weight per delay (Q_{max} in kg), distance of vibration measuring transducers from the blasting face (D in m) and recorded peak particle velocity (V in mm/s) using square root scaled distance as presented in Eq 1.

Table 2: Details of the observed Blast induced Ground Vibration and Air Overpressure at Pur Village, Bhilwara

Sr. No	Date of Blast	No. of Holes	Hole Depth	Max. Charge per Delay	Total Charge	Vibration Monitoring Location	Monitoring Distance	Peak Particle Velocity	Frequency	Air Overpressure
		(Nos.)	(m)	(Kg)	(kg)		(m)	(mm/s)	(Hz)	(dB(L))
1	1.02.20	90	4.0 - 12	60	9450	Tiranaga Temple	729	0.762	60.13	102.8
2	1.02.20	90	4.0 - 12	60	9450	Guru Kripa Restaurant	933	0.159	38.38	101
3	1.02.20	90	4.0 - 12	60	9450	Sunarogi Temple	1972	0.307	8.125	92.4
4	1.02.20	90	4.0 - 12	60	9450	Laxmi Bada Temple	2703	<0.25	NA	NA
5	1.02.20	166	3.5 - 11	190	8430	Tiranaga Temple	975	1.159	65.38	101.9
6	1.02.20	166	3.5 - 11	190	8430	Guru Kripa Restaurant	1156	0.603	50.63	101.9
7	1.02.20	166	3.5 - 11	190	8430	Sunarogi Temple	2174	<0.25	NA	NA
8	1.02.20	166	3.5 - 11	190	8430	Laxmi Bada Temple	2906	<0.25	NA	NA
9	3.02.20	195	3.5 - 6.0	50	8800	Tiranaga Temple	840	<0.25	NA	NA
10	3.02.20	195	3.5 - 6.0	50	8800	Guru Kripa Restaurant	1036	<0.25	NA	NA
11	3.02.20	195	3.5 - 6.0	50	8800	Sunarogi Temple	2075	<0.25	NA	NA
12	3.02.20	195	3.5 - 6.0	50	8800	Kali Babadi	2341	<0.25	NA	NA
13	4.02.20	88	6.0 - 11.8	60	9660	Tiranaga Temple	789	0.556	61	122.5
14	4.02.20	88	6.0 - 11.8	60	9660	Guru Kripa Restaurant	988	<0.25	NA	NA
15	4.02.20	88	6.0 - 11.8	60	9660	Road along Temple	1490	0.063	2.625	112.8
16	4.02.20	88	6.0 - 11.8	60	9660	Near house along road	1386	0.087	2.00	113.2

Table 2: Details of the observed Blast induced Ground Vibration and Air Overpressure at Pur Village, Bhilwara (contd..)

Sr. No	Date of Blast	No. of Holes	Hole Depth	Max. Charge per Delay	Total Charge	Vibration Monitoring Location	Monitoring Distance	Peak Particle Velocity	Frequency	Air Overpressure
	D/M/Y	(Nos.)	(m)	(Kg)	(kg)		(m)	(mm/s)	(Hz)	(dB(L))
17	5.02.20	88	7.0 - 12	60	9320	Tiranaga Temple	848	<0.25	NA	NA
18	5.02.20	88	7.0 - 12	60	9320	Behind Guru kripa Rest.	1040	<0.25	NA	NA
19	5.02.20	88	7.0 - 12	60	9320	Rajshree Kirana Stores	1373	0.364	16.75	101.2
20	5.02.20	88	7.0 - 12	60	9320	Eidgaah Masjid	2137	<0.25	NA	NA
21	5.02.20	116	7.0 - 12	60	5380	Tiranaga Temple	1138	0.968	58	111.2
22	5.02.20	116	7.0 - 12	60	5380	Road Behind Gurukripa	1331	0.619	16.25	108
23	5.02.20	116	7.0 - 12	60	5380	Rajshree Kirana Stores	1663	0.536	16.25	102.5
24	5.02.20	116	7.0 - 12	60	5380	Eidgaah Masjid	2427	<0.25	NA	NA
25	6.02.20	86	7.0 - 12	60	8720	Sunarogi Temple	2020	<0.25	NA	NA
26	6.02.20	86	7.0 - 12	60	8720	Jn Road Hanuman Temple	2256	<0.25	NA	NA
27	6.02.20	86	7.0 - 12	60	8720	Sunarogi Temple	1286	0.410	40.88	92.44
28	6.02.20	86	7.0 - 12	60	8720	Vill. House No. 4950	2562	<0.25	NA	NA
29	6.02.20	114	7.0 - 12	60	9500	Sunarogi Temple	1986	<0.25	NA	NA
30	6.02.20	114	7.0 - 12	60	9500	Hanuman Temple Road	2221	<0.25	NA	NA
31	6.02.20	114	7.0 - 12	60	9500	Near Sunarogi Temple	1248	0.394	32.13	100.2
32	6.02.20	114	7.0 - 12	60	9500	Vill. House No. 4950	2527	<0.25	NA	NA

Table 2: Details of the observed Blast induced Ground Vibration and Air Overpressure at Pur Village, Bhilwara (Contd..)

Sr. No	Date of Blast	No. of Holes	Hole Depth	Max. Charge per Delay	Total Charge	Vibration Monitoring Location	Monitoring Distance	Peak Particle Velocity	Frequency	Air Overpressure
		(Nos.)	(m)	(Kg)	(Kg)		(m)	(mm/s)	(Hz)	(dB(L))
33	3.03.20	76	4.0 - 6.0	85	3065	Near Tiranga Mata	1287	< 0.25	NA	NA
34	3.03.20	76	4.0 - 6.0	85	3065	Bhawar Lal Mali farm	1289	< 0.25	NA	NA
35	3.03.20	76	4.0 - 6.0	85	3065	Dariwa Mandal Road	2047	< 0.25	NA	NA
36	3.03.20	76	4.0 - 6.0	85	3065	Miththu Mali Farm	2075	<0.25	NA	NA
37	3.03.20	119	5.0 - 10	90	10365	Near Tiranga Mata	930	0.698	18.5	< 88.0
38	3.03.20	119	5.0 - 10	90	10365	Bhawar Lal Mali farm	987	<0.25	NA	NA
39	3.03.20	119	5.0 - 10	90	10365	Dariwa Mandal Road	1720	<0.25	NA	NA
40	3.03.20	119	5.0 - 10	90	10365	Miththu Mali Farm	1730	0.544	8.625	97.7
41	4.03.20	39	6.0 - 9.0	80	2800	JSL Weigh Bridge No.2	530	0.587	21.25	108.4
42	4.03.20	39	6.0 - 9.0	80	2800	JSL Electric Grid	337	1.639	8.0	111.3
43	4.03.20	39	6.0 - 9.0	80	2800	Near Dump Yard NW	312	3.46	10.5	<88
44	4.03.20	134	4.0 - 10	90	9790	JSL Weigh Bridge No.2	302	1.746	13.13	111.5
45	4.03.20	134	4.0 - 10	90	9790	JSL Electric Grid	158	11.14	23.63	121.6
46	4.03.20	134	4.0 - 10	90	9790	Near Dump Yard NW	550	1.671	13.88	<88
47	5.03.20	161	4.0 - 9.5	85	10080	Mine Site Office	342	3.397	17.75	131.8
48	5.03.20	161	4.0 - 9.5	85	10080	JSL Weigh Bridge No.2	425	1.365	18.38	120.3

Table 2: Details of the observed Blast induced Ground Vibration and Air Overpressure at Pur Village, Bhilwara (contd..)

Sr. No	Date of Blast	No. of Holes	Hole Depth	Max. Charge per Delay	Total Charge	Vibration Monitoring Location	Monitoring Distance	Peak Particle Velocity	Frequency	Air Overpressure
		(Nos.)	(m)	(Kg)	(kg)		(m)	(mm/s)	(Hz)	(dB(L))
49	5.03.20	161	4.0 - 9.5	85	10080	JSL Electric Grid	144	11.56	37.88	131.3
50	5.03.20	161	4.0 - 9.5	85	10080	Mill Tailing NE	187	10.16	18.00	133.7
51	6.03.20	75	4.0 - 6.0	55	4100	Mine Site Office	230	8.588	16.75	127.3
52	6.03.20	75	4.0 - 6.0	55	4100	Mill Tailing NE	307	1.947	13.50	126.0
53	6.03.20	75	4.0 - 6.0	55	4100	JSL Electric Grid	359	2.254	26.75	124.8
54	6.03.20	180	4.0 - 8.0	100	9400	Mine Site Office	337	2.508	23.88	124.2
55	6.03.20	180	4.0 - 8.0	100	9400	JSL Electric Grid	260	5.438	24.13	127.5
56	6.03.20	180	4.0 - 8.0	100	9400	Mill Tailing NE	322	1.576	12.88	124.3

Note: The vibration monitor instrument is set to a trigger level of 0.25 mm/s so that it does not record false value of vibration. Human activities such walking, closing of the doors/windows and movement of vehicle near geophone induce vibration level of more than 0.25 mm/s. Vibration below 0.25mm/s may not cause damage to structures. Safe permissible limit of the vibration at structures is 5.0 mm/s as per Directorate General of Mines Safety, Govt. of India, an statutory body to regulate mining operations.

NA: Indicates that the vibration values were less than the trigger level of vibration set to monitoring system and corresponding data is not available

The values of vibrations observed at different distances with different charge per delay (Q_{max}) at a mine site are plotted in **Figure 19** in log-log scale. The coefficient of correlation is 0.8353 which is acceptable for prediction of the vibration equation in rock engineering. As can be seen from the Figure 19, a mean line is drawn for the data obtained and presented in Eq, 2. A site-specific equations using 95% confidence interval is presented in Equation 3.

A similar empirical correlation between observed peak particle velocity and total charge used in a blast round is found out by analysing the data. The log-log plot of total charge in a blast round and observed peak particle velocity is resented in Figure 20. The relationship between Total Charge (Q_{TC}) and Observed peak particle velocity (V_{ppv}) is given in Eq. 4. Eq. 5 is site-specific equations using 95% confidence interval.

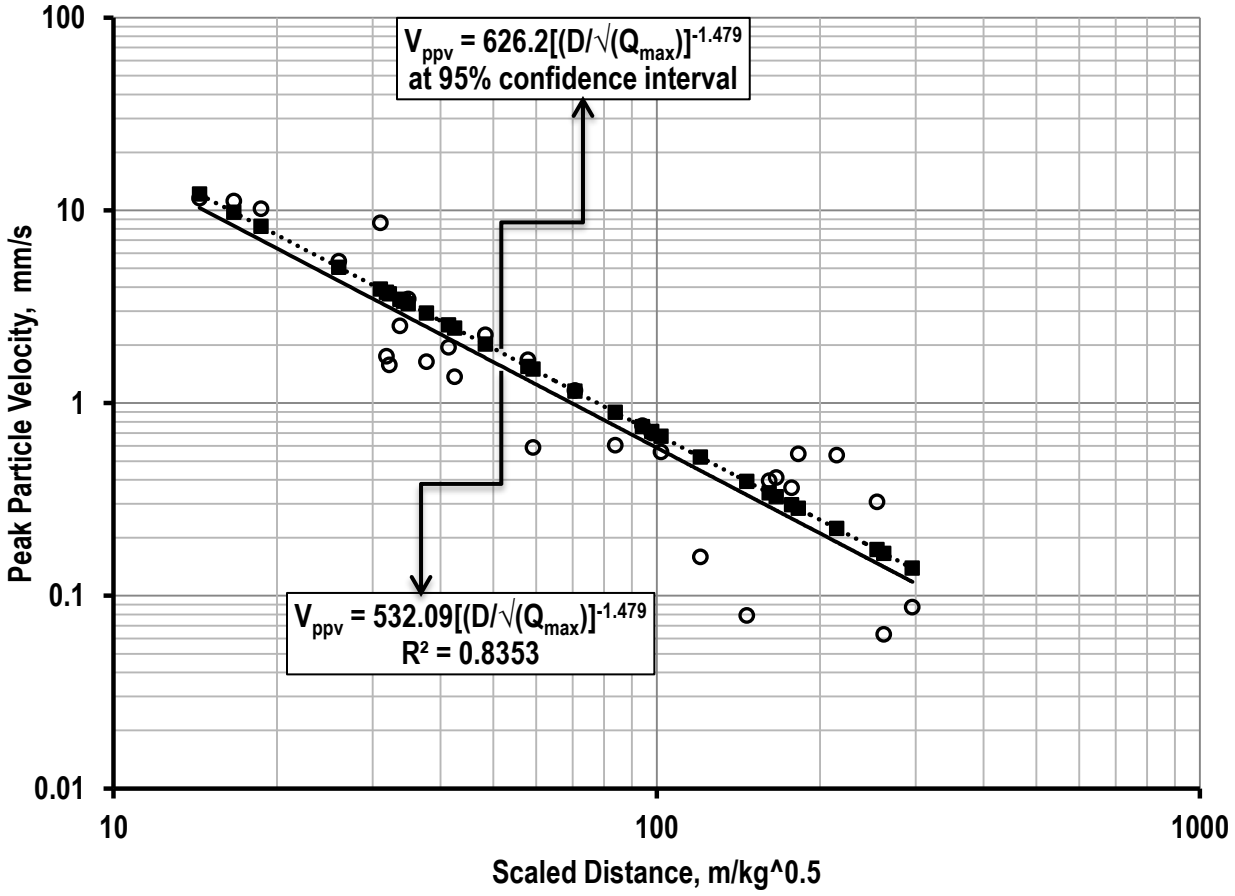


Fig. 19: Plot of peak particle velocity with scaled distance observed at Dhedwas Iron Ore Mine, Bhilwara

A similar empirical correlation between observed peak particle velocity and total charge used in a blast round is found out by analysing the data. The log-log plot of total charge in a blast round and observed peak particle velocity is resented in Figure 20. The relationship between Total Charge (Q_{TC}) and Observed peak particle velocity (V_{ppv}) is given in Eq. 4. The Eq. 5 is site-specific equations using 95% confidence interval.

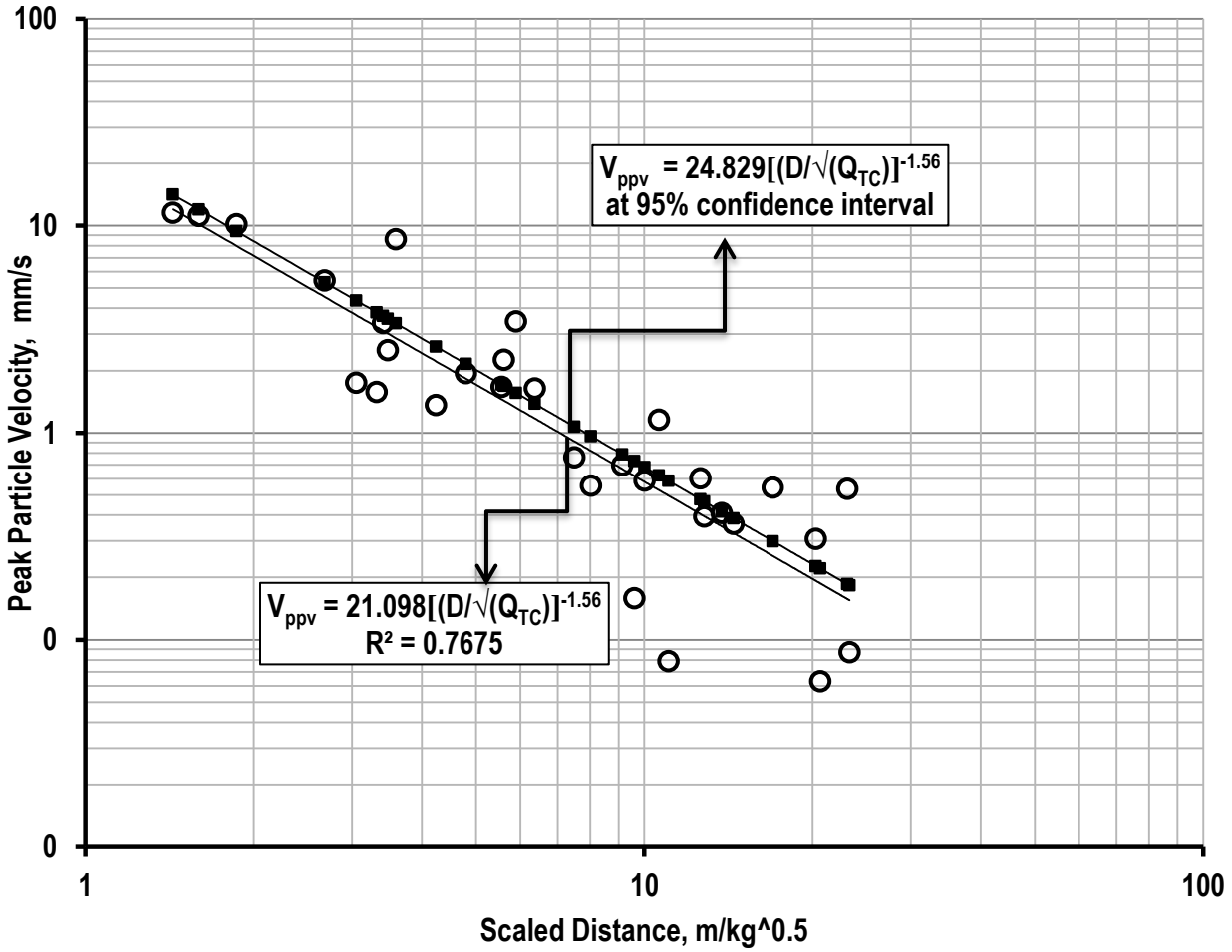


Fig. 20: Plot of peak particle velocity with scaled distance observed at Dhedwas Iron Ore Mine, Bhilwara

$$V_{ppv} = 532.09\left(\frac{D}{\sqrt{Q_{max}}}\right)^{-1.479} \quad \text{(Eq. 2)}$$

$$V_{ppv} = 626.2\left(\frac{D}{\sqrt{Q_{max}}}\right)^{-1.479} \quad \text{(Eq. 3)}$$

$$V_{ppv} = 21.098\left(\frac{D}{\sqrt{Q_{TC}}}\right)^{-1.56} \quad \text{(Eq. 4)}$$

$$V_{ppv} = 24.829\left(\frac{D}{\sqrt{Q_{TC}}}\right)^{-1.56} \quad \text{(Eq. 5)}$$

Where

V_{ppv} = peak particle velocity, mm/s

D = distance of measurement, m, and

Q_{max} = maximum charge per delay, kg.

Q_{TC} = total charge in a blast round, kg.

Similar to vibration analysis, AOP values observed during various field visits were analysed using cube root scaled distance and presented in Figure 21. The air overpressure decay equation is presented in Eq. 6. As the decay of air overpressure as compared to vibration is greater, conventionally, it has been taken as a proportionate to cube root scaled distance.

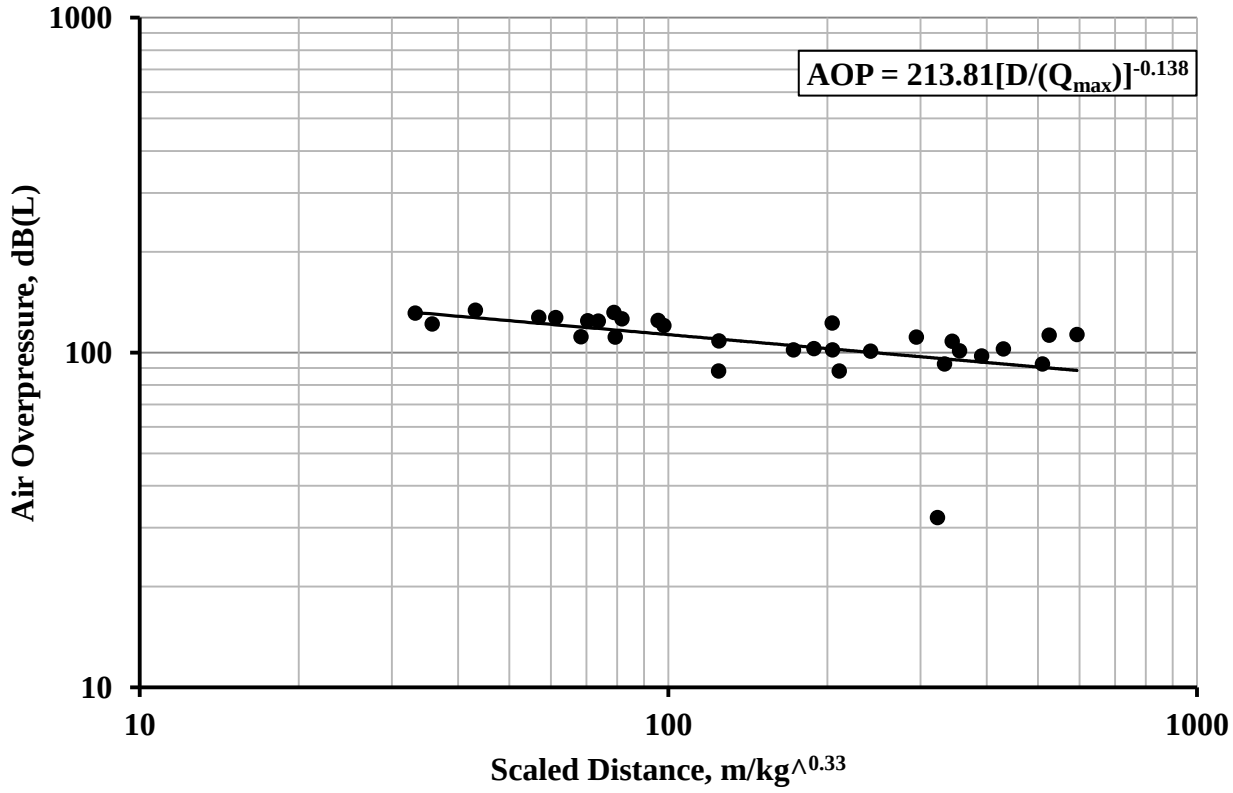


Fig. 21: Plot of observed air overpressure values with cube root scaled distance

$$AOP = 213.81\left(\frac{D}{\sqrt[3]{Q_{max}}}\right)^{-0.074} \quad \text{(Eq. 6)}$$

Where

AOP = air overpressure, dB(L)

D = distance of measurement, m, and

Q_{max} = maximum charge per delay, kg.

7.3 Frequency of the Ground Vibration

The present Indian standard of vibration as notified by Directorate General of Mines Safety (DGMS) (Tech) (S&T) Circular No. 7 dated 29th August, 1997 is frequency based criterion. Therefore, it is important to understand the dominant frequency of the blast induced ground vibration.

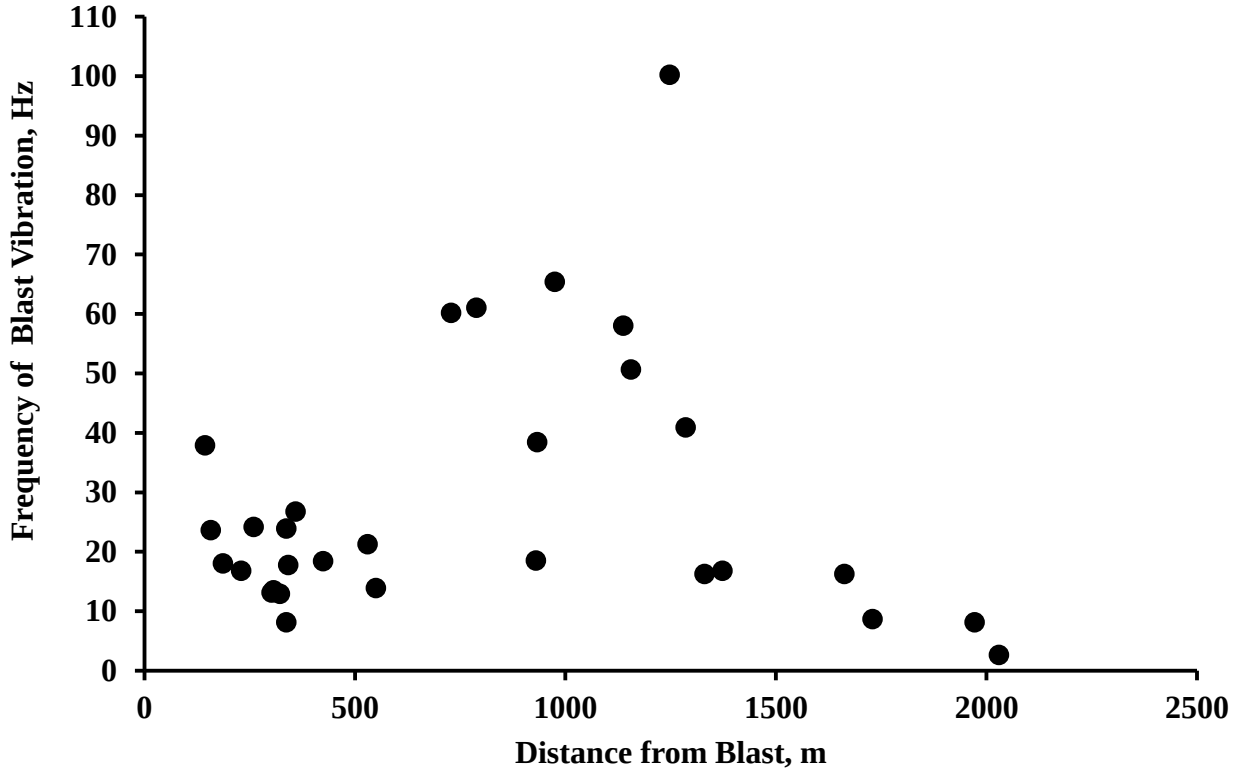


Fig. 22: Plot of dominant frequencies of blast waves recorded at various locations

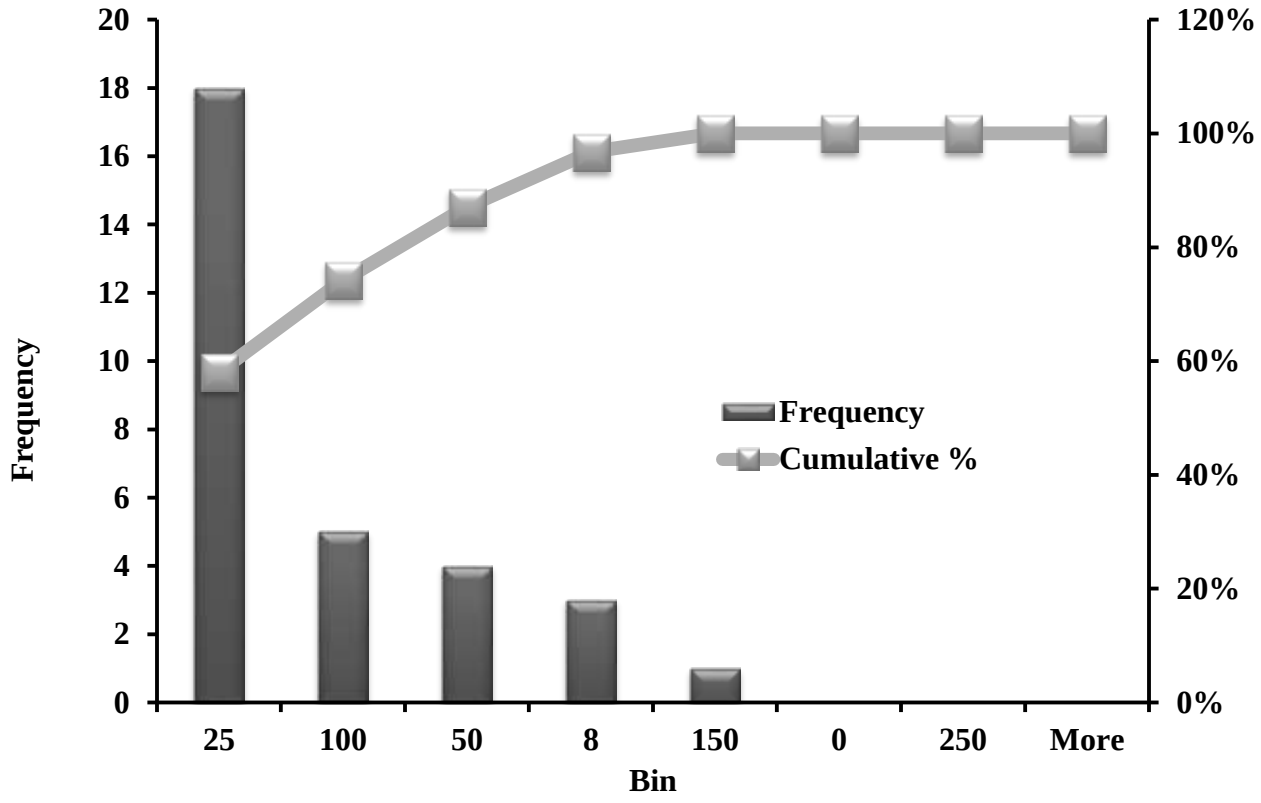


Fig 23: Statistical distribution of the observed frequency data

During various field visits to mine, more than 50 data of vibration, air overpressure and their associated frequency was recorded at different locations by conducting more than 15 experimental blasts. Dominant frequency of the recorded blast vibration is obtained through Fast Fourier Transform (FFT) analysis of each event. Statistical distribution of frequency of the observed data is presented in Figure 22 and Figure 23.

It is clear from Figure 22 and 23 that frequency of the blast induced ground vibration varies from 0 - 70 Hz. Three event have recorded values less than 8 Hz and majority of values lies between 8-30 Hz.

8.0 SAFE LIMIT OF VIBRATION AND AOP

Different countries adopt different standards of safe limit of vibration. Researchers throughout the world have experienced difficulty in defining acceptable damage standards. One of the main reason is the variability in standardization of structures and it's material of construction. In India, as per present Indian standards, as mentioned in DGMS (Tech) (S&T) Circular No. 7 dated 29th

August of 1997, depending on the type of structures and dominant excitation, the peak particle velocity (PPV) on the ground adjacent to the structure shall not exceed the values given in the Table 4.

Table 3: Permissible Peak Particle Velocity (PPV) in mm/s at the Foundation Level of Structures as per DGMS (India) Criterion

Type of Structures	Dominant Excitation Frequency, Hz		
	< 8 Hz	**8 - 25 Hz**	**> 25 Hz**
(A) Buildings/structures not belong to the owner			
Domestic houses /structures (Kuchha brick and cement)	**5**	10	15
Industrial buildings (RCC and framed structures)	**10**	20	25
Objects of historical importance and sensitive structures	**2**	5	10
(B) Building belonging to owner with limited span of life			
Domestic houses /structures (Kuchha brick and cement)	10	15	25
Industrial buildings (RCC and framed structures)	15	25	50

The present Indian standard (Table 3) is a frequency based criterion. As the frequency of vibration increases the threshold value of damage also increases. Indian Standard also recommends minimum PPV value of 5.0 mm/s for domestic houses which correspond to less than 8 Hz frequency. As the frequency increase above 8 Hz, the limiting PPV value enhances to 10 mm/s and 15 mm/s for frequency range 8- 25 Hz and greater than 25 Hz respectively.

The safe permissible limit of peak particle velocity (PPV) for domestic houses and industrial building not belonging to mine management is 5 mm/s and 10 mm/s respectively, corresponding to 0 – 8 Hz frequency range as per the present DGMS criterion. Although majority of the observed frequency values lies above 8 Hz, few frequency values are also found between 0-8 Hz. Therefore, peak particle velocity value of 5 mm/sec may be considered safe limit of the ground

vibration as per DGMS criterion corresponding o 0-8 Hz frequency rage. The observation is also similar to DGMS permission of 5 mm/s for the Tiranaga Block of Dhedwas iron ore mine.

DGMS (India) Circular suggests 90 dB-A as the threshold for continuous occupational exposure of noise up to 8 hours duration. However, there is no guideline from DGMS or Indian Bureau of Mines (IBM) regarding permissible safe level of air overpressure (AOP) produced due to blasting. For large scale surface mining operations, air overpressure can be characterized by lower frequency. For large scale operation, a common overpressure limit of 134 dB(L) is recommended by the United States Bureau of Mines (USBM) in RI 8507 (Siskind et al, 1980). USBM recommended values are presented in Table 4. As Table 4 is internationally accepted and the same has been adopted for evaluating the AOP threshold values in the present study for Dhedwas Iron ore mine, Bhilwara.

In light of above discussion, recommended safe limit of blast induced ground vibration and air overpressure for Dhedwas Iron ore mine, Bhilwara is 5 mm/s and 134dB(L) respectively.

Table 4: Typical Air overpressure criterion (Siskind et al, 1980)

Air Overpressure Limits dB(L)	Damage potential
180	Some structural Damage
171	General window breakages
140	Occasional Window breakage
134	US Bureau of mines recommendations for large-scale surface mine blasting.

9.0 DISCUSSION ON THE RESULTS

CSIR-CIMFR Team conducted 15 experimental blasts in Dhedwas Iron ore mine, Bhilwara with different permutation and combination of the blasting parameters. The parameters of the blasting experiments were chosen after review of the data on blasting operations corresponding to April 2018 to Dec 2019. The details of the experimental blast are presented in Table 1. Comprehensive blast vibration monitoring was done during blasting experiments. Monitoring was done both in

near field as well as far-field to evaluate the attenuation characteristics of the blast vibration and air overpressure. Vibration monitoring as closes as 158 m and as far as 2906 m has been done at Dhedwas mine site. The observed values of vibration ad air overpressure are presented in Table 2. Attenuation characteristics of the vibration and air overpressure are presented in Eq(s) 3 and 6 respectively. It may be noted from Table 2 that vibration has been monitored at 56 different locations in and around the blasting operation sites. The monitoring location includes domestic houses and other prominent structures of the Pur village such as Temple and Mosques and community hospital etc. Monitoring both at found and roof level of structures has been carried out. Emphasis has been made to measure vibration in places where cracks has been observed.

The observed values, as presented in Table 2 reveals that the blast induced ground vibration and air overpressure beyond a distance of 500 m from the blasting site remained less than 2.00 mm/s and 115 dB(L) against recommended safe values of 5.0 mm/s and 134 dB(L). Ground vibration beyond a distance of 1.5 km decayed to less than 1.0 mm/s in majority of the cases. A plot showing attenuation of the blast induced ground vibration with different values of maximum charge per delay obtained using Eq 3 is shown in Figure 24. Figure 24 shows that the vibration intensity expressed in terms peak particle velocity (PPV) remains less than 2.0 m/s beyond a distance of approximately 500 m and further reduces to value less than 1.0 mm/s beyond a distance of 1.5 mm/s. This trend is also obtained in actual measurement while conducting vibration monitoring at site during blasting experiments.

In Figure 24, three lines indicating recommended safe permissible limits of the PPV values as per DGMS criterion corresponding to frequency range of 0-8 Hz is also marked. It may be noted that at a distance of approx.. 700 m, vibration reduces to below 2.0 mm/s, which is safe limit even for historical objects. Corresponding safe permissible value is 5.0 mm/s for domestic houses. In case of Dedhwas iron ore mine, the vibration attenuates to value less than 5.0 mm/s at distance of 500 m. The safe limit of industrial structure is 10 mm/s corresponding to 0-8 Hz frequency as per DGMS recommendations. In present case, for MCD value of 200 kg, vibration upto 10 mm/s is recorded up to a distance of approx.. 250 m. and thereafter, it sharply attenuates and fall under safe limit. In case of lower maximum charge per delay such as 100 kg and 150 kg, the attenuation is faster and the 5.0 mm/s of recommended safe PPV limit is obtained at a distance lesser than 350 m only.

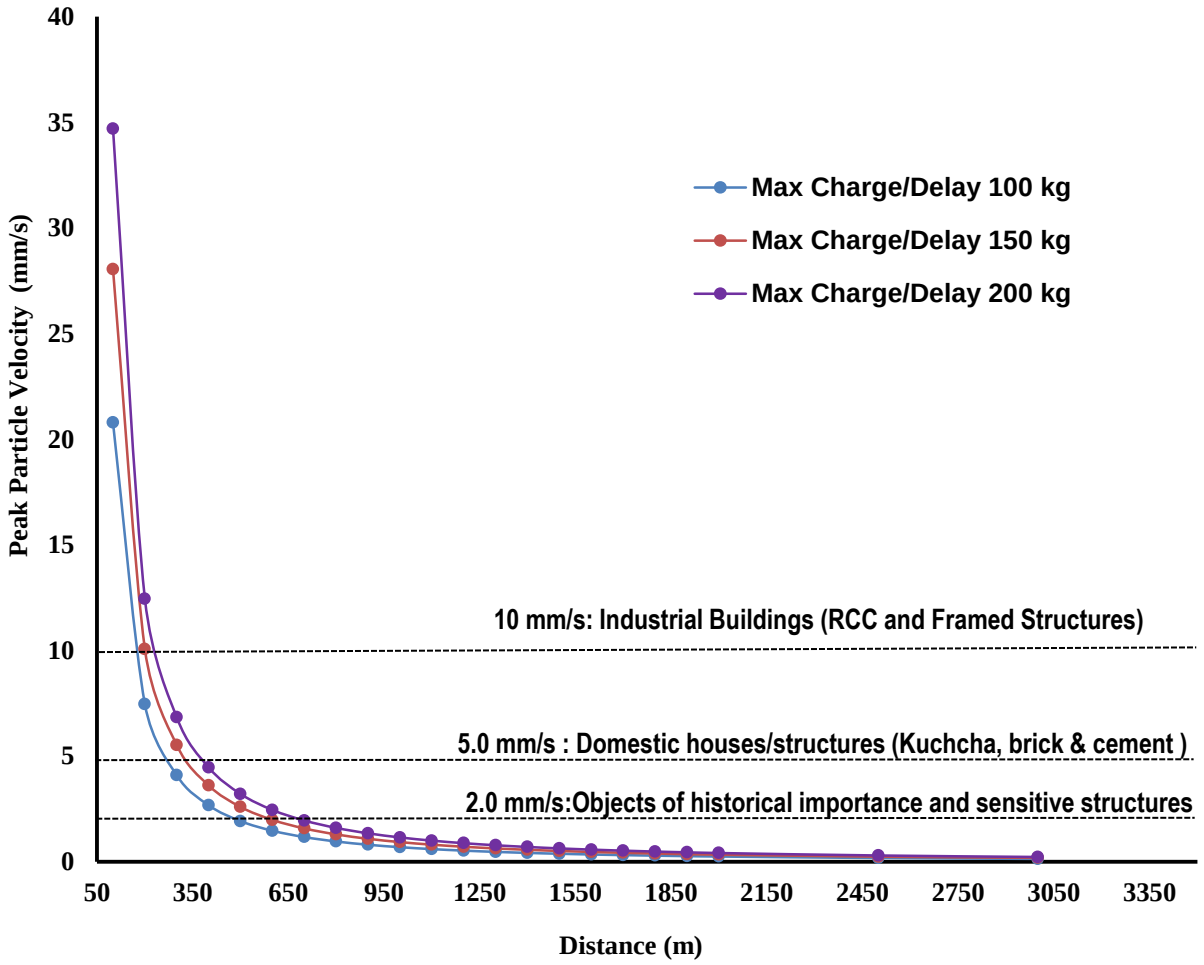


Fig. 24: Decay of vibration with different values of maximum charge per delay

Another plot showing attenuation of vibration in terms of peak particle velocity (PPV) with distance for different values of total charge in a blast round, developed using Eq. 5 is presented in Figure 25. Equation 5 corresponds to propagation characteristics of vibration at 95% confidence interval for total charge in blast round. Similar to case of Figure 24, three lines indicating recommended safe permissible limits of the PPV values as per DGMS criterion corresponding to frequency range of 0-8 Hz is also marked in Figure 25. Three case has been considered in this plot which are observed in the usual mine blasting operation at mine and also practices during experimental blasting operation of the investigating team. During review of the blasting operation carried out in mine, few blasts with 12 tons explosives quantity were observed. Therefore, analysis of 12 ton total charge is also considered. Other two cases are use of 8.0 ton and 10.0 total charge in blast round.

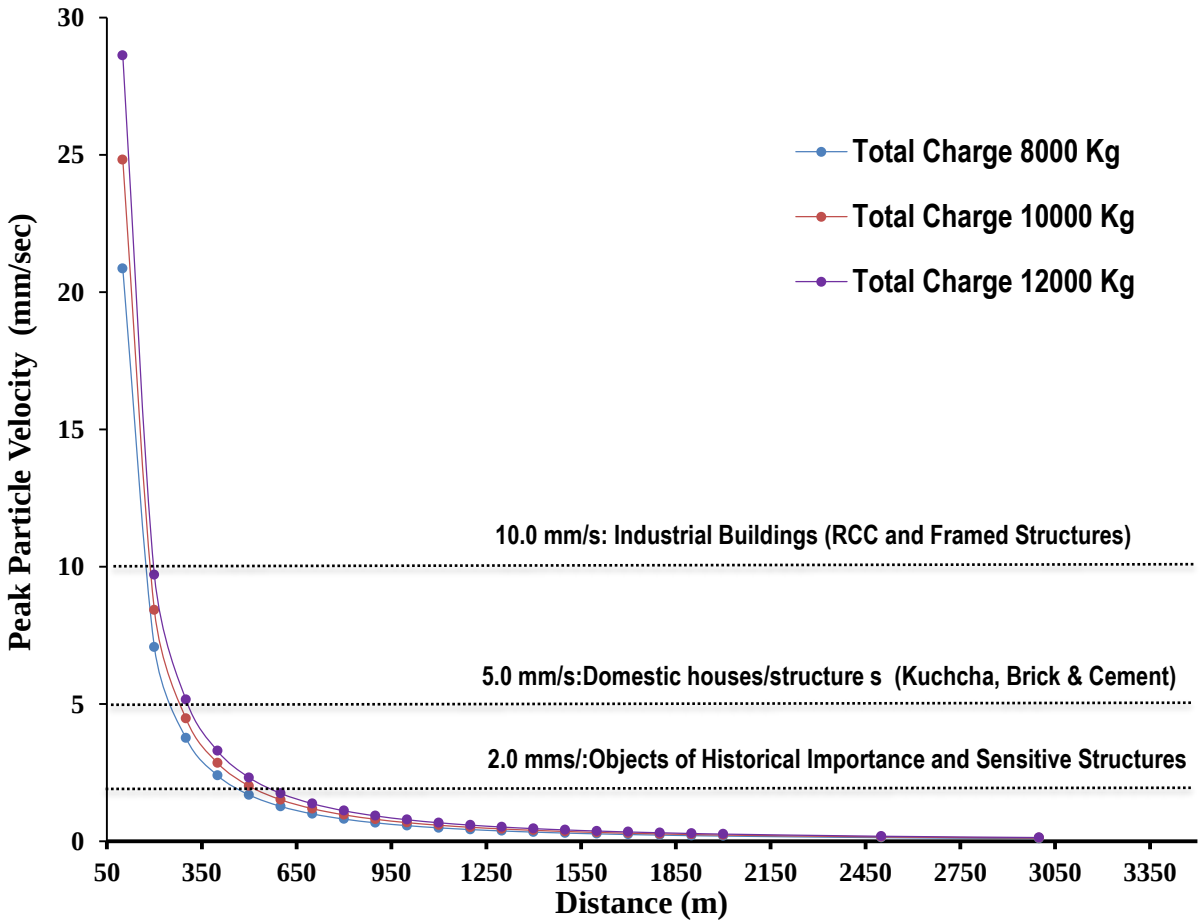


Fig. 25: Decay of vibration with different values of Total Charge (TC) in a blast round

Analysis of data as presented in Figure 25 shows similar trend as observed in Figure 24. PPV value corresponding to 12 tons total charge generates vibration of 2.0 mm/s upto a distance of approx.. 500 m and thereafter, it decays sharply. In case of safe permissible limit of vibration for domestic houses as per DGMS criterion, the values of 5.0 mm/s is observed upto a distance of 300 m. For industrial structure PPV values beyond a distance of 200 m is falling within the safe permissible limit of 10.0 mm/s as per DGMS criterion. The impact of total charge in blast round ins noticeable mostly in close field monitoring particularly upto a distance of 200 m. The values of PPV beyond a distance of 1.5 km are almost overlapping.

Foregoing discussion on analysis of the propagation characteristics of vibration reveals that the blast induced ground vibration induced by Dhedwas iron ore mine are well within the safe permissible limit as per DGMS criterion.

10.0 CONCLUSIONS AND RECOMMENDATIONS

CIMFR team have conducted study at Pur Village to evaluate damage potential of the blast induced ground vibration and air overpressure induced by blasting operations at Dhedwas Iron Ore Mine, Bhilwara. Altogether 15 experimental blast rounds were conducted in Dhedwas Iron Ore mine. Comprehensive vibration monitoring was carried out during blasting experiment. Altogether vibration was monitored at 56 different locations. The monitoring location includes domestic houses and other prominent structures of the Pur village such as Temple and Mosques and community hospital.

It is observed that the blast induced ground vibration and air overpressure beyond a distance of 500 m from the blasting site remained less than 2.00 mm/s and 115 dB(L) against recommended safe values of 5.0 mm/s and 134 dB(L). Ground vibration beyond a distance of 1.5 km decayed to less than 1.0 mm/s in majority of the cases. Therefore, it may be concluded that observed blast induced ground vibration values are safe and well within the permissible limit as per recommendations of Directorate General of Mine Safety (DGMS). Based on the findings of the study it is concluded that impact of blast induced ground vibration and air overpressure in causing damage to the housing structures of Pur village, approx., 2.5 km away is practically not possible. This is further corroborated by the facts that the houses which are between Dhedwas iron mine and Pur village does not have cracks and are not damaged. Cracks in the houses of Pur village may be accounted to hydrogeological set-up of the area and its interaction with the weak non-engineered structures of the Pur village.

It is recommended that an expert agency should be engaged to supervise blasting operations at Dhedwas Iron ore mine. Vibration monitoring shall be carried out by such expert agency in close co-ordination with representative of Pur village. Quarterly/six monthly report of such exercise shall be submitted to State Department of Mining and Geology (DMG)/District Magistrate Office. Such exercise will not only help in establishing mechanism for monitoring the blasting operation but will also enhance confidence of the local villager.

ACKNOWLEDGEMNET

CSIR-Central Institute of Mining and Fuel Research, Regional Research Centre Bilaspur thankfully acknowledges the support of officials from Bhilawara District Magistrate office for entrusting the study to CIMFR. CIMFR team would also like to place on record their gratitude for the sincere support and co-operation extended by the official and staff members in carrying out extensive field works at mine

site and Pur village. Extensive vibration monitoring has been carried out in domestic houses causing inconvenience to the house owners at time. Support received from the inhabitants of Pur villager, particularly Mr. Yogesh Soni and his team for co-ordination with CIMFR Team is also thankfully acknowledged.

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ANNEXURE – I

(Event Reports of Observed Vibration)

Event Report

Date/Time	Tran at 1:00:48 PM February 1, 2020
Trigger Source	Geo: 0.510 mm/s, Mic: 100.0 dB(L)
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps

Serial Number	BE13781 V 10.72-8.17 MiniMate Plus
Battery Level	6.1 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	O781IB6M.TC0

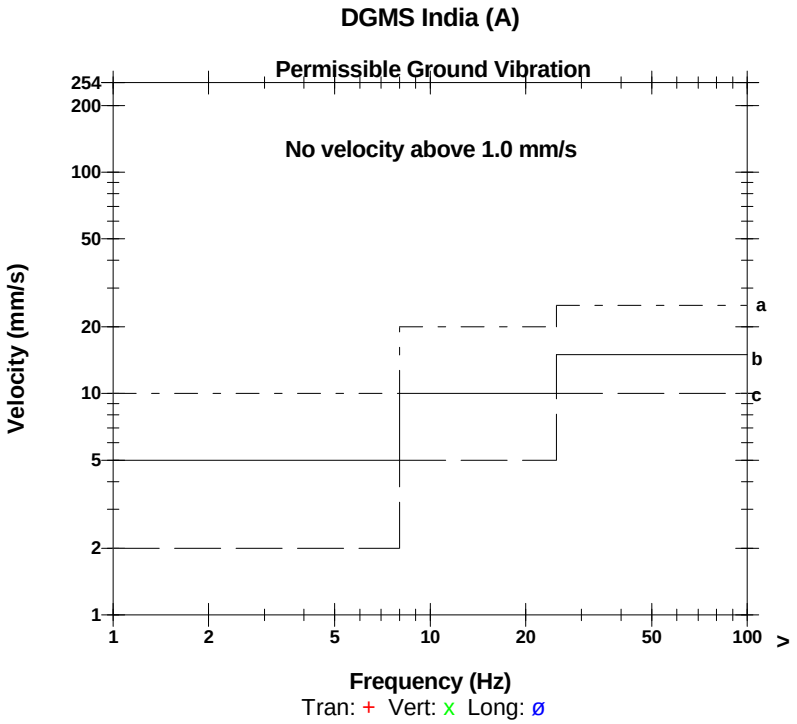
Notes
Location: Pur Village
Client:
User Name: CSIR-CIMFR, Bilaspur Research Centre
General:

Extended Notes
Scientific investigation of potenstial damage due to blast induced ground vibration and air over pressure in domestic houses in Pur Village, Bhilwara, Rajasthan, India.

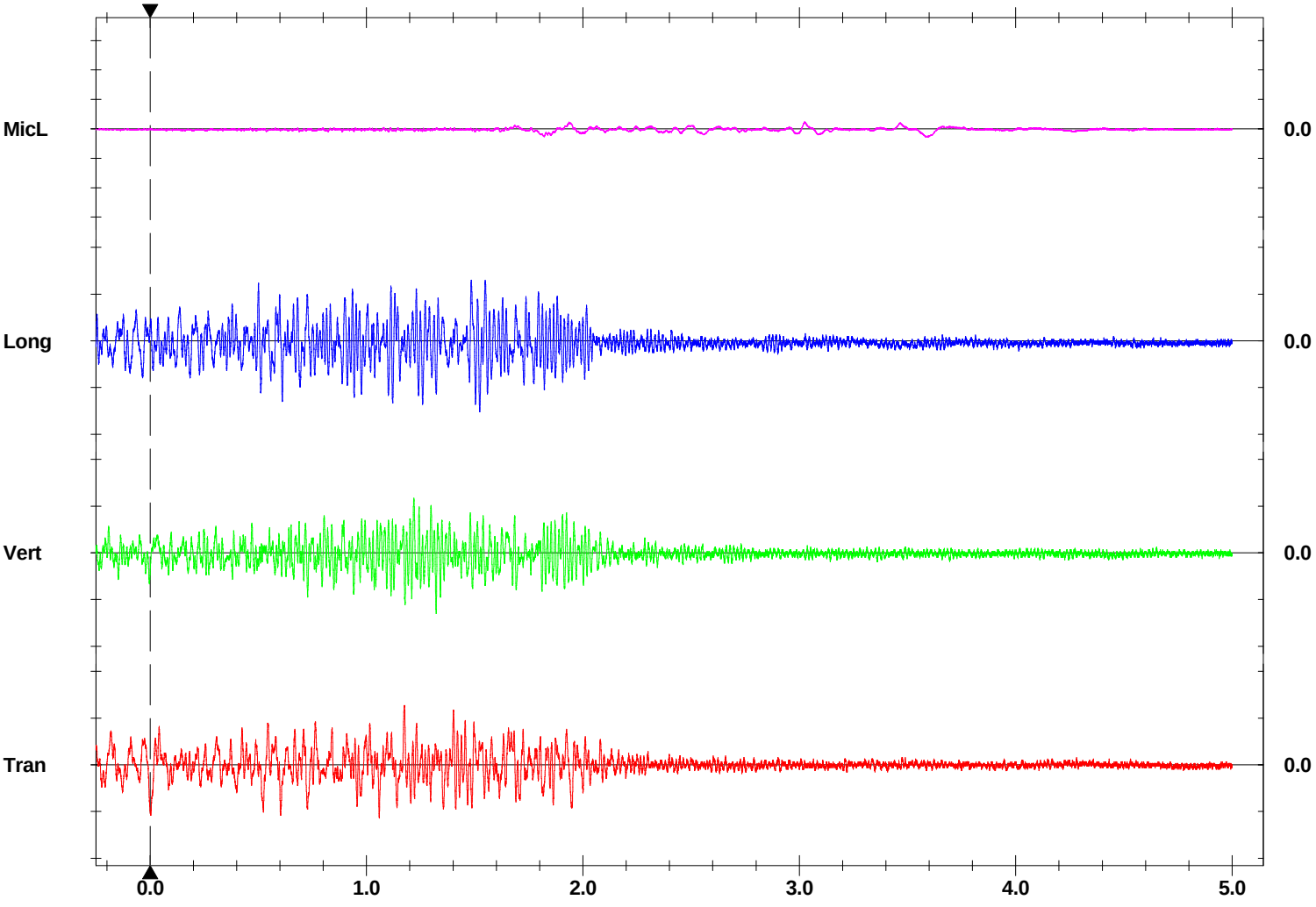
Microphone	Linear Weighting
PSPL	102.8 dB(L) 2.750 pa.(L) at 1.821 sec
ZC Freq	5.1 Hz
Channel Test	Passed (Freq = 20.1 Hz Amp = 544 mv)

	Tran	Vert	Long	
PPV	0.635	0.651	0.762	mm/s
ZC Freq	36.6	57	41	Hz
Time (Rel. to Trig)	1.174	1.321	1.523	sec
Peak Acceleration	0.033	0.040	0.040	g
Peak Displacement	0.004	0.002	0.003	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 0.873 mm/s at 1.322 sec



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 10.000 pa.(L)/div
Trigger =

Format © 1995-2014 Xmark Corporation

Event Report

Date/Time	MicL at 1:03:53 PM February 1, 2020
Trigger Source	Geo: 0.510 mm/s, Mic: 100.0 dB(L)
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps

Serial Number	BE13781 V 10.72-8.17 MiniMate Plus
Battery Level	6.1 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	O781IB6M.YH0

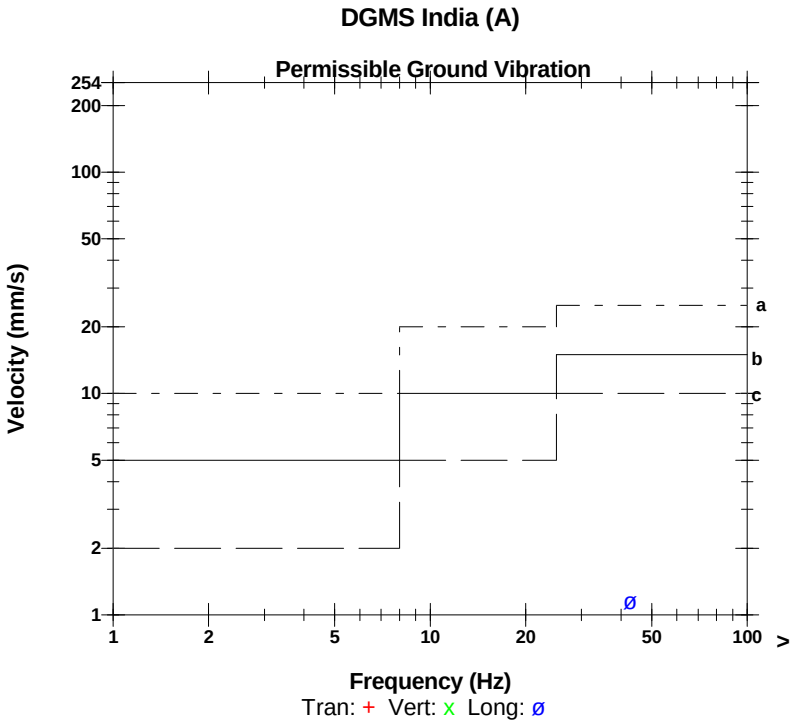
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Client:
User Name: CSIR-CIMFR, Bilaspur Research Centre
General:

Extended Notes
Scientific investigation of potenstial damage due to blast induced ground vibration and air over pressure in domestic houses in Pur Village, Bhilwara, Rajasthan, India.

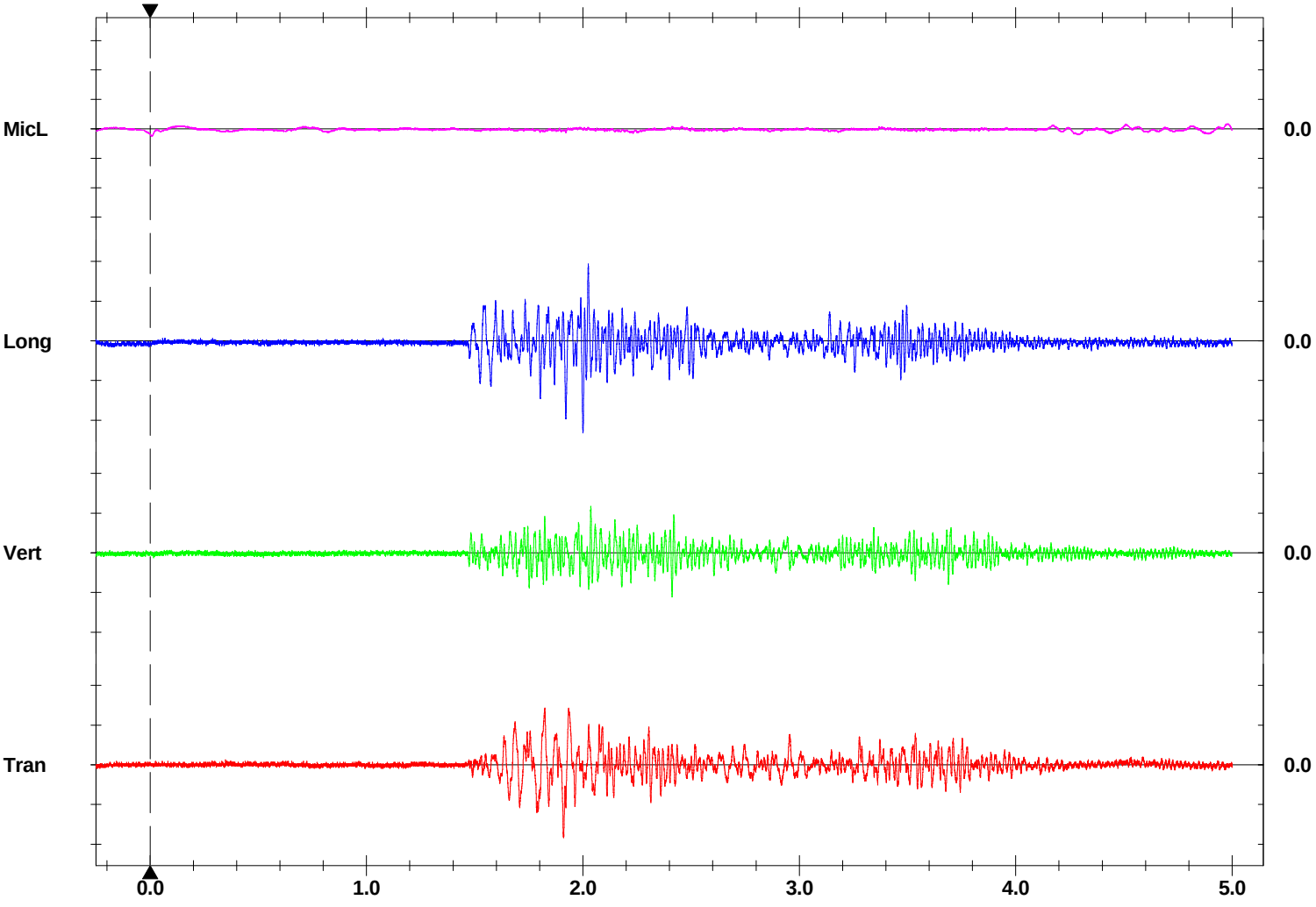
Microphone	Linear Weighting
PSPL	101.9 dB(L) 2.500 pa.(L) at 0.006 sec
ZC Freq	7.2 Hz
Channel Test	Passed (Freq = 20.1 Hz Amp = 544 mv)

	Tran	Vert	Long	
PPV	0.921	0.587	1.159	mm/s
ZC Freq	20.3	62	43	Hz
Time (Rel. to Trig)	1.910	2.036	2.000	sec
Peak Acceleration	0.040	0.033	0.040	g
Peak Displacement	0.006	0.002	0.004	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 1.170 mm/s at 2.000 sec



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 10.000 pa.(L)/div
Trigger =

Format © 1995-2014 Xmark Corporation

Event Report

Date/Time	MicL at 13:00:49 February 1, 2020
Trigger Source	Geo: 0.510 mm/s, Mic: 2.000 pa.(L)
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps

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Battery Level	6.4 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	R508IB6M.TD0

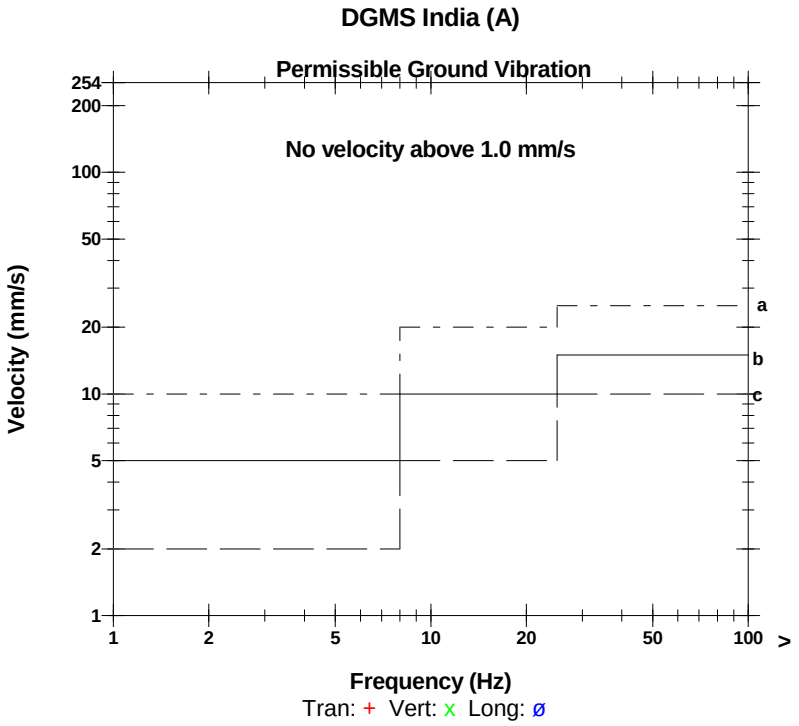
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Client:
User Name: CSIR-CIMFR, Bilaspur Research Centre
General:

Extended Notes
Scientific investigation of potenstial damage due to blast induced ground vibration and air over pressure in domestic houses in Pur Village, Bhilwara, Rajasthan, India.

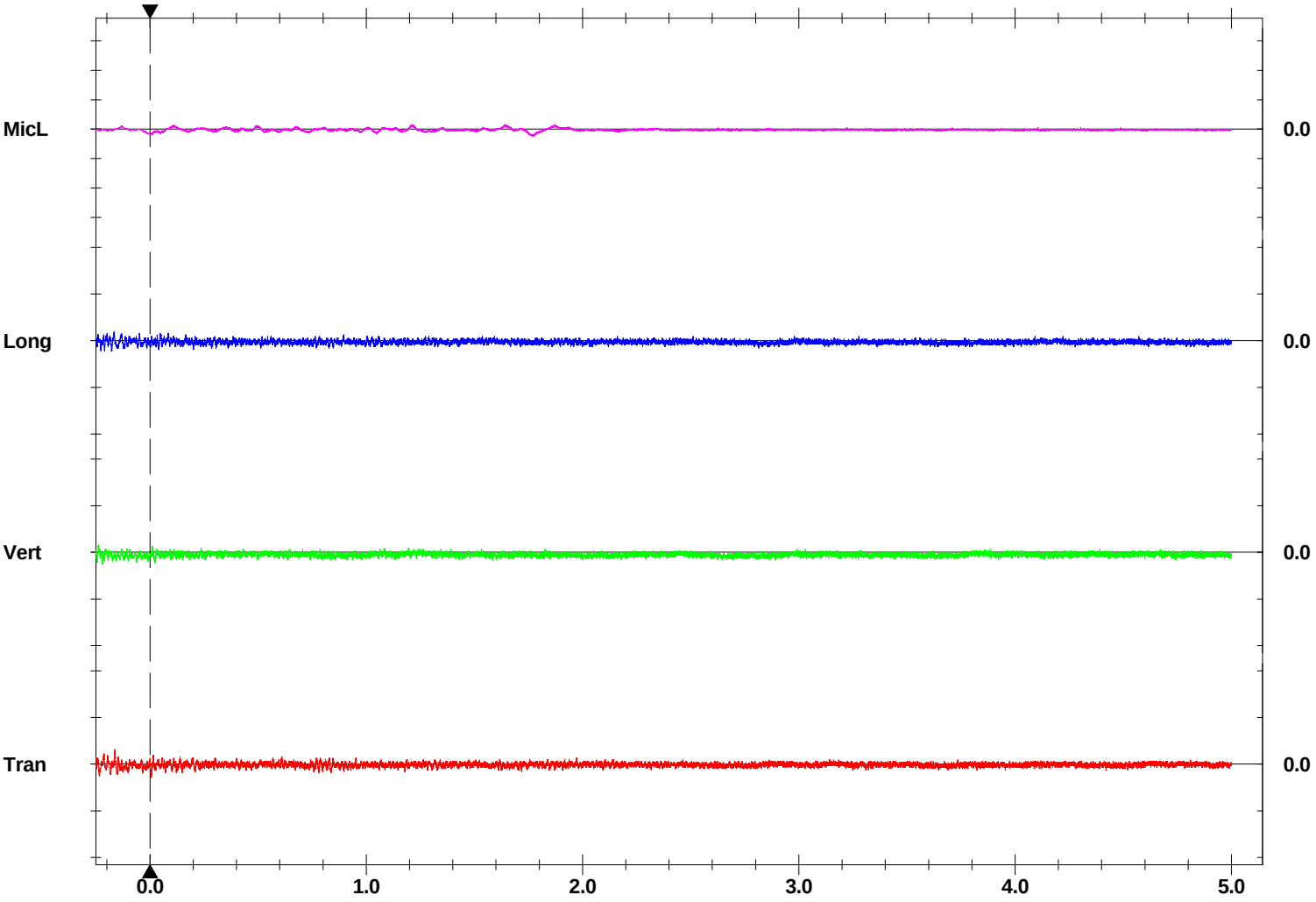
Microphone	Linear Weighting
PSPL	2.250 pa.(L) at 1.763 sec
ZC Freq	6.2 Hz
Channel Test	Passed (Freq = 20.1 Hz Amp = 515 mv)

	Tran	Vert	Long	
PPV	0.159	0.127	0.111	mm/s
ZC Freq	73	68	93	Hz
Time (Rel. to Trig)	-0.163	-0.220	-0.227	sec
Peak Acceleration	0.027	0.027	0.027	g
Peak Displacement	0.000	0.000	0.000	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 0.163 mm/s at -0.163 sec



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 10.000 pa.(L)/div
Trigger = ▶—— ——◀

Format © 1995-2015 Xmark Corporation

Event Report

Date/Time Long at 13:00:51 February 1, 2020
Trigger Source Geo: 0.250 mm/s
Range Geo: 254.0 mm/s
Record Time 5.0 sec at 2048 sps
Operator/Setup: Operator/CIMFR BLSPR.mmb

Serial Number UM12744 V 10-88 Micromate ISEE
Battery Level 3.8 Volts
Unit Calibration January 13, 2020 by UES New Delhi
File Name UM12744_20200201130051.IDFW

Post Event Notes
DMG, BHILWARA DIST, RAJASTHAN GOVT.

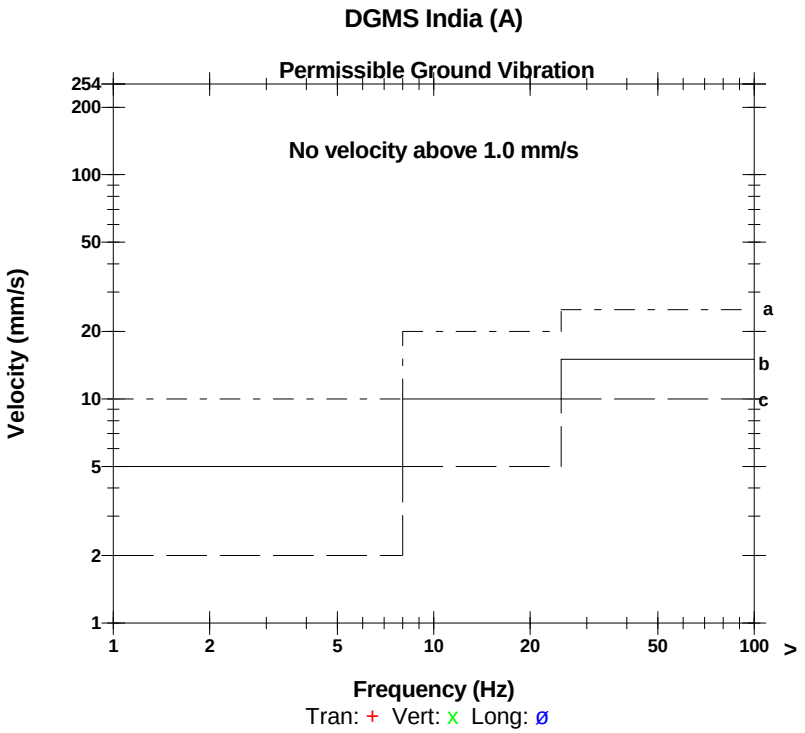
Notes
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Client:
User Name: CSIR-CIMFR Bilaspur Research Centre
General:

Extended Notes
Scientific investigation of damage potential due to blast induced ground vibration and airover pressure in domestic houses in Pur Village, Bhilwara, Rajasthan, India.

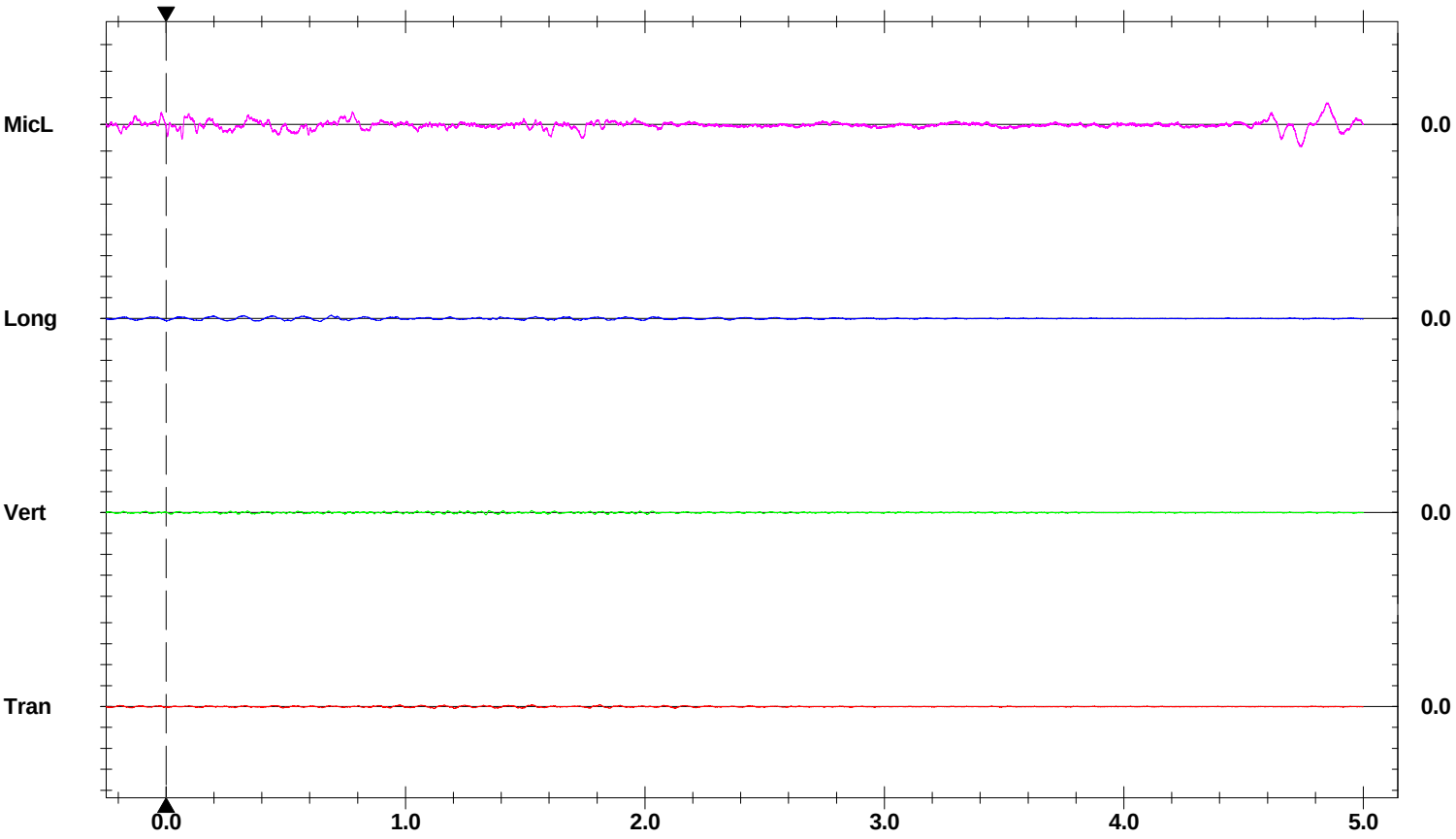
Microphone Linear Weighting
PSPL 0.838 pa.(L) at 4.740 sec
ZC Freq 7.7 Hz
Channel Test Passed (Freq = 19.7 Hz Amp = 1319 mv)

	Tran	Vert	Long	
PPV	0.205	0.244	0.307	mm/s
ZC Freq	10.9	24	8.1	Hz
Time (Rel. to Trig)	1.119	1.117	0.642	sec
Peak Acceleration	0.010	0.010	0.010	g
Peak Displacement	0.002	0.002	0.005	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 0.317 mm/s at 0.643 sec



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 2.000 mm/s/div Mic: 1.000 pa.(L)/div
Trigger = ▶—— ——◀

Format © 1995-2015 Xmark Corporation

Event Report

Date/Time	Tran at 13:03:54 February 1, 2020
Trigger Source	Geo: 0.510 mm/s, Mic: 2.000 pa.(L)
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps

Serial Number	BE16508 V 10.72-1.1 Minimate Blaster
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Unit Calibration	January 13, 2020 by UES New Delhi
File Name	R508IB6M.YI0

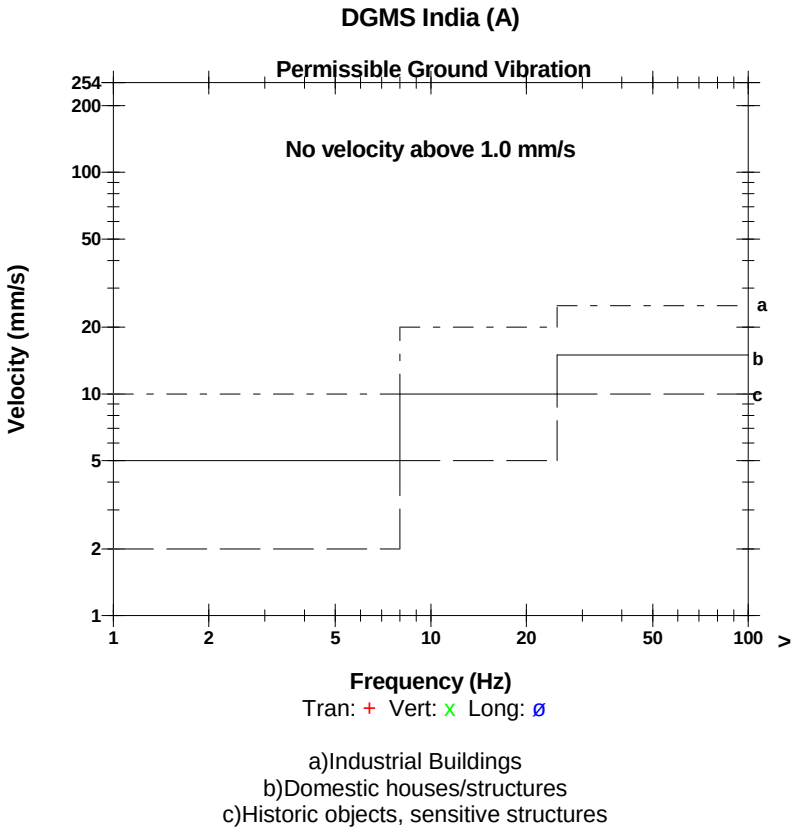
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General:

Extended Notes
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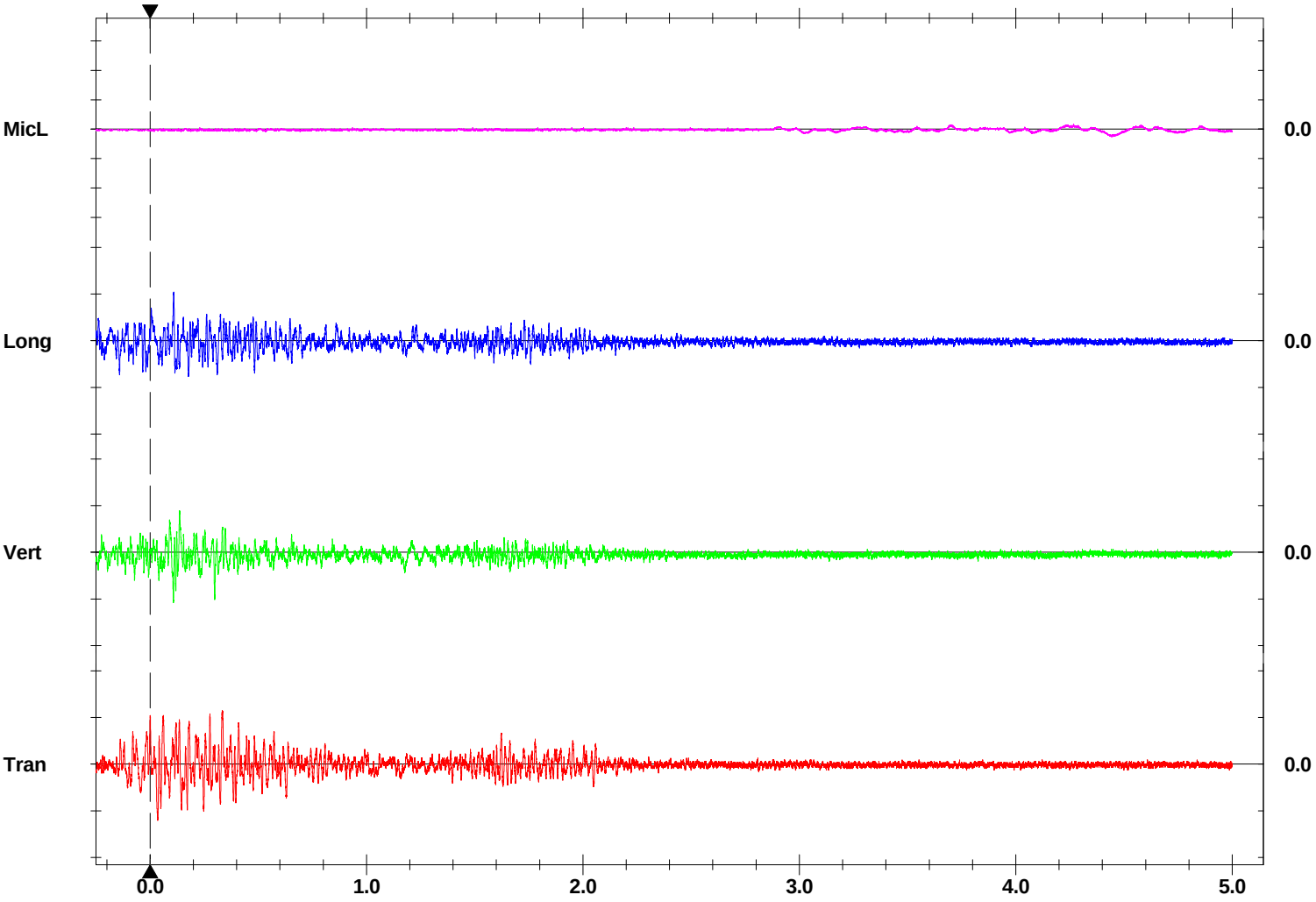
Microphone	Linear Weighting
PSPL	2.500 pa.(L) at 4.441 sec
ZC Freq	4.2 Hz
Channel Test	Passed (Freq = 20.1 Hz Amp = 515 mv)

	Tran	Vert	Long	
PPV	0.603	0.540	0.524	mm/s
ZC Freq	39.4	38.6	44	Hz
Time (Rel. to Trig)	0.035	0.107	0.109	sec
Peak Acceleration	0.040	0.040	0.040	g
Peak Displacement	0.003	0.002	0.002	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 0.714 mm/s at 0.108 sec



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 10.000 pa.(L)/div
Trigger = ▶—— ——◀

Format © 1995-2015 Xmark Corporation

Event Report

Date/Time	Long at 13:11:23 February 4, 2020
Trigger Source	Geo: 0.510 mm/s
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps

Serial Number	BE13781 V 10.72-8.17 MiniMate Plus
Battery Level	6.3 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	O781IBC7.AZ0

Notes
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User Name: CSIR-CIMFR, Bilaspur Research Centre
General:

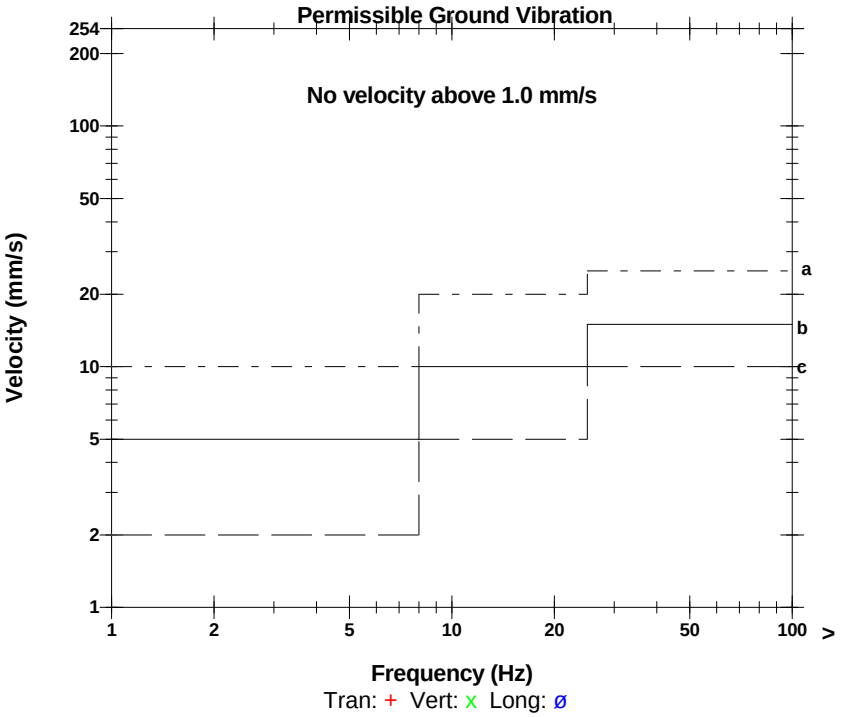
Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

Microphone	Linear Weighting
PSPL	26.75 pa.(L) at 0.558 sec
ZC Freq	9.2 Hz
Channel Test	Passed (Freq = 20.1 Hz Amp = 524 mv)

	Tran	Vert	Long	
PPV	0.540	0.444	0.556	mm/s
ZC Freq	32.0	59	23.8	Hz
Time (Rel. to Trig)	0.211	-0.081	0.155	sec
Peak Acceleration	0.033	0.033	0.033	g
Peak Displacement	0.002	0.002	0.002	mm
Sensor Check	Passed	Passed	Passed	

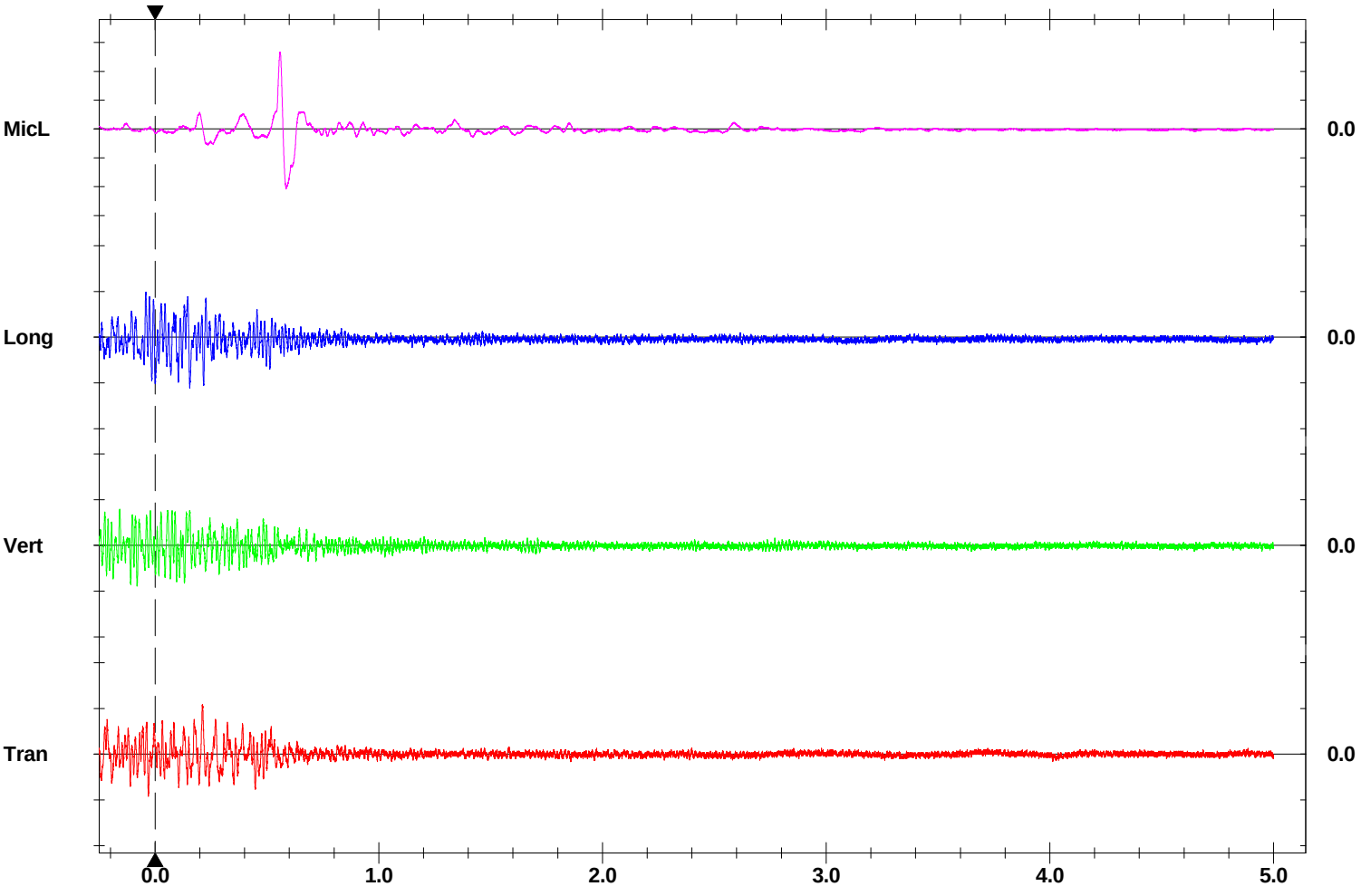
Peak Vector Sum 0.674 mm/s at 0.155 sec

DGMS India (A)



Tran: + Vert: x Long: ø

a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 10.000 pa.(L)/div
Trigger =

Format © 1995-2015 Xmark Corporation

Event Report

Date/Time	MicL at 13:11:33 February 4, 2020
Trigger Source	Geo: 0.250 mm/s, Mic: 6.325 pa.(L)
Range	Geo: 254.0 mm/s
Record Time	10.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR BLSPR.mmb

Serial Number	UM12452 V 10-89 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12452_20200204131133.IDFW

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User Name: CSIR-CIMFR, Bilaspur Research Centre
General:

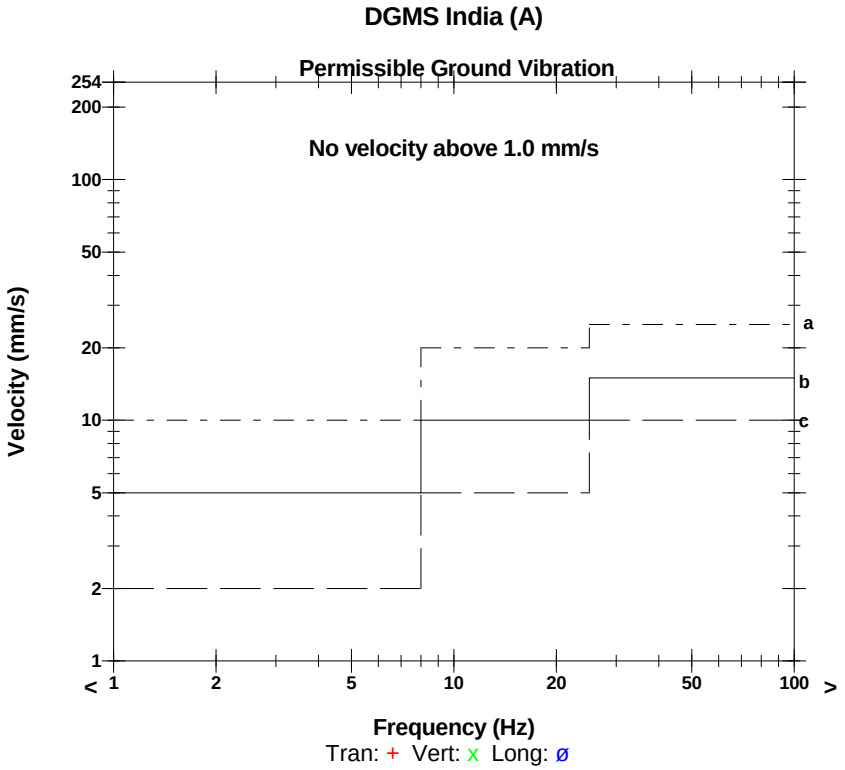
Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

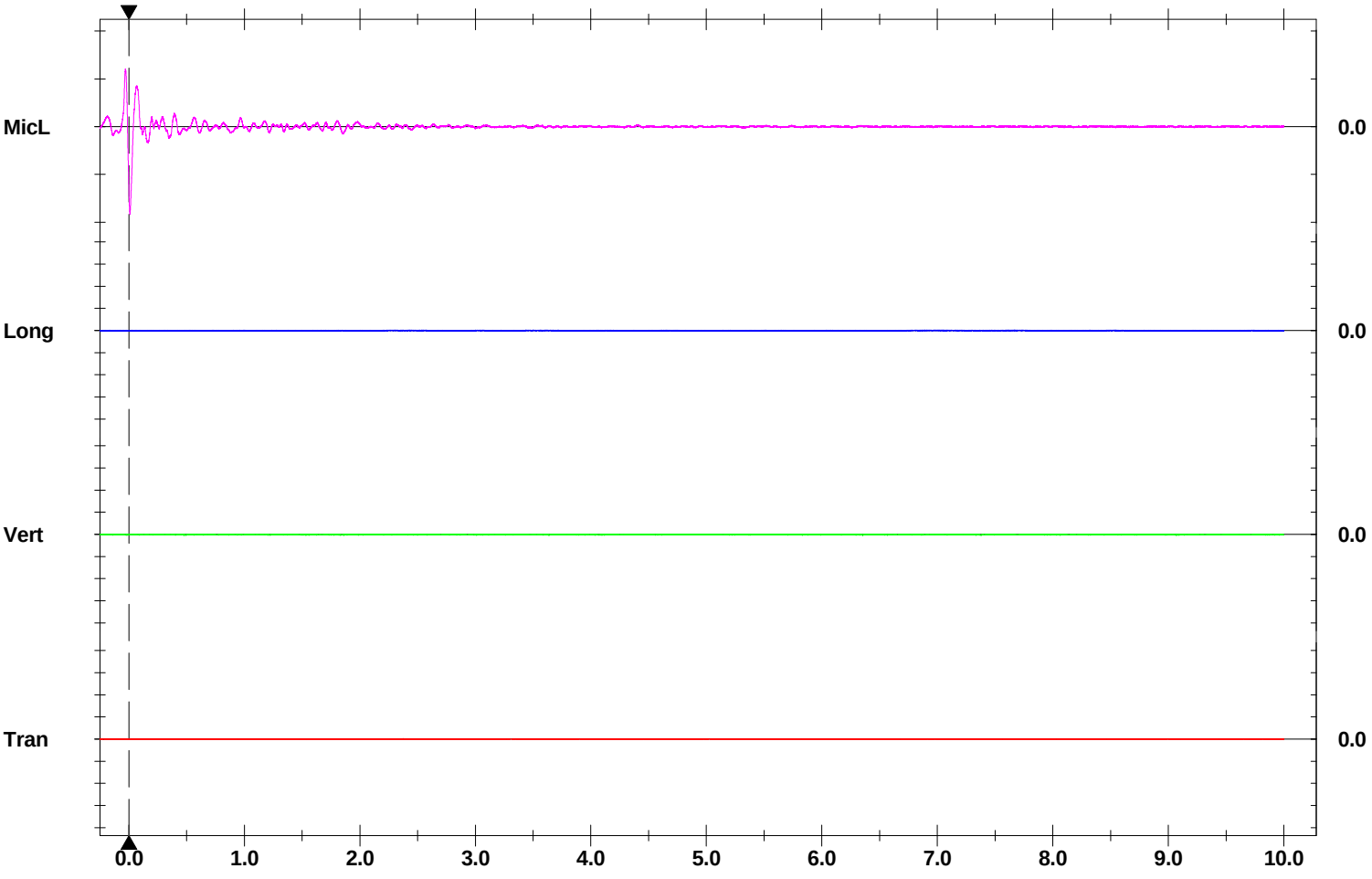
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PSPL	9.185 pa.(L) at 0.009 sec
ZC Freq	9.9 Hz
Channel Test	Passed (Freq = 19.7 Hz Amp = 1197 mv)

	Tran	Vert	Long	
PPV	0.047	0.087	0.055	mm/s
ZC Freq	186	2.6	50	Hz
Time (Rel. to Trig)	0.777	3.329	0.104	sec
Peak Acceleration	0.016	0.020	0.020	g
Peak Displacement	0.000	0.019	0.000	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 0.090 mm/s at 3.329 sec



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.50 sec/div **Amplitude Scale:** Geo: 2.000 mm/s/div Mic: 5.000 pa.(L)/div
Trigger = ▶— —◀

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Event Report

Date/Time	MicL at 13:11:33 February 4, 2020
Trigger Source	Geo: 0.250 mm/s, Mic: 6.325 pa.(L)
Range	Geo: 254.0 mm/s
Record Time	10.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR BLSPR.mmb

Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200204131133.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

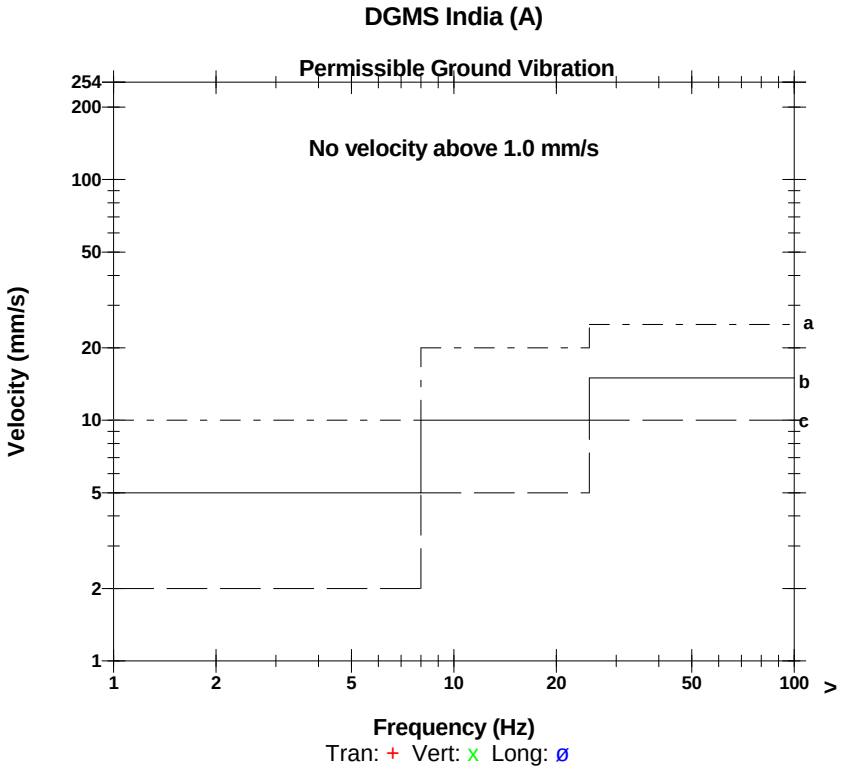
Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

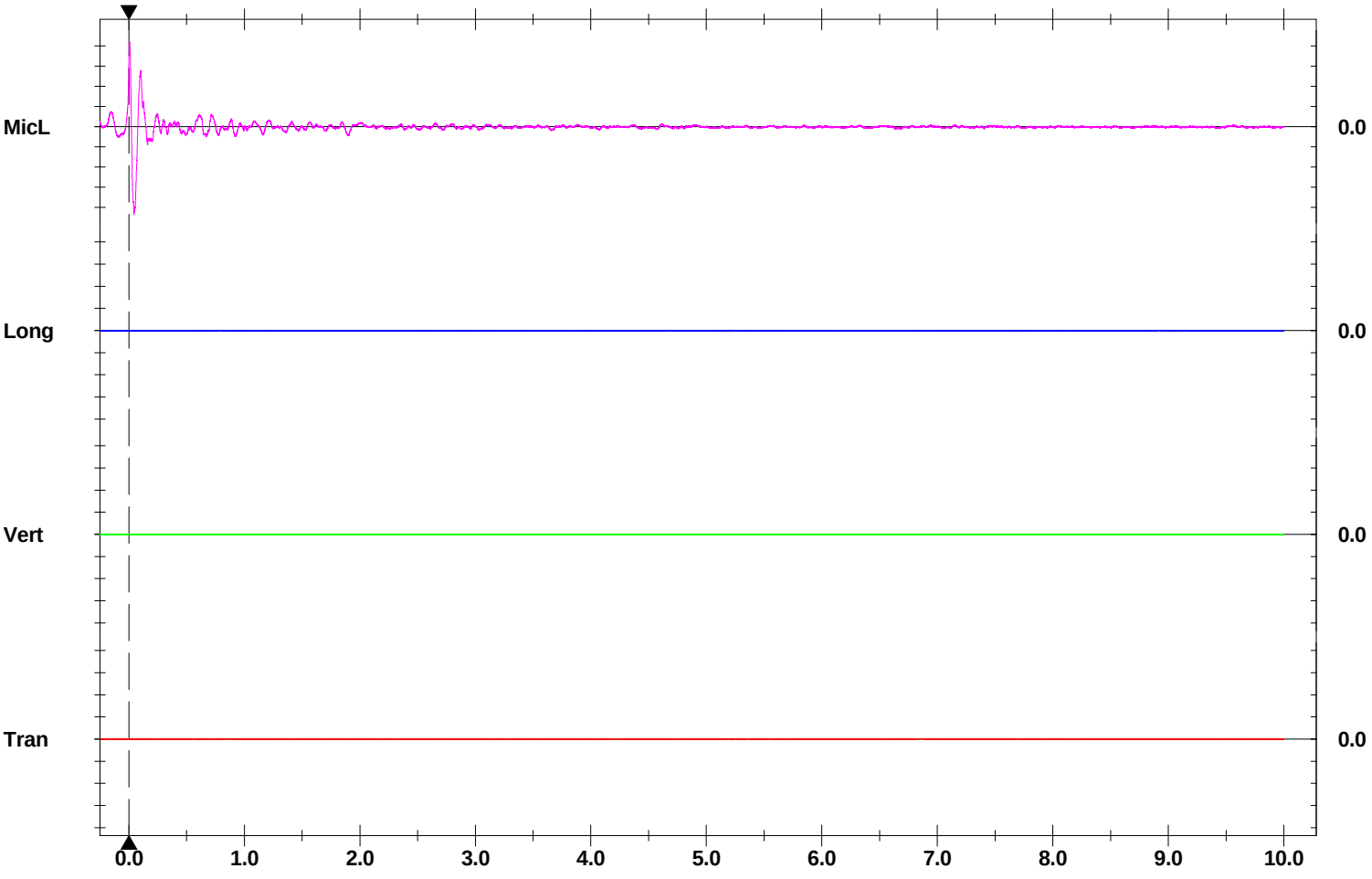
Microphone	Linear Weighting
PSPL	8.689 pa.(L) at 0.045 sec
ZC Freq	8.8 Hz
Channel Test	Passed (Freq = 19.7 Hz Amp = 1280 mv)

	Tran	Vert	Long	
PPV	0.047	0.063	0.047	mm/s
ZC Freq	128	26.6	57	Hz
Time (Rel. to Trig)	1.528	0.019	-0.205	sec
Peak Acceleration	0.020	0.020	0.020	g
Peak Displacement	0.000	0.000	0.000	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 0.065 mm/s at 0.019 sec



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.50 sec/div **Amplitude Scale:** Geo: 2.000 mm/s/div Mic: 2.000 pa.(L)/div
Trigger =

Format © 1995-2015 Xmark Corporation

Event Report

Date/Time	Long at 13:14:16 February 5, 2020
Trigger Source	Geo: 0.250 mm/s, Mic: 6.325 pa.(L)
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR BLSPR.mmb

Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200205131416.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

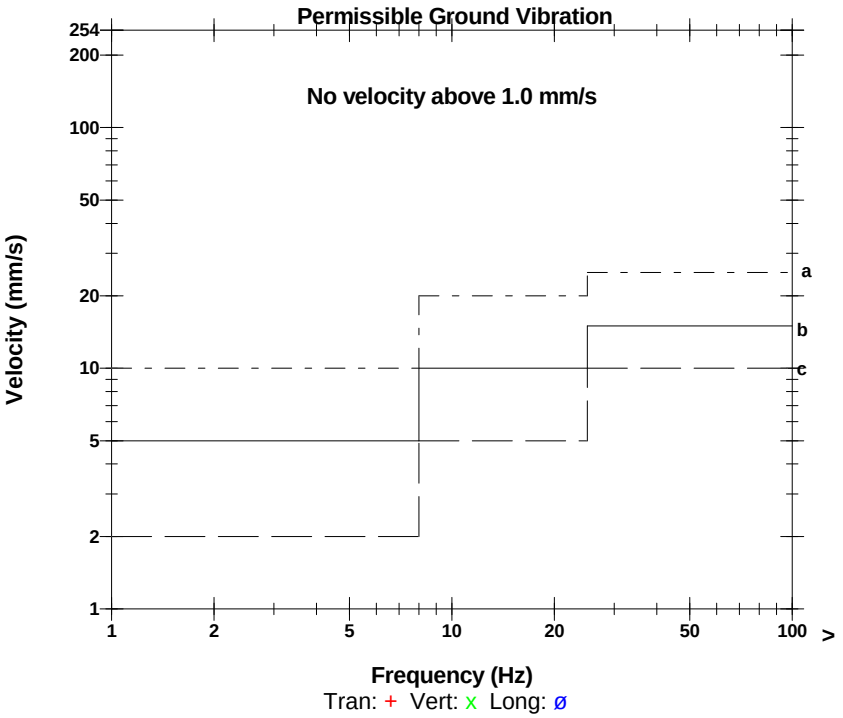
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

Microphone	Linear Weighting
PSPL	2.296 pa.(L) at 4.041 sec
ZC Freq	11.4 Hz
Channel Test	Passed (Freq = 19.7 Hz Amp = 1252 mv)

	Tran	Vert	Long	
PPV	0.363	0.189	0.292	mm/s
ZC Freq	14.8	32.0	17.8	Hz
Time (Rel. to Trig)	0.209	0.263	0.525	sec
Peak Acceleration	0.020	0.020	0.020	g
Peak Displacement	0.004	0.001	0.002	mm
Sensor Check	Passed	Passed	Passed	

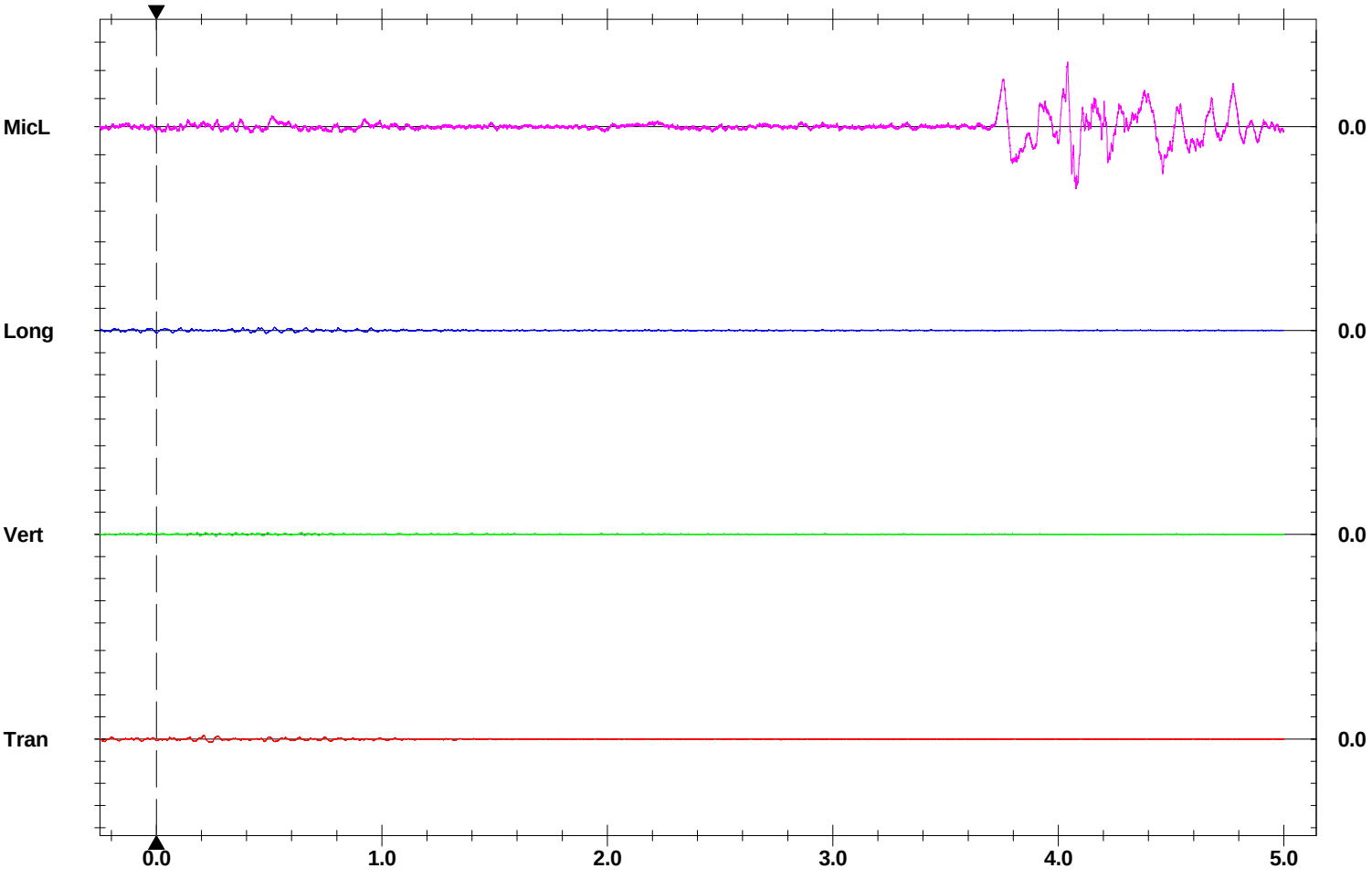
Peak Vector Sum 0.364 mm/s at 0.525 sec

DGMS India (A)



Tran: + Vert: x Long: ø

a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 2.000 mm/s/div Mic: 1.000 pa.(L)/div
Trigger =

Format © 1995-2015 Xmark Corporation

Event Report

Date/Time	Long at 13:15:06 February 5, 2020
Trigger Source	Geo: 0.510 mm/s, Mic: 6.325 pa.(L)
Range	Geo: 31.75 mm/s
Record Time	10.0 sec at 4096 sps

Serial Number	BE16508 V 10.72-1.1 Minimate Blaster
Battery Level	6.1 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	R508IBE2.560

Notes
Location: Pur Village
Client: Dist. Collector, Rajasthan Govt.
User Name: CSIR-CIMFR, Bilaspur Research Centre
General:

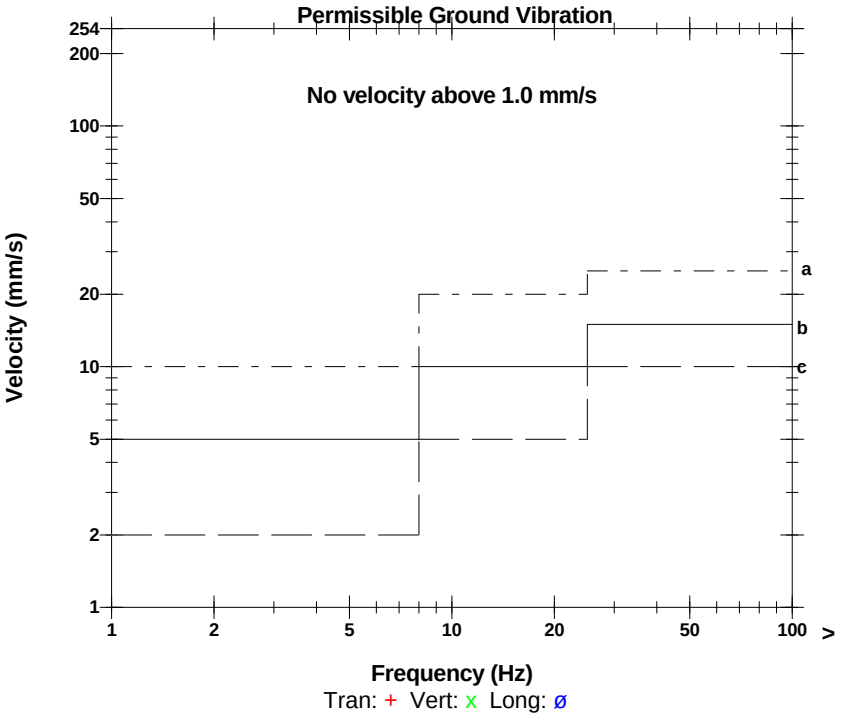
Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

Microphone	Linear Weighting
PSPL	5.000 pa.(L) at 0.725 sec
ZC Freq	6.5 Hz
Channel Test	Passed (Freq = 20.1 Hz Amp = 468 mv)

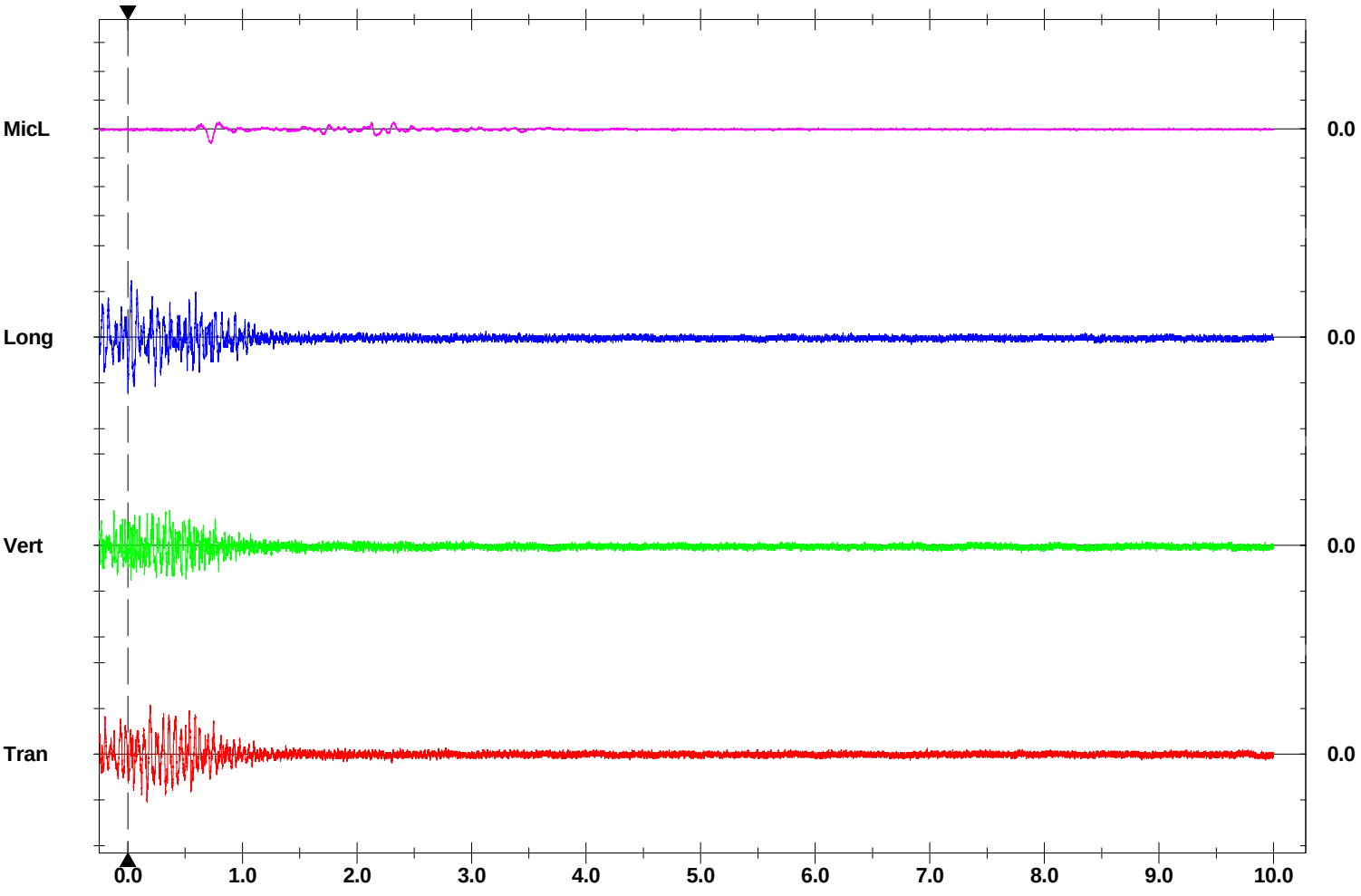
	Tran	Vert	Long	
PPV	0.540	0.381	0.619	mm/s
ZC Freq	18.1	68	22.8	Hz
Time (Rel. to Trig)	0.197	-0.121	0.032	sec
Peak Acceleration	0.033	0.040	0.033	g
Peak Displacement	0.004	0.003	0.005	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 0.696 mm/s at 0.026 sec

DGMS India (A)



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.50 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 10.000 pa.(L)/div
Trigger = ▶—— ——◀

Format © 1995-2015 Xmark Corporation

Event Report

Date/Time	Tran at 13:15:14 February 5, 2020
Trigger Source	Geo: 0.510 mm/s
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps

Serial Number	BE13781 V 10.72-8.17 MiniMate Plus
Battery Level	6.2 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	O781IBE2.5E0

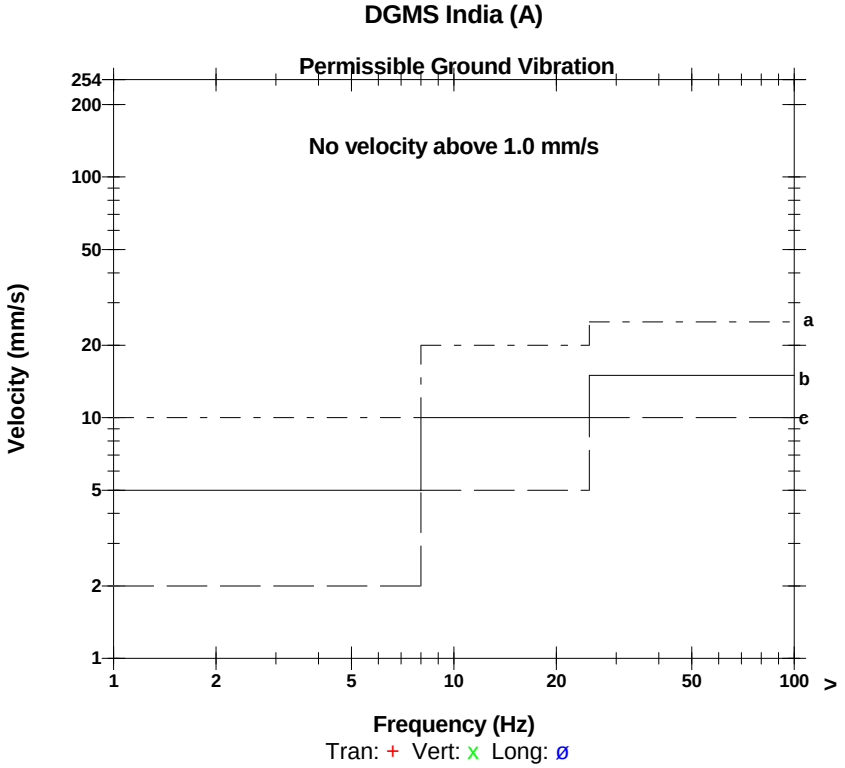
Notes
Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR, Bilaspur Research Centre
General:

Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

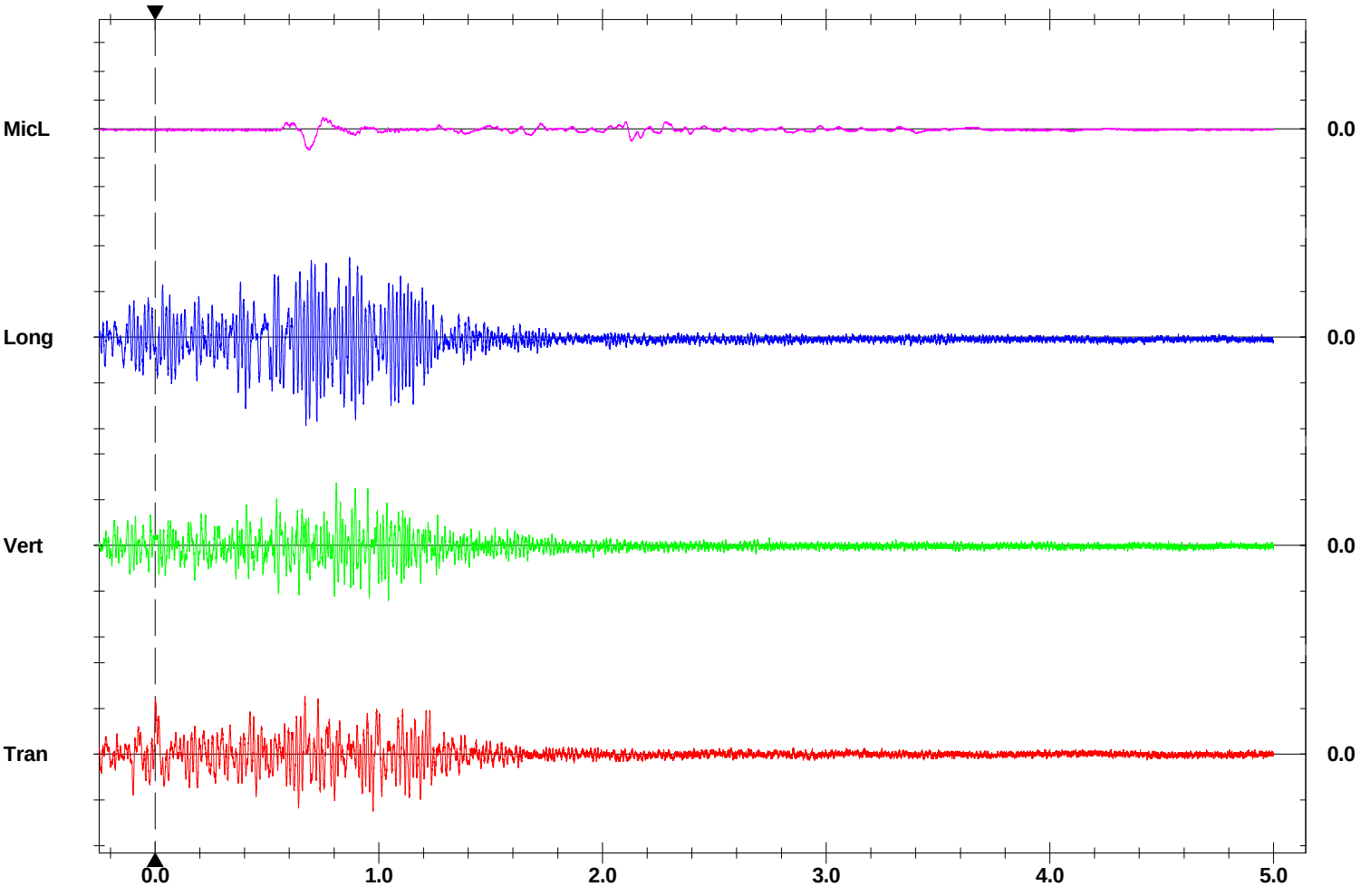
Microphone	Linear Weighting
PSPL	7.250 pa.(L) at 0.685 sec
ZC Freq	6.5 Hz
Channel Test	Passed (Freq = 20.1 Hz Amp = 524 mv)

	Tran	Vert	Long	
PPV	0.635	0.683	0.968	mm/s
ZC Freq	39.4	55	57	Hz
Time (Rel. to Trig)	0.670	0.810	0.674	sec
Peak Acceleration	0.033	0.046	0.053	g
Peak Displacement	0.004	0.002	0.003	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 1.088 mm/s at 0.895 sec



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 10.000 pa.(L)/div
Trigger =

Format © 1995-2015 Xmark Corporation

Event Report

Date/Time	Long at 13:15:21 February 5, 2020
Trigger Source	Geo: 0.250 mm/s, Mic: 6.325 pa.(L)
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR BLSPR.mmb

Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200205131521.IDFW

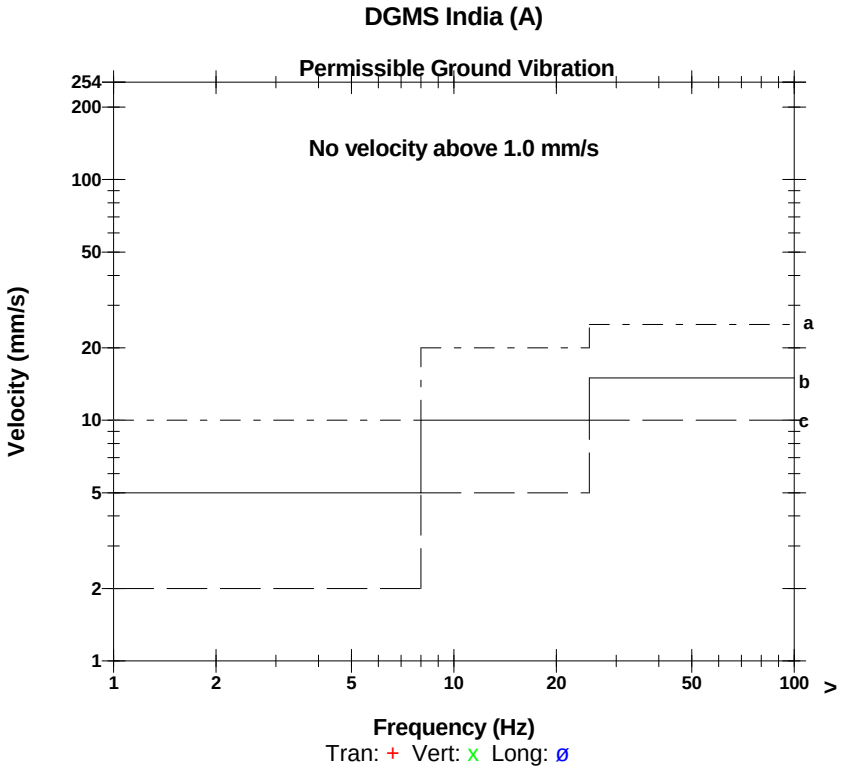
Notes
Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

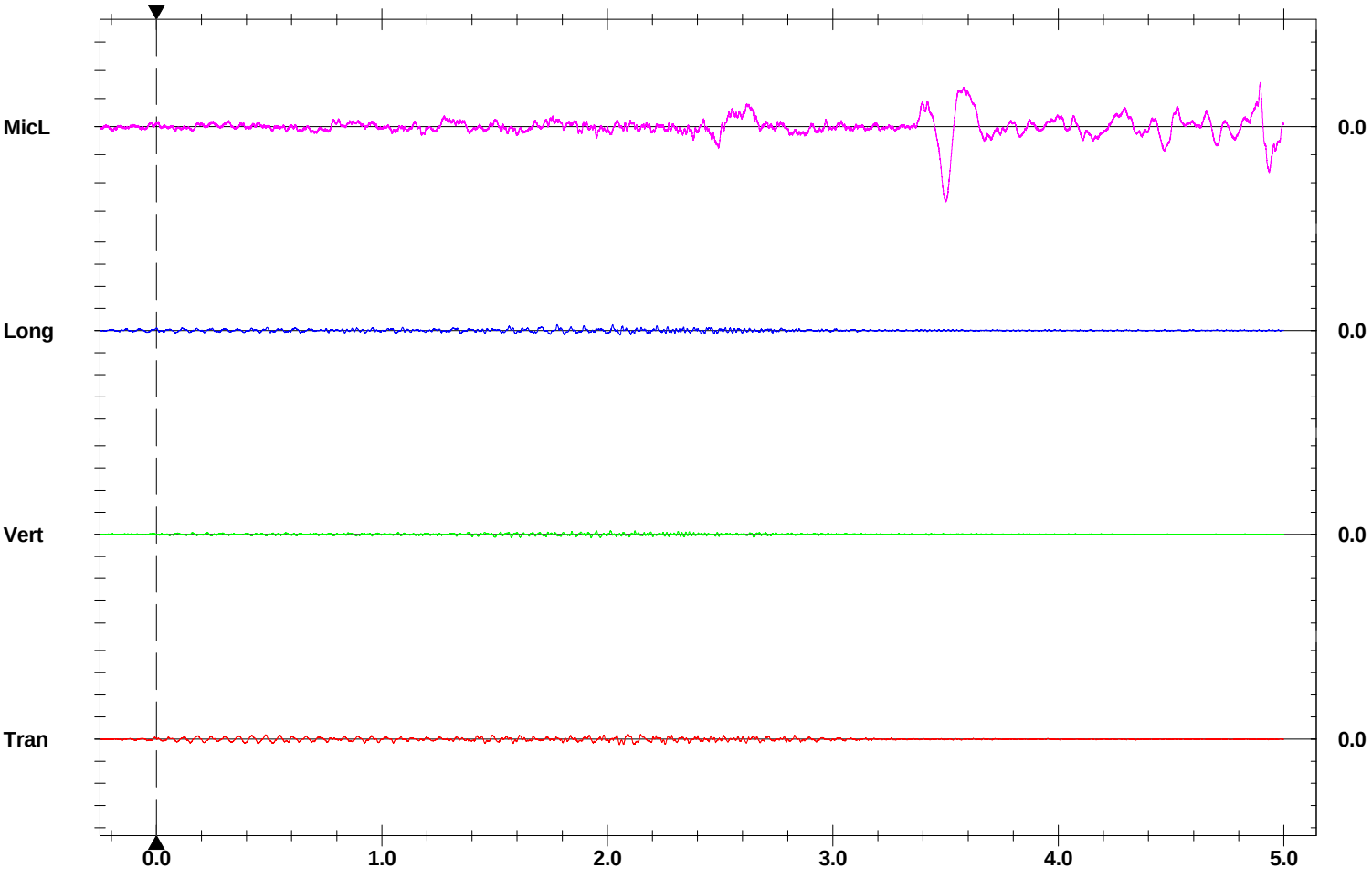
Microphone	Linear Weighting
PSPL	2.669 pa.(L) at 3.500 sec
ZC Freq	6.0 Hz
Channel Test	Passed (Freq = 19.7 Hz Amp = 1252 mv)

	Tran	Vert	Long	
PPV	0.497	0.323	0.536	mm/s
ZC Freq	16.1	33.0	14.7	Hz
Time (Rel. to Trig)	2.053	1.951	1.777	sec
Peak Acceleration	0.023	0.020	0.026	g
Peak Displacement	0.005	0.002	0.004	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 0.599 mm/s at 2.053 sec



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 2.000 mm/s/div Mic: 1.000 pa.(L)/div
Trigger =

Format © 1995-2015 Xmark Corporation

Event Report

Date/Time	Tran at 13:12:02 February 6, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR BLSPR.mmb

Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200206131202.IDFW

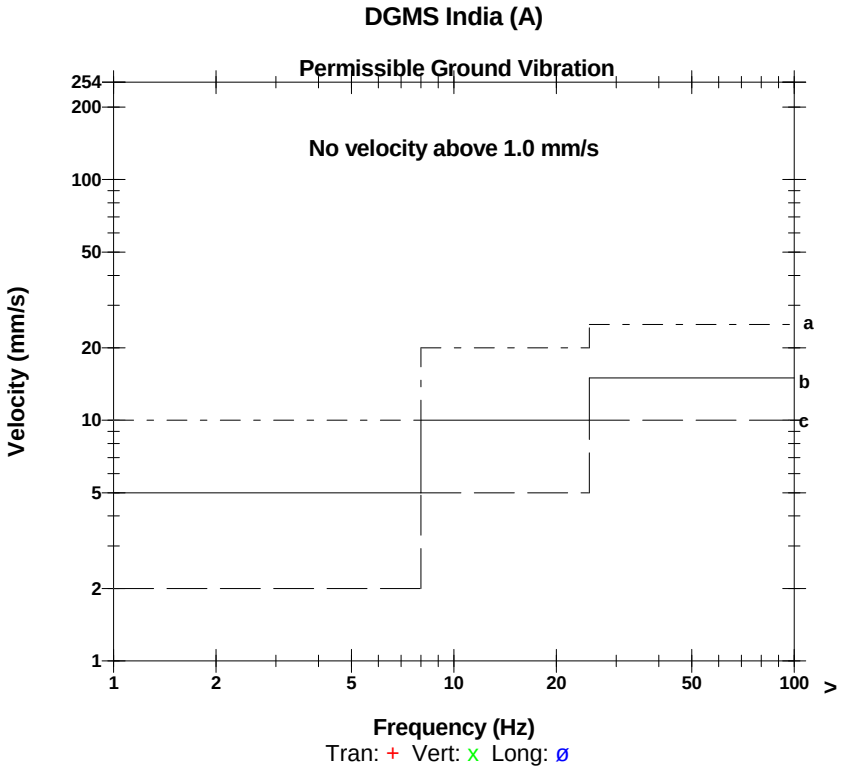
Notes
Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

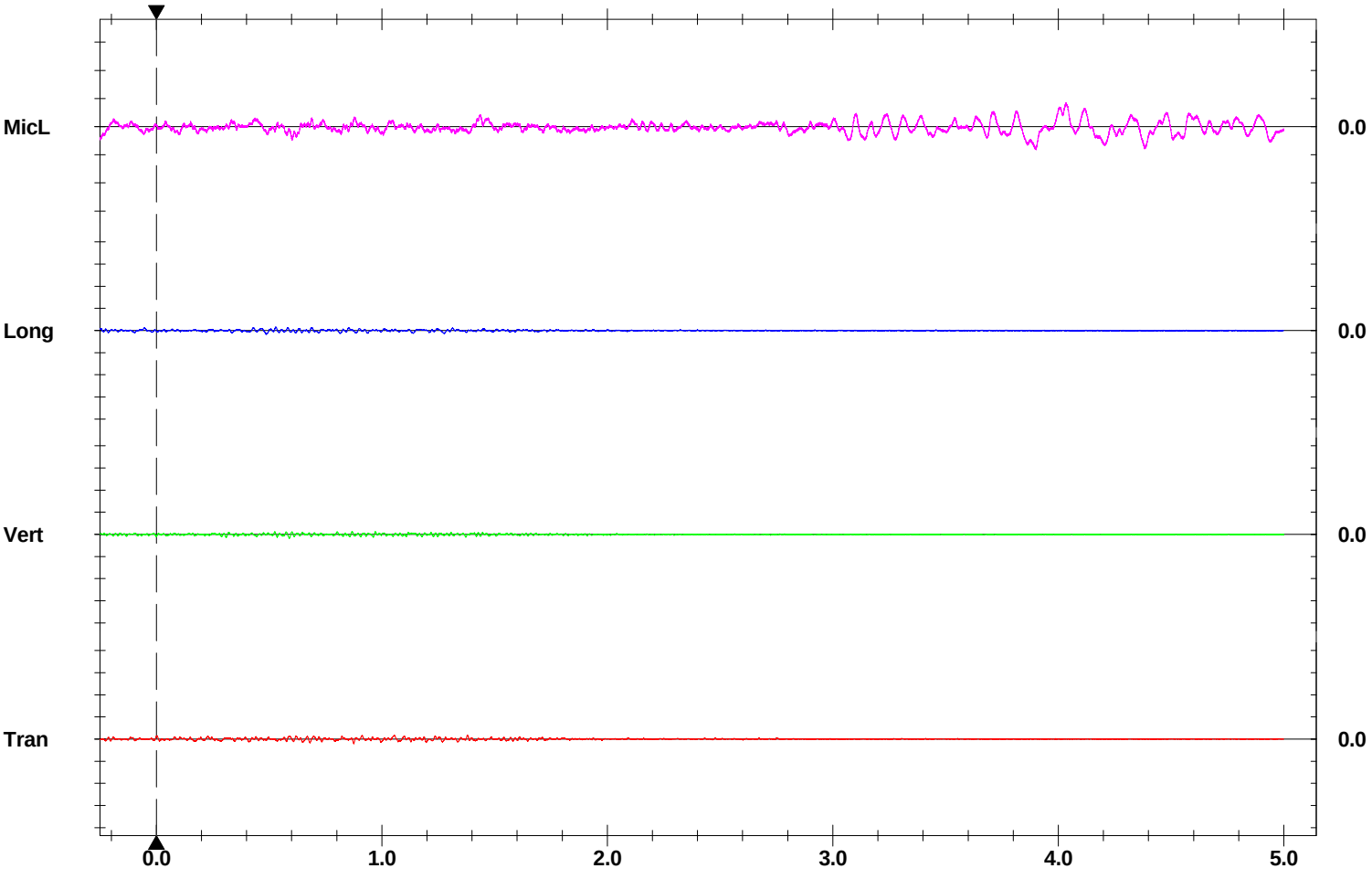
Microphone	Linear Weighting
PSPL	0.838 pa.(L) at 4.033 sec
ZC Freq	6.8 Hz
Channel Test	Passed (Freq = 19.7 Hz Amp = 1320 mv)

	Tran	Vert	Long	
PPV	0.410	0.331	0.347	mm/s
ZC Freq	44	35.3	21.8	Hz
Time (Rel. to Trig)	0.876	0.589	0.488	sec
Peak Acceleration	0.020	0.020	0.020	g
Peak Displacement	0.002	0.001	0.002	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 0.418 mm/s at 0.876 sec



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 2.000 mm/s/div Mic: 1.000 pa.(L)/div
Trigger =

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Event Report

Date/Time	Tran at 13:14:30 February 6, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR BLSPR.mmb

Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200206131430.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

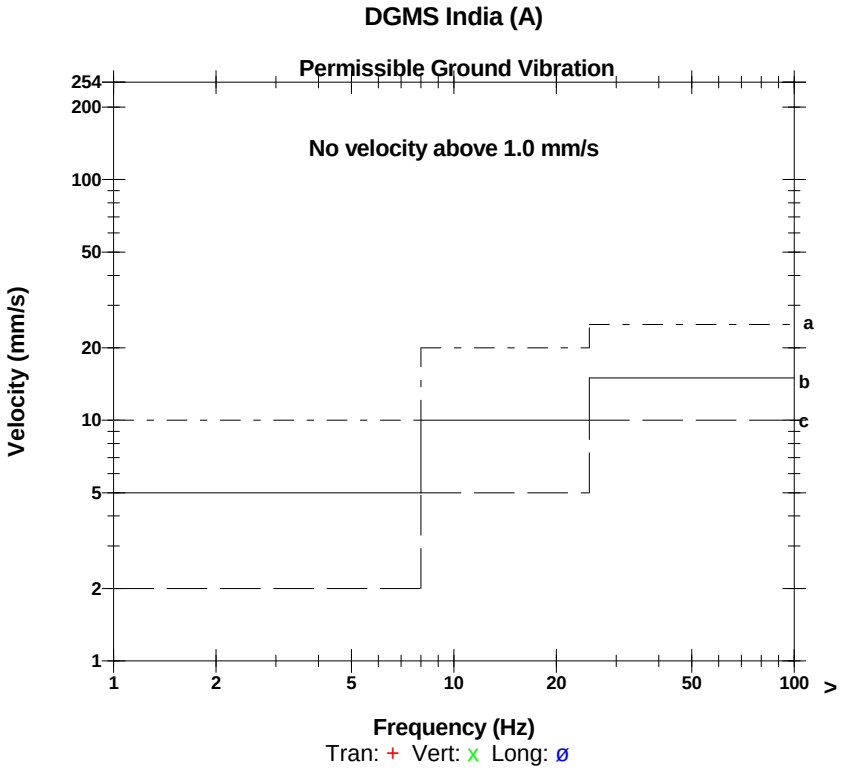
Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

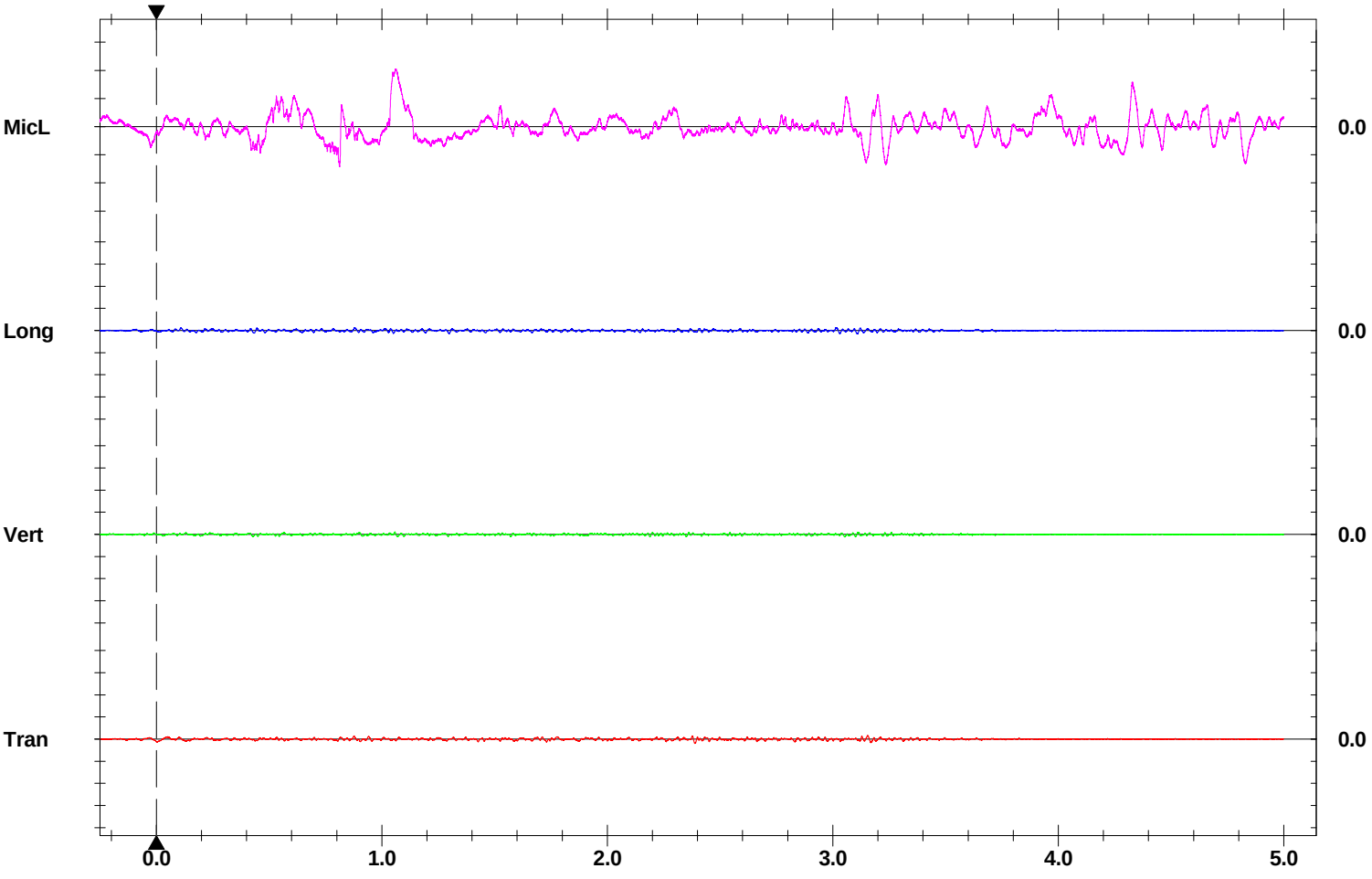
Microphone	Linear Weighting
PSPL	2.048 pa.(L) at 1.063 sec
ZC Freq	4.3 Hz
Channel Test	Passed (Freq = 19.7 Hz Amp = 1320 mv)

	Tran	Vert	Long	
PPV	0.394	0.236	0.315	mm/s
ZC Freq	35.9	33.6	32.0	Hz
Time (Rel. to Trig)	2.389	3.053	3.107	sec
Peak Acceleration	0.023	0.020	0.020	g
Peak Displacement	0.003	0.001	0.002	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 0.414 mm/s at 2.389 sec



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 2.000 mm/s/div Mic: 1.000 pa.(L)/div
Trigger = ▶—— —— ◀

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Event Report

Date/Time	Long at 13:29:26 March 3, 2020
Trigger Source	Geo: 0.500 mm/s
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps
Job Number:	1

Serial Number	BE18062 V 10.72-1.1 Minimate Blaster
Battery Level	6.2 Volts
Unit Calibration	March 29, 2019 by UES, New Delhi
File Name	T062ICS2.T20

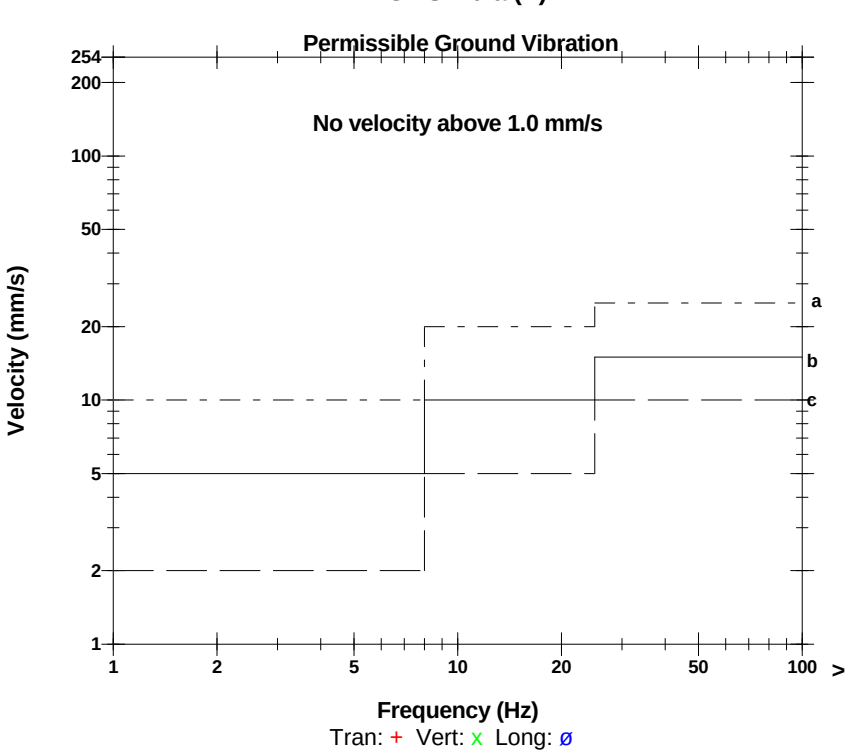
Notes
Location: Pur Village
Client: District collector Bhilwara, Rajasthan
User Name: CIMFR
General:

Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibation & Airover Pressure in Domestic Houses inPur Village, Bhilwara, Rajasthan.

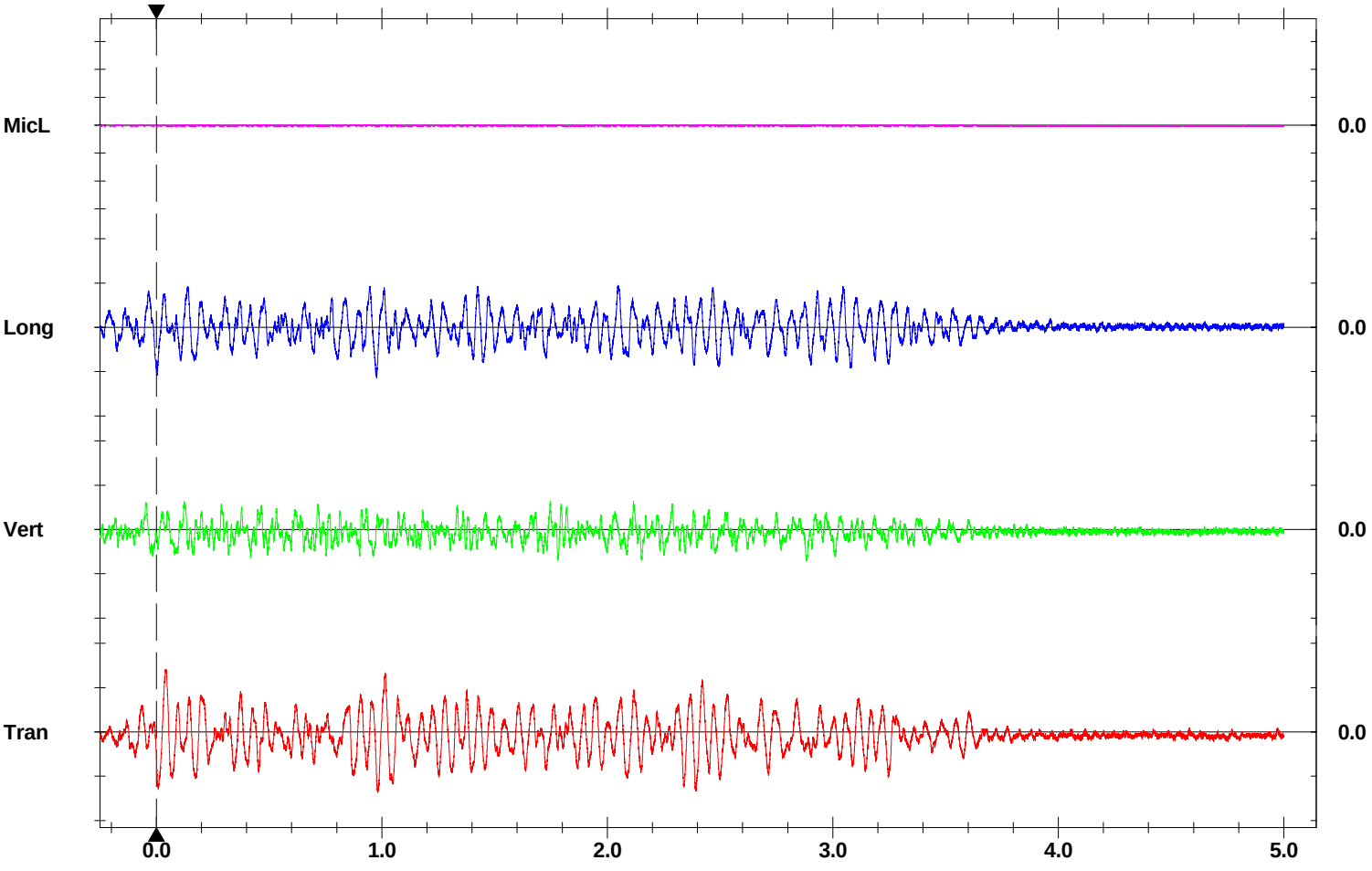
Microphone	Linear Weighting
PSPL	0.500 pa.(L) at -0.250 sec
ZC Freq	N/A
Channel Test	Check (Freq = 0.0 Hz Amp = 0 mv)

	Tran	Vert	Long	
PPV	0.698	0.349	0.571	mm/s
ZC Freq	17.5	35.3	16.9	Hz
Time (Rel. to Trig)	0.039	1.781	0.977	sec
Peak Acceleration	0.027	0.027	0.033	g
Peak Displacement	0.007	0.004	0.005	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 0.819 mm/s at 0.978 sec
N/A: Not Applicable



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 10.000 pa.(L)/div
Trigger = ▶—— ——◀

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Event Report

Date/Time	Long at 13:29:26 March 3, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

Serial Number	UM12452 V 10-89 Micromate ISEE
Battery Level	3.7 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12452_20200303132926.IDFW

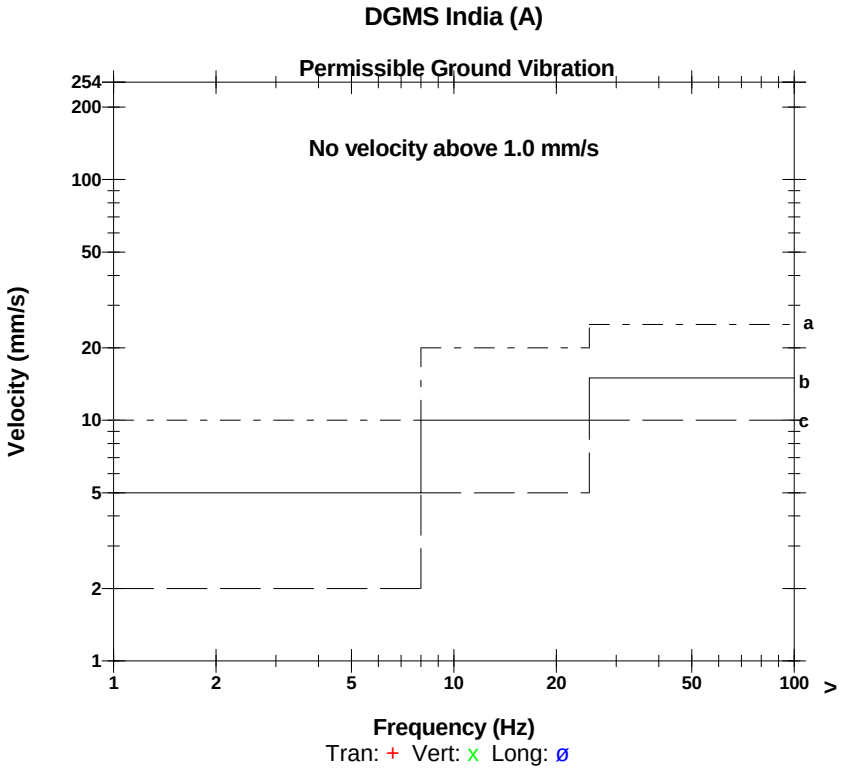
Notes
Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

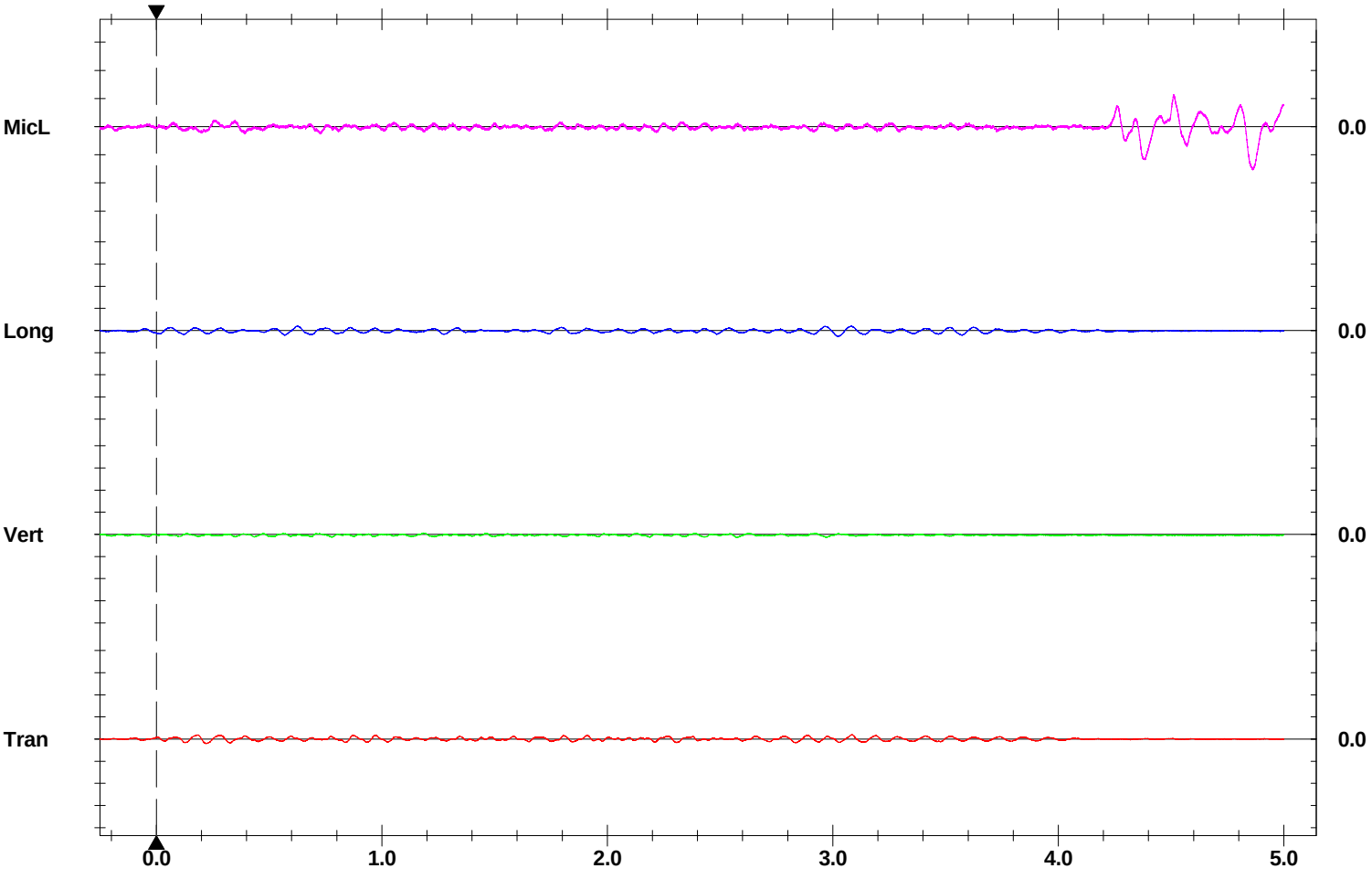
Microphone	Linear Weighting
PSPL	1.536 pa.(L) at 4.862 sec
ZC Freq	6.8 Hz
Channel Test	Passed (Freq = 19.7 Hz Amp = 1185 mv)

	Tran	Vert	Long	
PPV	0.418	0.284	0.544	mm/s
ZC Freq	10.6	8.7	8.4	Hz
Time (Rel. to Trig)	0.222	2.573	3.023	sec
Peak Acceleration	0.020	0.016	0.016	g
Peak Displacement	0.006	0.006	0.010	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 0.612 mm/s at 3.025 sec



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 2.000 mm/s/div Mic: 1.000 pa.(L)/div
Trigger = ▶—— ——◀

Format © 1995-2015 Xmark Corporation

Event Report

Date/Time	Long at 13:18:28 March 4, 2020
Trigger Source	Geo: 0.500 mm/s, Mic: 6.325 pa.(L)
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps

Serial Number	BE16508 V 10.72-1.1 Minimate Blaster
Battery Level	6.2 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	R508ICTW.YS0

Notes
Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

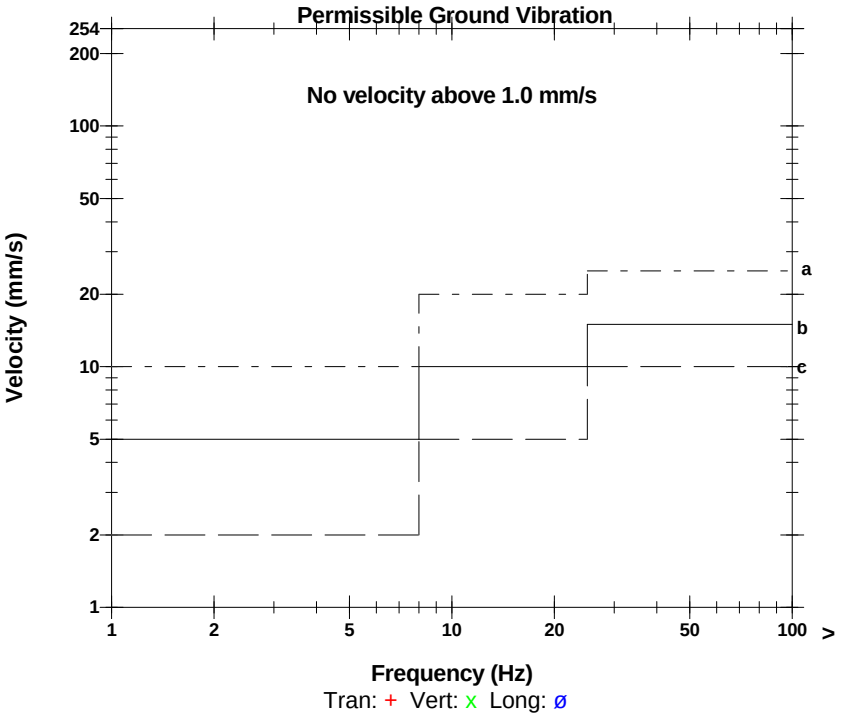
Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

Microphone	Linear Weighting
PSPL	5.250 pa.(L) at 1.506 sec
ZC Freq	5.9 Hz
Channel Test	Passed (Freq = 20.1 Hz Amp = 441 mv)

	Tran	Vert	Long	
PPV	0.587	0.270	0.540	mm/s
ZC Freq	26.6	21.8	20.7	Hz
Time (Rel. to Trig)	0.378	-0.054	0.304	sec
Peak Acceleration	0.027	0.027	0.027	g
Peak Displacement	0.004	0.002	0.004	mm
Sensor Check	Passed	Passed	Passed	

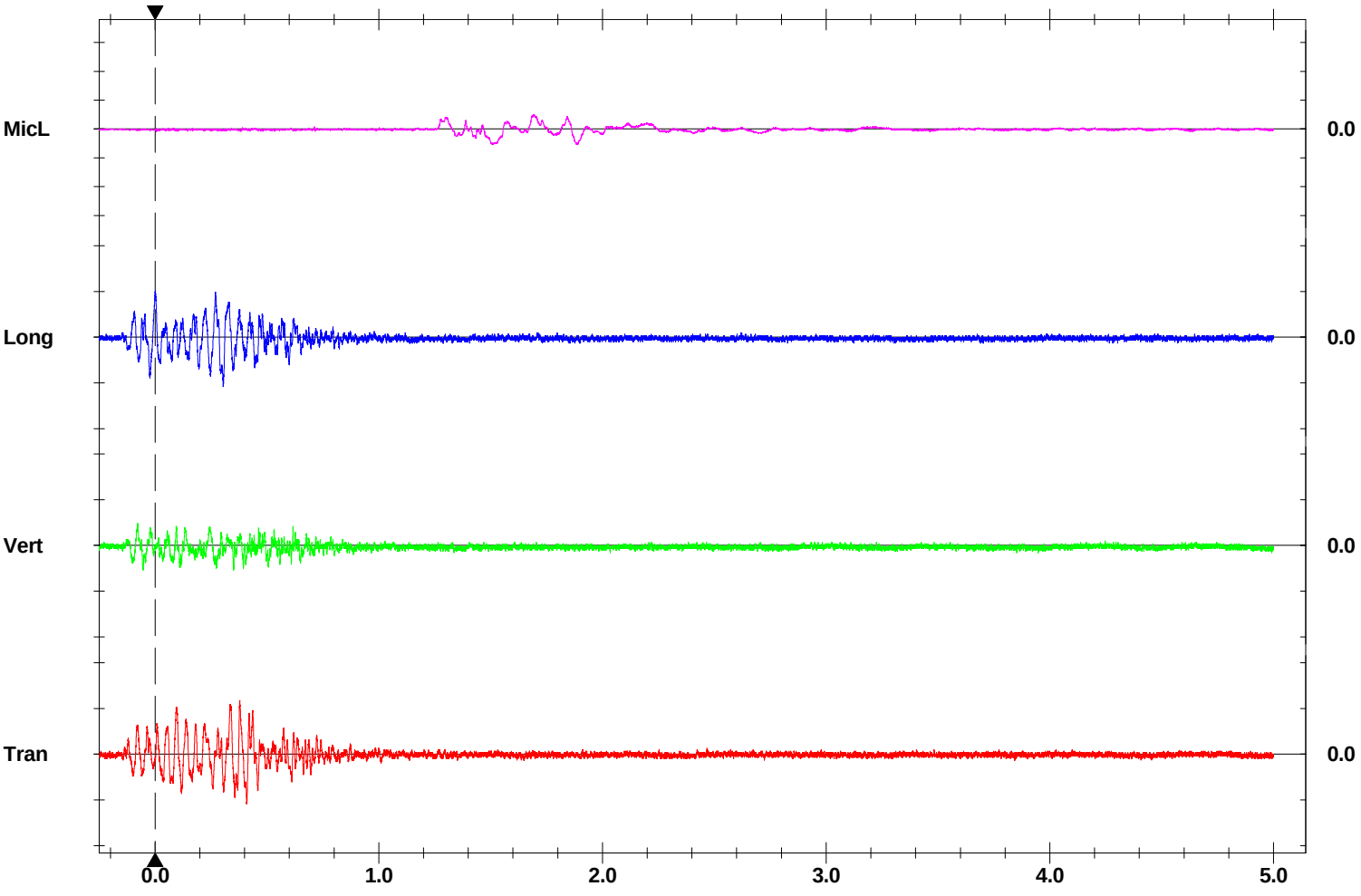
Peak Vector Sum 0.663 mm/s at 0.378 sec

DGMS India (A)



Tran: + Vert: x Long: ø

a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 10.000 pa.(L)/div
Trigger =

Format © 1995-2015 Xmark Corporation

Event Report

Date/Time	Long at 13:18:45 March 4, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200304131845.IDFW

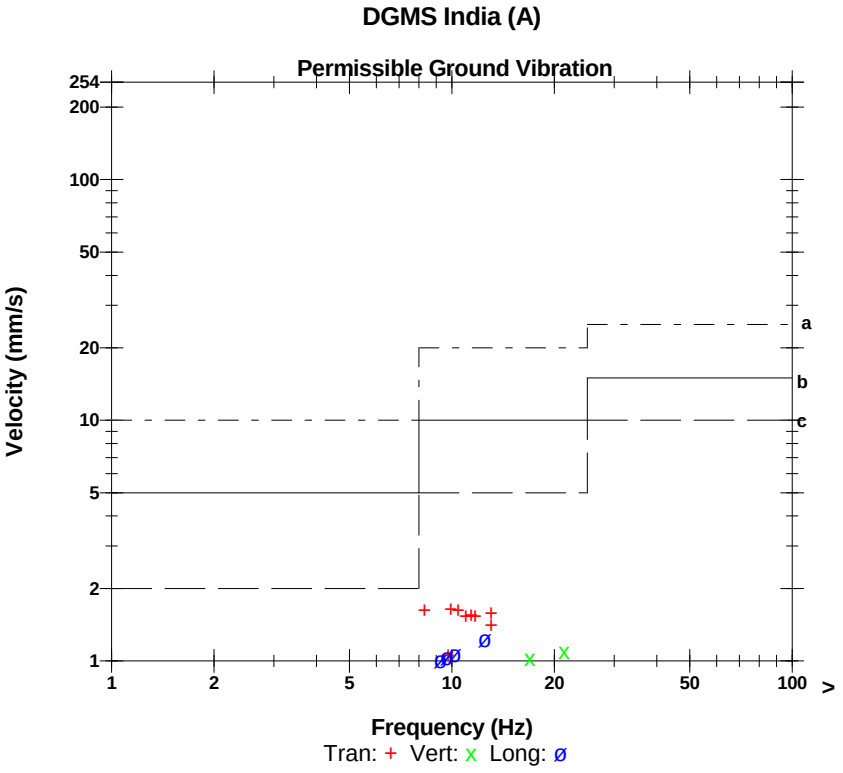
Notes
Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

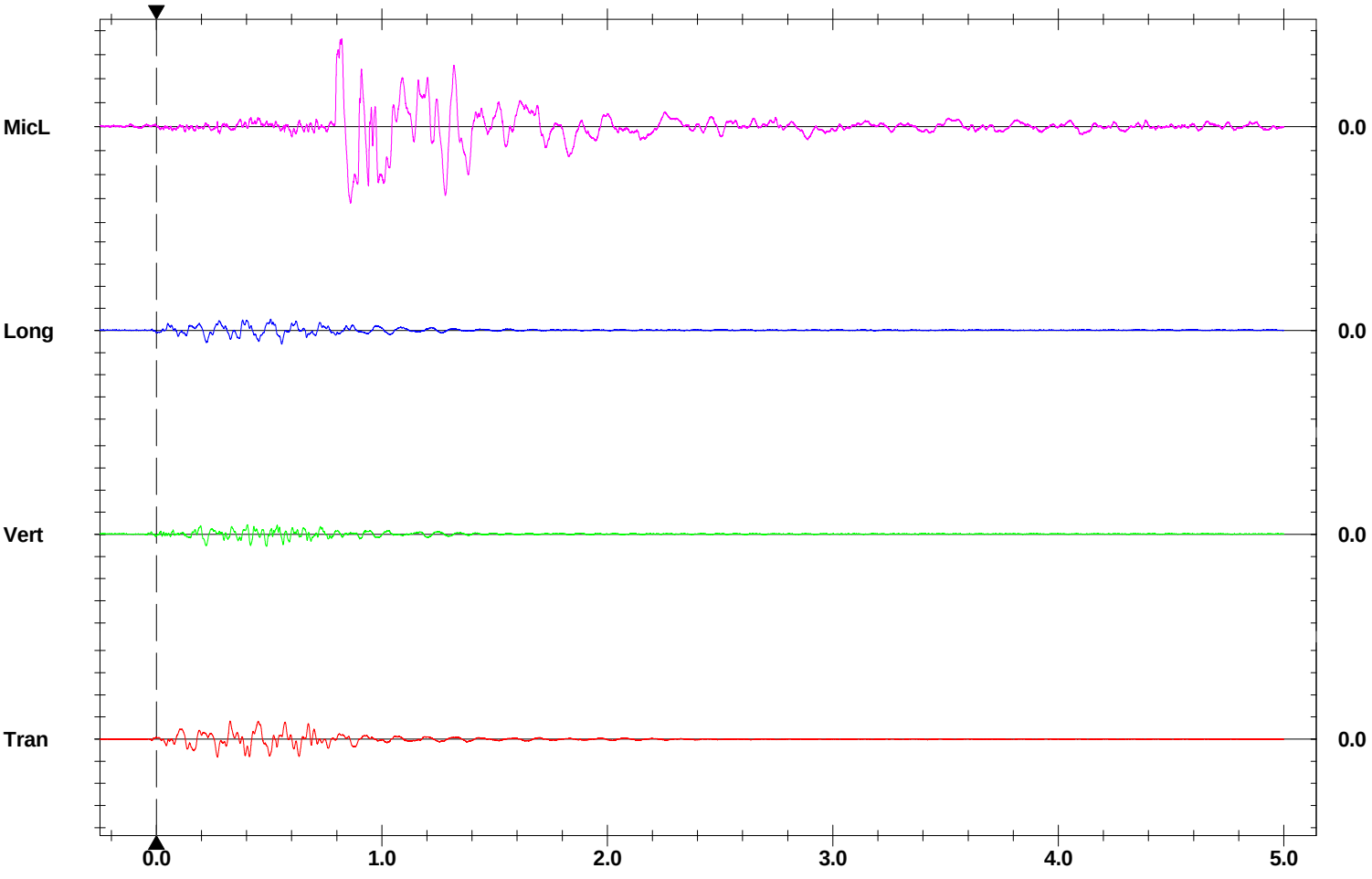
Microphone	Linear Weighting
PSPL	7.308 pa.(L) at 0.822 sec
ZC Freq	6.8 Hz
Channel Test	Passed (Freq = 19.7 Hz Amp = 1197 mv)

	Tran	Vert	Long	
PPV	1.639	1.096	1.230	mm/s
ZC Freq	9.9	21.3	12.5	Hz
Time (Rel. to Trig)	0.327	0.489	0.556	sec
Peak Acceleration	0.046	0.039	0.033	g
Peak Displacement	0.022	0.009	0.016	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 1.878 mm/s at 0.453 sec



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 2.000 mm/s/div Mic: 2.000 pa.(L)/div
Trigger =

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Event Report

Date/Time	Vert at 13:18:46 March 4, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

Serial Number	UM12452 V 10-89 Micromate ISEE
Battery Level	3.7 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12452_20200304131846.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

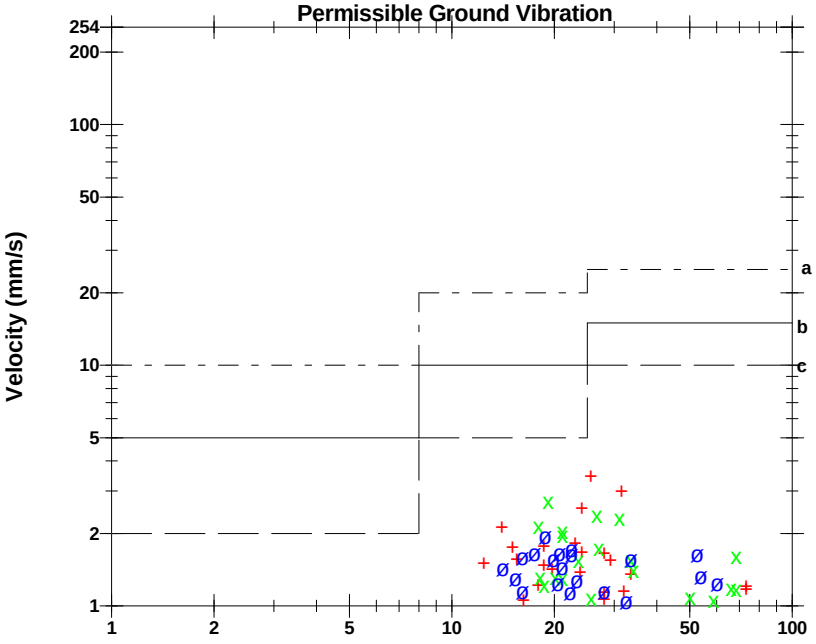
Microphone	Linear Weighting
PSPL	<0.500 pa.(L)
ZC Freq	N/A
Channel Test	Check (Freq = 0.0 Hz Amp = 0 mv)

	Tran	Vert	Long	
PPV	3.460	2.719	1.955	mm/s
ZC Freq	25.6	19.1	18.8	Hz
Time (Rel. to Trig)	0.313	0.502	0.383	sec
Peak Acceleration	0.118	0.112	0.079	g
Peak Displacement	0.018	0.017	0.015	mm
Sensor Check	Passed	Passed	Passed	

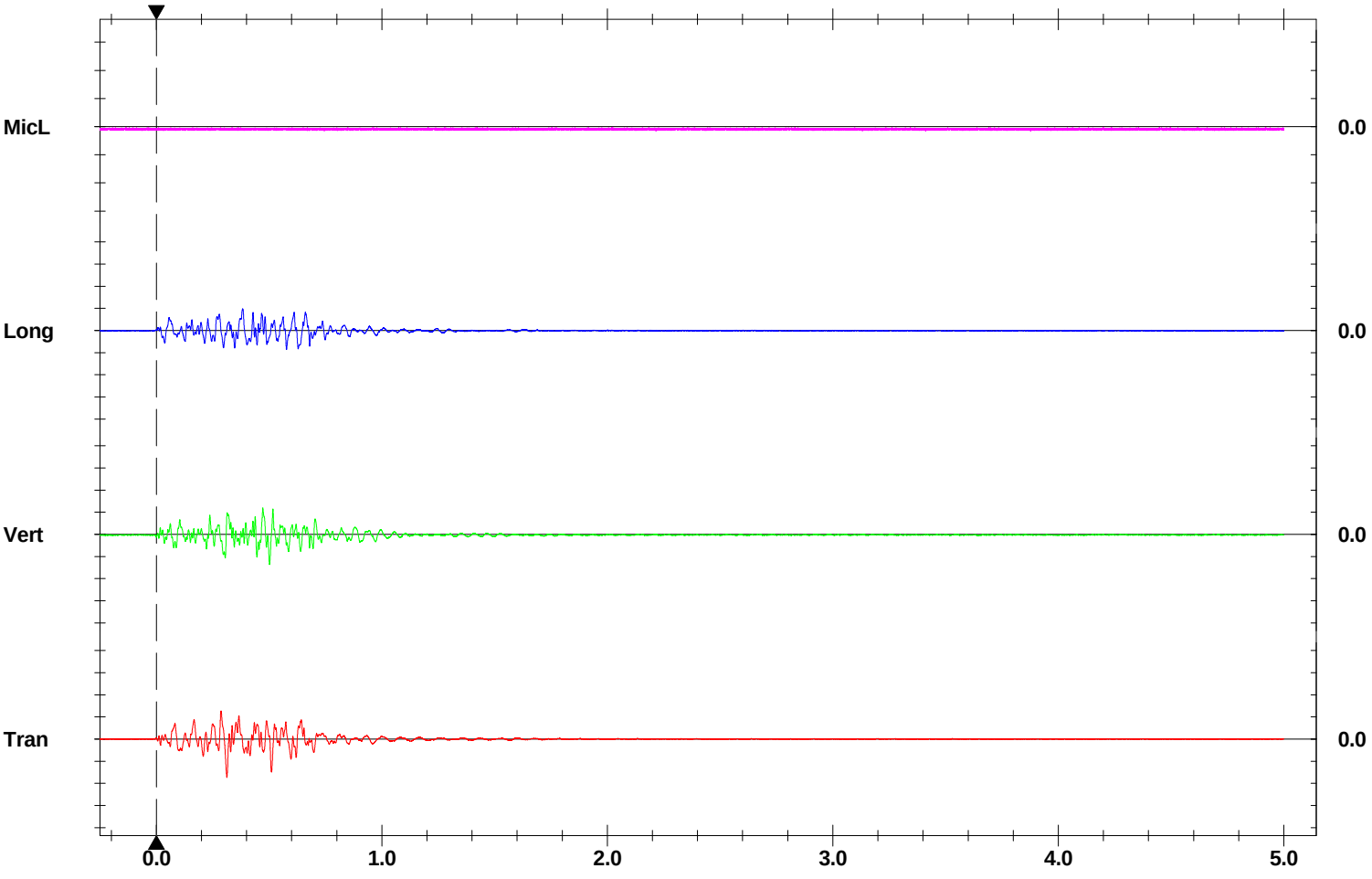
Peak Vector Sum 3.961 mm/s at 0.313 sec
N/A: Not Applicable

DGMS India (A)

Permissible Ground Vibration



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 2.000 mm/s/div Mic: 1.000 pa.(L)/div
Trigger = ▶—— —— ◀

Format © 1995-2015 Xmark Corporation

Event Report

Date/Time	Tran at 13:20:44 March 4, 2020
Trigger Source	Geo: 0.500 mm/s, Mic: 6.325 pa.(L)
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps

Serial Number	BE16508 V 10.72-1.1 Minimate Blaster
Battery Level	6.2 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	R508ICTX.2K0

Notes
Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

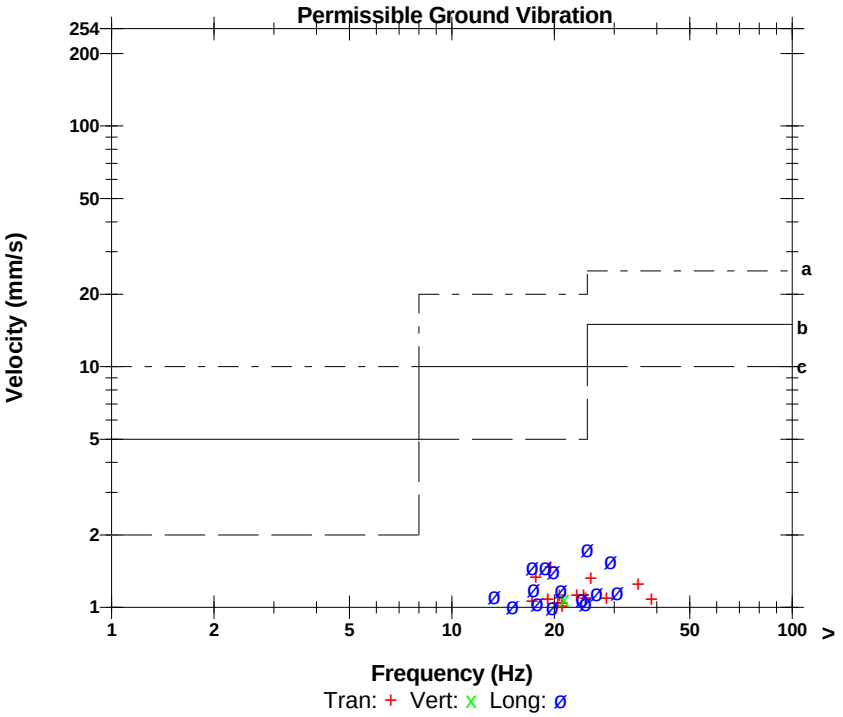
Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

Microphone	Linear Weighting
PSPL	7.500 pa.(L) at 1.309 sec
ZC Freq	9.4 Hz
Channel Test	Passed (Freq = 20.1 Hz Amp = 441 mv)

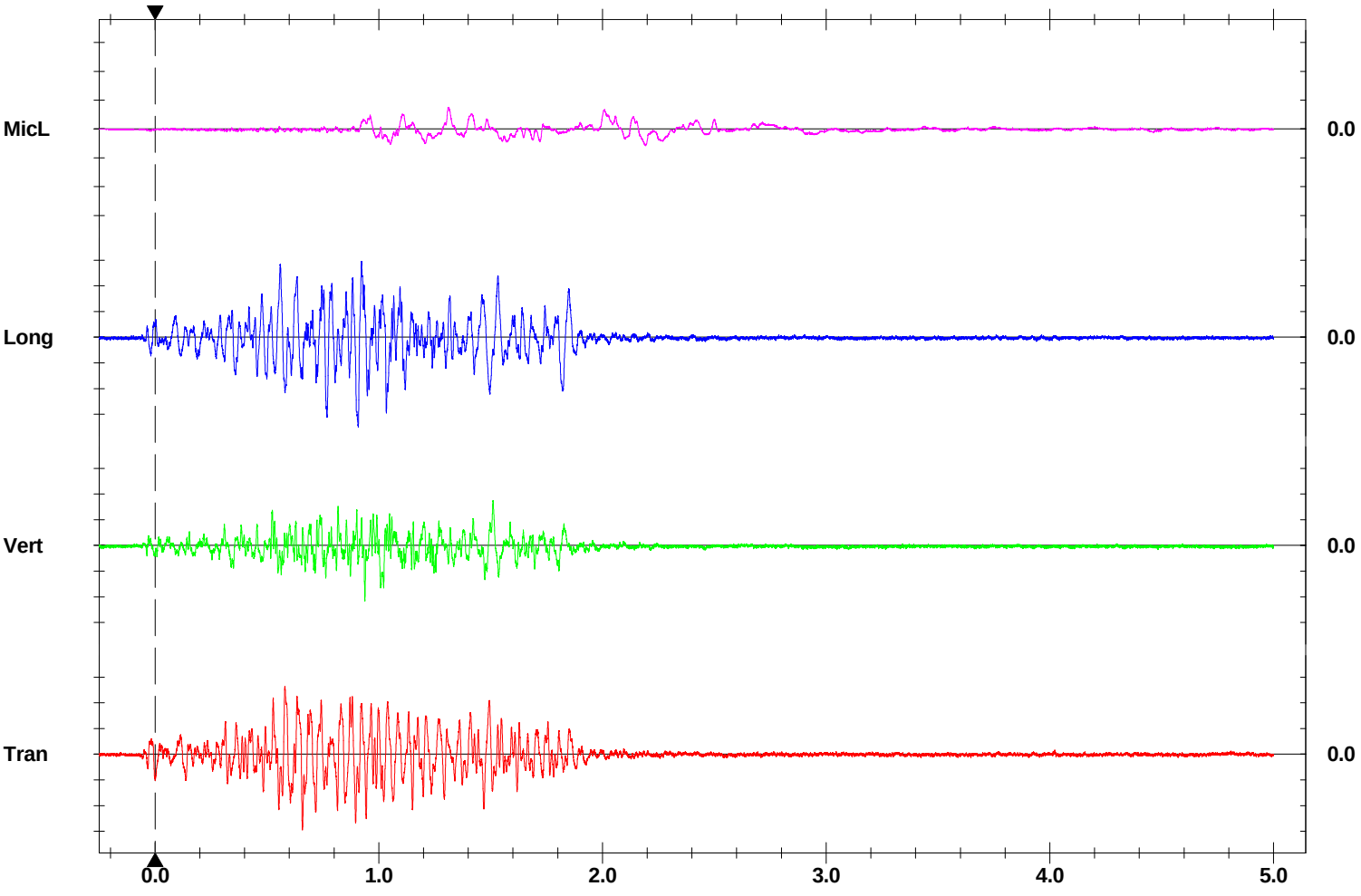
	Tran	Vert	Long	
PPV	1.476	1.079	1.746	mm/s
ZC Freq	19.5	21.3	25.0	Hz
Time (Rel. to Trig)	0.658	0.938	0.908	sec
Peak Acceleration	0.053	0.046	0.060	g
Peak Displacement	0.009	0.007	0.011	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 1.855 mm/s at 0.908 sec

DGMS India (A)



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 10.000 pa.(L)/div
Trigger = ▶—— ——◀

Format © 1995-2015 Xmark Corporation

Event Report

Date/Time	Vert at 13:21:02 March 4, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200304132102.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

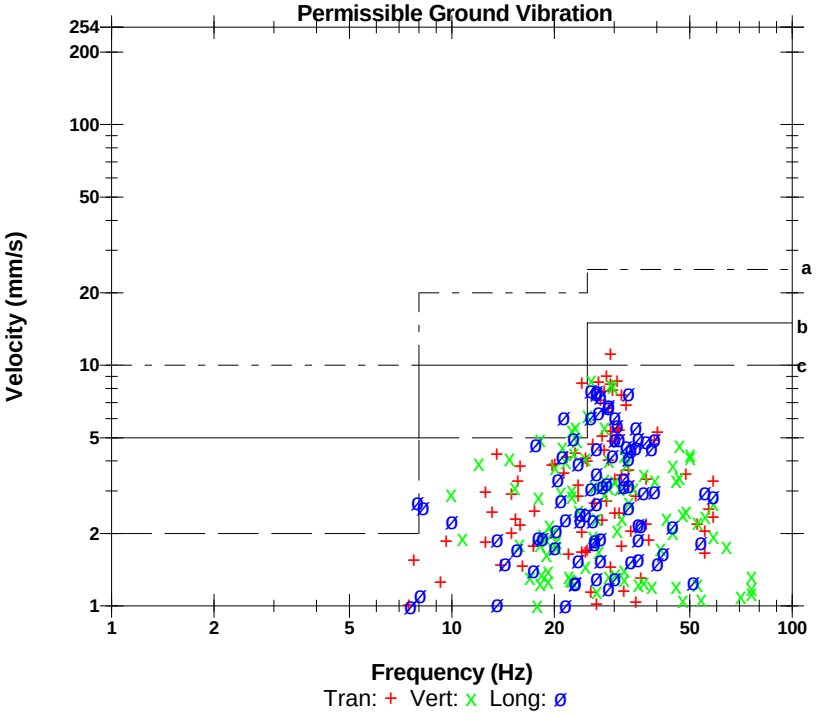
Microphone	Linear Weighting
PSPL	24.00 pa.(L) at 0.678 sec
ZC Freq	5.8 Hz
Channel Test	Passed (Freq = 19.7 Hz Amp = 1197 mv)

	Tran	Vert	Long	
PPV	11.14	8.686	7.850	mm/s
ZC Freq	29.3	25.6	25.6	Hz
Time (Rel. to Trig)	1.017	0.811	0.580	sec
Peak Acceleration	0.434	0.260	0.306	g
Peak Displacement	0.057	0.046	0.049	mm
Sensor Check	Passed	Passed	Passed	

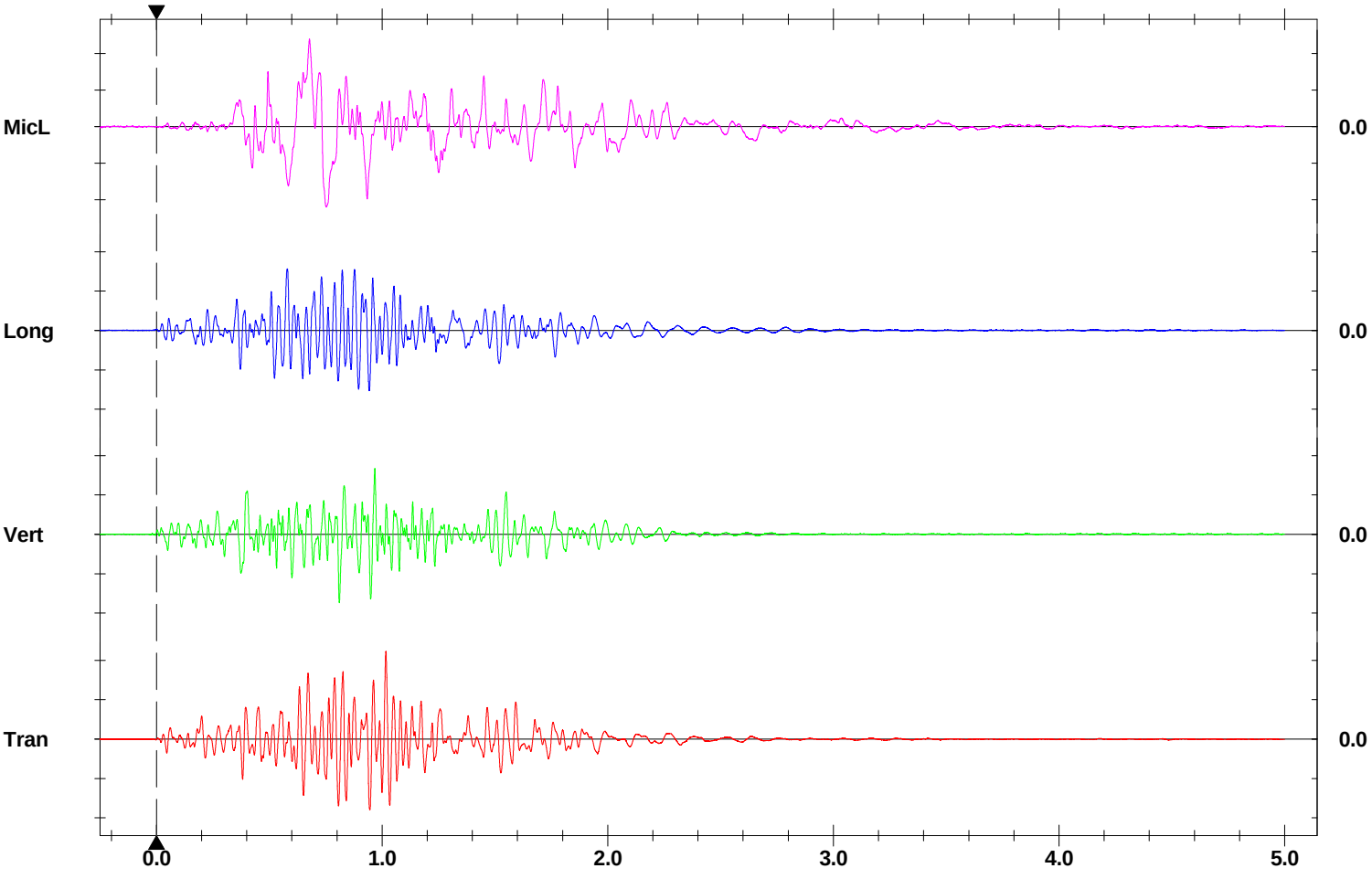
Peak Vector Sum 12.82 mm/s at 0.947 sec

DGMS India (A)

Permissible Ground Vibration



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 5.000 mm/s/div Mic: 10.000 pa.(L)/div
Trigger = ▶—— ——◀

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Event Report

Date/Time	Vert at 13:21:03 March 4, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

Serial Number	UM12452 V 10-89 Micromate ISEE
Battery Level	3.7 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12452_20200304132103.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

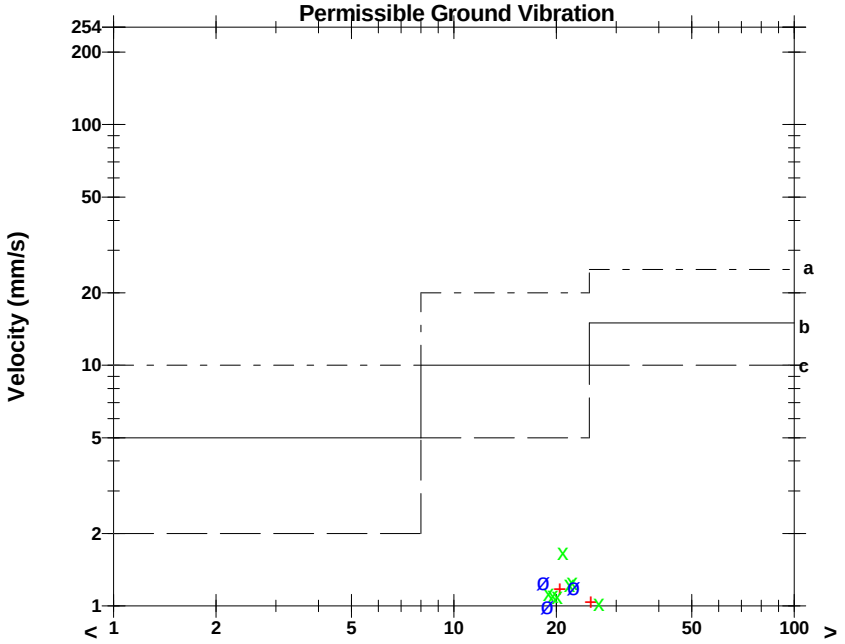
Microphone	Linear Weighting
PSPL	<0.500 pa.(L)
ZC Freq	N/A
Channel Test	Check (Freq = 0.0 Hz Amp = 0 mv)

	Tran	Vert	Long	
PPV	1.174	1.671	1.253	mm/s
ZC Freq	20.5	20.9	18.3	Hz
Time (Rel. to Trig)	0.560	0.495	0.977	sec
Peak Acceleration	0.039	0.030	0.043	g
Peak Displacement	0.010	0.015	0.010	mm
Sensor Check	Passed	Passed	Passed	

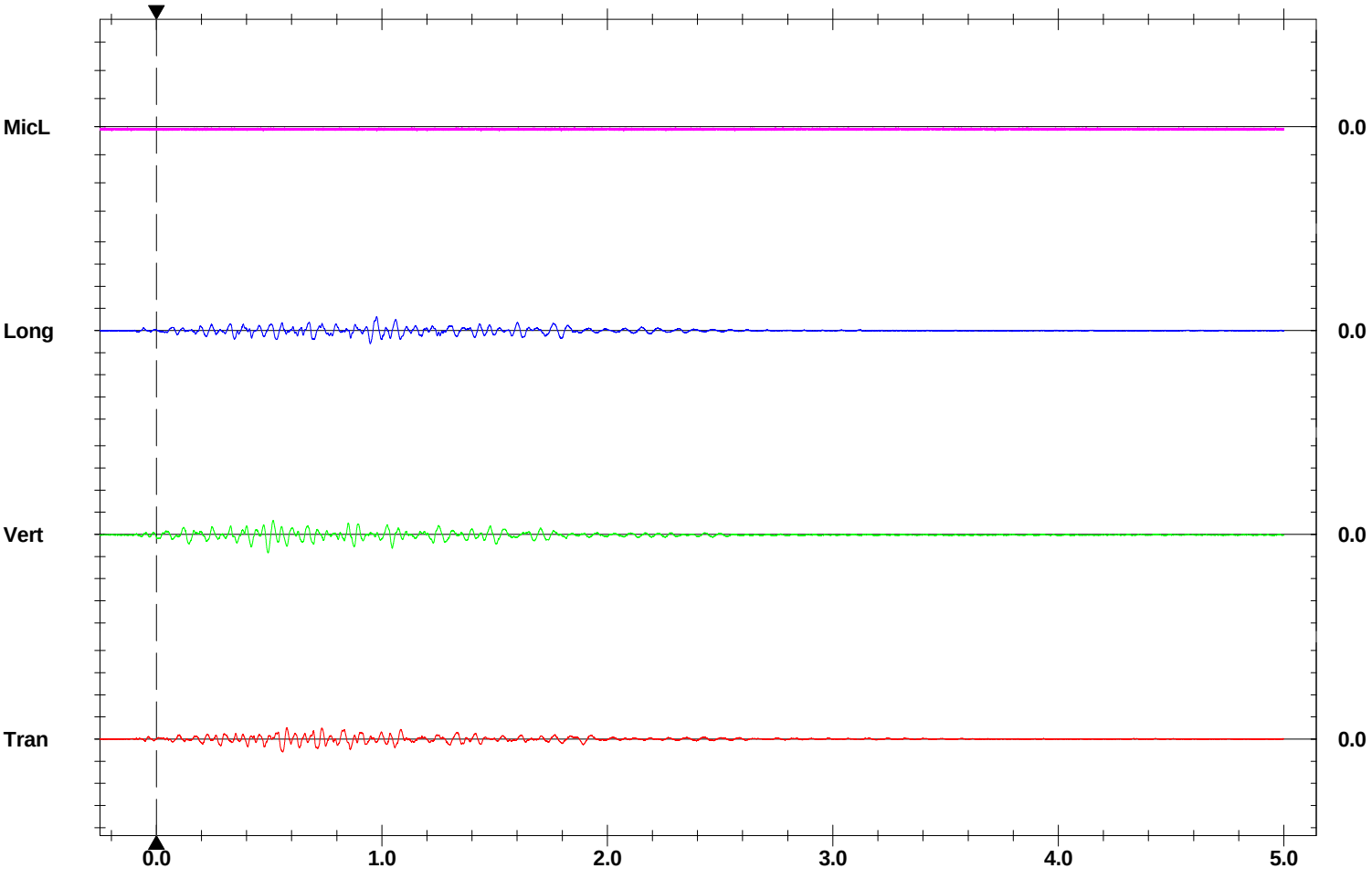
Peak Vector Sum 1.681 mm/s at 0.495 sec
N/A: Not Applicable

DGMS India (A)

Permissible Ground Vibration



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 2.000 mm/s/div Mic: 1.000 pa.(L)/div
Trigger = ▶— —◀

Format © 1995-2015 Xmark Corporation

Event Report

Date/Time	Tran at 13:17:59 March 5, 2020
Trigger Source	Geo: 0.500 mm/s, Mic: 6.325 pa.(L)
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps

Serial Number	BE16508 V 10.72-1.1 Minimate Blaster
Battery Level	6.3 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	R508ICVR.LZ0

Notes
Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

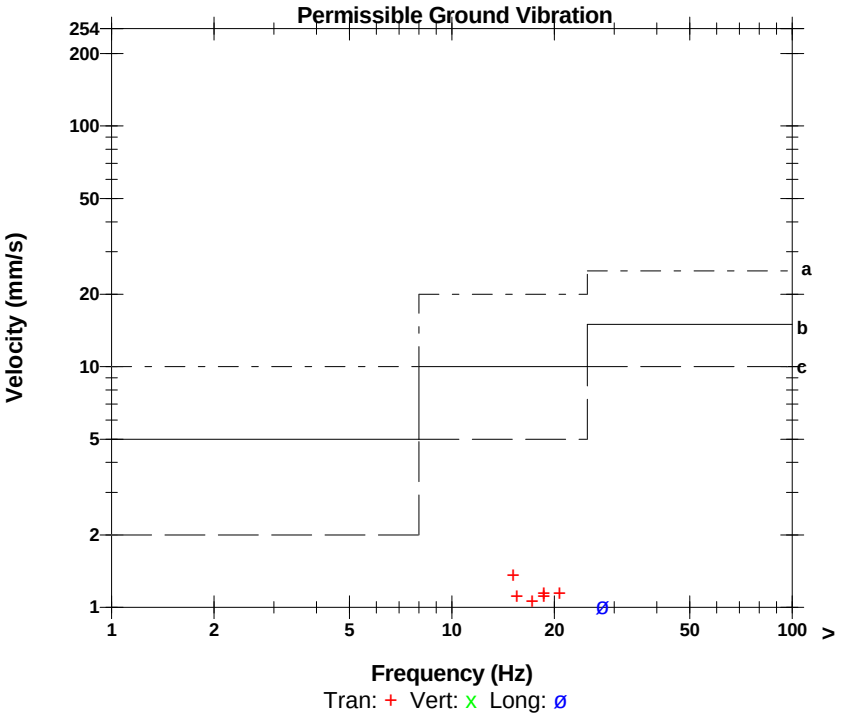
Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

Microphone	Linear Weighting
PSPL	20.75 pa.(L) at 1.104 sec
ZC Freq	6.1 Hz
Channel Test	Passed (Freq = 20.1 Hz Amp = 443 mv)

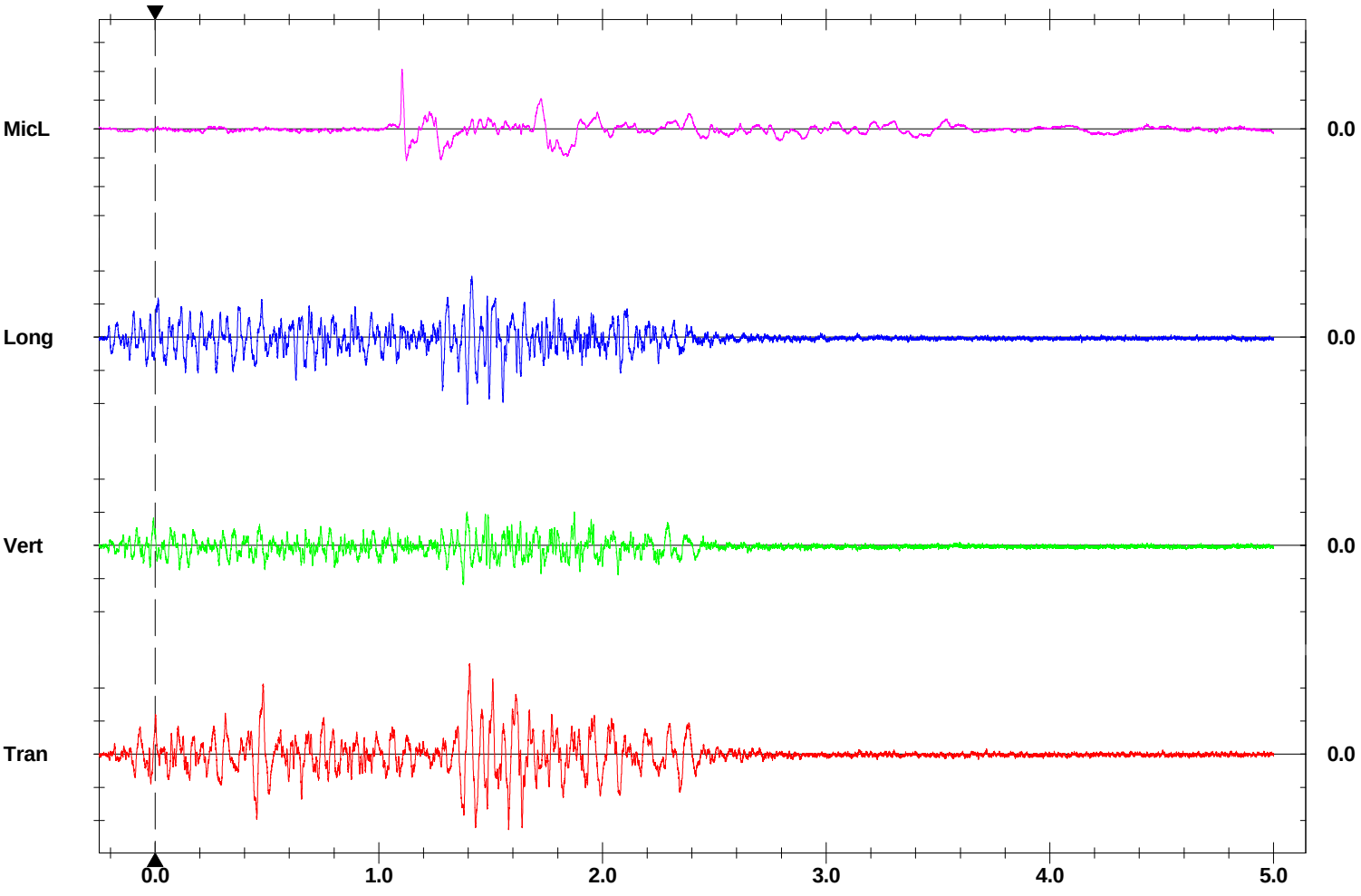
	Tran	Vert	Long	
PPV	1.365	0.587	1.016	mm/s
ZC Freq	15.2	24.1	27.7	Hz
Time (Rel. to Trig)	1.406	1.378	1.396	sec
Peak Acceleration	0.040	0.033	0.046	g
Peak Displacement	0.011	0.004	0.006	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 1.385 mm/s at 1.406 sec

DGMS India (A)



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 10.000 pa.(L)/div
Trigger =

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Event Report

Date/Time	Long at 13:18:19 March 5, 2020
Trigger Source	Geo: 0.500 mm/s
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps
Job Number:	1

Serial Number	BE18062 V 10.72-1.1 Minimate Blaster
Battery Level	6.1 Volts
Unit Calibration	March 29, 2019 by UES, New Delhi
File Name	T062ICVR.MJ0

Notes

Location: Pur Village
Client: District collector Bhilwara, Rajasthan
User Name: CIMFR
General:

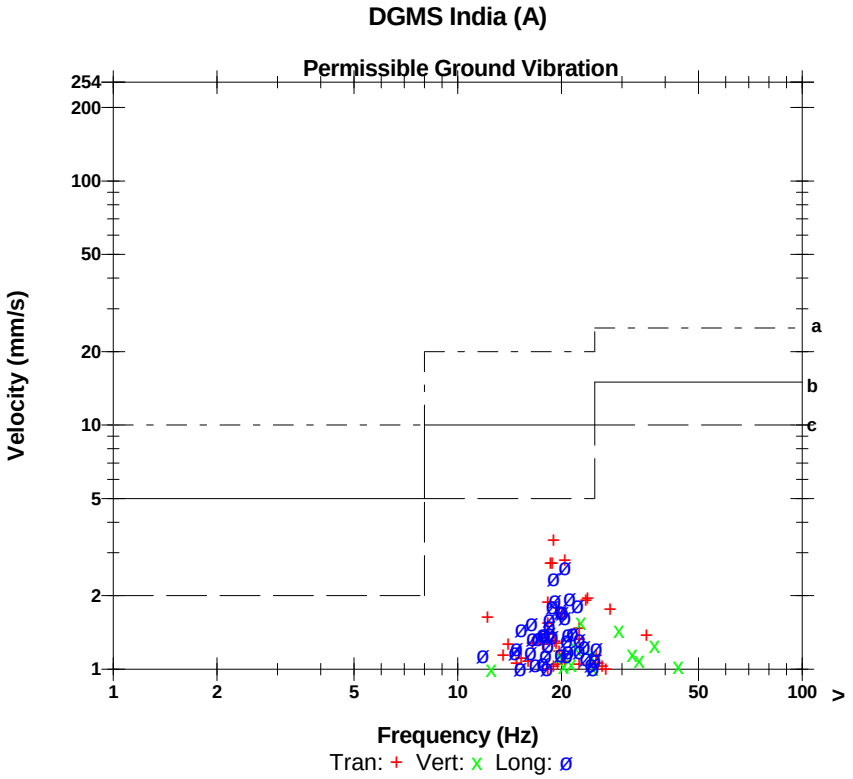
Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration & Airover Pressure in Domestic Houses inPur Village, Bhilwara, Rajasthan.

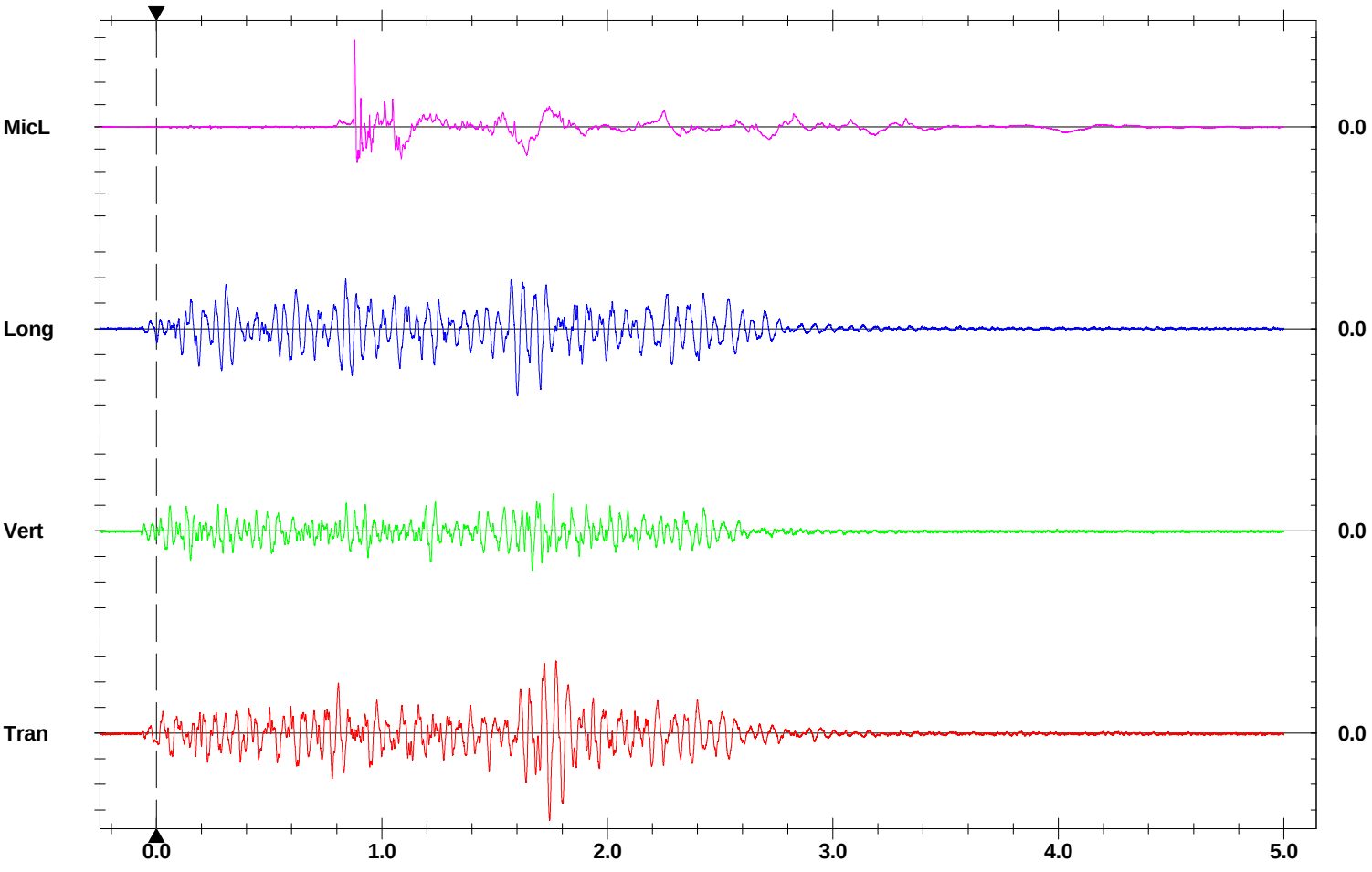
Microphone	Linear Weighting
PSPL	78.00 pa.(L) at 0.878 sec
ZC Freq	5.8 Hz
Channel Test	Passed (Freq = 20.5 Hz Amp = 473 mv)

	Tran	Vert	Long	
PPV	3.397	1.556	2.619	mm/s
ZC Freq	19.0	22.8	20.5	Hz
Time (Rel. to Trig)	1.743	1.667	1.603	sec
Peak Acceleration	0.073	0.053	0.046	g
Peak Displacement	0.024	0.009	0.020	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 3.414 mm/s at 1.745 sec



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 1.000 mm/s/div Mic: 20.00 pa.(L)/div
Trigger = ▶—— —— ◀

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Event Report

Date/Time	Vert at 13:18:23 March 5, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200305131823.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

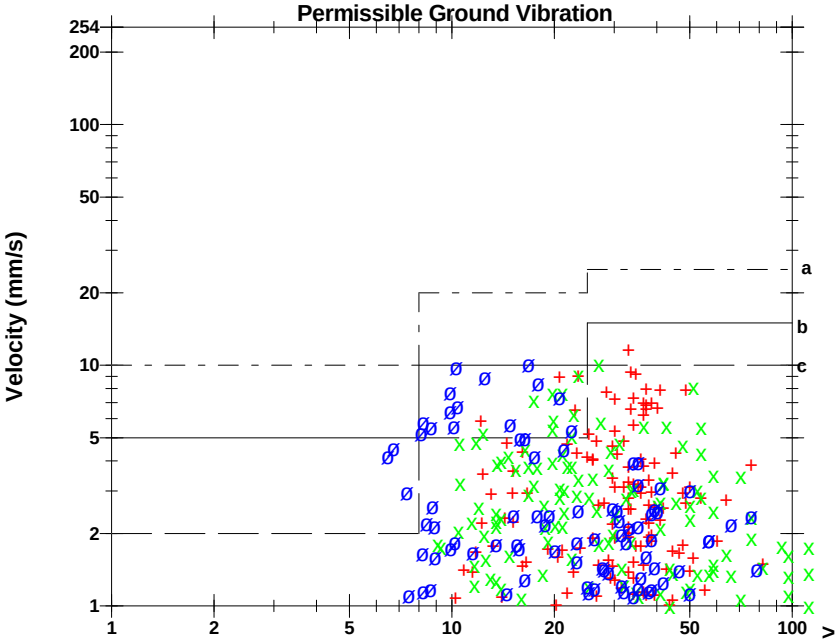
Microphone	Linear Weighting
PSPL	73.77 pa.(L) at 0.507 sec
ZC Freq	22.0 Hz
Channel Test	Passed (Freq = 19.7 Hz Amp = 1188 mv)

	Tran	Vert	Long	
PPV	11.56	10.09	10.17	mm/s
ZC Freq	33.0	26.9	16.8	Hz
Time (Rel. to Trig)	2.001	1.691	1.618	sec
Peak Acceleration	0.477	0.444	0.211	g
Peak Displacement	0.062	0.055	0.108	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 13.07 mm/s at 1.691 sec

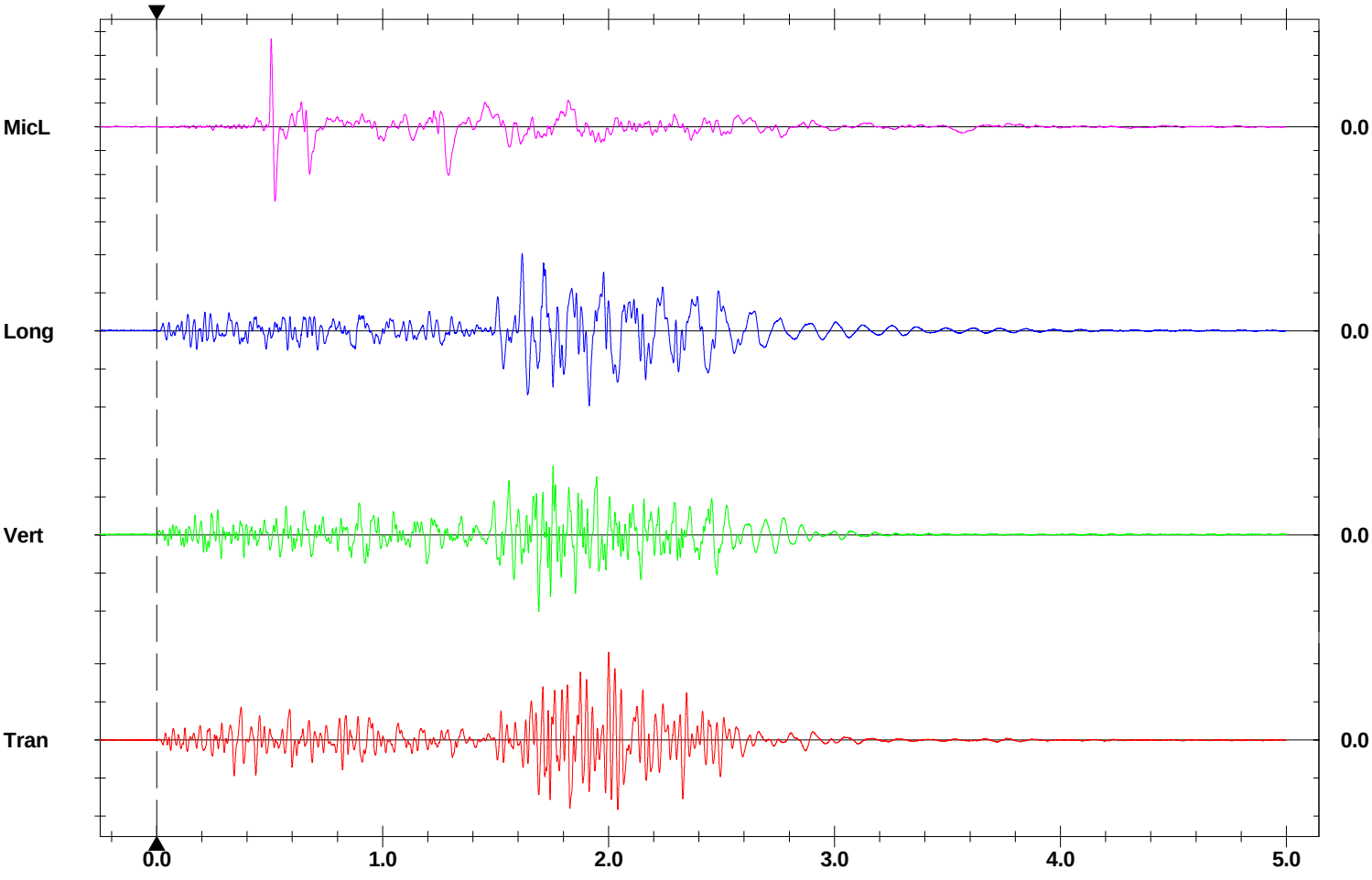
DGMS India (A)

Permissible Ground Vibration



Tran: + Vert: x Long: ø

a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 5.000 mm/s/div Mic: 20.00 pa.(L)/div
Trigger = ▶—— ——◀

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Event Report

Date/Time	Vert at 13:18:24 March 5, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

Serial Number	UM12452 V 10-89 Micromate ISEE
Battery Level	3.7 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12452_20200305131824.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

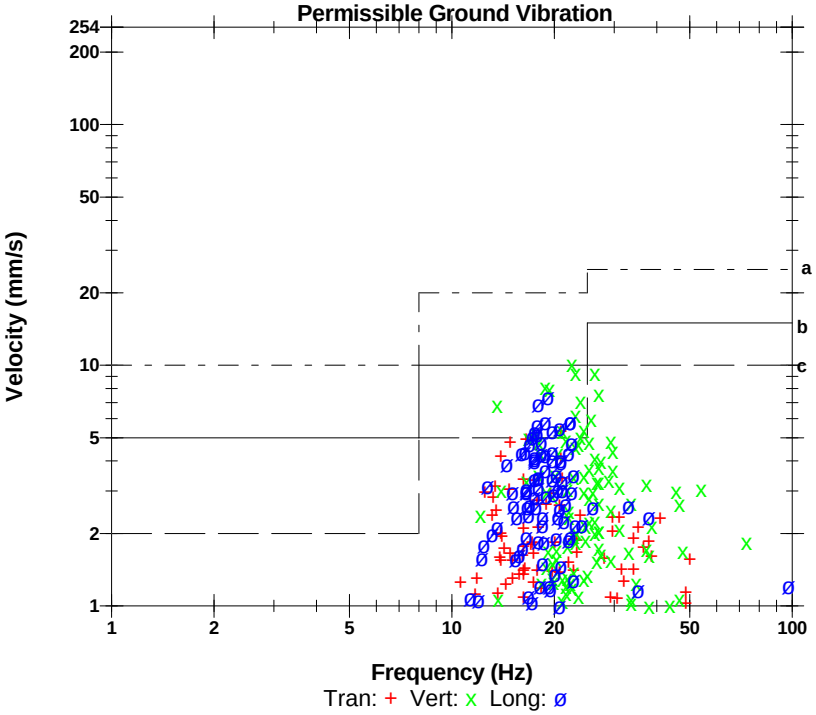
Microphone	Linear Weighting
PSPL	96.92 pa.(L) at 0.586 sec
ZC Freq	21.8 Hz
Channel Test	Passed (Freq = 19.7 Hz Amp = 1162 mv)

	Tran	Vert	Long	
PPV	5.344	10.16	7.393	mm/s
ZC Freq	20.9	22.5	19.1	Hz
Time (Rel. to Trig)	2.021	1.662	1.755	sec
Peak Acceleration	0.142	0.401	0.174	g
Peak Displacement	0.037	0.074	0.062	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 11.32 mm/s at 1.662 sec

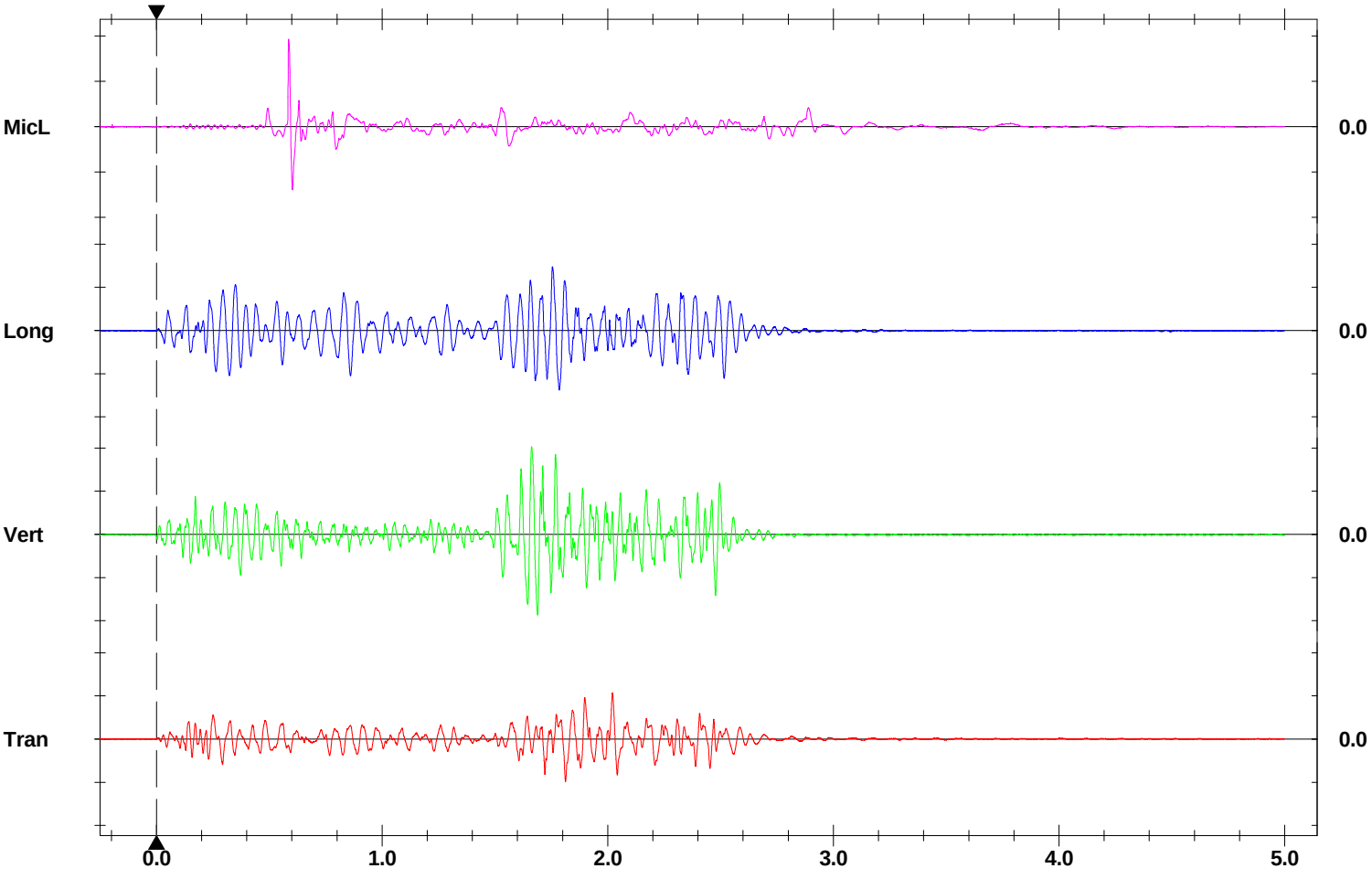
DGMS India (A)

Permissible Ground Vibration



Tran: + Vert: x Long: ø

a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 5.000 mm/s/div Mic: 50.00 pa.(L)/div
Trigger = ▶—— ——◀

Format © 1995-2015 Xmark Corporation

Event Report

Date/Time	Long at 13:16:32 March 6, 2020
Trigger Source	Geo: 0.500 mm/s
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps
Job Number:	1

Serial Number	BE18062 V 10.72-1.1 Minimate Blaster
Battery Level	6.0 Volts
Unit Calibration	March 29, 2019 by UES, New Delhi
File Name	T062ICXM.7K0

Notes
Location: Pur Village
Client: District collector Bhilwara, Rajasthan
User Name: CIMFR
General:

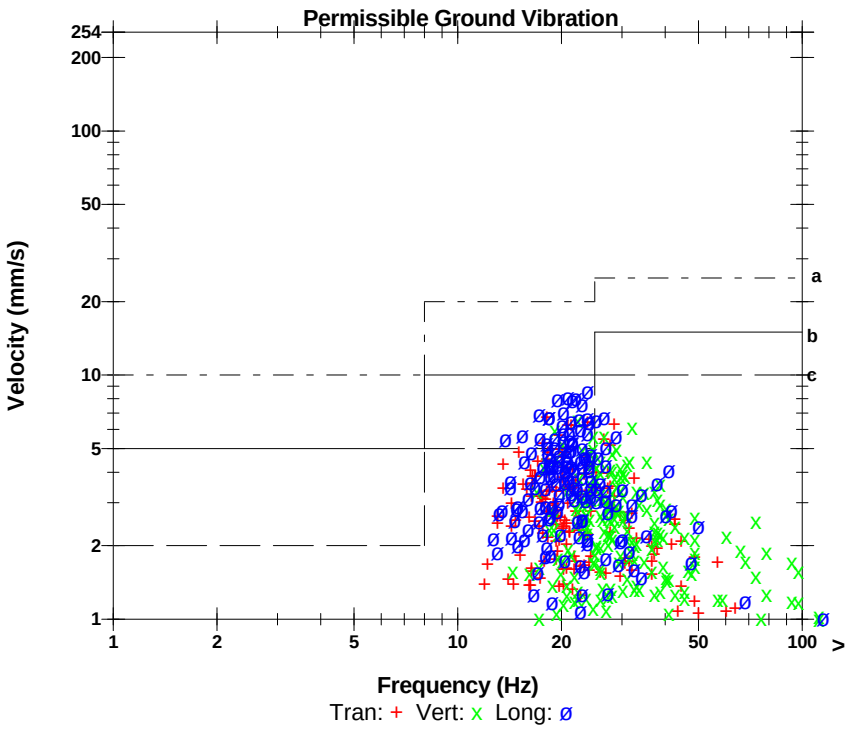
Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration & Airover Pressure in Domestic Houses inPur Village, Bhilwara, Rajasthan.

Microphone	Linear Weighting
PSPL	46.25 pa.(L) at 4.245 sec
ZC Freq	17.7 Hz
Channel Test	Passed (Freq = 20.1 Hz Amp = 485 mv)

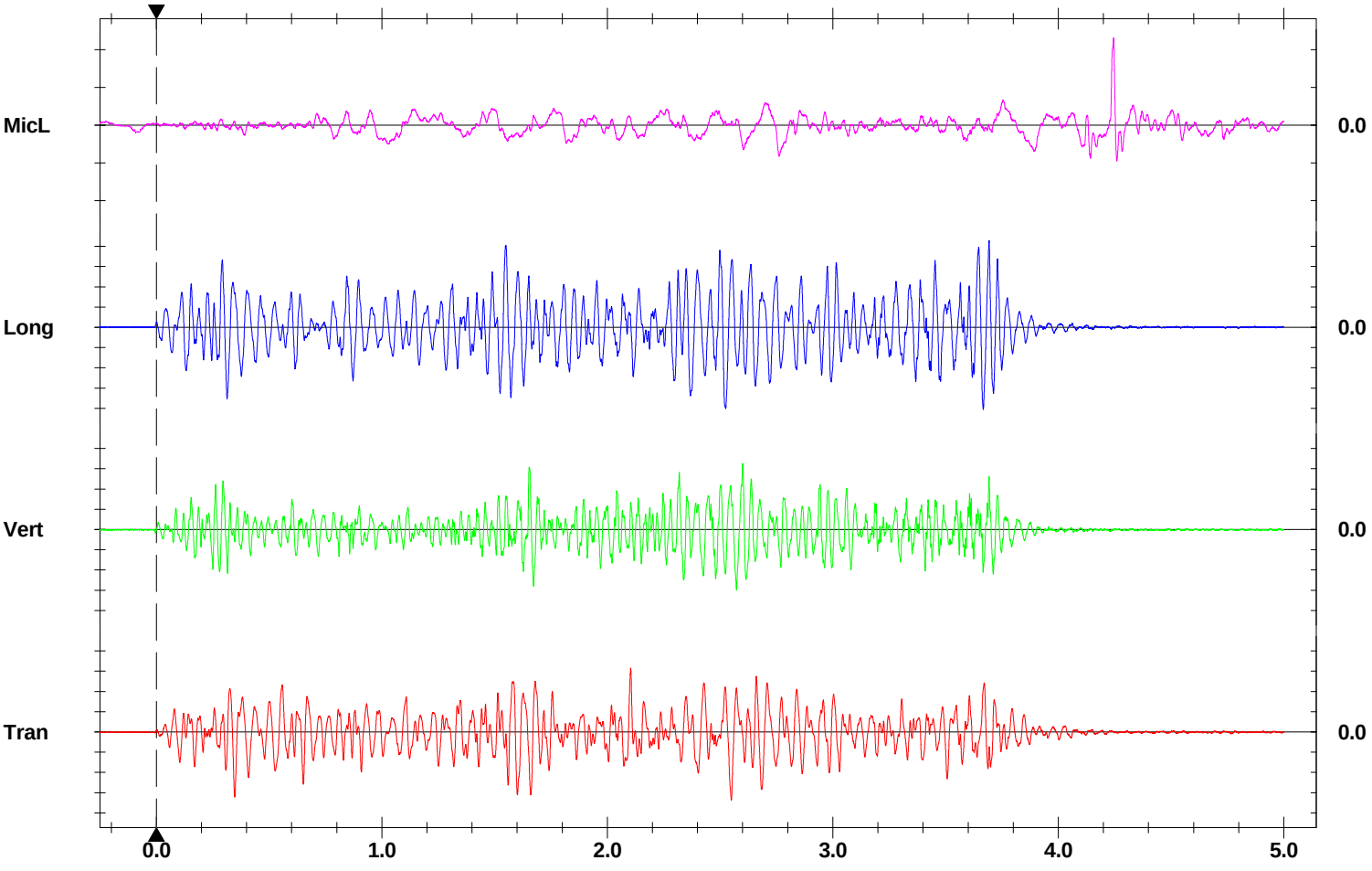
	Tran	Vert	Long	
PPV	6.731	6.525	8.588	mm/s
ZC Freq	18.1	22.3	23.8	Hz
Time (Rel. to Trig)	2.550	2.600	3.693	sec
Peak Acceleration	0.133	0.186	0.159	g
Peak Displacement	0.052	0.042	0.068	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 10.15 mm/s at 3.693 sec

DGMS India (A)



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 2.000 mm/s/div Mic: 20.00 pa.(L)/div
Trigger = ▶— — ◀

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Event Report

Date/Time	Long at 13:16:32 March 6, 2020
Trigger Source	Geo: 0.500 mm/s
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps
Job Number:	1

Serial Number	BE18062 V 10.72-1.1 Minimate Blaster
Battery Level	6.0 Volts
Unit Calibration	March 29, 2019 by UES, New Delhi
File Name	T062ICXM.7K0

Notes
Location: Pur Village
Client: District collector Bhilwara, Rajasthan
User Name: CIMFR
General:

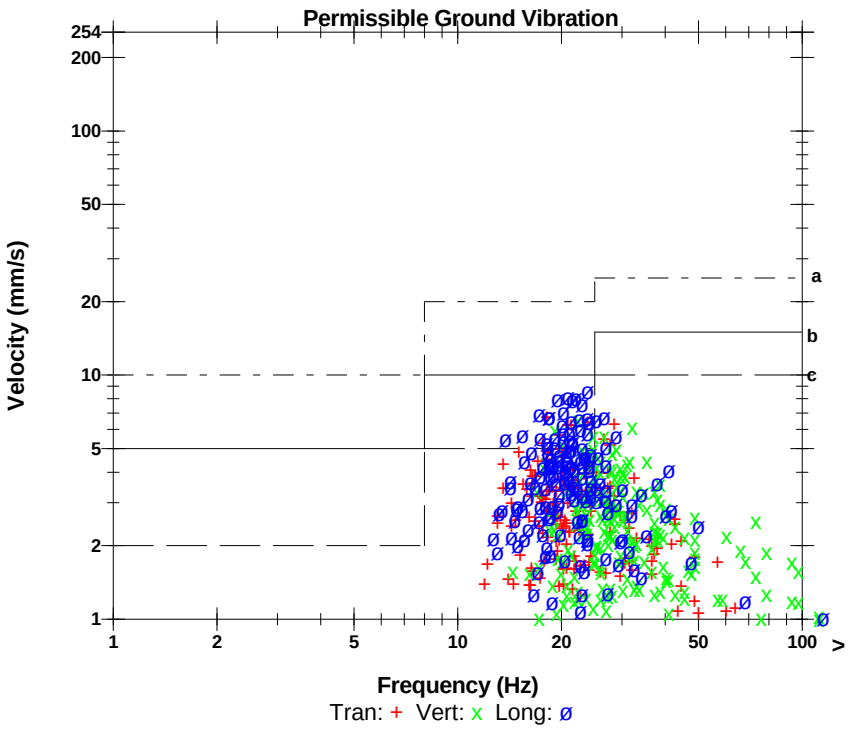
Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration & Airover Pressure in Domestic Houses inPur Village, Bhilwara, Rajasthan.

Microphone	Linear Weighting
PSPL	46.25 pa.(L) at 4.245 sec
ZC Freq	17.7 Hz
Channel Test	Passed (Freq = 20.1 Hz Amp = 485 mv)

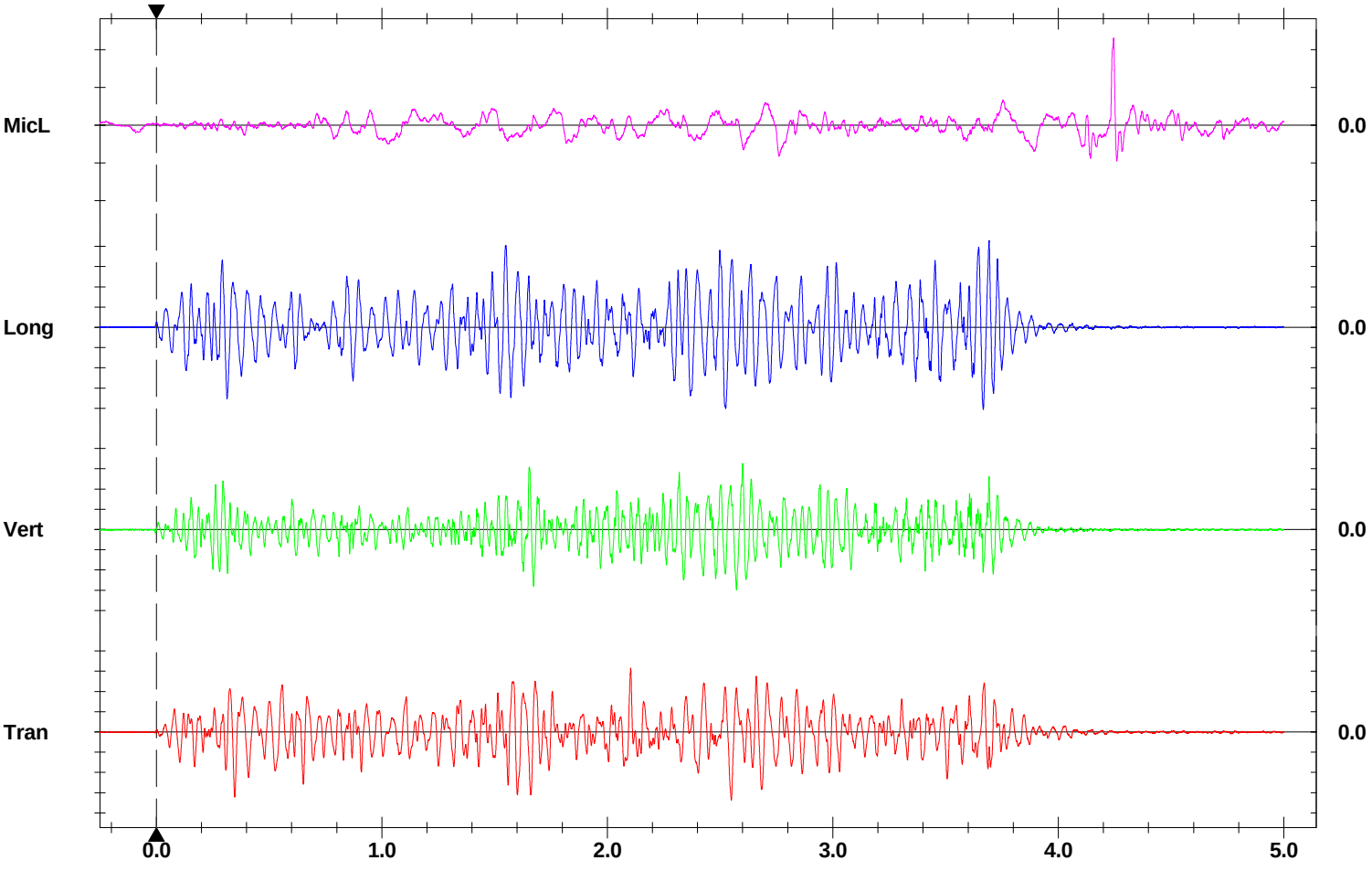
	Tran	Vert	Long	
PPV	6.731	6.525	8.588	mm/s
ZC Freq	18.1	22.3	23.8	Hz
Time (Rel. to Trig)	2.550	2.600	3.693	sec
Peak Acceleration	0.133	0.186	0.159	g
Peak Displacement	0.052	0.042	0.068	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 10.15 mm/s at 3.693 sec

DGMS India (A)



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 2.000 mm/s/div Mic: 20.00 pa.(L)/div
Trigger = ▶— — ◀

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Event Report

Date/Time	Long at 13:16:42 March 6, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200306131642.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

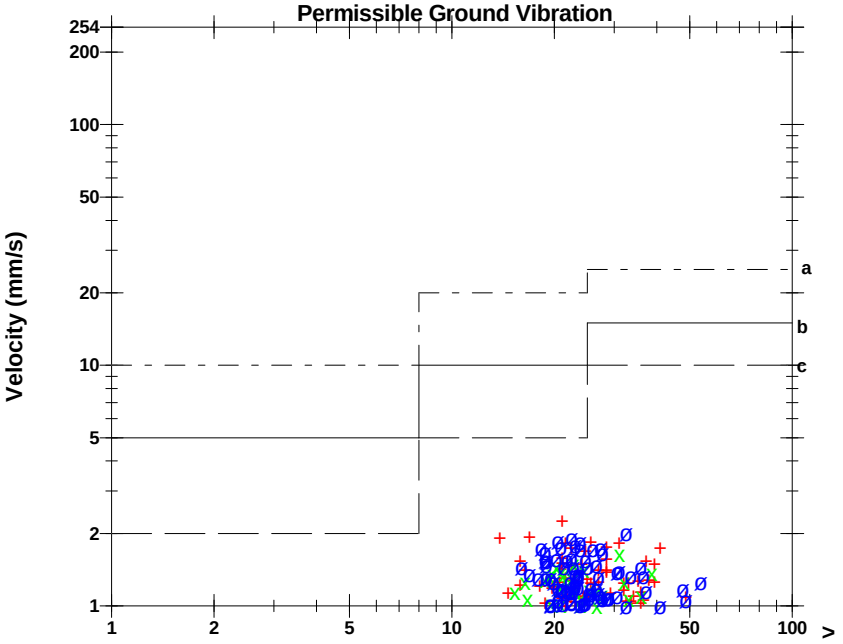
Microphone	Linear Weighting
PSPL	34.75 pa.(L) at 4.779 sec
ZC Freq	18.8 Hz
Channel Test	Passed (Freq = 19.7 Hz Amp = 1275 mv)

	Tran	Vert	Long	
PPV	2.254	1.647	2.002	mm/s
ZC Freq	21.1	31.0	32.5	Hz
Time (Rel. to Trig)	0.367	0.245	2.629	sec
Peak Acceleration	0.076	0.086	0.099	g
Peak Displacement	0.015	0.013	0.014	mm
Sensor Check	Passed	Passed	Passed	

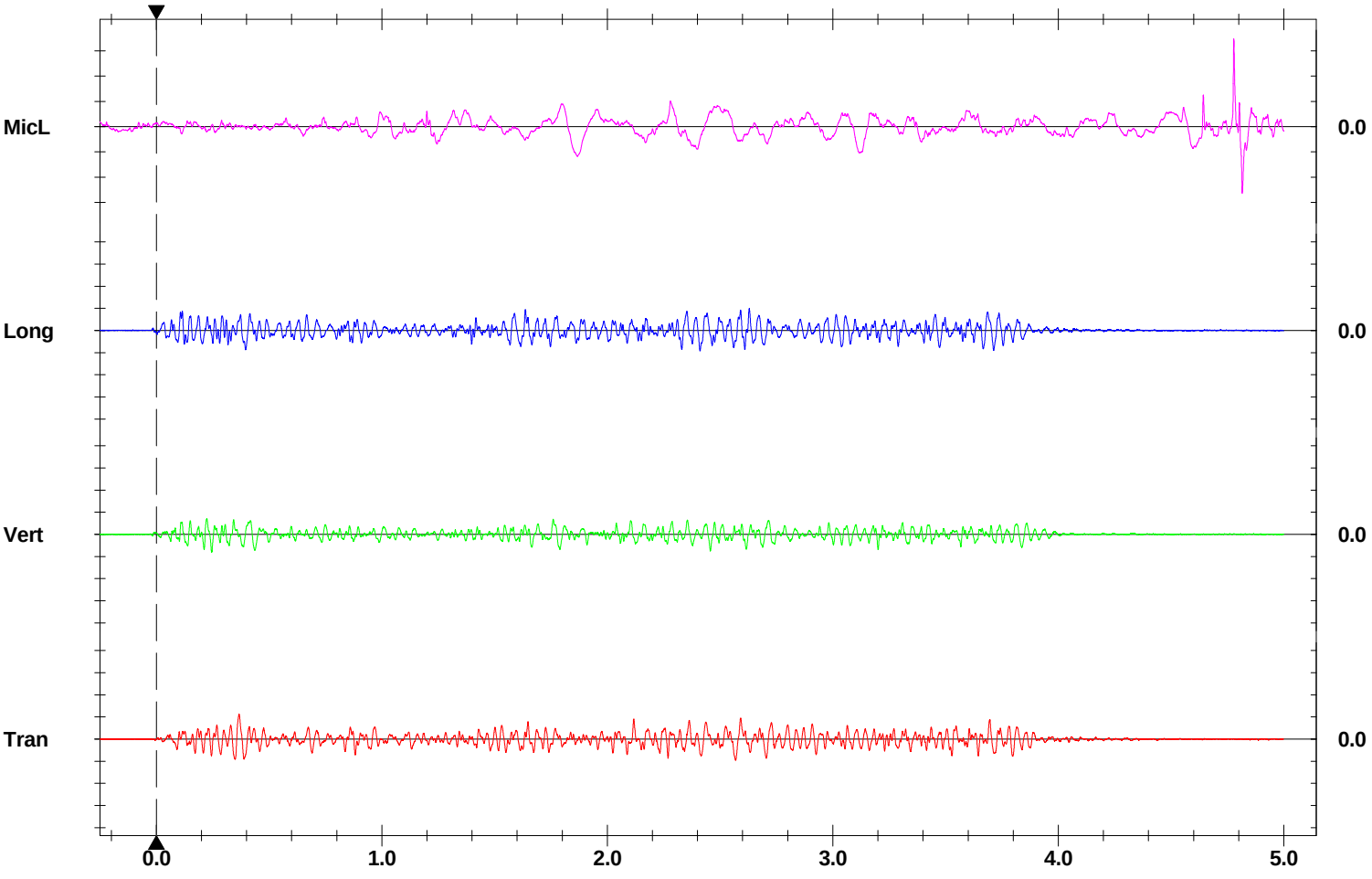
Peak Vector Sum 2.668 mm/s at 2.592 sec

DGMS India (A)

Permissible Ground Vibration



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 2.000 mm/s/div Mic: 10.000 pa.(L)/div
Trigger = ▶—— ——◀

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Event Report

Date/Time	Tran at 13:16:43 March 6, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

Serial Number	UM12452 V 10-89 Micromate ISEE
Battery Level	3.7 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12452_20200306131643.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

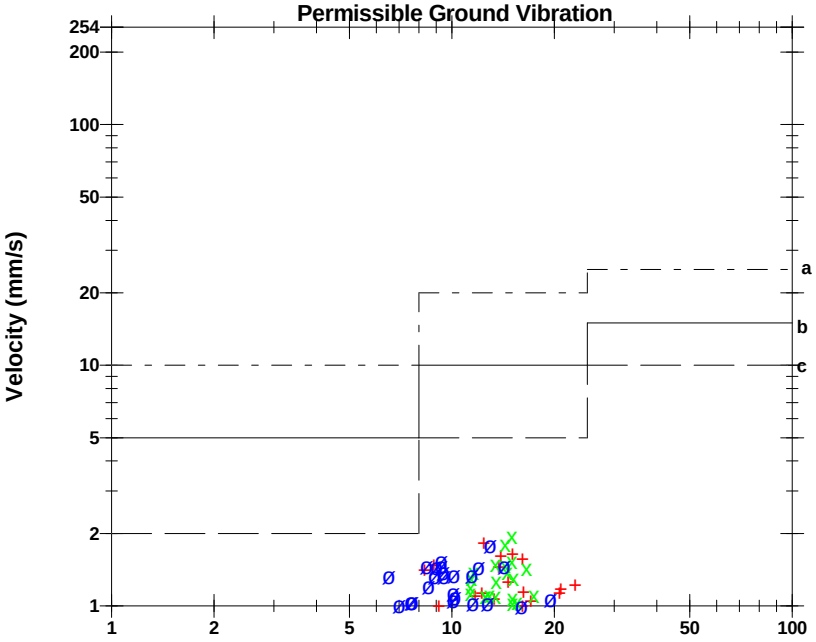
Microphone	Linear Weighting
PSPL	40.01 pa.(L) at 4.445 sec
ZC Freq	7.2 Hz
Channel Test	Passed (Freq = 19.7 Hz Amp = 1272 mv)

	Tran	Vert	Long	
PPV	1.821	1.947	1.797	mm/s
ZC Freq	12.4	14.9	13.0	Hz
Time (Rel. to Trig)	2.750	2.539	2.531	sec
Peak Acceleration	0.036	0.046	0.043	g
Peak Displacement	0.021	0.020	0.025	mm
Sensor Check	Passed	Passed	Passed	

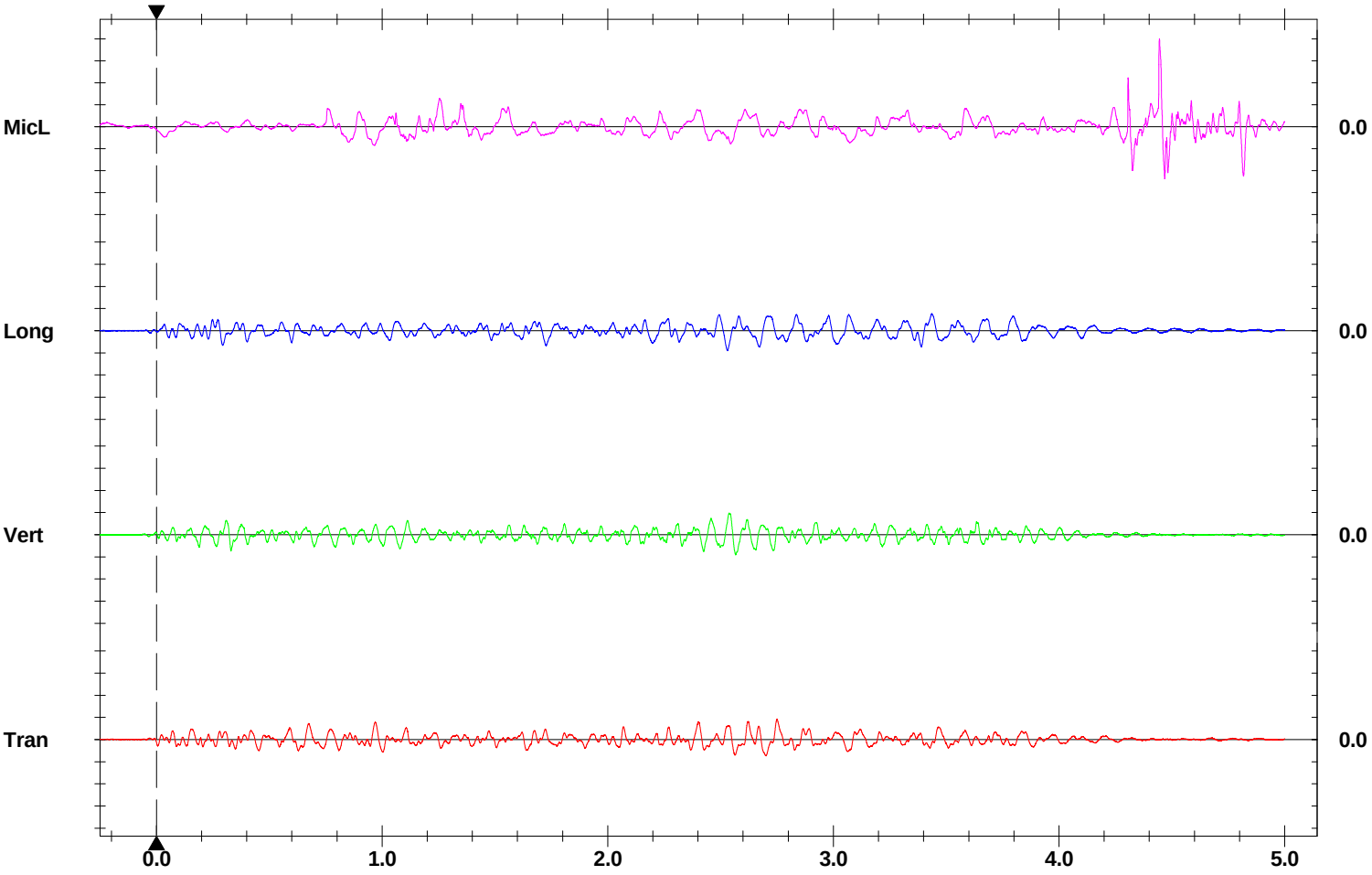
Peak Vector Sum 2.690 mm/s at 2.536 sec

DGMS India (A)

Permissible Ground Vibration



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 2.000 mm/s/div Mic: 10.000 pa.(L)/div
Trigger =

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Event Report

Date/Time	Long at 13:24:10 March 6, 2020
Trigger Source	Geo: 0.500 mm/s
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps
Job Number:	1

Serial Number	BE18062 V 10.72-1.1 Minimate Blaster
Battery Level	6.0 Volts
Unit Calibration	March 29, 2019 by UES, New Delhi
File Name	T062ICXM.KA0

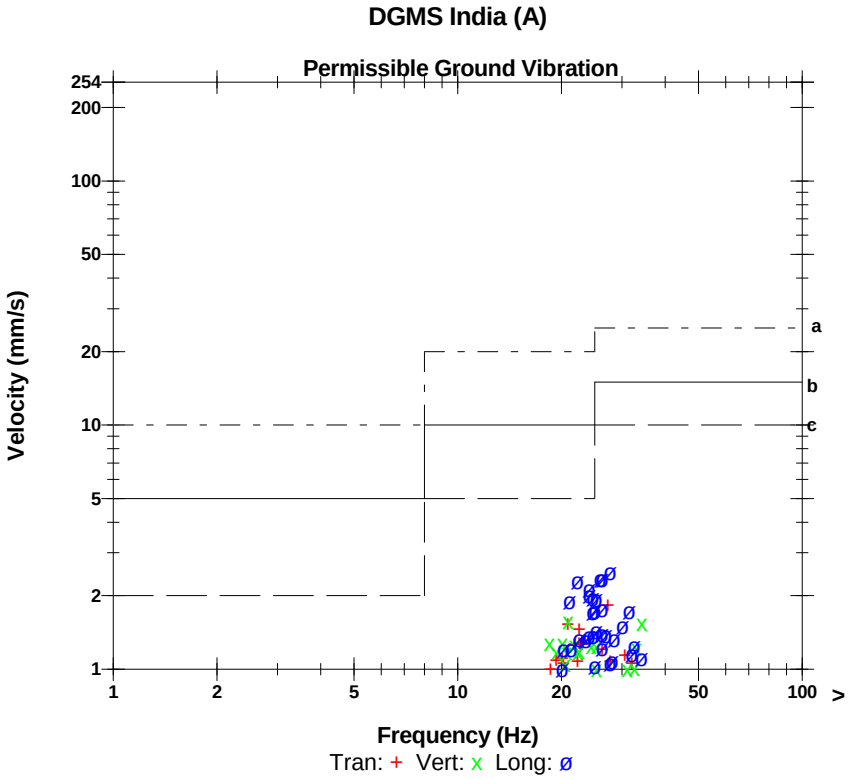
Notes
Location: Pur Village
Client: District collector Bhilwara, Rajasthan
User Name: CIMFR
General:

Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration & Airover Pressure in Domestic Houses inPur Village, Bhilwara, Rajasthan.

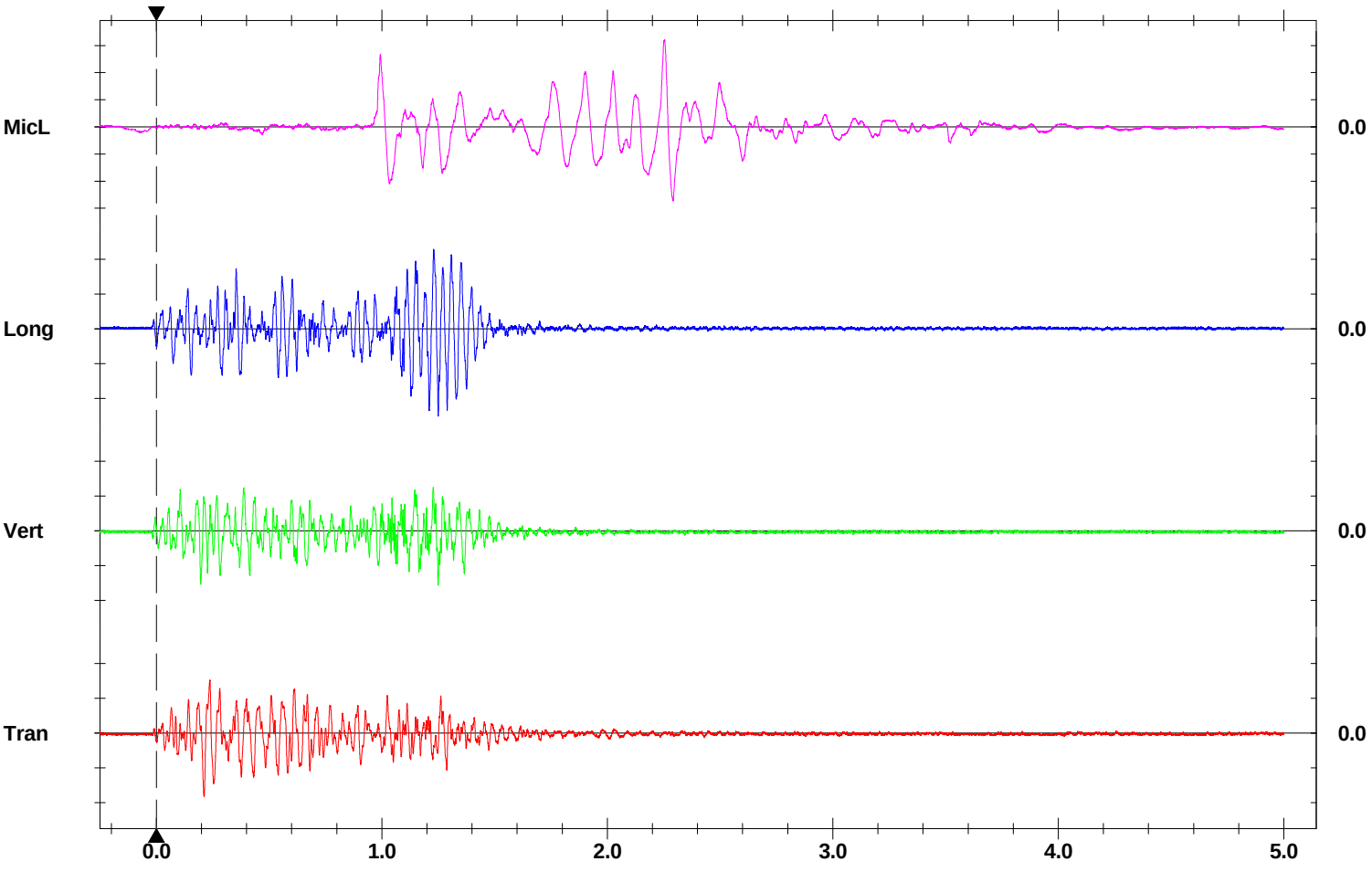
Microphone	Linear Weighting
PSPL	32.25 pa.(L) at 2.254 sec
ZC Freq	10.8 Hz
Channel Test	Passed (Freq = 20.1 Hz Amp = 485 mv)

	Tran	Vert	Long	
PPV	1.826	1.572	2.508	mm/s
ZC Freq	27.3	20.9	27.7	Hz
Time (Rel. to Trig)	0.211	1.250	1.250	sec
Peak Acceleration	0.046	0.066	0.066	g
Peak Displacement	0.011	0.009	0.015	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 2.980 mm/s at 1.250 sec



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 1.000 mm/s/div Mic: 10.000 pa.(L)/div
Trigger = ▶—— ——◀

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Event Report

Date/Time	Vert at 13:24:20 March 6, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200306132420.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

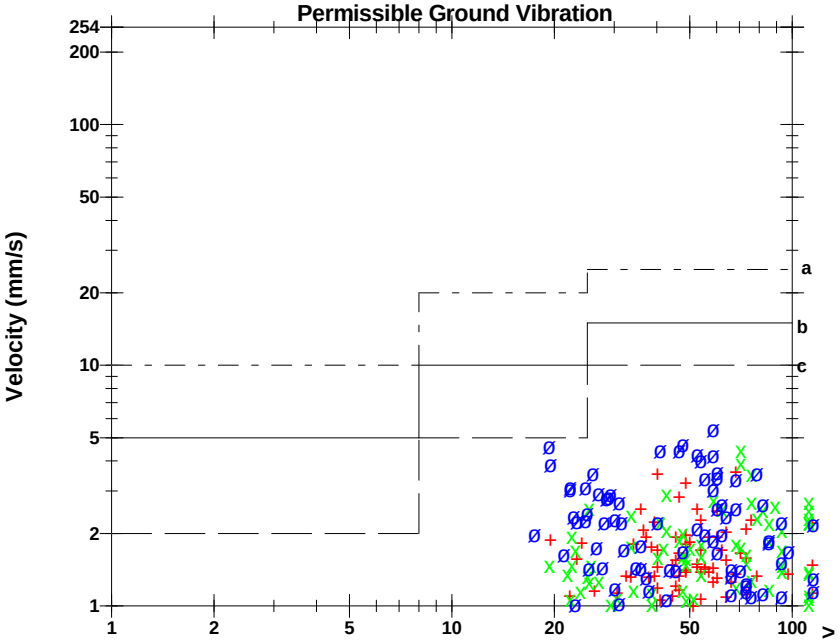
Microphone	Linear Weighting
PSPL	47.57 pa.(L) at 1.694 sec
ZC Freq	13.9 Hz
Channel Test	Passed (Freq = 19.7 Hz Amp = 1275 mv)

	Tran	Vert	Long	
PPV	3.602	4.461	5.438	mm/s
ZC Freq	68	71	59	Hz
Time (Rel. to Trig)	1.072	1.247	1.256	sec
Peak Acceleration	0.237	0.316	0.329	g
Peak Displacement	0.011	0.010	0.026	mm
Sensor Check	Passed	Passed	Passed	

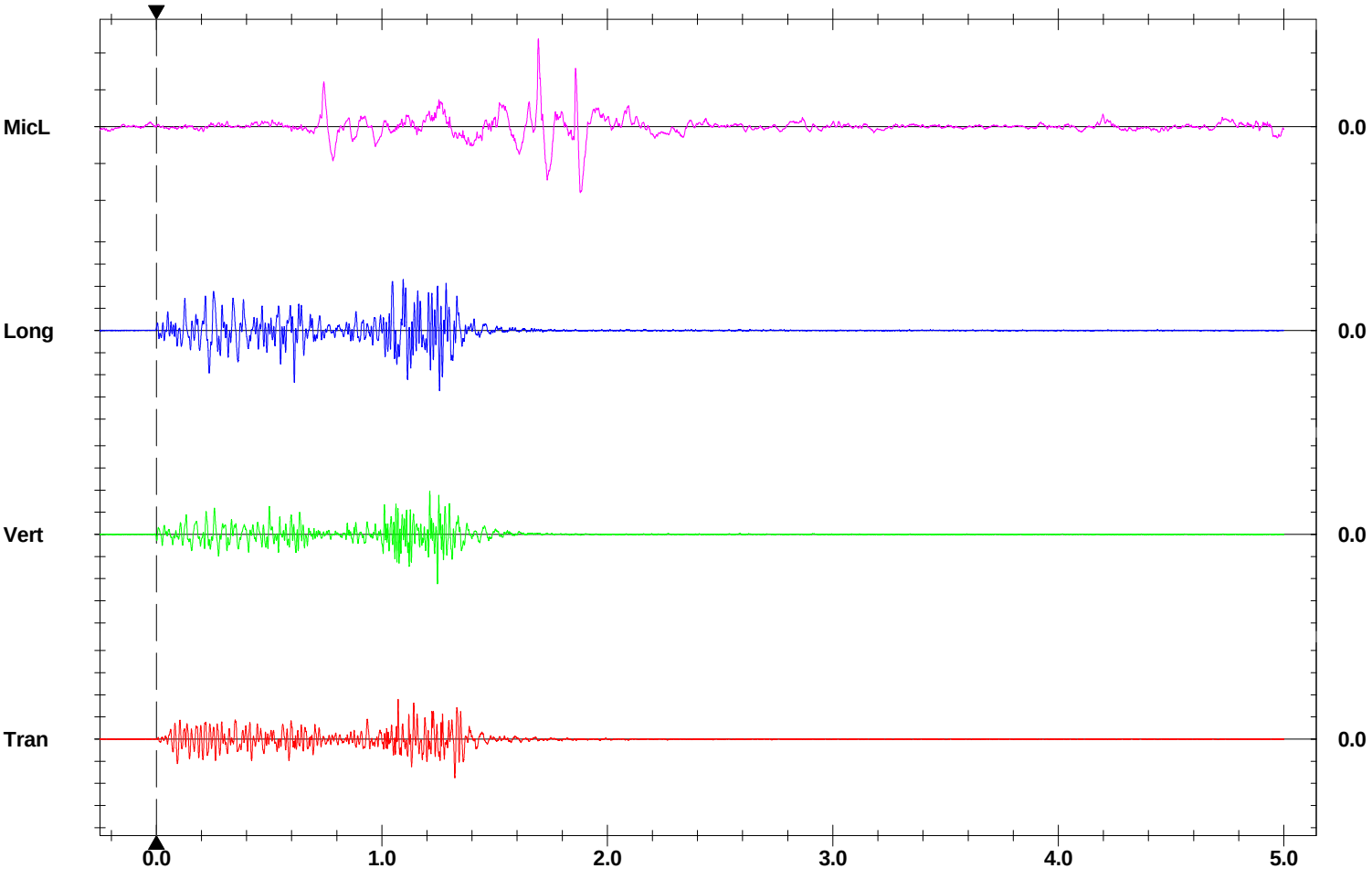
Peak Vector Sum 6.017 mm/s at 1.247 sec

DGMS India (A)

Permissible Ground Vibration



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 2.000 mm/s/div Mic: 20.00 pa.(L)/div
Trigger = ▶—— ——◀

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Event Report

Date/Time	Tran at 13:24:21 March 6, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

Serial Number	UM12452 V 10-89 Micromate ISEE
Battery Level	3.7 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12452_20200306132421.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

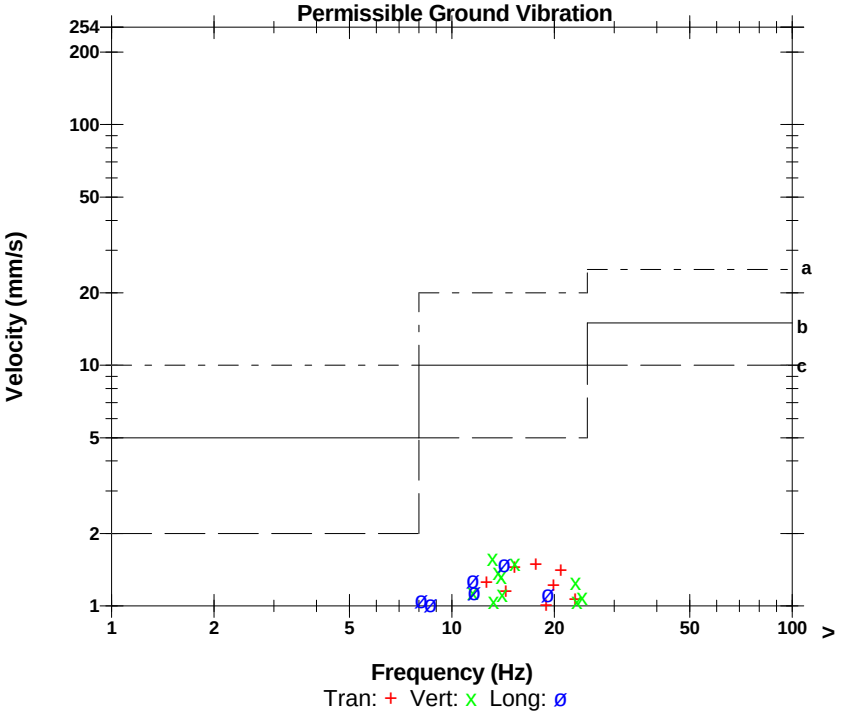
Microphone	Linear Weighting
PSPL	32.94 pa.(L) at 0.787 sec
ZC Freq	12.0 Hz
Channel Test	Passed (Freq = 19.7 Hz Amp = 1272 mv)

	Tran	Vert	Long	
PPV	1.490	1.576	1.490	mm/s
ZC Freq	17.7	13.1	14.2	Hz
Time (Rel. to Trig)	0.439	0.462	0.733	sec
Peak Acceleration	0.033	0.039	0.030	g
Peak Displacement	0.013	0.015	0.017	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 2.048 mm/s at 0.440 sec

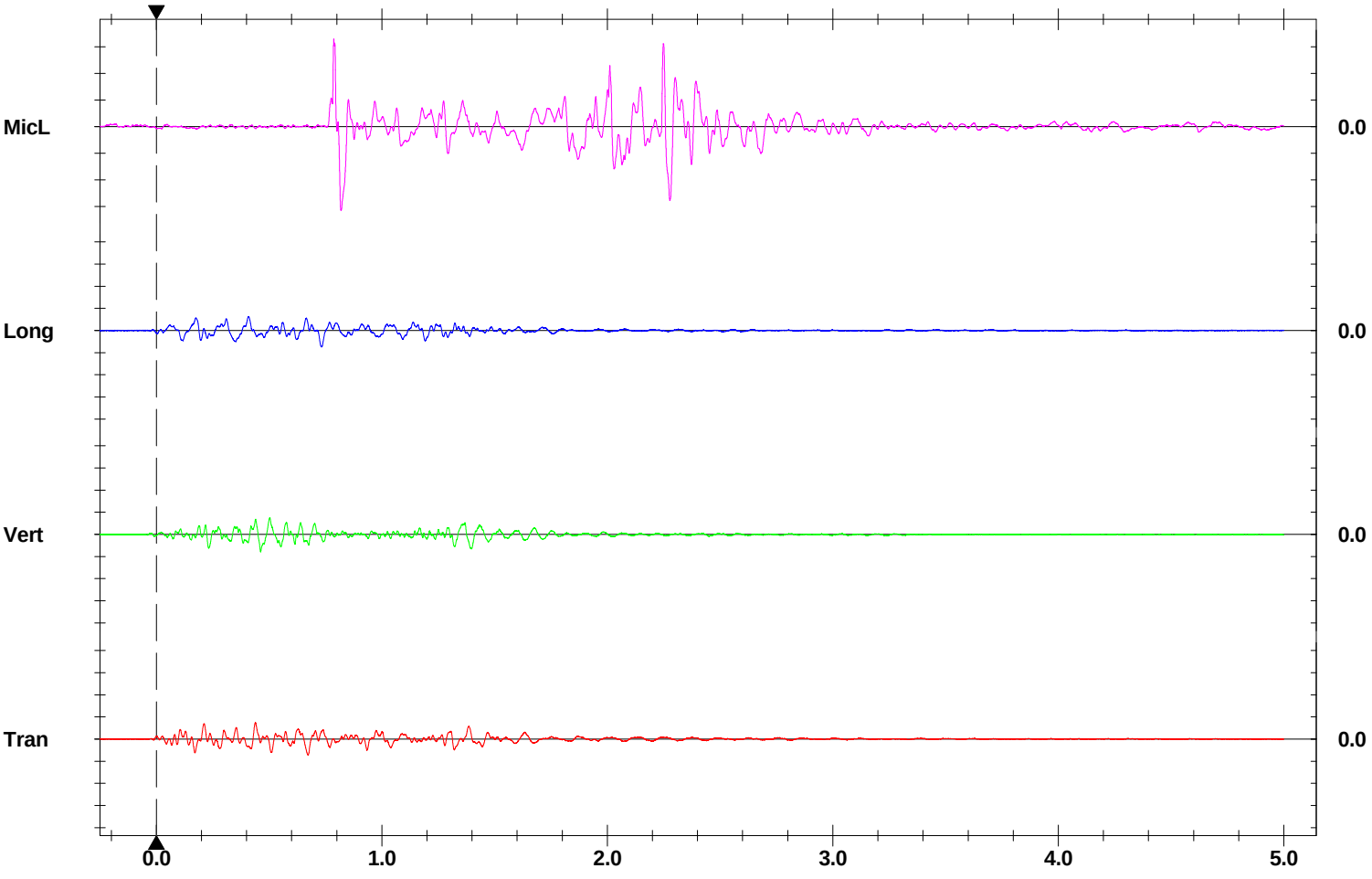
DGMS India (A)

Permissible Ground Vibration



Tran: + Vert: x Long: ø

a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 2.000 mm/s/div Mic: 10.000 pa.(L)/div
Trigger = ▶—— ——◀

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ANNEXURE – II

(FFT Reports of Observed Vibration)

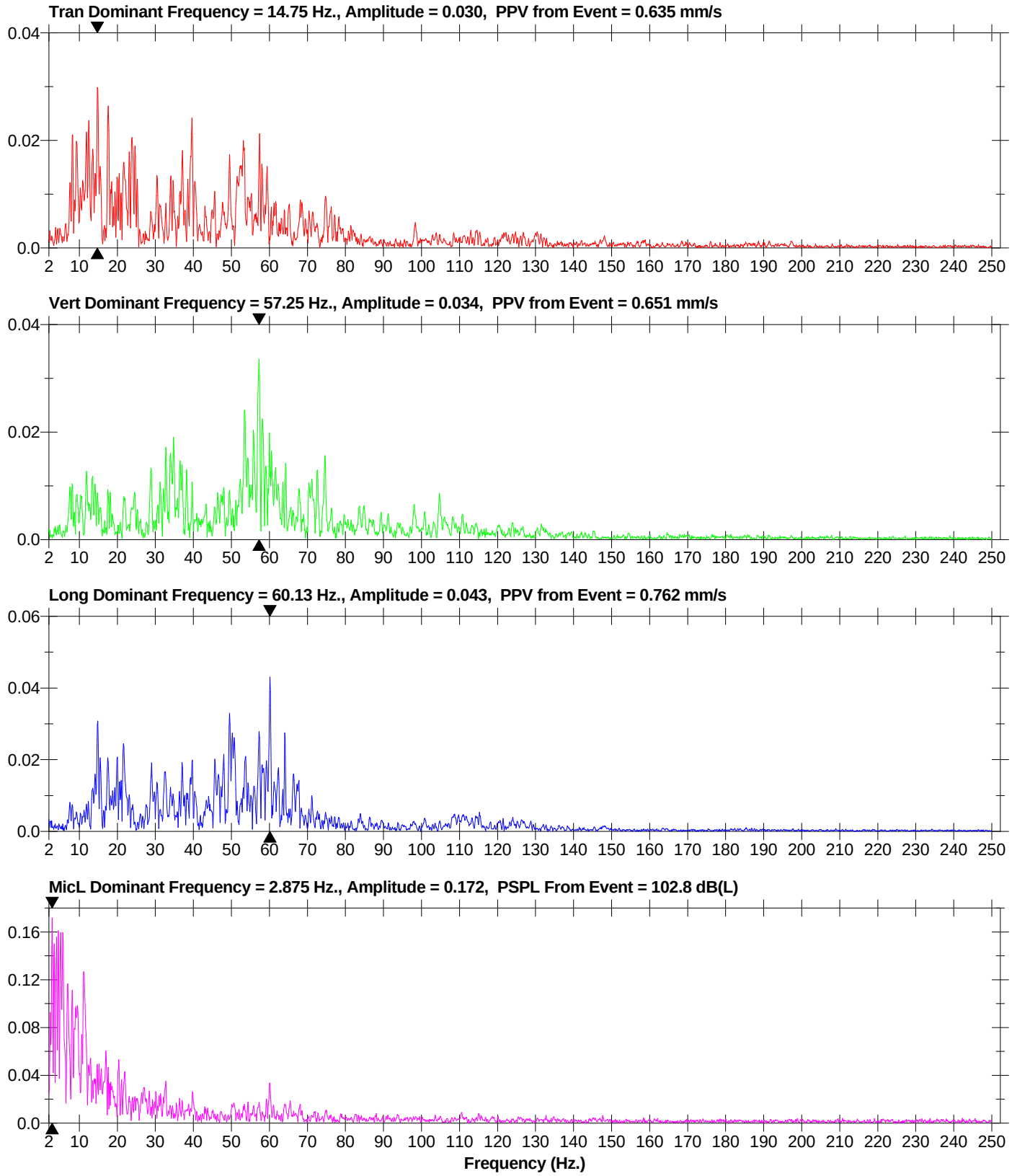
FFT Report

Date/Time	Tran at 1:00:48 PM February 1, 2020
Trigger Source	Geo: 0.510 mm/s, Mic: 100.0 dB(L)
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps

Serial Number	BE13781 V 10.72-8.17 MiniMate Plus
Battery Level	6.1 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	O781IB6M.TC0

Notes
Location: Pur Village
Client:
User Name: CSIR-CIMFR, Bilaspur Research Centre
General:

Extended Notes
Scientific investigation of potenstial damage due to blast induced ground vibration and air over pressure in domestic houses in Pur Village, Bhilwara, Rajasthan, India.



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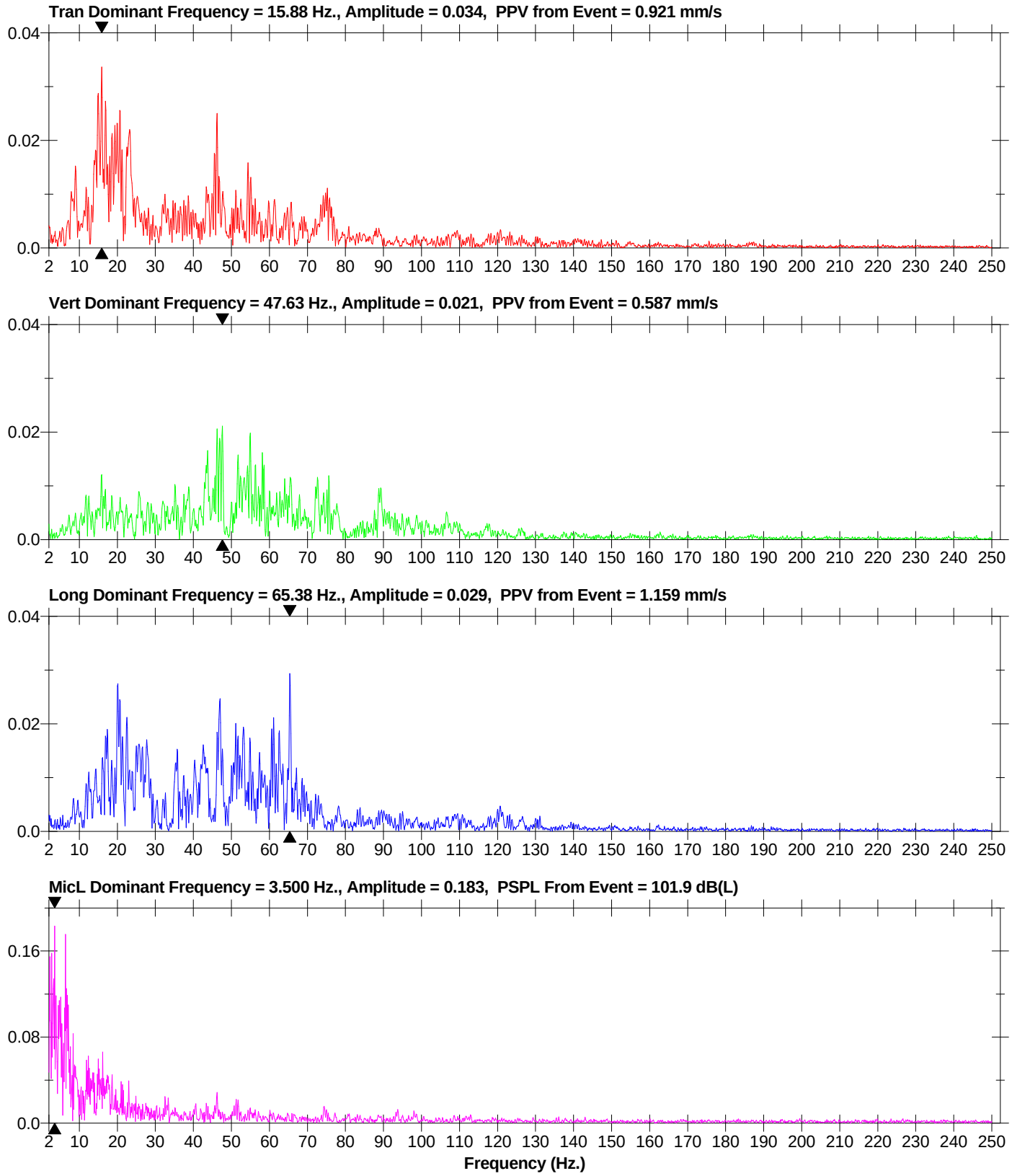
FFT Report

Date/Time	MicL at 1:03:53 PM February 1, 2020
Trigger Source	Geo: 0.510 mm/s, Mic: 100.0 dB(L)
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps

Serial Number	BE13781 V 10.72-8.17 MiniMate Plus
Battery Level	6.1 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	O781IB6M.YH0

Notes
Location: Pur Village
Client:
User Name: CSIR-CIMFR, Bilaspur Research Centre
General:

Extended Notes
Scientific investigation of potenstial damage due to blast induced ground vibration and air over pressure in domestic houses in Pur Village, Bhilwara, Rajasthan, India.



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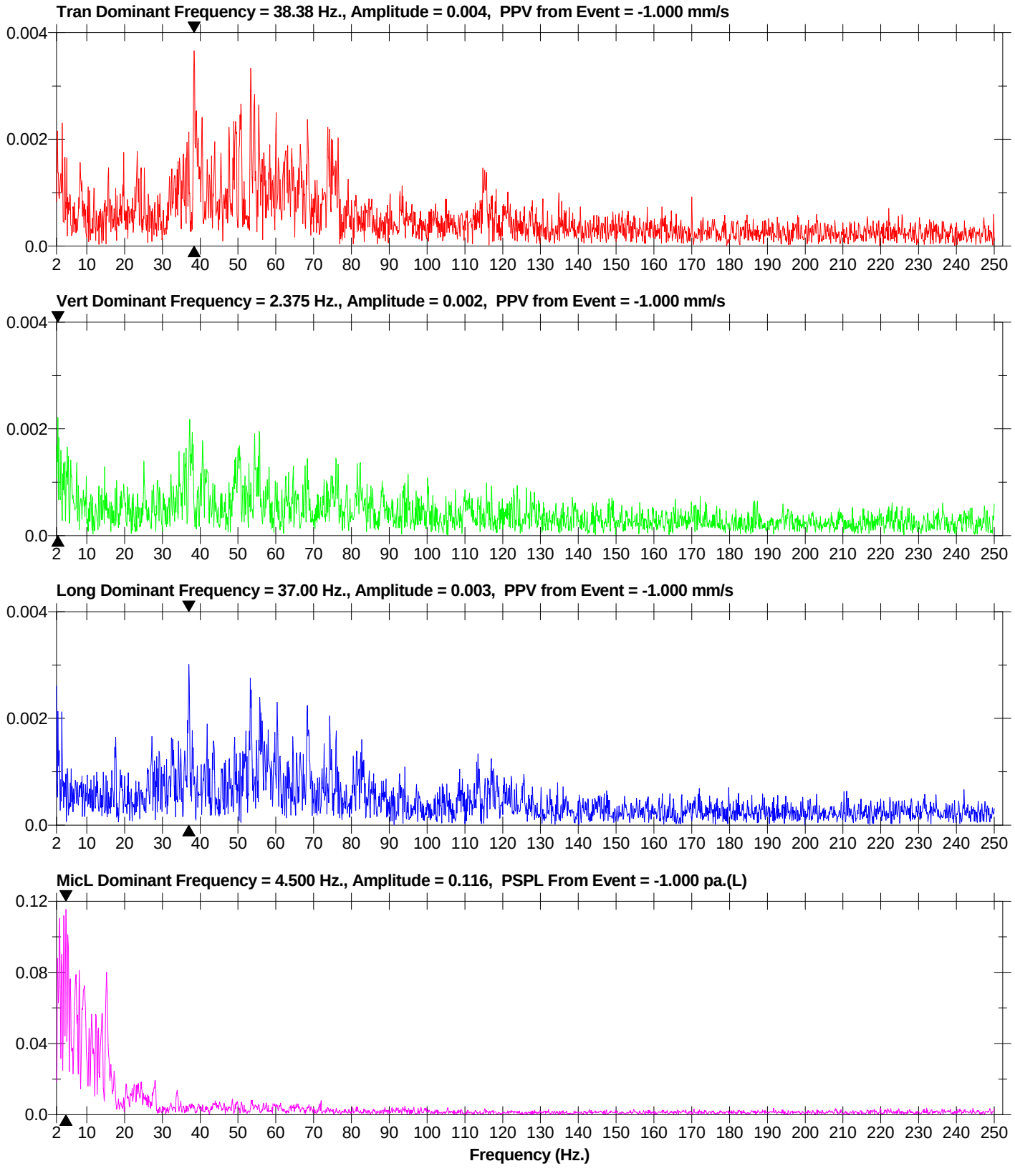
FFT Report

Date/Time	MicL at 13:00:49 February 1, 2020
Trigger Source	Geo: 0.510 mm/s, Mic: 2.000 pa.(L)
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps

Serial Number	BE16508 V 10.72-1.1 Minimate Blaster
Battery Level	6.4 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	R508IB6M.TD0

Notes
Location: Pur Village
Client:
User Name: CSIR-CIMFR, Bilaspur Research Centre
General:

Extended Notes
Scientific investigation of potenstial damage due to blast induced ground vibration and air over pressure in domestic houses in Pur Village, Bhilwara, Rajasthan, India.



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FFT Report

Date/Time	Long at 13:00:51 February 1, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 2048 sps
Operator/Setup:	Operator/CIMFR BLSPR.mmb

Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200201130051.IDFW

Notes

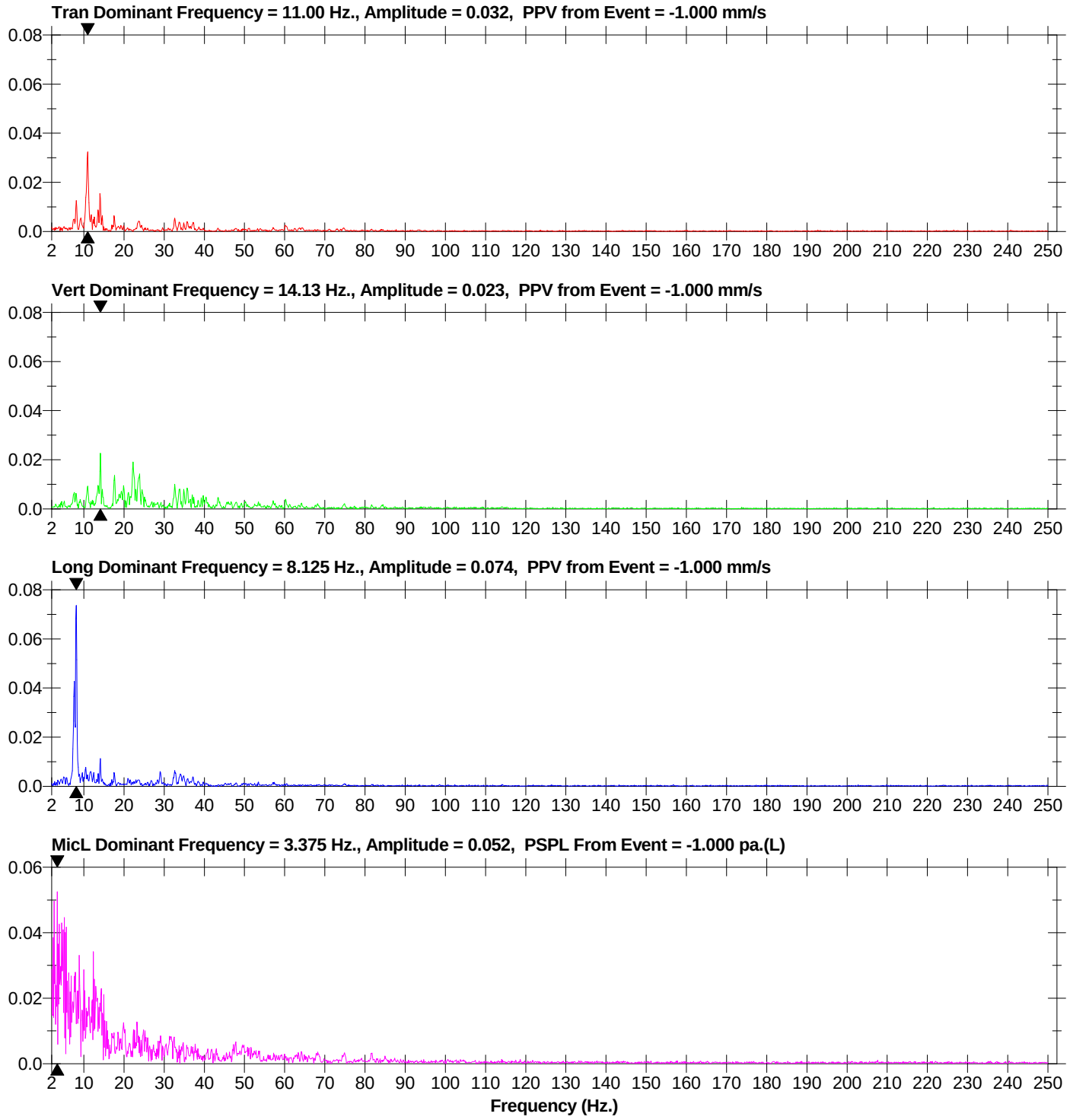
Location: PUR VILLAGE
Client:
User Name: CSIR-CIMFR Bilaspur Research Centre
General:

Extended Notes

Scientific investigation of damage potential due to blast induced ground vibration and airover pressure in domestic houses in Pur Village, Bhilwara, Rajasthan, India.

Post Event Notes

DMG, BHILWARA DIST, RAJASTHAN GOVT.



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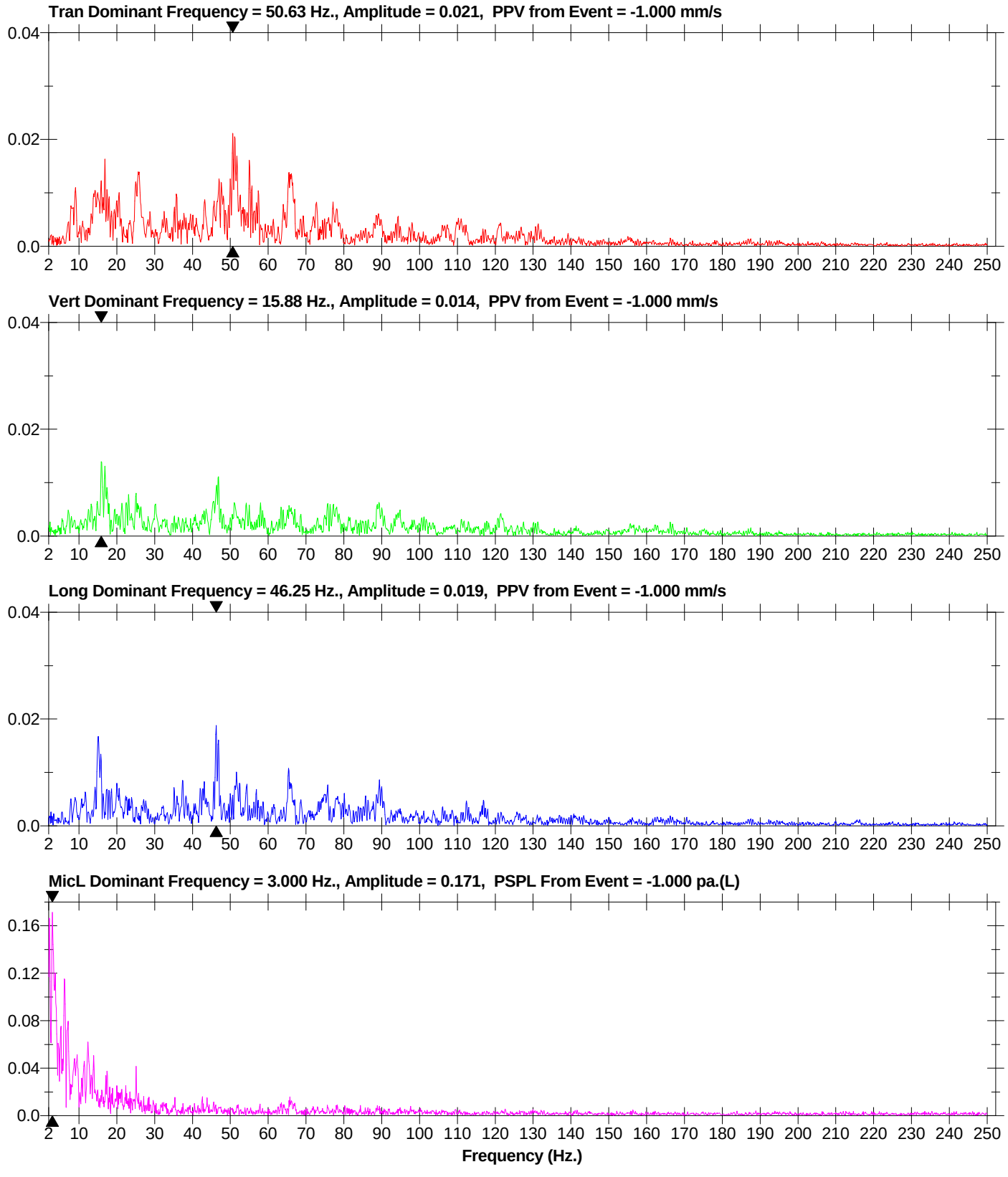
FFT Report

Date/Time	Tran at 13:03:54 February 1, 2020
Trigger Source	Geo: 0.510 mm/s, Mic: 2.000 pa.(L)
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps

Serial Number	BE16508 V 10.72-1.1 Minimate Blaster
Battery Level	6.4 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	R508IB6M.YI0

Notes
Location: Pur Village
Client:
User Name: CSIR-CIMFR, Bilaspur Research Centre
General:

Extended Notes
Scientific investigation of potenstial damage due to blast induced ground vibration and air over pressure in domestic houses in Pur Village, Bhilwara, Rajasthan, India.



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FFT Report

Date/Time	Long at 13:11:23 February 4, 2020
Trigger Source	Geo: 0.510 mm/s
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps

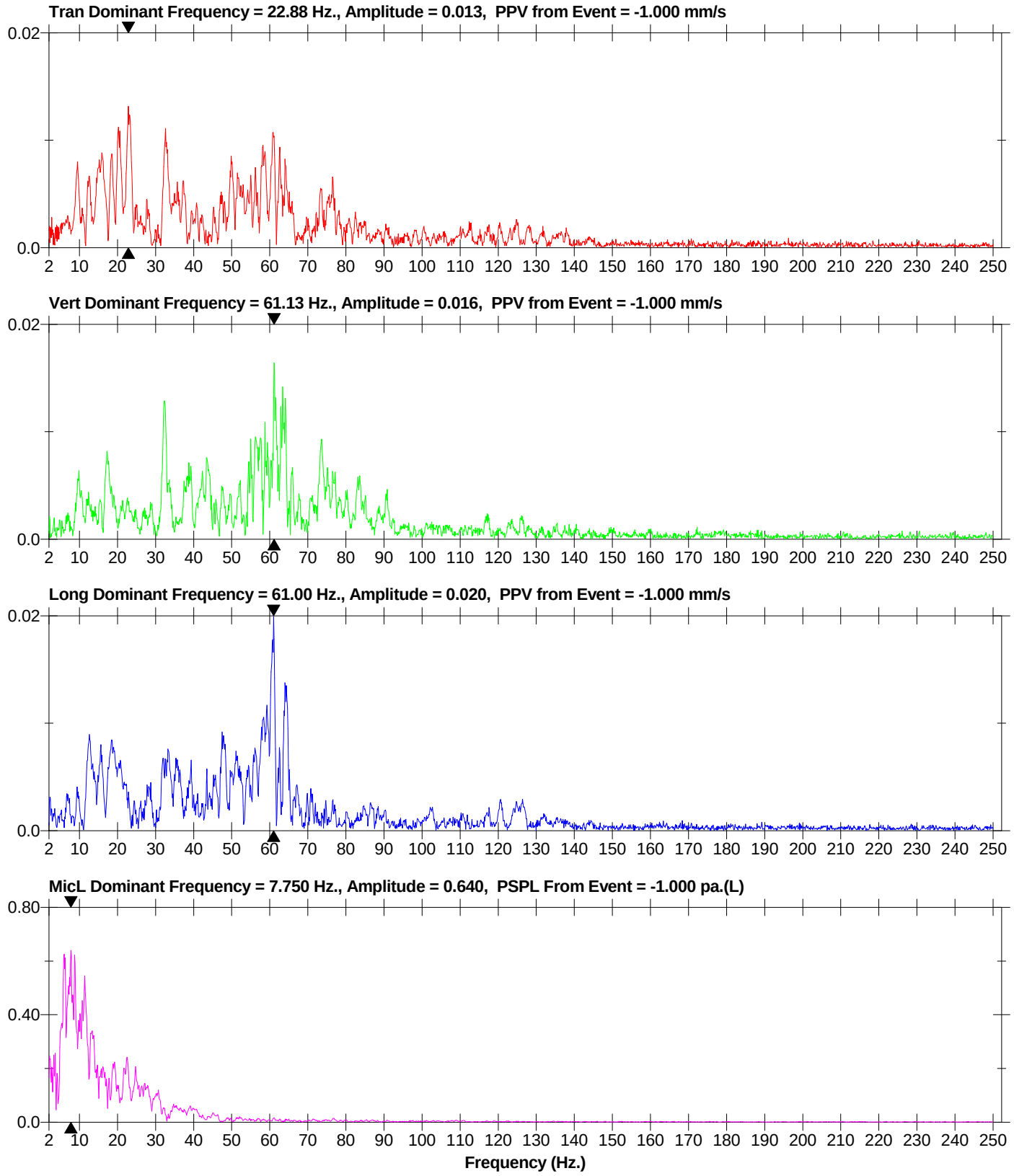
Serial Number	BE13781 V 10.72-8.17 MiniMate Plus
Battery Level	6.3 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	O781IBC7.AZ0

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR, Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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FFT Report

Date/Time	MicL at 13:11:33 February 4, 2020
Trigger Source	Geo: 0.250 mm/s, Mic: 6.325 pa.(L)
Range	Geo: 254.0 mm/s
Record Time	10.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR BLSPR.mmb

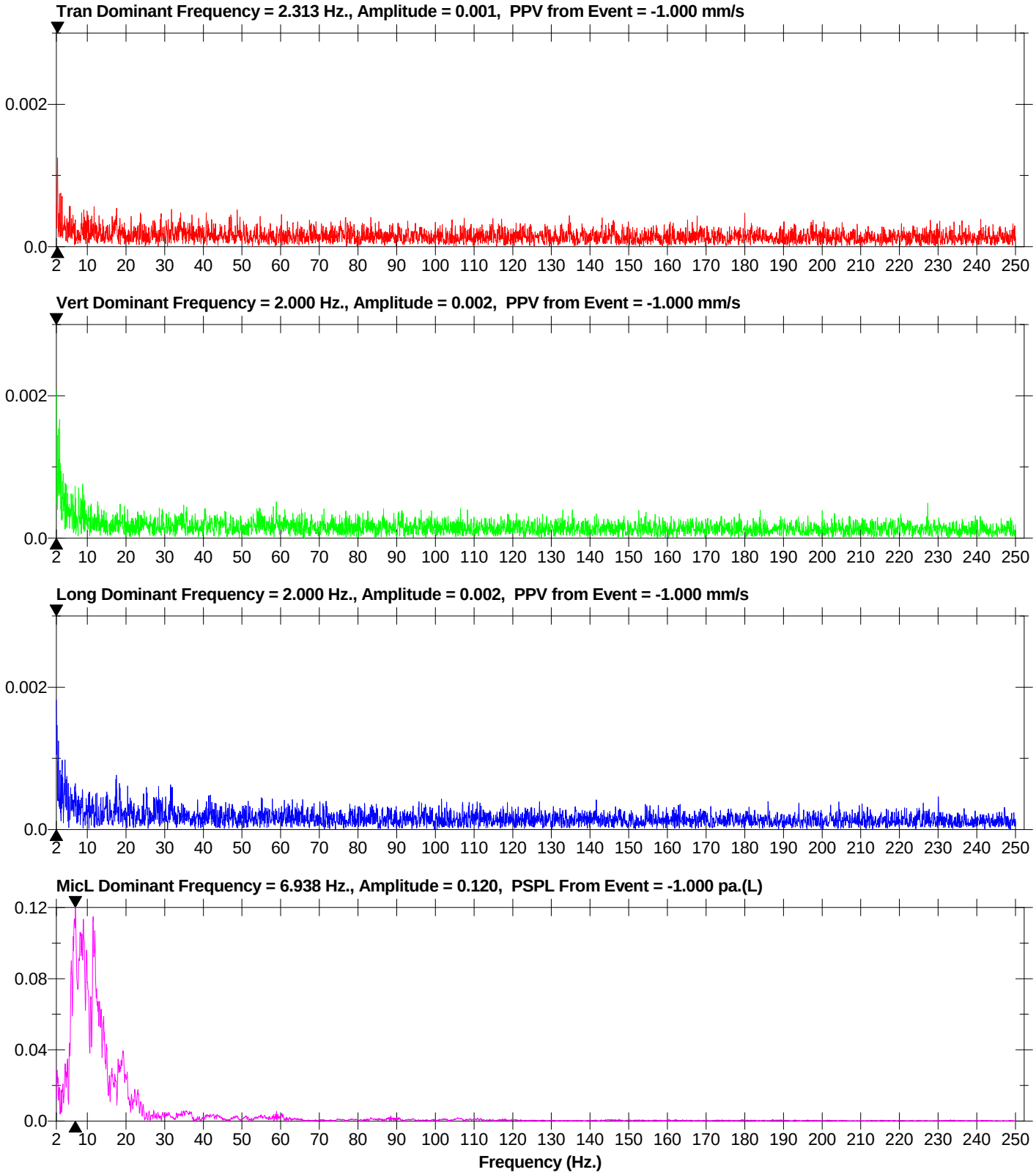
Serial Number	UM12452 V 10-89 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12452_20200204131133.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR, Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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FFT Report

Date/Time	MicL at 13:11:33 February 4, 2020
Trigger Source	Geo: 0.250 mm/s, Mic: 6.325 pa.(L)
Range	Geo: 254.0 mm/s
Record Time	10.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR BLSPR.mmb

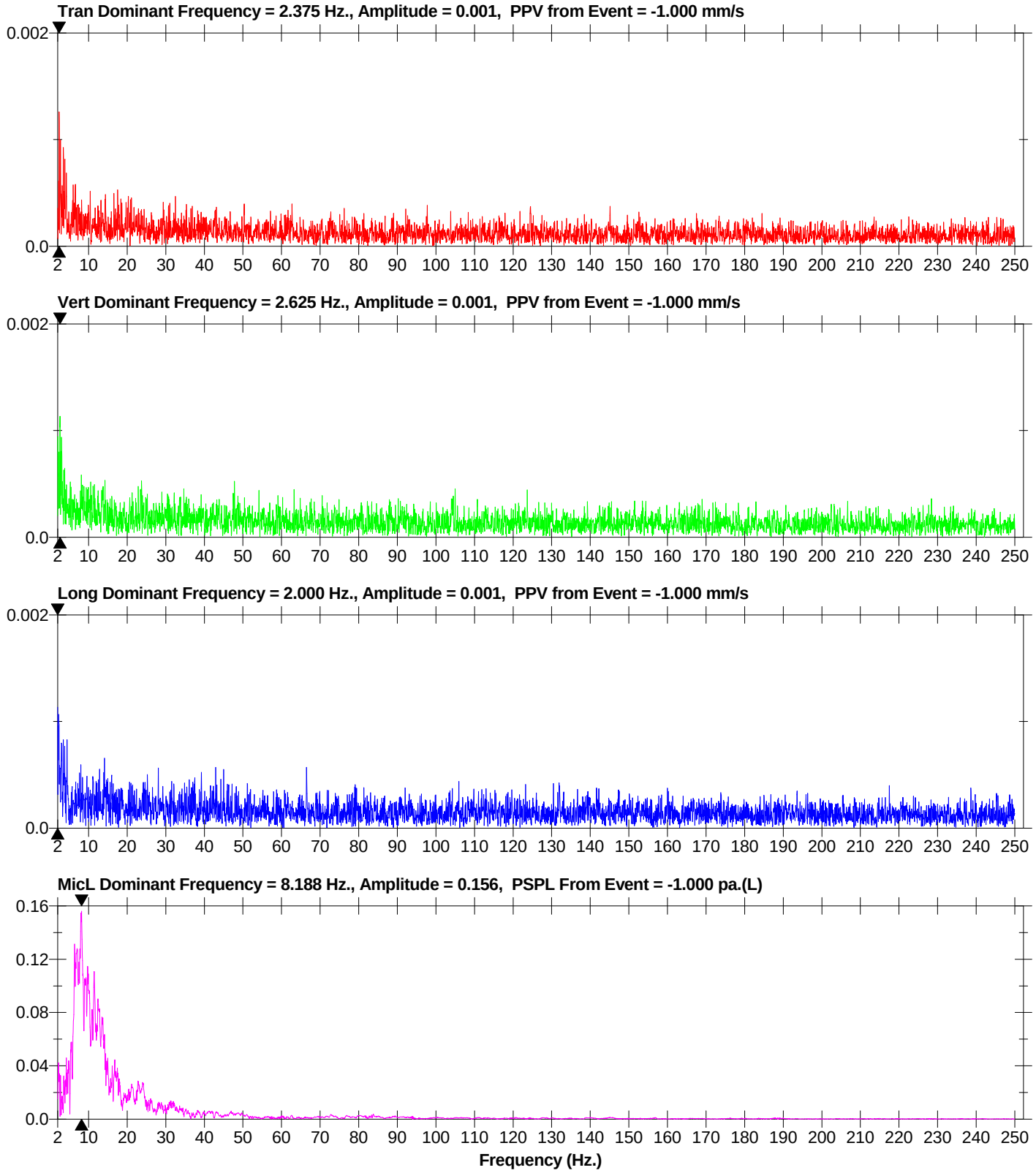
Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200204131133.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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FFT Report

Date/Time	Long at 13:14:16 February 5, 2020
Trigger Source	Geo: 0.250 mm/s, Mic: 6.325 pa.(L)
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR BLSPR.mmb

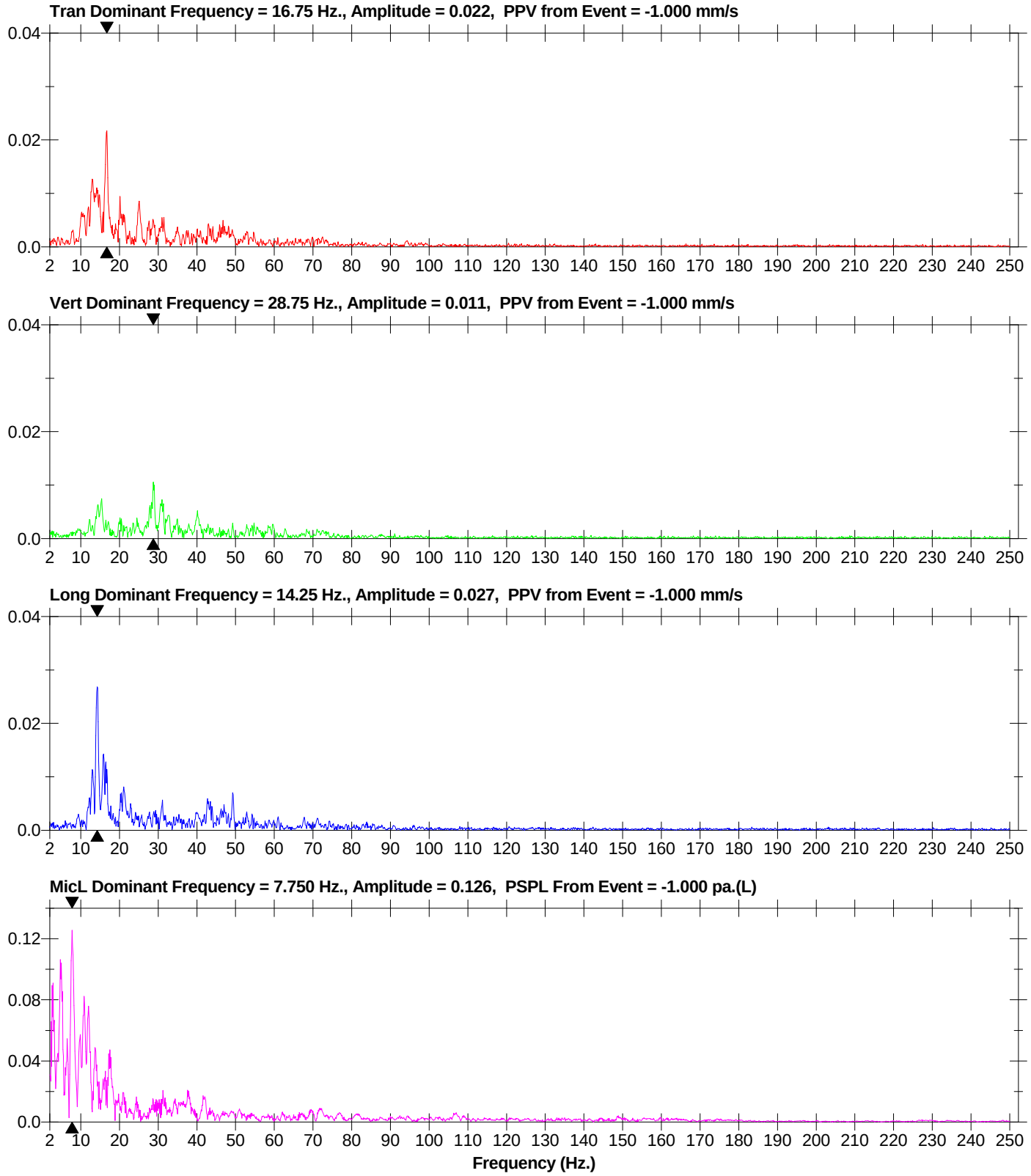
Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200205131416.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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FFT Report

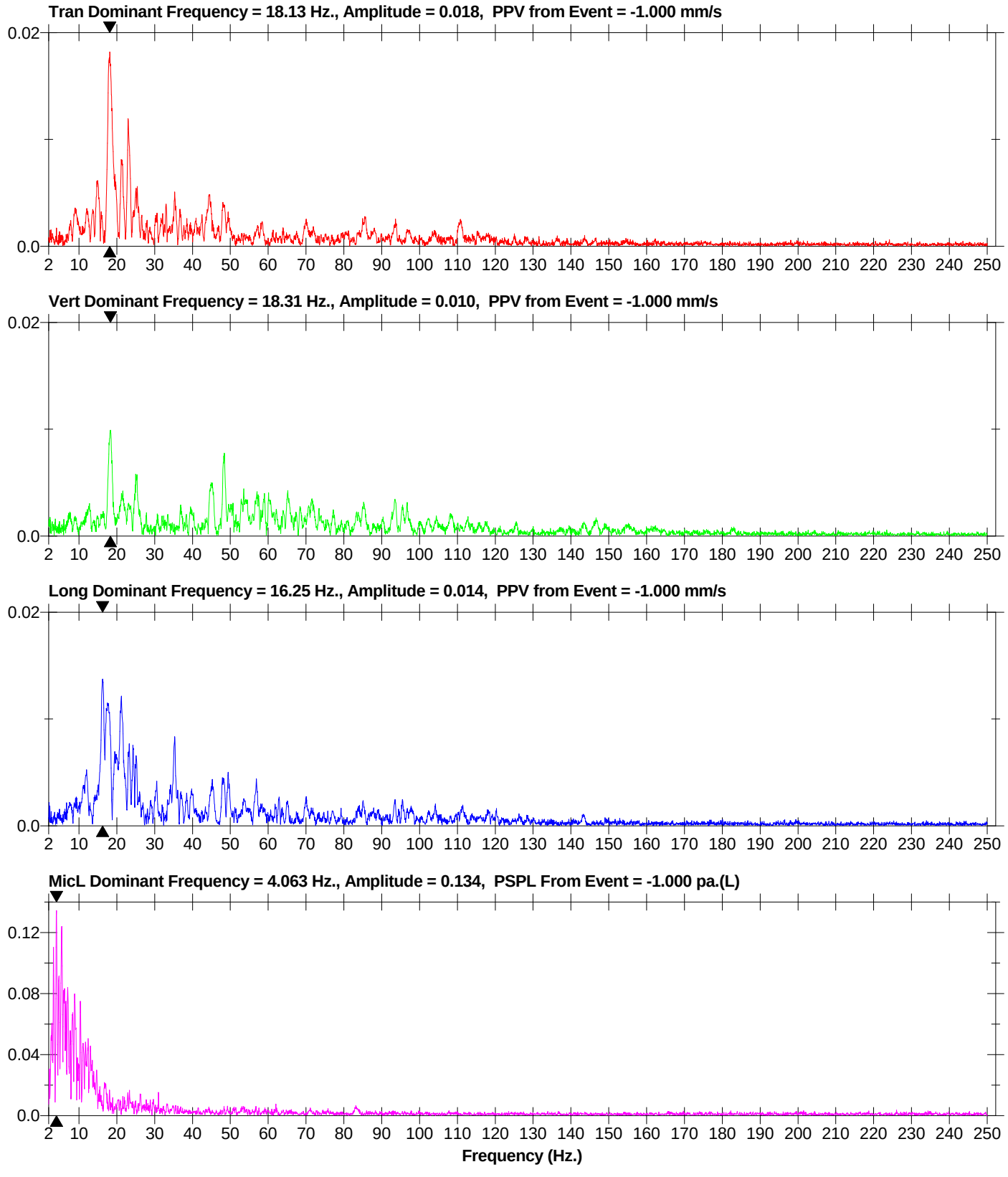
Date/Time	Long at 13:15:06 February 5, 2020
Trigger Source	Geo: 0.510 mm/s, Mic: 6.325 pa.(L)
Range	Geo: 31.75 mm/s
Record Time	10.0 sec at 4096 sps
Serial Number	BE16508 V 10.72-1.1 Minimate Blaster
Battery Level	6.1 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	R508IBE2.560

Notes

Location: Pur Village
Client: Dist. Collector, Rajasthan Govt.
User Name: CSIR-CIMFR, Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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FFT Report

Date/Time	Tran at 13:15:14 February 5, 2020
Trigger Source	Geo: 0.510 mm/s
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps

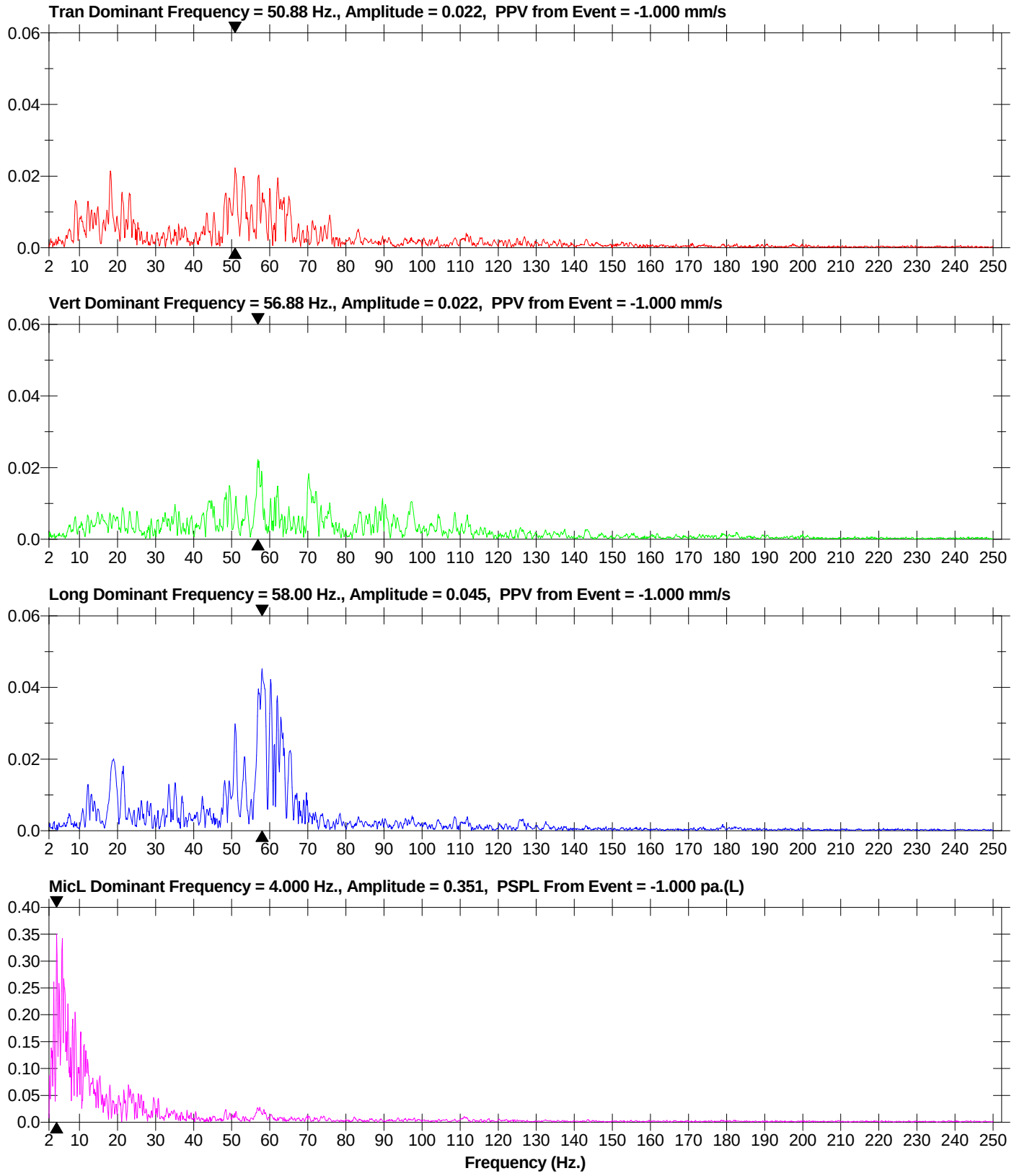
Serial Number	BE13781 V 10.72-8.17 MiniMate Plus
Battery Level	6.2 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	O781IBE2.5E0

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR, Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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FFT Report

Date/Time	Long at 13:15:21 February 5, 2020
Trigger Source	Geo: 0.250 mm/s, Mic: 6.325 pa.(L)
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR BLSPR.mmb

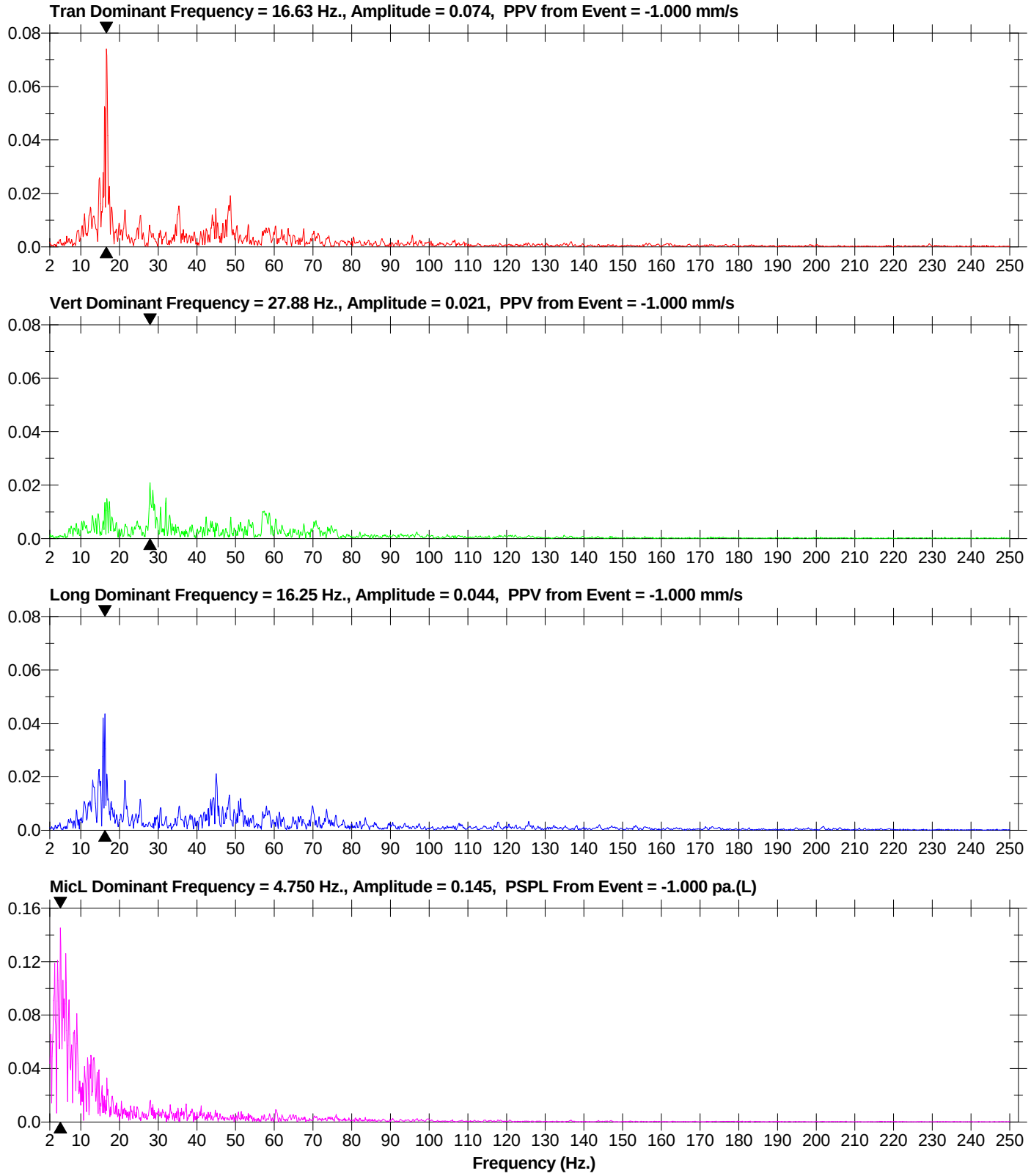
Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200205131521.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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FFT Report

Date/Time	Tran at 13:12:02 February 6, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR BLSPR.mmb

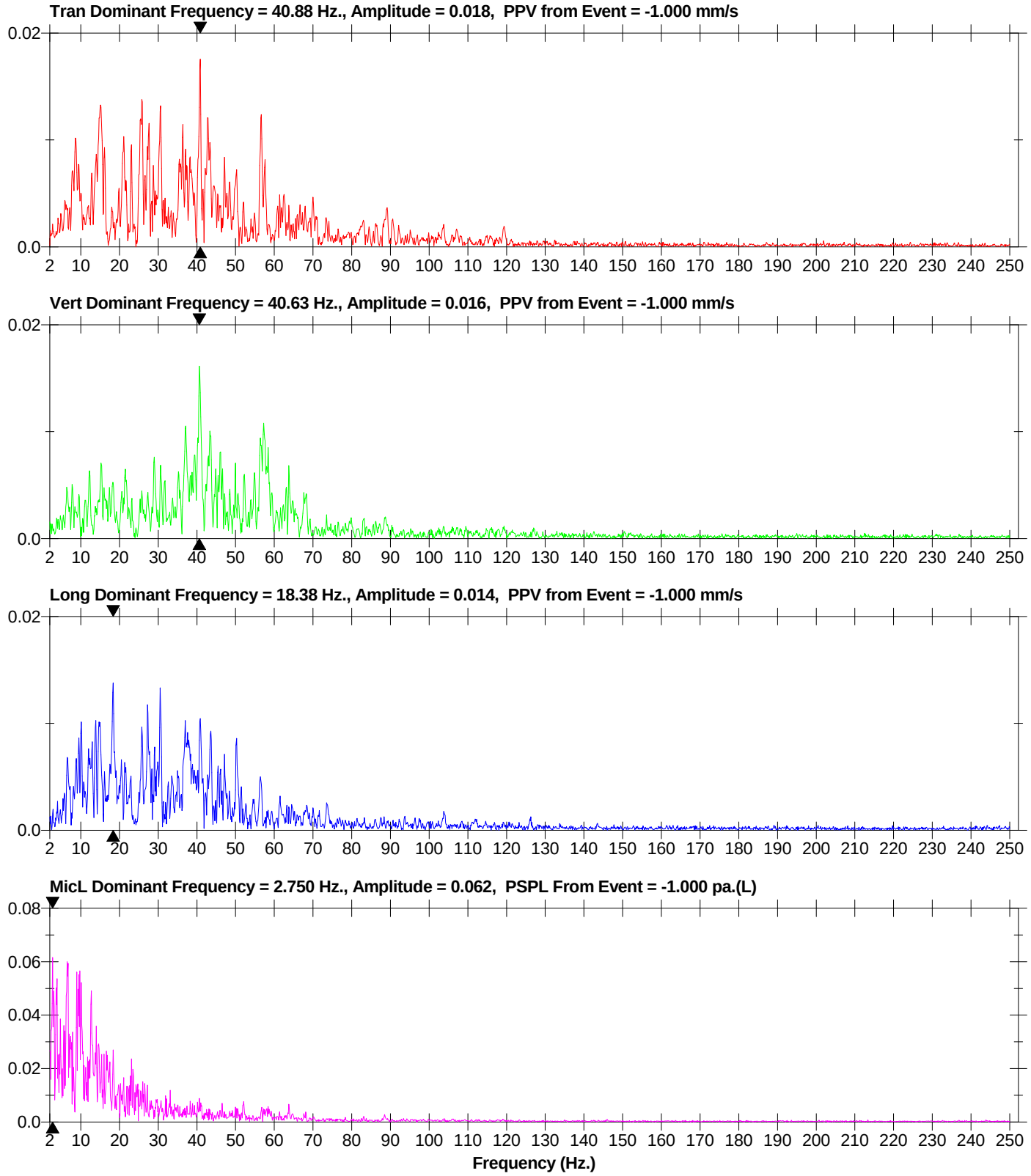
Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200206131202.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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FFT Report

Date/Time	Tran at 13:14:30 February 6, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR BLSPR.mmb

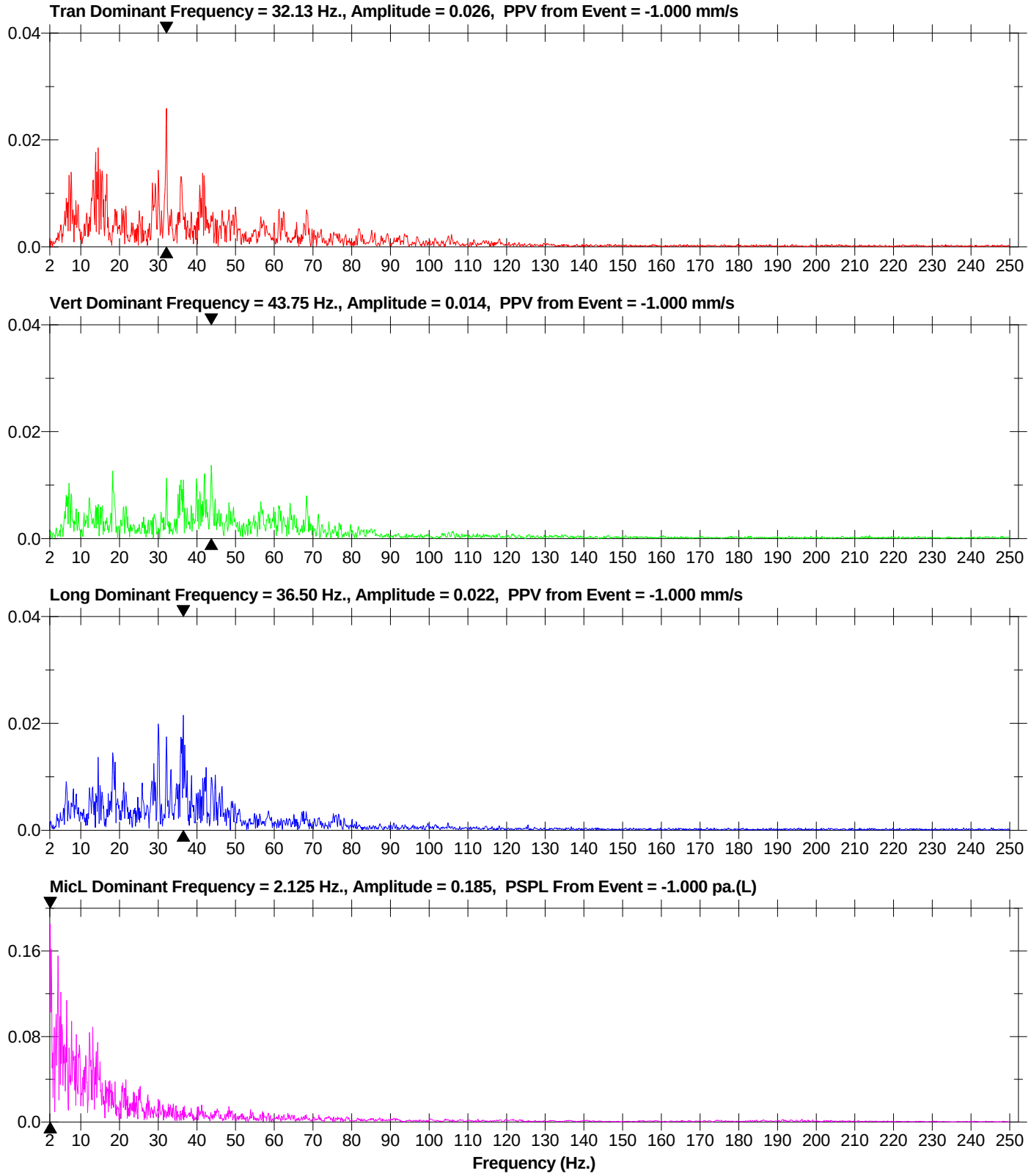
Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200206131430.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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FFT Report

Date/Time	Long at 13:29:26 March 3, 2020
Trigger Source	Geo: 0.500 mm/s
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps
Job Number:	1

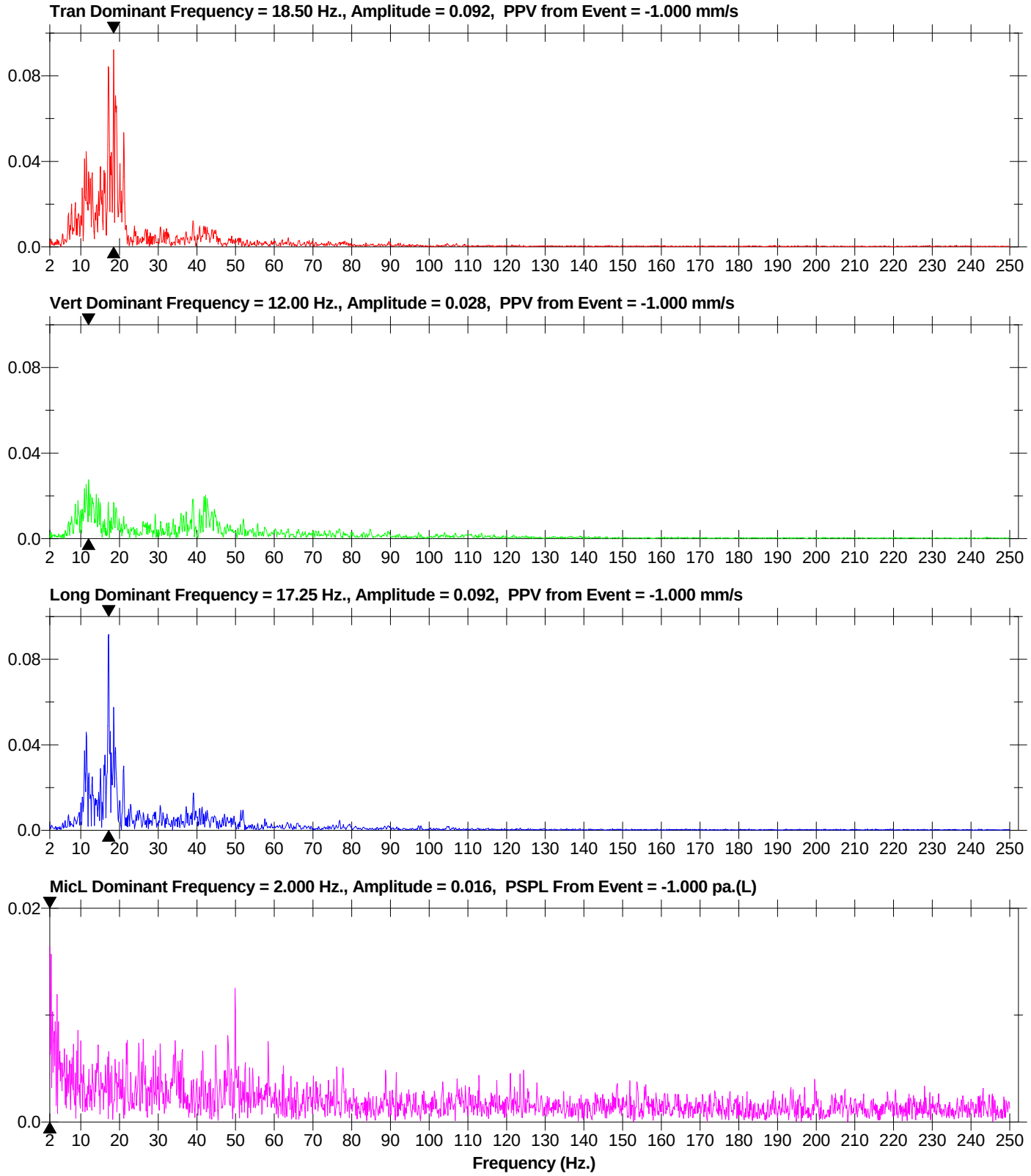
Serial Number	BE18062 V 10.72-1.1 Minimate Blaster
Battery Level	6.2 Volts
Unit Calibration	March 29, 2019 by UES, New Delhi
File Name	T062ICS2.T20

Notes

Location: Pur Village
Client: District collector Bhilwara, Rajasthan
User Name: CIMFR
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibation & Airover Pressure in Domestic Houses inPur Village, Bhilwara, Rajasthan.



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FFT Report

Date/Time	Long at 13:29:26 March 3, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

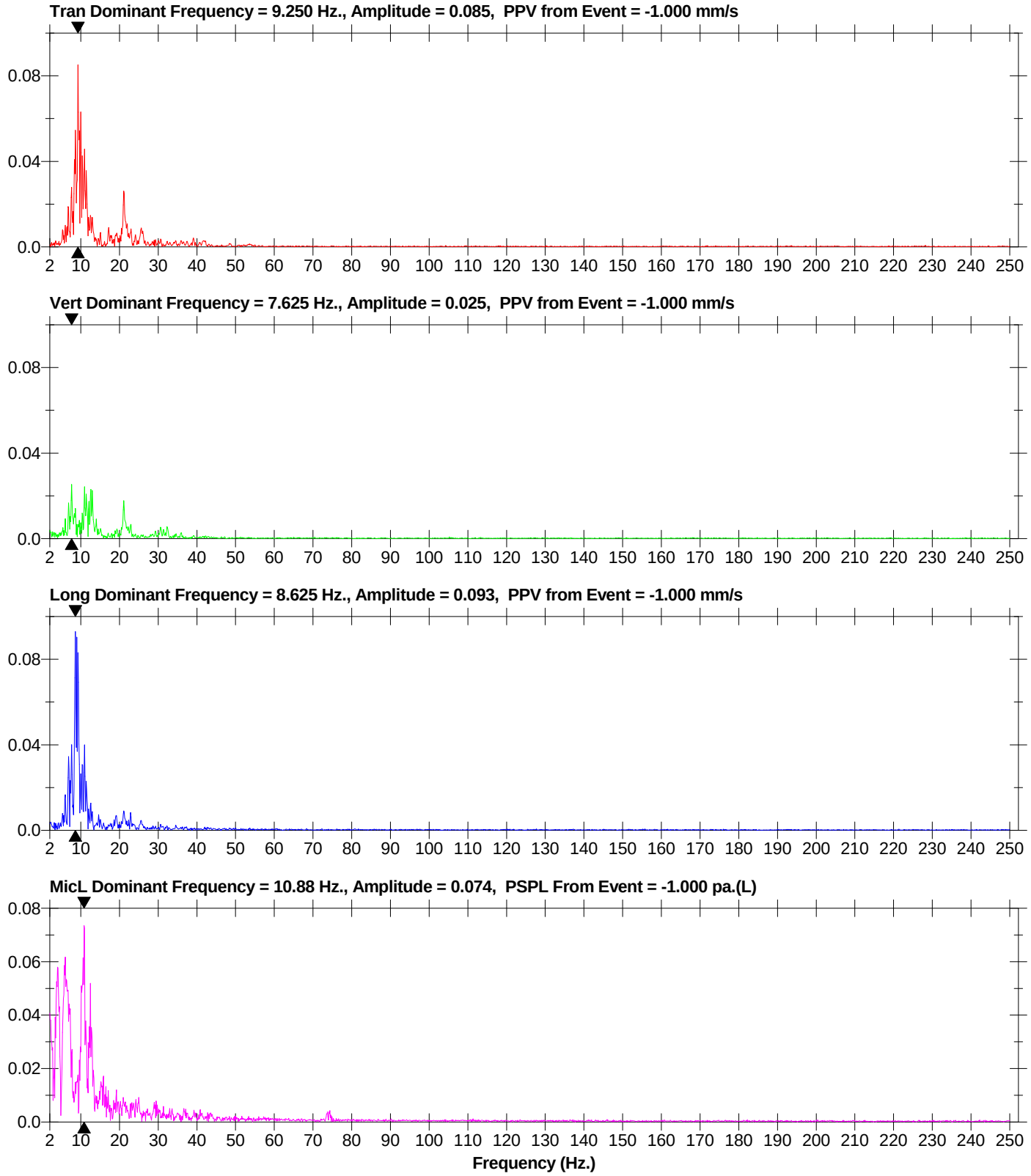
Serial Number	UM12452 V 10-89 Micromate ISEE
Battery Level	3.7 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12452_20200303132926.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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FFT Report

Date/Time	Long at 13:18:28 March 4, 2020
Trigger Source	Geo: 0.500 mm/s, Mic: 6.325 pa.(L)
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps

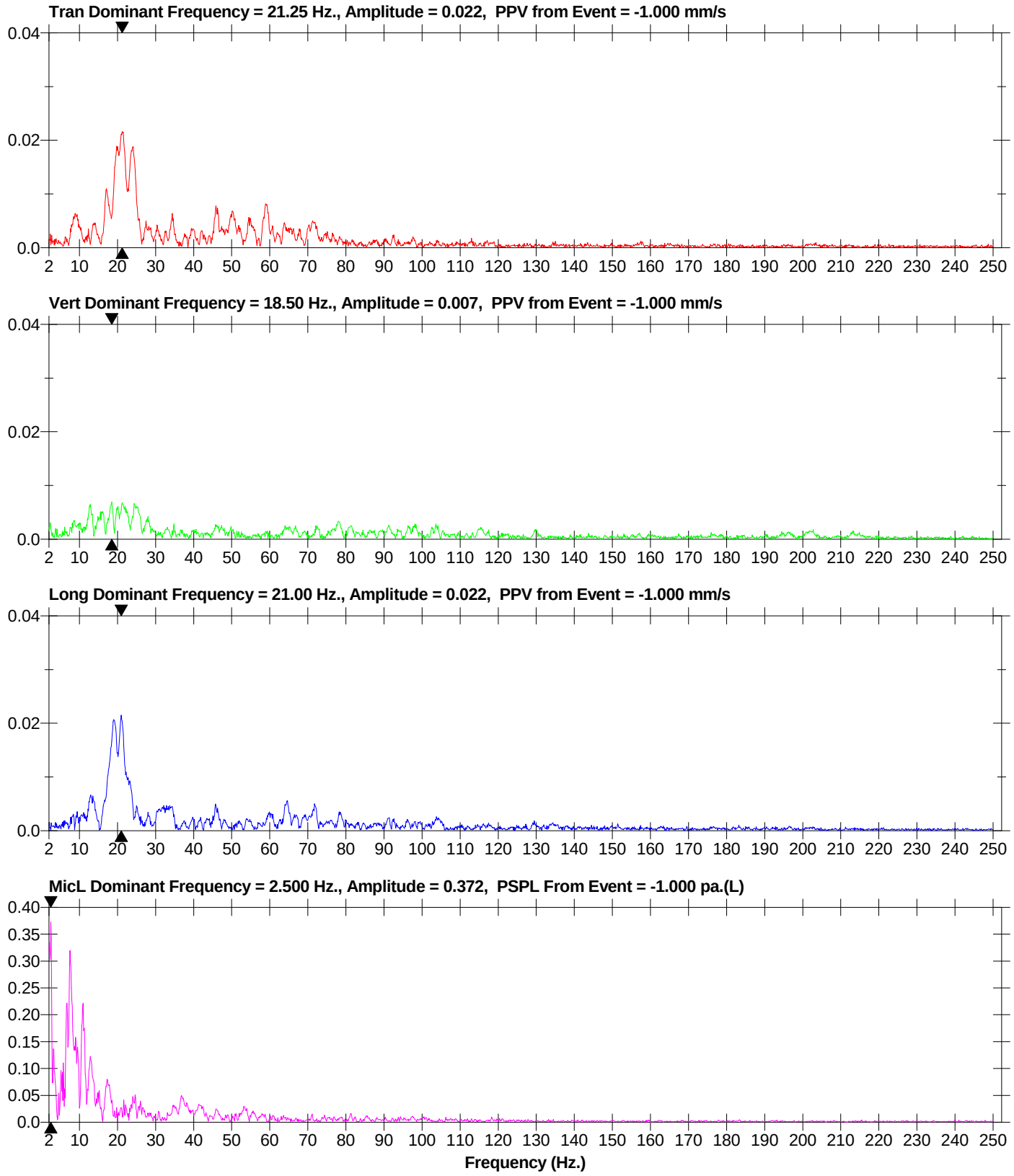
Serial Number	BE16508 V 10.72-1.1 Minimate Blaster
Battery Level	6.2 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	R508ICTW.YS0

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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FFT Report

Date/Time	Long at 13:18:45 March 4, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

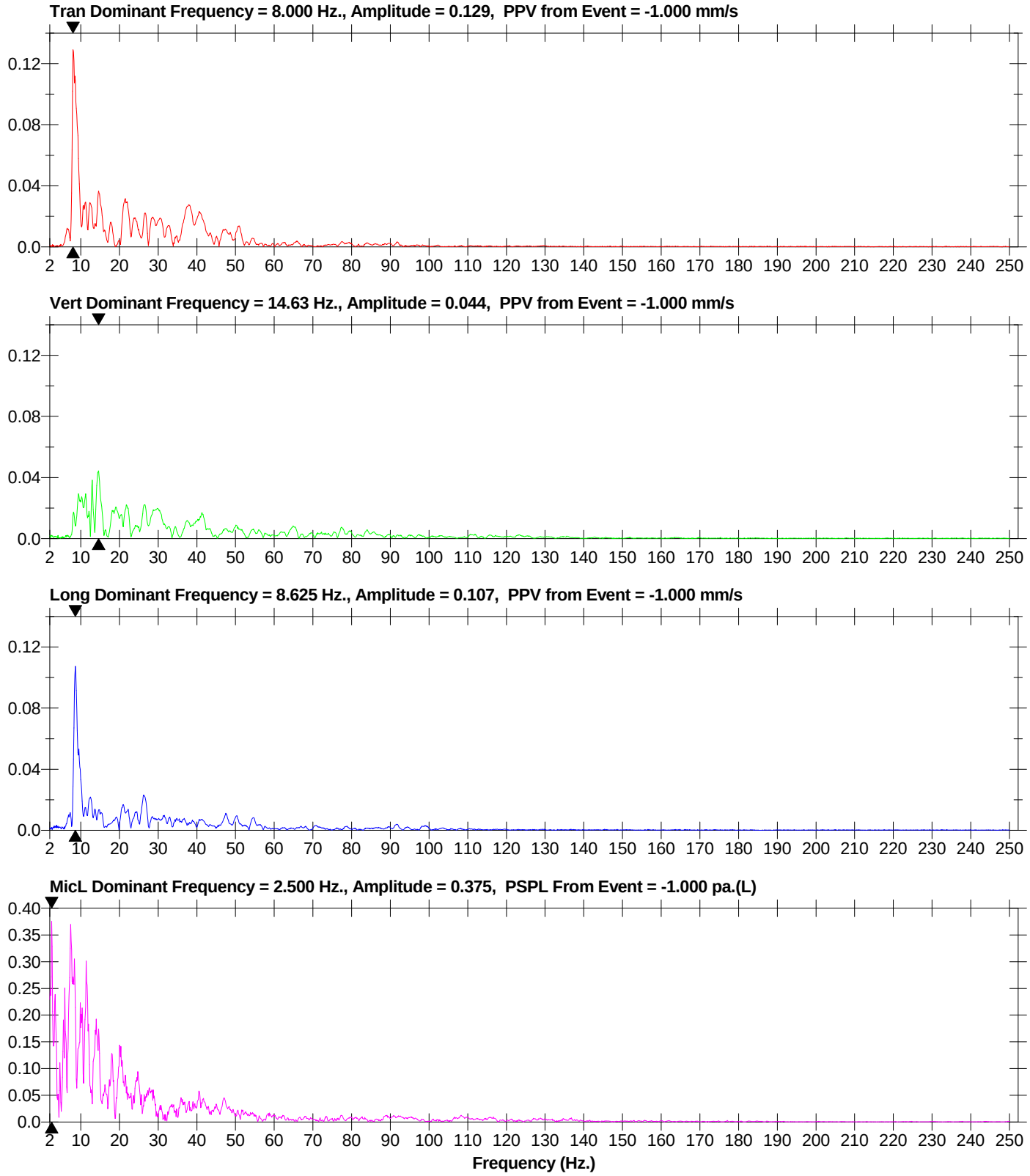
Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200304131845.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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FFT Report

Date/Time	Vert at 13:18:46 March 4, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

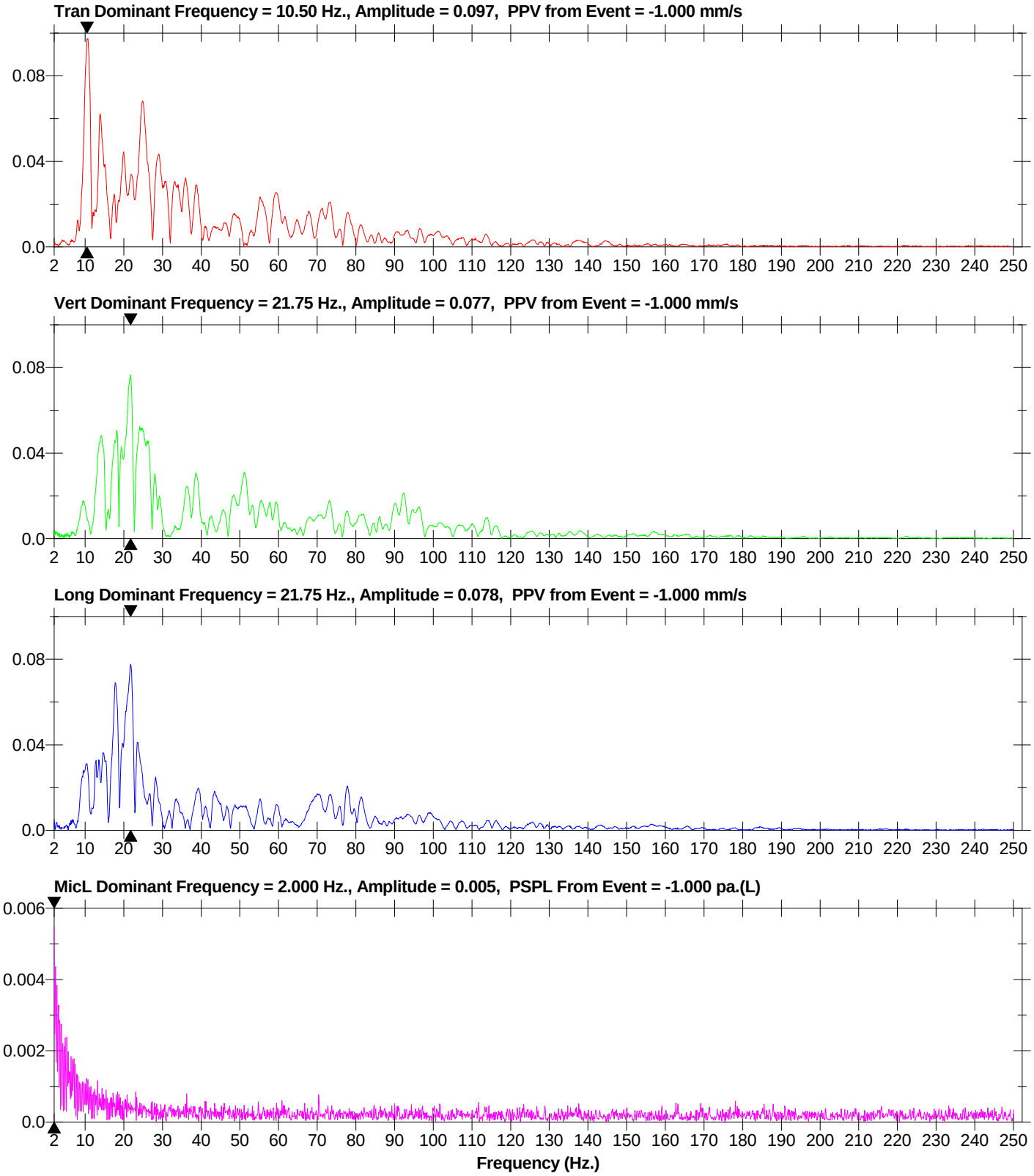
Serial Number	UM12452 V 10-89 Micromate ISEE
Battery Level	3.7 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12452_20200304131846.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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FFT Report

Date/Time	Tran at 13:20:44 March 4, 2020
Trigger Source	Geo: 0.500 mm/s, Mic: 6.325 pa.(L)
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps

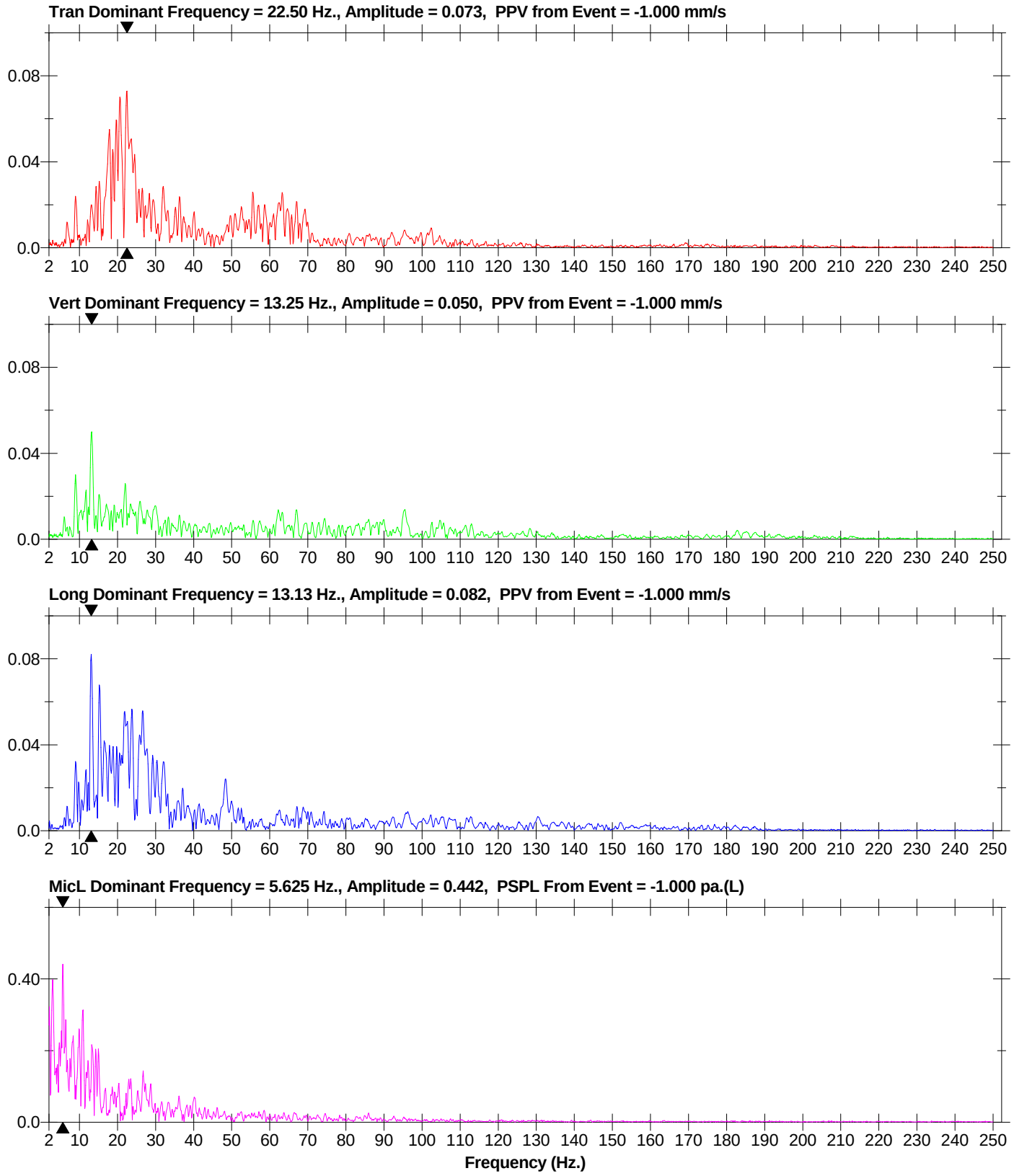
Serial Number	BE16508 V 10.72-1.1 Minimate Blaster
Battery Level	6.2 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	R508ICTX.2K0

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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FFT Report

Date/Time	Vert at 13:21:02 March 4, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

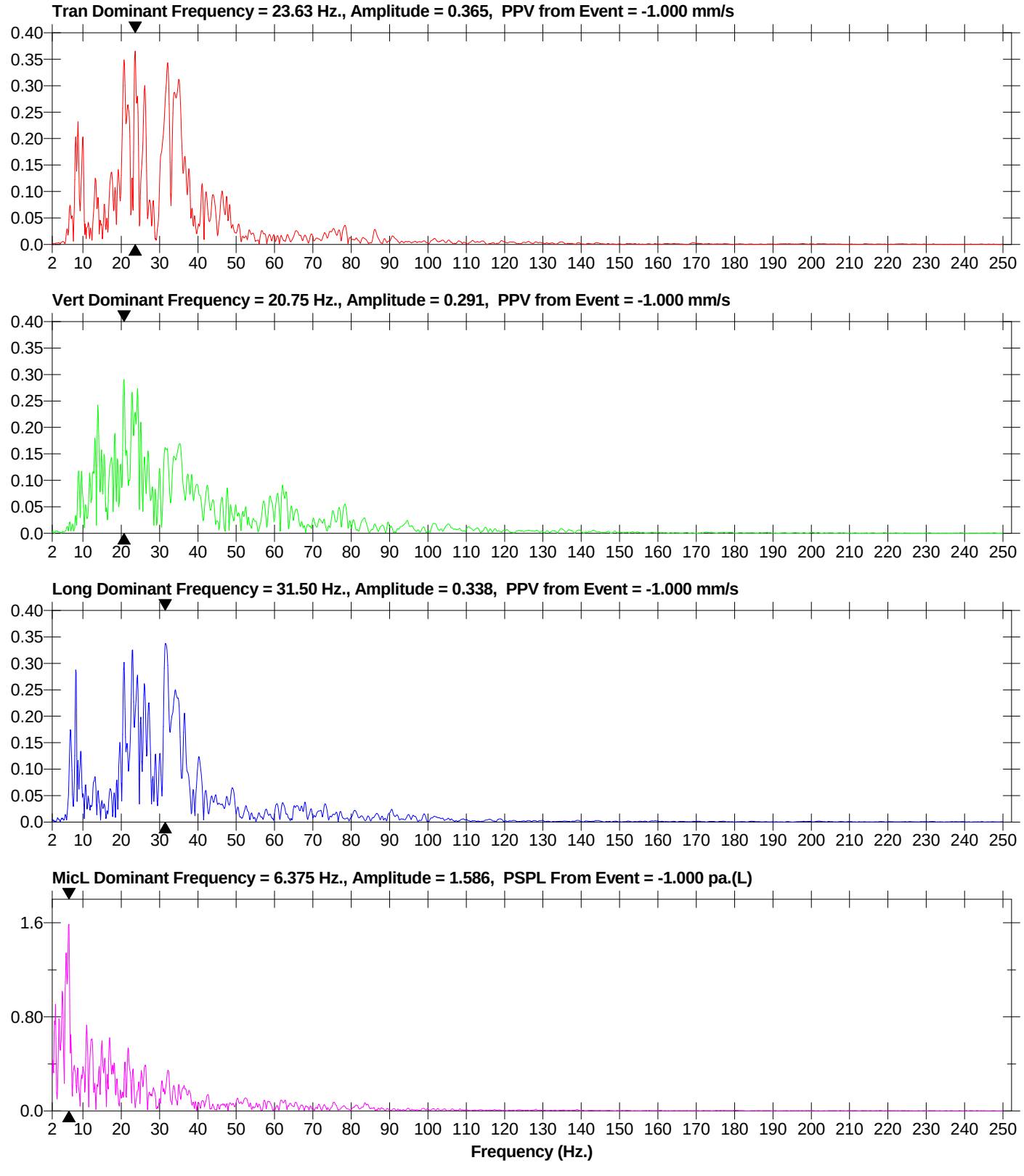
Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200304132102.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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FFT Report

Date/Time	Vert at 13:21:03 March 4, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

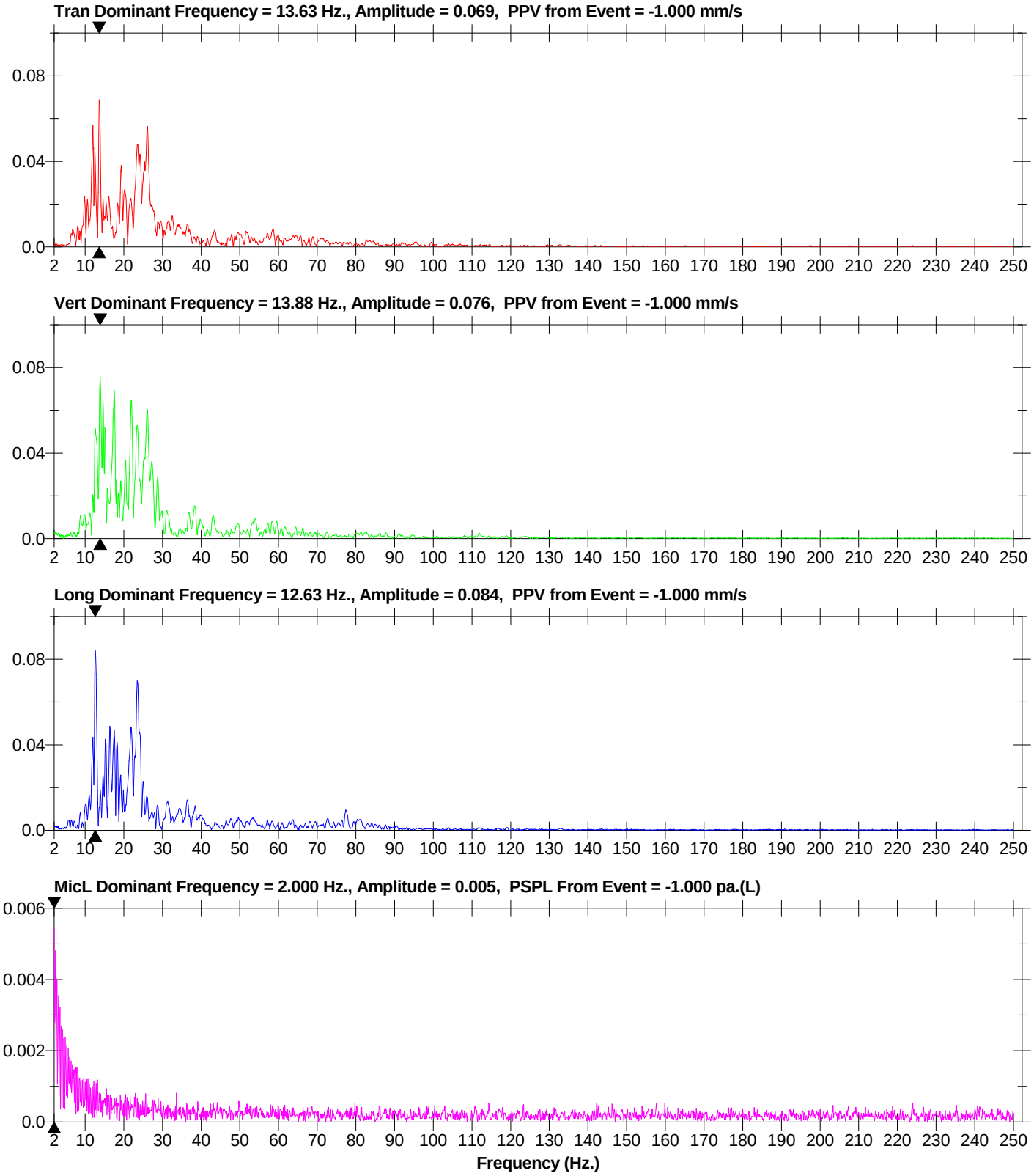
Serial Number	UM12452 V 10-89 Micromate ISEE
Battery Level	3.7 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12452_20200304132103.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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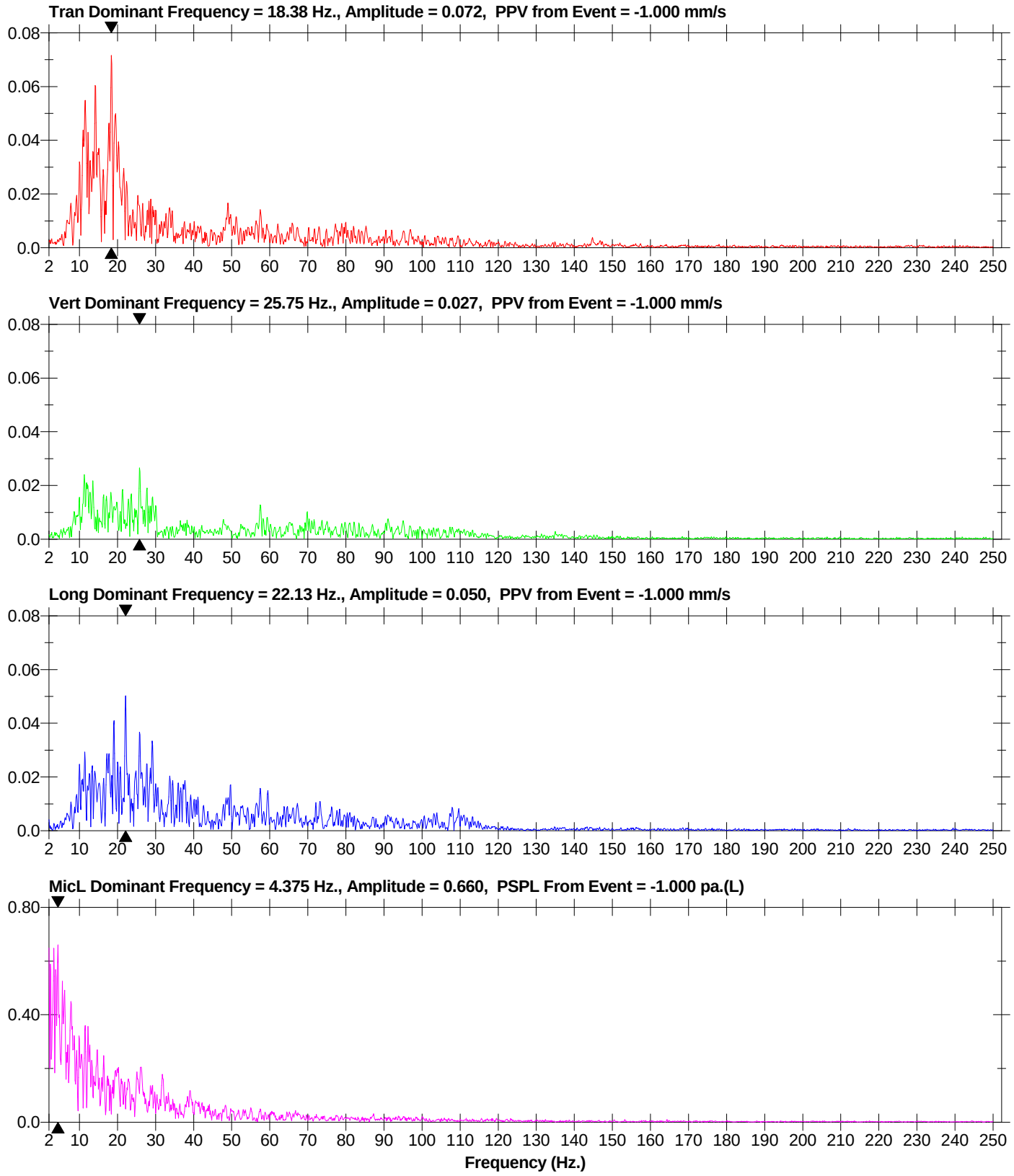
Date/Time	Tran at 13:17:59 March 5, 2020
Trigger Source	Geo: 0.500 mm/s, Mic: 6.325 pa.(L)
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps
Serial Number	BE16508 V 10.72-1.1 Minimate Blaster
Battery Level	6.3 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	R508ICVR.LZ0

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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FFT Report

Date/Time	Long at 13:18:19 March 5, 2020
Trigger Source	Geo: 0.500 mm/s
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps
Job Number:	1

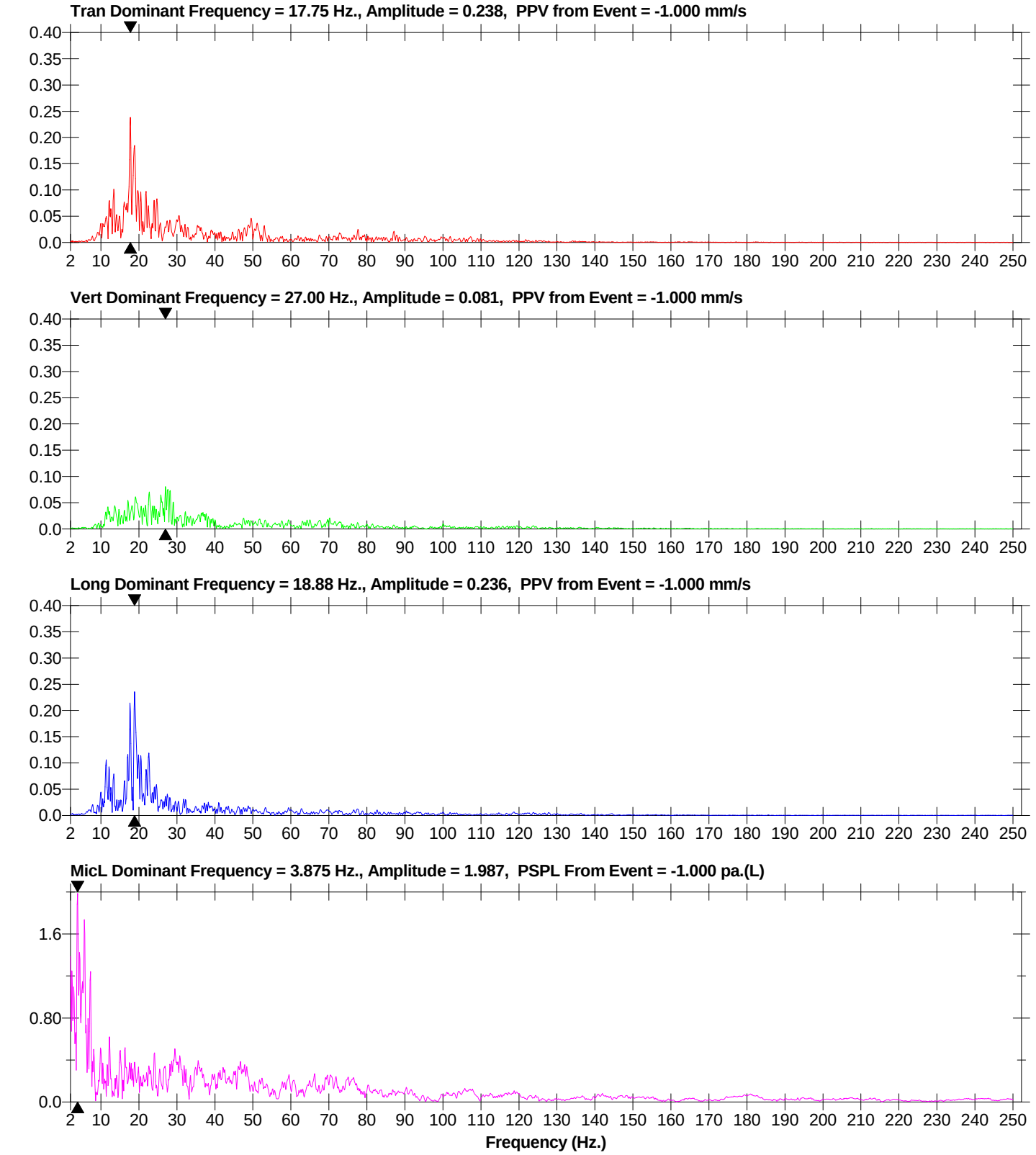
Serial Number	BE18062 V 10.72-1.1 Minimate Blaster
Battery Level	6.1 Volts
Unit Calibration	March 29, 2019 by UES, New Delhi
File Name	T062ICVR.MJ0

Notes

Location: Pur Village
Client: District collector Bhilwara, Rajasthan
User Name: CIMFR
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration & Airover Pressure in Domestic Houses inPur Village, Bhilwara, Rajasthan.



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FFT Report

Date/Time	Vert at 13:18:23 March 5, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

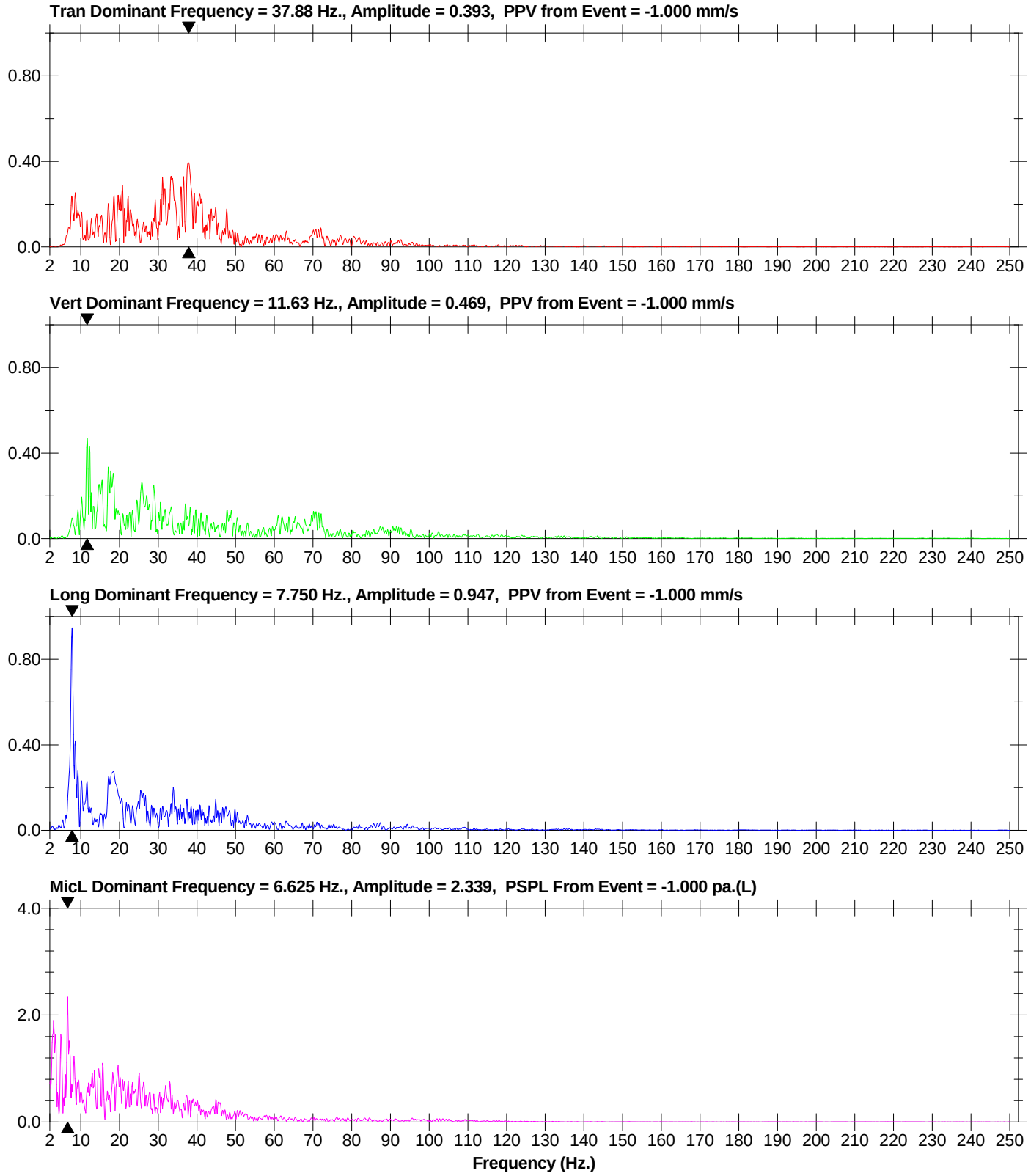
Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200305131823.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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FFT Report

Date/Time	Vert at 13:18:24 March 5, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

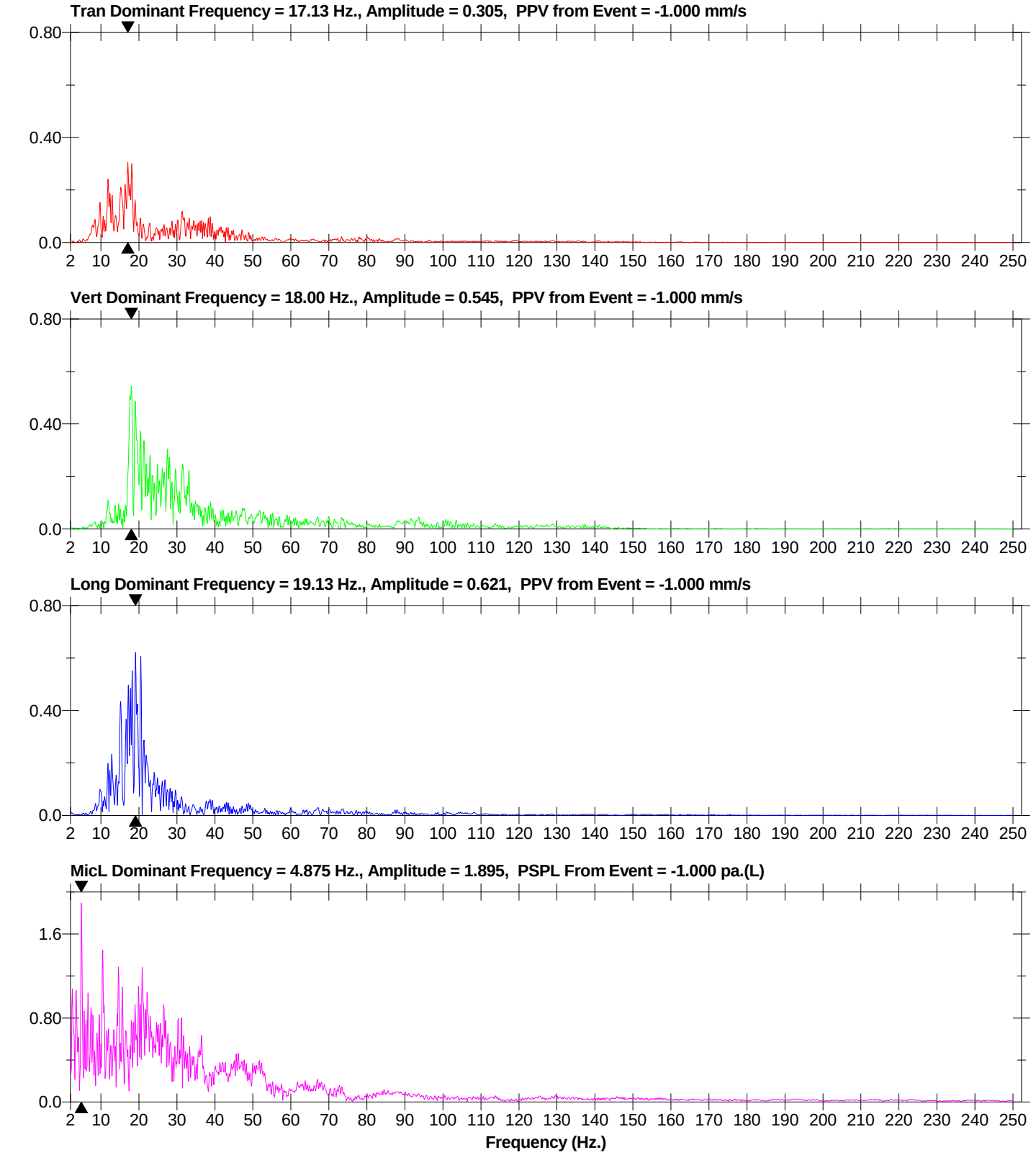
Serial Number	UM12452 V 10-89 Micromate ISEE
Battery Level	3.7 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12452_20200305131824.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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FFT Report

Date/Time	Long at 13:16:32 March 6, 2020
Trigger Source	Geo: 0.500 mm/s
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps
Job Number:	1

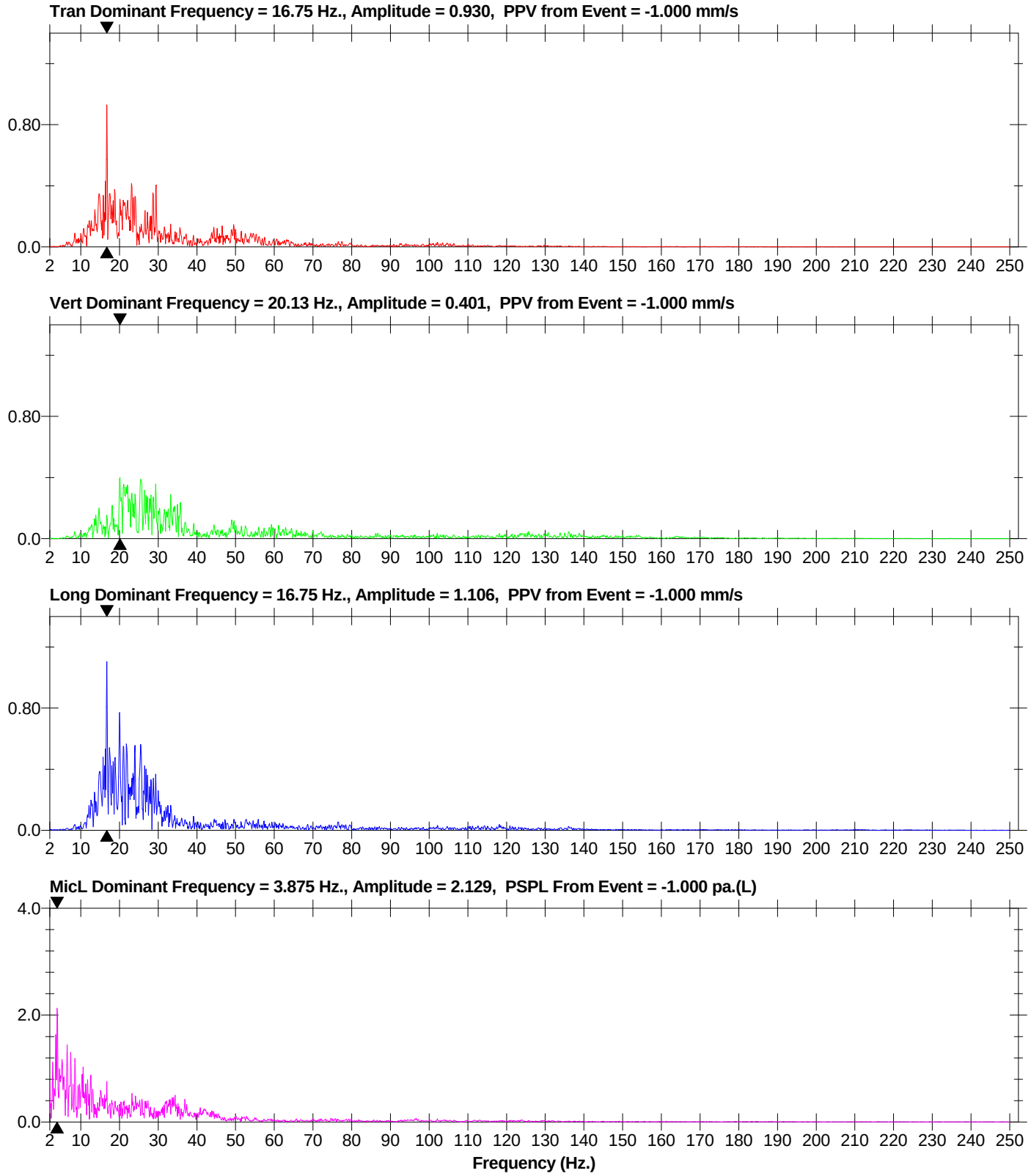
Serial Number	BE18062 V 10.72-1.1 Minimate Blaster
Battery Level	6.0 Volts
Unit Calibration	March 29, 2019 by UES, New Delhi
File Name	T062ICXM.7K0

Notes

Location: Pur Village
Client: District collector Bhilwara, Rajasthan
User Name: CIMFR
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration & Airover Pressure in Domestic Houses inPur Village, Bhilwara, Rajasthan.



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FFT Report

Date/Time	Long at 13:16:42 March 6, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

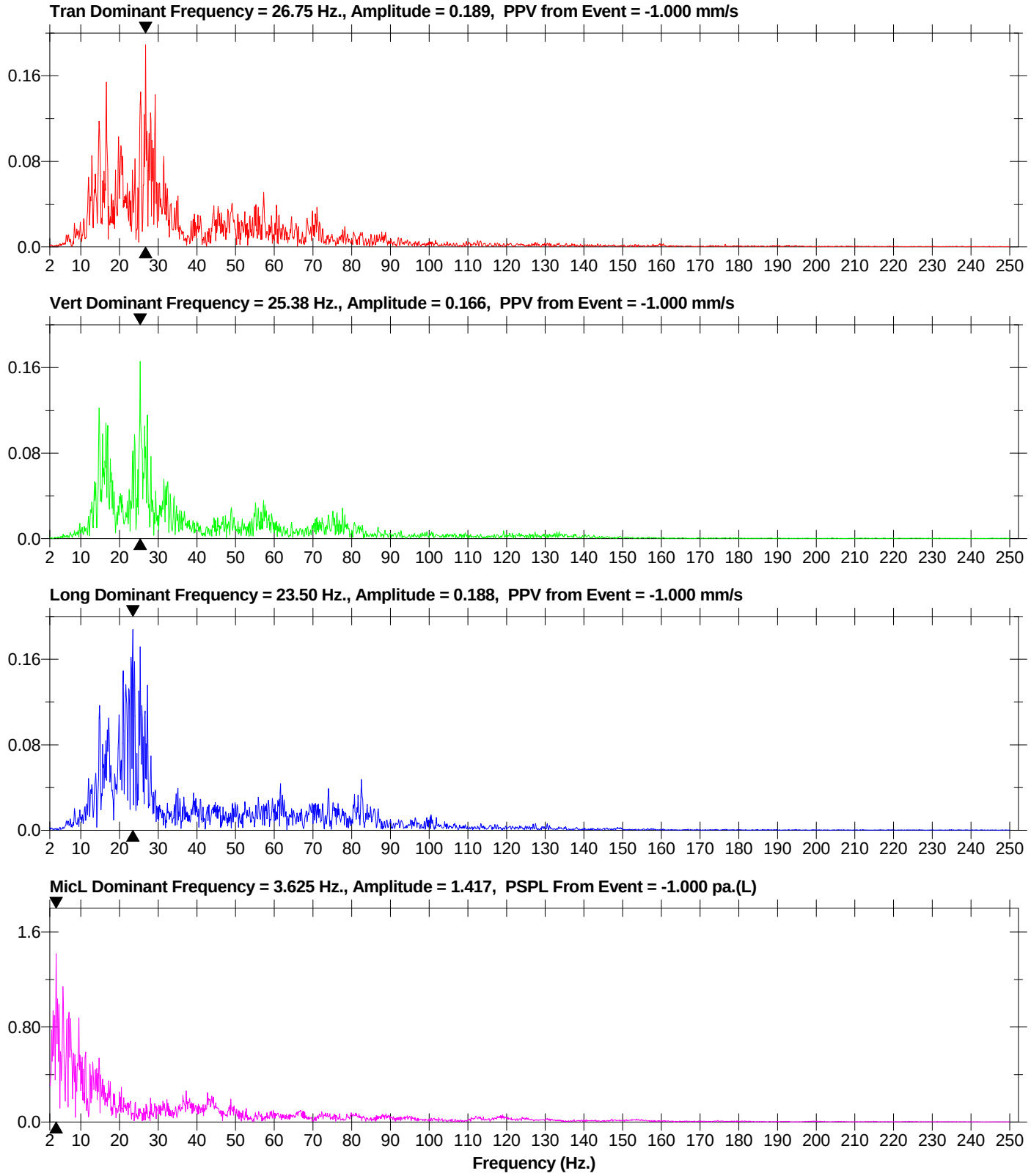
Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200306131642.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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FFT Report

Date/Time	Tran at 13:16:43 March 6, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

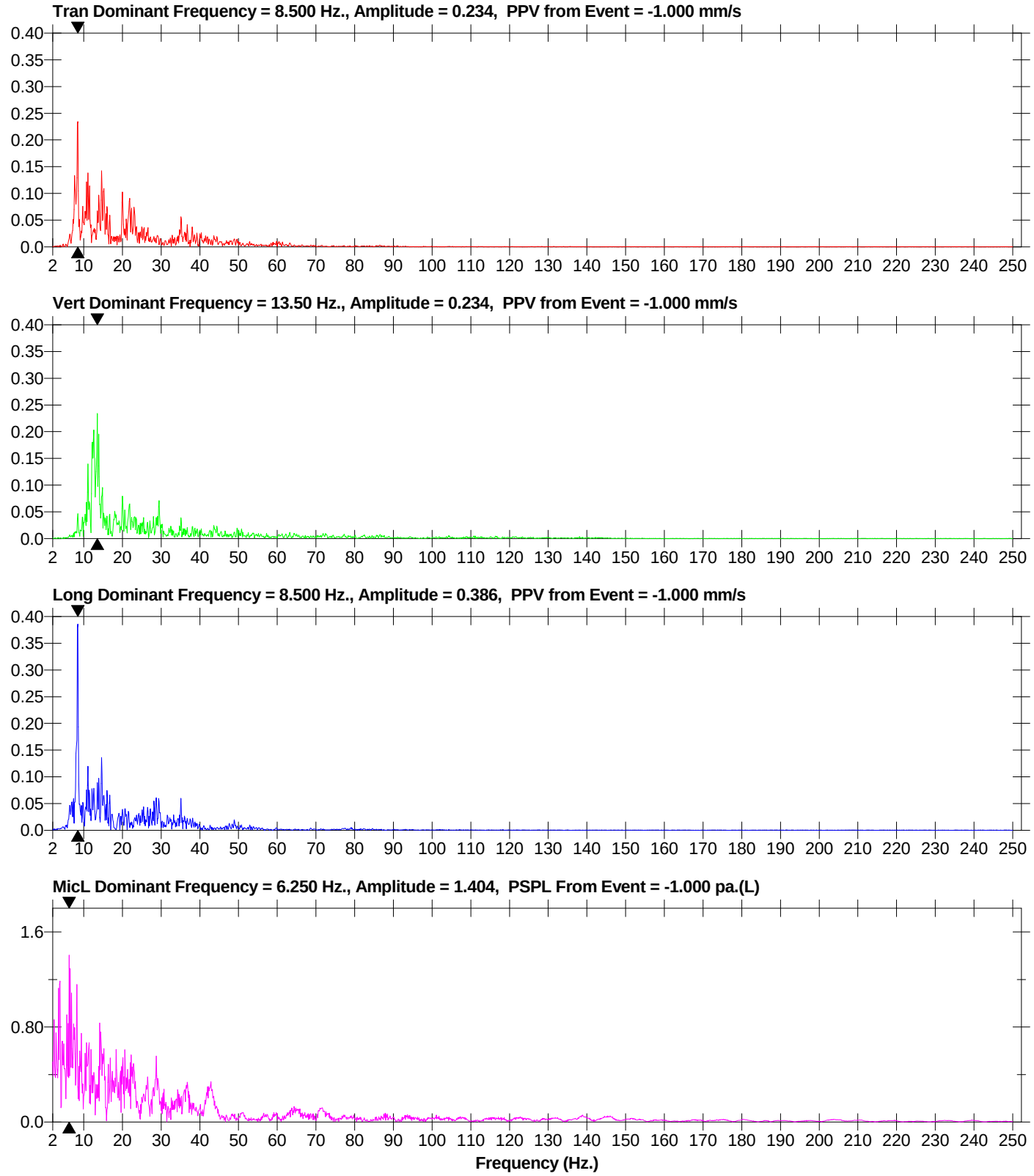
Serial Number	UM12452 V 10-89 Micromate ISEE
Battery Level	3.7 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12452_20200306131643.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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FFT Report

Date/Time	Long at 13:24:10 March 6, 2020
Trigger Source	Geo: 0.500 mm/s
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps
Job Number:	1

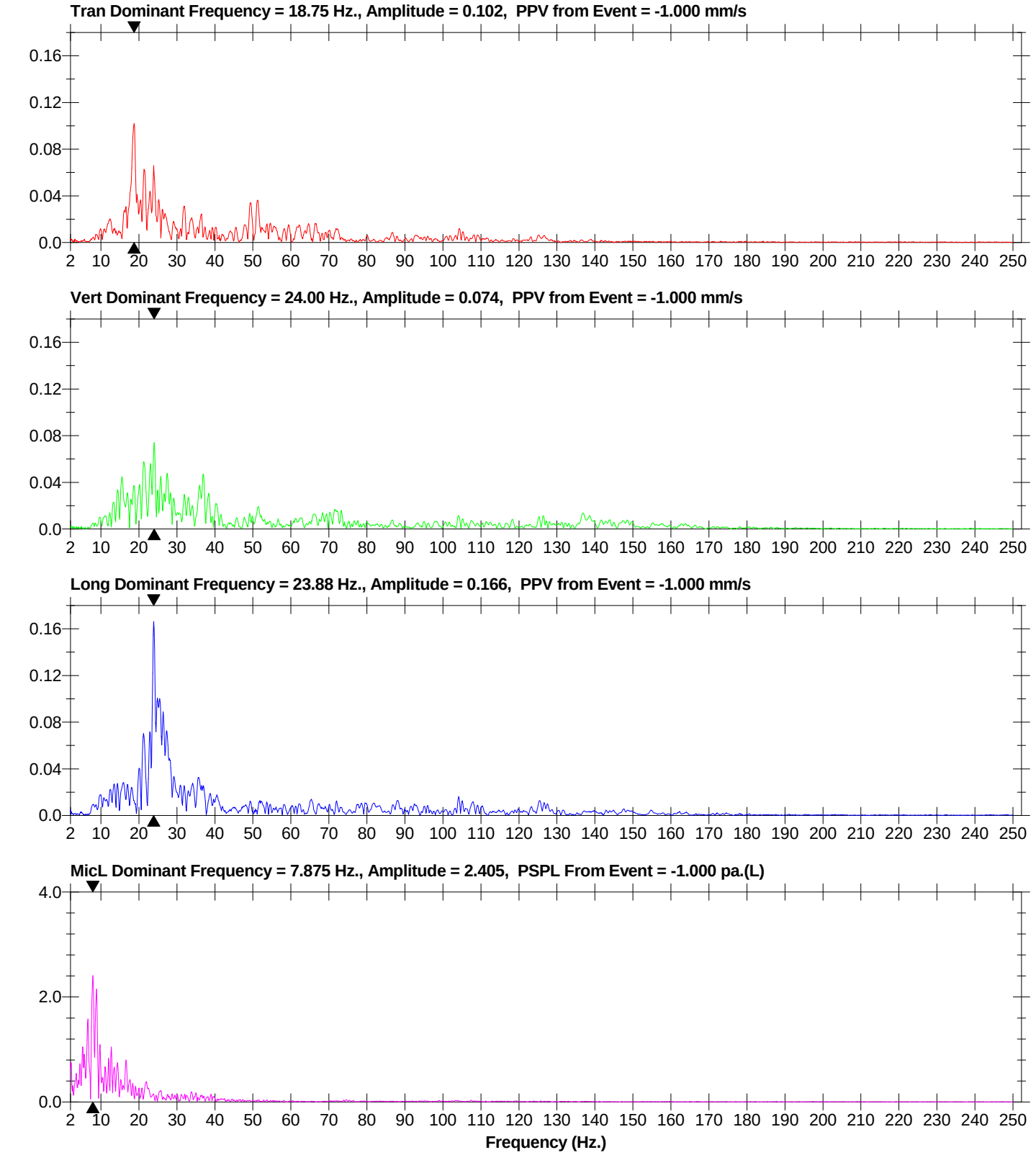
Serial Number	BE18062 V 10.72-1.1 Minimate Blaster
Battery Level	6.0 Volts
Unit Calibration	March 29, 2019 by UES, New Delhi
File Name	T062ICXM.KA0

Notes

Location: Pur Village
Client: District collector Bhilwara, Rajasthan
User Name: CIMFR
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration & Airover Pressure in Domestic Houses inPur Village, Bhilwara, Rajasthan.



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FFT Report

Date/Time	Vert at 13:24:20 March 6, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

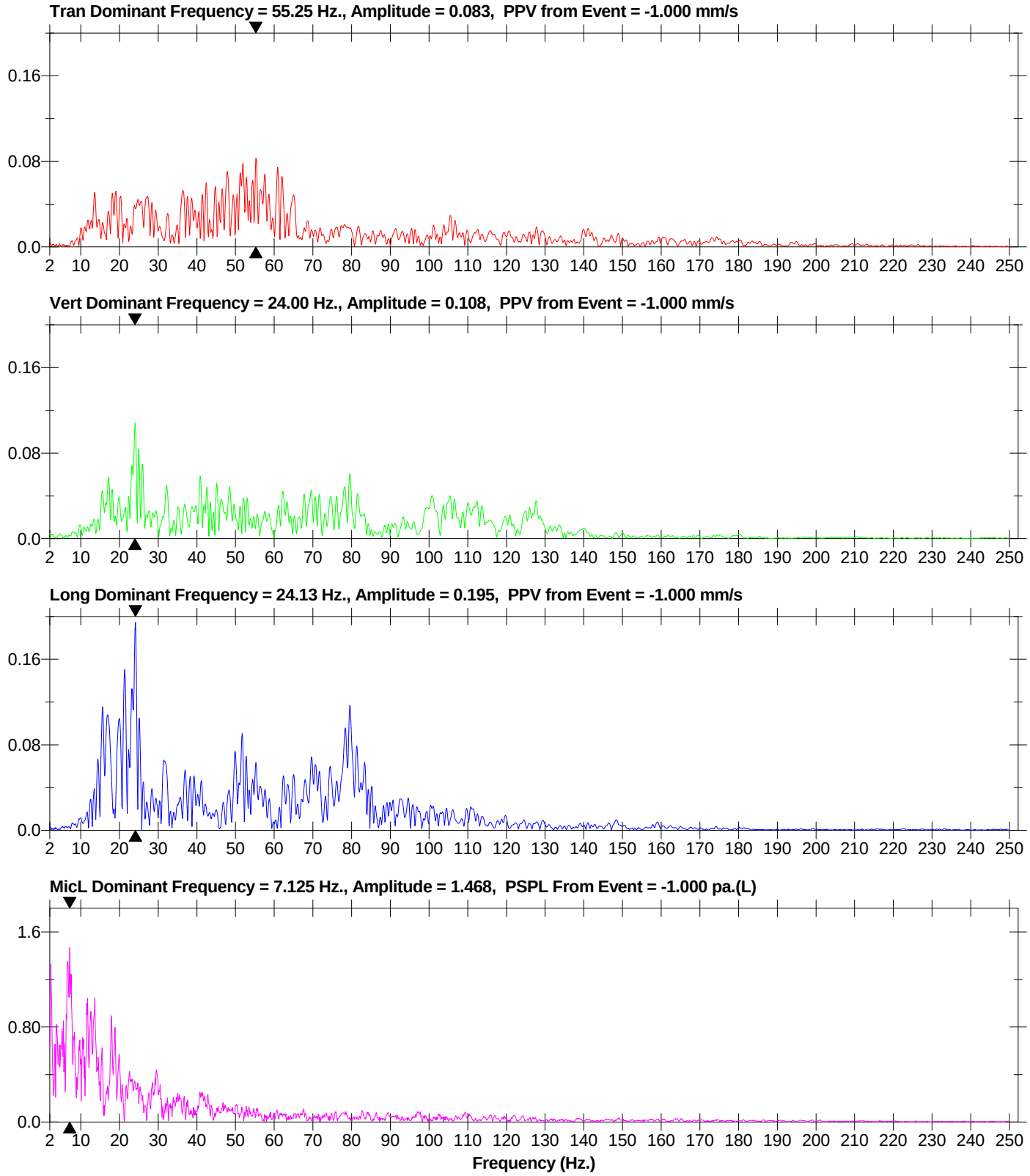
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Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200306132420.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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FFT Report

Date/Time	Tran at 13:24:21 March 6, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

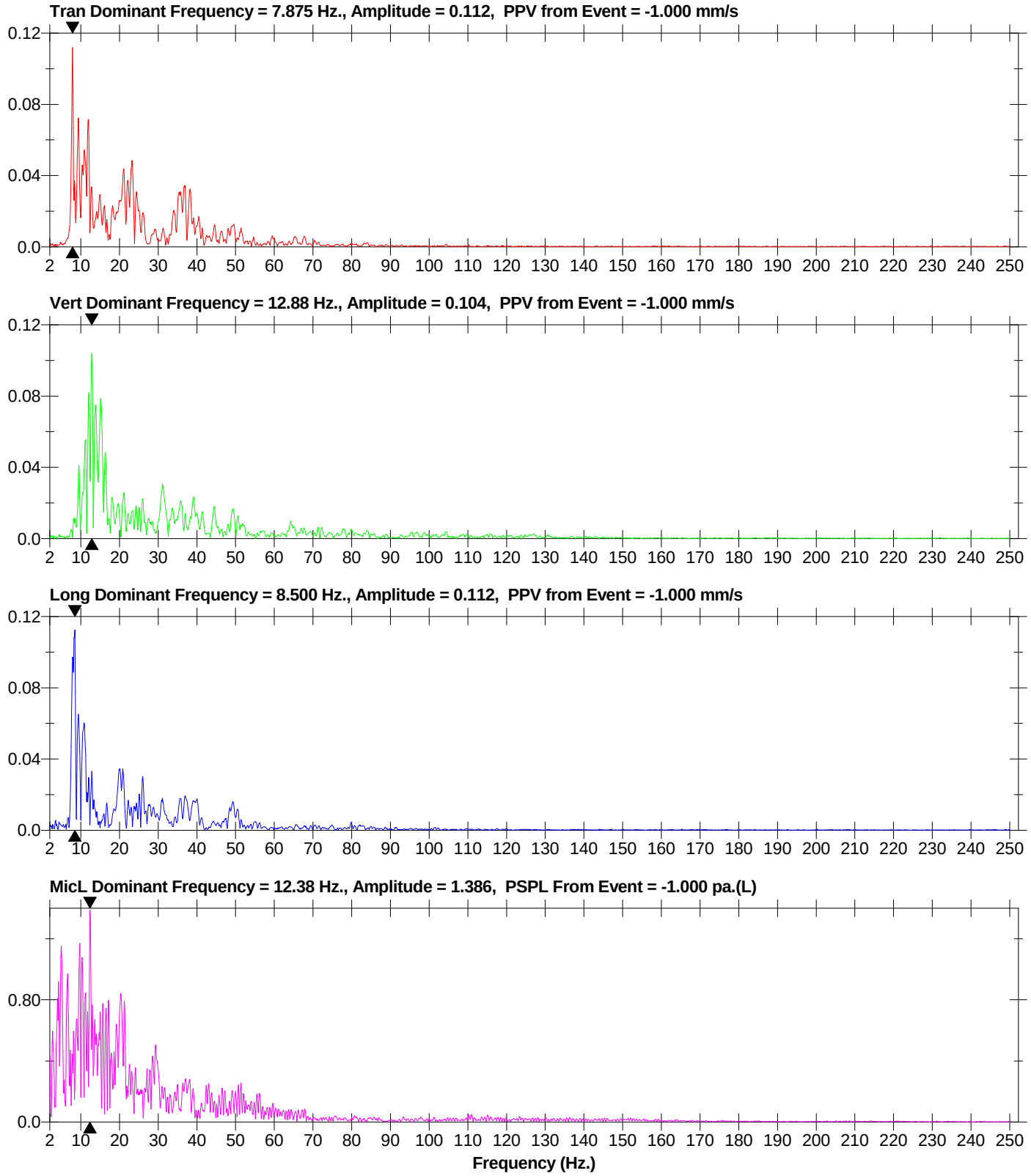
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Battery Level	3.7 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12452_20200306132421.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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ANNEXURE – III

(DGMS Approval Letter)

भारत सरकार / Govt.of India
श्रम एवं रोजगार मंत्रालय / Ministry of Labour & Employment
खान सुरक्षा महानिदेशालय / Directorate General of Mines Safety
अजमेर क्षेत्र / Ajmer Region
*****

ई मेल : dgmsajr@gmail.com
फैक्स 0145- 2425782, दूरभाष : 0145-2425537 (का)
आनासागर लिंक रोड, अजमेर- 305 001

पत्र संख्या: AJR/DMS/Perm -164(1-B)(a)/2018/ 5413 दिनांक 04/10/2018

प्रेषक:
खान सुरक्षा निदेशक
अजमेर क्षेत्र

रजिस्टर्ड
(REGISTERED)

सेवा में
अभिकर्ता
डेडवास आयरन ओर एवं एसोसिएटेड खान (एम.एल. स. 631 / 05)
मेसर्स जिन्दल सॉ लिमिटेड
खसरा संख्या 9697 / 6711, निकट तिरंगा हिल्स
गॉव पुर, तहसील एवं जिला भीलवाड़ा, राजस्थान

विषयः मेसर्स जिन्दल सॉ लिमिटेड की डेडवास आयरन ओर व एसोसिएटेड मिनरल खदान के आसपास स्थित स्थायी ढांचों के 300 मीटर के भीतर परंतु 100 मीटर के बाहर एक समय में दो किलोग्राम से अधिक मात्रा में विस्फोट के साथ ब्लास्टिंग की धातु खान विनियम 1961 के विनियम 164 (1-B) (a) के अंतर्गत अनुमति का नवीनीकरण।

महोदय

कृपया उल्लिखित विषय पर आपके पत्र संख्या JSL/BHL/MINES/2018-19/0062, dated 20.08.2018 और इसके साथ संलग्न सरफेस प्लान सं Dhed/Sur/2018A/Permission dated 20.08.2018 को संदर्भित करें।

The matter has since been considered in the light of what has been stated in your application under reference and shown on the accompanying plans.

The matter has since been considered in the light of what has been stated in your application under reference and plans and sections enclosed therewith. By virtue of the powers conferred on the Chief Inspector of Mines (also designated as Director-General of Mines Safety) under Regulation 164(1-B) of the Metalliferous Mines Regulations, 1961 and by virtue of the authorization granted to me by the Chief Inspector of Mines (also designated as Director General of Mines Safety) under Section 6(1) of the Mines Act,1952, I hereby renew the permission granted earlier by this directorate's L.N. AJR/DMS/164(1-B)(a)/2015 ,dated 04.03.2015 to conduct controlled deep hole blasting with more than two kilograms of explosive at one time to extract Iron ore within 300 m but beyond 100 m of surface structures not belonging to owner under Regulation 164(1-B) (a)of the Metalliferous Mines Regulations, 1961 at Dhedwas Iron Stone Mine of M/s Jindal Saw Ltd. situated near village Pur, Tehsil and district Bhilwara as indicated on Plan No. Dhed/Sur/2018A/Permission dated 20.08.2018 enclosed with your application under reference and subject to the following conditions being strictly complied with:

1.0 No blasting operations shall be conducted within 100 m of structures/dwellings not belonging to the owner and permanent nature without obtaining a separate permission under Regulation 164(1-B)(a) of the Metalliferous Mines Regulation, 1961.

1.1 The drilling, stemming and blasting operations shall be carried out under direct personal supervision of an Assistant Manager holder of Ist Class Certificate of Competency with specially trained supervisors and workers.

1.2 The Manager shall fix the time of blasting and the same shall be circulated to all concerned, including to the habitants of structures and dwellings, not belonging to the management. The timings shall also be conspicuously posted on the mine's notice board. Blasting shall be done only daylight hours.

2.0 Following blast design parameters, as recommended by the scientific institute in their report titled "Scientific studies and Establishment of Controlled Blasting Parameters For Dhedwas Iron, Copper and Associated minerals Mine (M.L No 631/05)", shall be strictly adhered to whilst conducting deep hole blasting, which are reproduced below:

Bench height (m)	Drill hole Dia(mm)	Max. No. of holes in a round	Pattern of holes(m)		
			Depth (m)	Spacing (m)	Burden (m)
8-10	115	200	9-10	3.0-3.5	2.5-3.0

2.1 (i) No drilling shall be commenced in an area where shots have been fired, until the shot-firer has made a thorough examination at all places, including remaining butts of old deep holes, for unexploded charges that the drill may strike.

(ii) The position of every deep hole to be drilled shall be distinctly marked so as to be readily seen by the drillers.

(iii) No drill or bore rod or pick shall be inserted in the butts of old deep holes even if an examination under Clause (i) has failed to reveal presence of explosives.

2.2 (i) Drilling operators shall not be carried out simultaneously on two benches at places directly on above the other.

(ii) Drilling and charging of deep holes shall not be carried out in the same area at the same time.

3.1 (a)The peak particlevelocity of blast-induced ground vibrations, at dwellings/structures falling within 300m of the place of blasting and not belonging to the management, shall not exceed 10mm/sec

(b) To limit the ppv to the thresh-hold limit of 5mm/sec in case of Tiranga Block, 10mm/sec in case of Dhulkhera Block (with frequency 8-25 Hz for both the blocks) and 15mm/sec (with frequency >25 Hz) for Suras Block, charge/delay as recommended by scientific institute in their report (for 115mm dia deep-holes), shall be strictly adhered to. The safe charges vis-à-vis distance of structures from site of blasting are reproduced below:

Tiranga Block

Distance (m)	100	150	200	250	300
Max. Charge per delay (kg.)	16.6	37.3	66.4	104	149

Dhulkhera Block

Distance (m)	100	150	200	250	300
Max. Charge per delay (kg.)	44.8	101	179	280	403

Suras Block

Distance (m)	100	150	200	250	300
Max. Charge per delay (kg.)	77.6	175	310	485	698

3.2 Only non-electric down-the-hole detonators of 450 ms in conjunction with detonating fuse shall be used for detonation/initiation of explosive column of deep-holes. Trunk line detonators of 17/25 ms delay intervals may be used to provide delay interval between holes in a row. Delay interval between the rows of deep-holes shall be 42 ms, as to comply with the charge restrictions stipulated as above.

3.3 In deep-hole blasting, cartridges of explosives shall be lowered down the hole carefully. The stemming length/length of hole left uncharged shall be measured to ascertain the length of explosive column and ensure that the cartridges of explosives lowered are in close contact and there is no air space. In case the measurements indicate presence of air space in the explosives column, the cartridges may be gently pushed down by a wooden rod only if slurry explosive is being used.

4.0 A safe code of blasting practice shall be framed by the manager and shall be circulated to all concerned for its strict compliance.

5.0 Shots shall not be fired beyond day light hours until adequate artificial light is provided. All holes charged on any one day shall be fired on the same day. Sleeping of holes shall not be permitted till the time specific permission in this regard is obtained.

5.1 During the approach and progress of an electric storm, the following precautions shall be taken:

(i) No explosive, particularly detonators shall be handled.
(ii) If charging operations have begun, the work shall be discontinued until the storm has passed.
(iii) If the blast is to be fired electrically all exposed wires shall be coiled up and if possible placed in the mouth of the holes, or kept covered by something other than a metal plate.
(iv) All wires shall be removed from contact with the steel rails of a haulage track so as to prevent the charge being exploded prematurely by a local strike of the lightening.

6.0 The Manager of the mine shall ensure that recommendations made by the scientific agency in respect of the controlled blasting are strictly followed.

7.0 To control flying fragments resulting out of blasting from projecting beyond a distance of 10 meters from the place of firing, following precautions shall be taken.

a) No shot hole shall be fired in crushed, broken or fractured ground/strata.
b) Blasting shall be done against a free face only. Blasted material shall be cleared off before commencement of drilling operations for succeeding round.
c) Top stemming column shall not be less than the burden.
d) Only such stemming material that is free from pebbles and stone chips shall be used. Moist sand shall be used for stemming of deep-holes.
e) The area falling within a distance of 100 cm from the collar of each blast hole shall be cleaned of loose stones, drill cuttings, debris and other loose material.
f) Variation in inclination of holes shall be within 5 degrees to avoid variation in crest and toe burden.
g) Shot holes shall be adequately and effectively muffled to ensure that no flying fragments projects beyond a distance of 10.0 m from the place of blasting. Muffling of shot holes shall be done with conveyor belt/wire netting having not more than 25 mm mesh overlain by adequate number of sand bags each not less than 40 Kg by weight.
h) Sand shall be used as stemming material and shall be tapped hard into the blast hole to prevent blown out of explosive from the hole.

8.0 Monitoring of peak particle velocity and of the dominant frequency shall be done with each round of deep-hole shots fired.

8.1 A proper record of blast parameters like spacing & burden of holes, hole depth, number of holes fired in the round, charge/hole, charge/delay, and charge/round, length of explosive column(s) & stemming column length(s), initiation pattern (with proper sketches wherever called for), manner of muffling, results of ground vibration observed (ppv, frequency & air over pressure) and distance upto which flying fragments resulting out of blasting projected, shall also be kept maintained in a bound paged book with each round of deep-hole shots fired. The records shall be duly signed by the Manager of the mine.

8.2 In case, with any of the rounds fired, the peak particle velocity of ground vibrations resulting out of blasting is observed to be more than 5mm/sec in case of Tiranga Block, 10mm/sec in case of Dhulkhera Block (with frequency 8-25 Hz) and 15mm/sec (with frequency >25 Hz) for Suras Block at dwellings/structures not belonging to the management, or the flying fragments project to a distance beyond 10m from the place of firing, blasting operations shall be discontinued and this Directorate shall informed immediately.The blasting operations connected with this permission shall not be resumed unless express permission in writing is accorded by this Directorate afresh.

9.0 (i) Precautions with regards to taking shelter etc., as laid down in Regulation 164 of the Metalliferous Mines Regulations, 1961 shall be complied with.

(ii) Notwithstanding what is contained under Regulation 164 of the Metalliferous Mines Regulations, 1961, no person other than shot firer and his assistants, if any, shall be permitted to remain within a radius of 20.0 m or within 60.0 on the same bench where charging of holes with explosives is being carried out.

9.1 (a) Before deep-holes are charged, stemmed and fired, sufficient warning by siren or other suitable means shall be given to warn persons within a radius of 500m, including to the habitants of structures and dwellings, not belonging to the owner.

(b)It shall be ensured that no person remains in the dwellings/structures falling within a radial distance of 500m of the place of firing at the time of blasting, unless the dwelling/structure provides adequate/proper shelter from flying fragments resulting out of blasting. Guards shall be posted to ensure that no person inadvertently enters the danger zone, and to ensure that all persons within the danger zone have taken proper shelter.

(c)Subsequent to blast, at least after 15.0 minutes, all clear signal shall be given. Hooters/siren or other efficient mechanism shall be installed for this purpose.

9.2 Guards shall be posted, one in either direction at the two extreme points of Metalled road which fall within the danger zone to warn passers-by and stop vehicular traffic, if any, and intimate the blaster about clearance of traffic by an efficient system of communication.

10.0 Owners of structures and dwellings and land, not belonging to the management and habitants/occupants of such dwellings/buildings shall be indemnified against damage to property/ injury to persons, if any, arising out of mining operations.

11.0 In the event of any change in the circumstances connected with this permission which is likely to endanger the life of workmen employed in the mine or endanger the mine, the mining operations for which this permission has been granted shall be stopped forthwith and intimation thereof shall be sent to this Directorate. The said mining operation shall not be resumed without express and fresh permission in writing from this Directorate.

12.0 If at any time any of the conditions subject to which this permission has been granted is violated or not complied with, this permission shall be deemed to have been revoked with immediate effect.

13.0 This permission may be amended or withdrawn at any time if considered necessary in the interest of safety and is being issued under Regulation 164(1F) of the Metalliferous Mines Regulations, 1961, only without prejudice to any other provisions of law which may be or may become applicable at any time.

14.0 Unless renewed, this relaxation shall be valid for a period of 3(three) years from the date of issue of this letter.

भवदीय

03/10/18

(अरविन्द कुमार)
खान सुरक्षा निदेशक
अजमेर क्षेत्र, अजमेर

NOTE

Report

on

Studies to Investigate the Reasons for Cracks Development in Buildings of Pur Village, Bhilwara, Rajasthan



Submitted to:

Office of District Collector and District Magistrate,
Bhilawara, Rajasthan State Govt.

CSIR-Central Building Research Institute
Roorkee – 247667 Uttarakhand, INDIA

January 2021

Final Report

on

Studies to Investigate the Reasons for Cracks Development in Buildings of Pur Village, Bhilwara, Rajasthan

Team of Consultants:

Dr. S. Sarkar, Chief Scientist
Prof. S. K. Singh, Sr. Pr. Scientist
Er. Manojit Samanta, Sr. Scientist
Er Md. Reyazur Rahman, Scientist
Er. Ajay Dwivedi, Sr. Technical Officer
Er. Rakesh Paswan, Scientist
Er. Koushik Pandit, Scientist
Er. Ashish Barthwal, Project Assistant
Mr Neeraj, Research Scholar
Mr Suvam Das, Research Scholar



CSIR-Central Building Research Institute
Roorkee – 247 667 Uttarakhand, INDIA

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75 Years of
CSIR Touching Lives

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25 Years of CSIR Touching Lives

Studies to Investigate the Reasons for Cracks Development in Buildings of Pur Village, Bhilwara, Rajasthan

1. Introduction

Pur village is situated very near to Bhilwara town of Rajasthan around 10.8 km towards South West direction. Bhilwara is a small town in the Mewar region of Rajasthan. Clusters of houses in the Pur village are continuously developing cracks in the buildings. The safety of houses of Pur village are concerning issues. Accordingly, District Administration, Bhilwara, Rajsthan entrusted CSIR-Central Building Research Institute (CBRI), Roorkee to investigate the reasons of cracks development in buildings of Pur village, Bhilwara, Rajasthan. The study mainly involves geotechnical investigations and damage assessment in the buildings based on crack monitoring. The scope of the study was as follows:

- Reconnaissance survey of the Pur village, Bhilwara
- Identification of buildings developing cracks
- Drilling of bore holes at selected locations
- Study of sub-surface geological strata
- Laboratory testing of soil and rock samples obtained from the bore holes
- Evaluation of geotechnical properties of soil and rocks
- Monitoring of cracks in selected houses
- Data analysis of crack monitoring to determine the nature of cracks
- Demarcation of houses having severe damage potential
- Possible causes for cracks development in the houses

A reconnaissance survey of the Pur village was conducted to observe the nature of cracks developed in the houses. The cracks were observed mostly in stone masonry buildings. The both types of cracks were observed i.e. non-structural and structural. Fig. 1 to Fig. 3 shows the typically damages in the buildings in the region categorized as severely damaged, moderately damaged and minor damaged structures. About 80 houses were randomly selected for crack monitoring. The damage pattern of buildings were dependant of the type of building structure. The damage patterns in non-engineered buildings (typically stone masonry) were found moderate to severe whereas the damages in reinforced moment-resisting concrete frame structure were negligible.

A detailed geotechnical investigation was carried out to evaluate the soil condition of the village. During investigation, a few bore holes were drilled in the village to investigate the subsurface strata and the geological formation. Laboratory testing was performed on the drilled samples to determine the geotechnical parameters of soil and rocks. Based on the investigation, possible causes for appearance of cracks in the buildings are pointed out.

2. Study Area

Pur village is situated adjacent to Bhilwara town around 10.8 km towards southwest direction. Bhilwara is a small town in the Mewar region of Rajasthan. It is located almost in the centre of the Rajasthan state covering an area of 10,455 km^2. It is bounded by latitudes 25°01' to 25°58' N and longitudes 74°01' to 75°28' E and it is surrounded by other districts, on the north by Ajmer district, on the east by Bundi district, on the south by Chittaurgarh district, and on the west by Rajsamand district. The average elevation of Bhilwara district is 421 metres (1381 feet). It is an elevated plateau. The Bhilwara district is intersected by the Aravali ranges at several places. There is a range of hills in the North-East corner of the district which extends right up to Jahajpur town. These ranges are predominant in the south east in Mandalgarh tehsil and in the north east in Jahajpur tehsil. The soil in this region varies from sandy loam to heavy loams.

Mean annual rainfall (1971-2012) of the district is 635.1 mm whereas normal rainfall (1901-70) is lower than average rainfall and placed at 603.3. Almost 95% of the total annual rainfall is received during the southwest monsoon, which enters the district in the last week of June and withdraws in the middle of September. Probability of average annual rainfall exceeding 900 mm is only 10%. However, there is 90% probability that the average rainfall will be more than 400 mm. The probability of occurrence of mean annual rainfall is 45%. Drought analysis based on agriculture criteria indicates that the district is prone to mild and normal types of droughts. Occurrence of severe and very severe types of droughts is very rare. January is the coldest month with mean maximum and minimum temperatures being lowest at 22.20° C and 7.30° C. Temperature in summer month of June reaches up to 46° C. There is a drop in temperature due to onset of monsoon and rises again in the month of September. Atmosphere is generally dry except during the monsoon period. The humidity is maximum in August with mean daily relative humidity at 80%. The annual potential evapo-transpiration in the district is 1495 mm and is the highest in the month of May (228 mm) (Ministry of "Environment, Forest and Climate Change" Dated 15th January, 2016).



Fig. 1. Severely damaged buildings

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Fig. 2. Moderately damaged buildings

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Fig. 3. Minor damaged buildings

PART I: GEOTECHNICAL INVESTIGATIONS

1. Geology of the area

Bhilwara district comes under the Survey of India toposheet no. 45K/11. Geologically the area is covered by Banded Iron Formation (BIF) and associated litho-units i.e. part of Pur-Banera Group of the Bhilwara Supergroup of Archean to Lower Proterozoic in age. The major rock types discernible in the area are banded iron formation including Banded Hematite Quartzite (BHQ) and Banded Magnetite Quartzite (BMQ). Other litho members of the area are conglomerate, garnetiferous mica-schist, calc-schist, amphibolite, calc-gneiss, calc-silicate marble and carbonate rocks with associated sulphide mineralization. Pur-Banera Group rocks un-conformably overlie the rocks of the Mangalwar Complex (Suwana Formation and Potla Formation). The Pur-Banera Group has been subdivided into five formations, Pur, Pansal, Rewara, Tiranga, and Samodi (Gupta, 1934). The investigated Pur village belongs to Pur formation. A regional geological map of the Bhilwara district is shown in the Figure 1.

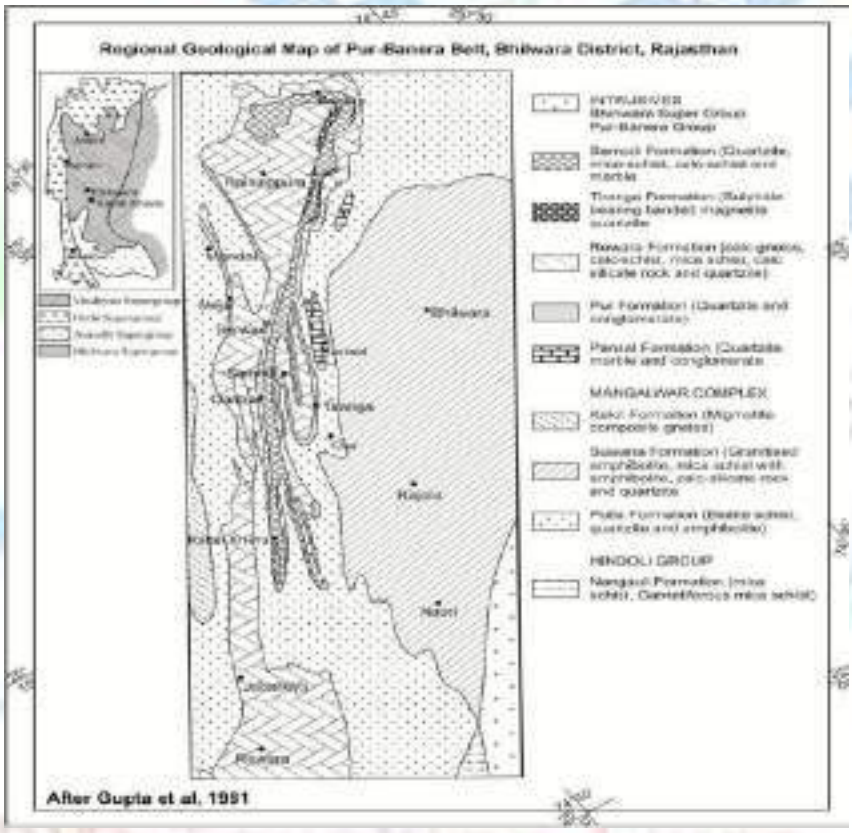


Fig.1 Geological map of the Bhilwara District (after GSI)

Table. 1 Geological stratigraphy of Bhilwara district

Era/ Peiod	Gelogical Cycle	Group	Lithology
Quarternery	-	-	Alluvium, blown sand
Upper Proterozie	Vindhyan Supergroup	Bhander Group	Shale, saadstone and limestone
PROTHROZOIC	Delhi Super Group	Kumbhalgarh Group	Calc-Schist, gneisses, marble, garnet-boitite schust, migmatites
		Gogunda Group	Quartzite, biotite schist, Calcschist, hornblende schist
	Aravalli Super Group	Dovda Group	Quartzite, dolomite marble, dolomite, amphibolites, cals-sillicates rocks, biotite schist, quartz-biotite gneiss and migmatites
	Igneous activity/Intrusives		Dolerite dykes and sills
ARCHEAN	Bhilwara Supergroup	Ranthambor Group	quartzite, shales and slates
		Igneous activity/ Intrusives	Berach granite and gneisses Jahajpur granite
		Pur-Banera Group	Calc-schist, gneisses, banded magnetite-quamtzite, dolomitic marble, quartzite, garnet-mica schist and amphibolites
		Jahajpur Group	Dolomite, Phyllite, Quartzite
		Hindoli Group	Shales, slates, phyllites, metagrawacke, limestone, dolomite, quartzite, mica shist, meta basics, volcanics.
		Mangalwar Complex	Migmatites, gneisses, mica schist, garnetiferous mica schist, para-amphibolites silicified mica schist.
		Sandmata Complex	Para-gneisses, migmatites, pyroxene-granulites, amphibolites, biotite-ultramatic rocks.
		Igneous activity/ Intrusive	Acidic and mafic bodies

1.1 Pur Formation

The Pur Formation is the beginning of Proterozoic age and it unconformable overlies the Potla Formation of the Mangalwar Complex and the formation is overlain by the Pansal Formation of

the Bhilwara Supergroup of Lower Proterozoic age. The iron ore (hematite and magnetite) bands are exposed between the Pur & Samodi Formation. The Pur Formation of the Bhilwara Supergroup is situated within the basement of the Pur-Banera Group of Bhilwara Supergroup. The Pur Formation extends from 5 km north-east direction of village Jasma in southern direction to vlillage Mandal along western limb while village Rasmi in the eastern direction to Banera, along the eastern limb. The name of this formation is after the Pur-village in the district and it comprises mainly of quartzite and conglomerate rocks. The Pur Formation mainly comprises of massive quartzite rock and thinly foliated schist. It shows gradational joining with the overlying calcareous metasedimentary rocks. The conglomerate bands are seen in the south-east direction of the study area and the ferruginous quartzite belt is exposed in the SW direction to the eastern direction of the study area near Pur village. The Pur pebbles are comprised of the veins of quartz & the beds of quartzite rock and are ellipsoidal of many sizes; the pebbles are very overstretched and deformed (Shrivastava, 1970) as shown in Fig. 2. Pebbles are set in a fine-grained matrix which consists of fine size sand particles and the pebbles are cemented by silica content & iron oxides (hematite and magnetite). The quartzite rock is composed essentially of the quartz with submissive amount of mica mineral, iron oxides and feldspars.

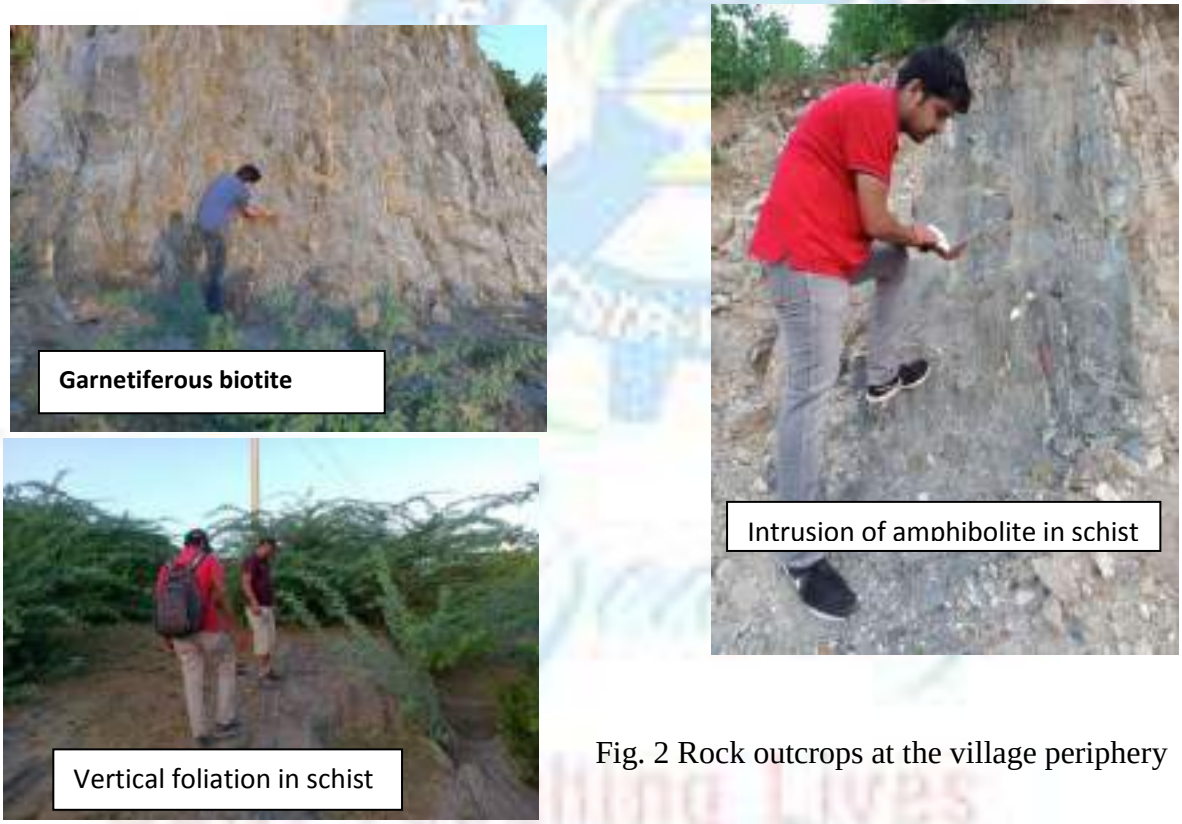


Fig. 2 Rock outcrops at the village periphery

2. Geotechnical Investigations

Geotechnical investigation was carried out by drilling bore holes at selected locations in the village as shown in Fig. 3 followed by laboratory investigation of soil and rock samples obtained from the drill holes. Four bore holes were drilled in different locations in the village. The sites were selected to know the sub-surface lithology of the surrounding region and also the central part of the village. Bore holes 1 and 4 are drilled at the periphery of the village while Bore holes 2 and 3 are drilled at the central part of the village where maximum damages found in the houses. These locations are:

- BH-1: Kaali Baawdi (12m drilling)
- BH-2: Mosque (12m drilling),
- BH-3: Sri Narayan Temple (16m drilling)
- BH-4: College campus of Pur Village (20m drilling)

The drilling locations are shown on the Google image (Fig.3)



Fig. 3 Borehole locations at the Pur village

2.1 Bore Hole Investigation

Bore Hole 1 (BH-1)

BH-1 was drilled at Kaali Baawdi upto a depth of 12m (Fig.4). The bore hole log is shown in the Fig.5. It was observed that the rock formation started right from the surface. Rock type present here is garnetiferous mica schist. The rocks found from 0 to 1.5m depth are highly weathered and having vertical foliation planes. The Rock Quality Designation (RQD) is varying with depth and reaches to 89.8% upto 7.5m depth. However, between 7.5 to 9.0m slickensides are observed and RQD reduces to 20.33%. The RQD is again observed more than 70% below the depth 9.0m. There are three joint planes observed at deeper depth. The ground water table observed to be at 5.5m. The core samples obtained is shown in the Figure 6.



Fig.4 Location of Bore Hole 1



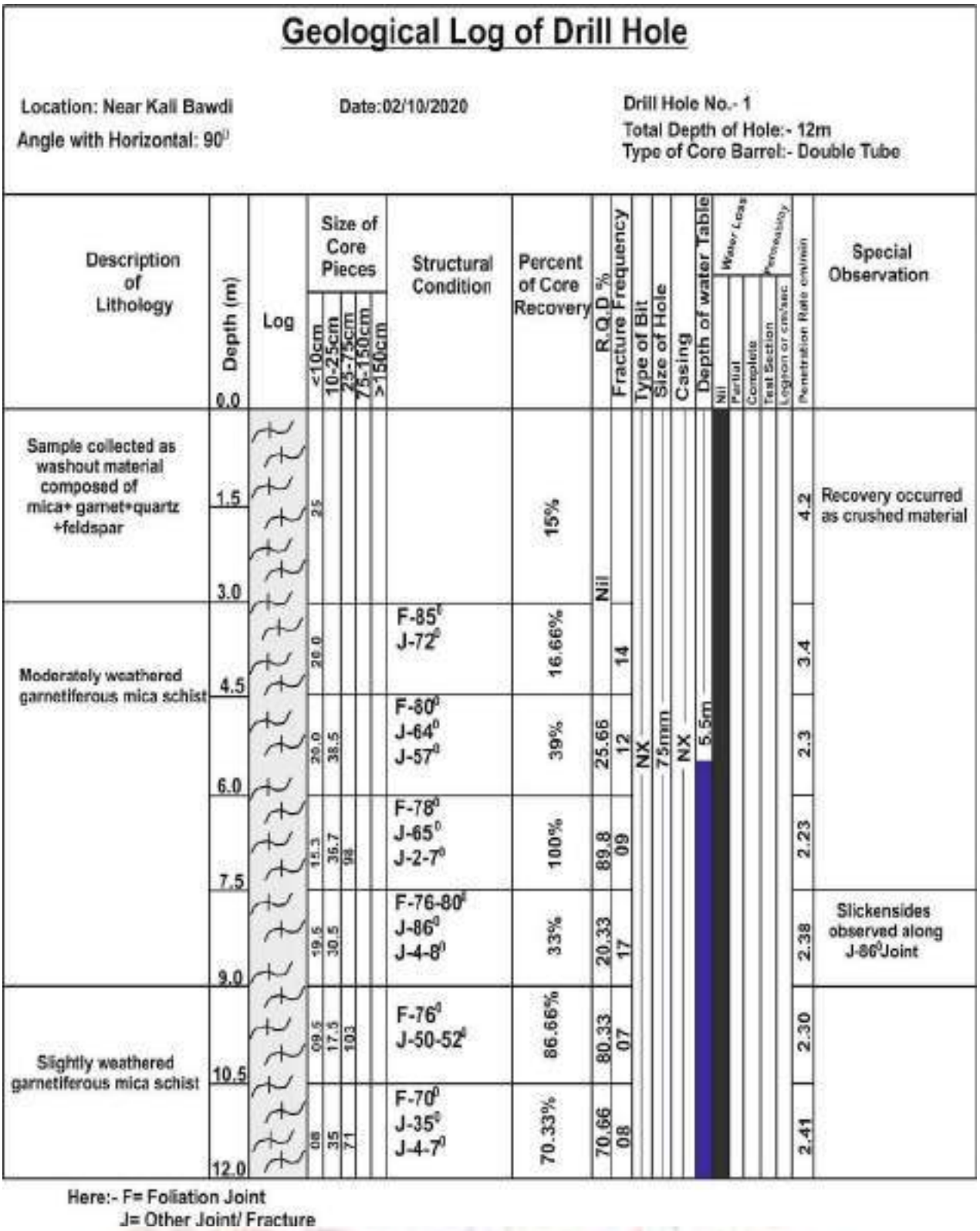


Fig. 5 Geological borehole log of BH-1 at Kaali Bawdi



Fig.6 Photograph of core samples obtained from BH-1

Bore Hole 2 (BH-2)

The BH-2 was drilled at Mosque up to a depth of 12m (Fig. 7). The borelog (Fig.8) shows boulders of greyish colour quartzite and brownish colour sand from 0 to 7.5m depth. There after rock cores started from 7.5m. The rock type present here also is garnetiferous mica schist. Three joint planes were observed from the core samples (Fig. 9). The RQD is very low (< 25%) up to a depth of 7.5 m and reaches on an average upto 38% beyond 7.5 m depth. In general, core recovery (C.R.) is very poor due to presence of boulders and pebbles at initial depth followed by fractured and jointed rocks at deeper depth. Ground water table in this borehole was not encountered up to exploration depth. The SPT test could not be carried out beyond 4.5 m due to refusal was observed. Direct shear tests have been carried out on the soil samples collected at 1.5 m and in between 3 and 4.5 m of depth. Undisturbed samples could not be obtained due to presence of pebbles and boulders in the soil matrix.



Fig.7 Location of Bore Hole 2 at Mosque

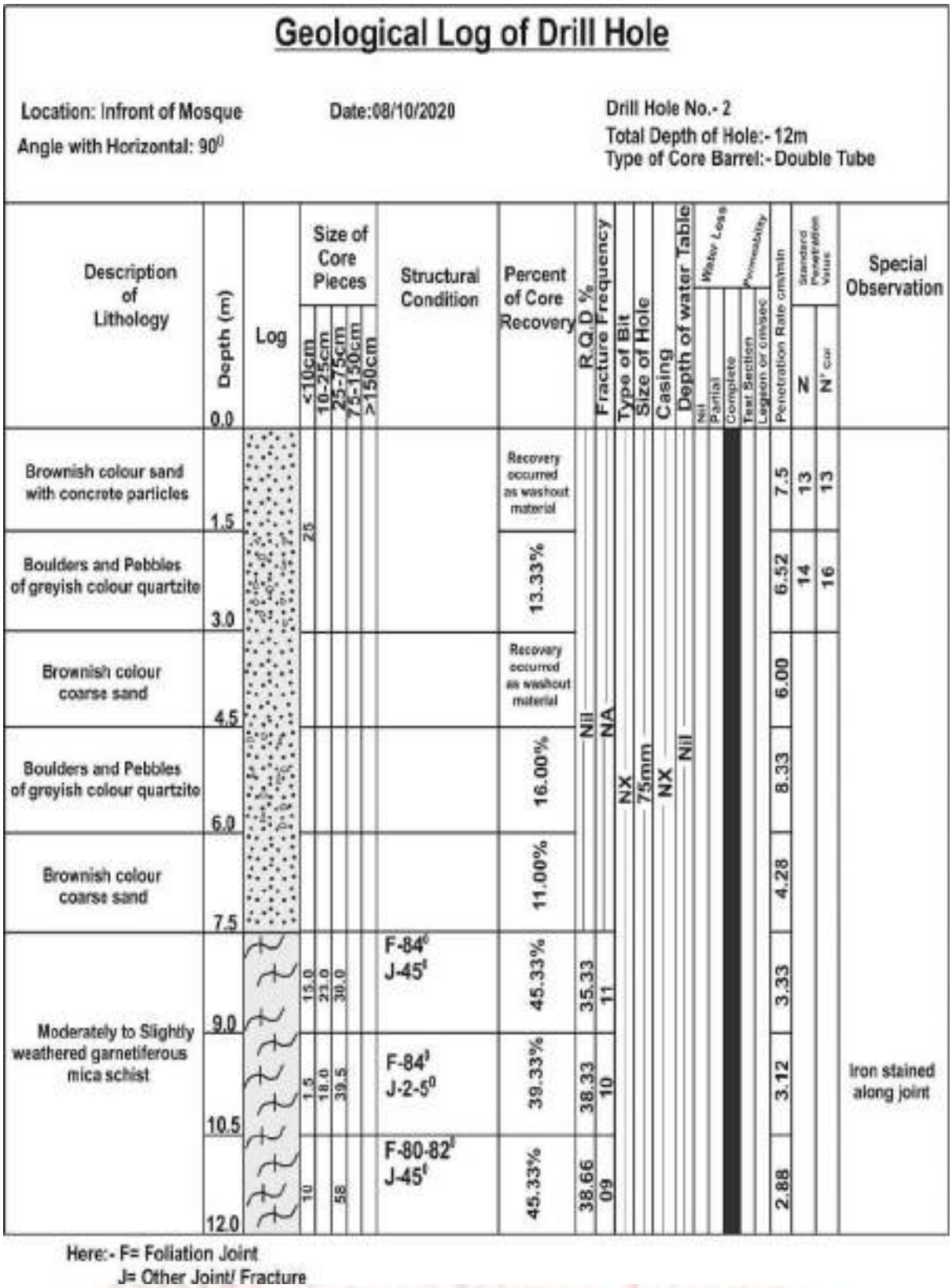


Fig.8 Geological borelog of BH-2 at Mosque

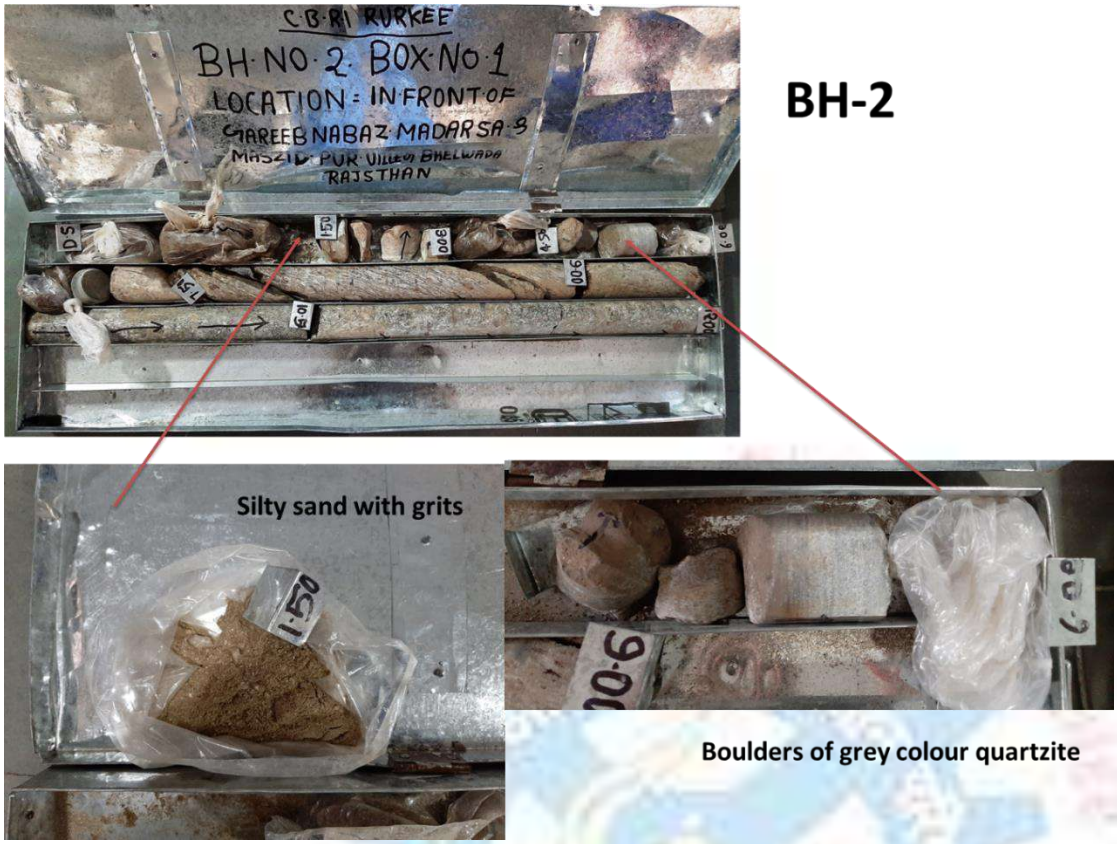


Fig.9 Core photograph of BH-2

Bore Hole 3 (BH-3)

The BH-3 was drilled at Shri Narayan Temple site up to 16m depth (Fig. 10). The borelog is shown in the Fig. 11. Initially, from 0 to 3.0m depth, brownish colour sand was observed and from 3.0m to 12.0m sand mixed with boulders is present. The rock layers start from 13.5m depth. Between 12.0m to 13.5m, clay with pebbles seem was encountered. The rock type is garnetiferous mica schist between 13.5 to 16.0m (Fig. 12) below the quartzite boulders mixed with sand. Ground water table in this borehole was not encountered up to 16m. Iron stained is present along the joints. There are three joint planes observed. RQD varies from 33 to 51.33%. Initially, the core recovery is very poor (ranging from 11 to 24%) up to a depth of 13.5m till the schistose rock layer starts appearing. The direct shear tests were carried out on soil samples collected in between 0 to 3.0 m depth whereas SPT test was terminated at 4.5 m due to refusal as matrix of sand mixed with boulders was observed.



Fig.10 Location of Bore Hole 3 at the temple site

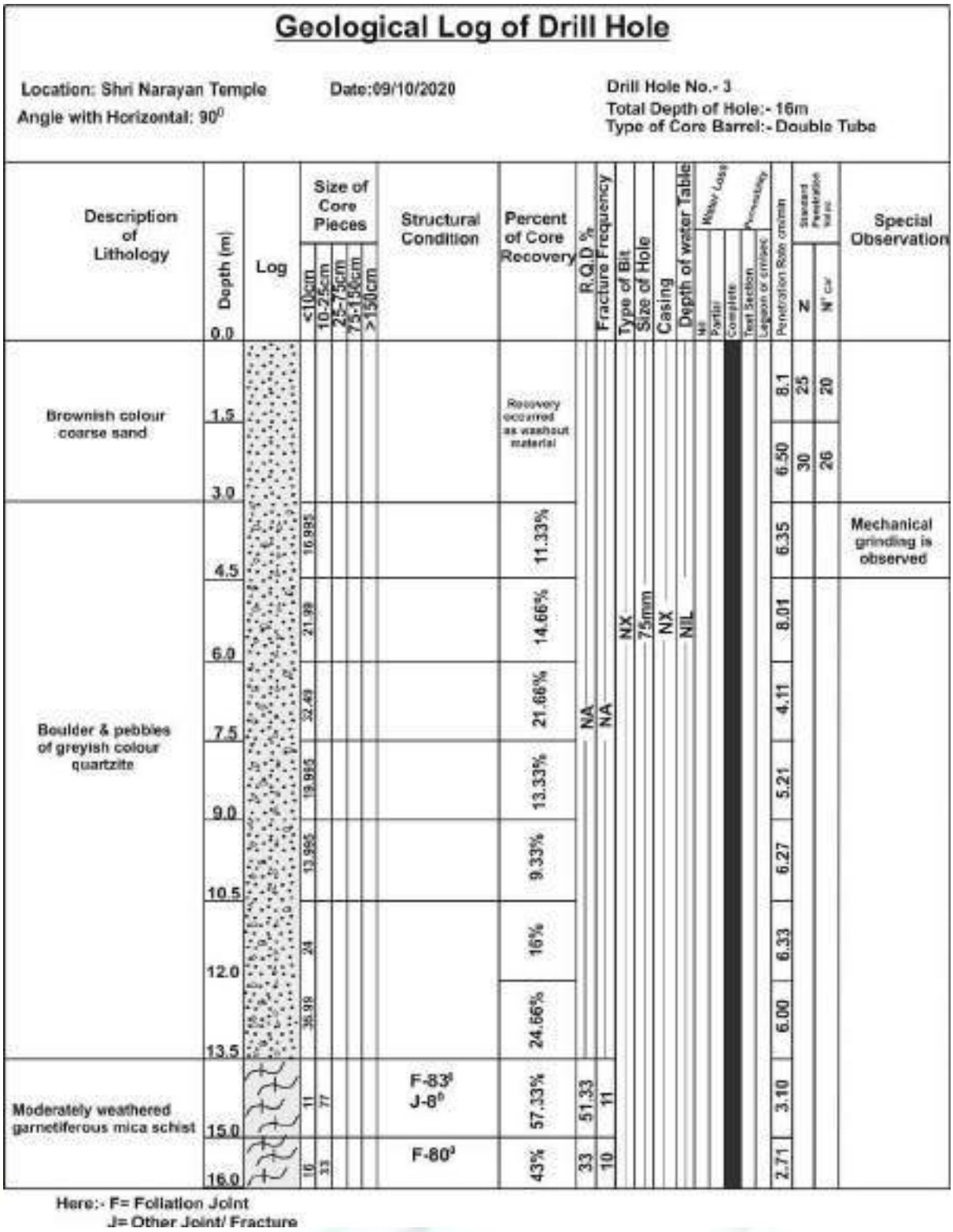


Fig.11 Geological borelog of BH-3 at Shri Narayan Temple



Fig.12 Photographs of cores obtained from BH-3

Bore Hole 4 (BH-4)

The BH-4 was drilled up to a depth of 20m at Inter College campus (Fig. 13). The borelog is shown in the Fig. 14. The initial layer up to 1.5m depth is only concrete and pebbles, filled up zone. The rock layer starts from 1.5m and continues up to 20m. Rock type is garnetiferous mica schist from 1.5 to 20.0m with highly weathered schist having very poor core recovery up to 3.0m depth. After that core recovery is found to be very good and it was 100% at 10.5m depth. The RQD varies from 59.33 to 90%. So, it can be stated here that rock quality is extremely good at this site. The core samples obtained are shown in the Fig. 15. There are three joint planes observed from the drilled cores. Ground water was encountered at 1.0m depth which may be due to the presence of some local water body as water seepage can be seen at the surface also.

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Fig.13 Location of Bore Hole 4 at the Inter College Campus

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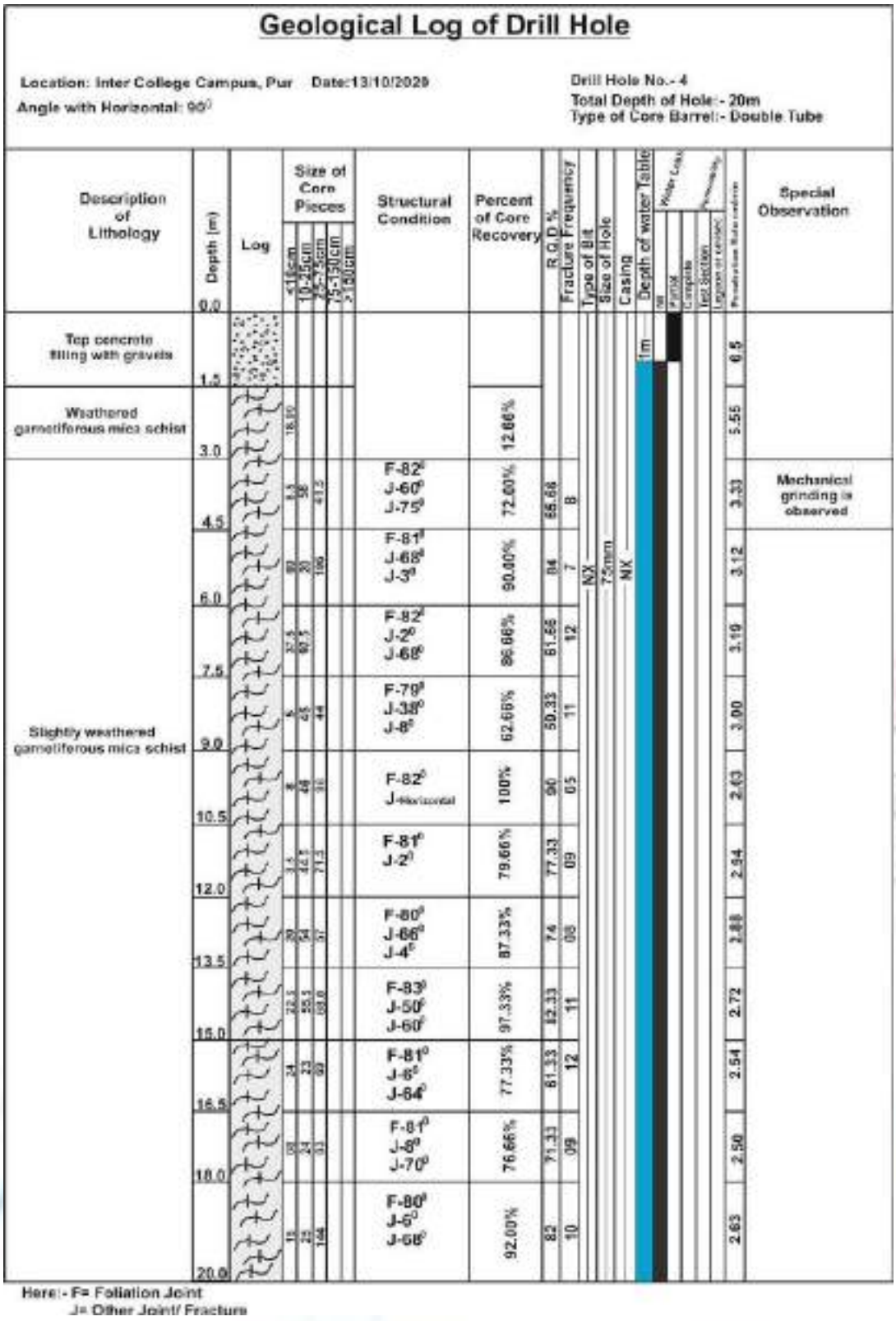


Fig. 14 Geological borelog of BH-4 at Inter College Campus, Pur Village



Fig. 15 Core photograph of BH-4

2.2 LABORATORY STUDIES

The rock and soil samples obtained from the boreholes were tested in the laboratory for determination of salient geotechnical properties. All the laboratory tests were carried out following relevant Indian Standards. All the samples were identified and classified as per relevant Indian Standard. The following laboratory tests were conducted on the selected soil samples collected from the boreholes.

2.2.1 Laboratory Tests of Soil Samples

The soil mixed with pebbles present in the top soil layer were tested in the laboratory. The details of the tests and their results are described below.

Grain Size Analysis

Grain size analysis was performed using sieve analysis. The different classes are shown in the Figure 16. The results of the analysis are shown in the Figures 17 and 18.



Fig. 16 Sieve analysis for grain size

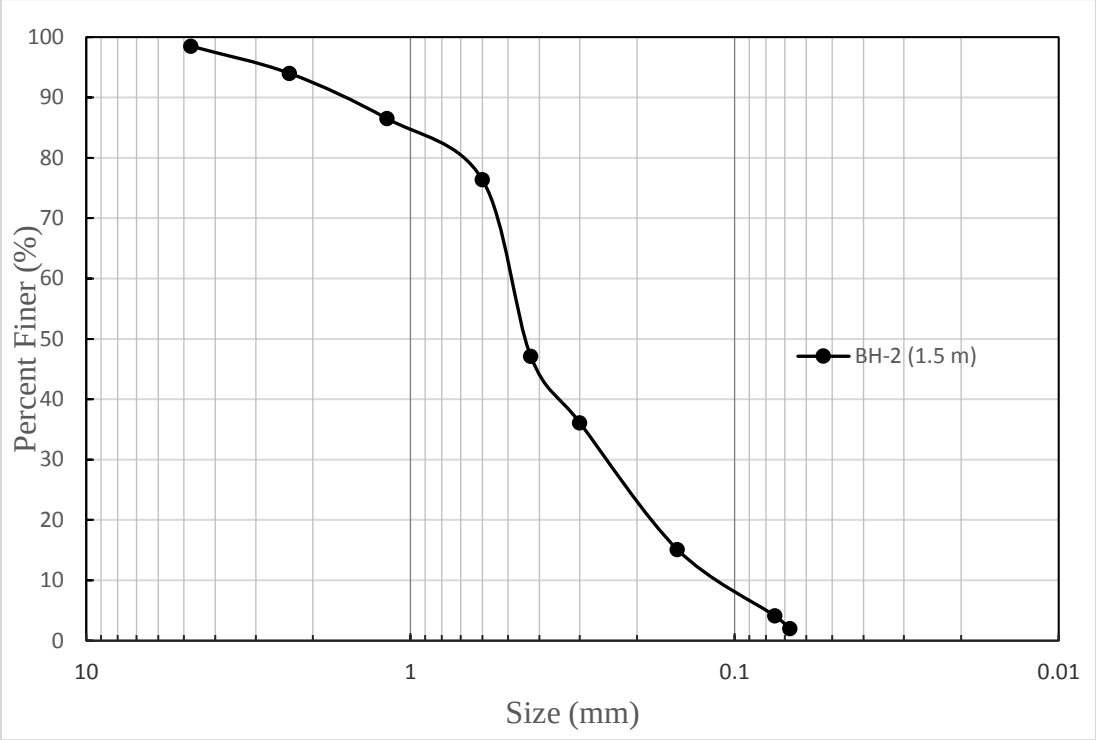


Fig. 17: Grain size distribution curve for BH-2 at depth 1.50 m

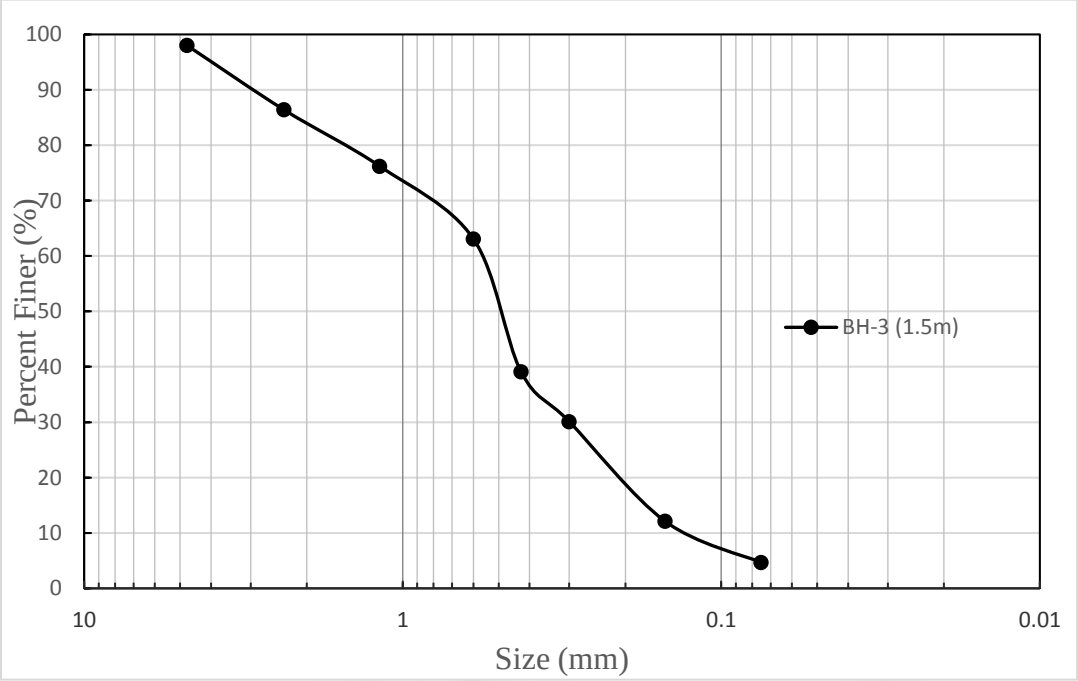


Fig. 18: Grain size distribution curve for BH-3 at depth 1.50 m

The soil samples are predominantly sand type as per the grain size curves. Also, the soil passing through 75-micron sieve is less than 5% and the C_c and C_u values are also not meeting the criteria for SW. Hence, the soil is characterised at both the borehole location as SP (IS code 1498-1970).

Specific Gravity

The Pycnometer was used for determination of specific gravity of soil particles of both fine grained and coarse grained soils. The determination of specific gravity of soil helps in the calculation of void ratio, degree of saturation and other different soil properties. Pycnometer is a glass jar of 1 liter capacity that is fitted at its top by a conical cap made of brass. The Pycnometer was cleaned, dried and cap was tightened. The mass M_1 was taken. The Pycnometer was marked with a vertical line parallel to the axis of the Pycnometer to ensure that the cap is screwed to the same mark each time. The cap was unscrewed and about 200 g of oven dried soil was placed in the Pycnometer. The cap was then tightened and the mass (M_2) was taken. The cap was unscrewed and sufficient amount of was water add to the Pycnometer so as to cover the soil. The Pycnometer was then connected to a vacuum pump to remove the entrapped air and after disconnecting the vacuum pump the Pycnometer was filled with water. The mass (M_3) was then taken. The Pycnometer was then emptied, cleaned, dried and filled with water only. The mass (M_4) was taken. The specific gravity of soil is determined using the relation:

$$G = \frac{M_2 - M_1}{(M_2 - M_1) - (M_3 - M_4)}$$

Where,

M_1=mass of empty Pycnometer, M_2= mass of the Pycnometer with dry soil

M_3= mass of the Pycnometer and soil and water, M_4 = mass of Pycnometer filled with water only, G= Specific gravity of soils.

The specific gravity obtained is 2.63

Moisture Content

Table 2 Moisture content test result for BH-2

Moisture Content of Soil (BH-2 depth= 0-1.5m)				
WT. of Container (g)	46	46	44	46
WT. of Container (g)+ Wet Soil (g)	100	88	76	66
WT. of Container+ Dry Soil (g)	98	85	75	64
WT. of Water (g)	2	3	1	2
WT. of Soil (g)	52	39	31	18
MC%	3.84	7.6	3.22	11.11
Mean Moisture content%	6.4425			

Table 3 Moisture content test result table for BH-3

Moisture Content of Soil (BH-3 depth= 0-1.5m)				
WT. of Container (g)	46	48	48	42
WT. of Container (g)+ Wet Soil (g)	100	116	94	86
WT. of Container+ Dry Soil (g)	94	108	90	80
WT. of Water (g)	6	8	4	6
WT. of Soil (g)	48	60	42	38
MC%	12.5	13.5	9.52	15.78
Mean Moisture content%	12.825			

Permeability Tests of Soil Samples

Permeability tests of soil samples obtained from BH-2 and BH-3 were conducted in the laboratory and test results are given in the Tables 4 and 5.

Table 4 Results of permeability tests for the soils obtained from BH-2

Permeability Test for BH-2 (3-4.5m depth)			
Length of specimen (L) cm	12.7		
Area of Specimen (A) cm^2	78.54		
Volume of Specimen (V) cm^3	997.458		
Experiment No.	1	2	3
Discharge Q (cm^3)	32.4	66	96.3
Time t (sec)	150	300	450
Height of water h (cm)	30	30	30
Temperature (°C)	25	25	25
Coefficient of Permeability at 25°C k = Q.L / (A.h.t) (cm/ sec)	0.001164	0.001186	0.001153
Average Permeability, k_t (cm/sec)	0.001167841		
Permeability at 25°C: $k_{25} = k_t \times \eta_t / \eta_{25}$ (cm/sec)	0.001221562		

Table 5 Results of permeability tests for the soils obtained from BH-3

Permeability Test for BH-3 (1.5-3.0m depth)			
Length of specimen (L) cm	12.5		
Area of Specimen (A) cm^2	78.69		
Volume of Specimen (V) cm^3	983.6581625		
Experiment No.	1	2	3
Discharge Q (cm^3)	38	78	119
Time t (sec)	150	300	450
Height of water h (cm)	30	30	30
Temperature (°C)	25	25	25
Coefficient of Permeability at 25°C k = Q.L / (A.h.t) (cm/ sec)	0.001341	0.001377	0.0014
Average Permeability, k_t (cm/sec)	0.001372788		
Permeability at 25°C: $k_{25} = k_t \times \eta_t / \eta_{25}$ (cm/sec)	0.001435936		

Direct Shear Test

Direct shear test is performed to determine the shear strength properties i.e. cohesion (c) and friction angle (Ø) of the material. The samples were made from the soil obtained from the bore hole for conducting shear tests. The direct shear test includes the testing of a square prism of soil that is laterally restrained and sheared along a mechanically involved horizontal plane while being subjected to pressure applied along a plane normal to the shearing plane. The soil sample is compacted in mould after bringing it to optimum moisture and dry density condition. Then sample is carefully transferred to the sample shear box. The shearing resistance was measured at regular intervals using data logger and tests were carried out with number of samples using different normal stress until the shearing resistance reached the maximum sustainable value. The relationship between measured shear stress at failure and normal applied stress obtained were noted to determine the shear strength parameters. Graphs were plotted between shear stress and normal stress obtained during the tests and c, Ø values of the soil were obtained (Figures 20 to 23).





Fig. 19 Direct shear test of soil

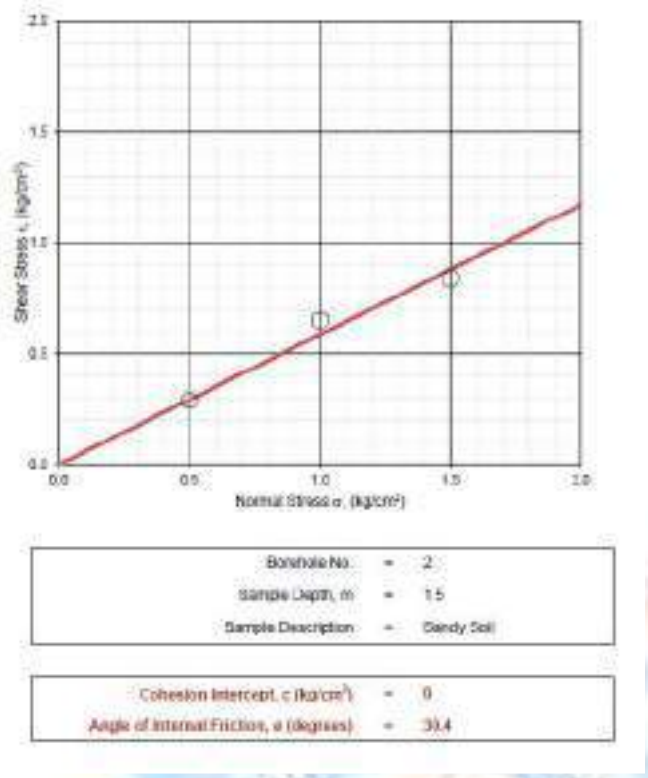


Fig. 20 Shear test of soil sample obtained at 1.5m depth from BH-2

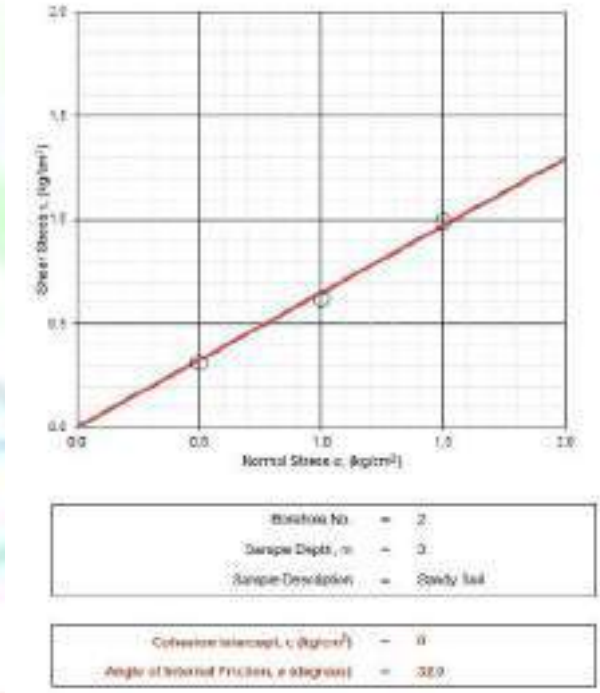


Fig.21 Shear test of soil sample obtained at 3m depth from BH-2

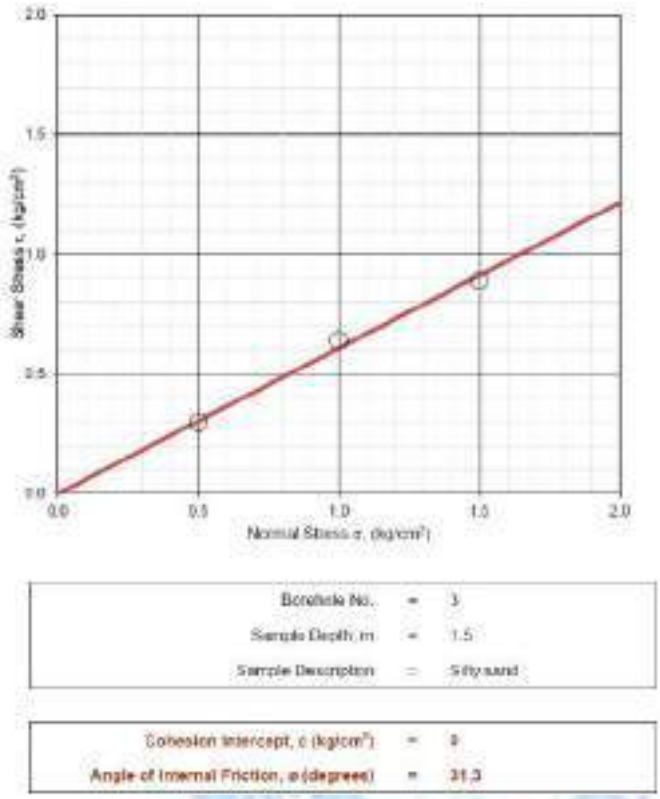


Fig.22 Shear test of soil sample obtained at 1.5m depth from BH-3

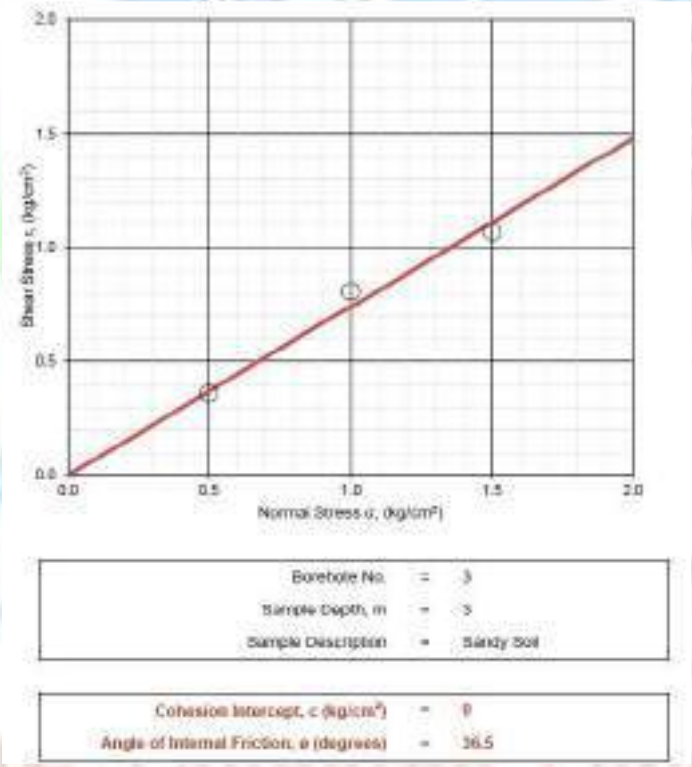


Fig. 23 Shear test of soil sample obtained at 3m depth from BH-3

2.2.2 LABORTORY TESTS OF ROCK SAMPLES

The rock cores obtained from the bore holes were tested for their engineering properties. Laboratory testing comprised of following tests conducted as per procedures given in relevant IS codes.

Slake Durability Tests

This test is done to find out the abrasion resistance offered by a rock sample to weathering and disintegration during wetting and drying cycles. The pebbles and boulders obtained from the bore hole were tested. The results are tabulated in the Tables 6 and 7.

Table 7 Slake durability test of samples of BH-2

Specimen No.	**BH-2**
Oven dried weight of drum+ sample, A (gm)	2.434
Oven dried weight of drum+ retained portion of the sample, after 1st cycle, B (gm)	2.42
Oven dried weight of drum+ retained portion of the sample, after 2nd cycle, C (gm)	2.416
Weight of drum, D (gm)	1.872
Slake durability Index (%) $[I_{d2}]$ =(C-D)/(A-D)*100%	96.797153

Table 8 Slake durability test of samples of BH-3

Specimen No.	**BH-3**
Oven dried weight of drum+ sample, A (gm)	2.446
Oven dried weight of drum+ retained portion of the sample, after 1st cycle, B (gm)	2.422
Oven dried weight of drum+ retained portion of the sample, after 2nd cycle, C (gm)	2.408
Weight of drum, D (gm)	1.874
Slake durability Index (%) $[I_{d2}]$ =(C-D)/(A-D)*100%	93.35664336

Uniaxial Compressive Strength of Rock Sample

UCS of the rock samples were determined following the relevant methods described in IS 9143 (1979, 2006).

$$\text{UCS} = \frac{P}{Change\ in\ area\ \times Correction\ Factor}$$

Where,

UCS = Unconfined Compressive Strength in MPa

P = Failure Load in N

Correction Factor = 0.77+0.46 (D/L) From IS 516 (1959)

D = Diameter and L = Length of core

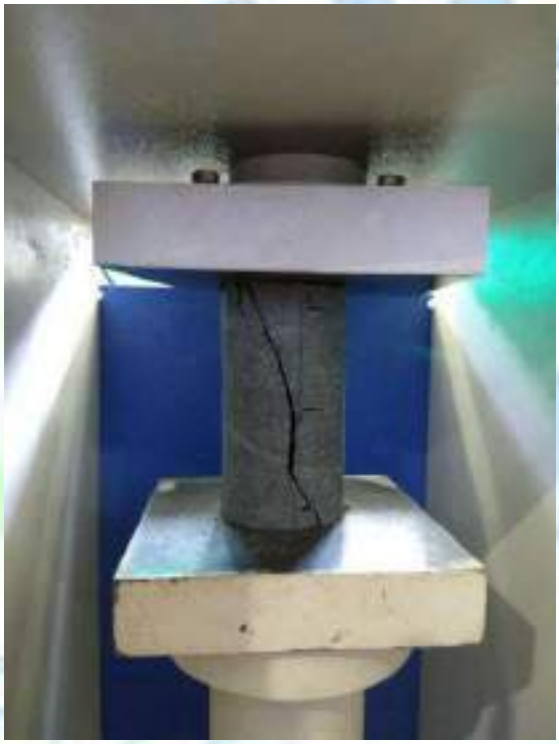


Fig. 24 UCS testing of rock core

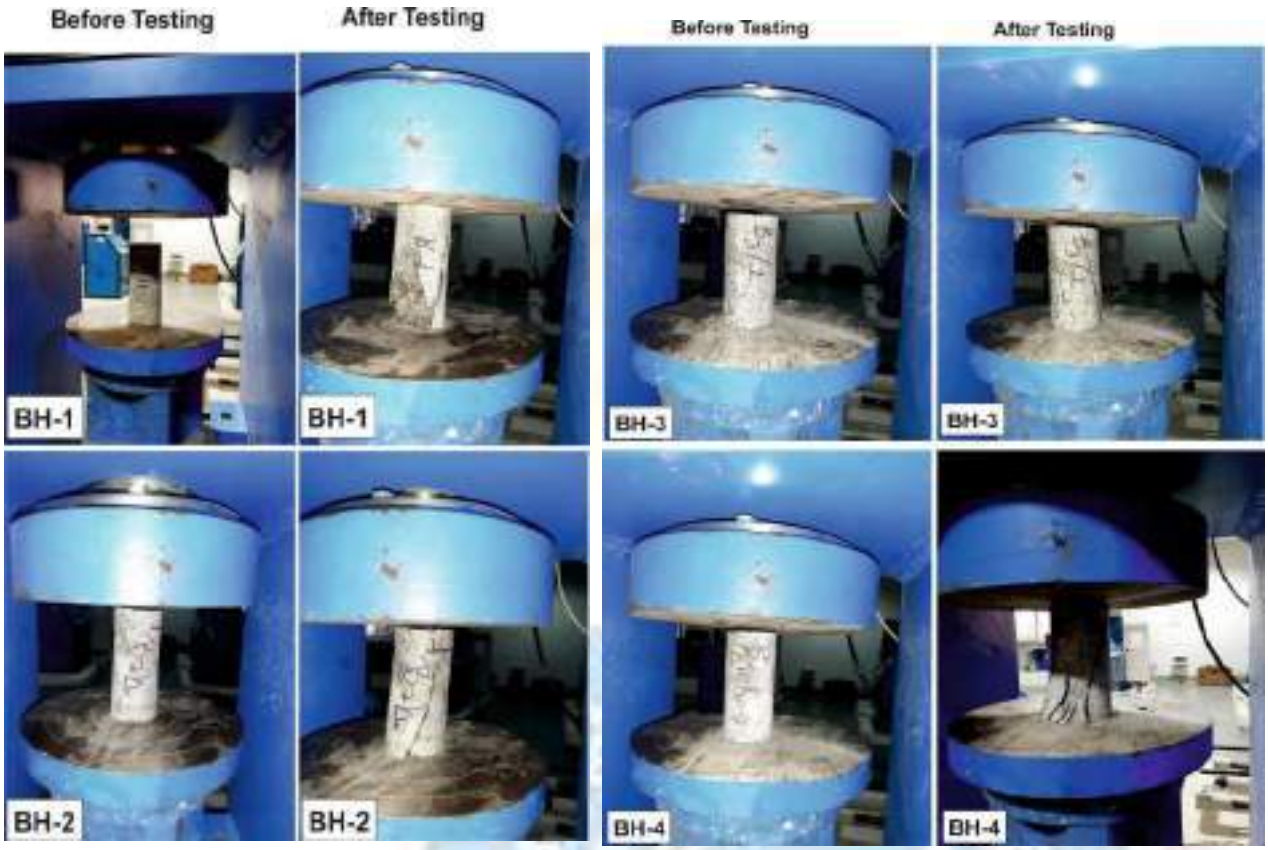


Fig. 25 UCS testing of rock cores showing before and after testing

Porosity and Density of Rock:

Porosity of the rock samples were determined on selected samples as per the relevant methods described in IS: 13030 (1991, 2016).

$$\text{Porosity (n in \%)} = (V_v/V)x100$$

$V_v = (M_{sat} - M_s) / p_w$

p_w= density of water at tempreture, t

M_{sat}=Saturated mass of sample

M_s=Mass of solid sample

V_v= Pore volume

V=Bulk volume of sample

$$\text{Dry density (p in kg/m}^3\text{)} = M_s/V$$

Water absorption of Rock

Water content of rock samples were determined on the samples as per the relevant methods described in IS: 13030 (1991, Reaff. 2016).

The water content was calculated from the following formula:

$$w = \frac{(m_2 - m_3)}{(m_3 - m_1)} \times 100$$

Where,

m_1 = Mass of the container with its lid at room temperature

m_2 = Mass of the container with its lid and the sample at room temperature.

m_3 = Mass of the container with its lid and the sample after drying.

Specific gravity of rock is determined as follow.

$$G = Gl \times (m_2 - m_1) / ((m_4 - m_1) - (m_3 - m_2))$$

Where,

Gl = Specific gravity of the liquid used at the constant temperature.

m_1 =Saturated-submerged mass of basket alone, in g

m_2 = Saturated-submerged mass of basket+specimen, in g

m_3 = Mass of container and lid in g.

m_4 = Saturated surface dry mass of the sample plus container in g.

m_5 = Dried mass of the container with sample in g.

The summary of the test results of rock cores are given in the Table 9.

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Table 9 Results of rock testing

S.N.	Bore Hole No.	Depth (m)	Speciman code	Sample Dimension		Volume of sample in mm^3	Air Dry Weight (gm)	Weight of sample in submereged condition (gm)	Saturated weight of sample (gm)	Oven Dry weight (gm)	Bulk Density	Specific Gravity	Water absorption %	Porosity %	UCS N/mm2
				Length (mm)	Diameter (mm)										
1	BH-1	9-10.5	BH-1/1	120	55	284955	782	288	784	778	2.74429296	2.71527778	0.51413882	2.10559562	22
			BH-1/2	120	55	284955	804	286	807	798	2.82149813	2.81118881	0.7518797	3.15839343	34
2	BH-2	3.50-5.00	BH-2/1	120	55	284955	840	301	843	839	2.94783387	2.79069767	0.11918951	1.40373041	38
		6.50-8.00	BH-2/2	120	55	284955	858	301	861	856	3.01100174	2.85049834	0.23364486	1.75466302	33.3
		11.00-14.00	BH-2/3	83	55	197093.9	834	300	836	833	4.23148614	2.78	0.12004802	1.52211732	31.1
3	BH-3	1.50-3.00	BH-3/1	83	55	197093.9	794	302	798	792	4.02853716	2.62913907	0.25252525	3.04423463	25.1
		3.00-4.50	BH-3/2	83	55	197093.9	812	292	814	810	4.1198642	2.78082192	0.24691358	2.02948975	33.2
		6.00-7.50	BH-3/3	120	55	284955	832	293	837	830	2.91975926	2.83959044	0.24096386	2.45652822	27.8
4	BH-4	6.00-7.50	BH-4/1	120	55	284955	834	296	836	830	2.92677791	2.81756757	0.48192771	2.10559562	37.3
		7.5 - 9.00	BH-4/2	120	55	284955	840	289	842	838	2.94783387	2.90657439	0.23866348	1.40373041	21.7

3. Computation of Bearing Capacity

Based on Direct Shear Test (Shear Criteria)

a) Site: Near Mosque (BH-2)

Depth of Foundation considered at 1.5m

Footing width assumed to be 1.5m

The angle of internal friction from direct shear test obtained is 30.4° and apparent cohesion 0.0 kg/cm^2.

Sc = 1.3 , Sq = 1.2, $S\gamma = 0.8$ (For Square Footing)

Assuming, ic = iq = $i\gamma$ =1

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Scenario 1: As per the borelog of BH-2, W′= 1 (Since no GWT encountered upto depth of exploration)

1(a) in case of general shear failure

For $\phi = 30.4°$;

Bearing Capacity Factor	IS : 6403 – 1981 R 1997		Interpolated Value for ϕ = 30.4°
	$\phi = 30°$	$\phi = 35°$	
N_c	30.14	46.12	31.42
Nq	18.40	33.30	19.59
Nγ	22.40	48.03	24.45

1(b) in case of Local shear failure

For $\phi = 30.4°$; $\phi' = \tan^{-1}(0.67 \tan 30.4°) = 21.45°$

Bearing Capacity Factor	IS : 6403 – 1981 R 1997		Interpolated Value for ϕ = 21.45°
	$\phi = 20°$	$\phi = 25°$	
N'_c	14.83	20.72	16.54
N'_q	6.40	10.66	7.64
N'_γ	5.39	10.88	6.98

Table 10 Interpolated values for intermediate shear failure (Cl. 5.2.1.1, IS 6403:1981)

Bearing Capacity Factor	IS : 6403 – 1981 R 1997		Interpolated Values
	$\phi = 30.4°$	$\phi = 21.45°$	
N_c	31.42	16.54	$16.54 + \frac{(31.42 - 16.54)(30.4 - 28.5)}{36 - 28.5} = 20.31$
N_q	19.59	7.64	$7.64 + \frac{(19.59 - 7.64)(30.4 - 28.5)}{36 - 28.5} = 10.67$
N_γ	24.45	6.98	$6.98 + \frac{(24.45 - 6.98)(30.4 - 28.5)}{36 - 28.5} = 11.41$

$N_\phi = \tan^2 (45° + \phi/2) = 3.0488$

$\sqrt{N_\phi} = 1.7461$

$dc = 1 + 0.2 (1.5/1.5) \times \sqrt{N_\phi} = 1.35$

$dq = d\gamma = 1 + [0.1 \times 1.5 \times \{\sqrt{N_\phi}\}/1.5] = 1.17$

The ultimate bearing capacity for footing resting on soil is calculated using following equation

$q_{ult} = c.N_c.s_c.d_c.i_c + q.(N_q - 1).s_q.d_q.i_q + ½ B.\gamma.N_\gamma.s_\gamma.d_\gamma.i_\gamma.W'$

q_{ult} = 0 (since c is zero)+ (16.5x 1.5)x (10.67-1) x 1.2 x 1.17 x 1

+0.5 x 1.5 x 16.5 x 11.41 x 0.8 x 1.17 x 1 x 1

= 0 + 336.02 + 132.16

= 468.18 kN/m^2

Using factor of safety 2.5

q_{safe} = 468.18 / 2.5 = 187.3 kN/m^2

Scenario 2: Assuming total submergence of footing, W′= 0.5

The ultimate bearing capacity for footing resting on soil is calculated using following equation

$q_{ult} = c.N_c.s_c.d_c.i_c + q.(N_q - 1).s_q.d_q.i_q + ½ B.\gamma.N_\gamma.s_\gamma.d_\gamma.i_\gamma.W'$

q_{ult} = 0 (since c is zero)+ (16.5x 1.5)x (10.67-1) x 1.2 x 1.17 x 1

+0.5 x 1.5 x 16.5 x 11.41 x 0.8 x 1.17 x 1 x 0.5

= 0 + 336.02 + 66.1

= 402.12 kN/m^2

Using factor of safety 2.5

q_{safe} = 402.12 / 2.5 = 161 kN/m^2

Based on Standard Penetration Test (Shear Criteria)

a) Site: Near Mosque (BH-2)

The SPT value corrected for the depth 1.5 is 13. The angle of internal friction $\phi = 31°$.

1(a) in case of general shear failure

For $\phi = 31°$;

Bearing Capacity Factor	IS : 6403 – 1981 R 1997		Interpolated Value for ϕ = 31°
	ϕ = 30°	ϕ = 35°	
N_c	30.14	46.12	33.34
Nq	18.40	33.30	21.38
Nγ	22.40	48.03	27.53

1(b) in case of Local shear failure

For ϕ = 31°; $\phi' = \tan^{-1}(0.67 \tan 31°) = 21.93°$

Bearing Capacity Factor	IS : 6403 – 1981 R 1997		Interpolated Value for ϕ = 21.93°
	ϕ = 20°	ϕ = 25°	
N'_c	14.83	20.72	17.10
N'_q	6.40	10.66	8.04
N'_γ	5.39	10.88	7.51

Table 11 Interpolated values for intermediate shear failure (Cl. 5.2.1.1, IS 6403:1981)

Bearing Capacity Factor	IS : 6403 – 1981 R 1997		Interpolated Values
	ϕ = 31°	ϕ = 21.93°	
N_c	33.34	17.10	$17.10 + \frac{(33.34 - 17.10)(31 - 28.5)}{36 - 28.5} = 22.51$
N_q	21.38	8.04	$8.04 + \frac{(21.38-8.04)(31-28.5)}{36-28.5} = 12.49$
N_γ	27.53	7.51	$7.51 + \frac{(27.53 - 7.51)(31 - 28.5)}{36 - 28.5} = 14.18$

$N_\phi = \tan^2(45° + \phi/2) = 3.124$

$\sqrt{N_\phi} = 1.767$

$dc = 1 + 0.2\ (1.5/1.5) \times \sqrt{N_\phi} = 1.35$

$dq = d\gamma = 1 + [0.1 \times 1.5 \times \{\sqrt{N_\phi}\}/1.5] = 1.18$

The ultimate bearing capacity for footing resting on soil is calculated using following equation

$q_{ult} = c.N_c.s_c.d_c.i_c + q.(N_q - 1).s_q.d_q.i_q + ½\ B.\gamma.N_\gamma.s_\gamma.d_\gamma.i_\gamma.W'$

$q_{ult} = 0$ (since c is zero)+ (16.5x 1.5)x (12.49-1) x 1.2 x 1.18 x 1

+0.5 x 1.5 x 16.5 x 14.18 x 0.8 x 1.18 x 1 x 1

= 0 + 402.68 + 165.65

= 568.33 kN/m^2

Using factor of safety 2.5

q_{safe} = 568.33 / 2.5 = 227.33 kN/m^2

Scenario 2: Assuming total submergence of footing, W′= 0.5

The ultimate bearing capacity for footing resting on soil is calculated using following equation

$q_{ult} = c.N_c.s_c.d_c.i_c + q.(N_q - 1).s_q.d_q.i_q + ½ B.\gamma.N_\gamma.s_\gamma.d_\gamma.i_\gamma.W'$

q_{ult} = 0 (since c is zero)+ (16.5x 1.5)x (12.49-1) x 1.2 x 1.18 x 1

+0.5 x 1.5 x 16.5 x 14.18 x 0.8 x 1.18 x 1 x 0.5

= 0 + 402.68 + 82.82

= 485.5 kN/m^2

Using factor of safety 2.5

q_{safe} = 485.5 / 2.5 = 194.2 kN/m^2

Computation of Bearing Capacity

Based on Direct Shear Test (Shear Criteria)

b) Site: Near Mandir (BH-3)

Depth of Foundation considered at 1.5m

Footing width assumed to be 1.5m

The angle of internal friction from direct shear test obtained is 32.9° and apparent cohesion 0.0 kg/cm^2.

Sc = 1.3 , Sq = 1.2, Sγ = 0.8 (For Square Footing)

Assuming, ic = iq = iγ =1

Scenario 1: As per the borelog of BH-2, W′= 1

1(a) in case of general shear failure

For ϕ = 32.9°;

Bearing Capacity Factor	IS : 6403 – 1981 R 1997		Interpolated Value for ϕ = 32.9°
	ϕ = 30°	ϕ = 35°	
N_c	30.14	46.12	39.41
Nq	18.40	33.30	27.042
Nγ	22.40	48.03	37.26

1(b) in case of Local shear failure

For ϕ = 32.9°; $\phi' = \tan^{-1}(0.67 \tan 32.9°) = 23.43°$

Bearing Capacity Factor	IS : 6403 – 1981 R 1997		Interpolated Value for ϕ = 23.43°
	ϕ = 20°	ϕ = 25°	
N'_c	14.83	20.72	18.87
N'_q	6.40	10.66	9.32
N'_γ	5.39	10.88	9.16

Table 12 Interpolated values for intermediate shear failure (Cl. 5.2.1.1, IS 6403:1981)

Bearing Capacity Factor	IS : 6403 – 1981 R 1997		Interpolated Values
	ϕ = 32.9°	ϕ = 23.43°	
N_c	39.41	18.87	$18.87 + \frac{(39.41 - 18.87)(32.9 - 28.5)}{36 - 28.5} = 30.92$
N_q	27.042	9.32	$9.32 + \frac{(27.042-9.32)(32.9-28.5)}{36-28.5} = 19.72$
N_γ	37.26	9.16	$9.16 + \frac{(37.26 - 9.16)(32.9 - 28.5)}{36 - 28.5} = 25.65$

$N_\phi = \tan^2(45° + \phi/2) = 3.378$

$\sqrt{N_\phi} = 1.838$

$dc = 1 + 0.2\ (1.5/1.5) \times \sqrt{N_\phi} = 1.37$

$dq = d\gamma = 1 + [0.1 \times 1.5 \times \{\sqrt{N_\phi}\}/1.5] = 1.18$

The ultimate bearing capacity for footing resting on soil is calculated using following equation

$q_{ult} = c.N_c.s_c.d_c.i_c + q.(N_q - 1).s_q.d_q.i_q + ½\ B.\gamma.N_\gamma.s_\gamma.d_\gamma.i_\gamma.W'$

q_{ult} = 0 (since c is zero)+ (16.5x 1.5)x (19.72-1) x 1.2 x 1.18 x 1

+0.5 x 1.5 x 16.5 x 25.65 x 0.8 x 1.18 x 1 x 1

= 0 + 656.1 + 299.6

= 955.7 kN/m^2

Using factor of safety 2.5

q_{safe} = 955.7 / 2.5 = 382.28 kN/m^2

Scenario 2: Assuming total submergence of footing, W′= 0.5

The ultimate bearing capacity for footing resting on soil is calculated using following equation

$q_{ult} = c.N_c.s_c.d_c.i_c + q .(N_q - 1).s_q.d_q.i_q + ½ B.\gamma.N_\gamma.s_\gamma.d_\gamma.i_\gamma.W'$

q_{ult} = 0 (since c is zero)+ (16.5x 1.5)x (19.72-1) x 1.2 x 1.18 x 1

+0.5 x 1.5 x 16.5 x 25.65 x 0.8 x 1.18 x 1 x 0.5

= 0 + 656.1 + 149.8

= 805.9 kN/m^2

Using factor of safety 2.5

q_{safe} = 805.9 / 2.5 = 322.36 kN/m^2

Based on Standard Penetration Test (Shear Criteria)

a) Site: Near Mandir (BH-3)

The SPT value corrected for the depth 1.5 is 20. The corresponding angle of internal friction ϕ = 33.5°.

1(a) in case of general shear failure

For ϕ = 33.5°;

Sc = 1.3 , Sq = 1.2, Sγ = 0.8 (For Square Footing)

Assuming, ic = iq = iγ =1

Scenario 1: As per the borelog of BH-3, W′= 1

1(a) in case of general shear failure

For ϕ = 33.5°;

Bearing Capacity Factor	IS : 6403 – 1981 R 1997		Interpolated Value for ϕ = 33.5°
	ϕ = 30°	ϕ = 35°	
N_c	30.14	46.12	41.33
Nq	18.40	33.30	28.83
Nγ	22.40	48.03	40.34

1(b) in case of Local shear failure

For ϕ = 33.5°; $\phi' = \tan^{-1}(0.67 \tan 33.5°) = 23.92°$

Bearing Capacity Factor	IS : 6403 – 1981 R 1997		Interpolated Value for ϕ = 23.92°
	ϕ = 20°	ϕ = 25°	
N'_c	14.83	20.72	19.45
N'_q	6.40	10.66	9.74
N'_γ	5.39	10.88	9.69

Table13 Interpolated values for intermediate shear failure (Cl. 5.2.1.1, IS 6403:1981)

Bearing Capacity Factor	IS : 6403 – 1981 R 1997		Interpolated Values
	ϕ = 33.5°	ϕ = 23.92°	
N_c	41.33	19.45	$19.45 + \frac{(41.33-19.45)(33.5-28.5)}{36-28.5} = 34.04$
N_q	28.83	9.74	$9.74 + \frac{(28.83-9.74)(33.5-28.5)}{36-28.5} = 22.47$
N_γ	40.34	9.69	$9.69 + \frac{(40.34-9.69)(33.5-28.5)}{36-28.5} = 30.12$

$N_\phi = \tan^2 (45° + \phi/2) = 3.464$

$\sqrt{N_\phi} = 1.861$

$dc = 1 + 0.2 (1.5/1.5) x\sqrt{N_\phi} = 1.37$

$dq = d\gamma = 1 + [0.1 x1.5 x\{ \sqrt{N_\phi}\}/1.5] = 1.19$

The ultimate bearing capacity for footing resting on soil is calculated using following equation

$q_{ult} = c.N_c.s_c.d_c.i_c + q .(N_q - 1).s_q.d_q.i_q + ½ B.\gamma.N_\gamma.s_\gamma.d_\gamma.i_\gamma.W'$

q_{ult} = 0 (since c is zero)+ (16.5x 1.5)x (22.47-1) x 1.2 x 1.19 x 1

+0.5 x 1.5 x 16.5 x 30.12 x 0.8 x 1.19 x 1 x 1

= 0 + 758.82 + 354.84

= 1113.66 kN/m^2

Using factor of safety 2.5

q_{safe} = 1113.66 / 2.5 = 445.5 kN/m^2

Scenario 2: Assuming total submergence of footing, W′= 0.5

The ultimate bearing capacity for footing resting on soil is calculated using following equation

$q_{ult} = c.N_c.s_c.d_c.i_c + q .(N_q - 1).s_q.d_q.i_q + ½ B.\gamma.N_\gamma.s_\gamma.d_\gamma.i_\gamma.W'$

q_{ult} = 0 (since c is zero)+ (16.5x 1.5)x (22.47-1) x 1.2 x 1.19 x 1

+0.5 x 1.5 x 16.5 x 30.12 x 0.8 x 1.19 x 1 x 0.5

= 0 + 758.82 + 177.42

= 936.24 kN/m^2

Using factor of safety 2.5

q_{safe} = 936.24 / 2.5 = 374.5 kN/m^2

Table 14 Bearing capacity of soil

Site Location	Bearing capacity based on shear strength parameters obtained			
	From Direct Shear Tests (t/m^2)		From field SPT values (t/m^2)	
	Present Field Condition	Assumed Submerged Condition	Present Field Condition	Assumed Submerged Condition
BH-2	18.73	16.10	22.73	19.42
BH-3	38.23	32.24	44.55	37.45

Considering the lower bearing capacity from the above two criteria, it is found that the net safe bearing capacity at location near Mosque (BH-2) is 18.73 and 16.1 t/m2 for the present scenario and in case of submergence of the foundation respectively. Similarly, at the location near Mandir (BH-3), the net safe bearing capacity is 38.23 and 32.24 t/m2 for the present scenario and in case of submergence of the foundation respectively.

4. Conclusions & Recommendation

The geological and geotechnical investigation were carried out in the Pur village to find out the causes for the development of cracks in the buildings. The study shows that the village is situated on schist, a high grade metamorphic rock with vertical foliation. The rock outcrops are clearly visible in the outer periphery of the village and most of the houses in this area are situated almost on the bedrock. The borelog study was carried out by drilling bore holes at selected sites. It was found that the soil thickness overlying the rocks in this area is very less, around 3m. The houses situated in this locality have not developed any crack. The inner region of the village has sand mixed with pebbles/boulders of rocks overlying the schist rocks. The overburden thickness of these loose rock fragments and soil above the bed rocks vary from 8m to 14m. In this central portion, many houses have developed cracks. The cracks developed on the floors and walls are clearly visible in these houses, temple and the mosque.

The geotechnical properties of the soil and rocks were determined from the laboratory investigation. The borehole investigation revealed that the overburden soil varies from sand particles to rock boulders. The shear strength properties show that the soil has apparently no cohesion (c=0) and friction angle value varies from 30.4° to 36.6°. The bearing capacity of the soil is found to be adequate, however it may decrease if gets saturated with water as the top layer is composed of boulder soil matrix. Also, the bearing capacity determined for the studied borehole locations significantly vary, hence, a lower bearing capacity in nearby areas cannot be ruled out. The uniaxial compressive strength (UCS) of the schist rocks vary from 22 to 38 MPa. This shows very low strength of the rock and this is obvious as schist is a soft rock having dominant mica content. The core recovery found is very low and the RQD% of the rock mass is nil up to a depth of 7m to 13m as no rock strata is present within this depth in the central region. In case of water percolating down to the vertically foliated weathered mica schist, there could be a possibility of weakening of the rock strata because of the swelling of mica minerals.

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Based on the above study the following conclusions are made:

I. In general, engineering properties of the soil layer is good and suitable for building foundation.

II. The bedrock below the soil layer at a depth of 8m to 14m is weathered schist having low strength with vertical foliation. This may undergo dilation if gets saturated with water because of dominating mica minerals having swelling property.

III. There is a thick heterogeneous soil layer comprises of sand and pebbles/boulders in the central part of the village where cracks are developed in the clusters of houses. There could be a possibility of washing out of fines due to water seepage in this soil layer creating some void spaces. This may cause settlement of buildings resulting in appearance of cracks. However, saturated zones were not encountered in the overburden soil layer during the drilling.

IV. Another cause of crack development in the buildings could be the thick heterogeneous soil layer subjected any kind of dynamic loading, causing loosening of the heterogeneous soil layer and creating void spaces.

V. It is inferred from the geotechnical investigation that the cracks are appeared only in the buildings, which are situated on the considerably thick heterogeneous soil in the central part of the village. The buildings situated at the village periphery having less overburden are less damaged than the buildings in the central part of the village where the loose soil mixed with rock fragments has a thickness varying from 8m to 14m.

VI. As a suggestive measure, it is advised to retrofit and strengthen the building foundations.

VII. The drainage network should be properly investigated and improved if there are any leakages or underground seepage problems.

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Part II: STRUCTURAL INVESTIGATIONS

1	Name of work	Studies to investigate the reasons of cracks development in buildings of Pur village, Bhilwara, Rajasthan
2	Institute	CSIR-Central Building Research Institute, Roorkee
3	Site	Pur Village, Bhilwara, Rajasthan
4	Date of visit	28th January 2020 to 3rd February 2020 28th September 2020 to 2nd October 2020
5	Type of work	Condition assessment, cracks mapping and monitoring of various buildings in Pur village, Bhilwara
6	Status of work	• Condition assessment of 6 important structures (3 Schools, 1 Hospital, 1 Temple & 1 Mosque) and more than 80 houses of Pur Village, Bhilwara has been carried out in respect to typology of buildings, structural systems, construction materials, mapping of structural and non-structural cracks and other observations. The buildings were identified and marked for monitoring at different locations in Pur village. • The monitoring of cracks in buildings were carried out after installation of Demec gauges at different locations in the building. • Total of about 237 locations were marked for crack monitoring and readings were taken. • Demec points locations and crack measurements are given in **Annexure A** • During studies, the cracks and other distresses in buildings were properly marked. The plan drawings of few buildings under distressed were prepared. Crack mapping and its pattern for all the structures/houses were carried out. Architectural drawing and crack mapping are provided in **Annexure B.**
7	Observations	• The building stocks in Pur village are mostly non-engineered type with stone masonry wall having thickness varying from 0.35m -0.45 m. • The majority of the houses in the village are single storied or G+1 structure. • The sand stone slabs are used as in roofing elements.

		• Kota stone has been used as flooring material in the most of houses. • Foundations of buildings were constructed with stone masonry with varying depth of about 0.5 m- 2.5 m. At a few places it was even deeper. • The roof slabs were made of sandstone supported with steel girders. A few houses also used wooden beams and I-Section for providing support to stone slabs. • Recently build houses were found to be constructed with RCC roof slab and having brick masonry. In few places both stone masonry and brick masonry were observed along with RCC roof slab and stone slab where new construction was done over/along the old structure. • The diagonal cracks were predominantly observed in walls mostly in non-engineered buildings and old structures. The cracks were also found between wall joints, surface floors, ceiling and skirting of walls. • Stone floorings were found dislocated at a few places causing gaps between stones, which make the surface uneven. • Most of cracks in walls were diagonal in nature and at some places cracks propagated from floor to wall and then to ceiling. • Water leakage problem from cracked underground water tank in various houses were also observed. • The damages and cracking in the buildings are mostly due to differential settlements. • The engineered buildings made with reinforced concrete framed or brick masonry load bearing buildings were found negligible damages except a few. • The cracks were found gradually increasing at several locations. The reading were found increase in cracks varying from 0.007 mm to 1.000 mm during 8 months period at most of the locations. However, a few cracks were found widened even about 3.300 mm. The crack widths found to be also decreased at several locations.
8.	Conclusions	• The damages were observed mainly in non-engineered old buildings. The crack pattern in the buildings clearly indicate towards differential settlements in foundation. Several buildings were found severely damaged, which need to be dismantled and reconstructed. • The cracks were found gradually progressing at several locations. It is also due to rearrangement in non-engineered building elements.

		• The foundations were found filled with stones only, where the cracks were observed. • The most water tanks are underground made with stone masonry walls. The tanks were also found damaged at several places. This leads to seepage of water into foundation areas causing settlements.
9.	Recommendations	Buildings in Pur Village, Bhilwara, Rajsthan are mostly affected by differential settlements. This leads to both non-structural and structural damages. These can be clearly differentiated. The severity of the structural damages were carefully studied and found that the damages were more prominent in non-engineered buildings as compared to engineered buildings. Before a decision by competent authority on repair and restoration or demolition of the buildings, a holistic approach is required. Often it has been seen that the recommendations are made in great haste create further problems. Therefore, it is advised that dismantling and reconstruction or repair and rehabilitation of buildings were taken after consultative meetings with affected residents. The proper categorization of the damages are therefore, of basic importance for post damage rehabilitation or reconstruction program. **Non-structural/Architectural repairs** The main purpose of these repairs is to bring back the architectural shape of the building so that all services start working and the functioning of building is resumed quickly. The actions will include the following: a) Patching up of defects such as cracks and fall of plaster. b) Repairing doors, windows, replacement of glass panes. c) Checking and repairing electric wiring. d) Checking and repairing gas pipes, water pipes and plumbing services. e) Rebuilding non-structural walls, smoke chimneys, boundary walls, etc. f) Replastering of walls as required. g) Rearranging disturbed roofing tiles. h) Relaying cracked flooring at ground level. i) Redecoration – white washing, painting etc. The architectural repairs as stated above do not restore the original structural strength of cracked walls or columns and may sometimes be very illusive, since the redecorated building will hide all the weaknesses and the building will suffer even more sever damages if shaken again by an equal shock since the original energy absorbing capacity will not be available.

Structural repairs or restoration

The main purpose of restoration is to carry out structure repairs to load bearing elements. It may involve cutting portion of the elements and rebuilding them or simply adding more structure material so that the original strength is more or less restored. The process may involve inserting temporary supports, underpinning etc. After assessing the damage of particular structural elements, suitable repair methods should be adopted component wise depending upon damage intensity. Some of the approaches are stated below:

a) Removal of portions of cracked masonry walls and piers and rebuilding them in richer mortar. Use of non-shrinking mortar will be preferable.

b) Addition of reinforcing mesh on both faces of the cracked wall, holding it to the wall through spikes or bolts and covering it suitably. The strength of the reinforced cover plates should be designed to more than balance the lost strength of the cracked elements.

c) Injecting epoxy, cement grout or like materials, or cement mortar which is strong in tension, into the cracks in columns, beams, walls etc., depending on the width of crack and lost strength to be restored.

Where structural repairs are considered necessary, these should be carried out prior to or simultaneously with the architectural repairs so that the total planning of work could be done in a coordinated manner and wastage is avoided.

Dismantling and Reconstruction

The main purpose of dismantling and reconstruction is to dismantle the existing building/ structure which is beyond repair. It may involve dismantling of the building and reconstruct them based on geotechnical investigation report in engineered manner. This requires proper planning and implementation.

Resettlements

The survey of building shows that damages in buildings were distributed in particular region near Laxmi Narayan temple and Madina Masjid. The information about damage distribution in this whole region, was prepared by block-by-block basis survey. Therefore, it is advised to resettle the affected people in some other stable locations.

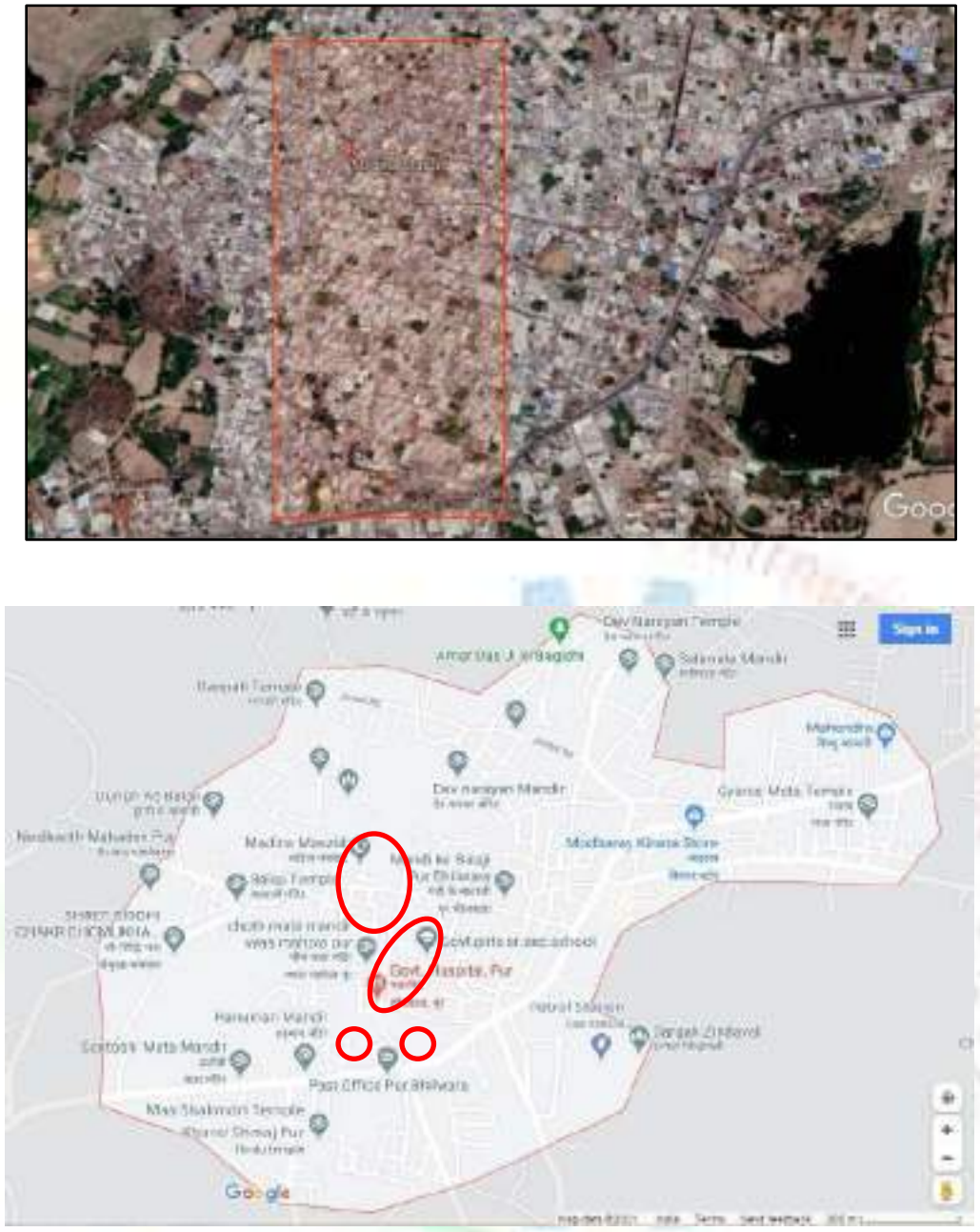


Fig. 1 (a). Satellite image of Pur village (hashed and red circled area)showing locations covered

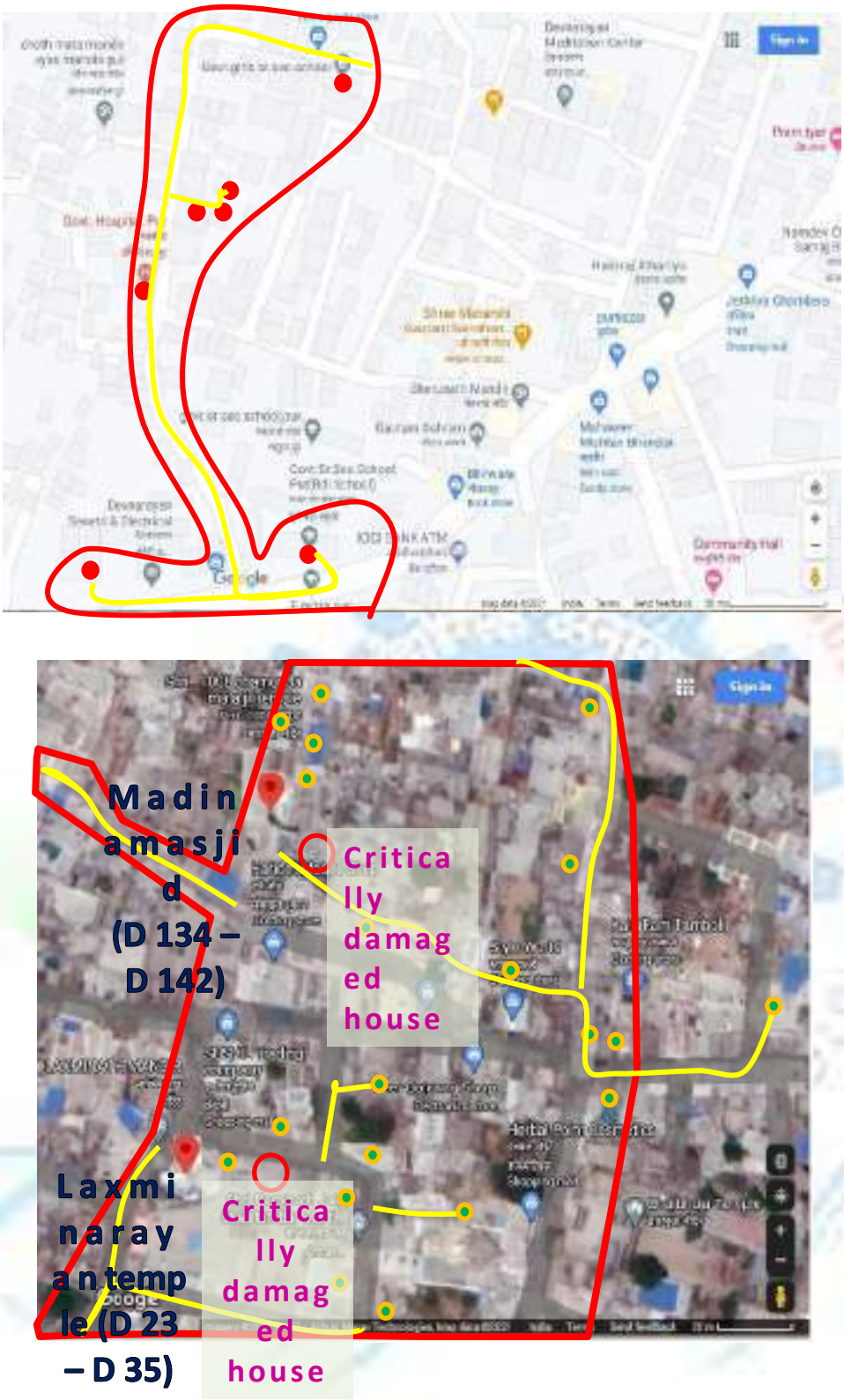


Fig. 1 (b). Locations of houses having demec points (marked red and green dots) installed

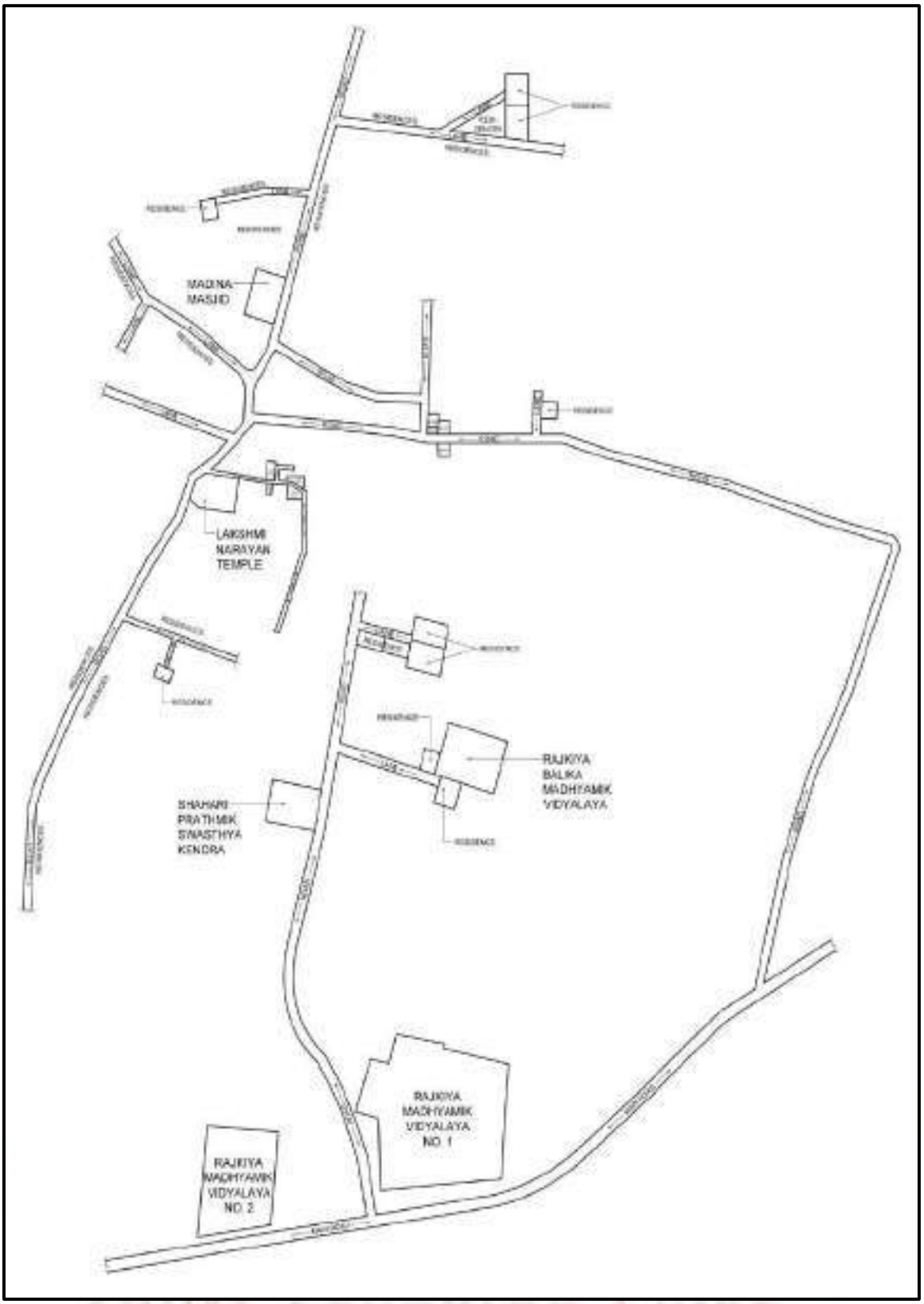


Fig. 2. Key Plan of Pur village

Survey Reports of the Buildings

1. Government Primary School

Observations:

- No. of stories built: Single.
- Occupancy: About 300 students.
- School was built around year 1995.
- Building was load bearing structure as shown in Fig. 3.
- Building walls are made of stone masonry in lime mortar and plastered with cement mortar.
- Cracks observed in middle of walls and near wall corners as shown in Fig. 4.
- Large width cracks observed propagating from walls to the roof slab.

Building type	Foundation type	Masonry type	Flooring	Roof type	Area
Load bearing structure	Stone masonry	Stone masonry	Kota stone	Stone slab	1271 sqm



Fig. 3. Govt. primary school building



Fig. 4. Vertical and horizontal cracks in school building

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2. Government Higher Secondary School

Observations:

- No. of Stories built: Single.
- Occupancy: About 800 students.
- Building was constructed around year 1995.
- Building was constructed in form of load bearing structure on stone masonry wall (Fig.5).
- Walls are made of stone masonry in lime mortar. The cement-sand plaster was carried out.
- Separation horizontal cracks were observed in walls of building particularly at floor level and slab level. Vertical cracks at beam column joints as shown in Fig. 6
- Water seepage was observed from ground at surface of walls as shown in Fig. 7.

Building type	Foundation type	Masonry type	Flooring	Roof type	Area
Load bearing structure	Stone masonry	Stone masonry	Kota stone	Flat stone girder	3180 sqm



Fig. 5. Govt. higher secondary school building

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Fig. 6. Vertical and horizontal cracks in beam and near column joint



Fig. 7. Water seepage in the premises of school building

3. Government Girls School

Observation:

- No. of stories built: G+1.
- Occupancy: About 370 students.
- Building constructed around year 2005.
- Cracks were found in many locations like walls, columns and floor.
- The building was load bearing structure and made of stone masonry with lime mortar as shown in Fig. 8.
- The surface of walls was finished with cement-sand mortar as plastering material.
- The cracks were both horizontal and vertical in nature.
- Horizontal cracks were found in the joints of roof slab and wall.
- Vertical cracking was observed in the toilet structure of the school as shown in Fig. 9.

Building type	Foundation type	Masonry type	Flooring	Roof type	Area
Load bearing structure	Stone masonry	Stone masonry	Kota stone	Stone slab	1365 sqm



Fig. 8. Government girls school building



Fig. 9.Vertical crack on external wall and horizontal crack in class room

4. Government General Hospital

Observations:

- No. of Stories built : Single.
- Occupancy: About 200 beds.
- Building constructed around year 1995.
- Building was load bearing structure as shown in Fig. 10.
- Walls were made of stone masonry in lime mortar. The cement-sand mortar was used for plastering.
- Severe cracks were observed in wards of the hospital.
- These were diagonal cracks as shown in Fig. 11, due to settlement of foundation.
- Cracks were also observed in beam-column joints.
- Cracks were observed in floor propagating towards the walls.
- Cracks were found propagating from walls to roof as shown in Fig. 11.
- Roof was of stone slab supported on I girders.

Building type	Foundation type	Masonry type	Flooring	Roof type	Area
Load bearing structure	Stone masonry	Stone masonry	Kota stone	Stone slab with I girder	391 sqm



Fig. 10.Village general hospital building



Fig. 11. Vertical and diagonal cracks in walls and near corners

5. Laxmi Narayana Temple

Observation:

- No. of stories built: Single.
- Occupancy: About 150 visitors.
- Temple was about 500 year old (Fig. 12) and a new room constructed inside the temple premises in 2014.
- Walls around the temple were made of rubble stone masonry.
- Lime mortar was found to be used in stone masonry of old structure.
- Major cracks were found inside the new room of temple and it was propagating from walls up to the roof as shown in Fig. 13.
- Cracks were also observed in boundary wall of temple as shown in Fig. 14 and Fig. 15.

Building type	Foundation type	Masonry type	Flooring	Roof type	Area
Load bearing structure	Stone masonry	Stone masonry	Marble stone	Conical and flat stone slab	375 sqm



Fig. 12. Laxmi Narayan temple structure



Fig. 13.Cracks on wall up to roof level



Fig. 14. Cracks on temple structure and periphery wall

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Fig. 15. Cracks on temple structure and periphery walls

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6. House no. 2249

Observations:

- No. of Stories built : G+1
- Occupancy: Zero (House is in dilapidated condition, hence vacated from occupants).
- Ground floor of house was built around year 1990 and first floor was built in year 2015.
- Major structural cracks were observed in building occurring diagonally as shown in Fig.16 to Fig. 21.
- The cracks were found propagating from floor to walls.
- Diagonal cracks were observed on parapet walls as shown in Fig. 17.
- The wall joints got seperated as shown in Fig. 18 due to differential settlement.
- First Floor ceiling was found severely damaged. Stone slab was used as roofing element which got separated as shown in Fig.19.
- Overhangs/ projects were also severely damaged at several locations.

Building type	Foundation type	Masonry type	Flooring	Roof type	Area
Load bearing structure	Stone masonry	Stone masonry	Marble	Stone slab	126 sqm



Fig.16. House no. 2249



Fig. 17. Damaged parapet and overhang

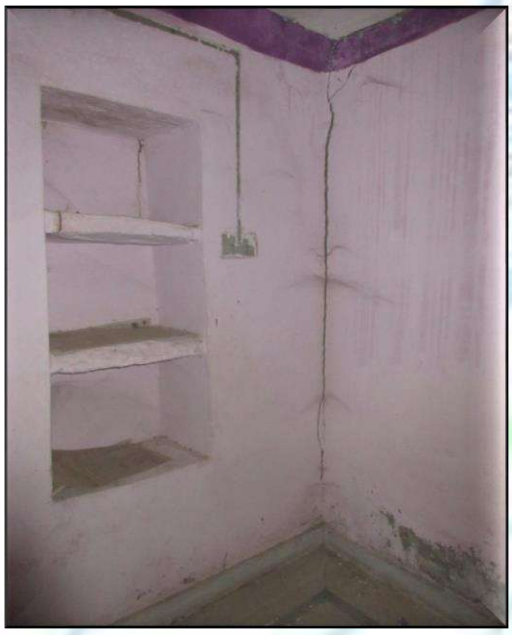


Fig.18. Opened wall joints



Fig. 19. Damaged First floor ceiling

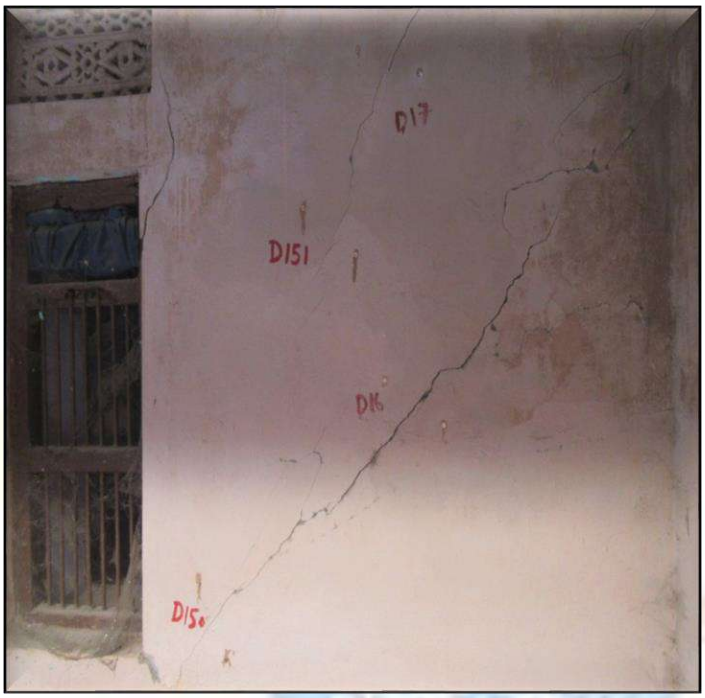


Fig.20. Diagonal cracks in walls with installed demec points (outside)



Fig.21. Diagonal cracks in walls with installed demec points (Inside)

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7. House no. 2245 (As shown in Fig. 22)

Observations:

- No. of Stories built: G+1.
- Occupancy: 2 people.
- House was constructed around 1980 and renovates in 2008.
- External projects/ balcony was found excessively deflected. The same was supported by temporary support (wooden shoring) as shown in Fig. 23.
- The cracks observed in walls/ roofs of the building as shown in Fig. 24 to Fig. 27.
- Horizontal cracks were observed in roof slabs as shown in Fig 25.
- Major cracks were observed near the joints of orthogonal walls.
- The cracks were found propagating from walls to roof as shown in Fig.24.
- Stone slabs in the roof were found to be displaced and gap was clearly visible between stones.
- Gap was also observed between walls and skirting.
- It was found that walls joint got opened and separated from each other as shown in Fig. 26.

Building type	Foundation type	Masonry type	Flooring	Roof type	Area
Load bearing structure	Stone masonry	Stone masonry	Marble	Stone slab	145 sqm



Fig.22. House no. 2245



Fig. 23. Temporary support (wooden shoring)



Fig. 24. Opened wall joints



Fig. 25. Horizontal cracks in roof slabs

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Fig. 26. Cracks in wall and near wall joints



Fig.27.Cracks in wall and installed demec points

8. House no. 1353

Observation:

- No. of stories built: G+1.
- Occupancy: 3 people (House was in dilapidated condition).
- Ground floor structure was built around year 1990 and first floor was built in year 2010.
- The structural cracks were found propagating up to ceiling from wall as shown in Fig. 28 to Fig. 30.
- Diagonal cracks and vertical cracks were observed in the walls of the building.
- Horizontal cracks were also observed in ceiling.
- Joints of wall were found opened as shown in Fig. 29.
- The cracks in walls were observed propagating into floor and ceiling as shown in Fig. 30.

Building type	Foundation type	Masonry type	Flooring	Roof type	Area
Load bearing structure	Stone masonry	Stone masonry	Cement flooring	Stone slab	45 Sq. m.



Fig.28. House no. 1353



Fig. 29. Opened joints of wall



Fig. 30 (a). Structural cracks on ceiling to wall

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Fig. 30 (b). Joint separation and cracks in wall/ cornor

9. House no. 2246

Observation:

- No. of stories built: G+2.
- Occupancy: Vacated.
- Major structural cracks were found on external walls as shown in Fig. 31.
- Diagonal cracks were observed in wall of the building near window opening as shown in Fig. 31.
- Cracks in walls were propagating up to ground from window level.

Buildingtype	Masonrytype	Flooring	Roof type
Load bearing structure	Stone masonry	Stone flooring	Flat girder

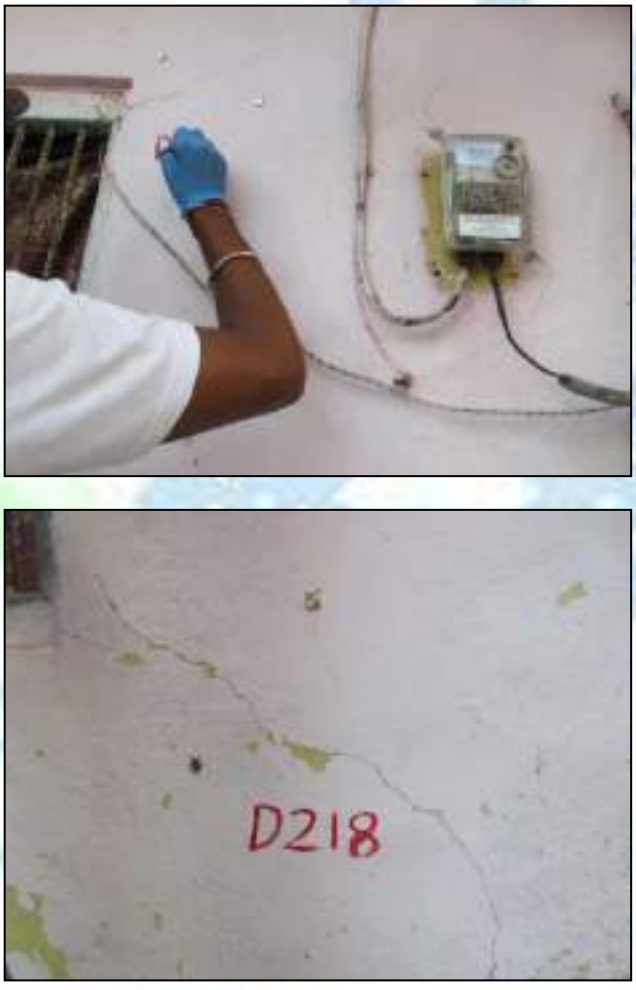


Fig. 31. House no. 1353 (Crack pattern and demec points)

10. House no. 2216

Observations:

- No. of Stories built: G+1.
- Occupancy: 8-10 people.
- House constructed around 1980.
- The building was load bearing structure as shown in Fig. 32.
- Vertical cracks observed in external front walls of the building as shown in Fig. 32 and Fig. 33.
- Most of the cracks were observed in the middle portion of the wall.
- The cracks were observed propagating from wall up to roof as shown in Fig. 32.
- The roof of the house was made of stone slabs supported on I girders.

Building type	Masonry type	Flooring	Roof type
Load bearing structure	Stone masonry	Stone floor	Stone slab with I girder

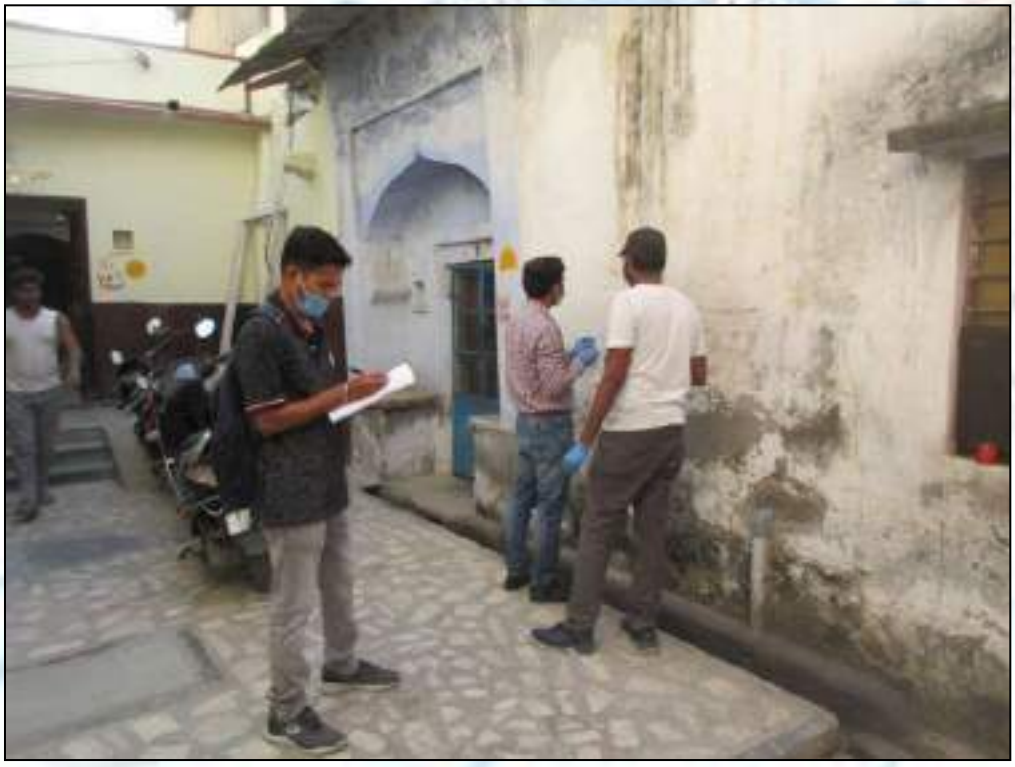


Fig. 32. House no. 2216



Fig. 33. Vertical crack on external wall and demec points

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11. House no. 2226

Observations:

- No. of stories built: G+2.
- Occupancy: 6-8 people.
- The house was found to be load bearing structure. The wall were made of stone masonry and cement mortar was used in plaster as shown in Fig. 34.
- Diagonal cracks were observed in walls of the building propagating up to the roof slab.

Building type	Masonry type	Flooring	Roof type
Load bearing structure	Stone masonry	Marble stone	Stone slab



Fig. 34. House no. 2226 (Crack pattern and demec point)

12. House no. 2225

Observations:

- No. of stories built : single.
- Occupancy: vacated.
- The house was found to be load bearing structure. The house is made of stone masonry and plastering work was done using cement-sand mortar as shown in Fig. 35.
- Horizontal cracks were also observed in the wall near window.
- The cracks were observed between entry door and adjacent window of the house as shown in Fig. 35.
- Diagonal cracks observed in walls of the house as shown in Fig. 36.
- Wide crack was found in the back side wall of the house. It was propagating from mid of the window opening up to ground level as shown in Fig. 36.

Building type	Masonry type	Flooring	Roof type
Load bearing structure	Stone masonry	Stone marble floor	Stone slabs



Fig. 35. House no. 2225





Fig. 36. Horizontal and diagonal cracks and demec points

13. House no. 2223

Observations:

- No. of stories built: Single.
- Occupancy: 10-12 people.
- House was constructed around year 1980.
- The building was load bearing structure. The wall was made of stone masonry as shown in Fig. 37.
- Diagonal cracks were observed in external walls of the building as shown in Fig. 37 and Fig. 38.
- The crack was propagating from walls to the roof level.
- Wide cracks were also observed at few locations as shown in Fig. 38.

Building type	Masonry type	Flooring	Roof type
Load bearing structure	Stone masonry	Stone flooring	Stone slabs



Fig. 37. House no. 2223



Fig. 38.Wide digonal crack on external wall

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14. House no. 544

Observations:

- No. of stories built: Single.
- Occupancy: 18 people.
- House was found to be constructed in two parts – front part was an old structure constructed in 1980 and inside part was newly constructed RCC structure.
- Wall was made of stone masonry in old structure and brick masonry has been used in new structure.
- The roof was found to be made of sandstone slab supported on MS girder in old structure.
- Diagonal cracks were observed in external walls of the old building as well as in new construction as shown in Fig. 39 and Fig. 40.
- The crack was found propagating along the height of walls.

Building type	Masonry type	Flooring	Roof type
Load bearing structure	Stone masonry	Stone floor	Flat girder



Fig. 39. House no. 544 (Diagonal crack on external wall)



Fig. 40. Diagonal crack on outer wall of inside house

15. House no. 910

Observation:

- No. of stories built: Single.
- Occupancy: 5 people.
- House was built in year around 1970.
- The structural cracks were found in external as well as inside walls.
- Diagonal cracks were observed in inside wall of the building as shown in Fig. 41.
- The building was load bearing structure made of stone masonry with lime mortar.
- The roof of house was made with tin sheds.

Building type	Masonrytype	Flooring	Roof type
Load bearing structure	Stonemasonry	Stone flooring	Tin sheds



Fig. 41. House no. 910 (crack on wall)

16. House no. 908

Observation:

- No. of stories built: Single.
- Occupancy: 5 people.
- The building was made of stone masonry. The walls were found to be plastered with cement-sand mortar.
- Cracks were observed in external wall of the house as shown in Fig. 42.
- Vertical cracks were also observed propagating along the height of the wall.

Building type	Masonry type	Flooring	Roof type
Load bearing structure	Stone masonry	Stone flooring	Stone slab



Fig. 42. House no. 908 (Vertical crack on external wall)

17. House no. 885

Observation:

- No. of stories built: G+1.
- Occupancy: 13 people.
- House was built around year 1980.
- The walls were found to be made of stone and brick masonry and cement-sand mortar has been used for plastering.
- Room on ground floor was found to be vacated due to severe cracking in walls and floor.
- Horizontal cracks were observed near joints and corners of roof in the room at first floor as shown in Fig. 43 and Fig. 44.
- Diagonal cracks were observed in bottom of the walls and at the staircase walls as shown in Fig. 45.
- Cracks were also noticed in the inner and outer walls.
- Cracks in walls were found propagating towards floor and ceiling.

Building type	Masonry type	Flooring	Roof type
Load bearing structure	Stone & brick masonry	Stone flooring	Stone slab



Fig. 43. House no. 885 and horizontal crack inside house



Fig. 44. Horizontal crack along roof and wall joint



Fig. 45. Diagonal crack and stone floor

CSIR Touching Lives

18. House no. 2835

Observation:

- No. of stories built: G+1.
- Occupancy: Vacated.
- Building was about 70-80 year old.
- The house was a load bearing structure as shown in Fig. 46.
- Roof was made of stone slab resting on I girders.
- Walls were found to be of rubble stone masonry and it was plastered using cement sand mortar.
- Cracks were found at several locations inside and outside the house.
- Some new construction using bricks and cement sand mortar was found inside the house to support the damaged portion as shown in Fig. 47.
- Diagonal cracks were observed in walls as shown in Fig. 47 and vertical cracks were found along the wall corners.

Building type	Foundation type	Masonry type	Flooring	Roof type	Area
Load bearing structure	Stone masonry	Stone masonry	Stone flooring	Stone slab on I girder	88 sqm



Fig. 46. House no. 2835



Fig. 47. Diagonal crack on wall inside house

CSIR Touching Lives

19. House no. 2836

Observation:

- No. of stories built: G+1.
- Occupancy: 26 people.
- The house was found to be constructed about 60-80 year before and some new house construction work was done around year 2005.
- Walls of old structure were of stone masonry (Fig. 48) and new construction was done using brick masonry.
- Wooden beams were used to support the stone roof slab in old structure whereas new construction was done with RCC.
- Cracks were found in old structure only as shown in Fig. 49 and Fig. 50.

Building type	Foundation type	Masonry type	Flooring	Roof type	Area
Load bearing structure	Stone masonry	Stone and brick masonry	Kota stone	Stone slab on wood and RCC beams	360 sqm



Fig. 48. House no. 2836



Fig. 49.Cracks on wall and roof joint and at wall bottom



Fig. 50.Vertical cracks on wall inside room above door

20. House no. 1095

Observations:

- No. of stories built: G+2.
- Occupancy: 8 people.
    - House was found to be constructed as a load bearing structure having walls made of stone as shown in Fig. 51.
- Lime mortar was used in masonry of wall and outside it was finished with cement mortar.
- Major cracks were found extending diagonally at exterior wall of house as shown in Fig. 52.
- Minor cracks have been also observed inside house as shown in Fig. 53.

Building type	Foundation type	Masonry type	Flooring	Roof type	Area
Load bearing structure	Stone masonry	Stone masonry	Kota stone	Stone slab	60 sqm



Fig. 51. House no. 1095



Fig. 52. Diagonal cracks in exterior wall at front side



Fig. 53. Vertical cracks in corner of wall

21. House no. 1089

Observations:

- No. of stories built: G+1.
- Occupancy: 8 people.
- Ground floor of the house was built around year 1980 and first floor has been constructed recently in year 2017.
- The house is load bearing structure and the wall were made of stone masonry as shown in Fig. 54.
- The work of stone masonry has been carried out using lime mortar and finished with cement sand mortar.
- The cracks were found in newly constructed septic tank which was built 3 years before.
- Minor vertical cracks were observed at first floor of house as shown in Fig. 55.

Building type	Foundation type	Masonry type	Flooring	Roof type	Area
Load bearing structure	Stone masonry	Stone masonry	Kota stone	Stone slab and GI sheet	46 sqm



Fig. 54. House no. 1089



Fig. 55. Vertical crack at first floor

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22. House no. 1093

Observations:

- No. of stories built: Single.
- Occupancy: 5 people.
- House was built around year 2008 and it is a load bearing structure as shown in Fig. 56.
- The walls of house were constructed using stone masonry and thereafter new construction has been done by using brick masonry.
- Vertical cracks were observed in walls inside house as shown in Fig. 57.
- Mud mortar and cement mortar was used in old structure and new construction respectively.

Building type	Foundation type	Masonry type	Flooring	Roof type	Area
Load bearing structure	Stone masonry	Stone and brick masonry	Cement	Stone slab	44 sqm



Fig. 56. House no. 1093



Fig. 57. Vertical crack in wall inside house

75 Years of
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23. House no. 841

Observations:

- No. of stories built: G+1.
- Occupancy: 20 people.
- House was built around year 1995.
- The building was found to be a partial load bearing structure with stone pillars erected at few locations as shown Fig. 58.
- Stone and brick masonry was used with lime mortar in construction of house.
- Vertical and diagonal cracks were observed in walls and wall corners of house as shown in Fig. 59.

Building type	Foundation type	Masonry type	Flooring	Roof type	Area
Load bearing structure	Stone masonry	Stone and brick masonry	Cement	Stone slab with I girders	160 sqm



Fig. 58. House no. 841



Fig. 59. Diagonal cracks in walls of house

24. House no. 1112

Observations:

- No. of stories built: G+1.
- Occupancy: 7 people.
- Ground floor of house was built around year 2010 as a partial load bearing structure with stone pillars whereas first floor constructed later in year 2015 as shown Fig. 60 and Fig. 61.
- The RCC columns were found to be constructed at first floor of house.
- The walls were made of stone masonry and it was plastered with cement-sand mortar.
- Diagonal cracks were observed at many locations of house as shown in Fig. 61.

Building type	Foundation type	Masonry type	Flooring	Roof type	Area
Load bearing structure	Stone masonry	Stone and brick masonry	Cement	Stone slab	70 sqm



Fig. 60. House no. 1112



Fig. 61. Diagonal cracks in walls of house

25 Years of
CSIR Touching Lives

25. House no. 891

Observation:

- No. of stories built: Single.
- Occupancy: Vacated.
- Building was built around 1980.
- Diagonal cracks were observed in external wall of the building.
- Cracks were found to be located near window and it was propagating to roof level.

Building type	Masonry type	Flooring	Roof type
Load bearing structure	Stone masonry	Stone flooring	Stone slab

26. House no. 886

Observation:

- No. of stories built: Single.
- Occupancy: Vacated.
- House was built around year 1980.
- The wall was observed to be made of stone masonry.
- Vertical cracks were observed between two entry doors in external wall of the building.
- Crack was found to be propagating up to roof level.

Building type	Masonry type	Flooring	Roof type
Load bearing structure	Stone masonry	Stone flooring	Stone slab

27. House no. 880

Observation:

- No. of stories built: G+1.
- Occupancy: 12 people.
- House was built in year 2002.
- The walls were found to be made of both stone and brick masonry.
- Diagonal cracks were observed on side wall of the building.
- Cracks in walls were observed propagating towards roof from window.

Building type	Masonrytype	Flooring	Roof type
Load bearing structure	Stone & brick masonry	Marble stone floor	Stone slab

75 Years of CSIR Touching Lives

Annexure - A

Table A1: Location of Demec points at various places in Pur village, Bhilwara

Sr. No.	Location	Demic Points
1	Govt. Primary School	D1, D2, D3, D188, D189
2	Govt. Higher Secondary School	D4, D5
3	Village General Hospital	D6, D6, D7, D8, D9, D10, D190, D191, D192, D217
4	Govt. Girls School	D11, D208, D209
5	Laxmi Narayan temple	D23, D24, D25, D26, D27, D28, D29, D30, D31, D32, D33, D34, D35, D184, D185, D186, D187
6	Madina Masjid	D134, D134, D135, D136, D137, D138, D139, D140, D141, D142
7	House no. 2835	D12, D13
8	House no. 2836	D14
9	House no.2249	D15, D16, D17, D18, D19, D20
10	House no. 2251	D21, D22
11	House no. 1936	D36
12	House no. 1952	D37, D38,39
13	House no. 1956	D40, D41, D42, D43,D45, D46
14	House no. 1962	D44
15	House no. 1970	D47
16	House no. 1982	D48
17	House no. 2213	D49
18	House no. 2377	D50, D51
19	House no. 2489	D52
20	House no. 2490	D53, D54, D55
21	House no. 2669	D56, D57
22	House no. 2491	D58
23	House no. 2496	D59, D60
24	House no. 2492	D61
25	House no. 2502	D62, D64
26	House no. 2505	D63, D65
27	Shop no. 1100	D66, D67, D68, D69
28	House no. 1095	D70, D71, D72, D100, D101
29	House no. 1089	D73
30	House no. 1092	D74
31	House no. 1093	D75, D76
32	House no. 841	D77, D78, D79, D80, D81
33	House no. 1064	D82, D83

34	House no. 1066	D84, D85
35	House no. 1068	D86, D87
36	House no. 1077	D88, D89
37	House no. 1073	D90
38	House no. 1067	D91, D92, D93
39	House no. 1079	D94
40	House no. 878	D95, D96
41	House no. 882	D97, D98, D99
42	House no. 1353	D102, D103, D104, D105, D106, D107, D108, D109
43	House no. 1372	D110, D111, D112, D113, D114
44	House no. 1375	D115, D116
45	House no. 1378	D117
46	Shop no. 1582	D118, D119
47	Shop no. 1581	D120, D121
48	Shop no. 1635	D122
49	House no. 1567	D123
50	House no. 112	D124, D125, D126
51	House no. 1126	D127
52	House no. 1122	D128
53	House no. 1132	D129
54	House no. 1135	D130
55	House no. 1141	D131, D132, D133
56	House no. 2245	D143, D144, D145, D146, D147, D148
57	House no.2249	D149, D150, D151, D152, D153, D153, D154, D155, D156, D157
58	House no. 2248	D158, D159, D160, D161, D162, D163, D164, D165, D166, D167
59	House no. 2235	D168, D169, D170, D171, D172
60	House no. 2234	D173, D174, D175, D176, D177
61	House no. 2237	D178, D179
62	House no. 2826	D180, D181, D182, D183
63	House no. 2822	D193, D194, D195, D196,
64	House no. 2824	D197, D198, D199, D200
65	House no. 2823	D201, D202, D203, D204, D205
66	House no. 2835	D206, D207
67	House no. 2324	D210, D211, D212, D213, D214, D215
68	House no. 1374	D216
69	House no. 2246	D218, D219
70	House no. 2216	D220,D221,D222

71	House no. 2226	D223
72	House no. 2225	D224, D225, D226
73	House no. 2223	D227
74	House no. 544	D228, D229, D230, D231, D232
75	House no. 910	D233
76	House no. 908	D234
77	House no. 891	D235
78	House no. 886	D236
79	House no. 880	D237

75 Years of CSIR Touching Lives

Table A2: Crack dimension of demec points installed at various important structures

Sr. No.	Location	Demec point No.	Demec Points ID	Crack widening (mm)
1	Govt. Primary School	1	D1	0.301
		2	D2	1.146
		3	D3	-0.238
		4	D188	Removed
		5	D189	-0.211
2	Govt. Higher Secondary School	6	D4	0.066
		7	D5	0.436
3	Village General Hospital	8	D6	-1.053
		9	D7	0.512
		10	D8	-0.869
		11	D9	-0.850
		12	D10	-0.337
		13	D190	0.181
		14	D191	-0.362
		15	D192	-0.395
		16	D217	-0.265
4	Govt. Girls School	17	D11	Repaired
		18	D208	Repaired
		19	D209	Repaired
5	Laxmi Narayan Temple	20	D23	3.243
		21	D24	2.095
		22	D25	-1.942
		23	D26	2.100
		24	D27	-1.323
		25	D28	0.088
		26	D29	0.755
		27	D30	-0.492
		28	D31	3.193
		29	D32	Removed
		30	D33	0.006
		31	D34	0.650
		32	D35	0.306
		33	D184	-0.216
		34	D185	Removed
		35	D186	0.130
		36	D187	Removed
6	MadinaMasjid	37	D134	Repaired

		38	D135	Repaired
		39	D136	-0.092
		40	D137	Removed
		41	D138	0.166
		42	D139	0.295
		43	D140	-0.099
		44	D141	-0.396
		45	D142	0.007

Table A3: Crack dimension of demec points installed at various houses in Pur village

Sr. No.	Location	Demec point No.	Demec Points ID	Cracking
7	House no. 2835	46	D12	0.226
		47	D13	0.081
8	House no. 2836	48	D14	-0.175
9	House no.2249	49	D15	Removed
		50	D16	-2.979
		51	D17	Removed
		52	D18	0.130
		53	D19	0.047
		54	D20	0.184
10	House no. 2251	55	D21	-0.030
		56	D22	0.091
11	House no. 1936	57	D36	0.09
12	House no. 1952	58	D37	-0.001
		59	D38	-0.425
		60	D39	0.024
13	House no. 1956	61	D40	0.036
		62	D41	-0.298
		63	D42	-0.034
		64	D43	0.077
		65	D45	Removed
		66	D46	0.321
14	House no. 1962	67	D44	0.145
15	House no. 1970	68	D47	0.151
16	House no. 1982	69	D48	Removed
17	House no. 2213	70	D49	Removed
18	House no. 2377	71	D50	2.984
		72	D51	3.310
19	House no. 2489	73	D52	0.122
20	House no. 2490	74	D53	-2.018

		75	D54	0.165
		76	D55	0.295
21	House no. 2669	77	D56	0.257
		78	D57	0.351
22	House no. 2491	79	D58	0.185
23	House no. 2496	80	D59	0.248
		81	D60	0.843
24	House no. 2492	82	D61	Repaired
25	House no. 2502	83	D62	0.058
		84	D64	-0.174
26	House no. 2505	85	D63	0.641
		86	D65	0.584
27	Shop no. 1100	87	D66	Removed
		88	D67	-0.139
		89	D68	Removed
		90	D69	0.522
28	House no. 1095	91	D70	Removed
		92	D71	Removed
		93	D72	0.878
		94	D100	-0.271
		95	D101	0.047
29	House no. 1089	96	D73	Removed
30	House no. 1092	97	D74	0.846
31	House no. 1093	98	D75	0.036
		99	D76	0.091
32	House no. 841	100	D77	0.446
		101	D78	0.327
		102	D79	0.238
		103	D80	0.241
		104	D81	0.336
33	House no. 1064	105	D82	0.315
		106	D83	-1.498
34	House no. 1066	107	D84	Removed
		108	D85	Removed
35	House no. 1068	109	D86	Repaired
		110	D87	Repaired
36	House no. 1077	111	D88	Removed
		112	D89	0.731
37	House no. 1073	113	D90	-1.227
38	House no. 1067	114	D91	-0.103
		115	D92	0.134
		116	D93	0.229
39	House no. 1079	117	D94	-0.024

40	House no. 878	118	D95	Removed
		119	D96	Removed
41	House no. 882	120	D97	0.180
		121	D98	0.228
		122	D99	0.361
42	House no. 1353	123	D102	Repaired
		124	D103	Repaired
		125	D104	Repaired
		126	D105	Removed
		127	D106	Repaired
		128	D107	Repaired
		129	D108	Repaired
		130	D109	Repaired
43	House no. 1372	131	D110	Removed
		132	D111	2.122
		133	D112	1.024
		134	D113	1.557
		135	D114	1.607
44	House no. 1375	136	D115	-0.856
		137	D116	Removed
45	House no. 1378	138	D117	1.743
46	Shop no. 1582	139	D118	-1.229
		140	D119	2.509
47	Shop no. 1581	141	D120	2.548
		142	D121	1.198
48	Shop no. 1635	143	D122	Removed
49	House no. 1567	144	D123	2.541
50	House no. 112	145	D124	1.889
		146	D125	Removed
		147	D126	-2.440
51	House no. 1126	148	D127	2.539
52	House no. 1122	149	D128	0.955
53	House no. 1132	150	D129	-0.097
54	House no. 1135	151	D130	2.970
55	House no. 1141	152	D131	Removed
		153	D132	Removed
		154	D133	2.900
56	House no. 2245	155	D143	1.570
		156	D144	0.340
		157	D145	2.539
		158	D146	0.076
		159	D147	1.897
		160	D148	0.000

57	House no.2249	161	D149	Removed
		162	D150	0.065
		163	D151	0.463
		164	D152	-0.066
		165	D153	0.050
		166	D154	0.281
		167	D155	1.209
		168	D156	0.042
		169	D157	0.402
58	House no. 2248	170	D158	Removed
		171	D159	Removed
		172	D160	Removed
		173	D161	Removed
		174	D162	-0.988
		175	D163	-0.998
		176	D164	-0.903
		177	D165	0.164
		178	D166	-0.012
		179	D167	0.174
59	House no. 2235	180	D168	0.281
		181	D169	0.184
		182	D170	0.237
		183	D171	Removed
		184	D172	0.090
60	House no. 2234	185	D173	-1.577
		186	D174	-0.773
		187	D175	1.906
		188	D176	-3.144
		189	D177	Removed
61	House no. 2237	190	D178	0.680
		191	D179	-0.057
62	House no. 2826	192	D180	1.801
		193	D181	-1.667
		194	D182	Removed
		195	D183	-3.180
63	House no. 2822	196	D193	0.106
		197	D194	0.019
		198	D195	0.525
		199	D196	0.338
64	House no. 2824	200	D197	0.071
		201	D198	0.080
		202	D199	-0.085
		203	D200	0.004

65	House no. 2823	204	D201	-0.630
		205	D202	-0.72
		206	D203	-0.903
		207	D204	-0.001
		208	D205	0.168
66	House no. 2835	209	D206	-0.014
		210	D207	0.147
67	House no. 2324	211	D210	0.53
		212	D211	2.331
		213	D212	1.277
		214	D213	0.739
		215	D214	0.402
		216	D215	0.283
68	House no. 1374	217	D216	Removed

75 Years of
CSIR Touching Lives

Table A4: Initial readings of demec points installed at additional locations in Pur village

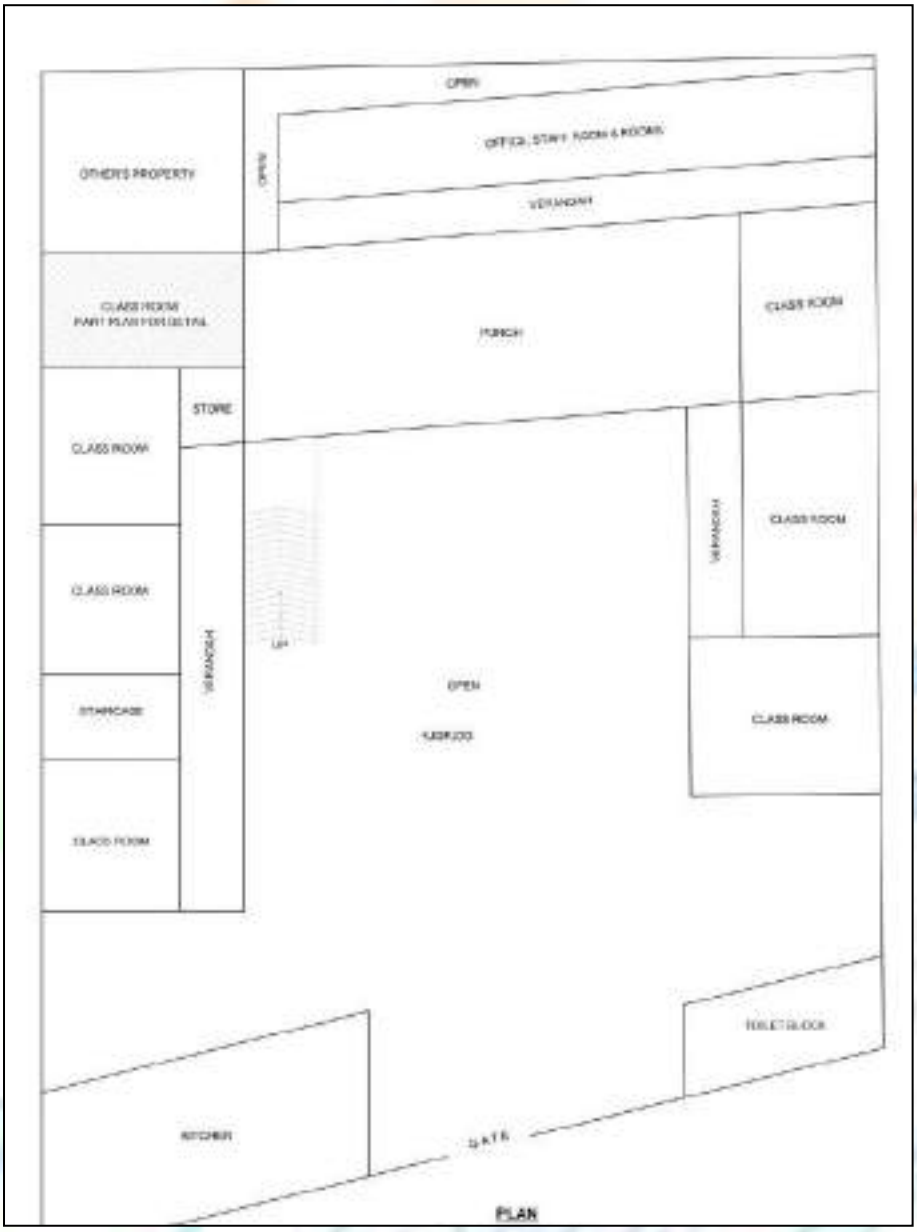
Sr. No.	Location	Demec point No.	Demec points ID	Initial reading
69	House no. 2246	218	D218	-0.934
		219	D219	0.117
70	House no. 2216	220	D220	1.935
		221	D221	0.341
		222	D222	2.159
71	House no. 2226	223	D223	2.023
72	House no. 2225	224	D224	-0.545
		225	D225	1.734
		226	D226	-0.091
73	House no. 2223	227	D227	2.298
74	House no. 544	228	D228	6.091
		229	D229	-0.650
		230	D230	3.190
		231	D231	5.237
		232	D232	7.538
75	House no. 910	233	D233	2.603
76	House no. 908	234	D234	1.335
77	House no. 891	235	D235	3.870
78	House no. 886	236	D236	6.524
79	House no. 880	237	D237	5.647

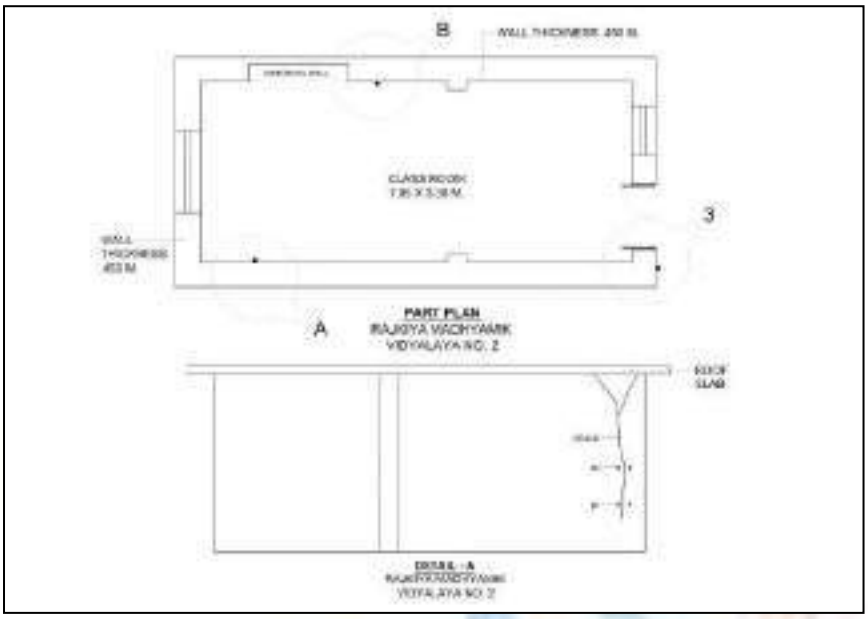
75 Years of CSIR Touching Lives

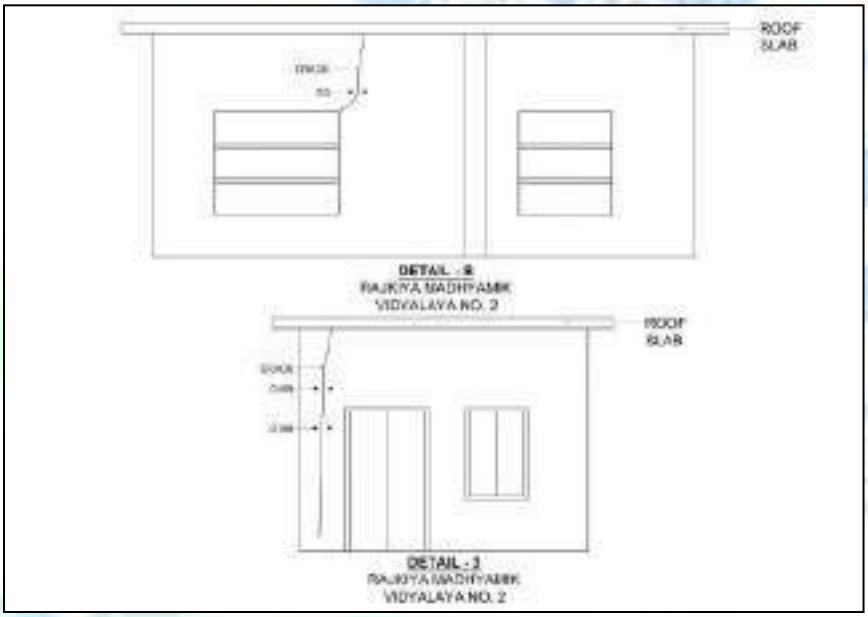
Annexure - B

Architectural drawings with crack detailing

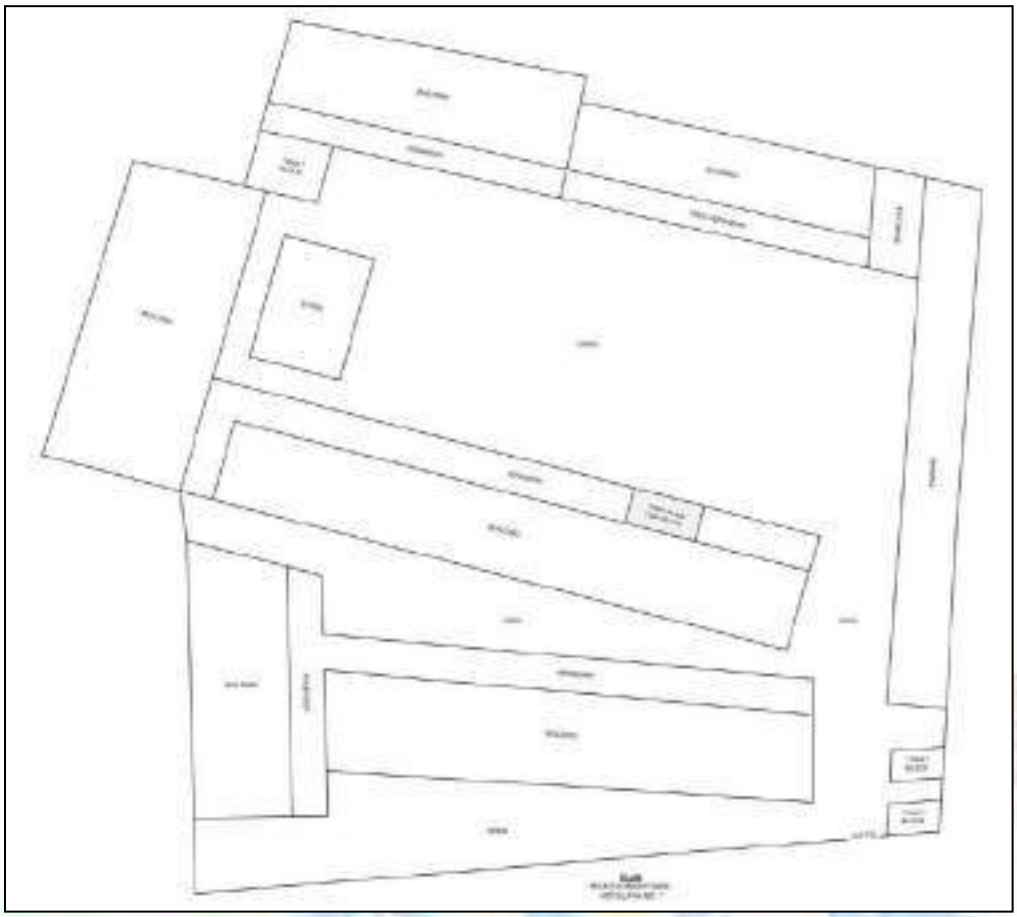
B1. Government Primary School

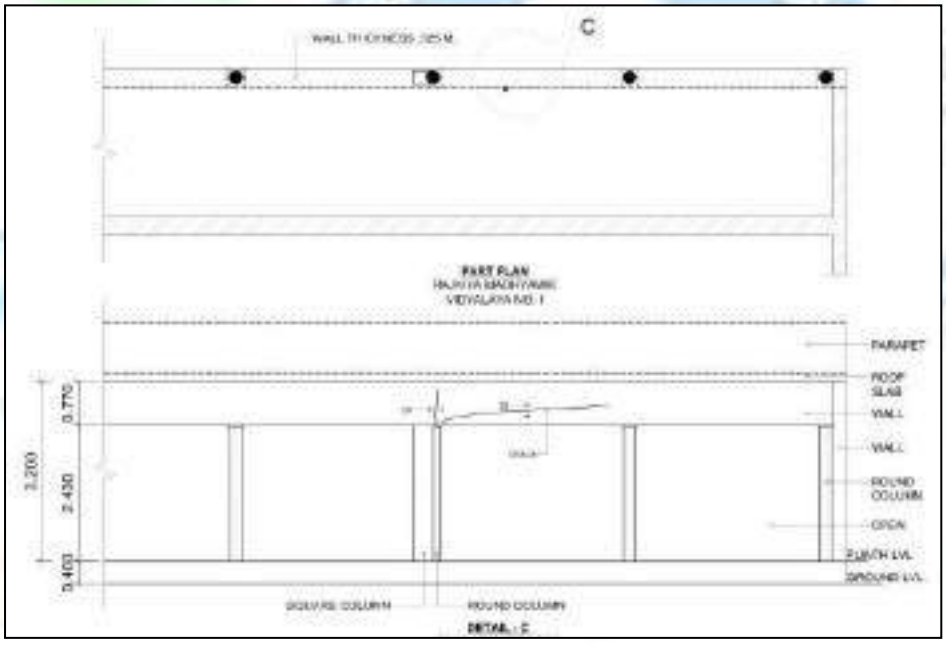



B
3
A
PART PLAN
RAJKIYA MADHYAMIK
VIDYALAYA NO. 2
ROOF
SLAB

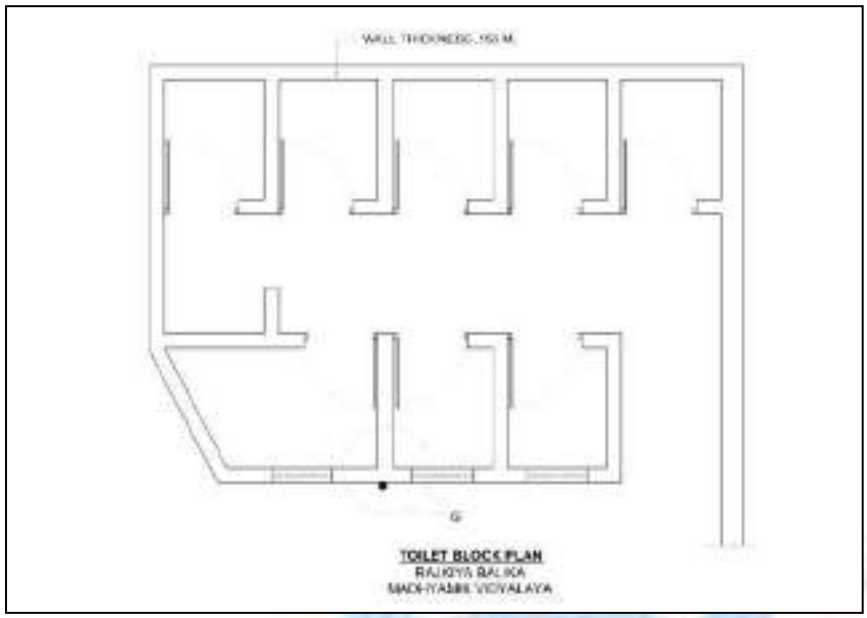

ROOF
SLAB
DETAIL - B
RAJKIYA MADHYAMIK
VIDYALAYA NO. 2
ROOF
SLAB
DETAIL - 3
RAJKIYA MADHYAMIK
VIDYALAYA NO. 2

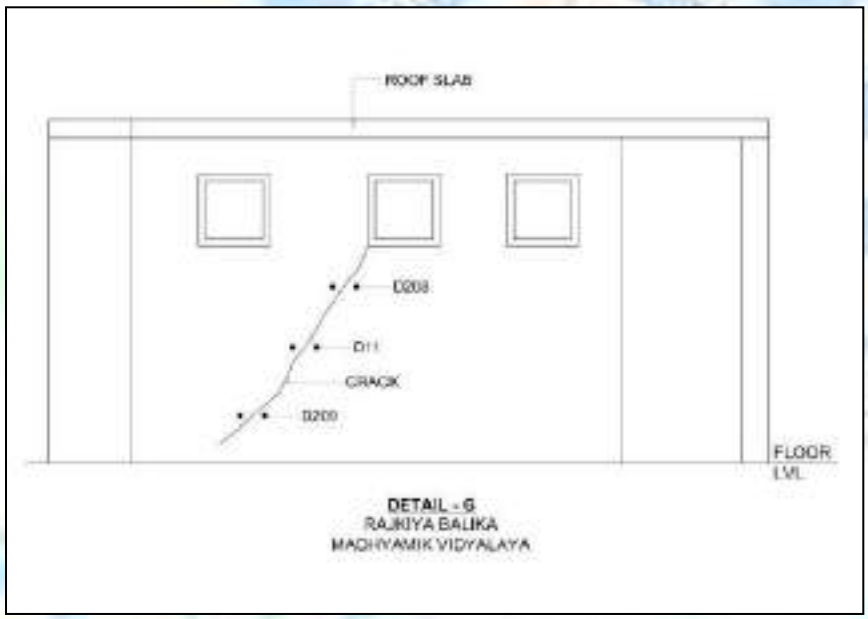
B2. Government Higher Secondary School



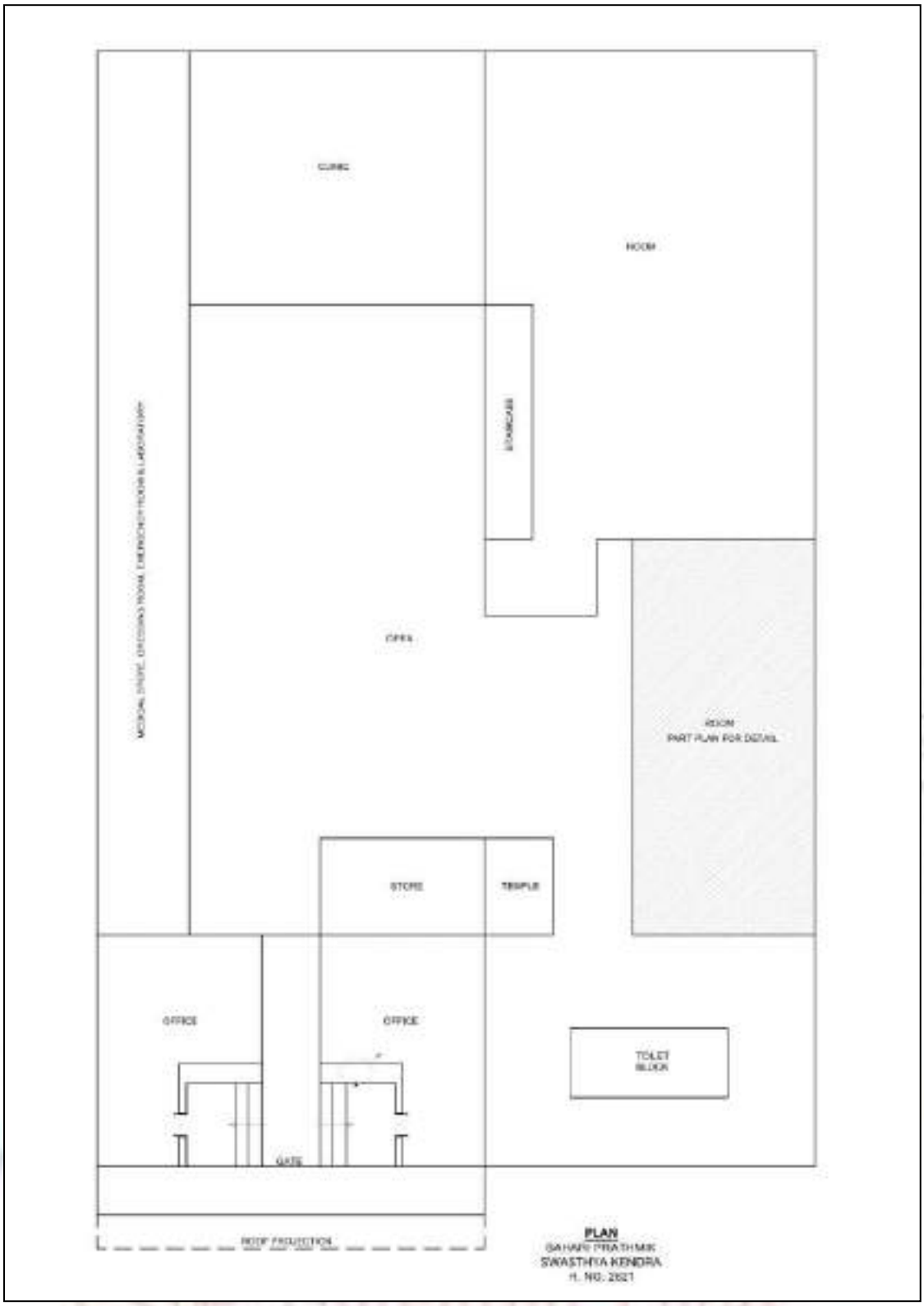


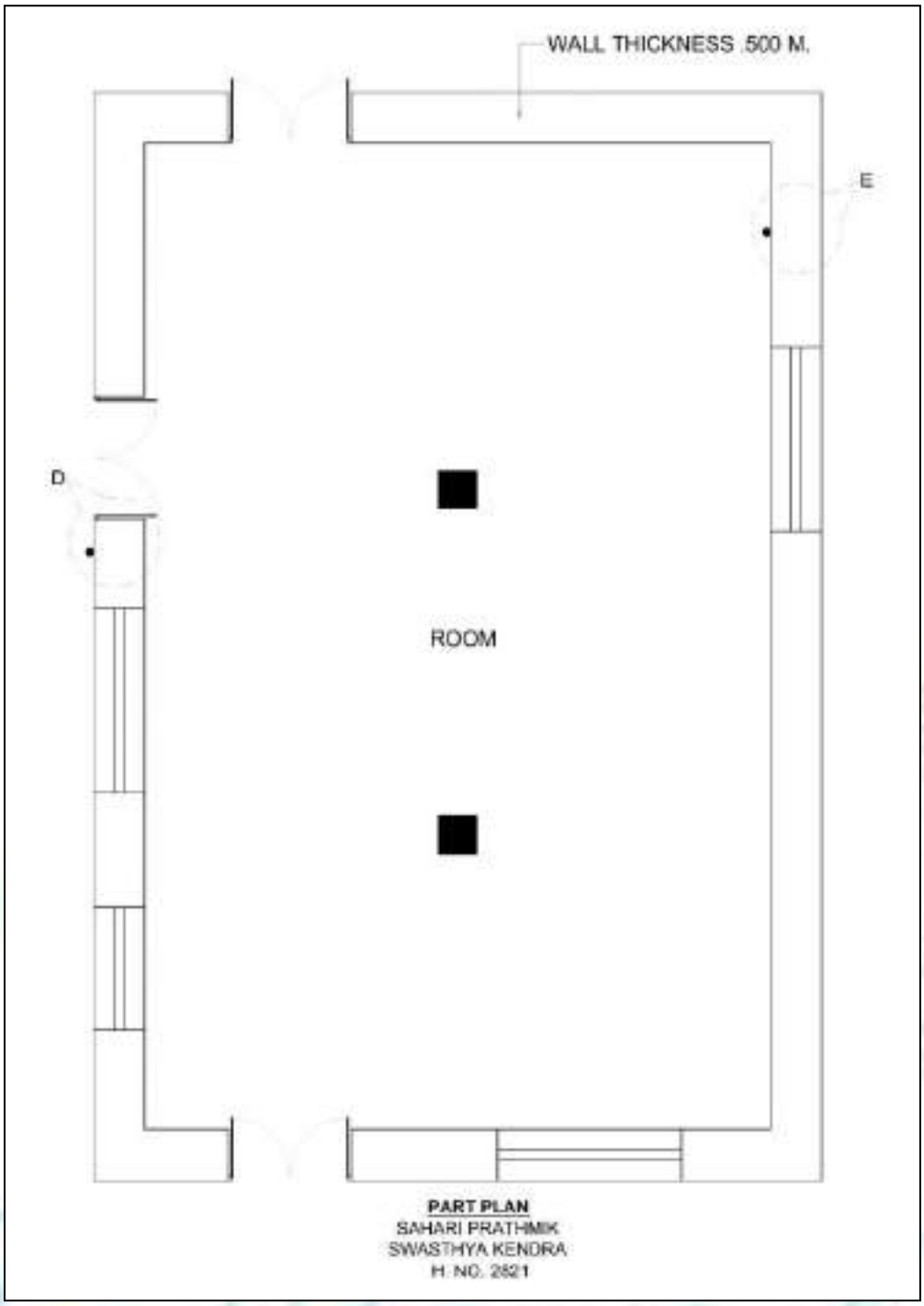
B3. Government Girls School



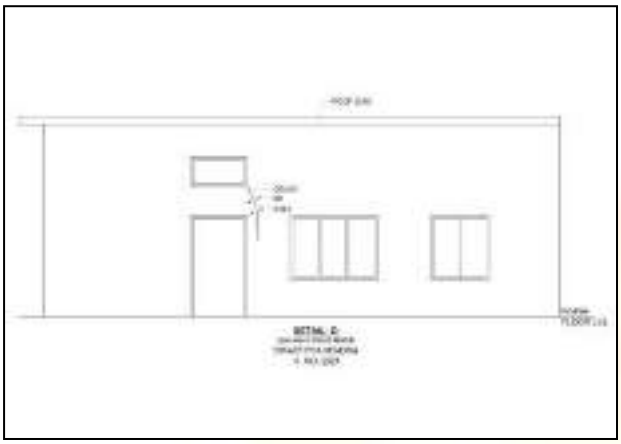


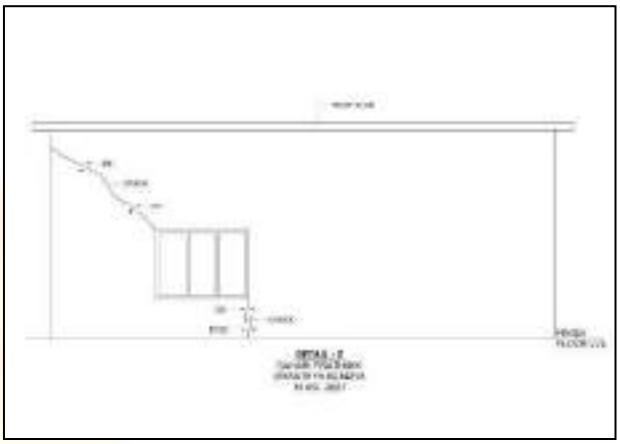
B4. Village General Hospital

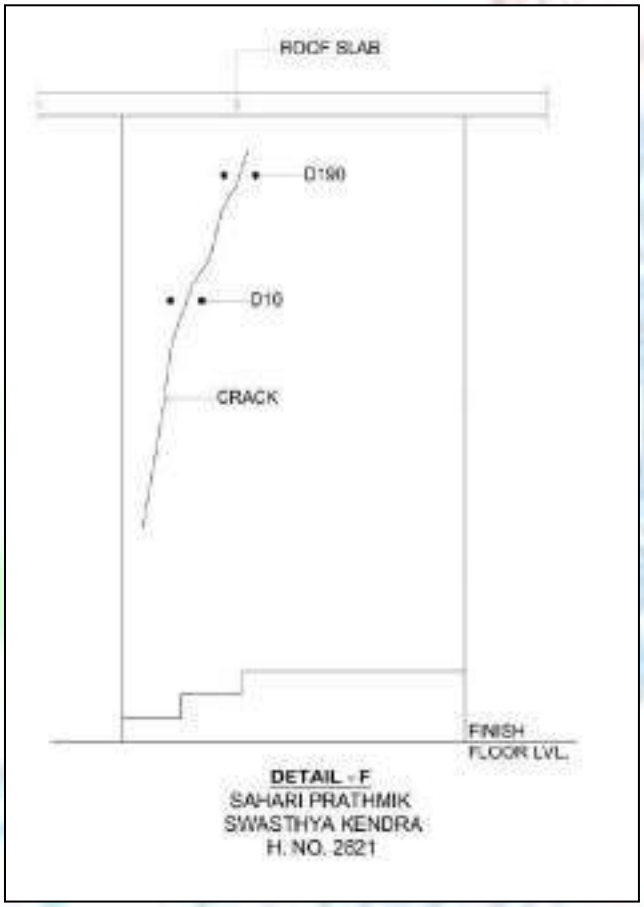




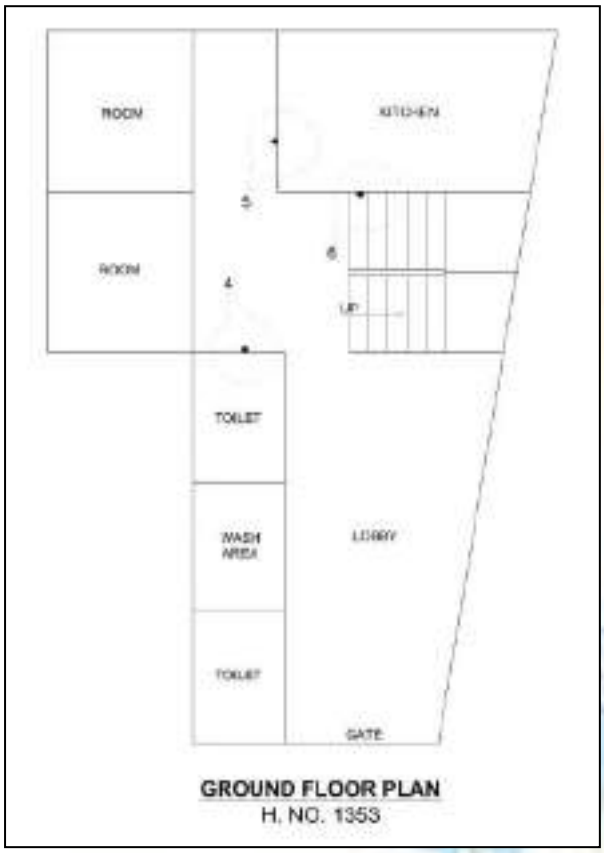
PART PLAN
SAHARI PRATHMIK
SWASTHYA KENDRA
H. NO. 2621



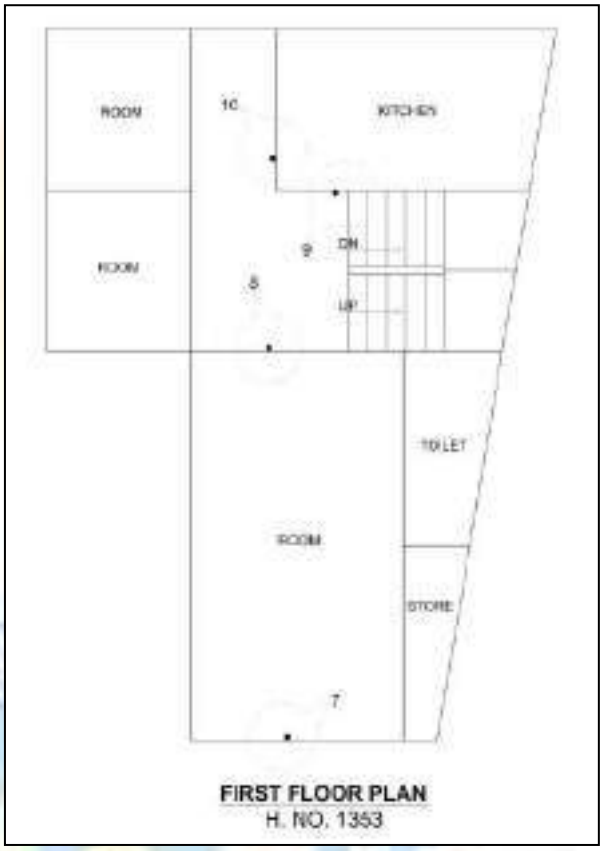



ROOF SLAB
D150
D10
CRACK
FINISH
FLOOR LVL.
DETAIL - F
SAHARI PRATHMIK
SWASTHYA KENDRA
H. NO. 2621

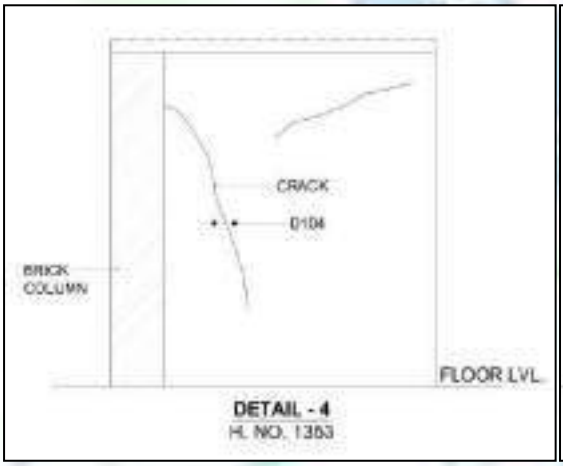
B5. House no. 1353



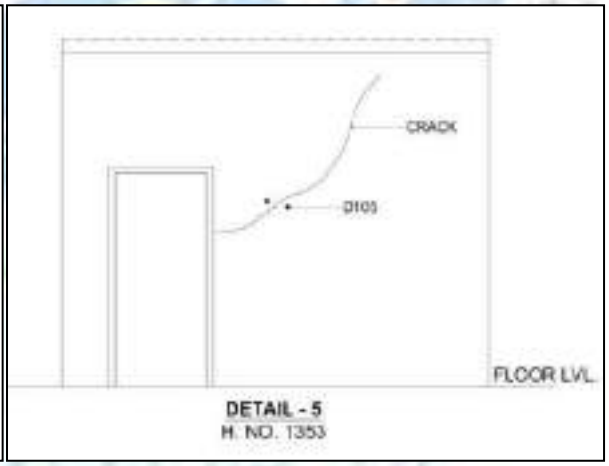
GROUND FLOOR PLAN
H. NO. 1353



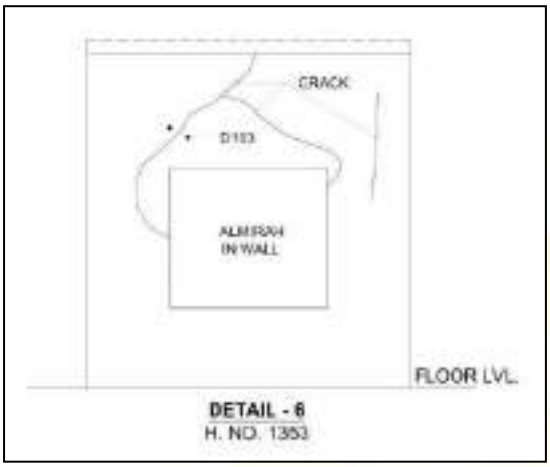
FIRST FLOOR PLAN
H. NO. 1353



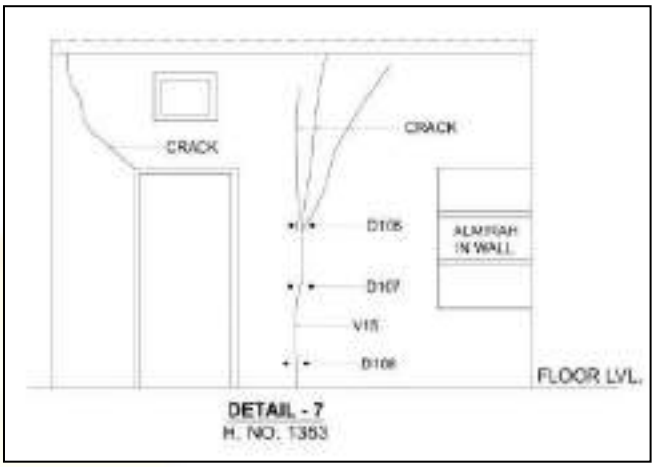
DETAIL - 4
H. NO. 1353



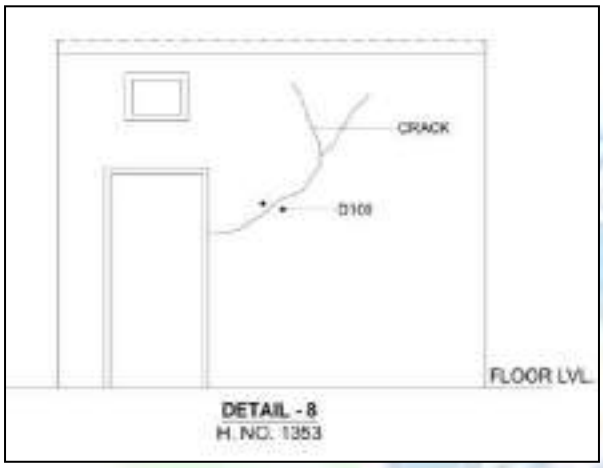
DETAIL - 5
H. NO. 1353



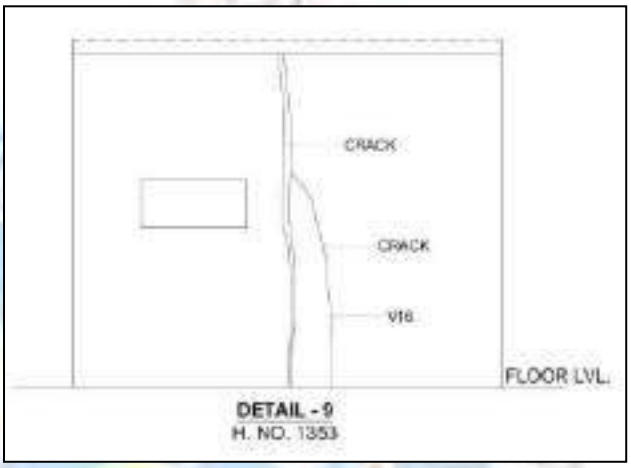
DETAIL - 6
H. NO. 1353



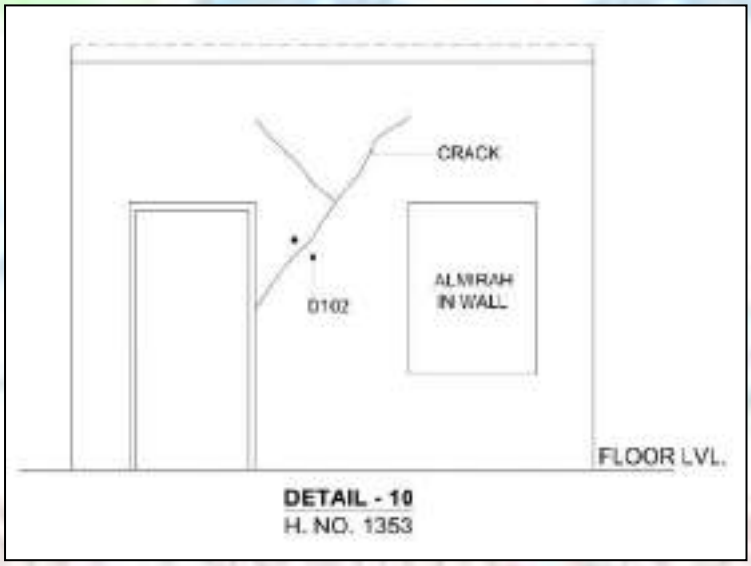
DETAIL - 7
H. NO. 1353



DETAIL - 8
H. NO. 1353

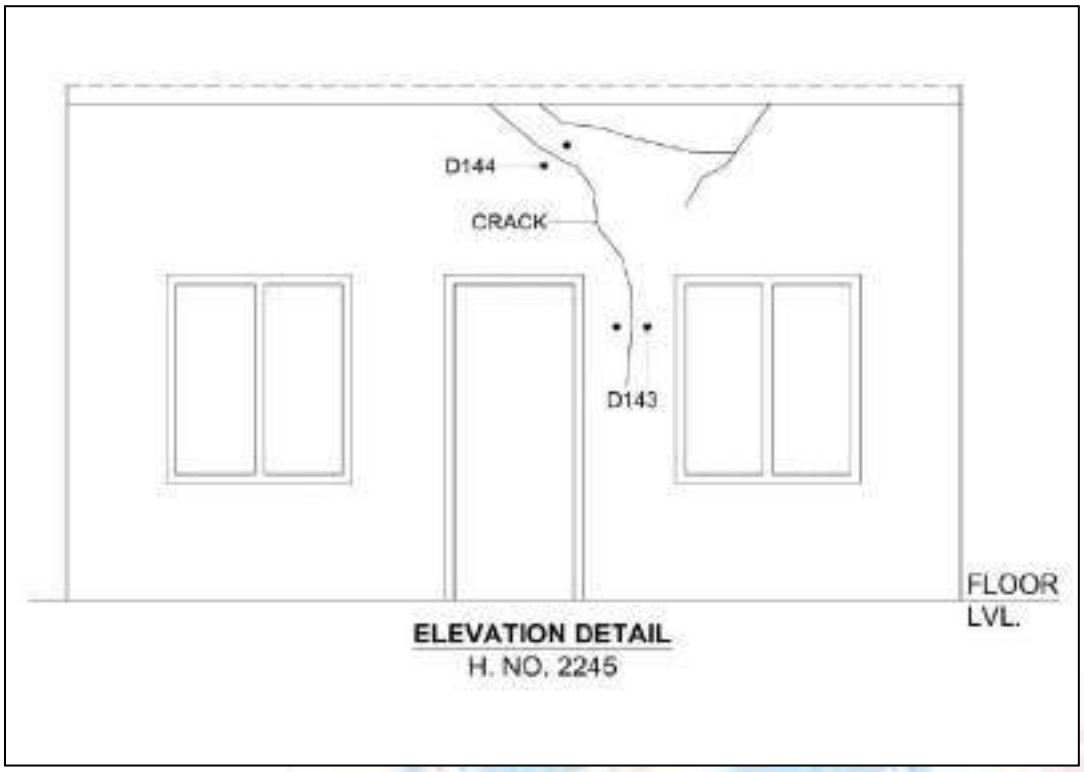


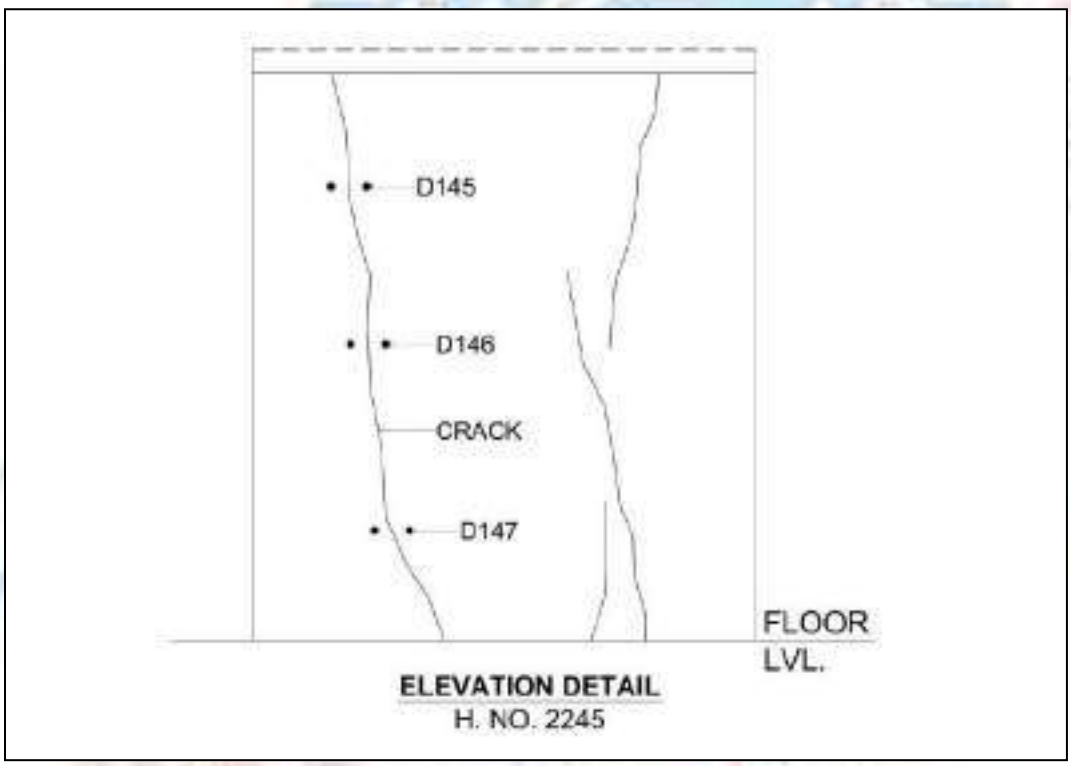
DETAIL - 9
H. NO. 1353



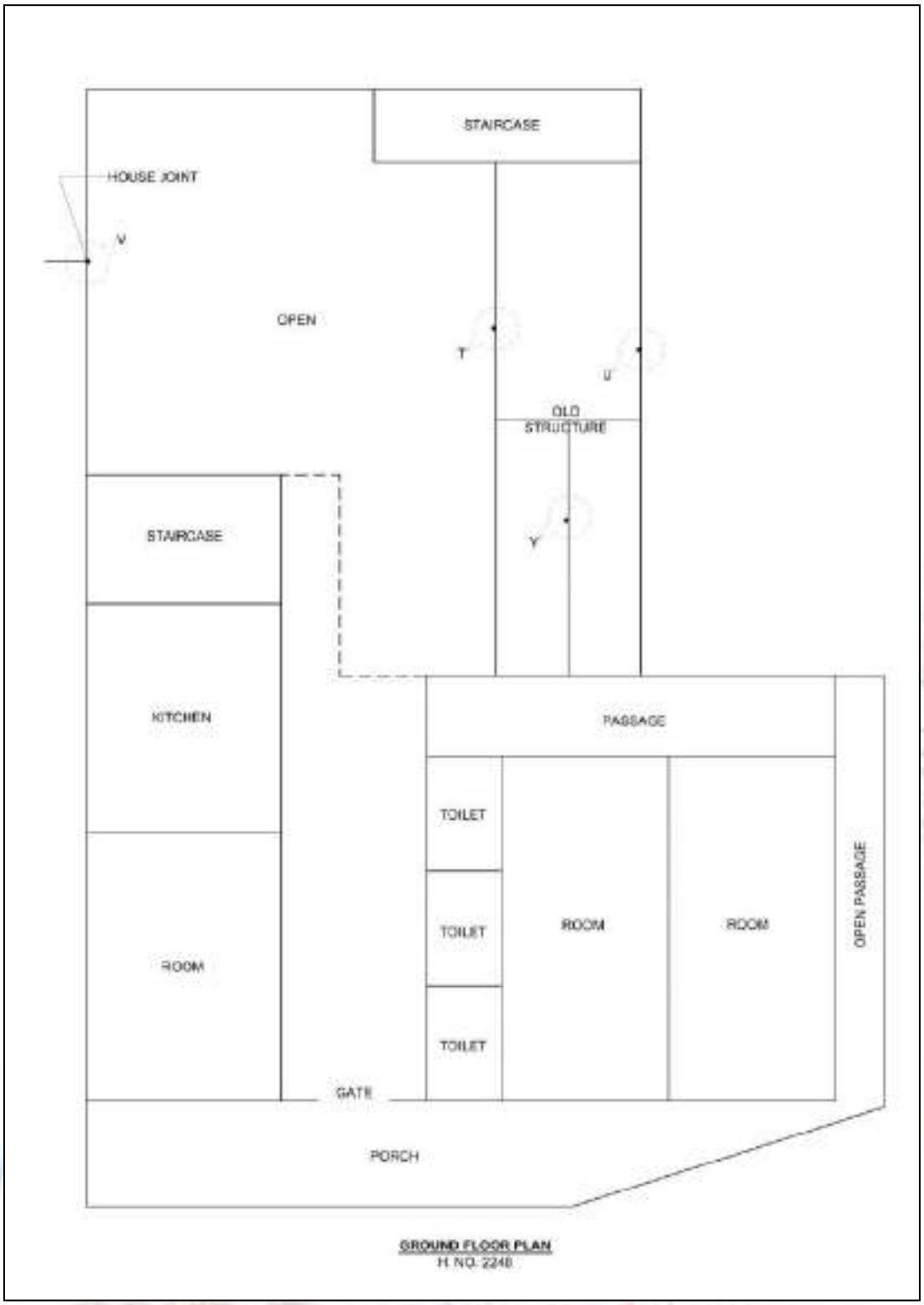
DETAIL - 10
H. NO. 1353

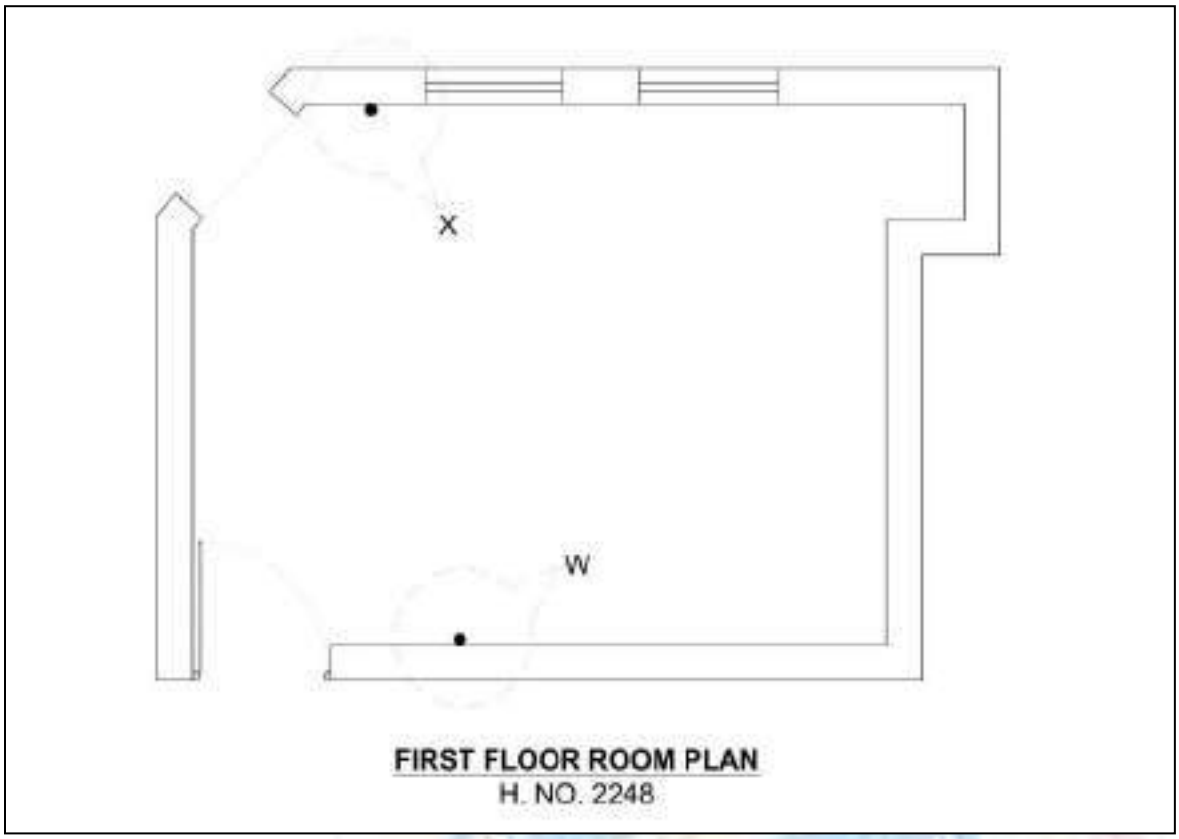
B6. House no. 2245



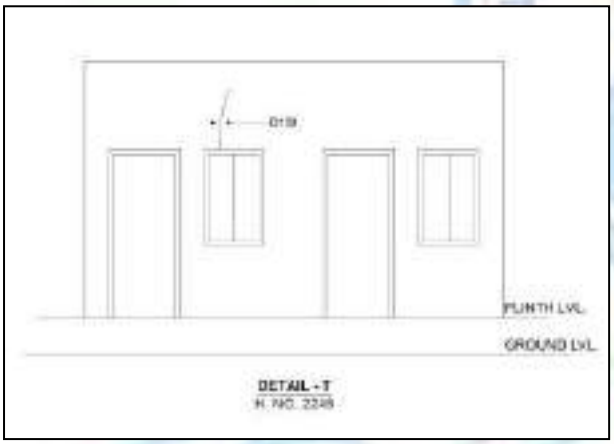


B7. House no. 2248

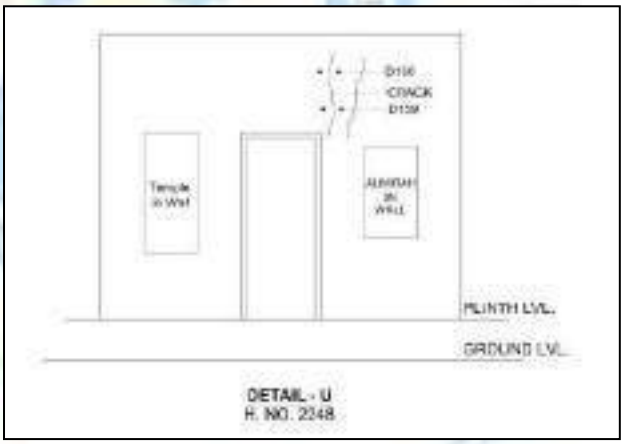




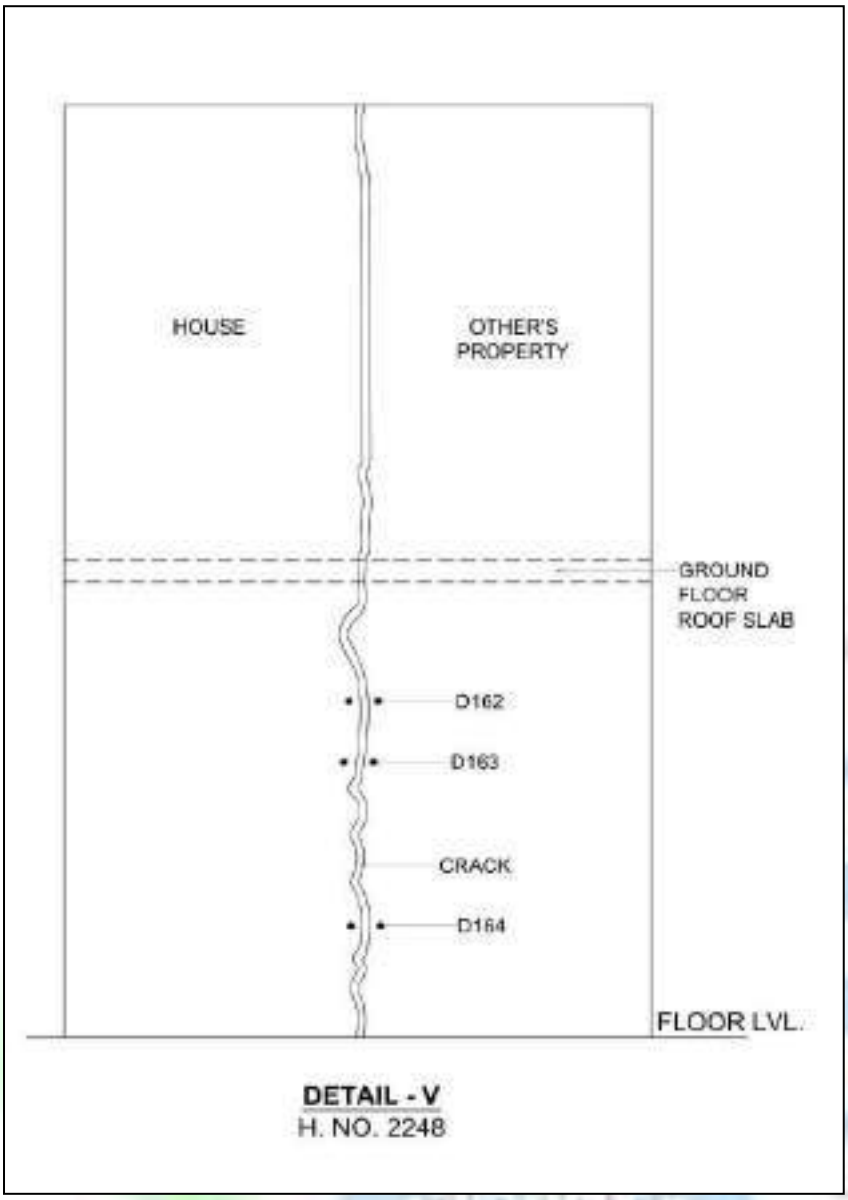
FIRST FLOOR ROOM PLAN
H. NO. 2248



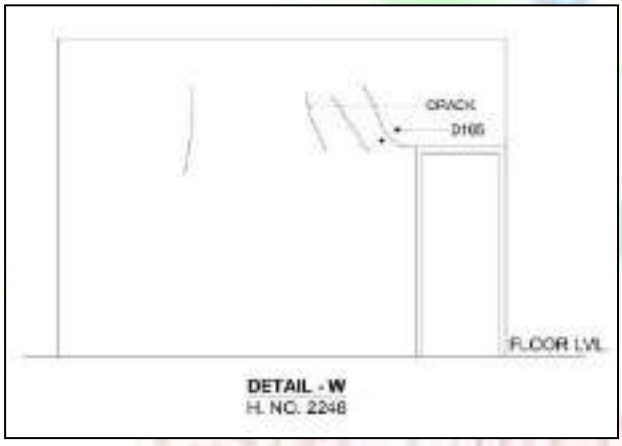
DETAIL - T
H. NO. 2248



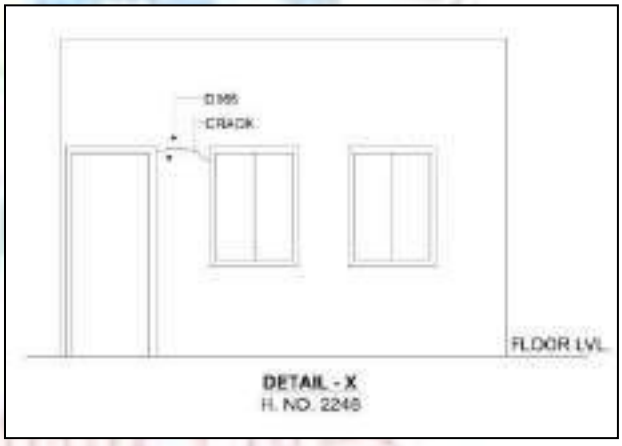
DETAIL - U
H. NO. 2248



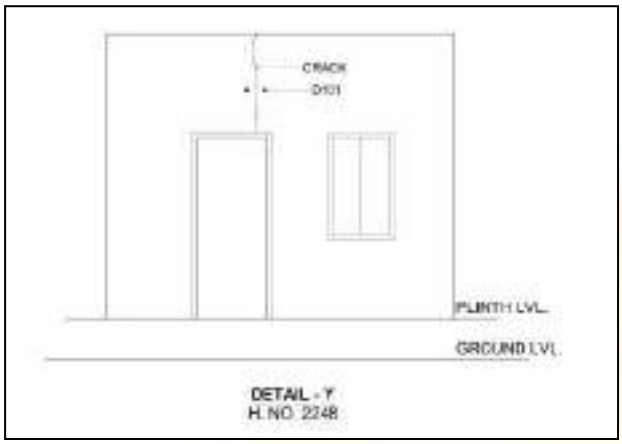
DETAIL - V
H. NO. 2248



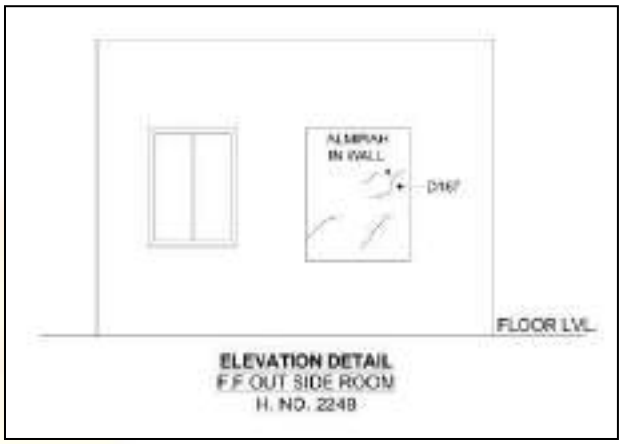
DETAIL - W
H. NO. 2248



DETAIL - X
H. NO. 2248



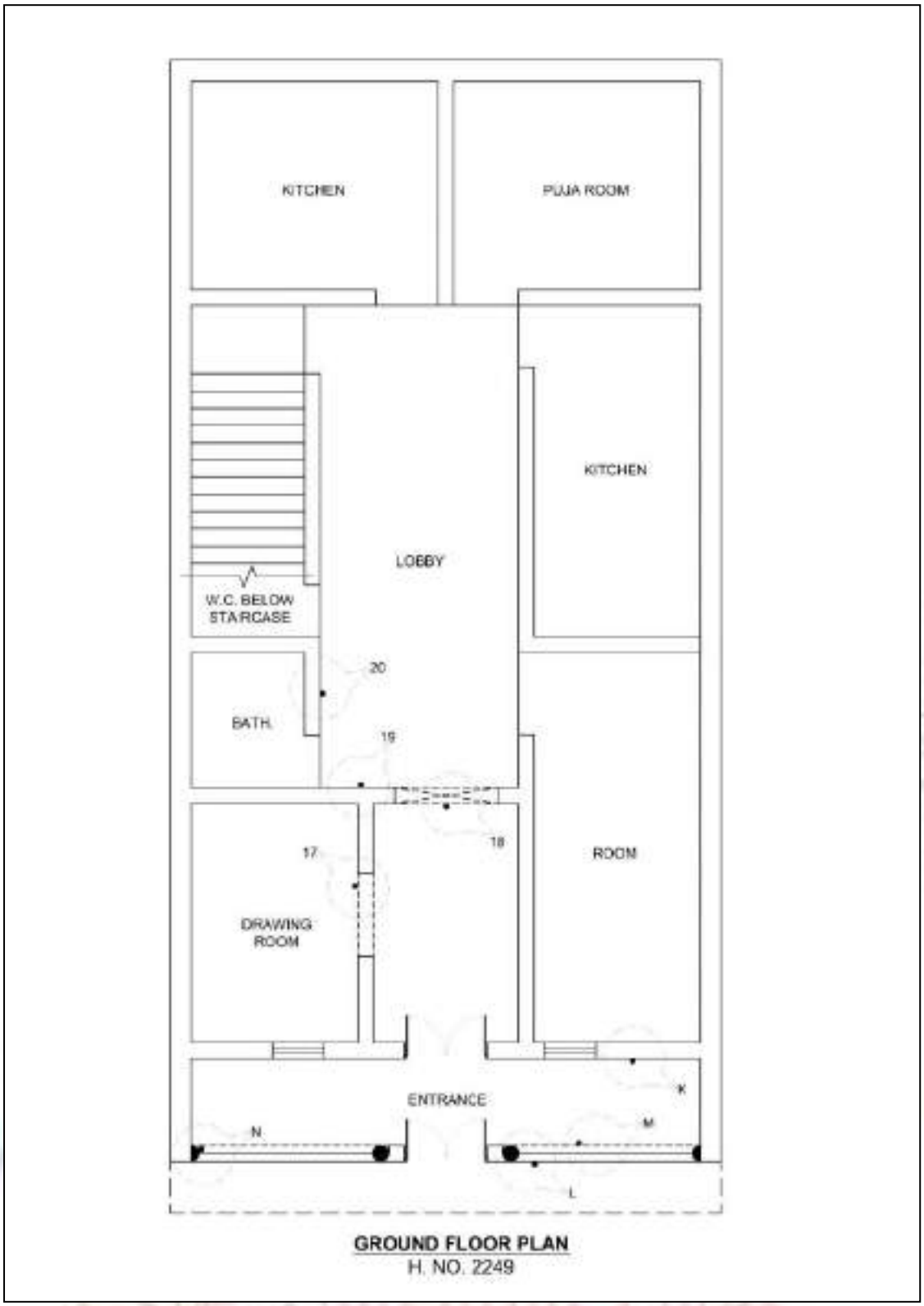
DETAIL - Y
H. NO. 2248



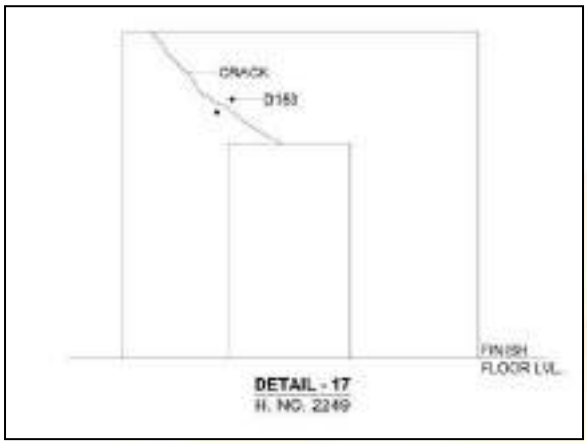
ELEVATION DETAIL
F.F. OUT SIDE ROOM
H. NO. 2248

75 Years of
CSIR Touching Lives

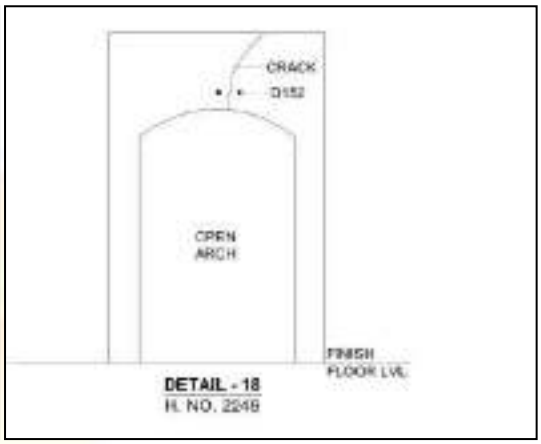
B8. House no. 2249



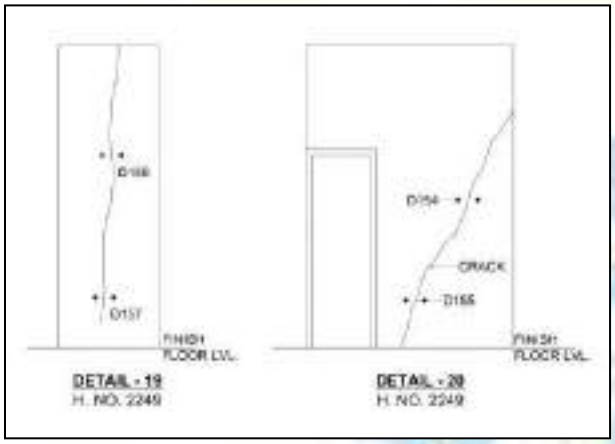
GROUND FLOOR PLAN
H. NO. 2249



DETAIL - 17
H. NO. 2249

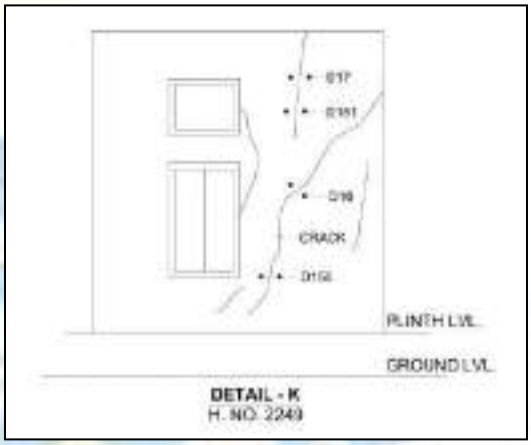


DETAIL - 18
H. NO. 2249

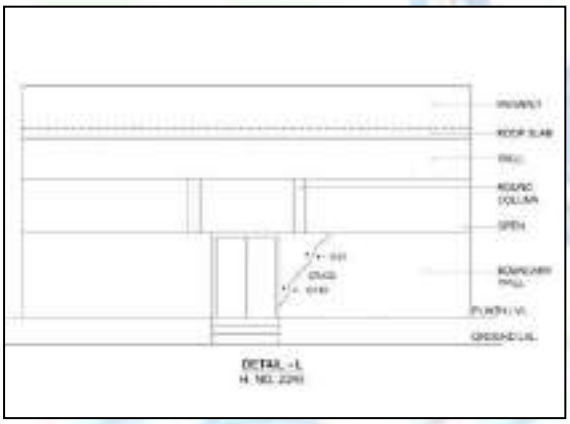


DETAIL - 19
H. NO. 2249

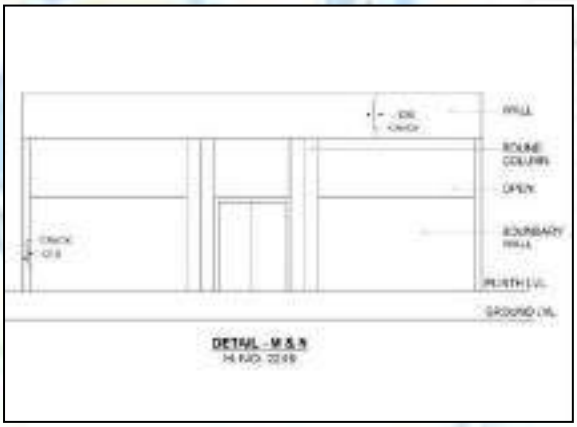
DETAIL - 20
H. NO. 2249



DETAIL - K
H. NO. 2249

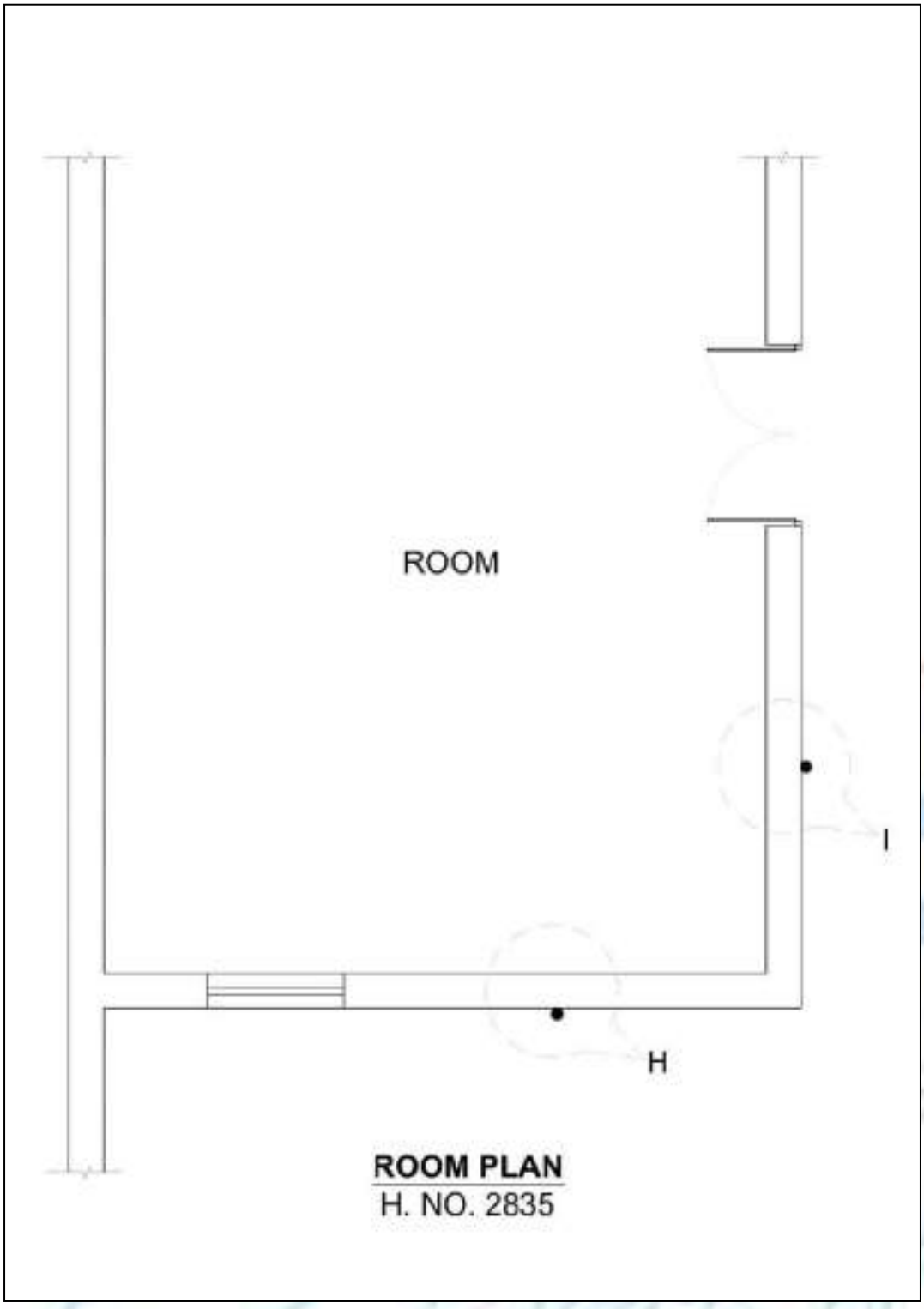


DETAIL - L
H. NO. 2249

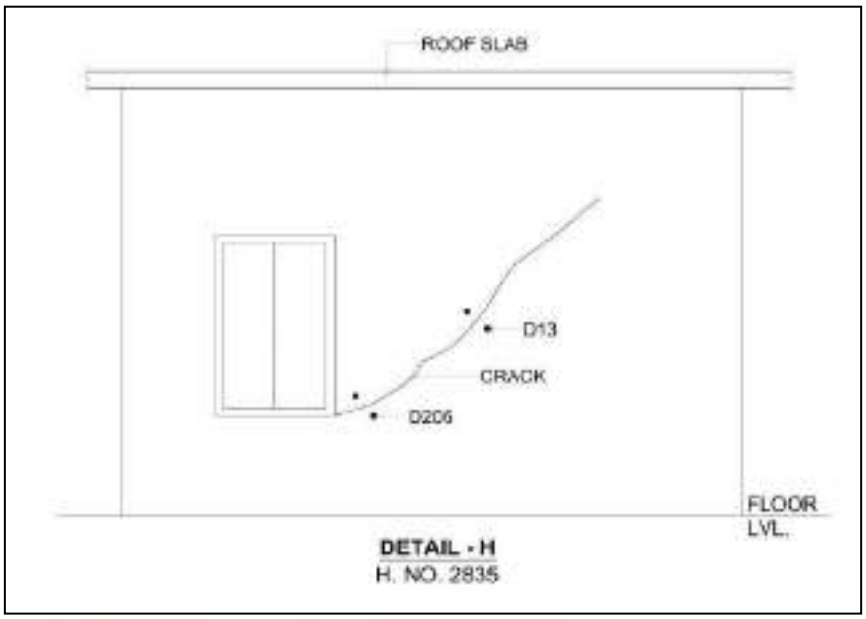


DETAIL - M & N
H. NO. 2249

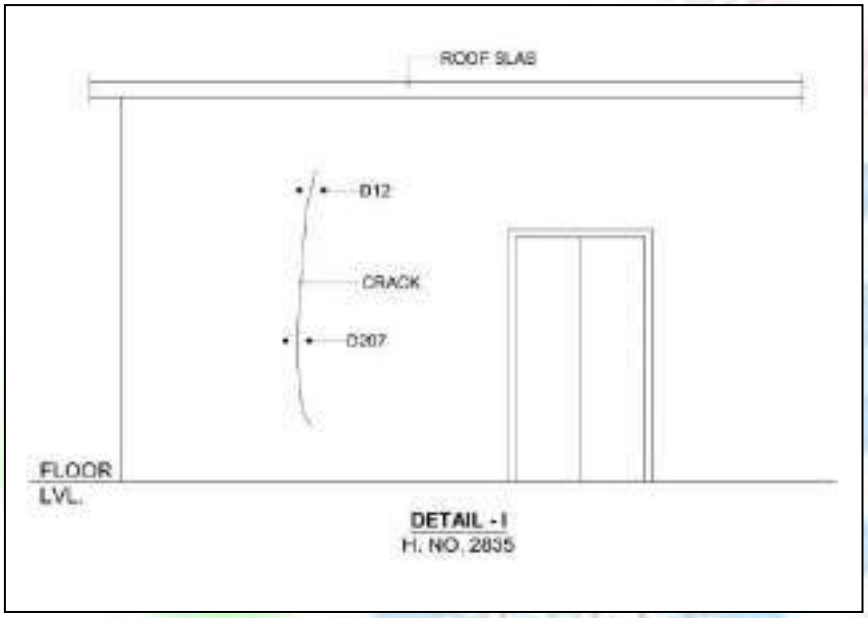
B9. House no. 2835



CSIR Touching Lives

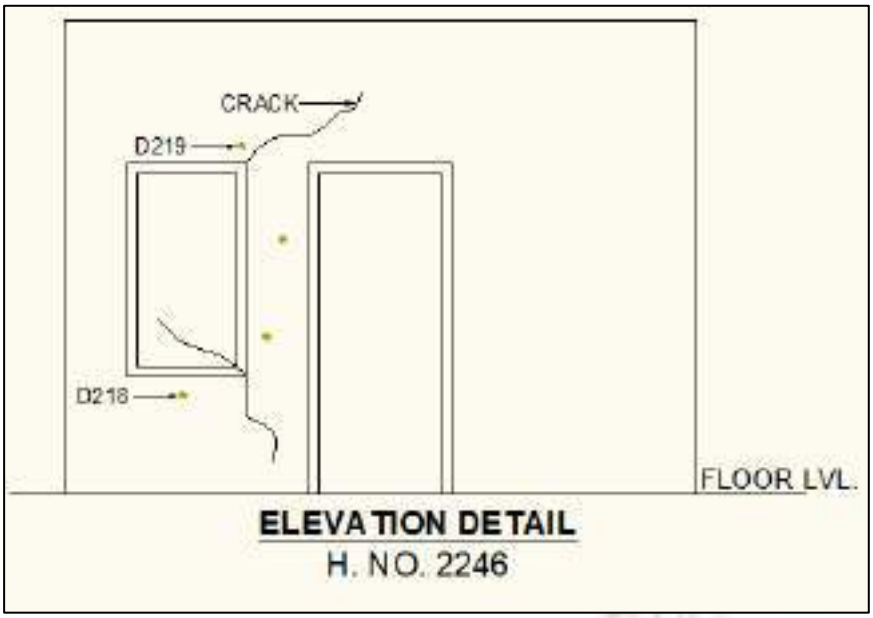


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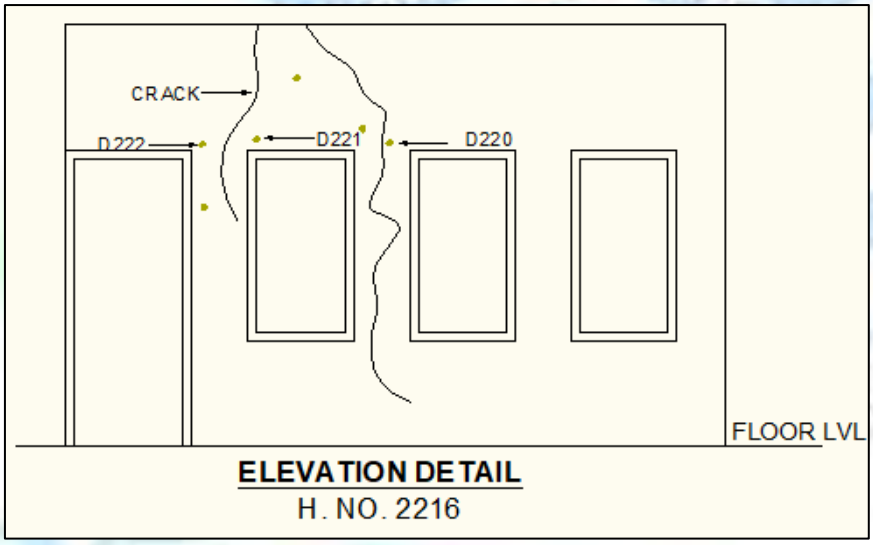


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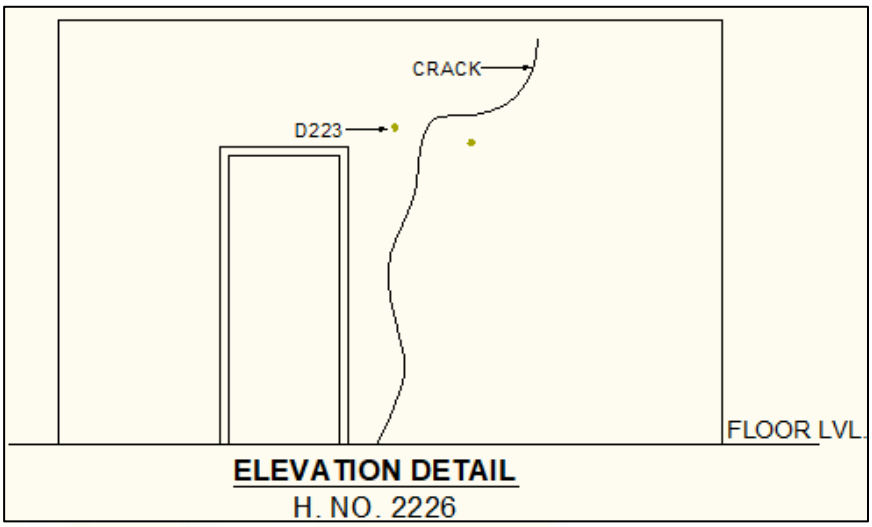
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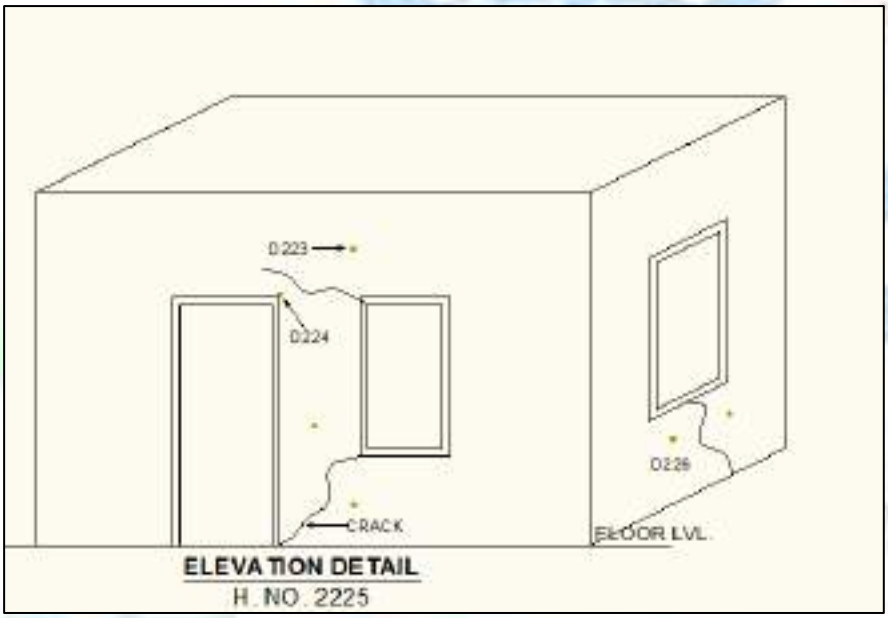
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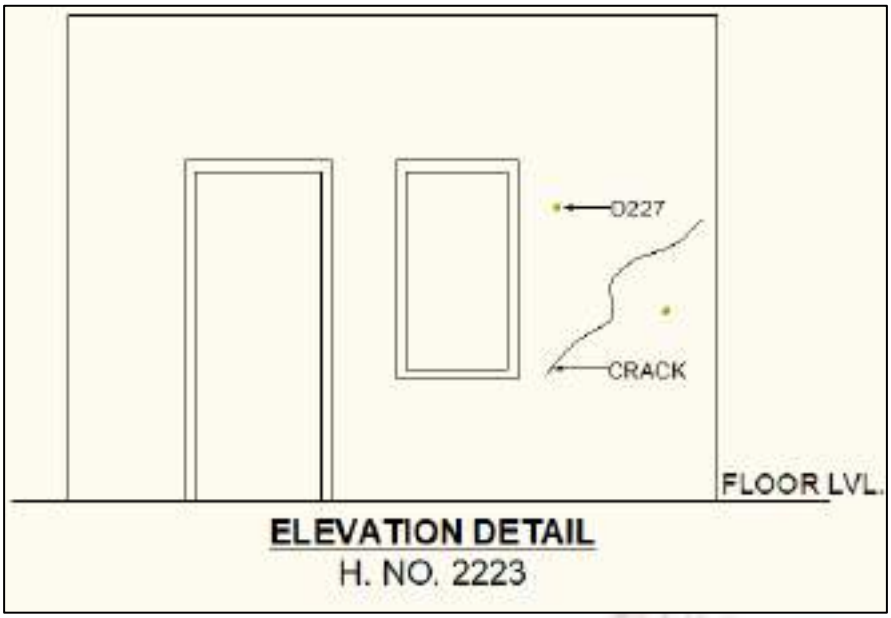
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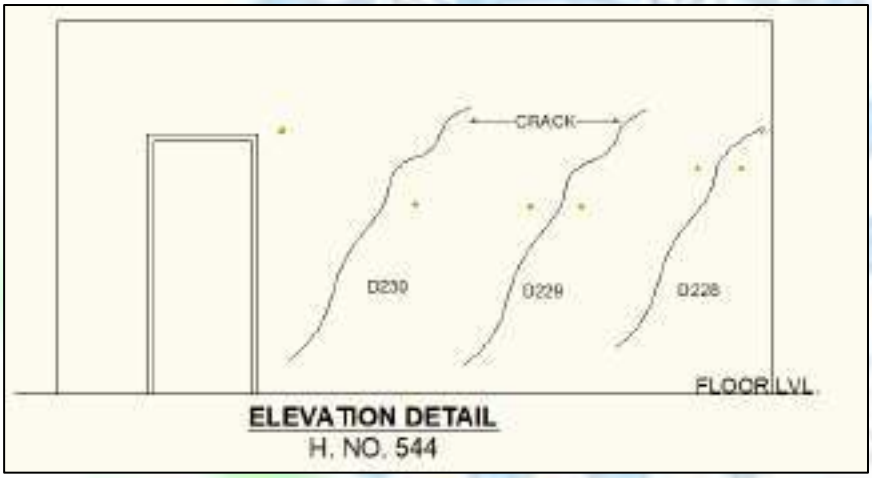
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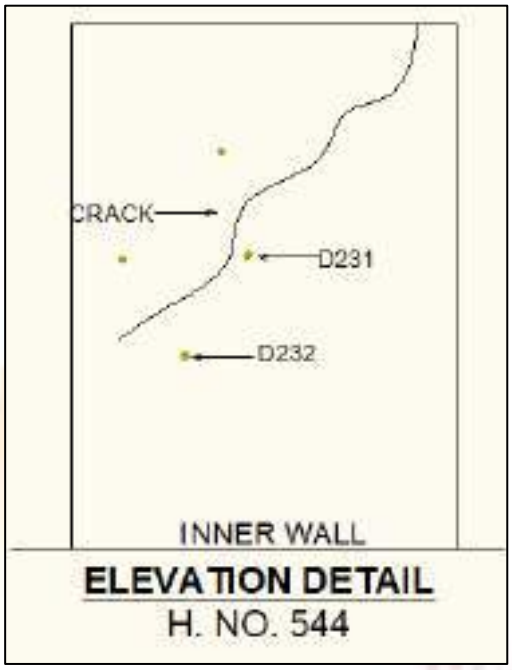


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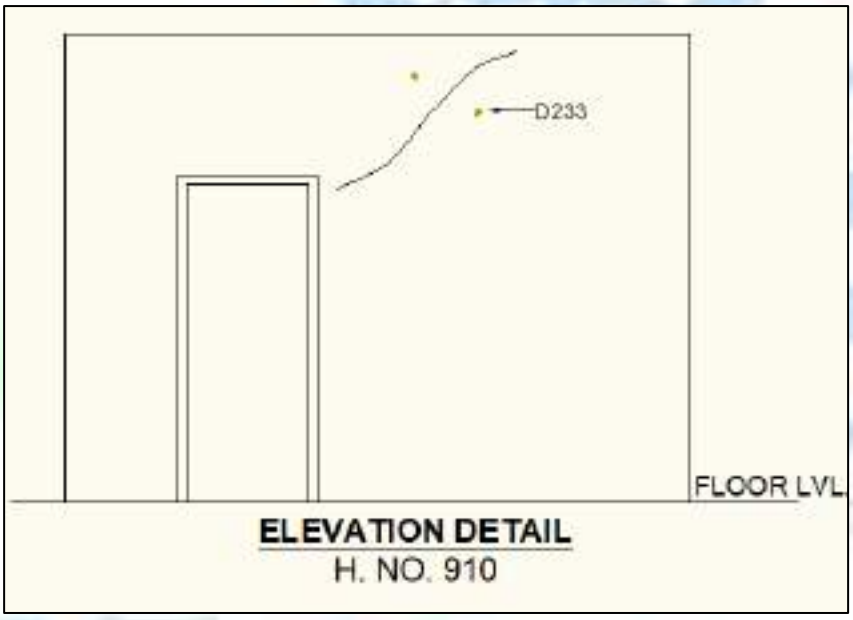


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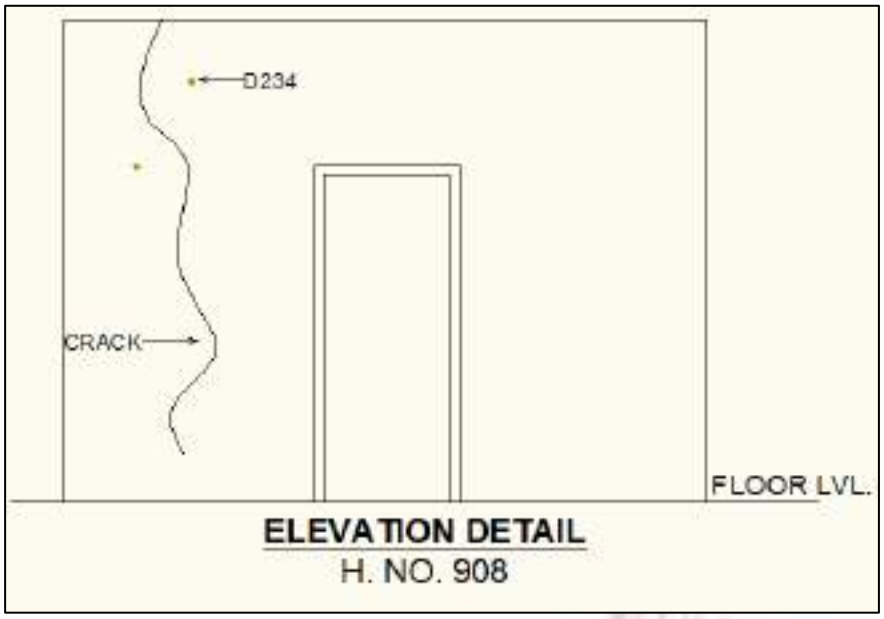




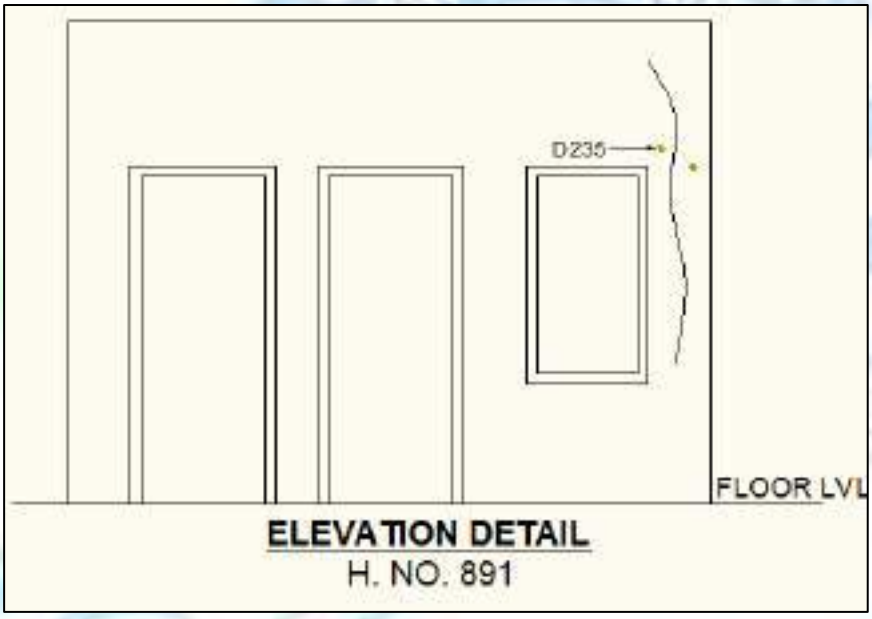
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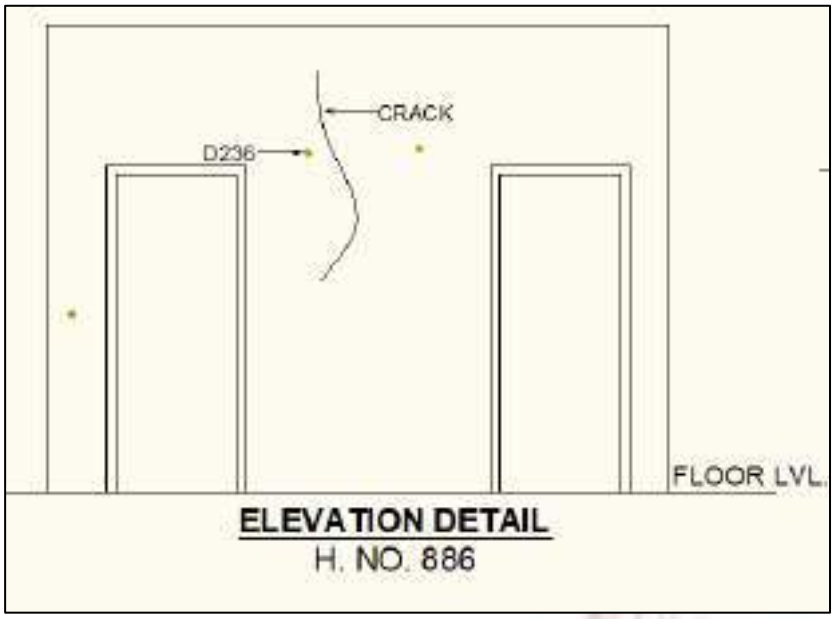
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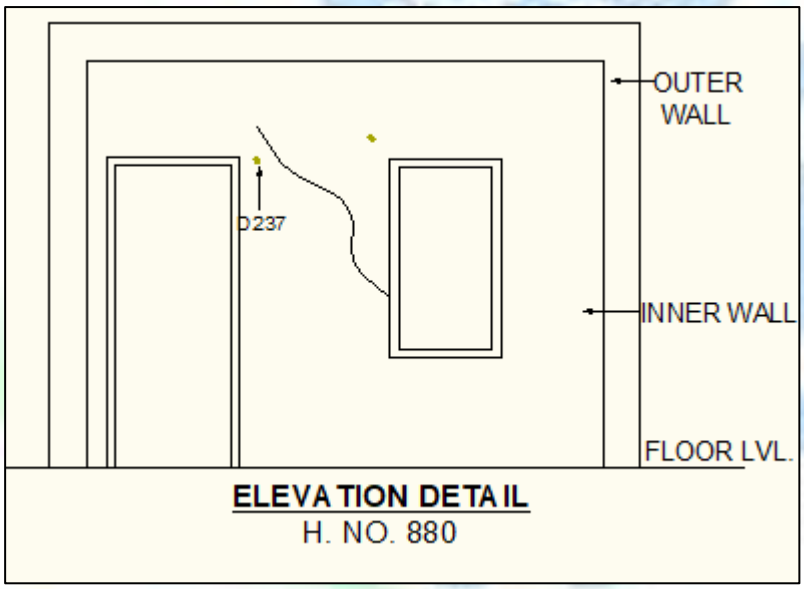
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B19. House no. 886



B20. House no. 880



NGT MATTER
MOST URGENT

राजस्थान–सरकार

कार्यालय जिला मजिस्ट्रेट, भीलवाडा

क्रमांक : न्याय/ 2021/22742 दिनांक : 25.03.2021

प्रेषिति,

क्षेत्रीय अधिकारी,
राजस्थान राज्य प्रदूषण नियंत्रण मण्डल,
भीलवाडा

विषय :– प्रार्थना पत्र 288/2019 श्री बालकिशन व्यास बनाम राजस्थान राज्य व अन्य में माननीय न्यायालय राष्ट्रीय हरित अधिकरण, प्रधान पीठ, नई दिल्ली के आदेश की पालना में रिपोर्ट प्रस्तुत करने के संबंध में।

उपर्युक्त विषयान्तर्गत लेख है कि माननीय न्यायालय राष्ट्रीय हरित अधिकरण, प्रधान पीठ, नई दिल्ली के आदेश की पालना में प्रार्थना पत्र 288/2019 श्री बालकिशन व्यास बनाम राजस्थान राज्य व अन्य में रिपोर्ट प्रस्तुत करनी है। प्रकरण में पेशी दिनांक 31.01.2021 नियत है। वर्तमान में उपनगर पुर में सर्वे एजेन्सियों द्वारा किये गये अनुसंधान के क्रम में उपखण्ड मजिस्ट्रेट, भीलवाडा के पत्र क्रमांक **376–77 दिनांक 30.01.21** से प्राप्त अद्यतन स्थिति का प्रतिवेदन संलग्न कर नियमानुसार राजहित में उचित कार्यवाही हेतु भिजवाया जा रहा है।

अतः आपको निर्देश दिये जाते है कि विषयक प्रकरण में माननीय न्यायालय राष्ट्रीय हरित अधिकरण, प्रधान पीठ, नई दिल्ली में नियत दिनांक से पूर्व संलग्न रिपोर्ट प्रस्तुत कर न्यायालय के आदेश की पालना से इस कार्यालय को अवगत करावें।

संलग्नः– उक्तानुसार

कृते जिला मजिस्ट्रेट,
भीलवाडा

राजस्थान सरकार

कार्यालय उपखण्ड मजिस्ट्रेट भीलवाड़ा

क्रमांक / न्याय / 2021 / 376-77 दिनांक 30.1.2021

श्रीमान् जिला मजिस्ट्रेट महोदय,
भीलवाड़ा।

विषय :– प्रार्थना पत्र 288 / 2019 श्री बालकिशन व्यास बनाम राजस्थान राज्य व अन्य में मा0एन0जी0टी0 न्यायालय नई दिल्ली के आदेश दिनांक 12.10.2020 की पालना रिपोर्ट के संबंधमें।

संदर्भ :– आपका पत्र कमांक / न्याय2 22200 दिनांक 27.1.2021

———

उपरोक्त विषयान्तर्गत संदर्भित पत्र के क्रम में निवेदन है कि प्रकरण में क्षेत्रीय अधिकारी, प्रदूषण नियंत्रण मण्डल भीलवाड़ा से निम्नानुसार रिपोर्ट प्राप्त कर पत्र के साथ संलग्न कर प्रेषित है'–

1– समेकित एजिक्यूटीव समरी एनेक्सर ए पेज 01 से 07 पीडीएफ कॉपी –
2– हाइड्रोजिकल रिपोर्ट आईआईटी रूडकी, एनेक्सर बी पेज 01 से 52 तक तथा आईआईटी रूडकी से प्राप्त ई–मेल फॉवरर्डिंग लेटर का प्रिन्ट ।
3– रिपोर्ट ऑन साइटिफिट स्टेडी ब्लास्ट बायबरसन, सीआईएमएफआर धनबाद, एनेक्सर सी कुल पेज 121(फ्रंट पेज, हस्ताक्षर पेज, समरी एवं इडनेक्स के छः पेज एवं मुख्य रिपोर्ट पेज 01 से 115 तक)
4– रिपोर्ट ऑन स्टेटडी टू इन्वेस्टीगेट केक्स, सीबीआरआई रूडकी एनेक्सर डी, कुल पेज 139 (हस्ताक्षरित फॉवरर्डिंग पेज, रिपोर्ट फ्रंट पेज, डिसक्लेमर एवं इडनेक्स के 5 पेज एवं मुख्य रिपोर्ट पेज 01 से 134 तक)
5– ड्राफट फॉवरर्डिंग लेटर टू मा0एन0जी0टी0, एनेक्सर ई कुल पेज 02

उल्लेखनीय है कि सीआईएमएफआर धनबाद तथा सीबीआरआई रूडकी से रिपोर्ट का हस्ताक्षरित फॉवरर्डिंग पेज संलग्न है तथापि आईआईटी रूडकी से हाइड्रोजिकल रिपोर्ट प्राप्त होने का ई–मेल का फॉवरर्डिंग पेज संलग्न है।

उपखण्ड मजिस्ट्रेट
भीलवाड़ा

संलग्न – उपरोक्तानुसार

प्रतिलिपि –

1–क्षेत्रीय अधिकारी, प्रदूषण नियंत्रण मण्डल भीलवाड़ा ।

उपखण्ड मजिस्ट्रेट
भीलवाड़ा

30/1/21

REGIONAL OFFICE

RAJASTHAN STATE POLLUTION CONTROL BOARD

18,Near Pannadhaya Circle,Azad Nagar,Bhilwara
Phone : 01482-241159; Email ID:-rorpcb.bhilwara@gmail.com

29-1-2021

283

No. RPCB/RO/BHL/NGT(2019)/L-4/ 1515 **Dated :** 29/01/2021

(Through Post/Email)

Urgent/NGT Matter(O.A. No. 288/2019)
Deadline of final report submission-31.01.2021
Date of Next Hearing-12.02.2021.

To,
Sub Divisional Officer,
Bhilwara (Raj.)
(Email:- sdobhilwara@gmail.com)

Subject:-.Regarding Compliance of directions passed by Hon'ble N.G.T.,Principal Bench,New Delhi in O.A. No. 288/2019, titled as Shri Balkrishan Vyas V/s State of Raj & Others.

Ref:- 1. Hon'ble N.G.T.,Principal Bench,New Delhi's order sheet dated 12.10.2020.
2. Office of the District Collector,Bhilwara's letter no. Nyay/2020/25258,dated 24.12.20.
3. Reports as received forwarded through this office email dated 21.01.2021.
4. This office letter dated 1491-1493 dated 25.01.2021 with supporting documents.
5. Telephonic conversation held with concerned section related to queries raised related to submission of reports.

Sir,

Apropos above, in continuation to this office letter dated 25.01.2021 and telephonic conversation held with concerned section related to queries raised related to submission of reports, it is submitted that :-

1. PDF copy as received from the esteemed agencies alongwith conciliated excutive summary has been forwarded to your good self vide this office email dated 21.01.2021.
2. Detailed letter for approval for onward submission to Hon'ble NGT bearing no. 1491-1493 dated 25.01.2021 has also been sent.
3. Further ,queries raised in aforesaid matter regarding annexure and paging ,details alongwith supporting are mentioned as under :-

S.No.	Short title of annexure	Name of Annexure	Total Pages	Paging details	Status of enclosed copy
1.	Consolidated executive summary	A	07	1 to 7	It is PDF copy and as per telephonic conversation with representative from IIT Roorki, informed that it is consolidated executive summary in Searchable PDF format as desired by Hon'ble NGT and same may be submitted as per

REGIONAL OFFICE
RAJASTHAN STATE POLLUTION CONTROL BOARD
18,Near Pannadhaya Circle,Azad Nagar,Bhilwara
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					prevailing practices as it is sent through our registered email however if needed, signed copy of consolidated copy may be arranged and sent within 1-2 days.
2.	Hydrological study report of Pur,Bhilwara by IIT Roorki	B	52	1 to52	It is a PDF copy and as per telephonic conversation with representative from IIT Roorki, informed that it is consolidated executive summary in Searchable PDF format as desired by Hon'ble NGT and same may be submitted as per prevailing practices as it is sent through our registered email however if needed, signed forwarding letter copy may be arranged and sent within 1-2 days.
3.	Report on scientific studies on blast induced ground vibration ..,By CIMFR(CSIR),Dhanbad	C	121	Front page, Signed page, executive summary and table of contents-06 pages and main report 1 to 115 pages=Total 121 pages.	It is a PDF copy along with signed report submission page dully signed by concerned institute officials.
4.	Report on studies to investigate the reasons for the cracks..,By CBRI-CSIR,Roorkee.	D	139	Signed forwarding letter, Front page, disclaimer	It is a PDF copy with along with signed forwarding letter dully signed by in charge of study of

REGIONAL OFFICE
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Phone : 01482-241159; Email ID:-rorpcb.bhilwara@gmail.com

				and table of contents-05 pages and main report 1 to 134 pages=Total 139 pages.	concerned institute .
5.	Draft letter addressed to Hon'ble NGT for submission of reports.	E	02	1 to 2	Draft letter to be send to Hon'ble NGT after approval.

Therefore, draft letter addressed to Hon'ble NGT for final online submission in aforesaid matter alongwith above referred reports (PDF copies) as available is herewith again submitted for approval please.

With regards,

Encl: As above.
(2 set)

Yours Sincerely,

(Mahaveer Mehta)
Regional Officer,
RSPCB, Bhilwara

राजस्थान प्रदूषण नियंत्रण मण्डल
भीलवाड़ा

Copy to followings for information:

1. District Collector, Bhilwara in compliance your office letter no.25258 dated 24.12.2020.
2. In charge Legal Cell , RSPCB, Jaipur.

Regional Officer,
RSPCB, Bhilwara

Annexure A (1)

Scientific study to ascertain the Causes and Effects of Development of Cracks in Buildings in and around Pur village, Bhilwara

Executive Summary

- District Magistrate and Collector, Bhilwara vide its letter no: Jud/19/26230 dated 22.07.2019 requested a few esteemed institutions to carry out the scientific study and find out causes and effects of development of cracks in buildings/ structures/ roads/ drains in and around Pur village, Bhilwara, Rajasthan being an interdisciplinary problem. The district administration had also requested to suggest the mitigation measures and action plan to district administration/ state government.

- Accordingly, a joint site visit by the representatives of CSIR-Central Institute of Mining and Fuel Research (CIMFR), Dhanbad, CSIR-Central Building Research Institute (CBRI), Roorkee, Uttrakhand and Indian Institute of Technology (IIT) Roorkee, Roorkee was carried out during 18-20 August 2019 to Pur village, Bhilwara. Subsequently a meeting in the office of the District Magistrate, Bhilwara District, Rajasthan was conducted for undertaking scientific studies to evaluate the possible causes of the crack in the buildings of Pur village, Bhilwara. In addition, the scope of works has been independently submitted by individual institutions to District Administration by CSIR-Central Institute of Mining and Fuel Research (CIMFR), Dhanbad, CSIR-Central Building Research Institute (CBRI), Roorkee, Uttrakhand and IIT Roorkee, Roorkee based mutually agreed terms and conditions by all the stake holders.

- District Magistrate and Collector, Bhilwara vide letter no: Jud/19/26667 dated 09.10.2019 requested CSIR-CIMFR Dhanbad *to evaluate the impact of the blast induced ground vibration.* Similarly, CSIR-CBRI, Roorkee was requested vide letter No. Jud/19/26668 dated 09.10.2019 *to carryout scientific study to investigate the reasons of cracks development in buildings of Pur Village, Bhilwara.* Also, IIT Roorkee was requested vide letter no: Jud/19/26669 dated 09.10.2019 *to carryout hydro-geological study of Pur Village Area, Bhilwara, Rajasthan.*

- The detailed study reports carried out by CSIR-Central Institute of Mining and Fuel Research (CIMFR), Dhanbad, CSIR-Central Building Research Institute (CBRI), Roorkee, Uttrakhand and Indian Institute of Technology (IIT) Roorkee, Roorkee were submitted individually. However, brief of studies comprising all the studies were summarized as under:

CSIR-CIMFR Dhanbad

- CSIR-CIMFR Dhanbad team have conducted altogether 15 experimental blast rounds at Dhedwas Iron Ore mine in different phases for the field investigations. The parameters of the experimental blast round were decided after reviewing the data of mine blasting operations carried out during April 2018 to Dec 2019.

- Experimental blasts have been conducted with different combination and range of parameters. Small as well as large blasts both in terms of number of holes and total explosive quantity were conducted both in overburden as well as in bottom benches.

- In experimental study, the blasts holes depths were varied from 3.5 m to 12.0m, total charge varied from 3.06 ton to as high as 10.06 tons, no of holes varied from 39 holes to 195 holes. Although, average maximum charge per delay in day to day mine blasting operation was 100 kg, experimental blast rounds upto 190 kg have been conducted to create a severe condition and to evaluate the impact of vibration. The range of experimental blast design parameter covered entire range of day-to-day blasting practices of Dhedwas iron ore mine, Bhilwara.

- Comprehensive vibration monitoring was carried out during blasting study. The complete exercise was carried out in presence of representatives from Pur village. Altogether vibration was monitored at 56 different locations. Monitoring locations were chosen considering size of blast, mine location the distance of the presence of any domestic structures. The monitoring locations include domestic houses and other prominent structures of the Pur village such as Temple and Mosques and community hospital. In all the cases, measurements were carried out in the direction with an intention to record maximum vibration as well as air overpressure intensity. Simultaneous vibration monitoring both in close-field as well as far-field using four set of four channel monitoring system was carried out. All these instruments are four-channel seismographs provided with one tri-axial transducer for monitoring of

vibration (in mm/s or inch/s) and one-channel for monitoring of air overpressure/noise in dB (L) or Pa. The instrument records vibrations in three orthogonal directions [i.e. Longitudinal (L), Vertical (V) and Transverse (T)] and peak frequency of vibration in individual directions as well as compute the peak vector sum of vibrations. The instruments also permit full wave recording at any instant of time for a preset duration. Sensors are having an articulation of spikes for proper coupling with the ground for more precise reading of particle velocity.

- Observed vibration data were analysis and a site specific mathematical relationship has been established correlating the maximum explosives weight per delay (Q_{max} in kg), distance of vibration measuring transducers from the blasting face (D in m) and recorded peak particle velocity (V in mm/s) using square root scaled distance at 95% confidence interval. The equation which shows attenuation characteristics of the blast induced ground vibration were further analysed in details to understand the damaging effect of vibration on domestic houses of Pur village with different blast design parameters.

- It is observed that the blast induced ground vibration and air overpressure beyond a distance of 500 m from the blasting site remained less than 2.00 mm/s (with frequency ranging from 2.0 Hz to 30 Hz) and 115 dB(L) against recommended safe values of 5.0 mm/s and 134 dB(L) respectively. Analysis of propagation characteristics of the vibration reveals that ground vibration beyond a distance of 1.5 km decayed to less than 1.0 mm/s in majority of the cases. In most of the housing structure beyond 2.0 km from the blast site, equipment did not record any vibration and the values were not noticeable by human body. Therefore, it is concluded that observed blast induced ground vibration values are safe and well within the permissible limit as per the recommendations of Directorate General of Mine Safety (DGMS).

- Based on the findings of the study it is concluded that impact of blast induced ground vibration and air overpressure in causing the damage to the housing structures of Pur village, approx., 2.5 km away is practically not possible. Cracks in the houses may be accounted to hydrogeological set-up of Pur village and its interaction with the weak non-engineered foundation of the houses.

- It is however, recommended that an expert agency may be engaged to supervise blasting operations at Dhedhwas iron ore mine. Vibration monitoring shall be carried out by such expert agency in close co-ordination with representative of Pur village.

CSIR-CBRI, Roorkee

- CSIR-CBRI, Roorkee has carried out survey of buildings stocks to assess the type of damages in the buildings and other structures. About 80 houses were randomly selected for crack monitoring by installing demec point. In addition, four bore holes were drilled in different locations in the Pur village of varying depths from 12m to 20 m. The different site locations were selected to know the sub-surface lithology of the surrounding region of the Pur Village, Bhilwara and also the central part of the Pur village.

- The Pur village is situated on schist, a high-grade metamorphic rock with vertical foliation. The bore log study found that the soil thickness overlying the rocks in the periphery of the village is very less, around 3m. However, in the inner region of the village, the fragmented rock, sand mixed with pebbles/boulders of rocks were found overlying the schist rocks. The overburden thickness of these loose rock fragments and soil above the bed rocks was found varying from 8m to 14m.

- The bedrock below the soil layer at a depth of 8m to 14m is weathered schist having low strength with vertical foliation. This may undergo dilation if saturated with water because of dominating mica minerals having swelling property. Although, the sandy soil was having adequate engineering properties.

- There is a thick heterogeneous soil layer comprises of sand and pebbles/boulders in the central part of the village where cracks are developed in the clusters of houses. There could be a possibility of washing out of fines due to water seepage in this soil layer or subjected to any kind of dynamic loading creating some void spaces. This may cause settlement of buildings resulting in appearance of cracks.

- It is inferred from the geotechnical investigations that the cracks are appeared in the buildings, which are situated on the considerably thick heterogeneous soil in the central part of the Pur village. The buildings situated at the village periphery having less overburden are

less damaged than the buildings in the central part of the village where the loose soil mixed with rock fragments has a thickness varying from 8m to 14m.

- The damages were observed mainly in non-engineered and old constructed buildings. The crack pattern in the buildings clearly indicate towards differential settlements in foundation. The damages were observed in the form of diagonal cracks, separation of the walls, separations of floors with wall. The roofs made of stone slab placed over steel/ wooden girders were also found damaged.

- The damages in buildings were found mild to severe depending on the construction types and foundation systems. During study, it was found that damages due to cracks were mainly in stone masonry structures(non-engineered type buildings).

- The majority of reinforced concrete framed structure buildings and properly constructed masonry buildings were found with only minor cracks on surface of plaster.

- The cracks were monitored for about 8 months and found gradually progressing at several locations. It is also due to progressive nature of differential settlements.

- Therefore, it is advised that dismantling and reconstruction or repair and rehabilitation of buildings were taken up after considering all factors with due consultative meetings with affected residents. The excessively damaged buildings need to be vacated and affected people may be relocated to other locations.

- Proper categorization of the damages are therefore, important for post damage rehabilitation or reconstruction program for Pur village. It is advised to retrofit and strengthen the building foundations before retrofitting to buildings.

Indian Institute of Technology (IIT) Roorkee

- IIT Roorkee carried out comprehensive site surveys followed by a series of field experiments conducted during 07-11 November 2019 and 28 January to 01 February 2020, to know the hydro-geological behaviour of the study area.

- Initial field observation around the village indicates that the in-situ rock exposures have been significantly affected as a result of growing inhabitations and only partially eroded/isolated

remnants of hillocks are found. Examination of one partially eroded hillock near '*Baoli Naka*' revealed fragile exposures of grey black mica-schists with dip of 75-80 degrees in the N-130 degrees direction, implying strike of N40-220 degrees. The spot examination of the geological formations in the Sukhadia stadium indicated presence of isolated outcrops of schistose quartzites within the alluvial expanse. The quartzites displayed dips of 80-85 degree towards southeast and a strike of N50-230 degree. The quartzites also showed clear evidence of displacement as manifested by presence of slicken sides with visible silicification on the steep rock face(s).

- The project area contains gneiss and schist (Bhilwara Super group); gneiss, schist, phyllite, slate and limestone (Aravalli Supergroup); sandstone, shale and limestone (Vindhyan Super group); and alluvium as the major water bearing formations. The aquifers are localized within the weathered, fractured and jointed hard rock zones.

- A total of 19 geophysical surveys were conducted in and around the village using 06 vertical electrical soundings (VES), 11 electrical resistivity tomography (ERT) surveys, and 02 Surface nuclear magnetic resonance (SNMR) surveys using ground magnetic resonance (GMR).

- Findings of VES surveys conducted around the village show that the area contains thin top soil/alluvium of thickness varying between 1-5 m. The top layer of sand is underlain by weathered hard rock (schistose quartzite) having thickness ranging from 2-7 m, with its maximum value at *Sukhadia stadium*. Besides, the top veneer is directly comprised of weathered hard rock at *Jindal Mata Mandir* as seen from the high resistivity of the topmost layer. The above interpretation is corroborated by the presence of isolated outcrops (schistose quartzite) dotting the area. The rocks in these outcrops show steep dips towards SE, with presence of slicken sides at *Sukhadia stadium*, pointing to the incidence of displacement of rocks in the geological past. The weathered schist/quartzite is indicated to be underlain by hard/compact Schist/quartzite at depths varying between 5 m below the surface at *Pathwari* site and 9.5 m below ground level at *Sukhadia stadium* site.

- The top soil depth in central part of the village is found thicker than the other sites situated at the village periphery particularly towards the mining industry. A sudden drop in resistivity

along the survey line observed from 2-D ERT inversion near *Bada (Teli) Mandir* shows a presence of vertical fracture/anomaly which continued throughout the depth. Furthermore, a saturated soil or soft material zones are visible in the ERT images at couple of places in the subsurface of this site. A substantial variation in subsurface formation is also observed vertically and horizontally at other locations.

- A significant variation in water content and hydraulic conductivity observed with depth of GMR surveys indicates towards the sudden change in subsurface strata. These types of subsurface anomalies are prone for differential land settlement.
- The evidences relating to proneness to displacement within hard rocks strengthen the possibility of generation of new cracks and fractures in the area. In general, the village geology of its top subsurface is found significantly heterogeneous in nature. It contains varying thickness of sand mixed with gravels underlain by weathered/hard schist at random places making it vulnerable under the possible vibrations, surface overburden or other (sub)surface modifications.
- Possible water seepage from leaky drainage network seems further aggravating the observed differential land settlement and associated cracks. Extreme rainfall event of 1023 mm observed in 2019 monsoon period appears contributing land settlement. The isotopic analysis indicates that properties of seepage water and groundwater are found close, and hence, the high groundwater table in the surrounding area of the school seems to be main cause of seepage and waterlogging.

29.01.2021

Brijesh Kumar Yadav
Digitally signed by Brijesh Kumar Yadav
DN: cn=Brijesh Kumar Yadav, o=Indian Institute of Technology Roorkee, ou=Department of Hydrology, email=brijesh.yadav@hy.iitr.ac.in, c=IN
Date: 2021.01.29 22:36:19 +05'30'

(H K Verma)	(S K Singh)	(S Sarkar)	(Brijesh Yadav)
CSIR-CIMFR Dhanbad	CSIR-CBRI Roorkee	CSIR-CBRI Roorkee	IIT Roorkee

Gmail RO RSPCB Bhilwara <rorpcb.bhilwara@gmail.com>

Hydrogeological Study to Investigate the Reasons for Cracks in Buildings of Pur Area of Bhilwara - Final report

1 message

Brijesh Kumar <brijesh.yadav@hy.iitr.ac.in> Mon, Jan 18, 2021 at 8:29 PM
To: dm-bhi-raj@nic.in, dm-jud-bhi-rj@nic.in
Cc: sdobhilwara@gmail.com, rorpcb.bhilwara@gmail.com, sksingh_cbri@yahoo.co.in, drharsh77@gmail.com, shantanu_cbri@yahoo.co.in, brijeshy <brijeshy@gmail.com>

Dear Sir,

The Hydrogeological study report of Pur area of Bhilwara is attached here along with the consolidated executive summary prepared by investigating teams of CIMFR Dhanbad, CBRI Roorkee and IIT Roorkee for your perusal. Thank you very much for your kind cooperation and patience.
Please convey our sincere thanks to all officers/staff of District Collector and District Magistrate Bhilwara for providing their full support during the entire work particularly in the fieldwork.

Kind regards,
Brijesh

--
Dr. Brijesh Kumar Yadav
Associate Professor, Department of Hydrology
Indian Institute of Technology Roorkee
Roorkee- 247667, Uttarakhand, India
Former Ramanujan Fellow
Email: brijesh.yadav@iitr.ac.in; brijkfhy@iitr.ac.in
tel +91-1332-284755
https://www.iitr.ac.in/~HY/Dr__Brijesh_Kumar_Yadav

2 attachments

Executive Summary-Final_Jan 2015.pdf
154K

Report_Jan18_IIT_Roorkee.pdf
5640K

Annexure-B (1)

Report on

Hydro-Geological Study of Pur Village Area, Bhilwara, Rajasthan

by

Dr. B.K. Yadav and Dr. P. K. Sharma
(Associate Professors)
Dr. D. C. Singhal
(Retired Professor)

Indian Institute of Technology Roorkee

Submitted to

District Magistrate
Bhilwara, Rajasthan
India

[January 18, 2020]

1. Introduction

A survey team comprised of Prof. Brijesh Kumar Yadav (Department of Hydrology), Prof. Pramod Kumar Sharma (Department of Civil Engineering), and Dr. Dinesh Chand Singhal (Retired Prof. Department of Hydrology), Mr. Manik Goel (Research Scholar), Mr. Shubham Tiwari (Research Scholar), Mr. Uttam Singh (Senior Research Scholar), Shri Raj Kumar (Senior Laboratory Technician), and Shri Ashok Kumar (Laboratory Technician) from IIT Roorkee visited the Pur village, Bhilwara, and its nearby areas along with the required instruments during 07 Nov to 11 November 2019 for conducting the field study. Mrs. Tina Dabi, SDM Bhilwara, along with her team from the DM office Bhilwara, joined the team during the field survey. All geological and hydrological data collected in this first field visit were analyzed in the laboratories of IIT Roorkee. A total of 06 one-dimensional Vertical Electrical Soundings (VES), 08 two-dimensional Electrical Resistivity Tomography (ERT) were conducted along with 02 surface nuclear magnetic resonance (SNMR) survey using ground magnetic resonance (GMR) equipment during this first field work. The results are assessed to find the existing hydro-geological conditions of the area for possible causes of the cracks in the village buildings. After assessing the results, it was observed that some additional locations in the target area were required to be covered for improving the findings of the first field work. Keeping this in mind, a second field visit was planned for collecting more data from eleven locations in the target area during 28 Jan to 01 Feb 2020. A total of three 2-D ERT soundings, two aquifer pumping tests, and thirteen water samples (surface and groundwater) from seven different locations were collected during the second field visit.

2. Scope of the study

The following scope of the study was mutually agreed after conducting a reconnaissance survey by the principal investigator.

a) Conducting in-depth Hydrogeological survey of the area within 2 km radius from center of the Pur village using a series of field experiments.

b) Development of a lithofacies map of subsurface zone of the study area using a series of geophysical investigation techniques. About 10-15 multidimensional electrical resistivity soundings will be performed based on availability of suitable sounding locations in and around the Pur village.

c) Aquifer characterization at different depths using appropriate pumping and recovery tests along with Ground magnetic resonance (GMR) equipment. Existing tube-wells and open well of the site will be used for conducting the pumping and recovery tests.

d) Estimating groundwater flow regime of the area based on field survey and other observed data of groundwater resources. Coordinates of all monitoring points to be taken and marked along with the existing groundwater flow pattern.

e) Chemical analysis of water supplied to the village and groundwater samples using existing hand-pumps/tube-well and groundwater outflow location observed in the village school. This is required to investigate interaction between water supply network of the village and existing groundwater resources of the site.

f) Preparation of general guidelines for effective measures of the existing problem.

3. Study Area

Bhilwara district in Rajasthan is famous for its mineral resources and textile industries. It is situated between latitude North 25.0167^0 to 25.967^0 and longitude East 74.01^0 to 75.467^0, covering a geographical area of 10,455 sq. Km. It is divided into 7 sub-divisions: Bhilwara, Shahpura, Gangapur, Gulabpura, Asind, Mandalgarh, and Jahajpur that are further divided into 12 tehsils having a total population of about 24.1 lakh as per the census of 2011. It is bounded from the north, east, south, and west by Ajmer, Bundi, Chittorgarh, and Rajsmand districts, respectively. Bhilwara district comprises of fairly open plains in the north and southeast with a few hillocks and undulating plains/hills in the south and northeastern part. Most of the district area drains to Banas river except the eastern part that drains to the Chambal river. Geologically, Bhilwara Super Group occupies a major part of the district. The area comprises of the Vindhyan group in the south-eastern part, the Gogunda group in the north-western part, and the Kumbhalgarh group in the southwestern part. The average groundwater table in the district varies from 3 to 23 m and 1 to 16 m bgl during pre- and post- monsoon seasons, respectively (CGWB Report, 2013).

The study revolves around the Pur village and the Jindal Saw Ltd. of Bhilwara District. The study area is located towards southwest of Bhilwara town, between the latitude $26^0 18'$-$26^0 20'$ N and longitude 74°31' – 74°33' E having an area of about 24 sq. Km. The map of the target area along with grid range marked by selected locations used for geophysical surveying during the first field work is shown in figure 1. The relative location of Pur village settlement and Dhedwas Iron Ore Mine is also shown in figure 2.

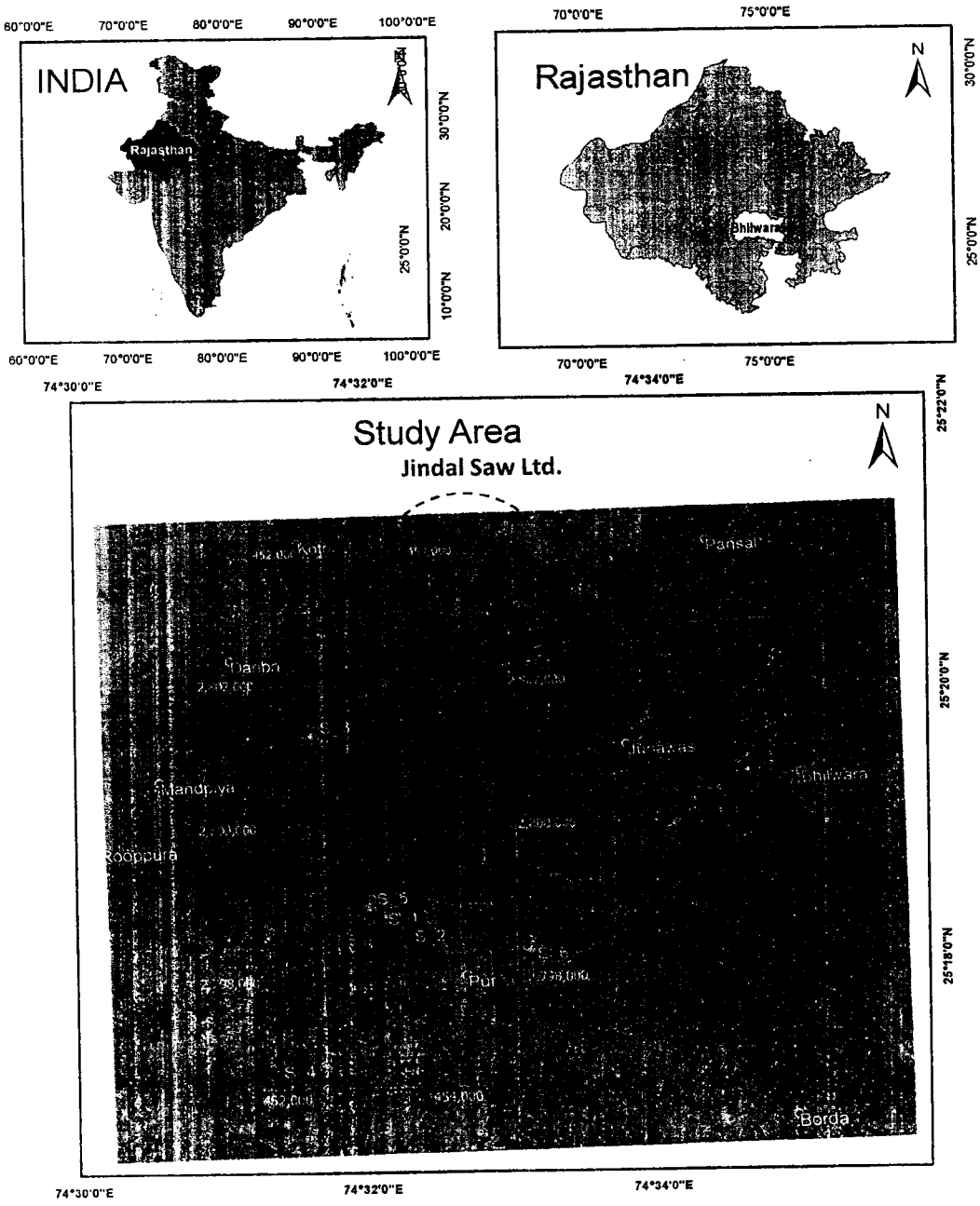


Figure 1: Figure showing the extent (grid) and location of the study area with marking for VES survey sites covered during the first field visit of the Pur village and it surrounding area.

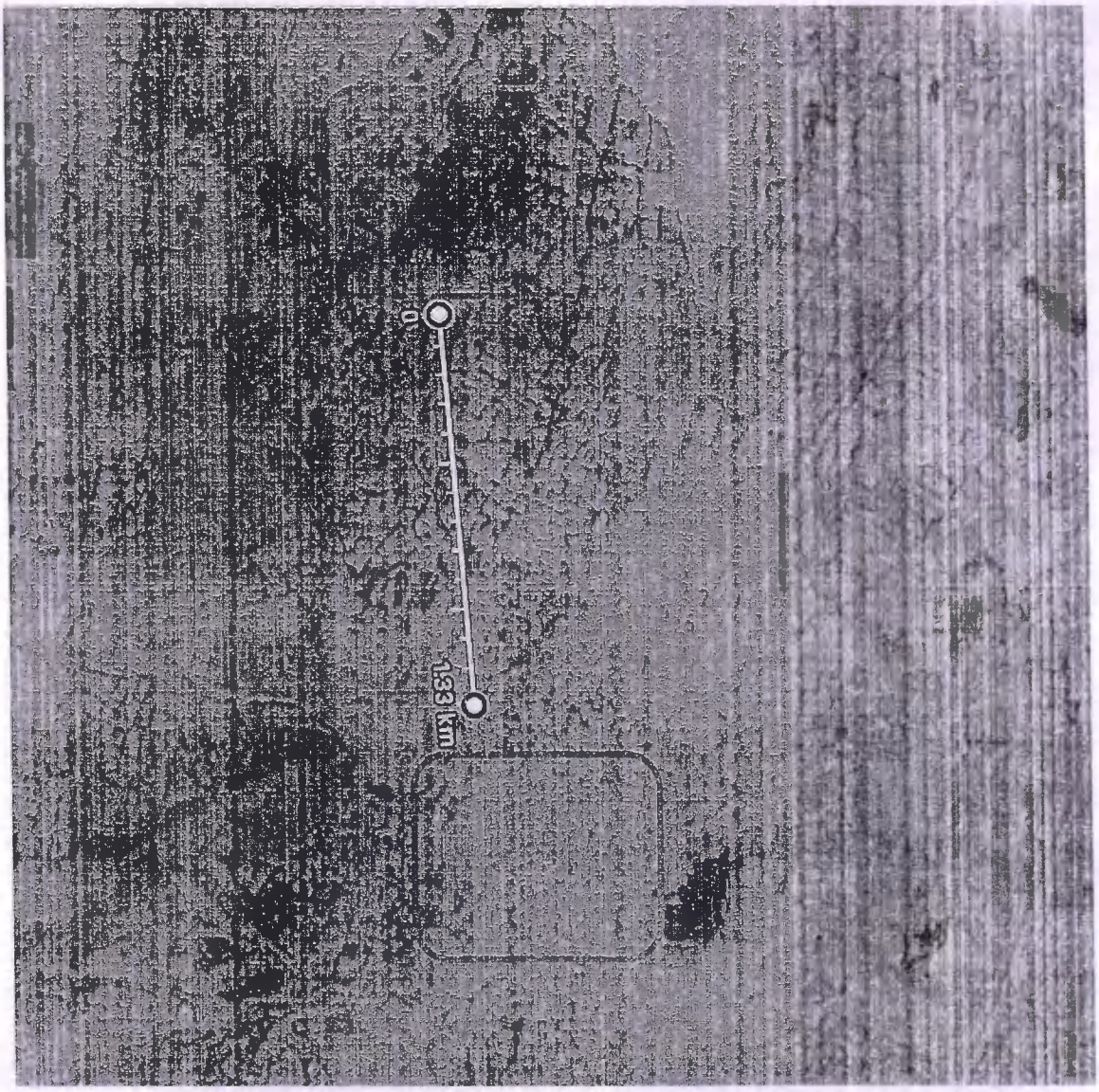


Figure 2: Map showing relative location of Jindal Saw Ltd Iron Ore Mine and Pur Village

The Digital Elevation Model (DEM) of the Bhilwara District showing the anomaly in surface elevation along with mark for the initial survey sites is shown in figure 3.

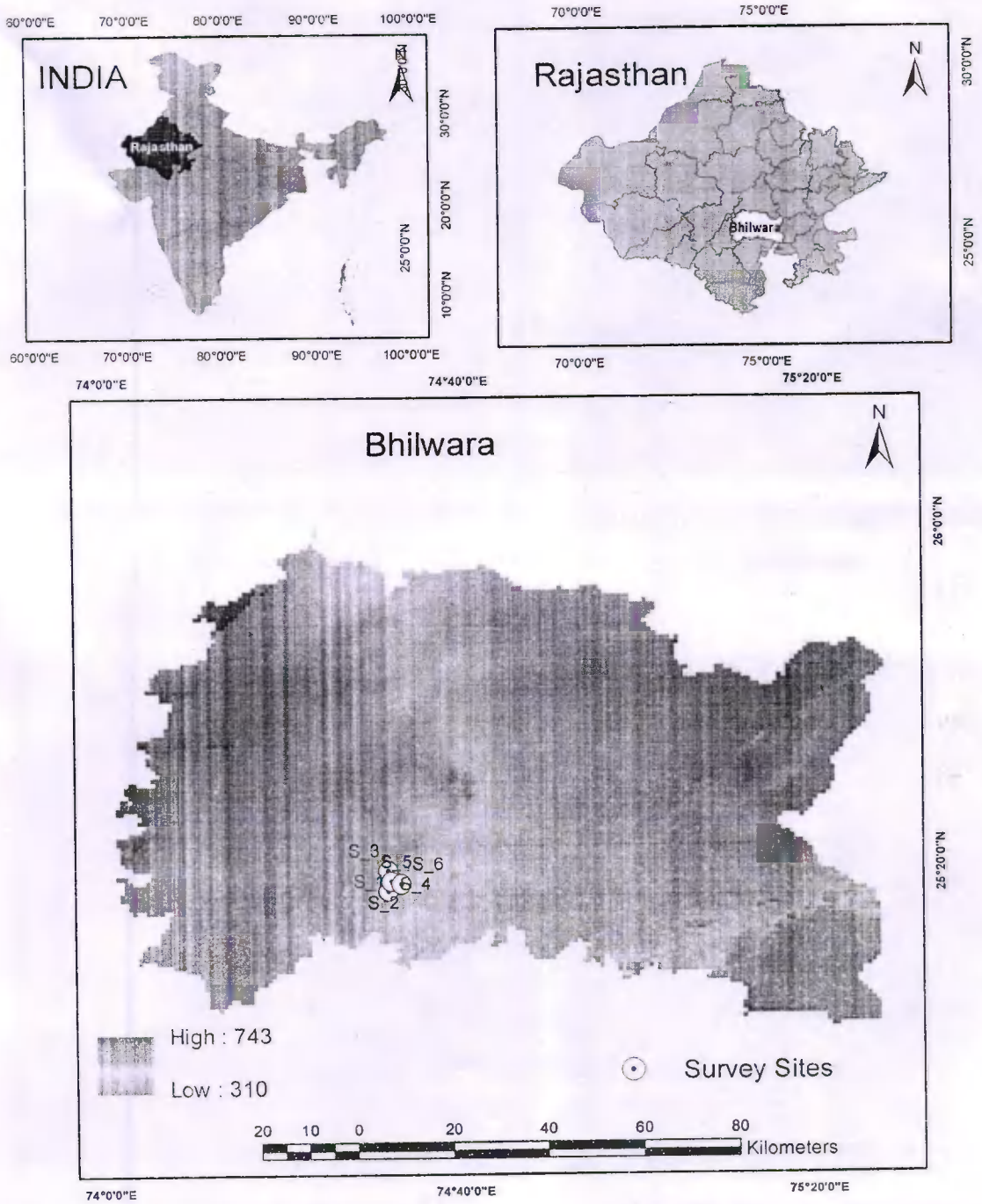
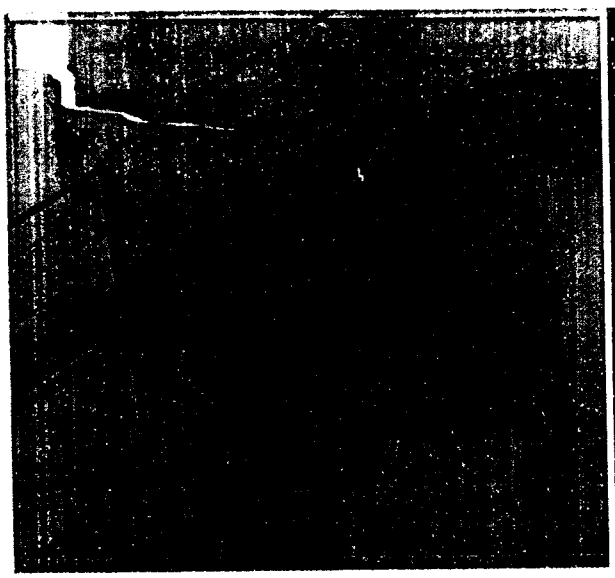
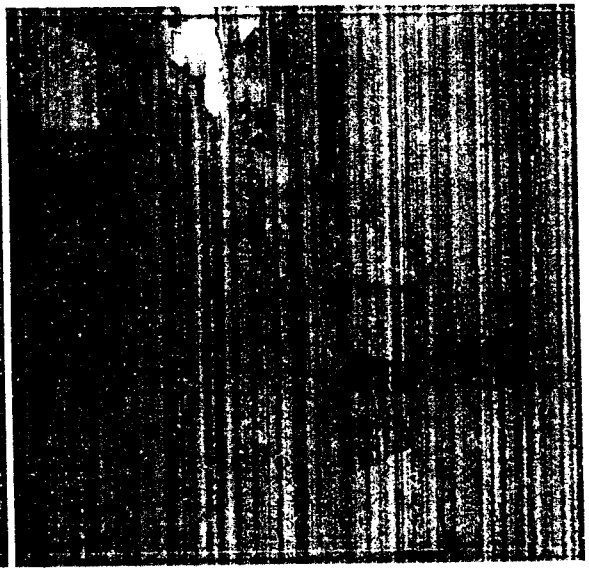


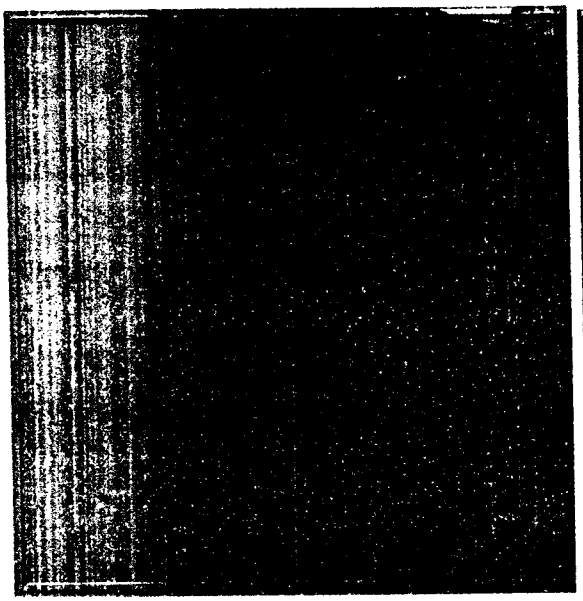
Figure 3: Digital elevation map (DEM) of the Bhilwara District showing surface elevation in meters with mark for survey sites.



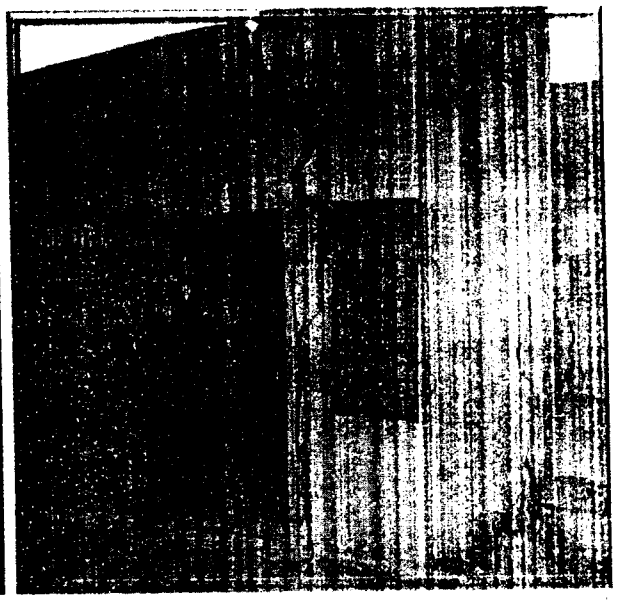
(a): Cracks along the joints of the domestic structures



(b): Cracks across the roads in Pur village



(c): Cracks across the wall of housing structure



(d): Cracks across the wall of a house widening from bottom to up



(e): Cracks along column in Laxminarayan Temple

Figure 4 a-e: Cracks developed in housing structures, roads and other structures of Pur settlement

3.1 Hydro-geological Setup

The project area contains gneiss and schist (Bhilwara Super group); gneiss, schist, phyllite, slate and limestone (Aravalli Supergroup); sandstone, shale and limestone (Vindhyan Supergroup) and alluvium as major water bearing formations. The aquifers are localized within the weathered, fractured and jointed hard rock areas zones. The geomorphological map of the area is shown in figure 5. Weathered gneiss forms upper part of the bedrock in the central part. Weathered gneiss with schist occupies most of the northern part under thin cover of alluvium. In schists, phyllites and slates, weathered zone extends to greater depth than in granites and gneisses. Muscovite schist often grades into gneiss. These have well-developed foliation and irregular joints and are intruded by granite, pegmatite and quartz veins. The contact between these intrusives and schists provides good channel for ground water circulation. These formations are intercalated with dolomitic limestone, quartzite and basic intrusive. Dolomitic limestone is grey to light brown and compact at the surface. It forms aquifer in intercalations with slates and phyllites in areas around Bagota, Laxmipura, Rampura, Amargarh, Dolpura, Kishangarh, Bakli, Bhajgarh, west of Banakhera, Mal Ka

Khera, northeast of Mohanpura, Ladpura and Ratiya Khera. Quartzites are generally intercalated with phyllites and slates which are brown coloured, hard and jointed.

Lithologs of eight boreholes derived from coring in the mining area merely 2-3 km towards north-northwest of Pur village have revealed that the subsurface geological formations in Pur area are mainly composed of garnetiferous, quartz-biotite, kyanite schist along with banded magnetite quartzite rocks and calc- gneisses with disseminations of pyrite, pyrrhotite and specks of sphalerite and chalcopyrite. The depth of these boreholes varied between 147 m and 307 m bgl and these are distributed on different parts of Tiranga hills, the main mining area of the Jindal Saw Ltd.

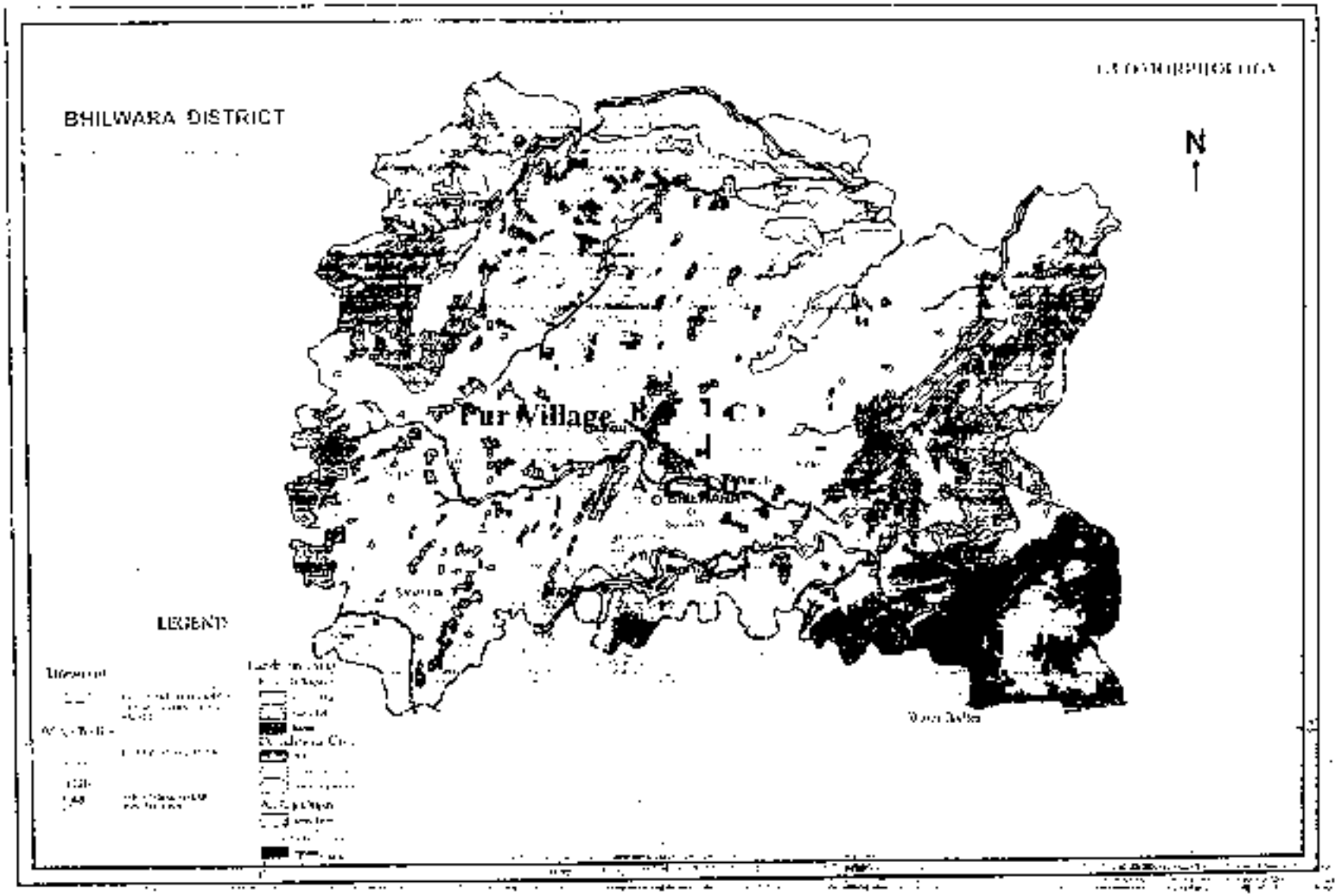


Figure 5: Geological map of the Bhilwara District, with marking of the target area (adopted from Indianwaterportal.org)

Geological Features Observed during the current Field Survey

It was observed that the in-situ rock exposures are significantly affected as a result of growing inhabitations in the area. Due to such incursions, only partially eroded and isolated remnants of hillocks are now found in the study area. Besides, many of the hillocks have virtually disappeared in the vastly expanding village. During our visit to the Laxmi (Teli) Mandir, prolific cracks and fissures were clearly observed in transverse, vertical-horizontal directions. As such, examination of one partially eroded hillock near 'Baoli Naka' revealed fragile exposures of grey black mica-schists with dip of 75-80 deg in the N-130 deg direction, implying strike of N40-220 deg, which also seems to be slightly disturbed in nature. The dip direction also seemed to be vaguely towards an adjoining pond. Further, in a nearby open lined dug well of Sh Radhey Shyam S/o Baloji, situated in the vicinity of the Mata 'mandir', the static water level was reported to hover around 20 feet bgl with the total well depth being approximately 60 feet. The well had a centrifugal pump and reportedly got empty within 3-4 hours of pumping which was reported to recover in 6-7 hours. An area of around 2 bigha farm is irrigated by the slight brackish groundwater pumped from the well. The spot examination of the geological formations at Sukhadia stadium, situated on the periphery of Pur indicated presence of isolated outcrops of schistose quartzites within the alluvial expanse. The quartzites displayed dips of 80-85 degree towards southeast and a strike of N50-230 degree. The quartzites also showed clear evidence of displacement due to faulting in the geological past as manifested by presence of slicken sides with visible silicification on the steep rock face(s).

3.2 Meteorological Information

The climate of Bhilwara is characterized by hot and dry climate receiving precipitation mostly in the form of southwest monsoon during July-September. The average annual rainfall of the area is 635.1 mm and the average monthly rainfall for the last decade is listed in table 1. Drought analysis based on agriculture index indicates that the area is prone to mild and normal types of droughts. Occurrence of severe and very severe types of droughts is very rare. The average air temperature of the area is 25.47^0 C. January is the coldest month with mean max and min temperatures of 22.2^{0}C and 7.3^{0}C respectively. Temperature in summer month of June reaches up to 46^{0}C. The humidity is highest in August with mean daily relative humidity at 80%. The annual potential evapotranspiration in the district is 1495 mm with average pressure of 1007.5 mb. A high rainfall of amount more than 1023 mm observed in 2019 was accompanied by aggravation of building cracks as reported by the villagers.

Table 1: The monthly rainfall average in mm from year 2010 to 2019 for the Bhilwara District

	January	February	March	April	May	June	July	August	September	October	November	December	Total
2020	7.7	12.27	2.2	21.6	33.34	15.04	240.58	376.1	150.01	14.13	0	0	872.97
2019	8.5	13.54	2.42	23.8	36.8	16.6	265.54	415.12	165.6	15.6	0	0	1023.52
2018	6.39	12.83	8.69	8.63	12	27.62	112.37	153.5	78.73	5.4	16.1	1.5	443.76
2017	23.27	2.32	8.42	13.74	5.37	21.6	64.65	83.7	66.08	0	1.22	15.49	305.86
2016	2.72	8.69	14.28	3.73	1.52	35.25	174.11	56.47	10.64	0	0	0.24	307.65
2015	4.25	13.83	51.15	13.98	1.38	21.44	126.11	100.57	52.26	1.1	2.01	4.32	392.4
2014	8.81	23.24	12.64	2.73	13.28	10.4	47.74	71.38	35.34	2.01	0	7.6	235.17
2013	13.83	31.9	7.64	4.78	2.67	98.61	179.29	129.95	16.15	7.96	0.49	2.41	495.68
2012	2.98	3.77	3	18.82	3.66	3.07	116.05	207.7	129.21	0.19	0.05	3.87	492.37
2011	3.45	13.12	2.01	16.69	26.55	64.81	162.39	232.82	76.55	5.07	0	0.47	603.93
2010	7.56	26.37	0.96	0.67	5.21	1.87	191.52	145.08	222.75	7.75	0.81	9.44	619.99

4.0 Field Test Results

Three main equipment setups comprising 1) Sounding Terrameter for 1-D VES, 2) Earth resistivity meter for 2-D ERT and 3) Surface nuclear magnetic resonance (SNMR) field study conducted by Ground magnetic resonance (GMR) instrument were used for this study along with the dip-meter, water quality probe and other relevant accessories. Six locations were selected for performing VES, ERT, and SNMR surveys during the first field visit based on the topography and area availability. Three more locations were selected for ERT during the second field visit. The locations and elevation above msl of sites are listed in table 2 and marked in figure 4. A total of 17 resistivity (6 VES and 11 ERT) soundings and 2 SNMR surveys were conducted during the whole field visits. In-situ water quality analysis was conducted at 4 different locations during the first visit while 9 water samples were collected during the second field visit for analysis of isotopic and other physio-chemical water quality parameters. It is to be noted that most of the soundings were performed at the periphery of the Pur village facing towards the mining site with the aim to map the existing hydrogeological profile of the severely affected area.

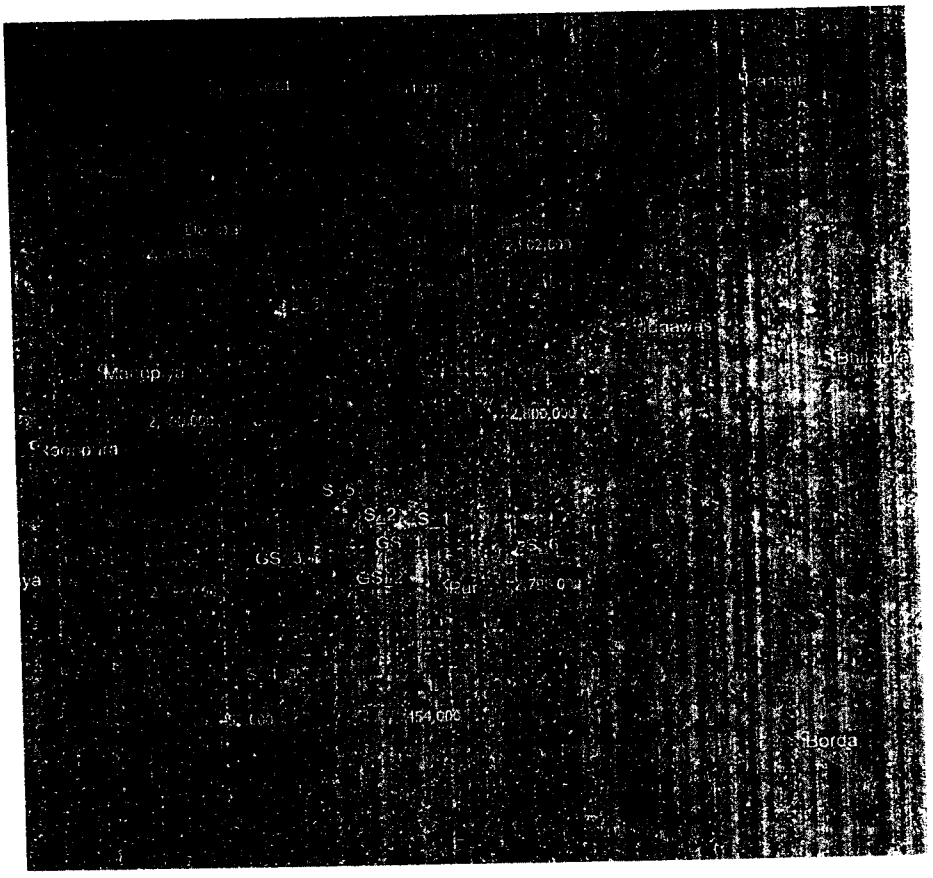


Figure 6: Locations of all survey sites used for resistivity and tomography surveys.

Table 2: Location of survey sites with their spatial coordinates in WGS 1984 coordinates system.

Site Code	Location	Latitude	Longitude	Elevation (m)	Performed Sounding			
					VES	SNMR	ERT	Total
S_1	Pathwari	25.301319	74.540528	455	1 (VES_1)	0	1	2
S_2	Ghati Ke Hanuman	25.303355	74.540543	454	0	1	1	2
S_3	Jindal Mata Mandir	25.325926	74.527081	456	1(VES_5)	0	1	2
S_4	Moldi Ke Shyam	25.2869106	74.52765	438	1(Ves-6)	1	1	3
S_5	Sukhadia Stadium	25.30495	74.53331666	448	2(VES_3 and VES_4)	1	4	7
S_6	Gyas Mata Colony	25.2998833	74.5520166	448	1(VES_2)		0	1
GS_1	Near Old Masjid	25.30305	74.53965	452	0	0	1	1
GS_2	Infront of Bada Mandir	25.297467	74.541183	457	0	0	1	1
GS_3	Ghata rani temple	25.2997167	74.53035	459	0	0	1	1

4.1 VES Survey using Terrameter

The ABEM SAS 300B terrameter shown in figure 5 was used for performing the one-dimensional vertical electrical soundings (VES) at sites denoted as S_1, S_3, S_4, S_5 and S_6. It is necessary to mention here that at the site S_5, two VES (one parallel and another perpendicular to the Strike direction, NE-SW, of the area) were conducted for better assessment of subsurface. The VES works on the principle of measuring resistivity anomaly in the subsurface. It gives the one dimensional geological characterization of the area in term of apparent electrical resistivity along the survey line.

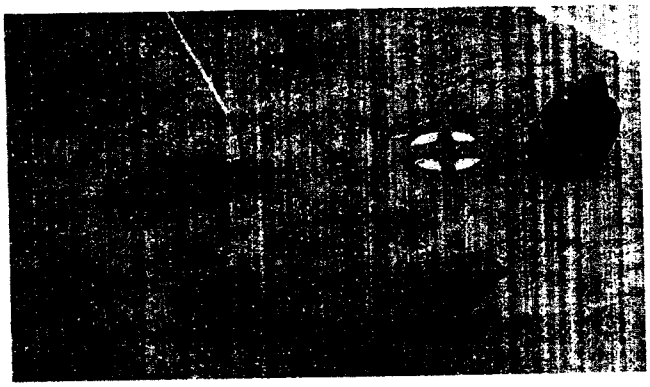


Figure 7: Terrameter installed in the field along with connecting cables and other supportive accessories.

Soundings are carried out using Schlumberger configuration with maximum current electrode spacing (AB) of 400 m to delineate the subsurface. The field data (Apparent resistivity and half current electrode separation, AB/2, along with the spatial coordinates of VES locations are interpreted using Master Curves and also by using a geophysical exploration software (Zondip 1D). The resistivity data is analyzed and depth to resistivity models are prepared using forward modelling followed by inverse modeling for more accurate results. The plots of field apparent resistivity versus AB/2 on log-log graph are given in figure 8 (a-f). The results of the interpretation of the field data in terms of layer thicknesses and true resistivity are shown in figure 9 (a-f). Along with the software interpretation, all the VES performed in the field are also interpreted manually. A perusal of the interpreted results indicates that each VES location is comprised of 2-5 layers and showing possibility of cracks, fissures, and fractures in the subsurface. In general, the top layer in the Project area of the Pur village is found to be composed of schist and quartzite rock, often overlain by a top layer of alluvial soil mixed with gravel and clay. The thickness of the soil layer is more in village central and is negligible towards the village periphery towards the mining zone.

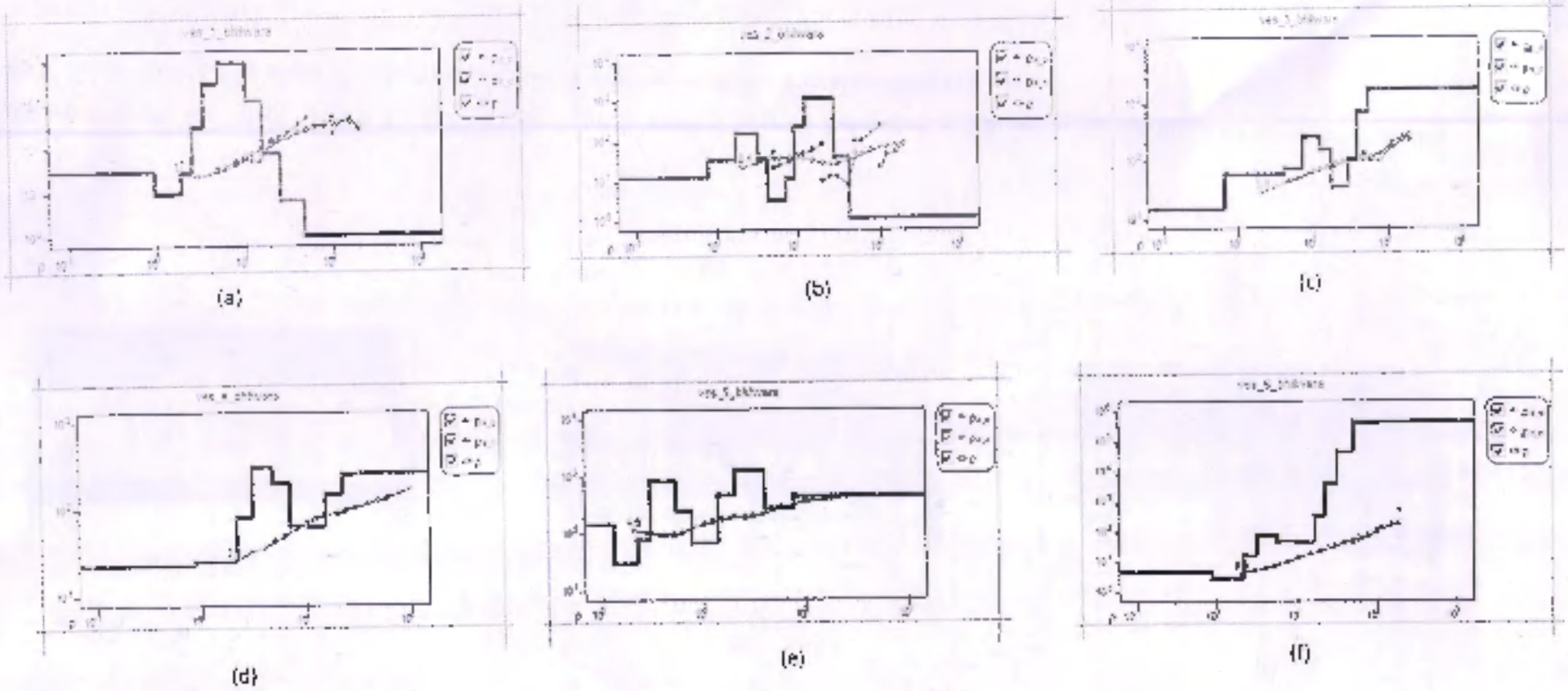


Figure 8. Field resistivity curves plotted by the Zondip 1D for the site: (a) S_1, (b) S_6. (c) S_5 parallel to dip, (d) S_5 perpendicular to strike direction, (e) S_3, and (f) S_4.

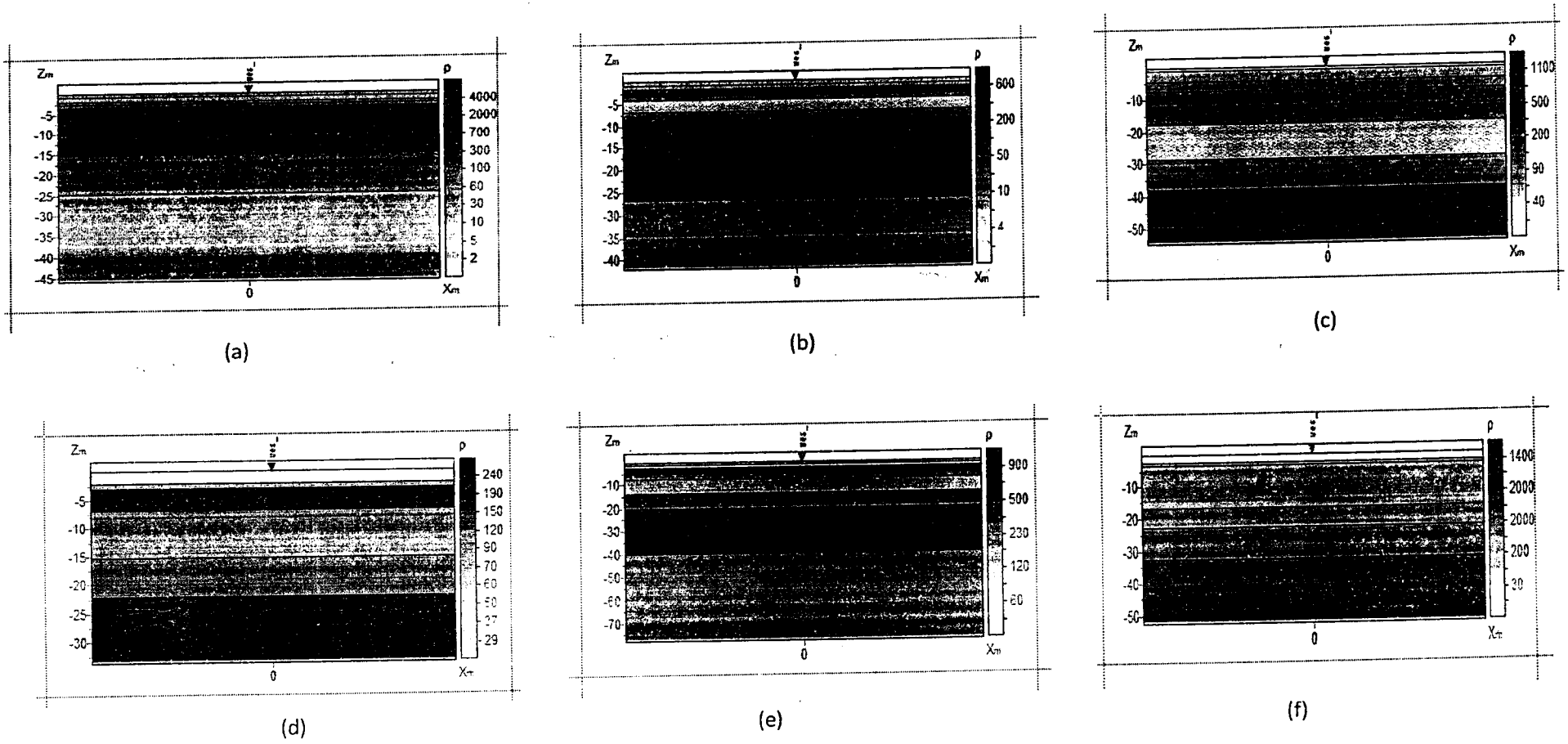
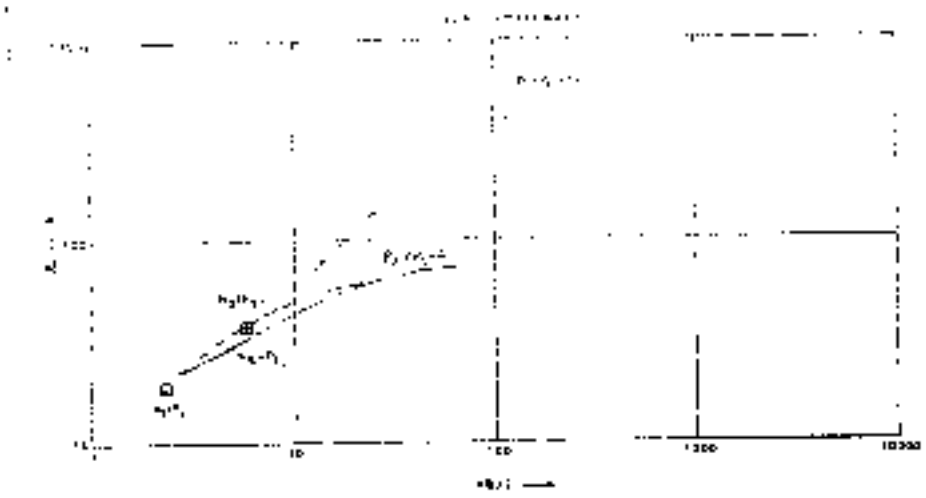
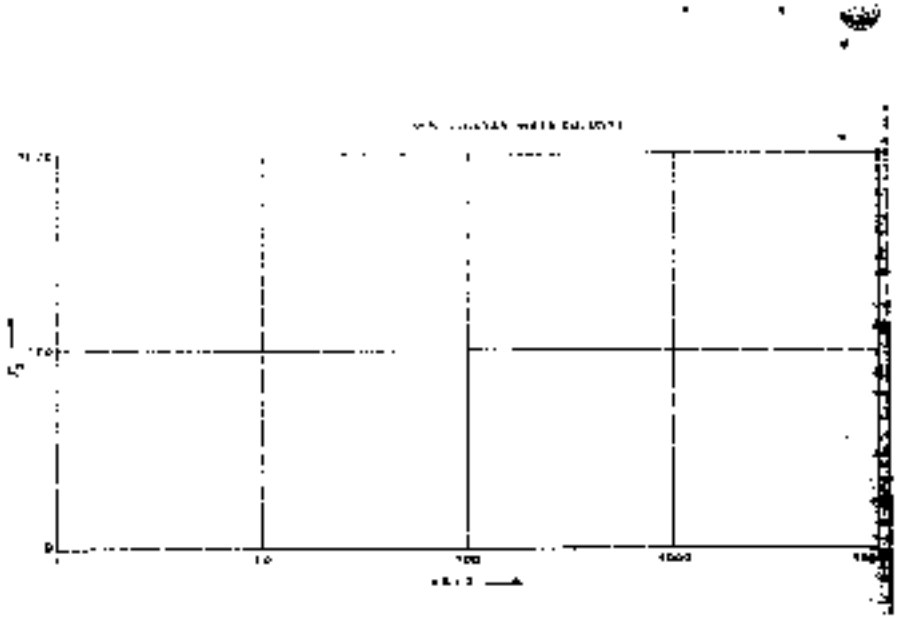


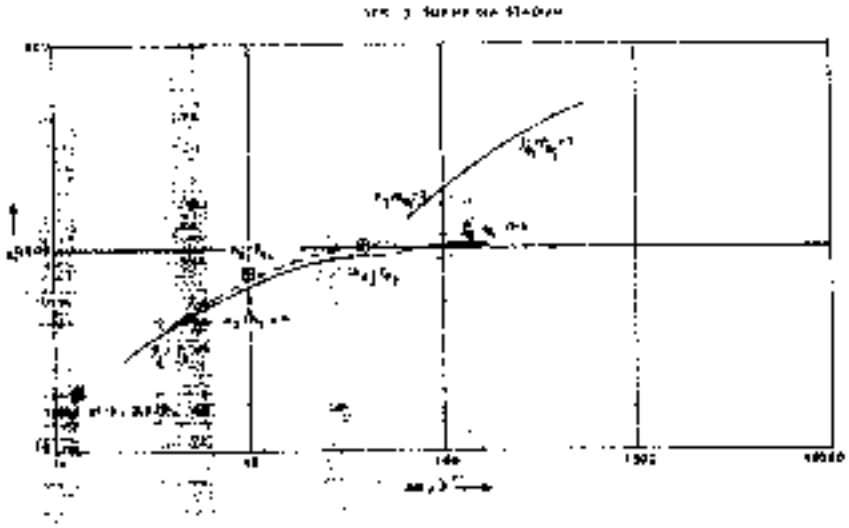
Figure 9: Depth-Resistivity models for the VES sites: (a) S_1, (b) S_6. (c) S_5 parallel to dip, (d) S_5 perpendicular to strike direction, (e) S_3, and (f) S_4. The depth (Z_m) is shown in meters and resistivity (ρ) is in Ohm-meters (Ω-m).



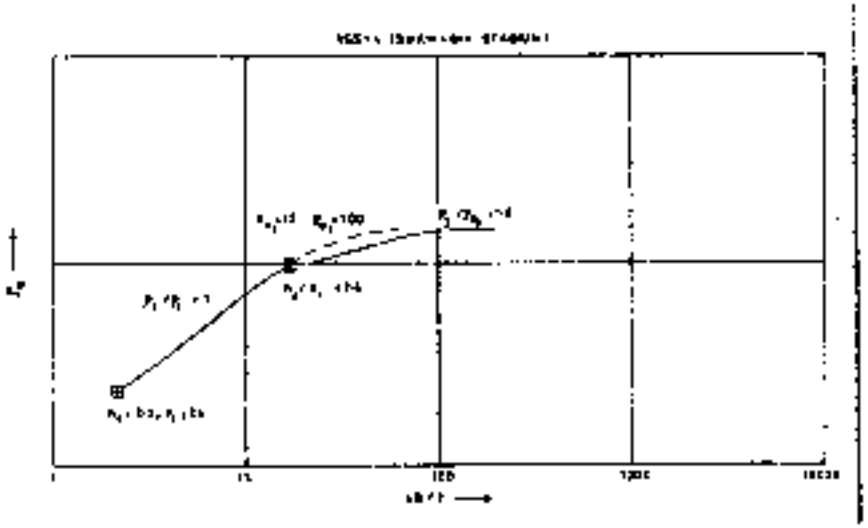
(a)



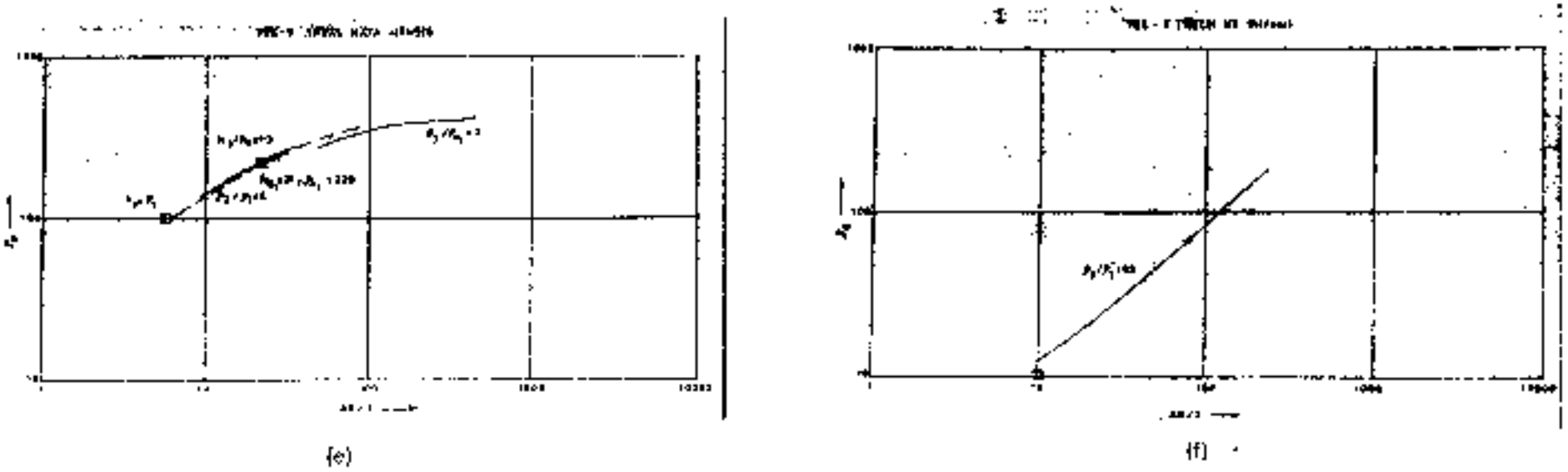
(b)



(c)



(d)



(e) (f)

Figure 10: Smoothened Field data curves matched over the master curve manually for the sites: (a) S_1 (VES_1), (b) S_6 (VES_2) (c) S_5 parallel to dip (VES_3) not relevant, (d) S_5 perpendicular to dip direction (VES_4) considered relevant, (e) S_3 (VES_5), and (f) S_4 (VES_6).

The data of plotted apparent resistivity curves are shown in Figures 10a-f. A visual analysis of these plots indicates that the curves display A-A (double ascending) pattern in general, whereas the plots recorded in Sukhadia stadium (VES 3 and VES 4) displayed K-A type of resistivity curves. However, the sounding VES-2 recorded at Gyas Mata colony (Figure 8b) displayed lot of scatter of plotted points, and thus could not be interpreted. The plotted graphs of apparent resistivity versus AB/2 were interpreted by partial curve matching techniques, using Master curves given by Orellana and Mooney (1966). Table 3 shows the data of true resistivities and layer thicknesses derived from the partial curve matching for all the soundings. Attempts made to interpret the field resistivity data using Zondip 1-D software were found comparatively inconsistent, mainly due to anisotropic nature of geological formation(s) in the area. Yet, the field resistivity data interpreted by inverse modeling are also presented in Figure 8.

A perusal of the table 4 generally indicates presence of a thin top soil/alluvium, having resistivity of 2 to 20 ohm-m, of thickness varying between 1m to 5 m. The top soil/alluvium is underlain by weathered rock, garnetiferous schistose quartzite, having resistivity in the range of 76 to 161 ohm-m and thickness ranging from 2 m to 7 m, with its maximum value at Sukhadia stadium observed in VES-4. Data of VES-3 is not relevant as its alignment is normal to rock strike. However, at VES-5 location nearby to Jindal Mata Mandir, the top veneer is directly comprised of weathered hard rock as seen from the higher resistivity of 100 ohm-m. The above interpretation is corroborated by the presence of isolated outcrops of schistose quartzite dotting the area. The rocks in some outcrops show steep dips towards SE, with presence of slicken sides in Sukhadia stadium, at sites VES-3 and VES-4, pointing to the incidence of displacement of rocks in the geological past. The weathered schist/quartzite is indicated to be underlain by hard/compact Schist/quartzite having resistivity of 440-9900 ohm-m at depths varying between 5 m below the surface at Pathwari and 9 m bgl at Sukhadia stadium.

It is to be noted that results from graphical interpretation are almost in line with the Zondip 1-D except for the site S_6 (Gyas Mata Colony). Hence, the results of VES performed in these sites are validated itself, indicating greater accuracy. The apparent resistivity points from the site S_6 (Figure 8b) are very scattered and almost invisible; so their manual interpretation in term of field curve could not be done. Depth-resistivity curves are further decoded in probable lithologs listed in table 4 (a-f) using the secondary data collected from the field and

available literature on subsurface lithology as revealed from coring data of eight bore wells in the Tiranga hill area.

Table 4: Subsurface characterization by depth-resistivity models prepared for VES at:

(a) Site S_1: Pathwari (VES_1)

Thickness Interval (m)	Resistivity(ohm-m)	Probable Lithologs
0 - 2.3	19	Silty Clay
2.3 - 4.8	76	phyllite
4.8 - (+∞)	684	Schistose Quartzite

(b) Site S_6: Gyas Mata Colony (VES_2)

Thickness Interval (m)	Resistivity (Ohm-m)	Probable Lithologs
0-2	12.65	Clayey sand
12-27	1185	Hard phyllite
[illegible]	40236	Weathered phyllite

(c) Site S_5: Sukhadia Stadium Parallel to Rock DIP (VES_3), not considered relevant

Thickness Interval (m)	Resistivity (Ohm-m)	Probable Lithologs
0 - 1.3	20	Surface Soils (Clayey)
1.3 - 36.5	100	Weathered phyllite/ Schistose Rock
36.5 - indefinite	700	Hard Quartzite rock

(d) Site S_5: Sukhadia Stadium Parallel to Strike (VES_4)

Thickness Interval (m)	Resistivity (Ohm-m)	Probable Lithologs
0 – 2.2	19	Surface Soil (Clayey)
2.2 – 9.7	161	Garnetiferous Schist
9.7 - indefinite	500	Schistose Quartzite rock

(e) Site S_3: Jindal Mata Mandir (VES_5)

Thickness Interval (m)	Resistivity (Ohm-m)	Probable Lithologs
0 – 5.5	100	Weathered Schistose Rock
5.5 – indefinite	400 – 440	Hard Quartzite (Schistose)

(f) Site S_4: Moldi Ke Shyam (VES_6)

Thickness Interval (m)	Resistivity (Ohm-m)	Probable Lithologs
0 – 10	10	Clayey Soil
10 – indefinite	990	Hard Quartzite (Schistose)

The table 4 is prepared considering the results from Zondip 1-D and graphical interpretations in combination with lithology of cored bore wells drilled in the past in Tiranga hill area. Whole area is found to be composed of garnetiferous schist and quartzite schist whether weathered, hard, or in saturated state. Hard quartzite (metamorphic rock) is found at a depth of 5m approximately at site S_1. Out of the two VES (3 and 4) performed at Survey site S_5, the VES-3 performed parallel to the dip seems to be lesslogical and inaccurate when compared to the VES-4 performed parallel to the Strike.

4.2 Electrical resistivity tomography (ERT)

The earth resistivity meter shown in figure 11 is a 4-point light 10W high precision instrument for determination of soil resistivity. The electrical resistivity allows determination of the water content in the soil and of the types of soils and rock. It is suitable for groundwater prospecting, mining, and other environmental investigations (Stummer et al., 2004). The phase shift between output current and voltage provides information about the induced polarization (IP). The accuracy of the instrument is about 0.1 % with a resolution of max. 100 nV. From the current I, the voltage U and a geometric configuration factor the specific electrical resistivity rho (Ohm-m) is calculated. The receiver of the instrument is highly selective and only records voltages at the set frequency. However, noise at the measurement frequency degrades the quality of the measurement and should be suppressed. Major reasons for noise may include Mains (electric) interferences, magnetic interferences, wind, rain, and mechanical instability of the electrodes. The ERT is performed over sites S_1, S_2, S_3, S_4, S_5, GS_1, GS_2, and GS_3 in this study.

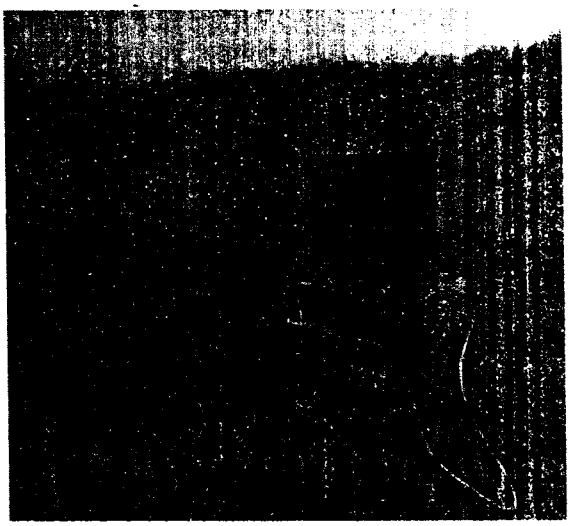


Figure 11: Earth Resistivity meter installed in the field

The resistivity values obtained by resistivity meter are interpolated in lithological formations using Palacky (1988). The 2-D inverse resistivity model and subsurface characterization for different sites are as follows:

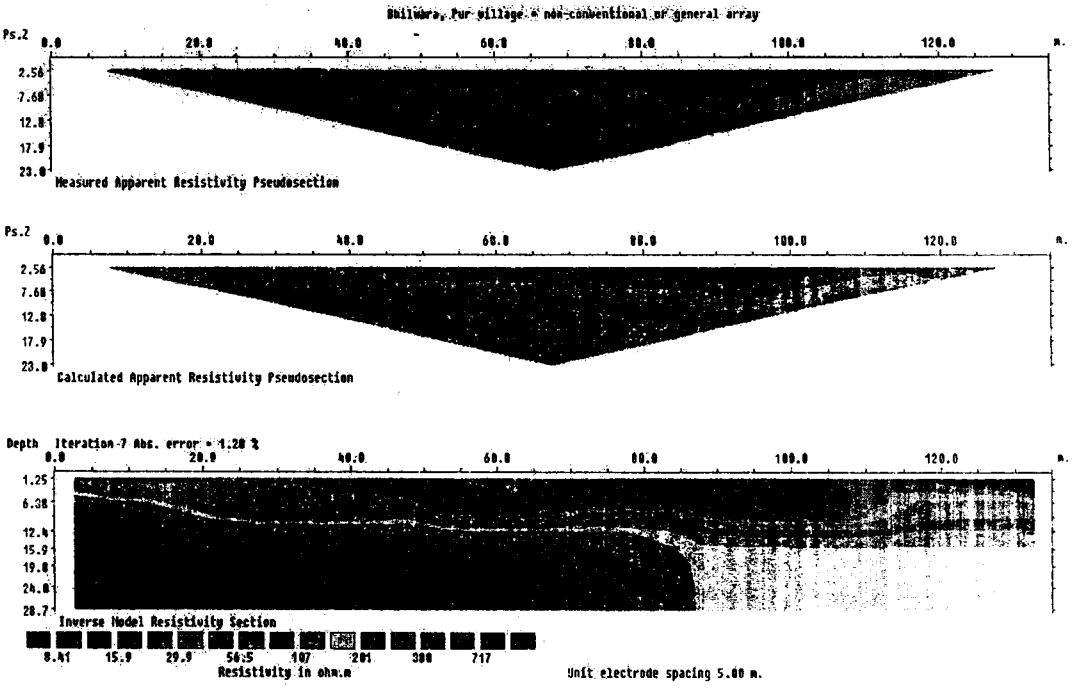


Figure 12: 2D resistivity inverse model by Wenner method at S_1 (Pathwari).

Table 4: Subsurface characterization by ERT at S_1 (Pathwari)

Depth of Investigation (meter)	Resistivity (Ohm-m)	ERT test Probable lithologs
		Sandy Soil
0-4	8.74-42.8	Sand and clay/Sandstone
4-12	42.8-463	Garnetiferous Quartzite/Schist
12-22	463-1024	
22-26	463-2266	Quartzite

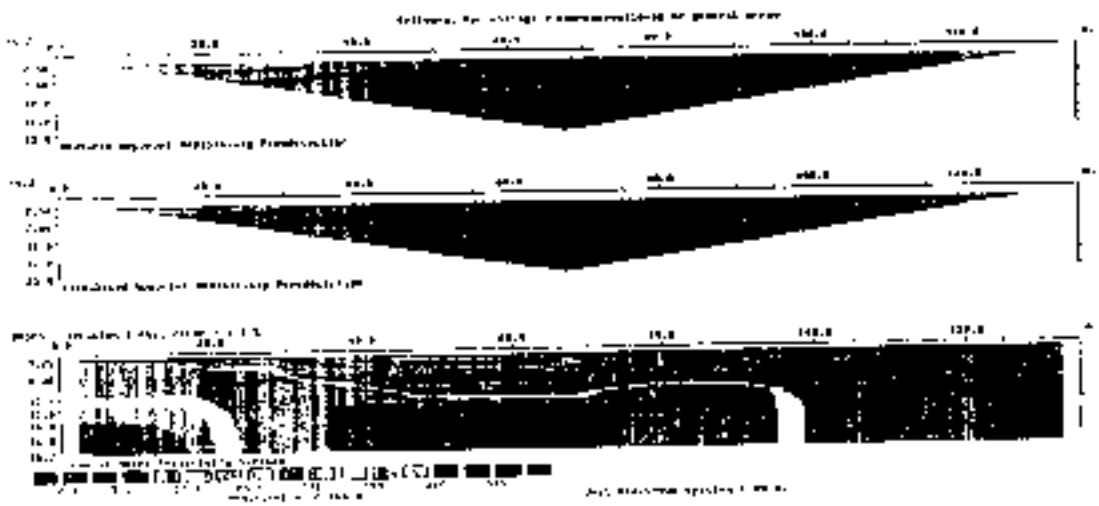


Figure 13: 2D resistivity inverse model result at site S_2 (Ghati Ke Hanuman).

Table 5: Subsurface characterization by electrical resistivity tomography (ERT) at S_2 (Ghati ke Hanuman)

Depth of Investigation (meter)	Resistivity (Ohm-m)	ERT test Probable lithologs
		Hard clayey soil
0-7	11.5-472	
7-26.2	137-877	Schistose Quartzite/gneiss with possible water in fractures

Site S_3 (Jindal Mata Mandir)

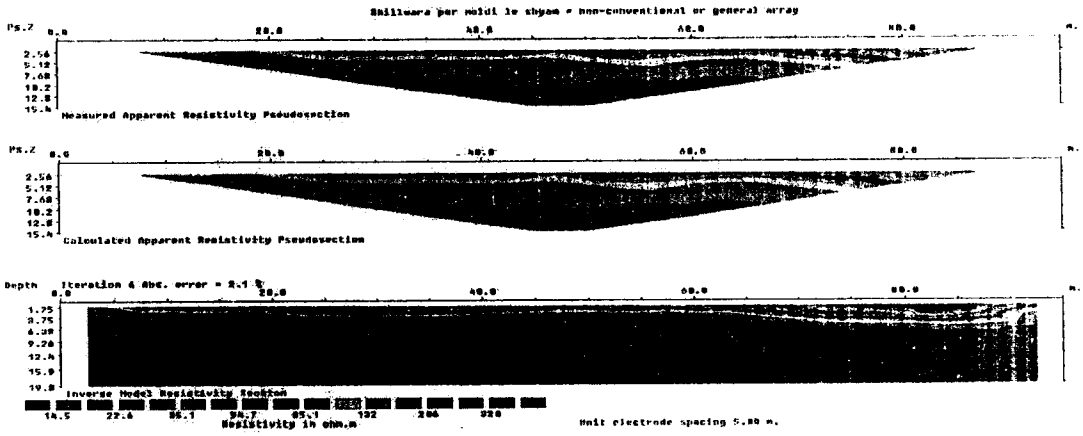


Figure 14: 2D resistivity inverse model by Wenner method at S_3.

Table 6: 2D resistivity inverse model by Wenner method at east direction of S_3.

Depth of Investigation (meter)	ERT test	
	Resistivity (Ohm-m)	Probable litho log
0-4	15.7-202	Topsoil and Schistose
4-32	202-308	Schist

Site S_4 (Moldi Ke Shyam)

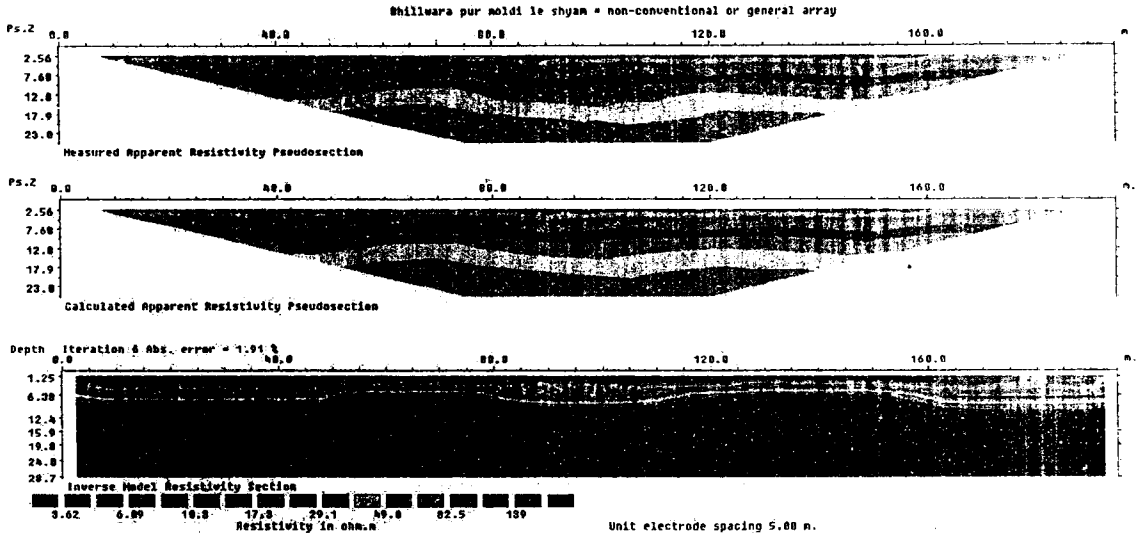


Figure 15: 2D resistivity inverse model by Wenner method at S_4.

Table 7: 2D resistivity inverse model by Wenner method at east direction of S_4

Depth of Investigation (meter)	ERT test	
	Resistivity (Ohm-m)	Probable litho log
0-7	3.53-38.2	Clayey soil
7-32	38.3-229	Schistose rock

Site S_5: Sukhadia Stadium

At this site, the survey was conducted in east, west, north and south direction up to 100-meter length on earth surface.

East

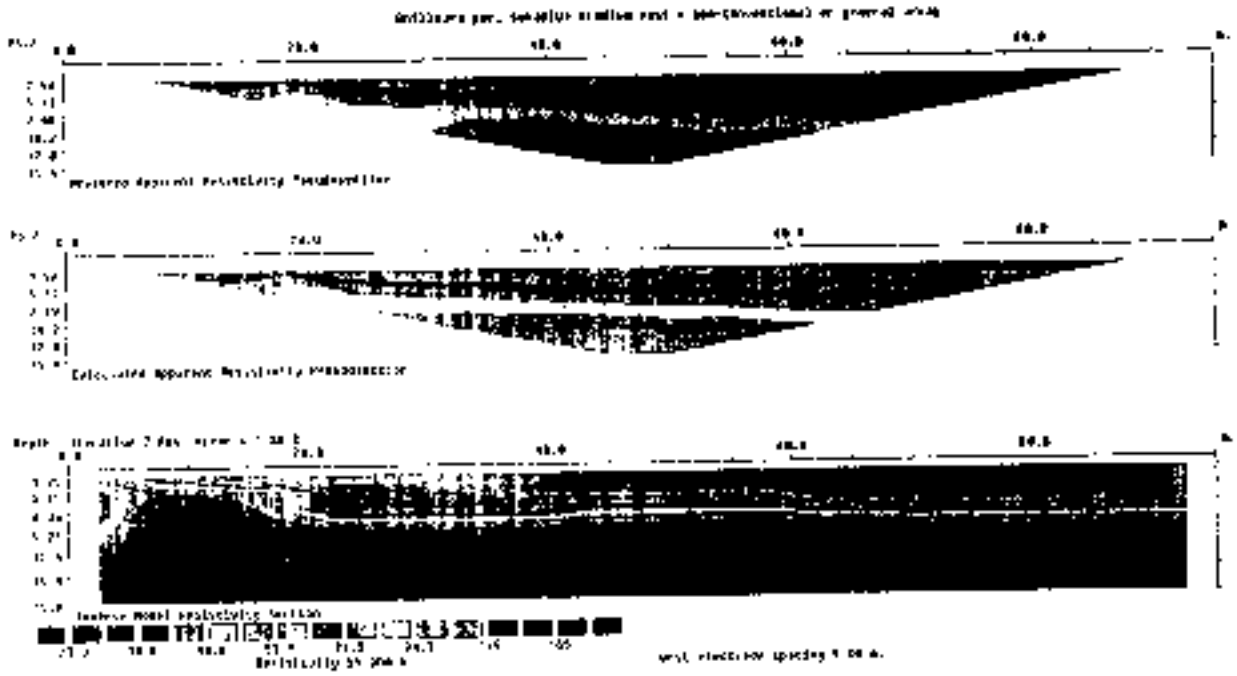


Figure 16: 2D resistivity model by Wenner method at east direction of Sukadiya stadium

Table 8: Subsurface characterization by electrical resistivity tomography at east direction of Sukadiya stadium

Depth of Investigation (meter)	ERT test	
	Resistivity (Ohm-m)	**Probable lithologs**
0-3	23.2-76.5	Clayey soil, highly weathered schist
3-10	76.5-114	Weathered sandstone/ schist
10-17.3	114-375	Schist

West

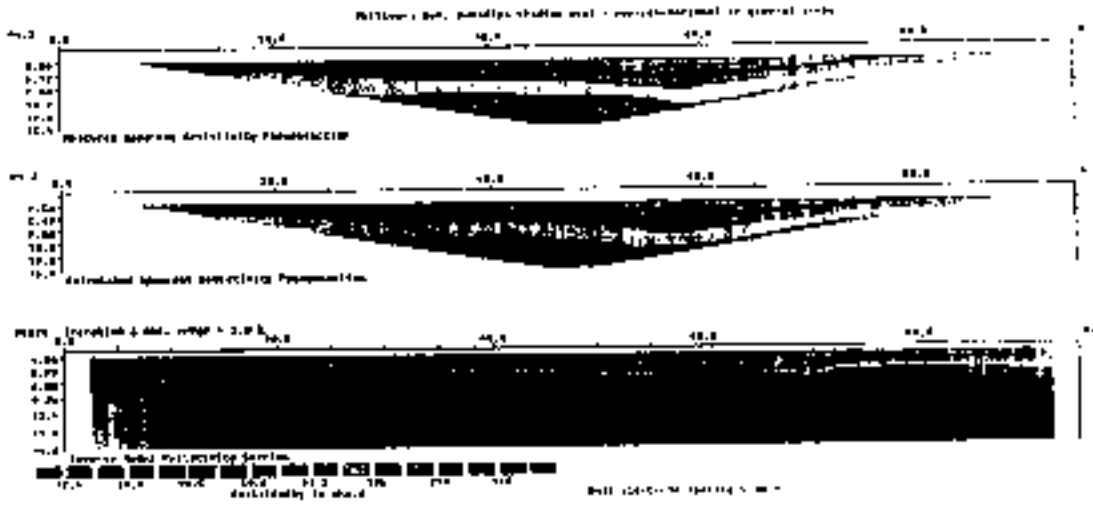


Figure 17: 2D resistivity model by Wenner method at West direction of Sukadiya stadium

Table 9: 2D resistivity inverse model by Wenner method at West direction of Sukadiya stadium

Depth of Investigation (meter)	ERT test	
	Resistivity (Ohm-m)	**Probable litho log**
0-3	16.7-215	Clayey soil
3-10	129-357	Partially saturated Schist
10-17.3	215-595	Schist

North

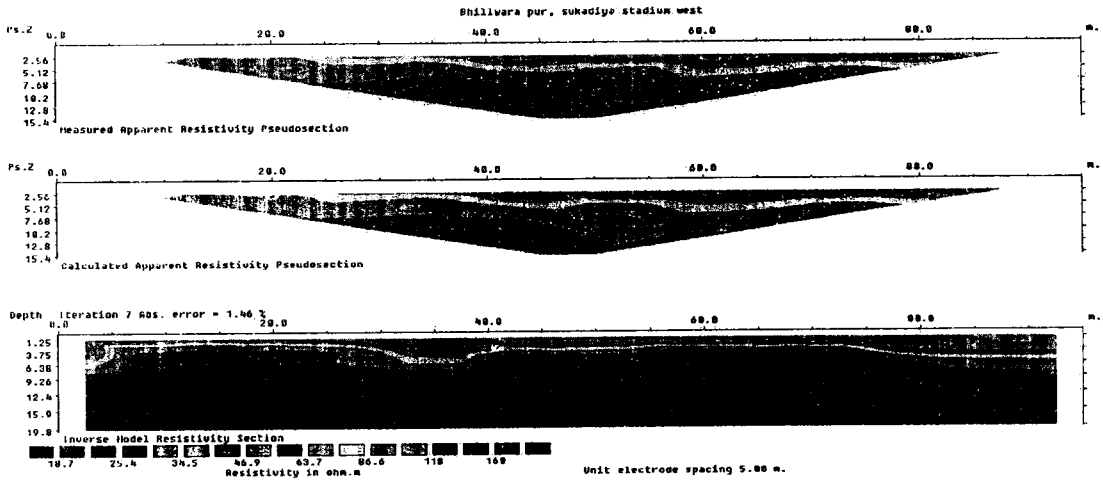


Figure 18: 2D resistivity model by Wenner method at north direction of Sukadiya stadium

Table 10: 2D resistivity inverse model by Wenner method at north direction of Sukadiya stadium

Depth of Investigation (meter)	ERT test	
	Resistivity (Ohm-m)	**Probable litho log**
0-3	10.4-86.7	Clayey soil, Sandstone (weathered)
3-17.3	86.7-161	Schist

South

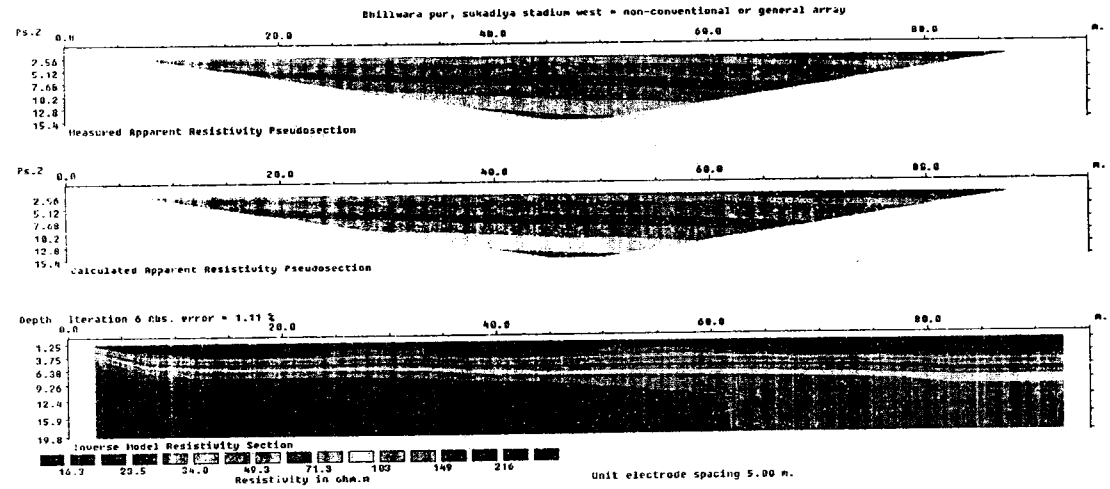


Figure 19: 2D resistivity model by Wenner method at south direction of Sukadiya stadium

Table 11: 2D resistivity inverse model by Wenner method at south direction of Sukadiya stadium

Depth of Investigation (meter)	ERT test	
	Resistivity (Ohm-m)	Probable litho log
0-3	15.8-90.4	Clayey soil
3-178	90.4-335	Schistose rock

Site GS_1: Near Old Masjid

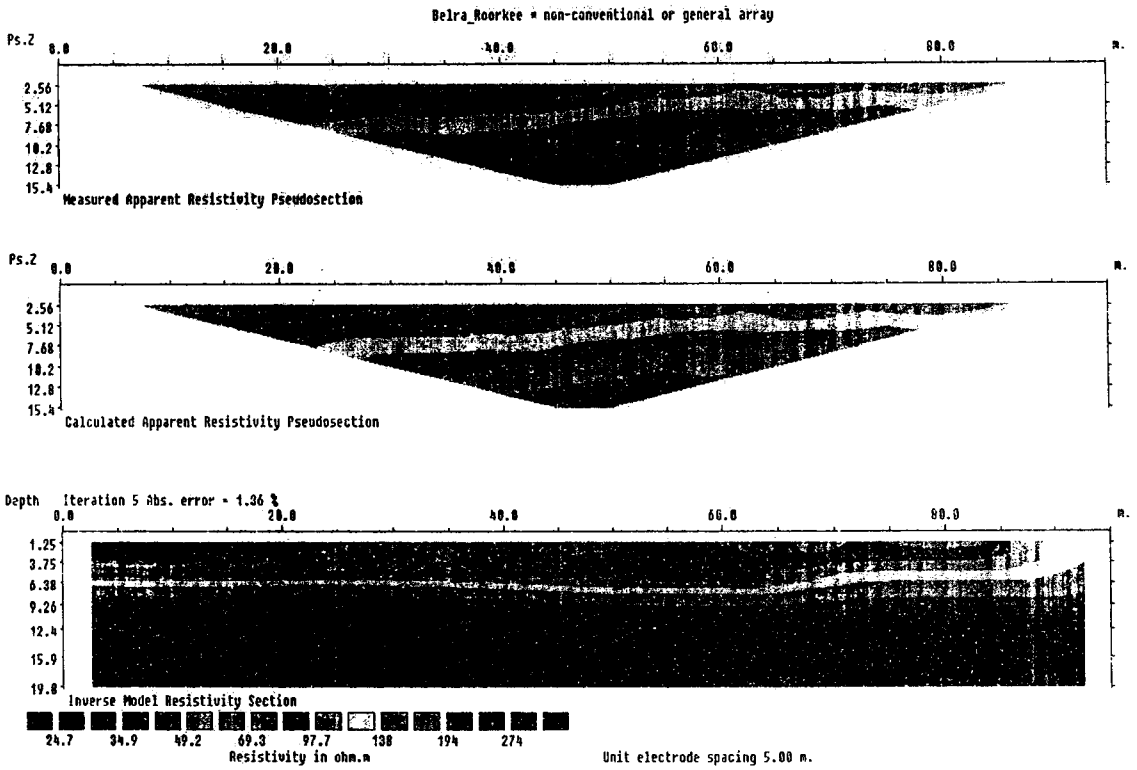


Figure 20: 2D resistivity inverse model by Wenner method near old masjid beside the pond

Table 12: Subsurface characterization by electrical resistivity tomography (ERT) at site GS_1

Depth of Investigation (meter)	ERT test Avg. Resistivity (Ohm-m)	Probable litho log
0-5	95	Top Soil
5-10	194	Schistose rock
10-25	274	Weathered Schist

Site GS_2: Near Bada Mandir

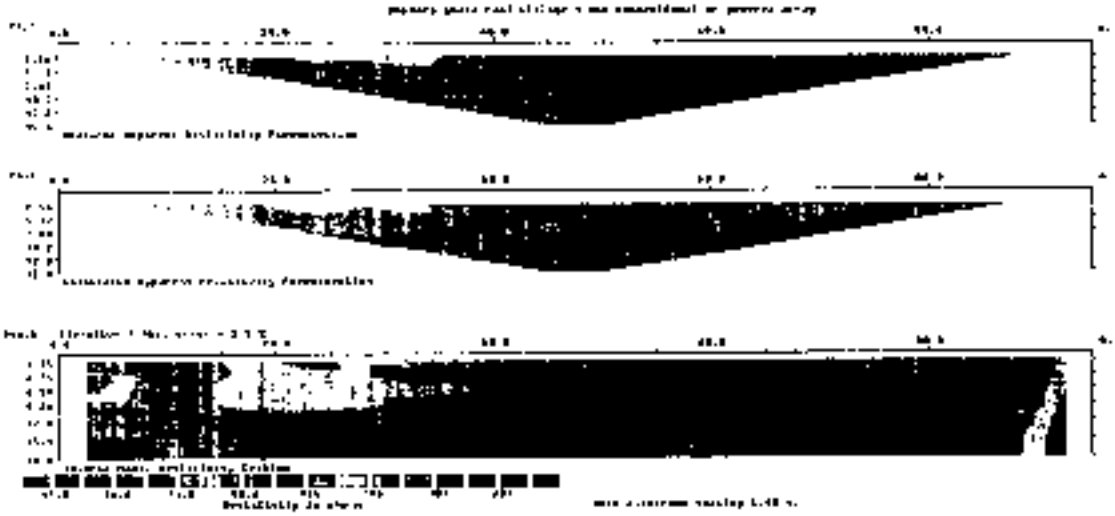


Figure 21: 2D resistivity inverse model by Wenner method near Bada Mandir

Table 13: Subsurface characterization by electrical resistivity tomography (ERT) at site GS_2

Depth of Investigation (meter)	ERT test Avg. Resistivity (Ohm-m)	Probable litho log
0-5	50	Top Soil
5-10	85	Fractured Schistose
10-15	228	Weathered schist
15-20	243	Weathered schist

Site GS_3: Near Ghata Rani Temple

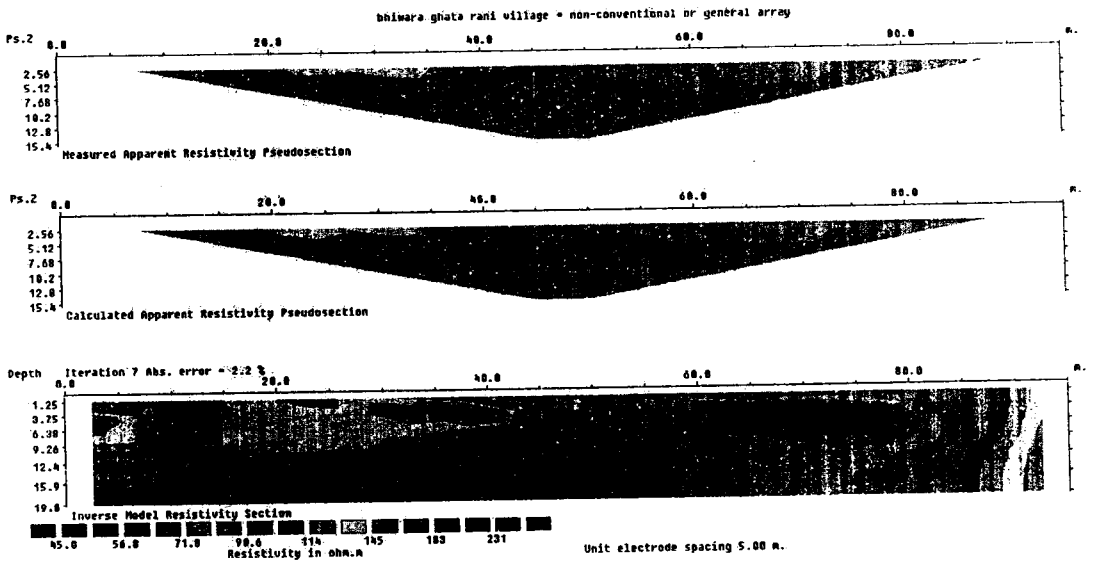


Figure 22: 2D resistivity inverse model by Wenner method near Bada Mandir.

Table 14: Subsurface characterization by ERT at site GS_2

Depth of Investigation (meter)	ERT test	
	Avg Resistivity (Ohm-m)	Probable litho log
0-5	126	Weathered phyllite
5-10	125	Weathered schist
10-20	104	Grey Phyllite

The findings of both 1-D vertical electrical soundings and 2-D electrical resistivity tomography give heterogeneous pattern of subsurface. It was observed from the 2D ERT inversion that a sandstone/soil present between 60m to 80m below 10m from the ground surface of the survey line at site S_1 as a sudden drop in resistivity from 717 Ohm-m to 201 Ohm-m is observed. A similar type of pattern was observed at S_3 site. A sudden drop in resistivity along the survey line can be observed from ERT inversion at GS_2 at 60m from the starting point. There is a high possibility of vertical fracture/anomaly here as resistivity value drops from 114 Ohm-m to 90 Ohm-m which continues throughout the depth. The similar pattern is observed between 80m-100m from the starting point showing vertical foliation in the underlying rock. Furthermore, a saturated soil seems to be present between

60-80 m away from the starting point throughout the subsurface depth. A similar type of soft material zone is also observed at 15-20 m depth below the weathered schist at the starting point of the ERT survey. A significant variation in subsurface formation is thus observed vertically and horizontally within the 100 m of the survey length in the problematic area. These types of subsurface anomalies are making the lithology of the Pur village vulnerable for differential land settlement.

Three-Dimensional modelling of Subsurface

The existing geological picture of the study area obtained by performing various VES and ERT can be understood by a professional hydro-geologist but may not be easy to conclude by others. In order to clearly explain the current geological scenario in the area, results of both these tests are clubbed together and 3-dimensional solid model, strip log diagrams, and fence diagrams are developed using ROCKWARE modelling software. The grid network used as base for 3-D lithological modelling is shown in figure 21. The problematic area i.e., in and around Pur village is situated near to edge AD of the grid whereas mining site is located near the BC edge of this grid.

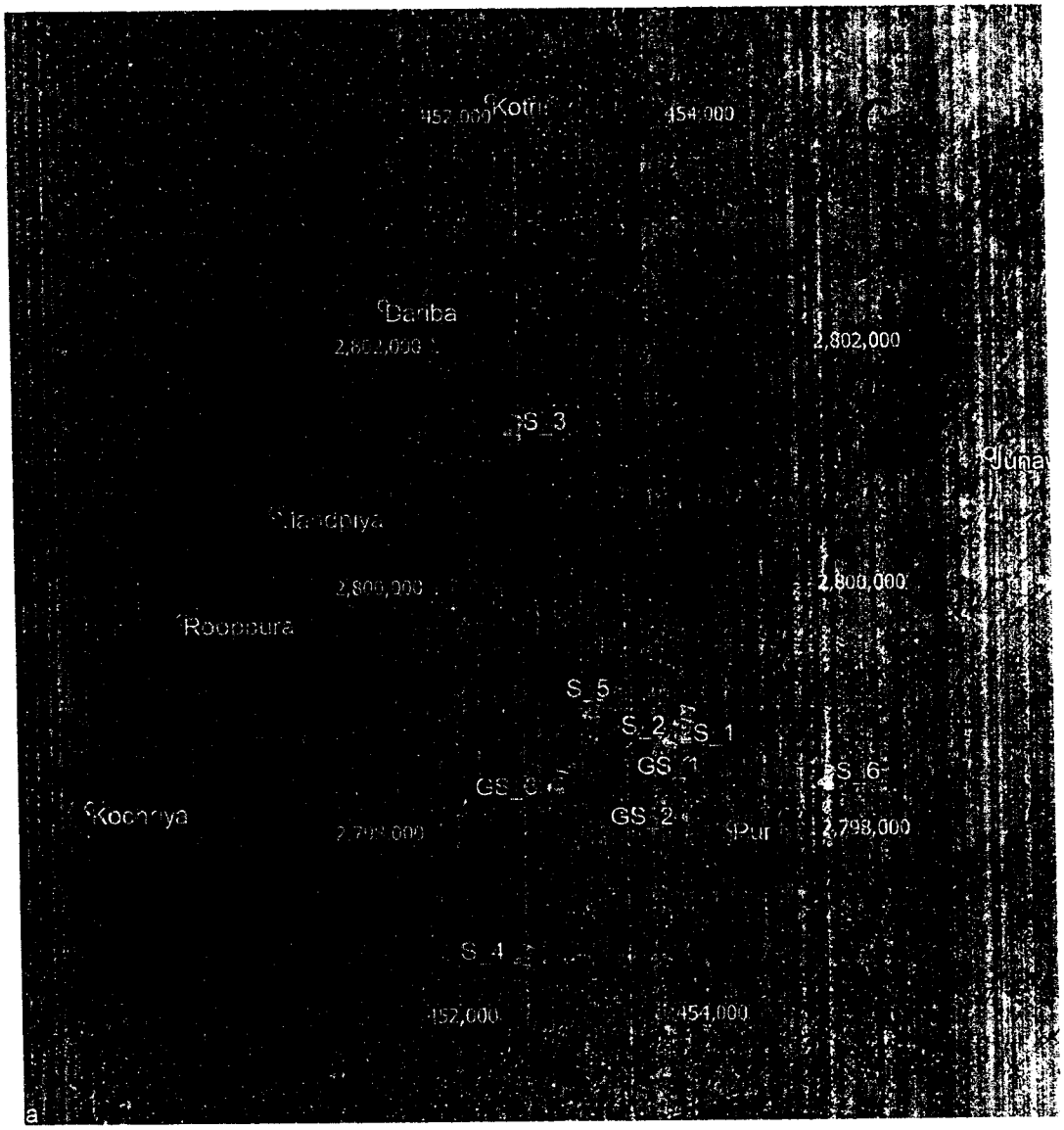


Figure 23: Google map of study area with marking for testing sites and grid ABCD used in lithological modelling.

A three dimensional geological model of the study area is shown in figure 24. This model gives the overall picture of the existing subsurface conditions in the area. As single view side of this complex model seems insufficient to deliver the whole information, the strip log diagram for these welllogs is shown in figures 23 and 24 with the South-East and South-West face forward.

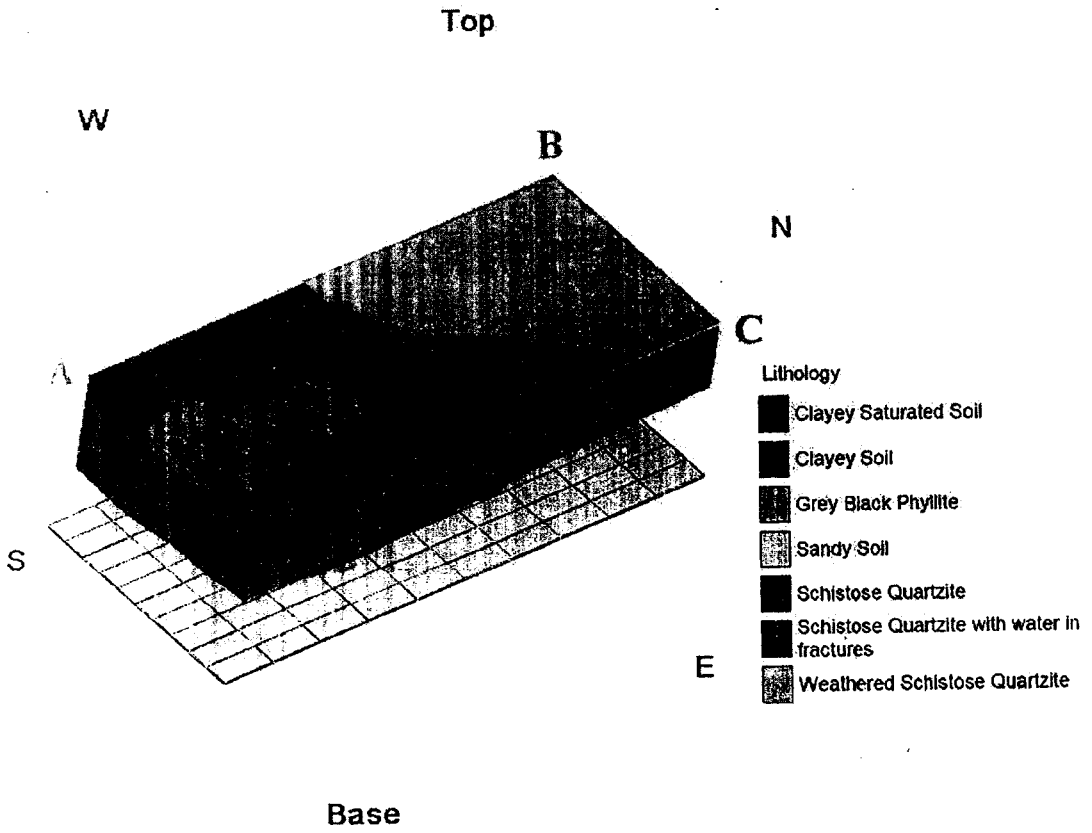


Figure 24: Three dimensional solid geological model of the study area with direction and grid marking for better understanding.

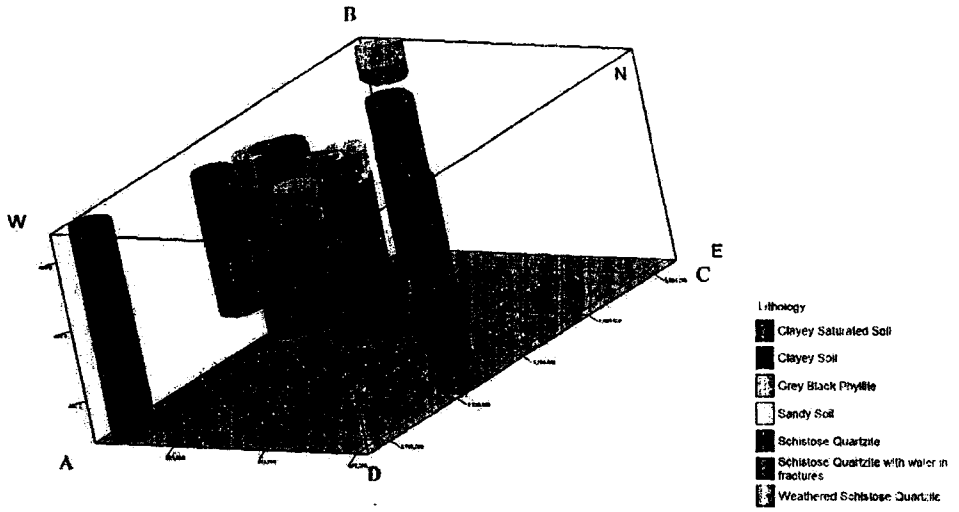


Figure 25: Three-D strip log model of the study area with South-East face forward.

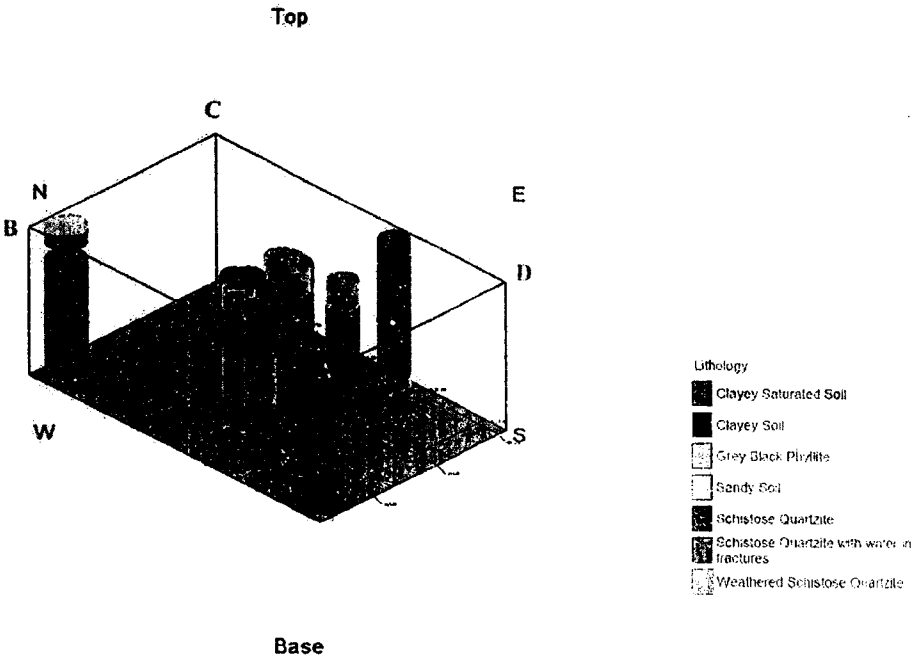
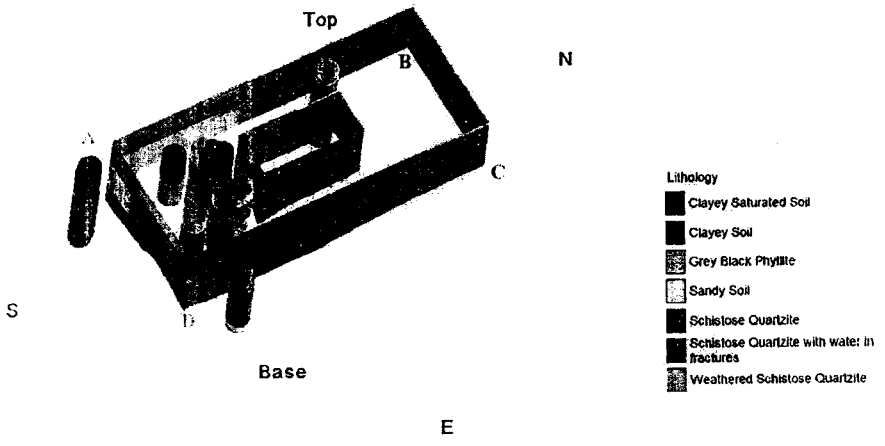


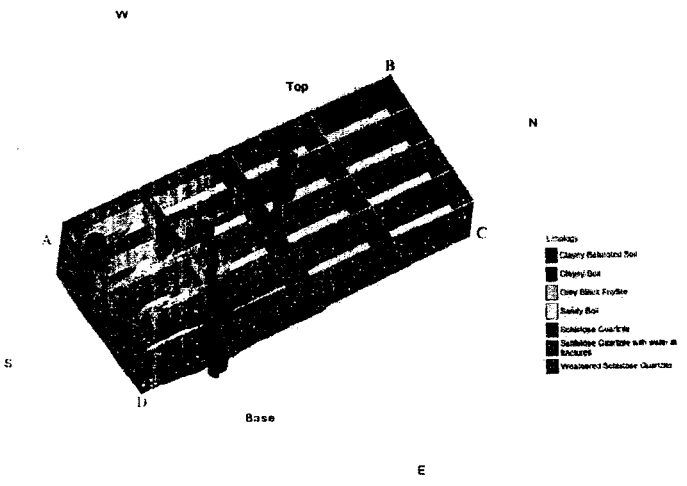
Figure 26: Three-D strip log model of the study area with South-West face forward.

Apart from solid 3-D model and strip log diagrams, fence diagram is useful to depict the geological condition more clearly. The fence diagram refers to three or more geologic

sections showing the relationship of wells to subsurface formations. The scales diminish with distance from the foreground to give a proper perspective of the whole area. Similar in some respect to a block diagram, fence diagram has the advantage of transparency, which is not possible in a block diagram. The fence diagrams for the study area are shown in figure 27 (a) and (b).



(a) Fence consisting of Collinear Rectangles



(b) Fence consisting of Collinear Grids

Figure 27: Three dimensional geological fence diagrams of the study area for different fence geometry

4.3 Surface nuclear magnetic resonance (SNMR) Survey using GMR

SNMR study was conducted by GMR system directly which detects the presence of soil water utilizing a phenomenon known as proton nuclear magnetic resonance (NMR). Proton NMR observed when proton spins associated with hydrogen atoms in groundwater are subjected to perturbation in the background magnetic field. In the static magnetic field, the proton spins preferentially align in the same direction as the field and so form a small magnetic moment. The SNMR system provides unambiguous detection of soil water because the measured signal is generated by hydrogen present in in soil water. By measuring the NMR properties of the subsurface, GMR provides quantitative images of moisture content along with estimation of hydro-geologic parameters, including specific yield and permeability (Vista Clara, 2009). The field setup of SNMR is shown in figure 28 which directs non-invasive imaging of subsurface to depths of approximately 100 m. Quantitative assessment of water content with its mobile/immobile water c

ontents is performed along with vadose zone characterization using this technique (Behroozmand et al., 2015). Factors like electric and magnetic interferences can affect the accuracy of the SNMR survey.

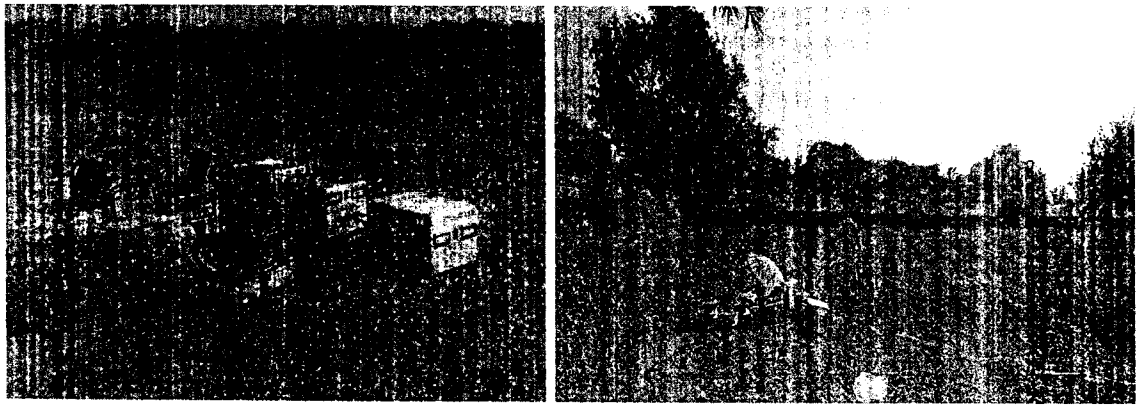


Figure 28: Field setup of SNMR survey using GMR

The sites S_2, S_4, and S_5 are initially selected for performing the SNMR survey. Data of SNMR survey at site S_2 cannot be able to conclude due to presence of high electromagnetic noise and residential area. Figures 29 and 30 show the variation of water content, hydraulic conductivity and soil strata at different depths below the surface of the soil at site S_4 and S_5.

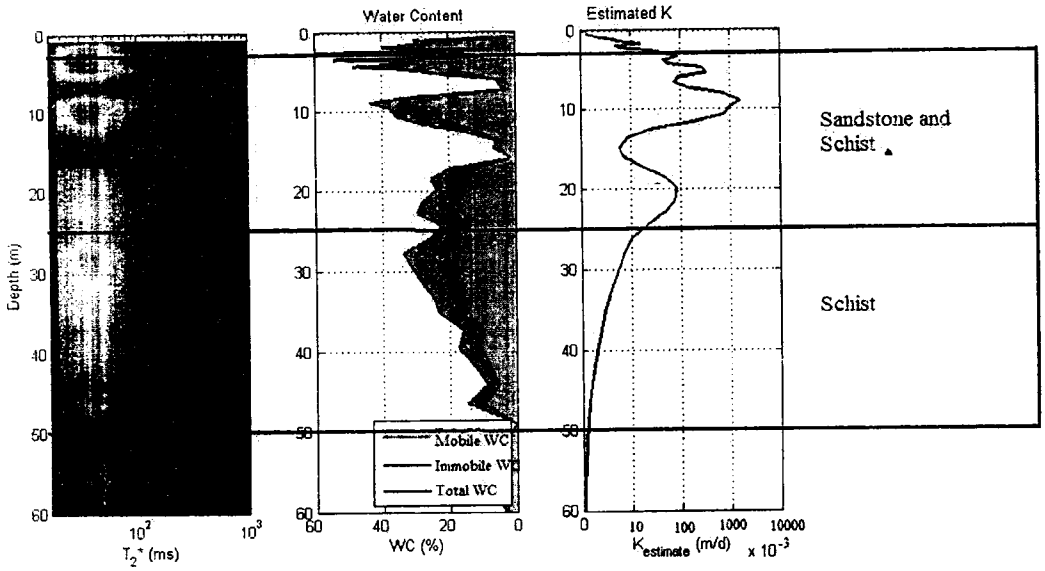


Figure 29. Distribution of water content, hydraulic conductivity and soil strata at site of Sukhadia stadium at Pur-Village

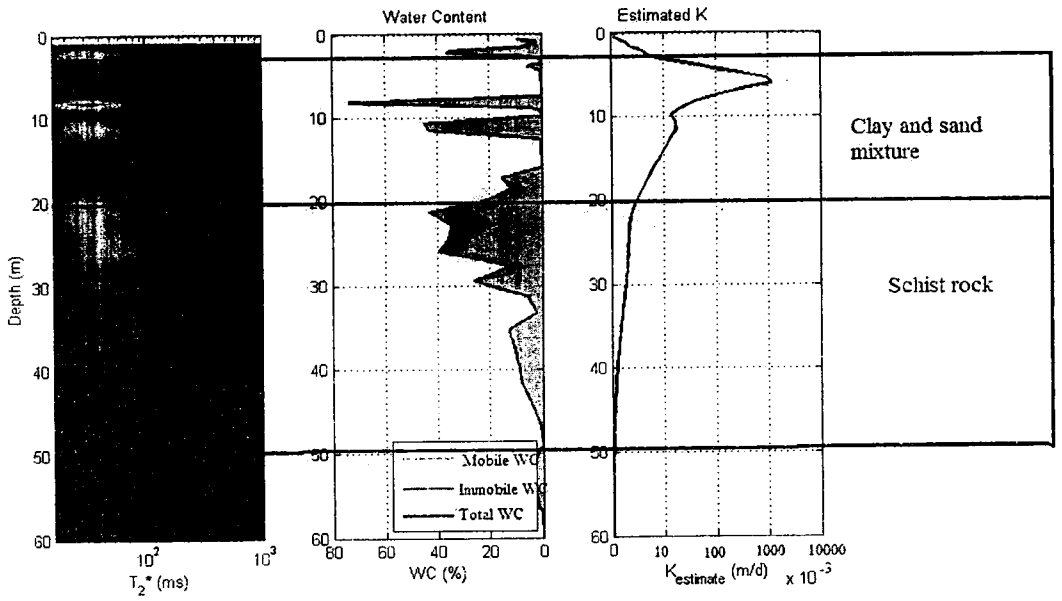


Figure 30. Distribution of water content, hydraulic conductivity and soil strata at site of Moldyka Shyam at Pur-Village

These results show that the soil moisture content is varying significantly from ground surface to subsurface even though there was no recent rainfall or irrigation event at those sites. This shows the presence of vertical heterogeneity in subsurface in form of different stratigraphic

layers observed with depth. Sharp change in moisture content particularly no observation of immobile water content at some depths shows the presence of cracks and fracture in subsurface. Variation in hydraulic conductivity of the strata fortifies the heterogeneous nature of the variably saturated zone. Negligible values of K at deeper locations at both the sites show the presence of hard rock.

4.4 Aquifer Tests

Aquifer test (pump test) is a field experiment performed in controlled condition for estimation of hydraulic properties of the aquifer system such as storativity (S) and transmissivity (T). It is often followed by recovery test for the validation of parameters obtained during the pumping time. Depending on the geology of the concerned area and available resources, aquifer test are performed either constant head or constant discharge type. The data collected in field test is then analyzed either using Theis, Cooper-Jacob, Neuman or any other suitable methods. The relationship between drawdown (s) and time (t) from start of pumping are used in these methods with well function W(u) defined as

$$s = \frac{Q}{4\Pi T} W(u)$$

The auxiliary parameter is defined as $u = \frac{r^2 S}{4Tt}$, where t is the time from start of pumping and r is the radial distance from the pumping well. Plot of drawdown (s) versus time since pumping starts (t), known as data curve is matched with the Theis type curve for obtaining the s and $r^2/4t$ values for a corresponding well function value. Then the value of S and T can be calculated from the well function. After pumping has stopped, value of residual drawdown (s') is also measured in the observation well. A plot of residual drawdown s' versus the logarithm of t/t ' is then plotted to obtain a best fit line. The slope of the line ($\Delta s'$ per log cycle of $\frac{t}{t'}$) given as

$$\Delta s' = \frac{2.303Q}{4\Pi T}$$

The results of recovery test are used to validate the pumping test results. In this study. two pump test at different sites (table 15 and figure 31) both followed by recovery tests are

performed in the study area for determining aquifer parameters, Storativity (S) and Transmissivity (T). The detail of test at both places is described below.



Figure 31: Images of well test locations

Table 15: Location of pumping well test sites

S.No.	Location Name	Latitude	Longitude	Type of Control Well
1	Banshi Mali ka kuwa **(WT_1)**	25.3038833	74.54033	Open Well
2	Mukesh Mali ka kuwa **(WT_2)**	25.3129166	74.53845	Bore Well

Test at Banshi Mali ka Kuwa: The test was performed on 31/01/2020 using an existing dug well of diameter 5m as control well and an existing bore well of diameter 0.1016m as observation well. Both the wells are situated in an unconfined aquifer of approximate thickness 25-30 m, extending from 8 to 35m bgl. Pump test with a constant discharge of 48.9645 m^3/day was performed for a period of 90 minutes followed by a recovery test for 20 minutes. The plot of time vs. drawdown data of monitoring well obtained from the pumping test is shown in figure 28. This data Curve is then matched with the Theis type curve with the

help of software AQTESOLV 4.5. Transmissivity (T) and Specific yield (S) of the aquifer system is calculated and were found as 35.46 m^2/day and 3% respectively. A plot of residual drawdown s′ vs. log (t/t′) is plotted (figure 33) and slope of best fit straight line is used for this calculation.

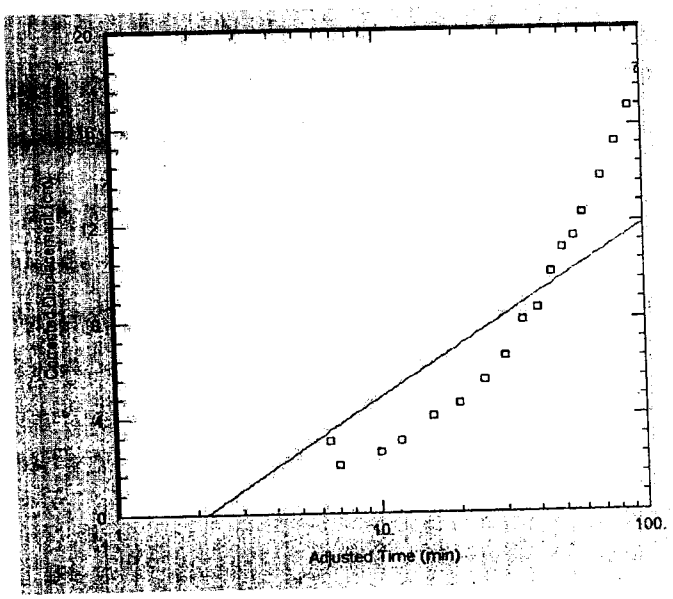


Figure 32: Data curve obtained after plotting the corrected drawdown recorded in the observation well against adjusted time since pumping start.

These values of T and S obtained are in good agreement with the study carried out by CGWB in 2013. Further the obtained hydraulic conductivity (K) of the aquifer is nearby to the unity which is also observed using the SNMR survey at nearby locations.

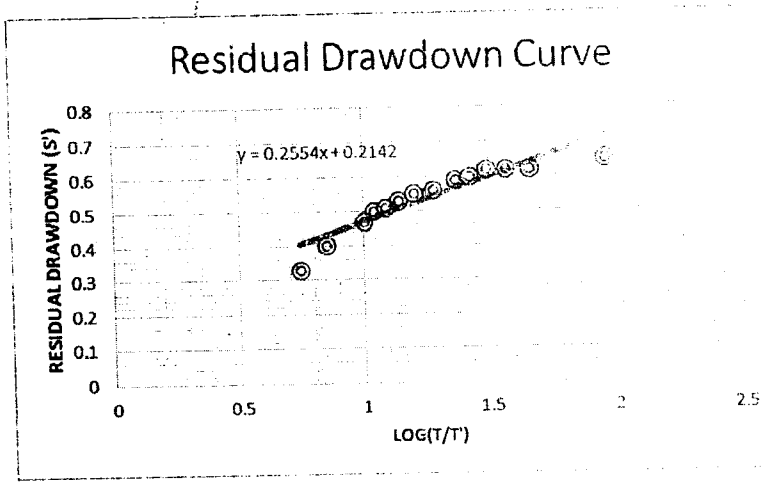


Figure 33: Recovery test plot of the observation well obtained after plotting the residual drawdown per log cycle of time.

Test at Sh. Mukesh Mali ka Kuwa: The test was performed on 31/01/2020 using two existing bore wells each of diameter 0.33 m as control well and observation well. Pump test with a constant discharge of 26.4835 m^3/day were performed for a period of 100 minutes followed by recovery test for 30 minutes. But the observed drawdown obtained from this test cannot be concluded to yield meaningful value of the aquifer parameters. This disturbance seems due to operating of one or more nearby wells either before or during the pump test without the knowledge of the investigators at the site.

4.5 Water Quality Parameters

A general water quality analysis for the study area is performed for assessment of chemical composition of its surface and groundwater. A total of 9 sampling points scattered in the entire area are selected for the analysis of various physio-chemical water quality parameters. The location, site code along with the source of water sample is mentioned in the table 16 and marked in figure 34. The direct and random samplings of groundwater from the wells of each site are used to collect the samples. Sample from Q_1, Q_2, Q_3, and Q_4 are analyzed in-situ using multi-meter sensors for temperature, total dissolved solids (TDS), resistivity, conductivity, salinity, pressure, and absolute conductivity as listed in table 17.

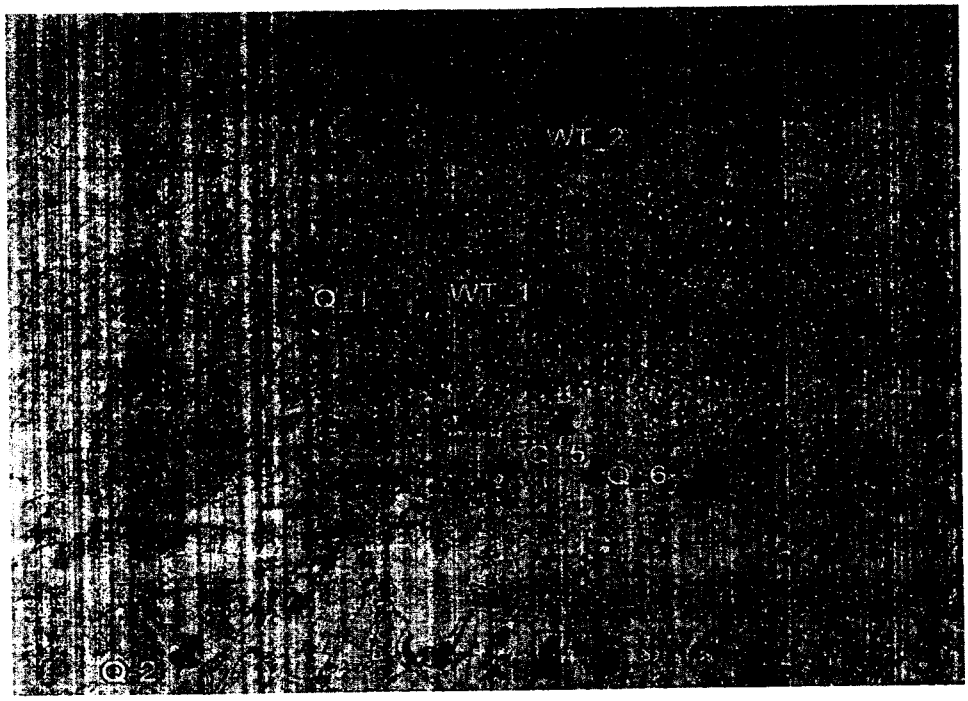


Figure 34: Location of sampling site for Water quality analysis.

Table 16: Location of water sample collection sites along with their respective site codes used in this study.

Site Code	*Sample Location*	*Latitude*	*Longitude*	*Source of Water*
Q_1	Shukhadia Stadium	25.30356	74.53331666	Hand Pump
Q_2	Bhramano Ka Kua	25.2869166	74.5276333	Open Well
Q_3	Ghati Ke Hanuman	25.303355	74.540543	Open Well
Q_4	Pumping Site	25.30395	74.5405433	Tube Well
Q_5	Bada Bagh	25.029755	74.5411833	Hand Pump
Q_6	School	25.29505	74.542683	Seepage water
Q_7	School	25.29505	74.542683	Water Supply
Q_8	School	25.29505	74.542683	Drain Water
Q_9	School	25.29505	74.542683	Handpump

Apart from the in-situ analysis, samples from the site Q_5, Q_6, Q_7, Q_8, and Q_9 are analyzed in the lab of Department of Hydrology, IIT Roorkee using the Atomic Adsorption Spectroscopy (AAS) and ICP-MS. Concentration of heavy metals and trace elements like Lithium, Sodium, Magnesium, Aluminum, Potassium, Calcium, Chromium, Manganese, Iron, Cobalt, Nickel, Copper, Zinc, Cadmium, and Lead are measured and are listed in table 18. The concentration of Na, K, Mg, Cd and Pb in water samples were estimated through Atomic Emission Spectroscopy. The study samples were diluted appropriately before undertaking the experiment. Calibration curves were plotted using various concentration of these elements along with the blank solution before the analysis. In general, groundwater of the area is found safe except the little high salinity at some locations.

Table 17: The in-situ measured values of the temperature, total dissolved solids (TDS), resistivity, conductivity, salinity, and absolute conductivity of collected groundwater samples in the study area.

Site Code	Temperature (^{0}C)	Conductivity (µS/cm)	Abs. Conductivity (µS/cm)	Resistivity(µΩ-cm)	TDS (ppm)	Salinity (PSU)
Q_1	29.6	1036	1126	963	519	0.51
Q_2	23.74	643	629	1553	322	0.31
Q_3	27.28	1178	1236	840	598	0.59
Q_4	26.9	1564	1617	644	774	0.77

Table 18: The concentration (in ppb) of the Lithium, Sodium, Magnesium, Aluminum, Potassium, Calcium, Chromium, Manganese, Iron, Cobalt, Nickel, Copper, Zinc, Cadmium, and Lead of collected water samples in the study area.

Site Code	Li	Na	Mg	Al	K	Ca	Cr	Mn	Fe	Co	Ni	Cu	Zn	Cd	Pb
Q_5	5.34	22653.39	2269.72	16.85	79672.61	4238.609	0.303	0.169	0	0.023	0.235	0.328	25.82	0.282	ND
Q_6	3.36	26204.02	1550.619	11.357	104548.06	1639.082	1.518	ND	0	0.041	0.142	1.922	8.003	0.09	0.021
Q_7	0.25	2373.903	1223.062	28.774	1398.69	4279.941	ND	4.415	0	0.388	0.29	4.014	205.784	0.717	2.841
Q_8	2.34	26840.59	4359.73	11.197	57642.56	12221.14	0.333	ND	0	0.043	0.346	1.216	9.064	0.734	ND
Q_9	3.98	44323.83	8933.544	5.671	95448.49	10091.815	0.043	6.969	0	0.138	0.445	0.792	96.545	0.185	ND

ND: not detected

4.6 Groundwater Flow Pattern

The groundwater table levels of various locations distributed throughout the study area are observed during the field visits. The observed heads are collected from both open wells and tube wells. The groundwater table is then interpolated by inverse distance weightage (IDW) technique to prepare the overall distribution of groundwater table throughout the area, as shown in figures 35 a-b.

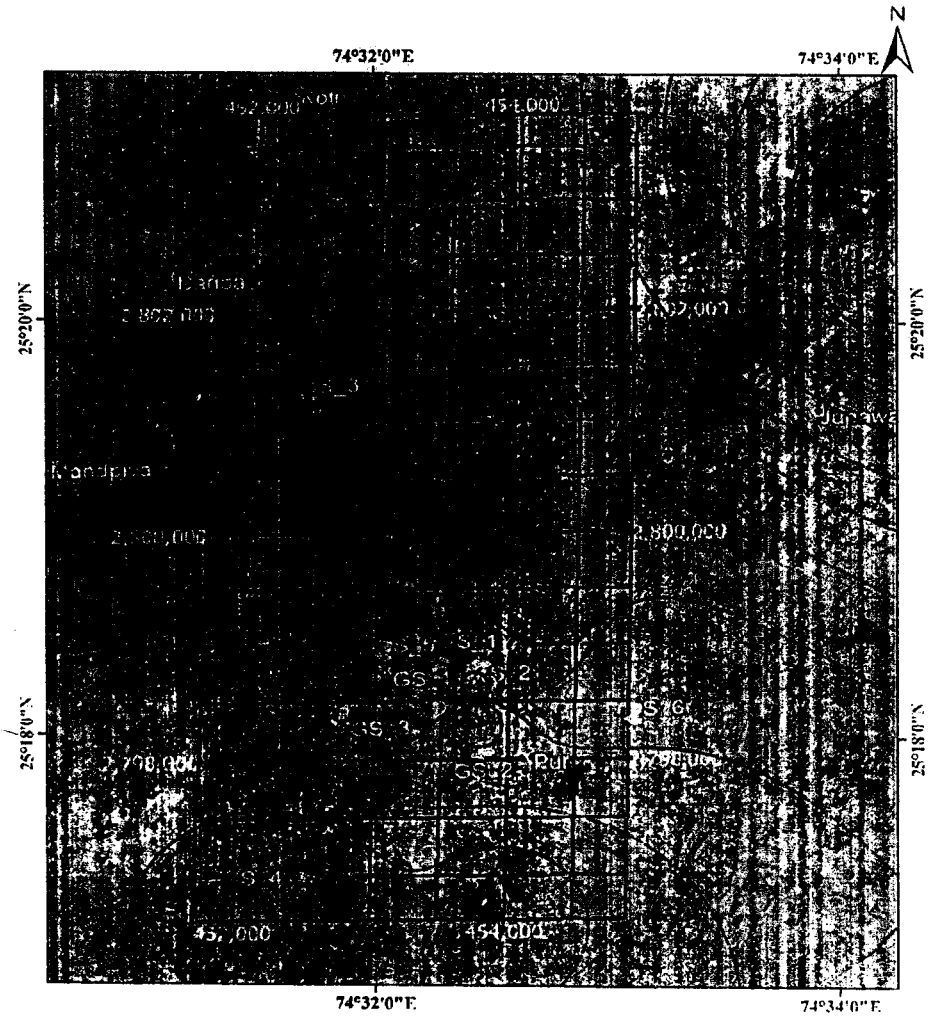


Figure 35 a: Variation of Groundwater table (Hydraulic head) in and around the study area with grid mark ABCD for better understanding.

As groundwater flows from a higher hydraulic head to lower, general groundwater flow direction is found to be from Southwest to Northeast direction i.e., from village to Jindal Industries. Groundwater flow below the Pur settlement could be established due to non-availability of the reliable groundwater level data.

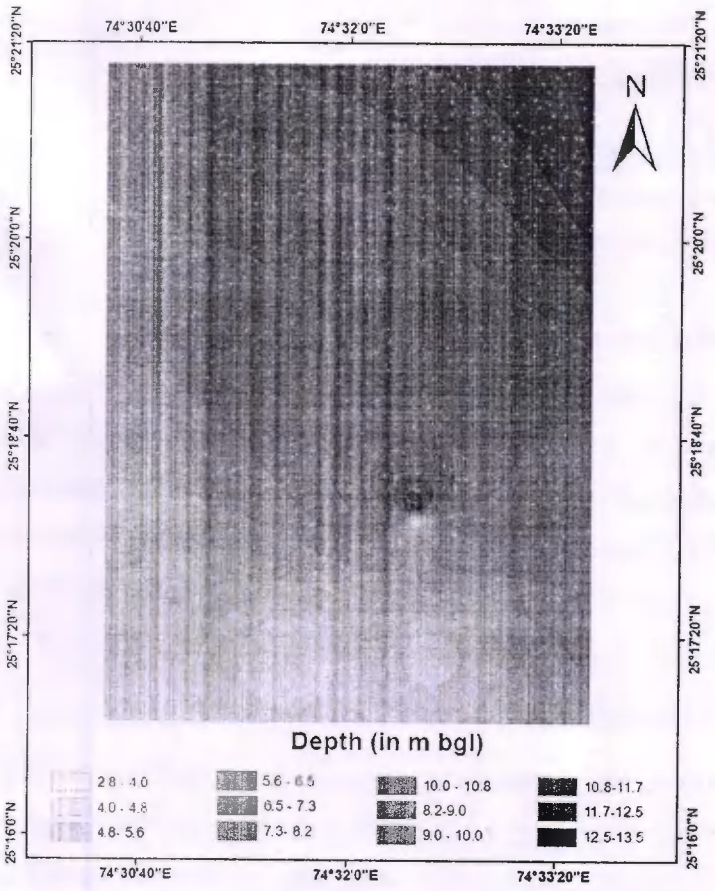


Figure 35B) Variation of Groundwater table (Hydraulic head) in and around the study area with grid mark ABCD for better understanding

4.7 Isotopic Analysis

Isotopes are the element having same atomic number with different molecular masses. Water (H_2O) is composed of two hydrogen and one oxygen atom. Oxygen has three stable isotopes, ^{16}O, ^{17}O, and ^{18}O whereas hydrogen has two stable isotopes, ^{1}H (Portion or P) and ^{2}H (deuterium or D), and one radioactive isotope, ^{3}H (Tritium or T). The oxygen and hydrogen combine in various forms to make water, thus making their isotopic composition a powerful tracer of the hydrosphere. Water resources develop unique isotopic compositions that can be indicative of their source or the processes that formed them. Isotopic composition differs for sea water, polar ice, atmospheric water vapor, and meteoric water. There are nine possible isotopic configurations for water, which are distinguished by their mass numbers as well as their characteristics. However, because of the low abundance of the heavier isotopes, almost all water molecules are of three isotopic combinations. Table 19 indicates the characteristics of three isotopic combination of water found generally.

Table 19: Characteristics of Water molecules with different isotopic combination

Properties	$^{1}H_2^{16}O$	$^{2}H_2^{16}O$	$^{1}H_2^{18}O$
Density @ 20°C	0.997	1.1051	1.1106
Boiling Point	100.0	101.42	100.14
Temperatory Density Max	3.98	11.24	4.30

Oxygen and hydrogen isotopic ratios are measured using gas source isotope ratio mass spectrometry (IRMS). Oxygen and hydrogen compositions are reported as delta values. Delta values (δ) are commonly used in light stable isotope geochemistry to express isotopic composition in terms of per mil (‰) deviation from a standard. Stable isotope ratios of deuterium/hydrogen ($^{2}H/^{1}H$) and $^{18}O/^{16}O$ of water are conventionally expressed as a per mil (‰) deviation from Standard Mean Ocean Water (SMOW) or VSMOW (Vienna SMOW). In carbonates, the isotopic composition of oxygen is sometimes compared instead to PDB, a standard based on the Peedee formation, a carbonate rock found in South Carolina.

Isotopic study is carried out in this study on four water samples collected from Rajkiya Uchh Madhaymik Vidhayalaya Pur (school in Pur village), which has a problem of water logging from the ground surface. As per the School authority, this water logging issue has started in July 2018. The isotope analysis is conducted to identify the source of this seepage water in the school premise. Measure of the ratio of stable isotopes oxygen-18 and oxygen-16, $\delta^{18}O$ and deuterium D are measured for the groundwater samples collected from a nearby hand pump, Drains (flowing outside from school), Government supply water, and seepage water from the school. Table 20 shows the location, source, isotope analysis results, EC and pH of collected water samples. The results from this analysis indicate that properties of seepage water and groundwater are found closer, and hence, a high groundwater table in this area is the main cause of waterlogging.

Table 20: Result of Isotope analysis along with code, source, and isotopic analysis along with In-situ measured Electrical Conductivity and pH.

S. No.	Code	Location	Source	δD	δO18	EC (mS/cm)	pH
1	BW4	N 25-degree 17.703 m E 074-degree 32.561 m (School)	Seepage	-16.43	-1.54	2.4	9.22
2	BW5		Water supply from chambal	-45.28	-6.11	0.32	8
3	BW6		Drain water from school	-33.17	-4.15	2.06	7.15
4	BW7		Hand pump	-22.69	-2.47	4.37	7.55

Summary and conclusion

Based on the comprehensive site surveys followed by a series of field experiments conducted during 07-11 November 2019 and 28 January to 01 February 2020, the findings of this study are concluded in this section. Preliminary observations based on the field survey and secondary data gathered from different sources of the project site are mentioned first. The results of various field experiments and laboratory analysis in context of the existing building cracks are concluded next followed by the recommended guidelines to mitigate the problem.

Preliminary observations

Initial field observation around the Pur village indicates that the in-situ rock exposures have been significantly affected as a result of growing inhabitations in the area. Due to such incursions, only partially eroded and isolated remnants of hillocks are found in the study area. Besides, many of the hillocks have virtually disappeared in the vastly expanding village. During the visit to the Laxmi temple (*Teli mandir*), prolific cracks and fissures were clearly visible in transverse and vertical-horizontal directions. As such, examination of one partially eroded hillock near '*Baoli Naka*' revealed fragile exposures of grey black mica-schists with dip of 75-80 degrees in the N-130 degrees direction, implying strike of N40-220 degrees, which also seems to be slightly disturbed in nature. The dip direction also seemed to be vaguely towards the adjoining pond. The spot examination of the geological formations in the Sukhadia stadium, situated on the periphery of Pur village indicated presence of isolated outcrops of schistose quartzites within the alluvial expanse. The quartzites displayed dips of 80-85 degree towards southeast and a strike of N50-230 degree. The quartzites also showed clear evidence of displacement due to faulting in the geological past as manifested by presence of slicken sides with visible silicification on the steep rock face(s). The project area contains gneiss and schist (Bhilwara Super group); gneiss, schist, phyllite, slate and limestone (Aravalli Supergroup); sandstone, shale and limestone (Vindhyan Super group); and alluvium as the major water bearing formations. The aquifers are localized within the weathered, fractured and jointed hard rock zones.

Observations from field experiments

A total of 19 geophysical surveys were conducted around the village using 06 vertical electrical soundings (VES), 11 electrical resistivity tomography (ERT) surveys, and 02 Surface nuclear magnetic resonance (SNMR) surveys using ground magnetic resonance

(GMR). Findings of these VES surveys show that the study area contains thin top soil/alluvium of thickness varying between 1-5 m. The top layer of sand is underlain by weathered hard rock (schistose quartzite) having thickness ranging from 2-7 m, with its maximum value at *Sukhadia stadium*. Besides, the top veneer is directly comprised of weathered hard rock at *Jindal Mata Mandir* as seen from the high resistivity of the topmost layer. The above interpretation is corroborated by the presence of isolated outcrops (schistose quartzite) dotting the area. The rocks in these outcrops show steep dips towards SE, with presence of slicken sides at *Sukhadia stadium*, pointing to the incidence of displacement of rocks in the geological past. The weathered schist/quartzite is indicated to be underlain by hard/compact Schist/quartzite at depths varying between 5 m below the surface at *Pathwari* site and 9.5 m below ground level at *Sukhadia stadium* site.

The findings of 2-D electrical resistivity tomography are matching well with the 1-D VES results and showing the similar lithological pattern at the common sites around the Pur village. Further, it was observed from the 2D ERT inversion that a sandstone/soil is present below 10m from the ground surface between 60m to 80m of the survey at site S_1 (*Pathwari*) as a sudden drop in resistivity from 717 Ohm-m to 201 Ohm-m was observed. A similar type of pattern was observed at S_3 (*Jindal Mata Mandir*) site. It is to be noted that the top soil depth at GS-2 site present nearby to *Bada Mandir* in the problematic area is found more as compared to the other sites situated at the village periphery towards the mining industry. A sudden drop in resistivity along the survey line was also observed from ERT inversion at GS_2 around 60m from the starting point. This shows a presence of vertical fracture/anomaly as resistivity value was found to drop from 114 Ohm-m to 90 Ohm-m which continued throughout the depth. The similar pattern was observed between 80m-100m from the starting point showing vertical foliation in the underlying rock. Furthermore, a saturated soil seems to be present between 60-80 m away from the starting point throughout the subsurface depth. A similar type of soft material zone is also observed at 15-20 m depth below the weathered schist at the starting point of the ERT survey. A significant variation in subsurface formation is thus observed vertically and horizontally within the survey length in the problematic area.

A significant variation in water content and hydraulic conductivity observed with depth of SNMR survey performed at two sites further indicates towards the existence of soil strata heterogeneity. ERT at *Ghati ke Hanuman* area revealed that the area is having heterogeneous geology both laterally and in vertical direction. Fractured schistose quartzite/gneiss possibly filled water in fractures upto a depth of about 27 m was observed at this site. ERTs near *Old*

masjid and near *Bada mandir* area revealed that the geology is composed of schistose quartzite some in solid and remaining in weathered form. Sudden drops in resistivity along/vertical to the survey lines were observed from ERT surveys in and around the Pur village. This shows a high possibility of vertical and lateral fracture/anomaly existence in the top subsurface. Furthermore, saturated soil zones are also observed at some random depths along the survey lines below the weathered schist. These types of subsurface anomalies are prone for differential land settlement. The average water quality parameters are found to be within safe limits for potable water (BIS) except observing slightly brackish water at some locations.

A perusal of the interpreted results from these hydro-geophysical surveys shows that the top subsurface of 40 m at the target area is comprised of 2-4 different geological layers and is indicating presence of fractures/anomalies. The evidences relating to proneness to displacement within hard rocks strengthen the possibility of generation of new cracks and fractures in the area. In general, the village geology of its top subsurface is found significantly heterogeneous in nature. It contains varying thickness of sand mixed with gravels underlain by weathered/hard schist at random places making it susceptible under the possible vibrations, surface overburden or other (sub)surface modifications. Likely water seepage taking place from leaky drainage network seems further aggravating the differential land settlement. Extreme rainfall event of 1023 mm observed in 2019 monsoon period appears contributing in land settlement. The isotopic analysis indicates that properties of seepage water and groundwater are found close, and hence, the high groundwater table in the surrounding area of the school seems causing seepage and waterlogging.

Recommendations

Based on the hydrogeological survey of the Pur village site, the following guidelines are proposed for tackling the existing problem of building cracks.

- The top subsurface of the village area is heterogeneous with patches of weathered/hard rocks and soil, particularly in the central part of the village, and seems sensitive in the context of differential land settlement. Increased water content, any forms of vibrations, surface overburden, and any other (sub)surface modifications would trigger the existing problem and must be avoided in future.
- The observed signature mapping of surface and groundwater show that the village area is lacking the proper surface and subsurface drainage facility. The existing surface drainage

network needs maintenance for checking household water effluent seepage to the underlying subsurface formations. Proper drainage of runoff water generated during the rainfall storms is also required to avoid its recharge in the village area.

- The study reveals that some areas of the village settlement are having localized high groundwater table resulting in the problem of groundwater seepage and waterlogging. The *Rajkiya Uchh Madhaymik Vidhayalaya Pur* (school in Pur village), is currently facing a problem of water leakage from the ground surface. It is proposed to build a subsurface drainage ditch at the up-gradient side to collect and remove the drainage water to tackle the existing waterlogging issue in the school premise.

- Groundwater quality of the study area is found safe except it's slight brackish nature at some places. The executive summary of this investigation is prepared altogether with CIMFR and CBRI teams and is also attached herewith.

Brijesh Kumar Yadav

Digitally signed by Brijesh Kumar Yadav
DN: cn=Brijesh Kumar Yadav, o=Indian Institute of Technology Roorkee, ou=Department of Hydrology, email=brijesh.yadav@hy.iitr.ac.in, c=IN
Date: 2021.01.29 22:45:41 +05'30'

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Brijesh Kumar Yadav

Digitally signed by Brijesh Kumar Yadav
DN: cn=Brijesh Kumar Yadav, o=Indian Institute of Technology Roorkee, ou=Department of Hydrology, email=brijesh.yadav@hy iitr.ac.in, c=IN
Date: 2021.01.29 22:45:15 +05'30'

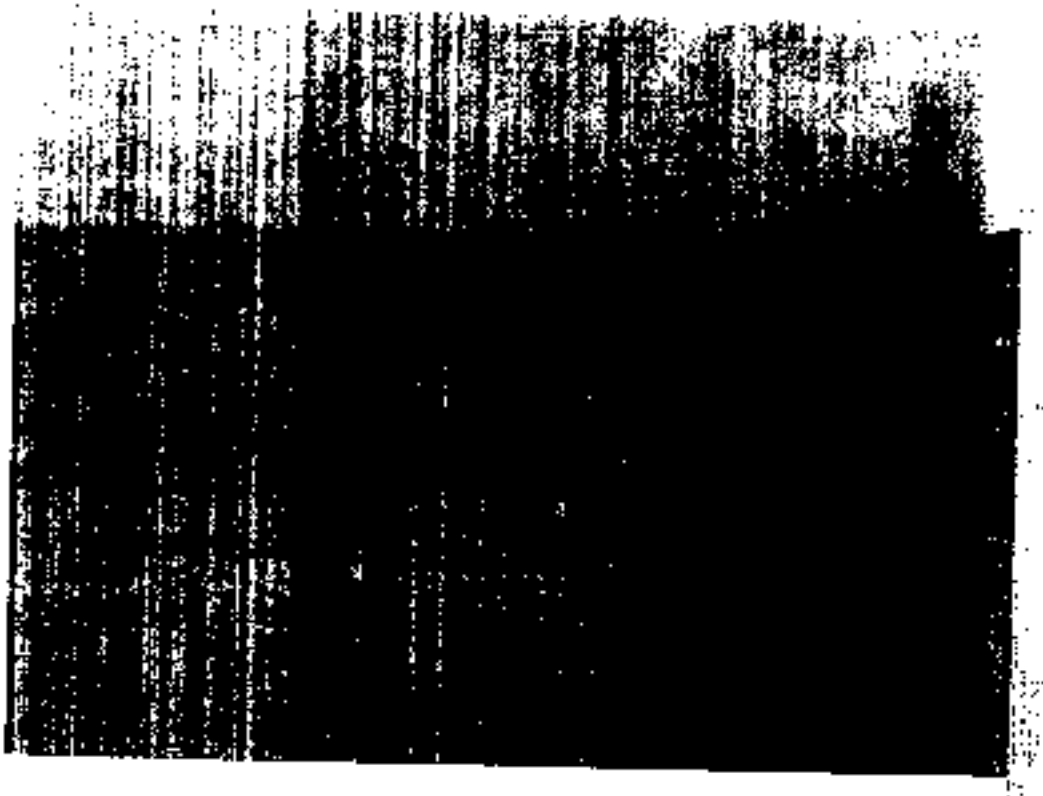
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PROJECT NO.
SSP/R/421/19-20

Report

on

Scientific Studies on Blast Induced Ground Vibration & Air Overpressure and Investigation on its Damage Potential vis-à-vis Housing Structures in Pur Village, Bhilwara, Rajasthan



Submitted to

Office of District Collector and District Magistrate,
Bhilawara, Rajasthan State Govt.

By

CENTRAL INSTITUTE OF MINING & FUEL RESEARCH
(Council of Scientific and Industrial Research, New Delhi, Govt. of India)
Regional Research Centre, Bilaspur (CG) 495001
Telefax: +91-7752-271582, www.cimfr.nic.in

Report
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Project No.: SSP/R/421/19-20

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Signature of the Project Proponents

15.01.2021

(Harsh Kr. Verma)
Sr. Pr. Scientist & Project Leader
CSIR-CIMFR Research Centre Bilaspur

15/01/2021

(S P Singh)
Scientist-in-Charge
CSIR-CIMFR Research Centre Bilaspur

CSIR-CIMFR Authorized Signatures

15/01/2021

(P.K. Mishra)
Sr. Principal Scientist & HOS,
Project Monitoring & Evaluation

18/01/2021

(R. V. K. Singh)
Chief Scientist & HOS
Business Development & Industrial Liaison

CENTRAL INSTITUTE OF MINING & FUEL RESEARCH, DHANBAD

(COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH)

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BY

INVESTIGATING TEAM

Dr. H. K. Verma,	***Sr. Pr. Scientist & Project Leader***
Dr. P B Chaudhary	***Sr. Pr. Scientist***
Mr. M K Meena	***Technical Officer***
Dr. R. D. Dwivedi	***Sr. Pr. Scientist***
Mr. Anil Swarup	***Sr. Pr. Scientist***
Dr. J K Mohnot	***Chief Scientist***
Dr. R. K. Goel	***Retd. Chief Scientist***
Dr. P. K. Singh	***Director***

Executive Summary

District Magistrate and Collector, Bhilwara vid their Letter no Ref: Jud/19/26667 dated 09.10.2019 requested CSIR-CIMFR Dhanbad to evaluate the impact of the blast induced ground vibration. A team of scientist and technical officers of CSIR-Central Institute of Mining and Fuel Research, Dhanbad and Regional Research Centres at Bilaspur, Roorkee and Nagpur carried out a detailed investigation in the mine site as well as houses in the Pur village in three rounds of field investigations.

CIMFR team have conducted altogether 15 experimental blast rounds at Dhedwas Iron Ore mine in different phases of field investigations. The parameters of the experimental blast round were decided after review of the data of mine blasting operations carried out during April 2018 to Dec 2019. It may be noted that experimental blasts have been conducted with different combination and range of parameters. Small as well as large blasts both in terms of number of holes and total explosive quantity in blasts rounds were conducted both in overburden as well as in bottom benches. In experimental blasts holes depth varied from 3.5 m to 12.0m, total charge varied from 3.06 ton to as high as 10.06 tons, no of holes varied from 39 holes to 195 holes. Although, average maximum charge per delay in day to day mine blasting operation is 100 kg, experimental blast rounds upto 190 kg have been conducted to create a sever condition and to evaluate the impact of vibration. The range of experimental blast design parameter covered entire range of day to day blasting practices of Dhedwas iron ore mine, Bhilwara.

Comprehensive vibration monitoring was carried out during blasting experiment. The complete exercise was carried out in presence of representatives from Pur village. Altogether vibration was monitored at 56 different locations. Monitoring locations were chosen considering size of blast, mine location the distance of the presence of any domestic structures. The monitoring locations include domestic houses and other prominent structures of the Pur village such as Temple and Mosques and community hospital. In all the cases, measurements were carried out in the direction with an intention to record maximum vibration as well as air overpressure intensity. Simultaneous vibration monitoring both in close-field as well as far-field using four set of four channel monitoring system was carried out. All these instruments are four-channel seismographs provided with one tri-axial transducer for monitoring of vibration (in mm/s or inch/s) and one-channel for monitoring of air overpressure/noise in dB (L) or Pa. The

instrument records vibrations in three orthogonal directions [i.e. Longitudinal (L), Vertical (V) and Transverse (T)] and peak frequency of vibration in individual directions as well as compute the peak vector sum of vibrations. The instruments also permit full wave recording at any instant of time for a preset duration. Sensors are having an articulation of spikes for proper coupling with the ground for more precise reading of particle velocity.

Observed vibration data were analysis and a site specific mathematical relationship has been established correlating the maximum explosives weight per delay (Q_{max} in kg), distance of vibration measuring transducers from the blasting face (D in m) and recorded peak particle velocity (V in mm/s) using square root scaled distance at 95% confidence interval. The equation which shows attenuation characteristics of the blast induced ground vibration were further analysed in details to understand the damaging effect of vibration on domestic houses of Pur village with different blast design parameters.

It is observed that the blast induced ground vibration and air overpressure beyond a distance of 500 m from the blasting site remained less than 2.00 mm/s (with frequency ranging from 2.0 Hz to 30 Hz) and 115 dB(L) against recommended safe values of 5.0 mm/s and 134 dB(L) respectively. Analysis of propagation characteristics of the vibration reveals that ground vibration beyond a distance of 1.5 km decayed to less than 1.0 mm/s in majority of the cases. In most of the housing structure beyond 2.0 km from the blast site, equipment did not record any vibration and the values were not noticeable by human body. Therefore, it is concluded that observed blast induced ground vibration values are safe and well within the permissible limit as per the recommendations of Directorate General of Mine Safety (DGMS). Based on the findings of the study it is concluded that impact of blast induced ground vibration and air overpressure in causing damage to the housing structures of Pur village, approx., 2.5 km away is practically not possible. This is further corroborated by the facts that the houses which are between Dhedwas iron mine and Pur village does not have cracks and are not damaged. Cracks in the houses may be accounted to hydrogeological set-up of Pur village and its interaction with the weak non-engineered foundation of the houses.

It is however, recommended that an expert agency may be engaged to supervise blasting operations at Dhedhwas iron ore mine. Vibration monitoring shall be carried out by such expert agency in close co-ordination with representative of Pur village.

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Report on

Scientific Studies on Blast Induced Ground Vibration & Air overpressure and Investigation on its Damage Potential vis-à-vis Housing Structures in Pur Village, Bhilwara District, Rajasthan

1.0 INTRODUCTION

Pur is a village located in Bhilwara District of Rajasthan. Geographically, it is situated at 25°27°50'N & 74°03°75°50'E & 410 m above the Mean Sea Level (MSL). Population of Pur village is approximately 250000 and there are roughly 4500 housing structures. Many of the houses/structures/roads/drains in and around the village have developed cracks and major structural damage rendering structures non-habitable.

It is pertinent to mention here that there is a low grade iron ore (Magnetite) reserve near Pur village. This reserve is allotted to Dhedwas Iron Ore and Associated Mineral Mine of M/s Jindal Saw Limited (JSL) for commercial exploitation. M/s JSL is carrying out mining activities. The rock containing iron ore is broken down in small pieces by drill and blasting method. The fragmented rock material is further processed to prepare iron pallets for use in steel industry. Villagers have made complaints to District Magistrate that the blasting operation in the Dhedwas Iron Ore mine is the primary cause of the cracks in the domestic houses. The mine is approx.. 2.5 km away from the village. A location map showing relative position of the Dhedwas Iron Ore mine and Pur village is presented in Figure 1.

A high level committee meeting chaired by Chief secretary, Govt of Rajasthan was held on 5th July 2019 at Jaipur and it was decided to carry out a comprehensive scientific study to identify and characterize the root causes of cracks in the housing structures of Pur village by engaging expert institutions. It was decided in this meeting that three institutes namely IIT Roorkee, CSIR-Central Building Research Institute (CBRI), Roorkee and CSIR-Central Institute of Mining and Fuel Research (CIMFR), Dhanbad be engaged for scientific investigations. IIT Roorkee was entrusted to carry out investigation of crack by evaluating hydro-geological and sub-surface investigation. CBRI Roorkee was advised to look into the contribution of building foundation and geotechnical part.

Similarly, District Magistrate and Collector, Bhilwara vid their Letter no Ref: Jud/19/26667 dated 09.10.2019 requested CSIR-CIMFR Dhanbad to evaluate the impact of the blast induced ground vibration.

CSIR-CIMFR Team have carried out scientific study by conducting field trials in the Dhedwas Iron Ore mine by conducting blasting experiments by varying various blast design parameters and investigation of blast Induced ground vibration & air overpressure (AOP) in and around houses and mine near Pur Village. This report is record of the investigations carried out by CSIR-CIMFR Team at Pur village. This report includes details of the blasting field trials in the mine, monitoring of the blast induced ground vibration, analysis of the data, and final recommendations and concussions as an outcome of the scientific investigation.

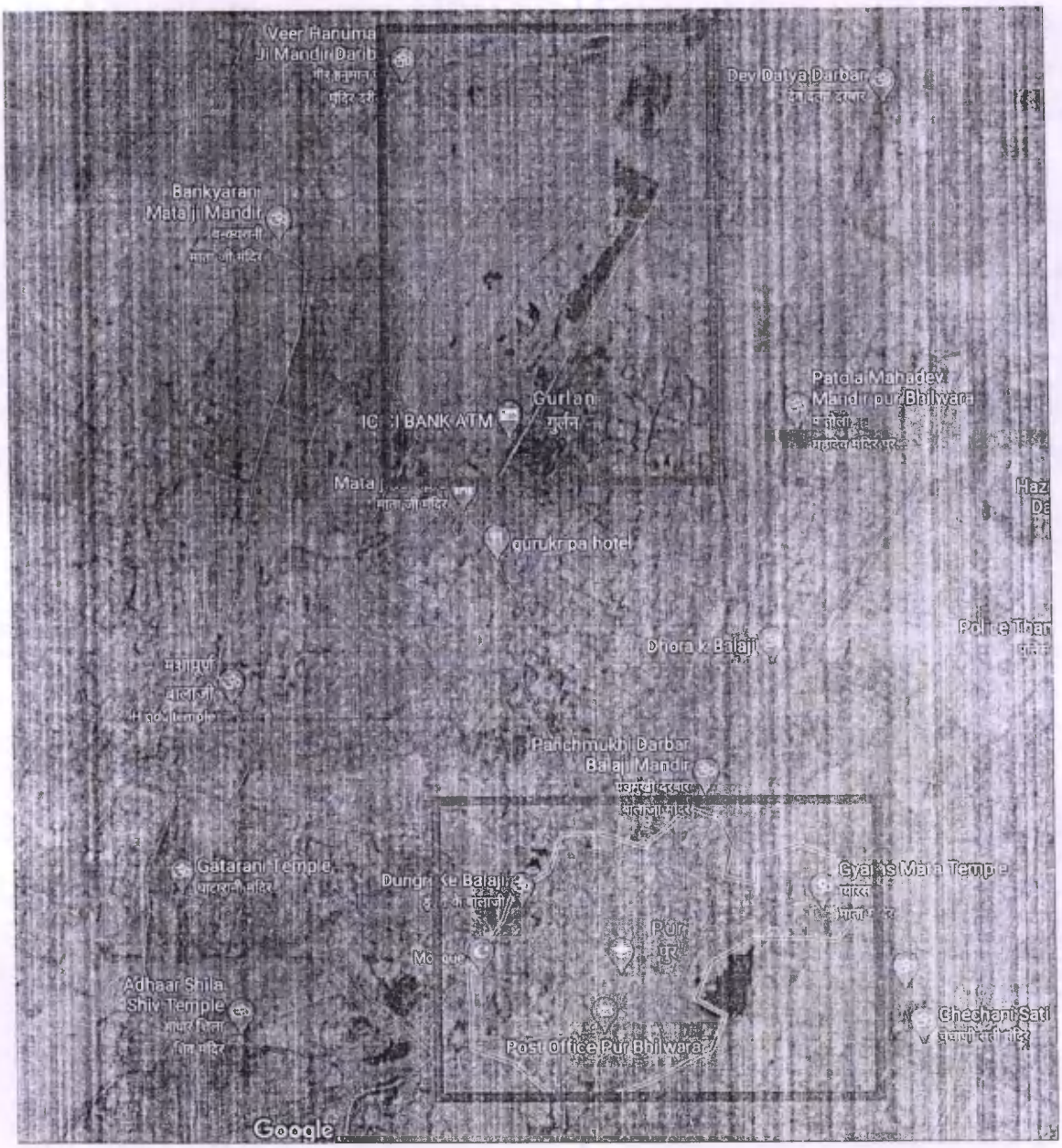


Fig. 1: Map showing relative location of Dhedwas Iron Ore Mine and Pur Village

2.0 STATEMENT OF THE PROBLEM

CSIR-CIMFR team initially made survey of the damage in the housing structures of Pur village. Various domestic houses were surveyed and the team have taken observation on cracks, their characteristics, location, width etc. Photographs of the cracks in the domestic houses and temple of Pur village are presented in Fig(s) 2 to 10.

Initially CSIR-CIMFR Team carried out a detailed survey of the house to evaluate the problem of the cracks in the housing structures along with district administration team. During survey of the cracks in the housing structures, it was informed by the local authorities that there are more than 350 buildings in which cracks developed. These cracks were present in the double storey as well as single storey buildings. Cracks were present almost in every location of the house such as outer wall, inner wall and floor in the houses, celling and floor level. Crack in walls were vertical to sub-vertical cracks. It was also noticed that this crack prone area is situated at higher elevation compare to other locality of the Pur village. The elevation of the village varies from 410m to 435m above MSL. It is important to mention here that the mine is approx. 2.5 km from the village. Most of the houses having cracks are at certain elevated location of the village. Some of houses closer to mine does not have cracks. Further, as per IMD data, no seismic activity has taken place during period of July, 2018 to January, 2019. It is surprising to note that > 350 buildings have suffered such kind of damage without any seismic event.

During interaction with the villagers, they have an apprehension that the crack were developed due to blasting activities carried out at Dhedwas Iron Ore mine. Team of Scientists of CSIR-Central Institute of Mining and Fuel Research was entrusted to carry out scientific investigation to evaluate the damage potential of the blasting vibration and contribution of the blasting vibration in development of the crack in the housing structures of the village.

CSIR-CIMFR Team conducted three round of the field visits to Pur village and mine site as part of this investigation. During these field visits, a comprehensive investigation was carried out by conducting experimental blast in stages in mine site and concurrently vibration monitoring were carried out at more than 50 different locations around mine and Pur village.

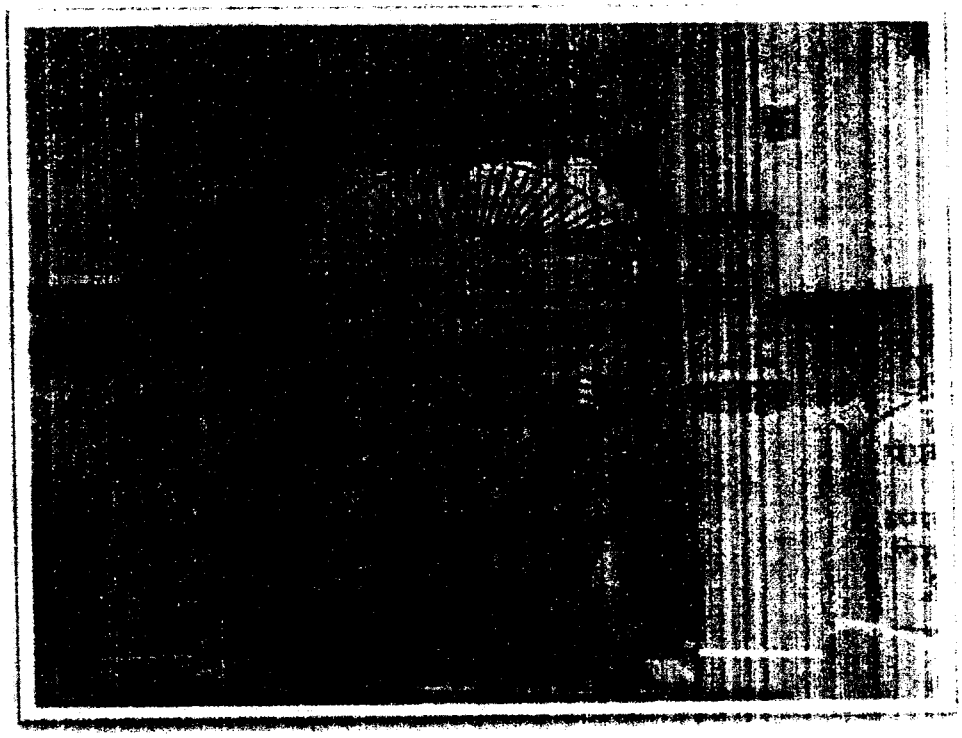


Fig 2: Cracks along column in Laxminarayan Temple

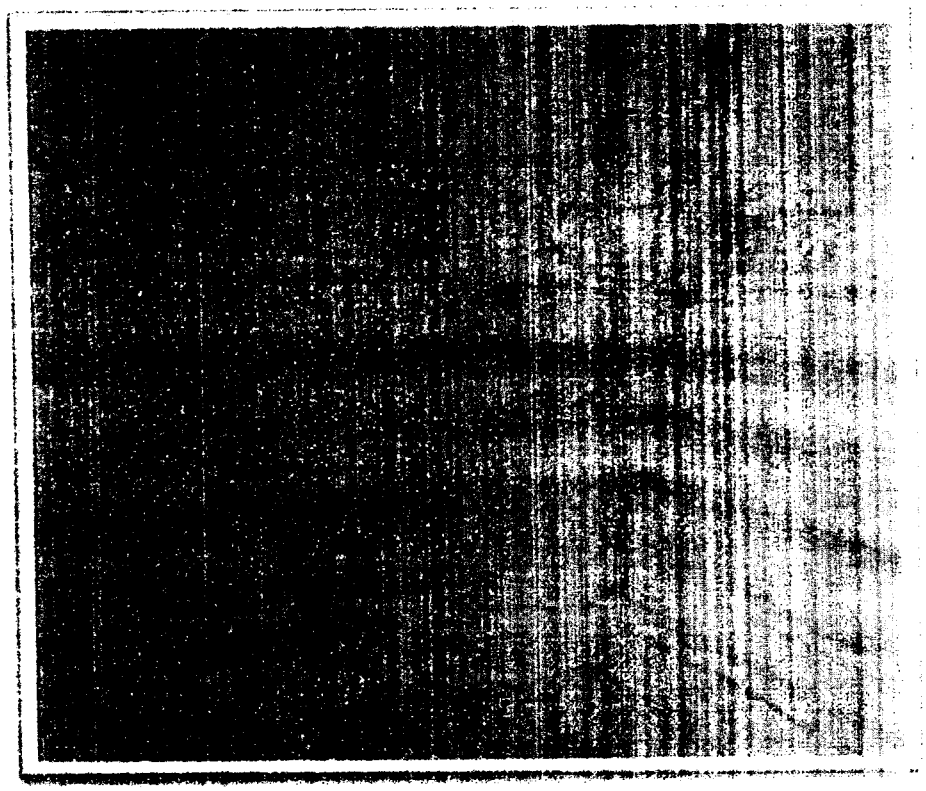


Fig 3: Cracks in the corners of the Laxminarayan Temple



Fig. 4: Cracks in the housing structure at middle level



Fig 5: Cracks along the joints of the domestic structures

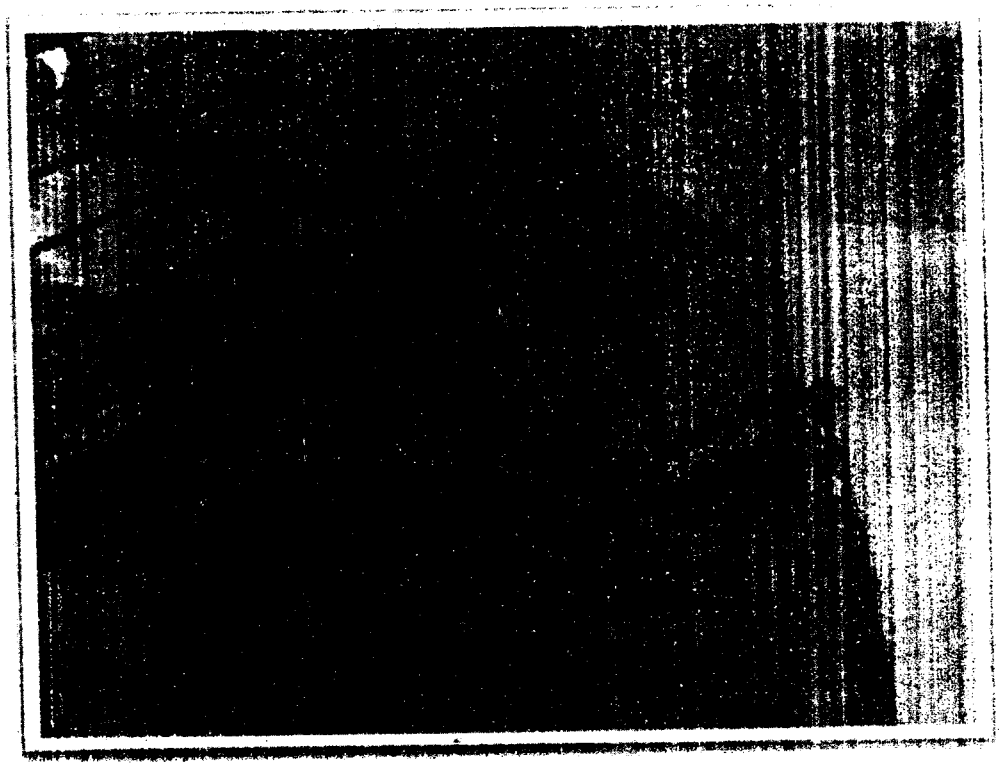


Fig 6: Cracks along the joints of the domestic structures

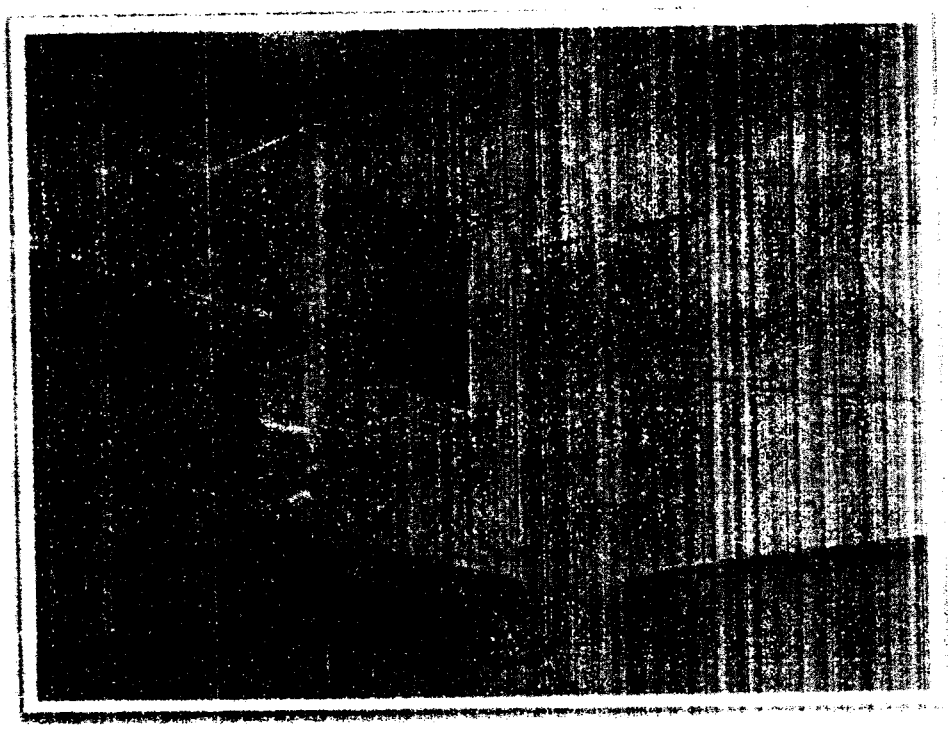


Fig 7: Widening of Separation joint along two joints indicating settlement of the foundation



Fig 8: Cracks across the beam and column of housing structure

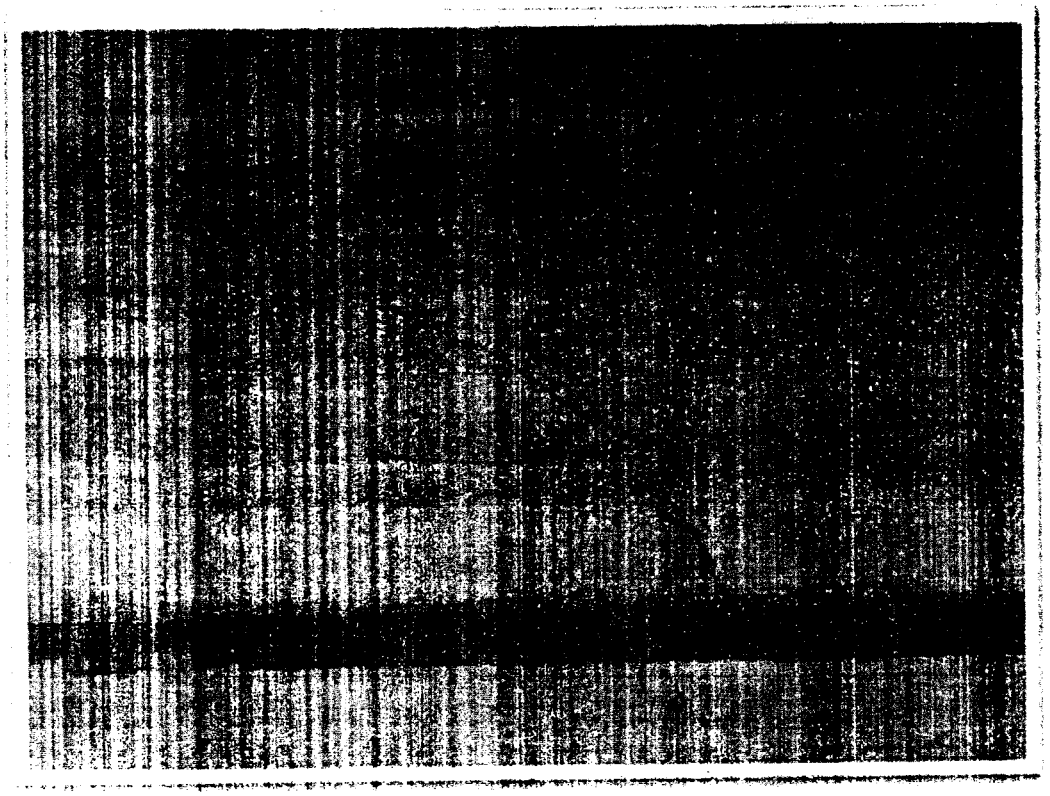


Fig 9: Cracks in the floor level of housing structures

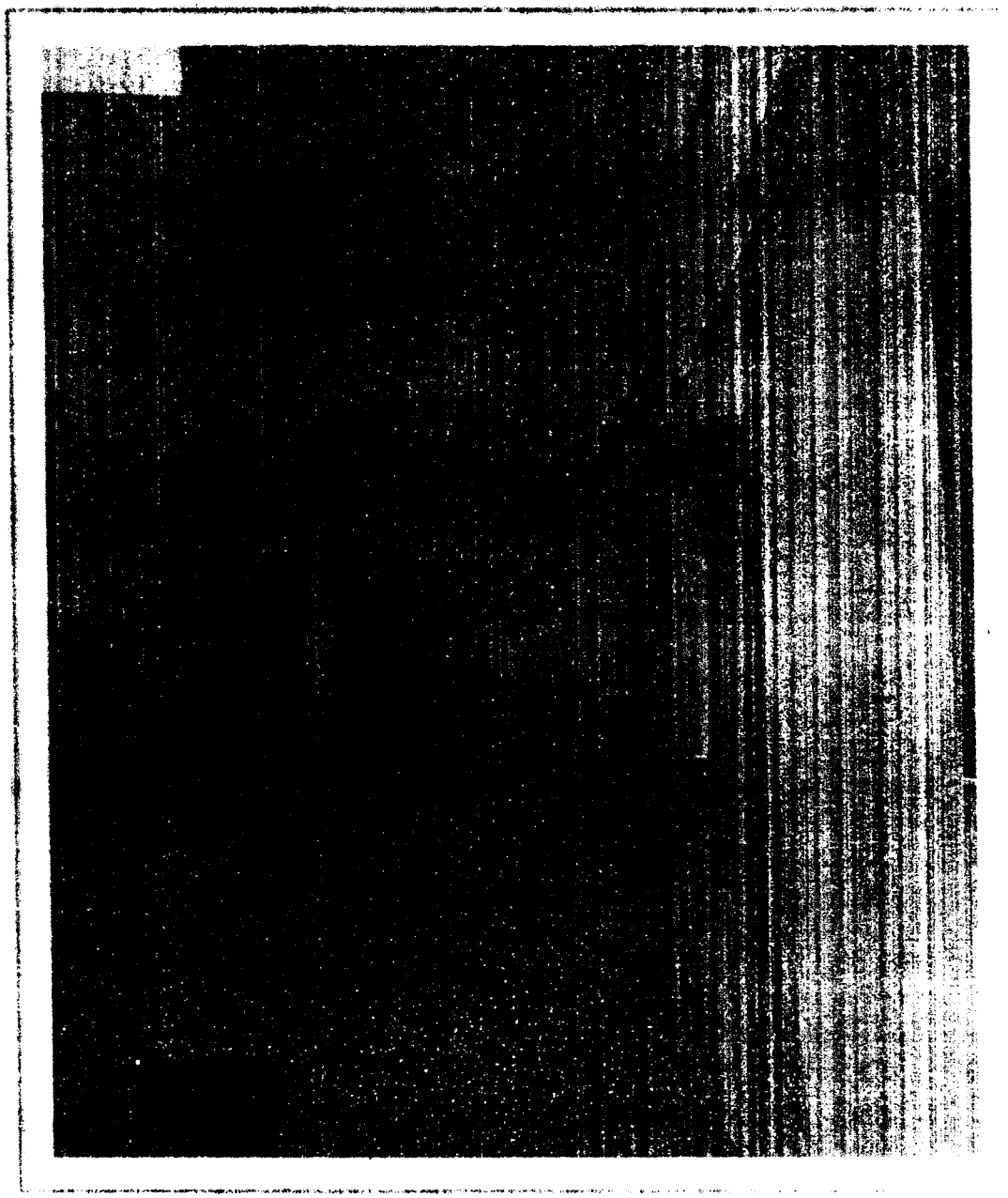


Fig 10: Cracks in the floor level of housing structures

3.0 OBJECTIVES OF THE STUDY

In light of above discussion as presented in the preceding section 2.0: Statement of the Problem, following objectives of the studies were mutually identified in consultation all stake holders including representative of the Pur village.

a. CSIR-CIMFR Team will jointly conduct study with CBRI Roorkee and IIT Roorkee to investigate impact of blast induced ground vibration and air overpressure, directly or indirectly as cause of cracks in the housing structures of Pur village, Bhilwara District.

b. CIMFR Team will carry out comprehensive blast vibration and air overpressure study using multiple seismographs at Pur village and records blast vibration and air overpressure induced by the blasting operation in the Iron Ore mine of M/s Jindal Saw Ltd., Dhedwas, Bhilwara.

c. Simultaneous blast vibration and air overpressure monitoring at different distance will be carried out in different phases of field investigations to evaluate the impact of various blast design parameters on the intensity of the blast induced ground vibration and air overpressure. Efforts will be made to record and analyse all possible combination of the blast design parameters which represent the blasting operations conducted by the Iron Ore mines of M/s Jindal Saw Ltd., (JSL) Dhedwas, Bhilwara

d. CSIR-CIMFR Team will carry out measurement of blast induced vibrations and air overpressure at different structures, both foundation and ceiling level depending on the site requirement with due consideration to vulnerability and proximity of the critical structures. Following parameters of blast induced vibration will be measured and calculated on during field investigations:

   i. Ground vibration in terms of peak particle velocity (mm/s)
   ii. Ground acceleration in term of "g"
   iii. Displacement (mm)
   iv. Vibration frequency, Hz.
   v. Air Overpressure/ Noise in term of dB (L)
   vi. Peak Vector Sum, mm/s

e. Analysis of the blast induced ground vibration and air overpressure to derive precisely attenuation characteristics and its damage potential in light of various national and other international standards.

f. CSIR–CIMFR will submit a technical report to District Administration incorporating details of the field investigations, analysis of the observed vibration and air overpressure data along with conclusion and recommendations.

4.0 REVIEW OF BLASTING PRACTICES IN DHEDWAS IRON ORE MINE

Before commencement of the field investigation, CIMFR team collected all previous blasting related data pertaining to period from April 2018 to Dec 2019. It was reported that the cracks were observed during this period only. The period CSIR-CIMFR Team also reviewed blasting practices of the iron ore mine by collecting all the blasting data since April 2018 to Dec 2019. Cracks in the housing structures of Pur village were reported to have developed during this period only. The review of the blasting operation were done in light of the permission granted by Directorate General of Mines

(10)

Safety (DGMS) vide letter No. AJR/DMS/Perm-164(1-B)(a)/20183 dated 04.10.2018 (copy enclosed as Annexure-III). DGMS has recommended following parameters for deep hole controlled blasting at Tiranga Block of Dhedwas Iron Mine based on scientific studies

Bench Height (m)	Drill Hole Dia (mm)	Max. No of Holes in a Round	Pattern of Holes(m)		
			Depth (m)	Spacing (m)	Burden (m)
8 - 10	115	200	9 - 10	3.0 - 3.5	2.5 - 3.0

DGMS has given permission of 10 mm/s as safe vibration limit at dwellings/structures falling within 300 m of the place of blasting and not belonging to the management. In addition to above, DGMS have recommended safe limit of vibration to be 5 mm/s for Tiranga Block, 10 mm/s for Dhulkhera Block (with frequency 8-25 Hz for both the blocks and 15 mm/s for Sura block having frequency greater than 25 Hz. The detailed recommendation of DGMS is appended in Annexure-III,

M/s Jindal Saw Ltd., Bhilwara submitted all the blasting related data for the period April 2018 to Dec 2019. Review of the blasting operation performed in the past at Dhedwas mine reveals that blasting practices in the mine have holes depth ranging from 6.0 m to 10.0 m. Few blasts with 12.0 m depth have also been taken in the past. Site mixed emulsion explosive with cast booster is used for blasting operation. The total charges in blasting round as per usual practice are mostly in the range of 8 tons-10 tons. No of holes in blasting round are in the range of 100 -- 150 holes having dia. 115 mm. The blasting practices were found to be in accordance with the DGMS permission in majority of the cases.

While conducting the blasting experiment as a part of this scientific investigation, parameters of previous blasting practices were also included. Efforts were made to create severe blasting experimental conditions and monitor impact of such blasting on the vibration attenuation characteristics and resulting damage potential of the blast induced ground vibration on domestic structures.

5.0 GEOLOGY OF THE PROJECT AREA

Predominant geological formation includes rock types belonging to Bhilwara Super Group, Aravallis and Vindhyan Super group. The depth of soil varies from 5 to 10 m, and in some areas rock outcrops are seen above the ground. Predominant soil found in the area are Clay loam or medium black (in northeastern hilly areas), loam (predominant soil type) and, sand and sandy loam (near the banks of rivers/streams). The origin of landform is fluvial (alluvial) along River Kothari, dunudational (buried pediment) in most places, and structural hills in the northeastern outskirts of the city.

The topography of the area is characterized as rugged in North- Eastern and South- Western part and the remaining part is nearly peneplain. The maximum elevation is 529 m above msl towards the North- Western direction of the Pur village and the minimum elevation is 410 m above msl near the Government Senior Secondary school, Pur. Kothari River with several nallas forms the main drainage of the area. Drainage pattern in the area is dendritic. Small water bodies are present.

Pur village is located on the southern edge of Aravali hills. This area comes under the Potla Formation of the Mangalwar Group. Its basement is basically consisting of Granite gneiss-amphibole gneiss and garnetiferous mica schist trending NE-SW moderate to high dip towards NW Bhilwara super group.

As per the seismic zoning map of India, Pur Village, Bhilwara District falls under the Zone II, which is the lowest earthquake risk zone in India. This zone is termed as "low damage risk zone.

Bhilwara is located near the right bank of River Kothari, a tributary of River Banas, an important river of Rajasthan. River Kothari originates in the eastern slopes of the Aravali ranges in Rajsamand District. The river flows through Rajsamand and Bhilwara Districts for about 51 km in a hilly region, and 100 km through plains, before joining the Banas near Nandrai village in Bhilwara District. The other tributaries of Banas in Bhilwara District are Bedach and Khari. River is rain-fed and is a seasonal flowing river. River carries good flow during normal and above normal rainfall years. Meja Baandh (Meja Dam) constructed across Khari River, about 20 km northwest of Bhilwara is an important source of water for irrigation, industrial and drinking purposes.

Major water bearing formations are gneiss and schist (Bhilwara Supergroup); gneiss, schist, phyllite, slate and limestone (Aravalli Supergroup); sandstone, shale and limestone (Vindhyan Supergroup) and alluvium. Ground water occurs under unconfined to semi-confined condition.

Weathered zone below the water table acts as a good storage. The joints, fissures and other plains of structural weakness as well as their extent, size, opening and inter connection control occurrence & movement of ground water. Phyllites and schists are predominating in Bhilwara City and these formations are intercalated with dolomitic limestone, quartzite and basic intrusive.

6.0 FIELD INVESTIGATIONS

Before commencement of the field investigations, a team was constituted in co-ordination with the district officials which have representative from villagers to ensure transparency and witnessing of the experimental blasts. Two persons from the Pur villager were nominated by the district official to represent the villagers and they were made part of all the experimental blasting study in all the field visits. Fig 10 shows Photographs of Dhedwas Iron Ore mine working in different benches. Photograph of CSIR-CIMFR team along with representatives of Pur village is presented in Fig. 12.

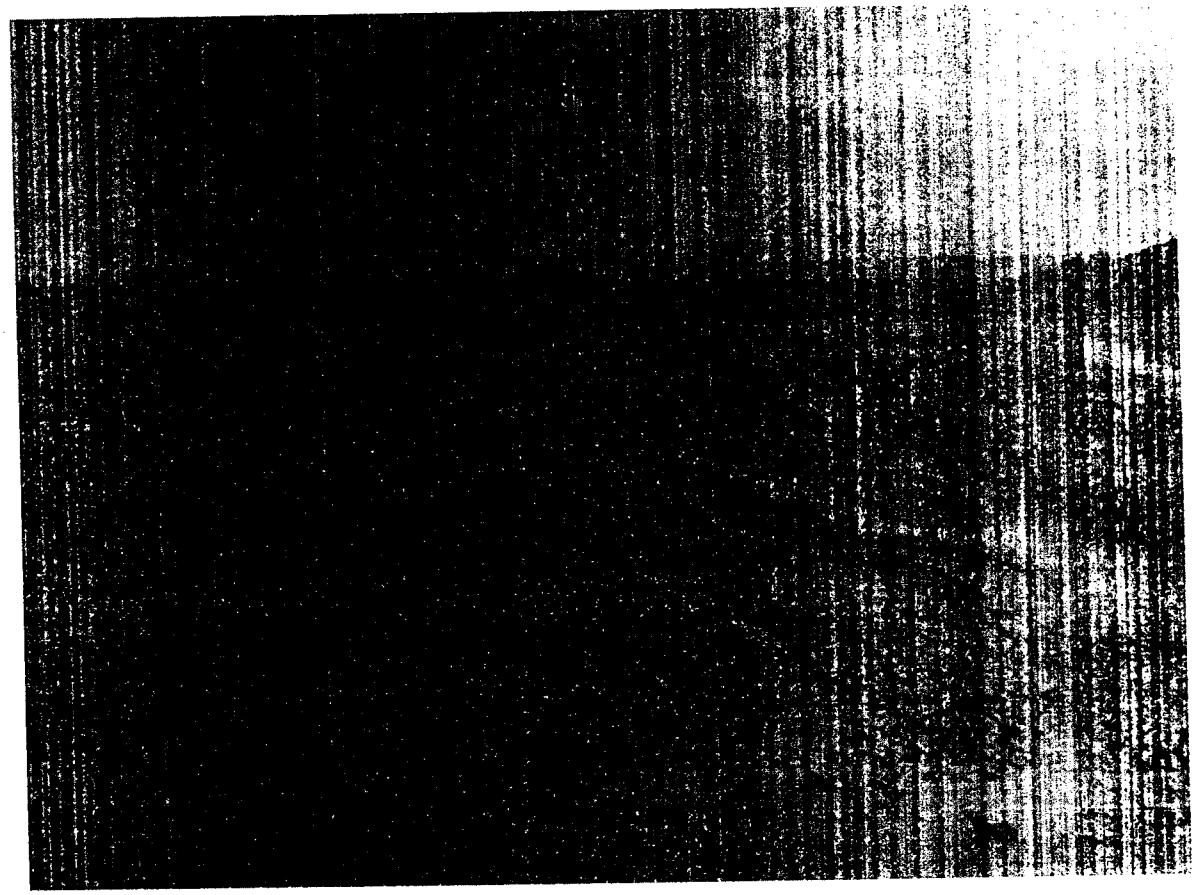


Fig 11: Photograph showing Dhedwas Iron Ore mine near Pur Village



Fig. 12: CSIR-CIMFR team along with representatives of Pur Village at Dhedwas Iron Ore mine during field experiment in the mine.

CSIR-CIMFR Team also reviewed blasting practices of the iron ore mine by collecting all the blasting data since April 2018 to Dec 2019. Most of the cracks were reported to have developed during this period only. The parameters of the experimental blast were decided to represent the day to day blasting operations of iron ore mine. The experimental blast design parameters were chosen to represent day to day blasting operation with an endeavor to constitute severe condition so that the maximum damage potential of the blast vibration may be evaluated and its impact of the surrounding housing structure of the Pur village be quantified.

During field experiment comprehensive vibration and air overpressure monitoring was also carried out. The monitoring locations were chosen in close consultation with the all the stake holders including representative from the Pur village. The objective of the team was to conduct the experimental blasts and monitor the blast induced ground vibration and air over pressure at different locations in Pur village and to analyse its adverse impact on domestic houses/structures in Pur village.

(14)

6.1 Details of Experimental Blasts

CSIR- CIMFR Team conducted altogether 15 experimental blast rounds in two different phases of field investigation at the Dhedwas Iron ore mine of M/s Jindal Saw Ltd., Bhilwara. First phase of experimental blasts and monitoring was carried out during 01.02.2020 to 06.02.2020 and second phase of the investigations was carried out in during 03.03.2020 to 06.03.2020. The parameters of the experimental blast round were decided after review of the data of mine blasting operations carried out during April 2018 to Dec 2019. The parameters of the experimental blast round are presented in Table 1.

Experimental blasts were conducted in both overburden (upper benches) and iron ore benches (lower benches) of JSL mine. Bulk explosive were used for charging the blast holes along with cast booster of 100g as primer charge. Bottom hole initiation is done using Down-The-Hole Shock tube/NONEL initiation system. The blast holes having depth more than 10m were double decked with solid decking. Two shock tubes were used with deck separating two explosive decks in one blast hole. Shock tube with lower delay time of 450ms was used in bottom and of 500ms was kept in top deck. Trunk line connection was done by using Shock tube/NONEL of varying length and different delay for providing delay between holes and rows in a blast round.

Detailed data of blasting experiment data are presented in Table 1 which include detailed parameters of experimental blasts such as date of blast, number of holes, average hole depth, Total and maximum chare per delay, average burden and spacing used in experiment blast rounds. Different steps involved in charging and firing of the blast holes during experimental blast at mine site are presented in Fig(s) 13(A to F) for a detailed illustration. Locations of various experimental blasts in mine are presented in Fig 14.

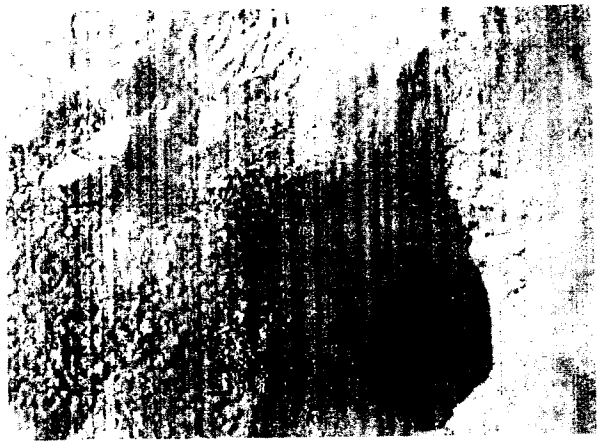
It may be noted that experimental blasts have been conducted with different combination and range of parameters. Small as well as large blasts both in terms of number of holes and total explosive quantity in blasts rounds were conducted both in overburden as well as in bottom benches. In experimental blasts holes depth varied from 3.5 m to 12.0m, total charge varied from 3.06 ton to as high as 10.06 tons, no of holes varied from 39 holes to 195 holes. The range of experimental blast design parameter covered the day to day blasting practices of Dhedwas iron ore mine, Bhilwara.



13(A): 10 Ton Capacity Site Mix Emulsion (SME) Truck



13(B): Measuring of Explosive Density at Site before loading into blast holes



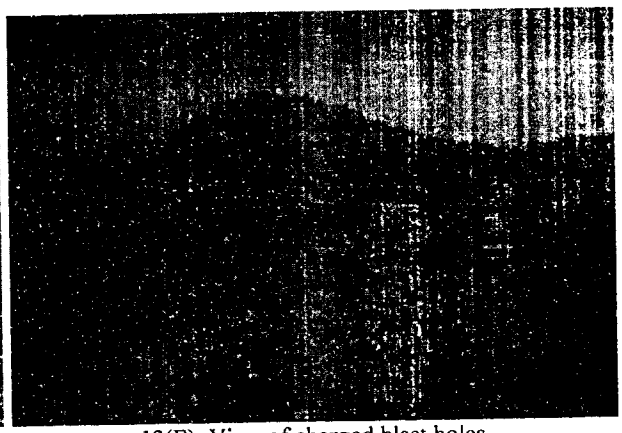
13(C): Double decked loaded blast holes



13(D): Stemming in loaded blast holes



13(E): Use of TLD for surface connection of blast holes



13(F): View of charged blast holes

Fig. 13: Photographs of different steps involved during experimental blast conducted at Dhedwas Iron ore Mine

Table 1: Details of the parameters experimental blasts conducted by CSIR-CIMFR Team at Dhedwas Iron Ore Mine, Bhilwara

Sr. No	Date	No of Holes	Hole Depth	Average Burden (m)	Average Spacing (m)	Average Stemming (m)	Max. Charge Per Delay (Kg)	Total Charge (kg)	Blast Location (RL) (m)	Blast Location (Bench No)
1	1.02.2020	90	4.0 - 12	4	4	2.8 - 9.4	60	9450	478	BENCH-1
2	1.02.2020	166	3.5 - 11	3.5	4	2.8 - 7.02	190	8430	470	BENCH-1
3	3.02.2020	195	3.5 - 6.0	3.5	4	2.8 – 4.0	50	8800	471	BENCH-1
4	4.02.2020	88	6.0 - 11.8	4	4	2.04- 9.1	60	9660	474	BENCH-1
5	5.02.2020	88	7.0 - 12	4	4	2.4 - 4.3	60	9320	474	BENCH-1
6	5.02.2020	116	7.0 - 12	3	4	2.4 - 9.2	60	6380	458	BENCH-3
7	6.02.2020	86	7.0 - 12	4	4	2.4 - 9.3	60	8720	472	BENCH-1
8	6.02.2020	114	7.0 - 12	4	4	2.8 - 4.0	60	9500	480	BENCH-1
9	3.03.2020	76	4.0 - 6.0	3	4	2.8 - 4.0	85	3065	425	BENCH-5
10	3.03.2020	119	5.0 - 10	4	4	3.4 - 6.5	90	10365	465	BENCH-2
11	4.03.2020	39	6.0 - 9.0	4	4	4.0 - 6.0	80	2800	432	BENCH-5
12	4.03.2020	134	4.0 - 10	4	4	2.8 - 6.5	90	9790	465	BENCH-2
13	5.03.2020	161	4.0 - 9.5	4	4	2.8 - 6.2	85	10080	459	BENCH-3
14	6.03.2020	75	4.0 - 6.0	4	4	2.8 - 4.0	55	4100	445	BENCH-4
15	6.03.2020	180	4.0 - 8.0	3	4	2.8-5.0	100	9400	437	BENCH-5

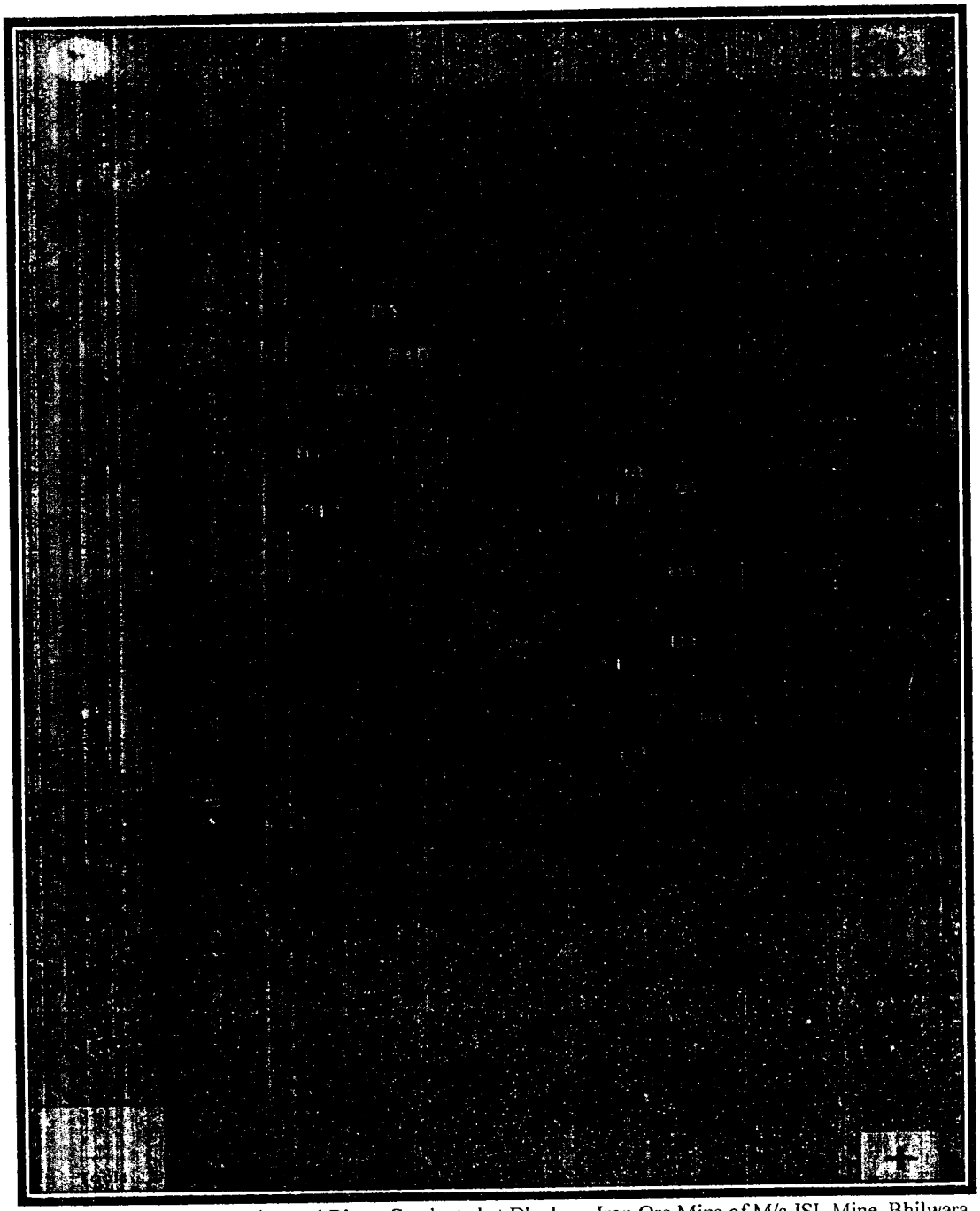


Fig. 14: Location of Experimental Blasts Conducted at Dhedwas Iron Ore Mine of M/s JSL Mine, Bhilwara

6.2 Monitoring of Blast Induced Ground Vibration and AOP

During two rounds of the field investigations altogether 15 experimental blast have been carried out incorporating vide range of blast design parameters which represent the day to day blasting

operation at Dhedwas iron ore mine of M/s JSL, Bhilwara. Blast vibration and air overpressure monitoring have been carried out at more than 60 locations such as housing structures, temples, mosque in and around Pur village during experimental blasts. In each phase of field investigations, four set of engineering seismographs of Instantel Canada Make have been used. All these instruments are four-channel seismographs provided with one tri-axial transducer for monitoring of vibration (in mm/s or inch/s) and one-channel for monitoring of air overpressure/noise in dB (L) or Pa. The instrument records vibrations in three orthogonal directions [i.e. Longitudinal (L), Vertical (V) and Transverse (T)] and peak frequency of vibration in individual directions as well as compute the peak vector sum of vibrations. The instruments permit full wave recording at any instant of time for a preset duration. Sensors are having an articulation of spikes for proper coupling with the ground for more precise reading of particle velocity. One such seismographs namely MiniMate Blaster is viewed in **Figure-15**.

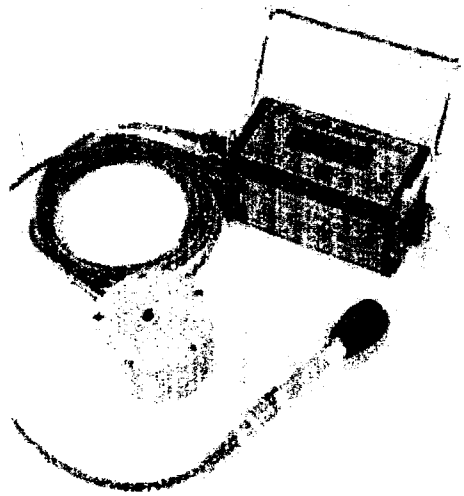


Figure 15: View of MiniMate Seismograph along with external geophone and microphone

One of the most critical aspects of ground vibration monitoring is the mounting (placement) of transducers in the field. Good coupling refers to the transducer that maintains proper contact with the ground. Poor coupling can cause slippage or toppling of the transducer resulting in distorted, often higher vibration levels. Most recommendations agree that the best coupling can be

achieved by burying the transducer when the measurement surface consists of soil and by bolting or quick setting cement (plaster of paris) when the measurement on surface consists of rock or concrete. Burial is desirable for particle acceleration exceeding 0.2 g but it is essential if it is greater than 1.0 g (Dowding, 1996; Stagg and Engler, 1980; ISEE, 2005, ISRM, 1991). Coupling of sensors is illustrated in Fig 16.



Fig 16: Photograph illustrating sensor coupling using Plaster of Paris during vibration monitoring

In this study, coupling of the transducers were carried out using burial techniques in soil and plaster of paris (POP) in case of hard rock surface (**Figure-16**). During most of the blasting experiments simultaneous monitoring at different housing structure and ground surface using velocity meter were carried out.

During all these blasting experiments, monitoring of vibration and air overpressure/ noise in more than 50 locations were carried out using different types of engineering seismographs. Monitoring locations were chosen considering size of blast, mine location the distance of the presence of any domestic structures. In all the cases, measurements were carried out in the

direction with an intention to record maximum vibration as well as air overpressure intensity. The geophone trigger level for all the seismographs were fixed at 0.5mm/s. This indicates that the vibration value of ≥0.5mm/s will be recorded in instrument. The consolidated plan showing different vibration monitoring locations are presented in Figure 17.

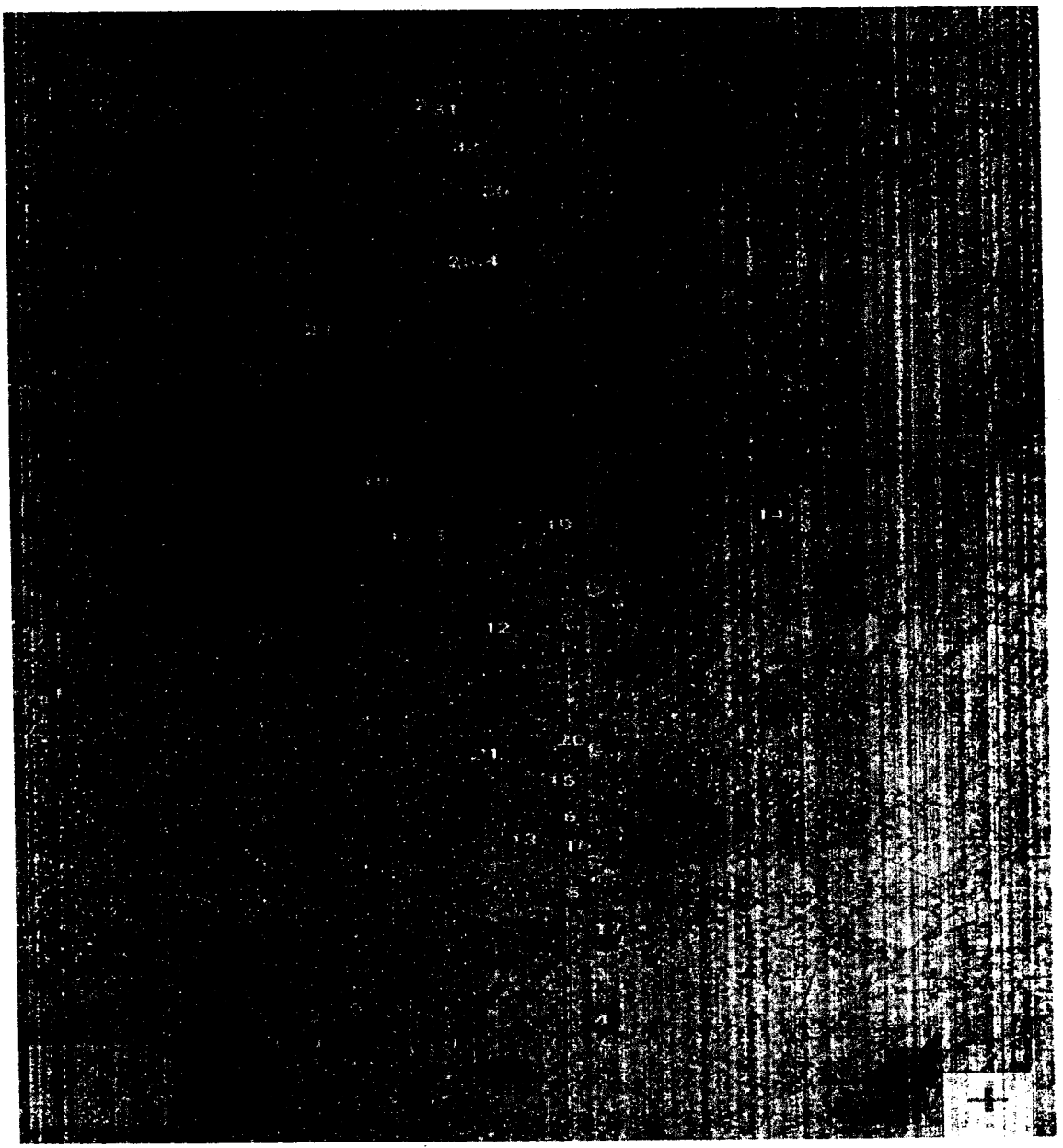
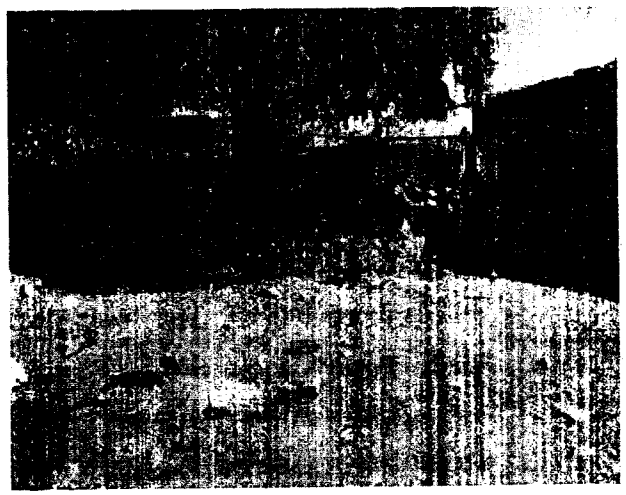


Fig. 17: Location of blast induced ground vibration & AOP monitors in Mine and Pur Village, Bhilwara

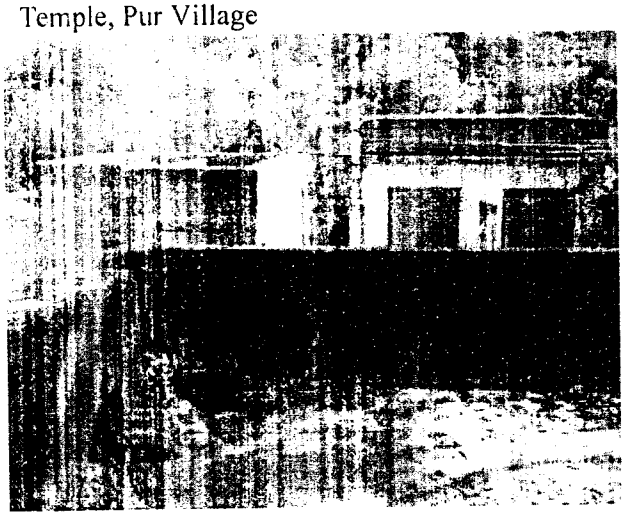
It is important to mention here that during initial rounds field investigation in the month of Feb 2020, far-field monitoring was carried out. Most of the houses of the monitoring was in the village houses of Pur Village. In second phase of investigation, close field monitoring of the vibration was carried out. Therefore, in second phase experimental investigations, majority of the minoring locations were intermediate location between mines and Pur village and few monitoring locations within the mine premises. This is required for developing mathematical model of blast vibration propagation characteristics precisely. Photographs of the vibration and air overpressure monitoring locations during experimental investigations are presented in Figure 18 (A-P).



A. Near mine Gate 1, Jindal plant,Tiranaga Mata Temple, Pur Village



B. Guru-Kripa Restaurant, Roadside, Pur Village

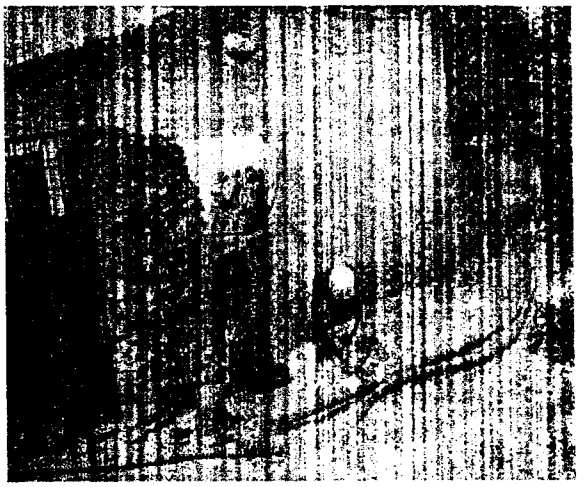




C. Roof top, Sunarogi Temple, Pur Village



D. House near Kali Babadi, Pur Village

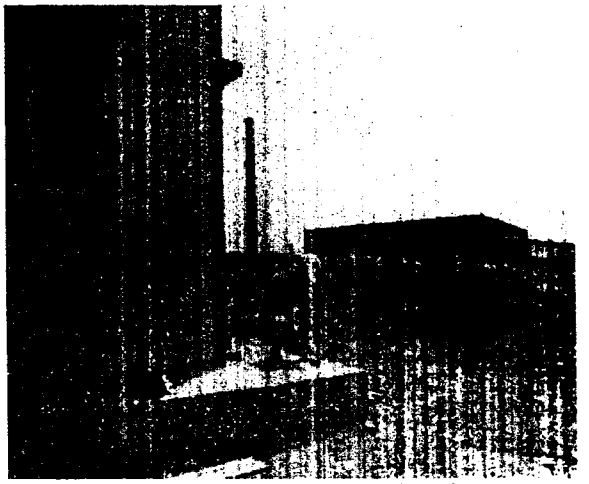


E. House in Mundar road, Pur Village

F. Miththu Ji Mali Farm House, along Pur Road



G. Laxminath Bada Madir



H . JSL Electric Grid, M/s JSL Mine



I. Mine site office, in M/s JSL Mine



J. JSL Weigh bridge no.2, in M/s JSL Mine



K. Mill Tailing Road, NE in M/s JSL Mine



L. Dump yard road in M/s JSL mine



M. Sunarogi Temple, Pur Village



N. Eidgaah Masjid, Pur Village



O. Rajshree Kirana & Bhojnalay, Pur village



P. Hanuman Temple, Pur Village

Fig. 18 (A-P): Various vibration monitoring location completed by CSIR-CIMFR Team during two phases of field investigations in Pur Village

7.0 ANALYSIS OF THE DATA

7.1 Observed Vibration and AOP Data

CSIR-CIMFR Team conducted 15 rounds of the blasting experiment with different permutation and combination of the blasting parameters. The parameters of the blasting experiments are presented in Table 1. The values of observed peak particle velocity, frequency, air overpressure (AOP), monitoring location, distance of the monitoring are given in Table 2.

7.2 Attenuation Characteristics of Vibration and Air Overpressure

When an explosive is detonated in a blast hole, large amount of energy is generated and it transmits along the ground. Part of this energy is utilized for breaking and throwing the rock for fragmentation and a major portion of the vibration is transmitted through the surrounding medium in the form of shock waves which is called blast-induced ground vibration. Ground vibration is measured in terms of peak particle velocity (PPV) in mm/s. Poor blast design results in higher intensity of the vibration and it may inflicts damage to the nearby structures. Therefore, it is important to design blast in a scientific manner and control the intensity of vibration. Vibrations attenuate with distance (D) of the point of interest (here monitoring station) from the blast site and have a relationship with the maximum charge per delay (Q_{max}). Vibration is generally measured in terms of peak particle velocity in three orthogonal directions. A vector sum of individual measurement is called Peak Vector Sum (V_{max}). The relationship yields two site parameters (K & β) which can be used to calculate the permissible Q_{max}. The relationship between V_{max}, distance (D) and Maximum Charge per Delay, Q_{max} is expressed as given by Eq. 1.

$$V_{ppv} = K\left(\frac{D}{\sqrt{Q_{max}}}\right)^{-\beta} \qquad \text{Eq. 1}$$

Equation 1 gives a fair idea about the maximum charge per delay that can be used to achieve a prescribed level of vibrations for safe blasting in the area. Statistical analysis of ground vibrations and air overpressure data have been carried out to develop mathematical model of attenuation characteristics of vibration An site specific empirical relationship has been established correlating the maximum explosives weight per delay (Q_{max} in kg), distance of vibration measuring transducers from the blasting face (D in m) and recorded peak particle velocity (V in mm/s) using square root scaled distance as presented in Eq 1.

Table 2: Details of the observed Blast induced Ground Vibration and Air Overpressure at Pur Village, Bhilwara

Sr. No	Date of Blast	No. of Holes	Hole Depth	Max. Charge per Delay	Total Charge	Vibration Monitoring Location	Monitoring Distance	Peak Particle Velocity	Frequency	Air Overpressure
		(Nos.)	(m)	(Kg)	(kg)		(m)	(mm/s)	(Hz)	(dB(L))
1	1.02.20	90	4.0 - 12	60	9450	Tiranaga Temple	729	0.762	60.13	102.8
2	1.02.20	90	4.0 - 12	60	9450	Guru Kripa Restaurant	933	0.159	38.38	101
3	1.02.20	90	4.0 - 12	60	9450	Sunarogi Temple	1972	0.307	8.125	92.4
4	1.02.20	90	4.0 - 12	60	9450	Laxmi Bada Temple	2703	<0.25	NA	NA
5	1.02.20	166	3.5 - 11	190	8430	Tiranaga Temple	975	1.159	65.38	101.9
6	1.02.20	166	3.5 - 11	190	8430	Guru Kripa Restaurant	1156	0.603	50.63	101.9
7	1.02.20	166	3.5 - 11	190	8430	Sunarogi Temple	2174	<0.25	NA	NA
8	1.02.20	166	3.5 - 11	190	8430	Laxmi Bada Temple	2906	<0.25	NA	NA
9	3.02.20	195	3.5 - 6.0	50	8800	Tiranaga Temple	840	<0.25	NA	NA
10	3.02.20	195	3.5 - 6.0	50	8800	Guru Kripa Restaurant	1036	<0.25	NA	NA
11	3.02.20	195	3.5 - 6.0	50	8800	Sunarogi Temple	2075	<0.25	NA	NA
12	3.02.20	195	3.5 - 6.0	50	8800	Kali Babadi	2341	<0.25	NA	NA
13	4.02.20	88	6.0 - 11.8	60	9660	Tiranaga Temple	789	0.556	61	122.5
14	4.02.20	88	6.0 - 11.8	60	9660	Guru Kripa Restaurant	988	<0.25	NA	NA
15	4.02.20	88	6.0 - 11.8	60	9660	Road along Temple	1490	0.063	2.625	112.8
16	4.02.20	88	6.0 - 11.8	60	9660	Near house along road	1386	0.087	2.00	113.2

Table 2: Details of the observed Blast induced Ground Vibration and Air Overpressure at Pur Village, Bhilwara (contd..)

Sr. No	Date of Blast	No. of Holes	Hole Depth	Max. Charge per Delay	Total Charge	Vibration Monitoring Location	Monitoring Distance	Peak Particle Velocity	Frequency	Air Overpressure
	D/M/Y	(Nos.)	(m)	(Kg)	(kg)		(m)	(mm/s)	(Hz)	(dB(L))
17	5.02.20	88	7.0 - 12	60	9320	Tiranaga Temple	848	<0.25	NA	NA
18	5.02.20	88	7.0 - 12	60	9320	Behind Guru kripa Rest.	1040	<0.25	NA	NA
19	5.02.20	88	7.0 - 12	60	9320	Rajshree Kirana Stores	1373	0.364	16.75	101.2
20	5.02.20	88	7.0 - 12	60	9320	Eidgaah Masjid	2137	<0.25	NA	NA
21	5.02.20	116	7.0 - 12	60	5380	Tiranaga Temple	1138	0.968	58	111.2
22	5.02.20	116	7.0 - 12	60	5380	Road Behind Gurukripa	1331	0.619	16.25	108
23	5.02.20	116	7.0 - 12	60	5380	Rajshree Kirana Stores	1663	0.536	16.25	102.5
24	5.02.20	116	7.0 - 12	60	5380	Eidgaah Masjid	2427	<0.25	NA	NA
25	6.02.20	86	7.0 - 12	60	8720	Sunarogi Temple	2020	<0.25	NA	NA
26	6.02.20	86	7.0 - 12	60	8720	Jn Road Hanuman Temple	2256	<0.25	NA	NA
27	6.02.20	86	7.0 - 12	60	8720	Sunarogi Temple	1286	0.410	40.88	92.44
28	6.02.20	86	7.0 - 12	60	8720	Vill. House No. 4950	2562	<0.25	NA	NA
29	6.02.20	114	7.0 - 12	60	9500	Sunarogi Temple	1986	<0.25	NA	NA
30	6.02.20	114	7.0 - 12	60	9500	Hanuman Temple Road	2221	<0.25	NA	NA
31	6.02.20	114	7.0 - 12	60	9500	Near Sunarogi Temple	1248	0.394	32.13	100.2
32	6.02.20	114	7.0 - 12	60	9500	Vill. House No. 4950	2527	<0.25	NA	NA

Table 2: Details of the observed Blast induced Ground Vibration and Air Overpressure at Pur Village, Bhilwara (Contd..)

Sr. No	Date of Blast	No. of Holes	Hole Depth	Max. Charge per Delay	Total Charge	Vibration Monitoring Location	Monitoring Distance	Peak Particle Velocity	Frequency	Air Overpressure
		(Nos.)	(m)	(Kg)	(Kg)		(m)	(mm/s)	(Hz)	(dB(L))
33	3.03.20	76	4.0 - 6.0	85	3065	Near Tiranga Mata	1287	< 0.25	NA	NA
34	3.03.20	76	4.0 - 6.0	85	3065	Bhawar Lal Mali farm	1289	< 0.25	NA	NA
35	3.03.20	76	4.0 - 6.0	85	3065	Dariwa Mandal Road	2047	< 0.25	NA	NA
36	3.03.20	76	4.0 - 6.0	85	3065	Miththu Mali Farm	2075	<0.25	NA	NA
37	3.03.20	119	5.0 - 10	90	10365	Near Tiranga Mata	930	0.698	18.5	< 88.0
38	3.03.20	119	5.0 - 10	90	10365	Bhawar Lal Mali farm	987	<0.25	NA	NA
39	3.03.20	119	5.0 - 10	90	10365	Dariwa Mandal Road	1720	<0.25	NA	NA
40	3.03.20	119	5.0 - 10	90	10365	Miththu Mali Farm	1730	0.544	8.625	97.7
41	4.03.20	39	6.0 - 9.0	80	2800	JSL Weigh Bridge No.2	530	0.587	21.25	108.4
42	4.03.20	39	6.0 - 9.0	80	2800	JSL Electric Grid	337	1.639	8.0	111.3
43	4.03.20	39	6.0 - 9.0	80	2800	Near Dump Yard NW	312	3.46	10.5	<88
44	4.03.20	134	4.0 - 10	90	9790	JSL Weigh Bridge No.2	302	1.746	13.13	111.5
45	4.03.20	134	4.0 - 10	90	9790	JSL Electric Grid	158	11.14	23.63	121.6
46	4.03.20	134	4.0 - 10	90	9790	Near Dump Yard NW	550	1.671	13.88	<88
47	5.03.20	161	4.0 - 9.5	85	10080	Mine Site Office	342	3.397	17.75	131.8
48	5.03.20	161	4.0 - 9.5	85	10080	JSL Weigh Bridge No.2	425	1.365	18.38	120.3

Table 2: Details of the observed Blast induced Ground Vibration and Air Overpressure at Pur Village, Bhilwara (contd..)

Sr. No	Date of Blast	No. of Holes	Hole Depth	Max. Charge per Delay	Total Charge	Vibration Monitoring Location	Monitoring Distance	Peak Particle Velocity	Frequency	Air Overpressure
		(Nos.)	(m)	(Kg)	(kg)		(m)	(mm/s)	(Hz)	(dB(L))
49	5.03.20	161	4.0 - 9.5	85	10080	JSL Electric Grid	144	11.56	37.88	131.3
50	5.03.20	161	4.0 - 9.5	85	10080	Mill Tailing NE	187	10.16	18.00	133.7
51	6.03.20	75	4.0 - 6.0	55	4100	Mine Site Office	230	8.588	16.75	127.3
52	6.03.20	75	4.0 - 6.0	55	4100	Mill Tailing NE	307	1.947	13.50	126.0
53	6.03.20	75	4.0 - 6.0	55	4100	JSL Electric Grid	359	2.254	26.75	124.8
54	6.03.20	180	4.0 - 8.0	100	9400	Mine Site Office	337	2.508	23.88	124.2
55	6.03.20	180	4.0 - 8.0	100	9400	JSL Electric Grid	260	5.438	24.13	127.5
56	6.03.20	180	4.0 - 8.0	100	9400	Mill Tailing NE	322	1.576	12.88	124.3

Note: The vibration monitor instrument is set to a trigger level of 0.25 mm/s so that it does not record false value of vibration. Human activities such walking, closing of the doors/windows and movement of vehicle near geophone induce vibration level of more than 0.25 mm/s. Vibration below 0.25mm/s may not cause damage to structures. Safe permissible limit of the vibration at structures is 5.0 mm/s as per Directorate General of Mines Safety, Govt. of India, an statutory body to regulate mining operations.

NA: Indicates that the vibration values were less than the trigger level of vibration set to monitoring system and corresponding data is not available

The values of vibrations observed at different distances with different charge per delay (Q_{max}) at a mine site are plotted in **Figure 19** in log-log scale. The coefficient of correlation is 0.8353 which is acceptable for prediction of the vibration equation in rock engineering. As can be seen from the Figure 19, a mean line is drawn for the data obtained and presented in Eq. 2. A site-specific equations using 95% confidence interval is presented in Equation 3.

A similar empirical correlation between observed peak particle velocity and total charge used in a blast round is found out by analysing the data. The log-log plot of total charge in a blast round and observed peak particle velocity is resented in Figure 20. The relationship between Total Charge (Q_{TC}) and Observed peak particle velocity (V_{ppv}) is given in Eq. 4. Eq. 5 is site-specific equations using 95% confidence interval.

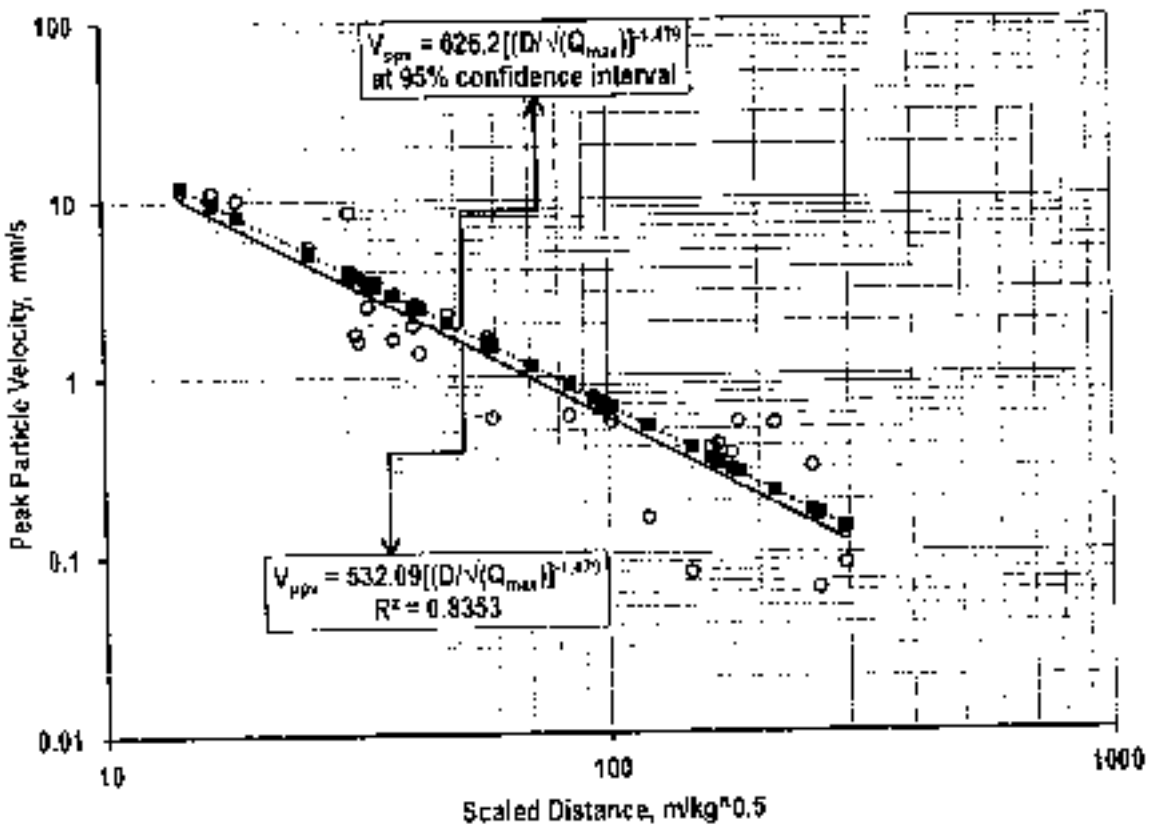


Fig. 19: Plot of peak particle velocity with scaled distance observed at Dhedwas Iron Ore Mine, Bhilwara

A similar empirical correlation between observed peak particle velocity and total charge used in a blast round is found out by analysing the data. The log-log plot of total charge in a blast round and observed peak particle velocity is resented in Figure 20. The relationship between Total Charge (Q_{TC}) and Observed peak particle velocity (V_{ppv}) is given in Eq. 4. The Eq. 5 is site-specific equations using 95% confidence interval.

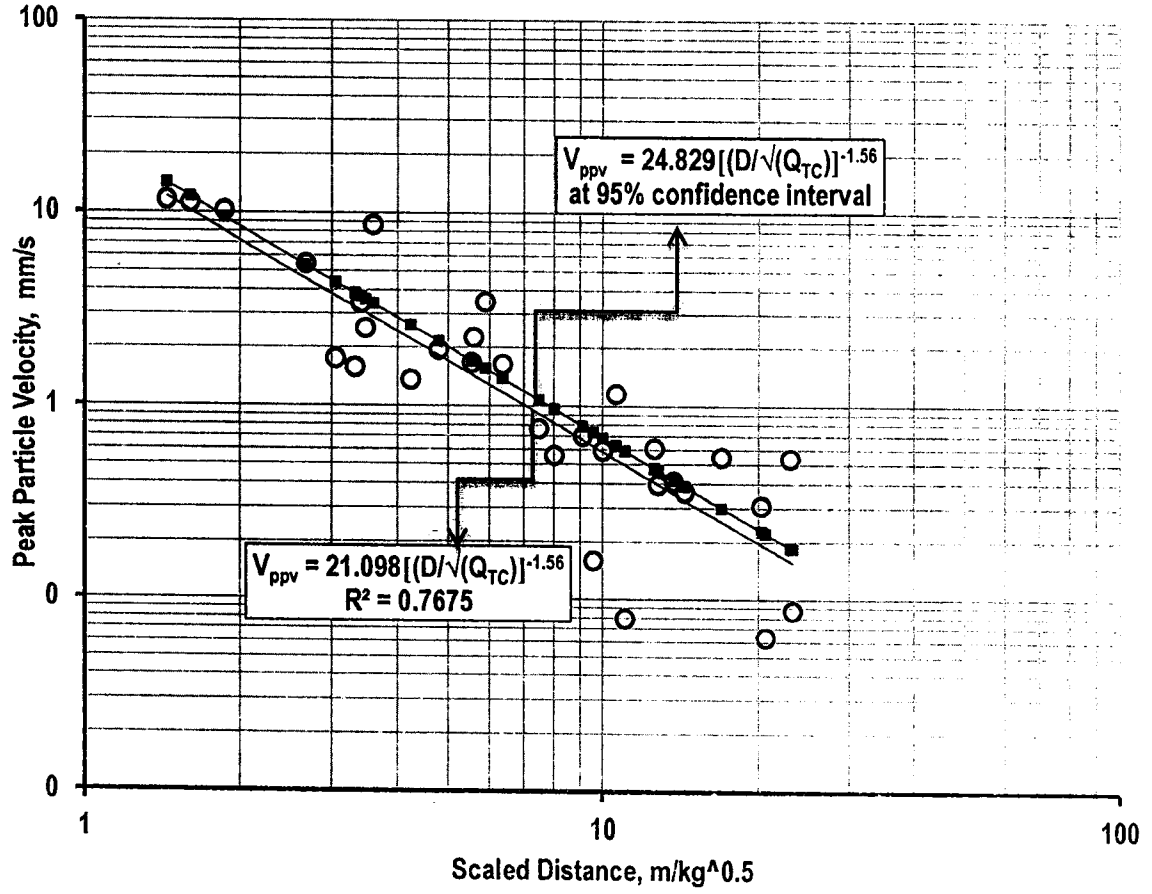


Fig. 20: Plot of peak particle velocity with scaled distance observed at Dhedwas Iron Ore Mine, Bhilwara

$$V_{ppv} = 532.09\left(\frac{D}{\sqrt{Q_{max}}}\right)^{-1.479} \quad \text{(Eq. 2)}$$

$$V_{ppv} = 626.2\left(\frac{D}{\sqrt{Q_{max}}}\right)^{-1.479} \quad \text{(Eq. 3)}$$

$$V_{ppv} = 21.098\left(\frac{D}{\sqrt{Q_{TC}}}\right)^{-1.56} \quad \text{(Eq. 4)}$$

$$V_{ppv} = 24.829\left(\frac{D}{\sqrt{Q_{TC}}}\right)^{-1.56} \quad \text{(Eq. 5)}$$

Where

V_{ppv} = peak particle velocity, mm/s

D = distance of measurement, m, and

Q_{max} = maximum charge per delay, kg.

Q_{TC} = total charge in a blast round, kg.

Similar to vibration analysis, AOP values observed during various field visits were analysed using cube root scaled distance and presented in Figure 21. The air overpressure decay equation is presented in Eq. 6. As the decay of air overpressure as compared to vibration is greater, conventionally, it has been taken as a proportionate to cube root scaled distance.

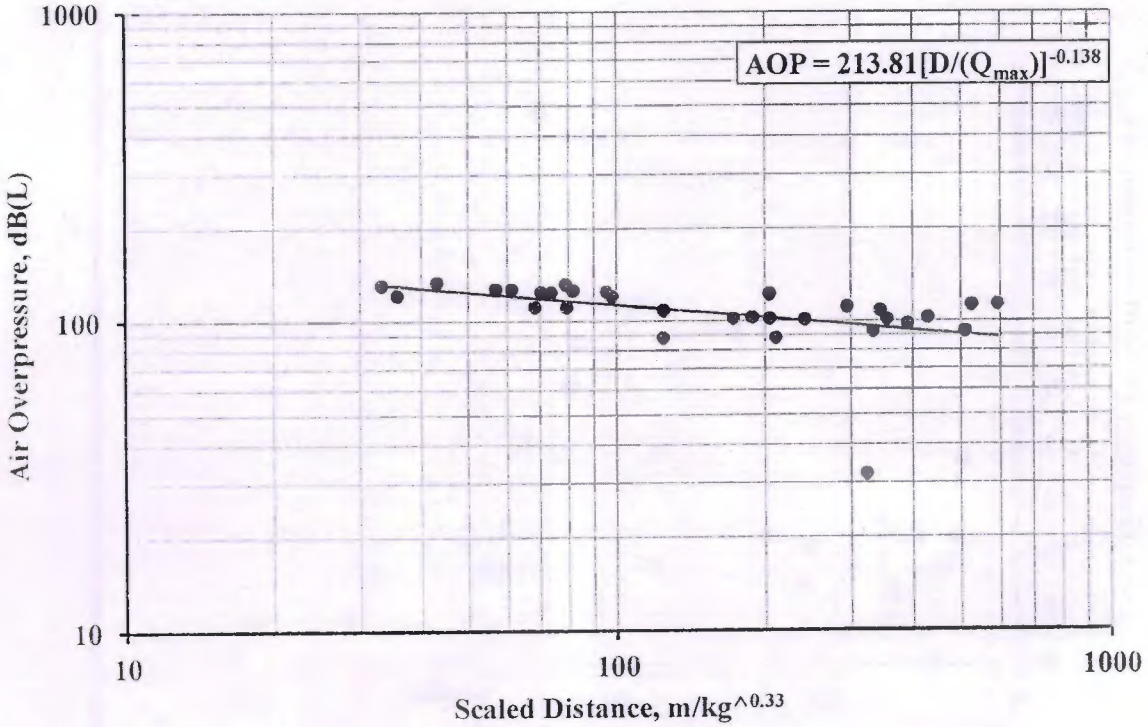


Fig. 21: Plot of observed air overpressure values with cube root scaled distance

$$AOP = 213.81\left(\frac{D}{\sqrt[3]{Q_{max}}}\right)^{-0.074} \quad \text{(Eq. 6)}$$

Where

AOP = air overpressure, dB(L)

D = distance of measurement, m, and

Q_{max} = maximum charge per delay, kg.

7.3 Frequency of the Ground Vibration

The present Indian standard of vibration as notified by Directorate General of Mines Safety (DGMS) (Tech) (S&T) Circular No. 7 dated 29th August, 1997 is frequency based criterion. Therefore, it is important to understand the dominant frequency of the blast induced ground vibration.

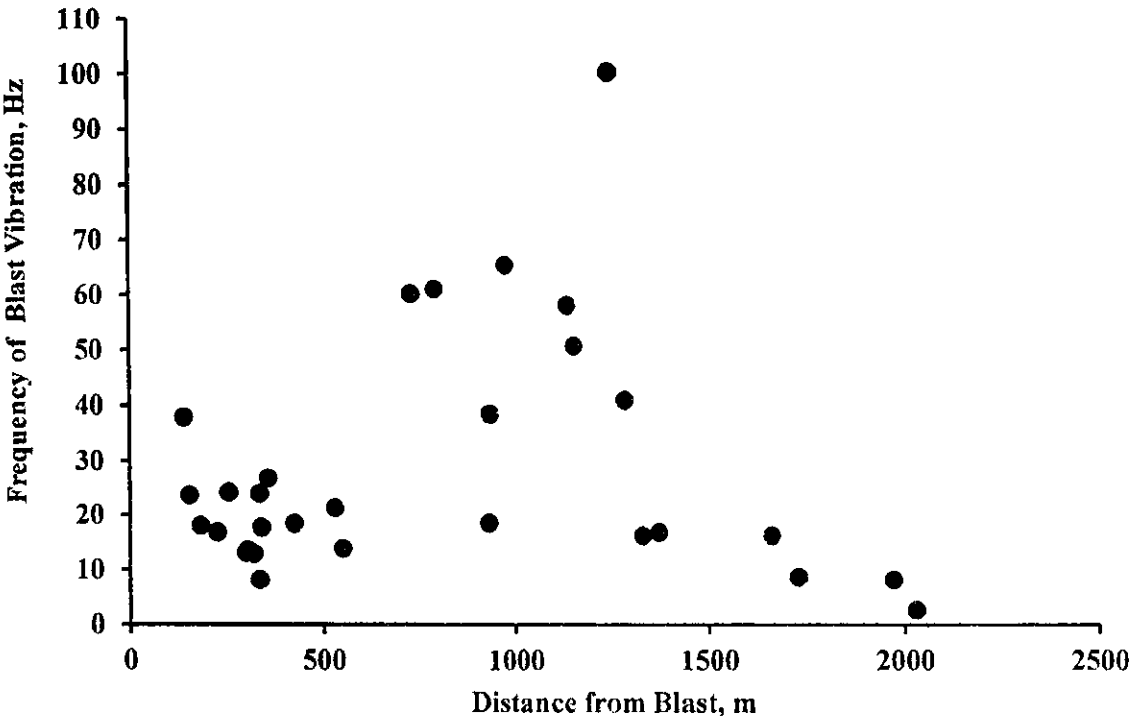


Fig. 22: Plot of dominant frequencies of blast waves recorded at various locations

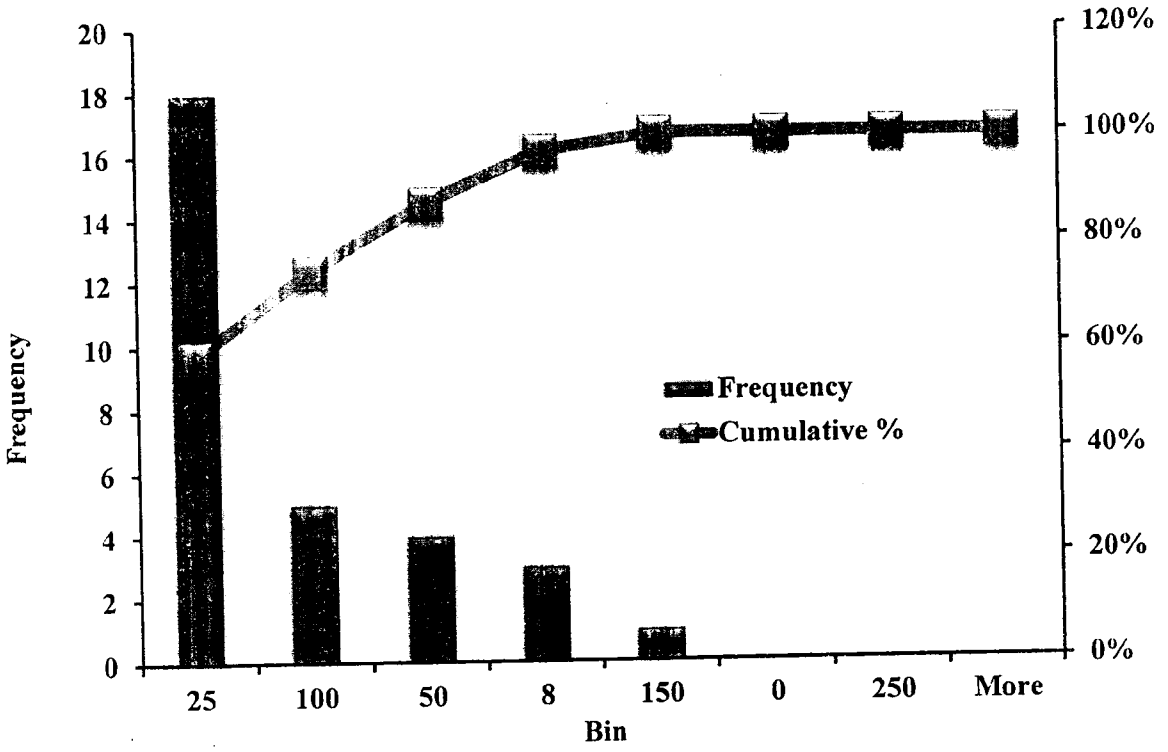


Fig 23: Statistical distribution of the observed frequency data

During various field visits to mine, more than 50 data of vibration, air overpressure and their associated frequency was recorded at different locations by conducting more than 15 experimental blasts. Dominant frequency of the recorded blast vibration is obtained through Fast Fourier Transform (FFT) analysis of each event. Statistical distribution of frequency of the observed data is presented in Figure 22 and Figure 23.

It is clear from Figure 22 and 23 that frequency of the blast induced ground vibration varies from 0 - 70 Hz. Three event have recorded values less than 8 Hz and majority of values lies between 8-30 Hz.

8.0 SAFE LIMIT OF VIBRATION AND AOP

Different countries adopt different standards of safe limit of vibration. Researchers throughout the world have experienced difficulty in defining acceptable damage standards. One of the main reason is the variability in standardization of structures and it's material of construction. In India, as per present Indian standards, as mentioned in DGMS (Tech) (S&T) Circular No. 7 dated 29th

August of 1997, depending on the type of structures and dominant excitation, the peak particle velocity (PPV) on the ground adjacent to the structure shall not exceed the values given in the Table 4.

Table 3: Permissible Peak Particle Velocity (PPV) in mm/s at the Foundation Level of Structures as per DGMS (India) Criterion

Type of Structures	Dominant Excitation Frequency, Hz		
	< 8 Hz	8 - 25 Hz	> 25 Hz
(A) Buildings/structures not belong to the owner			
Domestic houses /structures (Kuchha brick and cement)	**5**	10	15
Industrial buildings (RCC and framed structures)	**10**	20	25
Objects of historical importance and sensitive structures	**2**	5	10
(B) Building belonging to owner with limited span of life			
Domestic houses /structures (Kuchha brick and cement)	10	15	25
Industrial buildings (RCC and framed structures)	15	25	50

The present Indian standard (Table 3) is a frequency based criterion. As the frequency of vibration increases the threshold value of damage also increases. Indian Standard also recommends minimum PPV value of 5.0 mm/s for domestic houses which correspond to less than 8 Hz frequency. As the frequency increase above 8 Hz, the limiting PPV value enhances to 10 mm/s and 15 mm/s for frequency range 8- 25 Hz and greater than 25 Hz respectively.

The safe permissible limit of peak particle velocity (PPV) for domestic houses and industrial building not belonging to mine management is 5 mm/s and 10 mm/s respectively, corresponding to 0 – 8 Hz frequency range as per the present DGMS criterion. Although majority of the observed frequency values lies above 8 Hz, few frequency values are also found between 0-8 Hz. Therefore, peak particle velocity value of 5 mm/sec may be considered safe limit of the ground

vibration as per DGMS criterion corresponding o 0-8 Hz frequency rage. The observation is also similar to DGMS permission of 5 mm/s for the Tiranaga Block of Dhedwas iron ore mine.

DGMS (India) Circular suggests 90 dB-A as the threshold for continuous occupational exposure of noise up to 8 hours duration. However, there is no guideline from DGMS or Indian Bureau of Mines (IBM) regarding permissible safe level of air overpressure (AOP) produced due to blasting. For large scale surface mining operations, air overpressure can be characterized by lower frequency. For large scale operation, a common overpressure limit of 134 dB(L) is recommended by the United States Bureau of Mines (USBM) in RI 8507 (Siskind et al, 1980). USBM recommended values are presented in Table 4. As Table 4 is internationally accepted and the same has been adopted for evaluating the AOP threshold values in the present study for Dhedwas Iron ore mine, Bhilwara.

In light of above discussion, recommended safe limit of blast induced ground vibration and air overpressure for Dhedwas Iron ore mine, Bhilwara is 5 mm/s and 134dB(L) respectively.

Table 4: Typical Air overpressure criterion (Siskind et al, 1980)

Air Overpressure Limits, dB(L)	Damage potential
180	Some structural Damage
171	General window breakages
140	Occasional Window breakage
134	US Bureau of mines recommendations for large-scale surface mine blasting.

9.0 DISCUSSION ON THE RESULTS

CSIR-CIMFR Team conducted 15 experimental blasts in Dhedwas Iron ore mine, Bhilwara with different permutation and combination of the blasting parameters. The parameters of the blasting experiments were chosen after review of the data on blasting operations corresponding to April 2018 to Dec 2019. The details of the experimental blast are presented in Table 1. Comprehensive blast vibration monitoring was done during blasting experiments. Monitoring was done both in

near field as well as far-field to evaluate the attenuation characteristics of the blast vibration and air overpressure. Vibration monitoring as closes as 158 m and as far as 2906 m has been done at Dhedwas mine site. The observed values of vibration ad air overpressure are presented in Table 2. Attenuation characteristics of the vibration and air overpressure are presented in Eq(s) 3 and 6 respectively. It may be noted from Table 2 that vibration has been monitored at 56 different locations in and around the blasting operation sites. The monitoring location includes domestic houses and other prominent structures of the Pur village such as Temple and Mosques and community hospital etc. Monitoring both at found and roof level of structures has been carried out. Emphasis has been made to measure vibration in places where cracks has been observed.

The observed values, as presented in Table 2 reveals that the blast induced ground vibration and air overpressure beyond a distance of 500 m from the blasting site remained less than 2.00 mm/s and 115 dB(L) against recommended safe values of 5.0 mm/s and 134 dB(L). Ground vibration beyond a distance of 1.5 km decayed to less than 1.0 mm/s in majority of the cases. A plot showing attenuation of the blast induced ground vibration with different values of maximum charge per delay obtained using Eq 3 is shown in Figure 24. Figure 24 shows that the vibration intensity expressed in terms peak particle velocity (PPV) remains less than 2.0 m/s beyond a distance of approximately 500 m and further reduces to value less than 1.0 mm/s beyond a distance of 1.5 mm/s. This trend is also obtained in actual measurement while conducting vibration monitoring at site during blasting experiments.

In Figure 24, three lines indicating recommended safe permissible limits of the PPV values as per DGMS criterion corresponding to frequency range of 0-8 Hz is also marked. It may be noted that at a distance of approx.. 700 m, vibration reduces to below 2.0 mm/s, which is safe limit even for historical objects. Corresponding safe permissible value is 5.0 mm/s for domestic houses. In case of Dedhwas iron ore mine, the vibration attenuates to value less than 5.0 mm/s at distance of 500 m. The safe limit of industrial structure is 10 mm/s corresponding to 0-8 Hz frequency as per DGMS recommendations. In present case, for MCD value of 200 kg, vibration upto 10 mm/s is recorded up to a distance of approx.. 250 m. and thereafter, it sharply attenuates and fall under safe limit. In case of lower maximum charge per delay such as 100 kg and 150 kg, the attenuation is faster and the 5.0 mm/s of recommended safe PPV limit is obtained at a distance lesser than 350 m only.

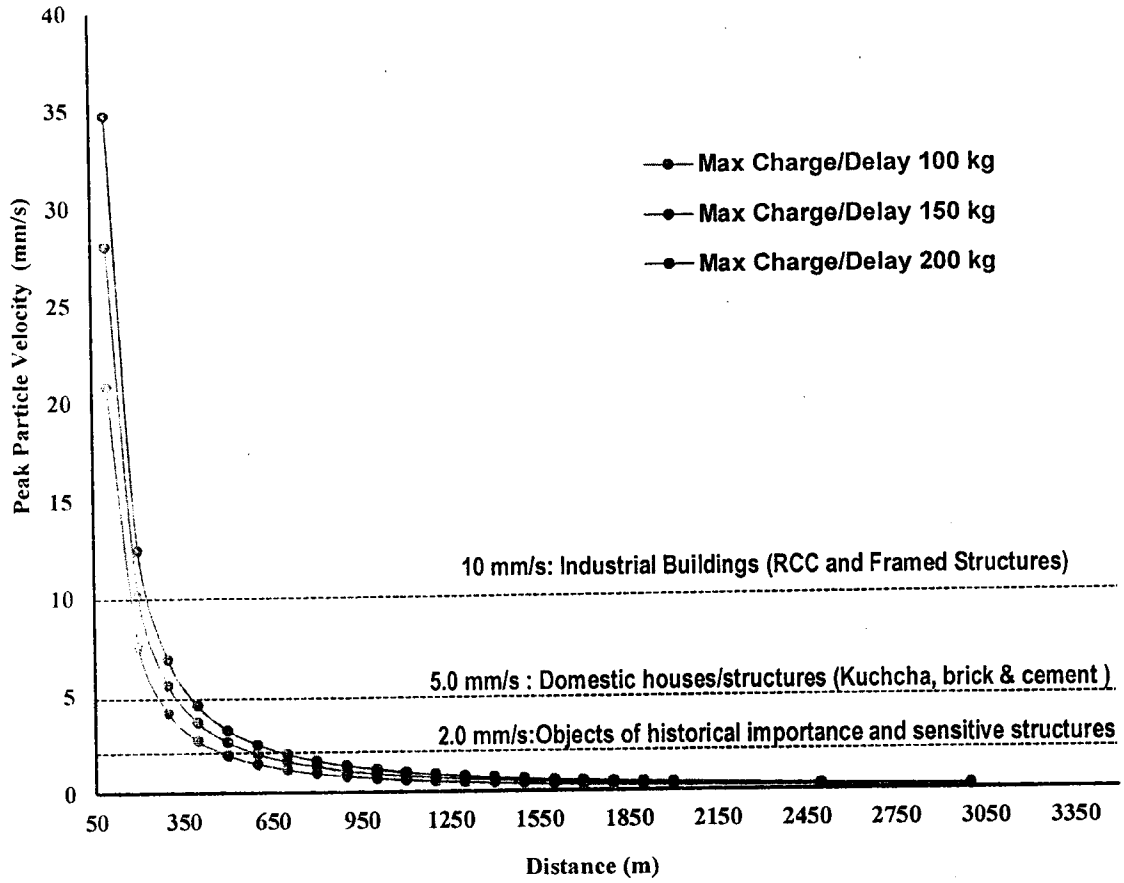


Fig. 24: Decay of vibration with different values of maximum charge per delay

Another plot showing attenuation of vibration in terms of peak particle velocity (PPV) with distance for different values of total charge in a blast round, developed using Eq. 5 is presented in Figure 25. Equation 5 corresponds to propagation characteristics of vibration at 95% confidence interval for total charge in blast round. Similar to case of Figure 24, three lines indicating recommended safe permissible limits of the PPV values as per DGMS criterion corresponding to frequency range of 0-8 Hz is also marked in Figure 25. Three case has been considered in this plot which are observed in the usual mine blasting operation at mine and also practices during experimental blasting operation of the investigating team. During review of the blasting operation carried out in mine, few blasts with 12 tons explosives quantity were observed. Therefore, analysis of 12 ton total charge is also considered. Other two cases are use of 8.0 ton and 10.0 total charge in blast round.

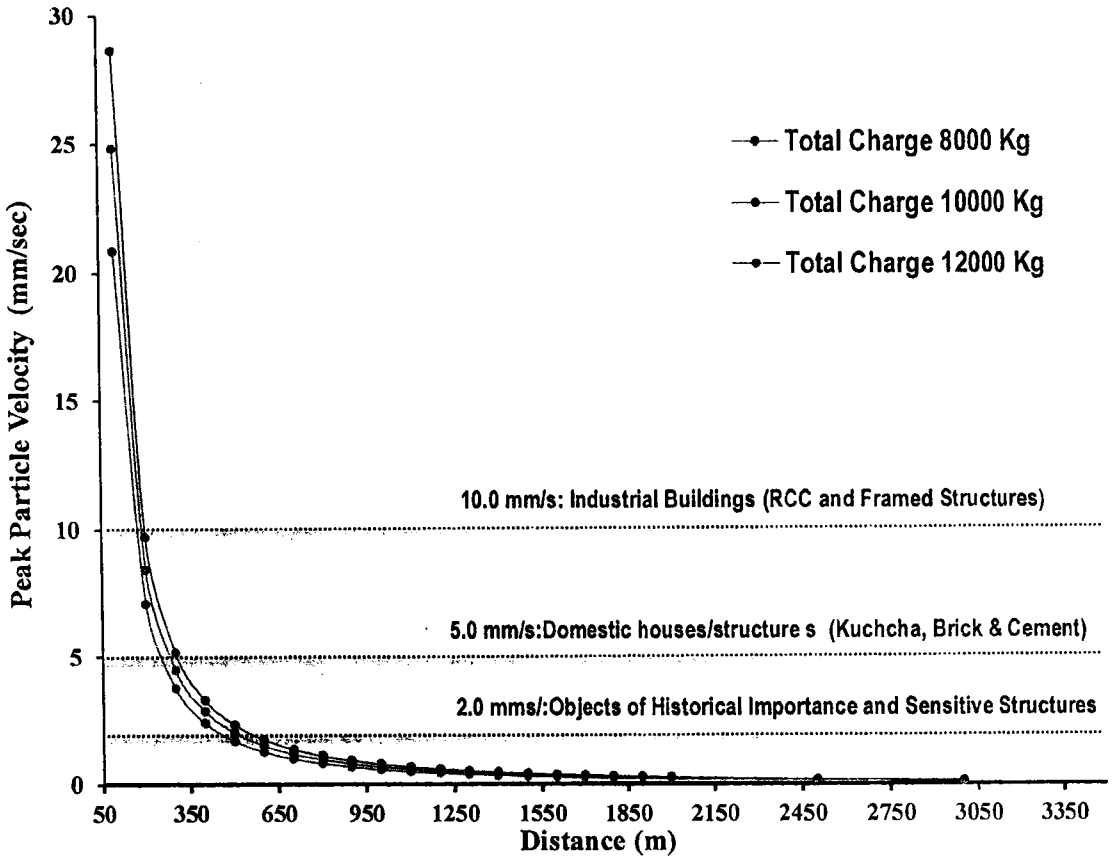


Fig. 25: Decay of vibration with different values of Total Charge (TC) in a blast round

Analysis of data as presented in Figure 25 shows similar trend as observed in Figure 24. PPV value corresponding to 12 tons total charge generates vibration of 2.0 mm/s upto a distance of approx.. 500 m and thereafter, it decays sharply. In case of safe permissible limit of vibration for domestic houses as per DGMS criterion, the values of 5.0 mm/s is observed upto a distance of 300 m. For industrial structure PPV values beyond a distance of 200 m is falling within the safe permissible limit of 10.0 mm/s as per DGMS criterion. The impact of total charge in blast round ins noticeable mostly in close field monitoring particularly upto a distance of 200 m. The values of PPV beyond a distance of 1.5 km are almost overlapping.

Foregoing discussion on analysis of the propagation characteristics of vibration reveals that the blast induced ground vibration induced by Dhedwas iron ore mine are well within the safe permissible limit as per DGMS criterion.

10.0 CONCLUSIONS AND RECOMMENDATIONS

CIMFR team have conducted study at Pur Village to evaluate damage potential of the blast induced ground vibration and air overpressure induced by blasting operations at Dhedwas Iron Ore Mine, Bhilwara. Altogether 15 experimental blast rounds were conducted in Dhedwas Iron Ore mine. Comprehensive vibration monitoring was carried out during blasting experiment. Altogether vibration was monitored at 56 different locations. The monitoring location includes domestic houses and other prominent structures of the Pur village such as Temple and Mosques and community hospital.

It is observed that the blast induced ground vibration and air overpressure beyond a distance of 500 m from the blasting site remained less than 2.00 mm/s and 115 dB(L) against recommended safe values of 5.0 mm/s and 134 dB(L). Ground vibration beyond a distance of 1.5 km decayed to less than 1.0 mm/s in majority of the cases. Therefore, it may be concluded that observed blast induced ground vibration values are safe and well within the permissible limit as per recommendations of Directorate General of Mine Safety (DGMS). Based on the findings of the study it is concluded that impact of blast induced ground vibration and air overpressure in causing damage to the housing structures of Pur village, approx., 2.5 km away is practically not possible. This is further corroborated by the facts that the houses which are between Dhedwas iron mine and Pur village does not have cracks and are not damaged. Cracks in the houses of Pur village may be accounted to hydrogeological set-up of the area and its interaction with the weak non-engineered structures of the Pur village.

It is recommended that an expert agency should be engaged to supervise blasting operations at Dhedwas Iron ore mine. Vibration monitoring shall be carried out by such expert agency in close co-ordination with representative of Pur village. Quarterly/six monthly report of such exercise shall be submitted to State Department of Mining and Geology (DMG)/District Magistrate Office. Such exercise will not only help in establishing mechanism for monitoring the blasting operation but will also enhance confidence of the local villager.

ACKNOWLEDGEMNET

CSIR-Central Institute of Mining and Fuel Research, Regional Research Centre Bilaspur thankfully acknowledges the support of officials from Bhilawara District Magistrate office for entrusting the study to CIMFR. CIMFR team would also like to place on record their gratitude for the sincere support and co-operation extended by the official and staff members in carrying out extensive field works at mine

site and Pur village. Extensive vibration monitoring has been carried out in domestic houses causing inconvenience to the house owners at time. Support received from the inhabitants of Pur villager, particularly Mr. Yogesh Soni and his team for co-ordination with CIMFR Team is also thankfully acknowledged.

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ANNEXURE – 1

(Event Reports of Observed Vibration)

Date-Time	Tran at 1:00:48 PM February 1, 2020
Trigger Source	Geo: 0.510 mm/s, Mic: 100.0 dB(L)
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4.096 sps

Notes
Location Pur Village
Client
User Name CSIR-CMPF, Bilaspur Research Centre
General

Extended Notes
Scientific investigation of potential damage due to blast induced ground vibration and air over pressure in domestic houses in Pur Village, Bhilwara, Rajasthan, India.

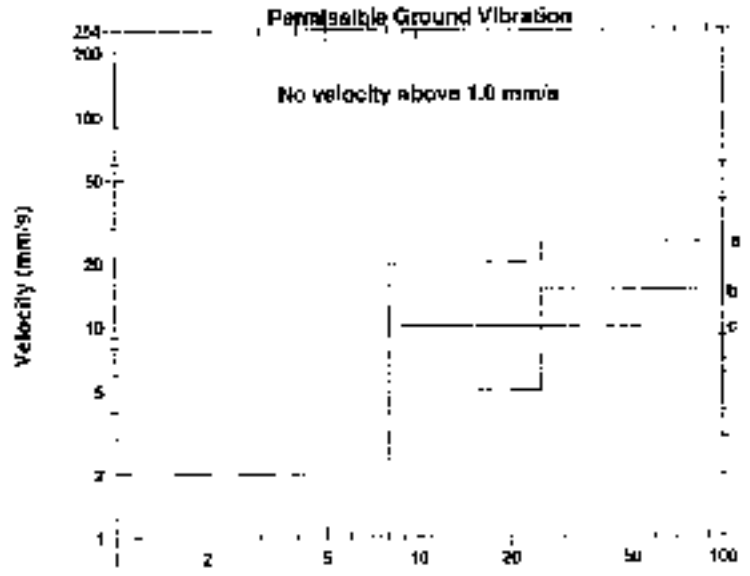
Microphone	Linear Weighting
PSPL	103.6 dB(L) 2.750 pa.(L) at 1.821 sec
ZC Freq	5.1 Hz
Channel Test	Passed (Freq = 20.1 Hz Amp = 544 mv)

	Tran	Vert	Long	
PPV	0.635	0.651	0.702	mm/s
ZC Freq	36.6	57	41	Hz
Time (Rel. to Trig)	1.174	1.321	1.520	sec
Peak Acceleration	0.033	0.040	0.046	g
Peak Displacement	0.004	0.002	0.003	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 0.973 mm/s at 1.322 sec

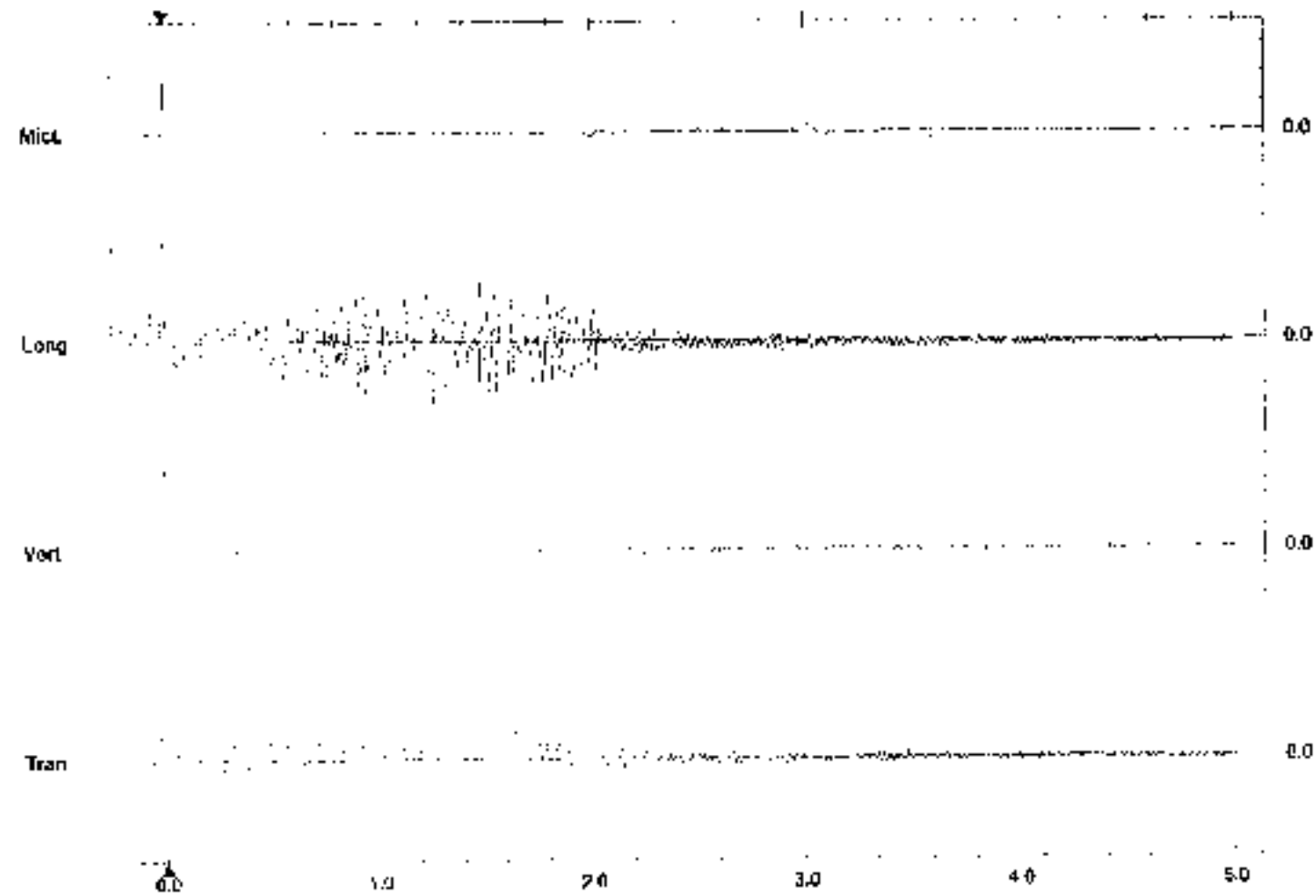
Serial Number	BE13761 V 10.72-8.17 MinMate Plus
Battery Level	6.1 Volts
Unit Calibration	January 13, 2020 by LES New Delhi
File Name	07811B6M.TC0

DGMS India (A)



Frequency (Hz)
Tran + Vert + Long

a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div Amplitude Scale: Geo: 0.501 mm/s/div Mic: 10.000 psi (L)/div
Trigger = ▶ ◀

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14

Instantel Event Report

Date/Time	MicL at 1:03:53 PM February 1, 2020
Trigger Source	Geo: 0.510 mm/s, Mic: 100.0 dB(L)
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps

Serial Number	BE13781 V 10.72-8.17 MiniMate Plus
Battery Level	6.1 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	O781IB6M.YH0

Notes
Location: Pur Village
Client:
User Name: CSIR-CIMFR, Bilaspur Research Centre
General:

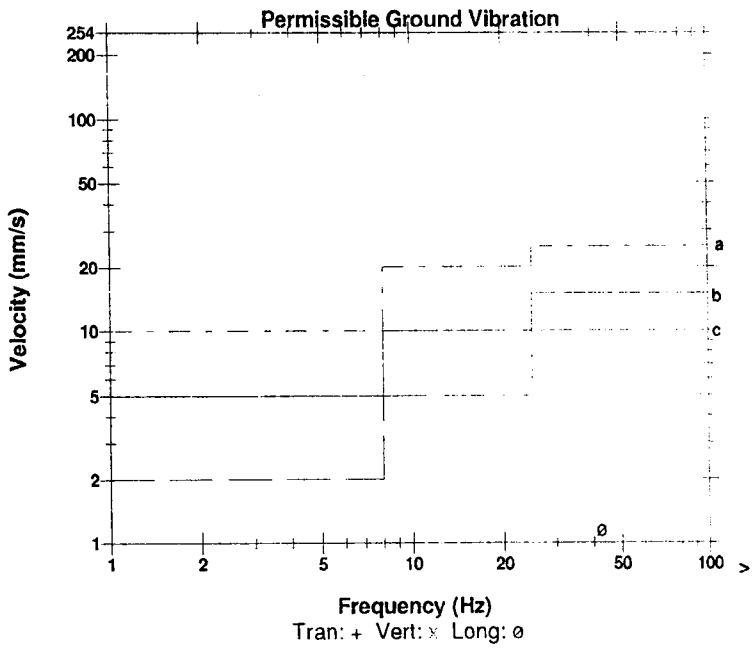
Extended Notes
Scientific investigation of potenstial damage due to blast induced ground vibration and air over pressure in domestic houses in Pur Village, Bhilwara, Rajasthan, India.

Microphone	Linear Weighting
PSPL	101.9 dB(L) 2.500 pa.(L) at 0.006 sec
ZC Freq	7.2 Hz
Channel Test	Passed (Freq = 20.1 Hz Amp = 544 mv)

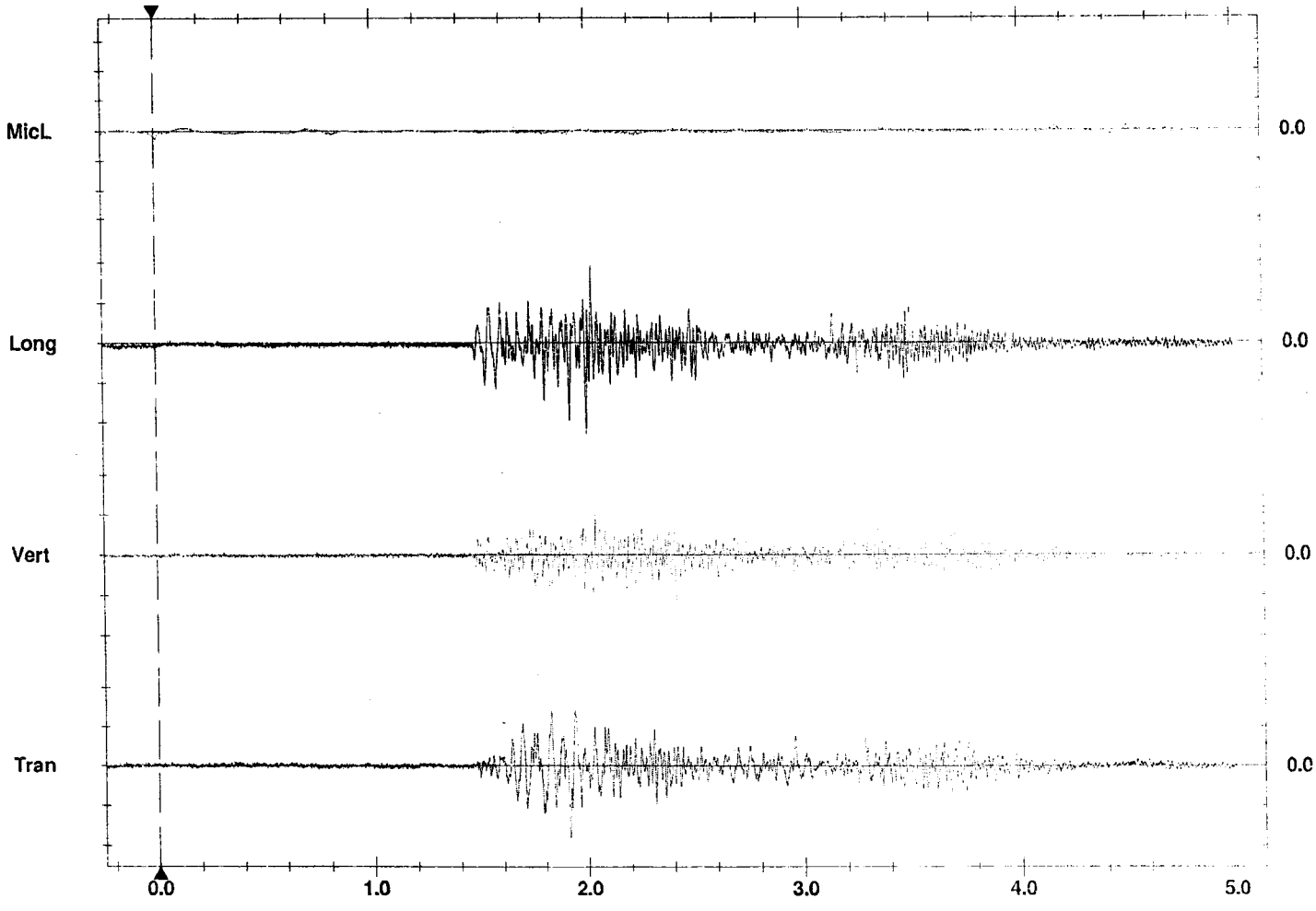
	Tran	Vert	Long	
PPV	0.921	0.587	1.159	mm/s
ZC Freq	20.3	62	43	Hz
Time (Rel. to Trig)	1.910	2.036	2.000	sec
Peak Acceleration	0.040	0.033	0.040	g
Peak Displacement	0.006	0.002	0.004	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 1.170 mm/s at 2.000 sec

DGMS India (A)



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 10.000 pa.(L)/div
Trigger = ▶—— ——◀

Format © 1995-2014 Xmark Corporation

Instantel Event Report

(45)

Date/Time	MicL at 13:00:49 February 1, 2020
Trigger Source	Geo: 0.510 mm/s, Mic: 2.000 pa.(L)
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps

Notes
Location: Pur Village
Client:
User Name: CSIR-CIMFR, Bilaspur Research Centre
General:

Extended Notes
Scientific investigation of potenstial damage due to blast induced ground vibration and air over pressure in domestic houses in Pur Village, Bhilwara, Rajasthan, India.

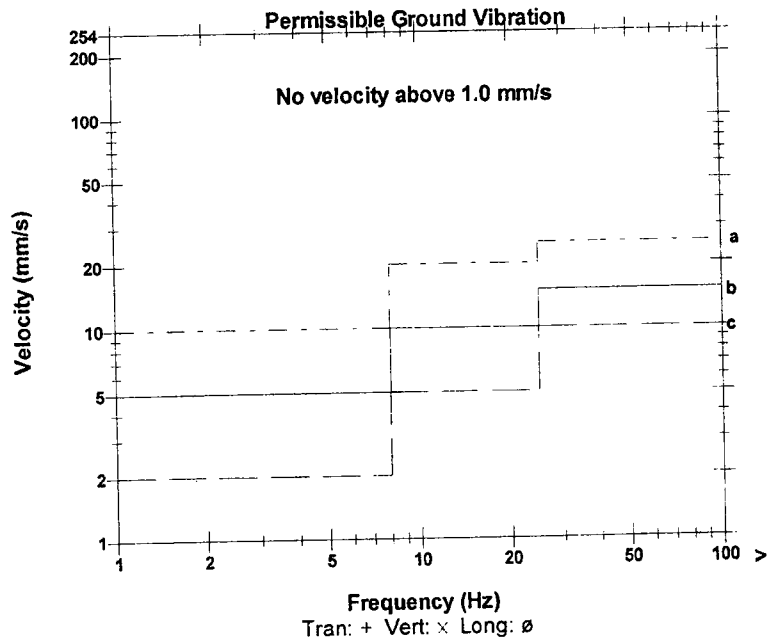
Microphone	Linear Weighting
PSPL	2.250 pa.(L) at 1.763 sec
ZC Freq	6.2 Hz
Channel Test	Passed (Freq = 20.1 Hz Amp = 515 mv)

	Tran	Vert	Long	
PPV	0.159	0.127	0.111	mm/s
ZC Freq	73	68	93	Hz
Time (Rel. to Trig)	-0.163	-0.220	-0.227	sec
Peak Acceleration	0.027	0.027	0.027	g
Peak Displacement	0.000	0.000	0.000	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 0.163 mm/s at -0.163 sec

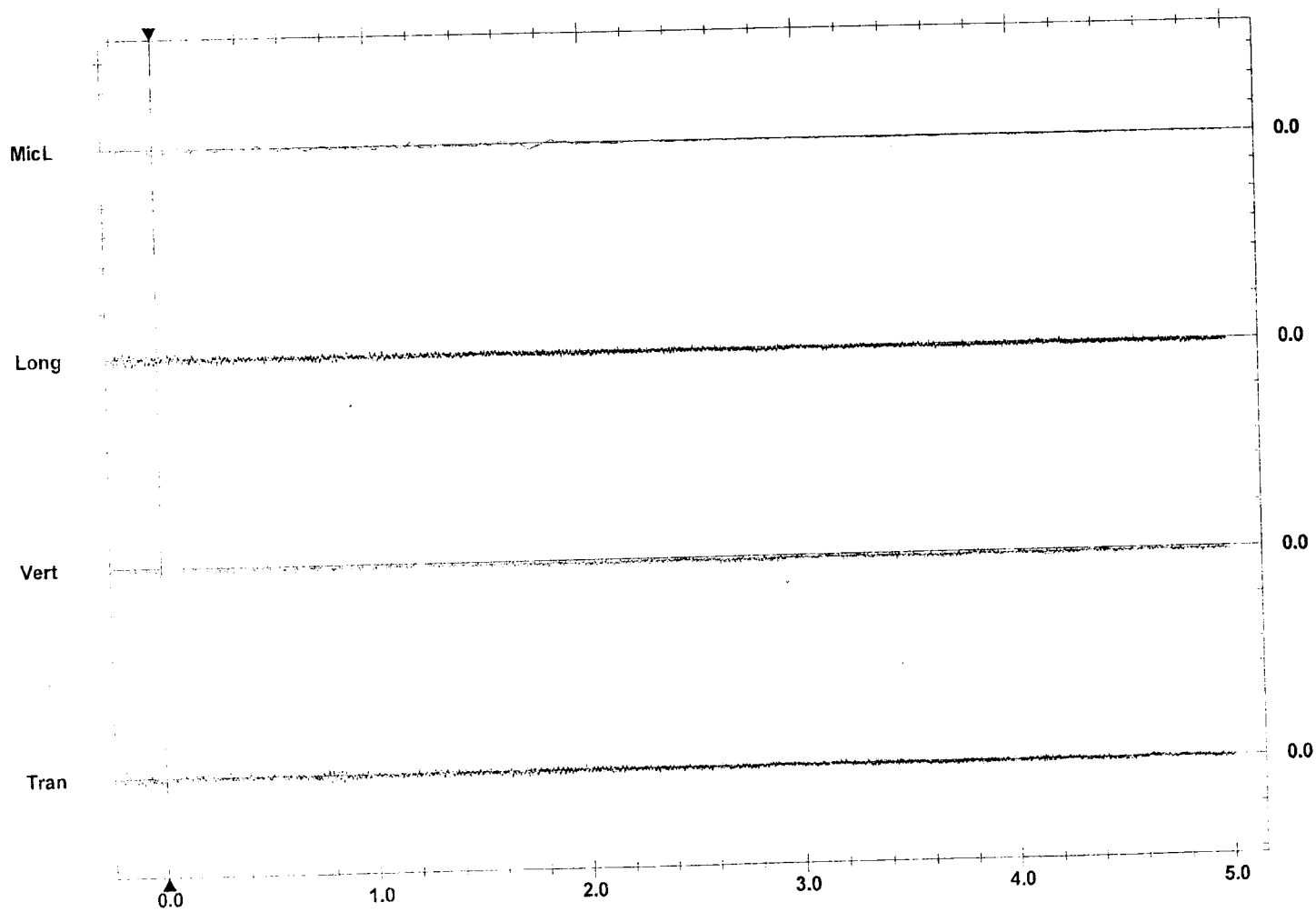
Serial Number	BE16508 V 10.72-1.1 Minimate Blaster
Battery Level	6.4 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	R508IB6M.TD0

DGMS India (A)



Frequency (Hz)
Tran: + Vert: × Long: ø

a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 10.000 pa.(L)/div
Trigger = ▶---◀

Printed: December 31, 2020 (V 10.74)

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Y6

Instantel Event Report

Date/Time	Long at 13:00:51 February 1, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 2048 sps
Operator/Setup:	Operator/CIMFR BLSPR.mmb

Notes
Location: PUR VILLAGE
Client:
User Name: CSIR-CIMFR Bilaspur Research Centre
General:

Extended Notes
Scientific investigation of damage potential due to blast induced ground vibration and airover pressure in domestic houses in Pur Village, Bhilwara, Rajasthan, India.

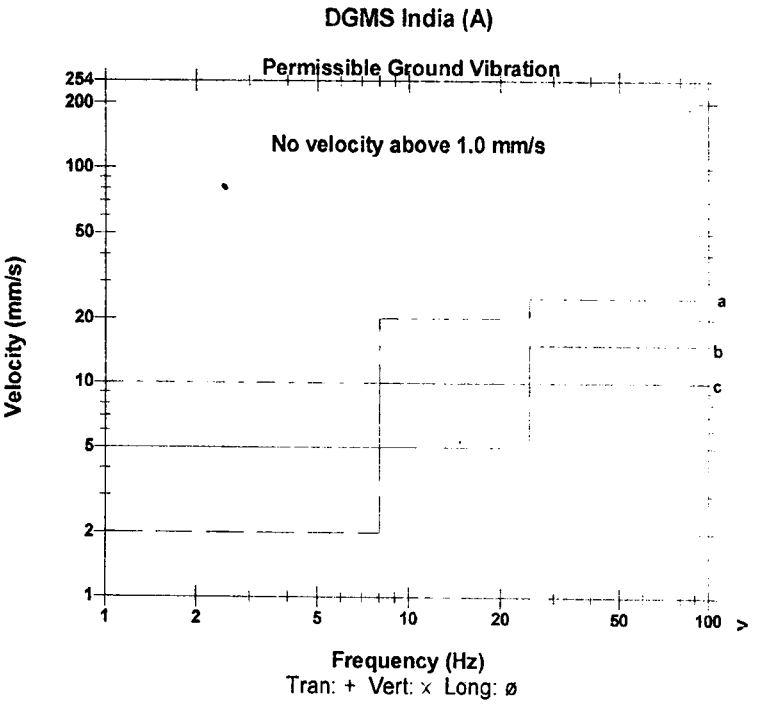
Microphone	Linear Weighting
PSPL	0.838 pa.(L) at 4.740 sec
ZC Freq	7.7 Hz
Channel Test	Passed (Freq = 19.7 Hz Amp = 1319 mv)

	Tran	Vert	Long	
PPV	0.205	0.244	0.307	mm/s
ZC Freq	10.9	24	8.1	Hz
Time (Rel. to Trig)	1.119	1.117	0.642	sec
Peak Acceleration	0.010	0.010	0.010	g
Peak Displacement	0.002	0.002	0.005	mm
Sensor Check	Passed	Passed	Passed	

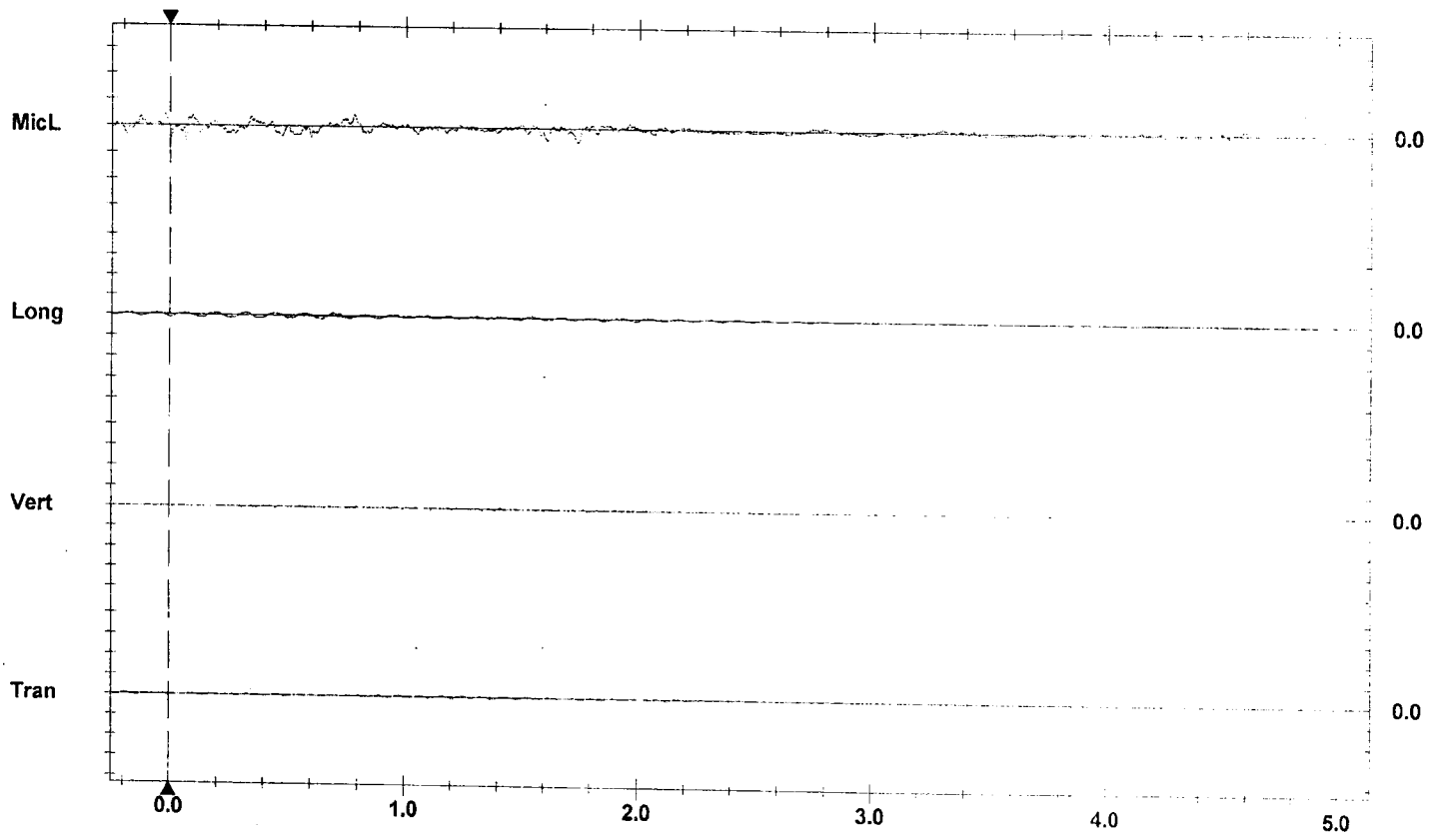
Peak Vector Sum 0.317 mm/s at 0.643 sec

Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200201130051.IDFW

Post Event Notes
DMG, BHILWARA DIST, RAJASTHAN GOVT.



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 2.000 mm/s/div Mic: 1.000 pa.(L)/div
Trigger = ▶— —◀

Printed: December 31, 2020 (V 10.74)

Format © 1995-2015 Xmark Corporation

Event Report

Date/Time	Tran at 13:03:54 February 1, 2020
Trigger Source	Geo: 0.510 mm/s, Mic: 2.000 pa.(L)
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps

Notes
Location: Pur Village
Client:
User Name: CSIR-CIMFR, Bilaspur Research Centre
General:

Extended Notes
Scientific investigation of potenstial damage due to blast induced ground vibration and air over pressure in domestic houses in Pur Village, Bhiiwara, Rajasthan, India.

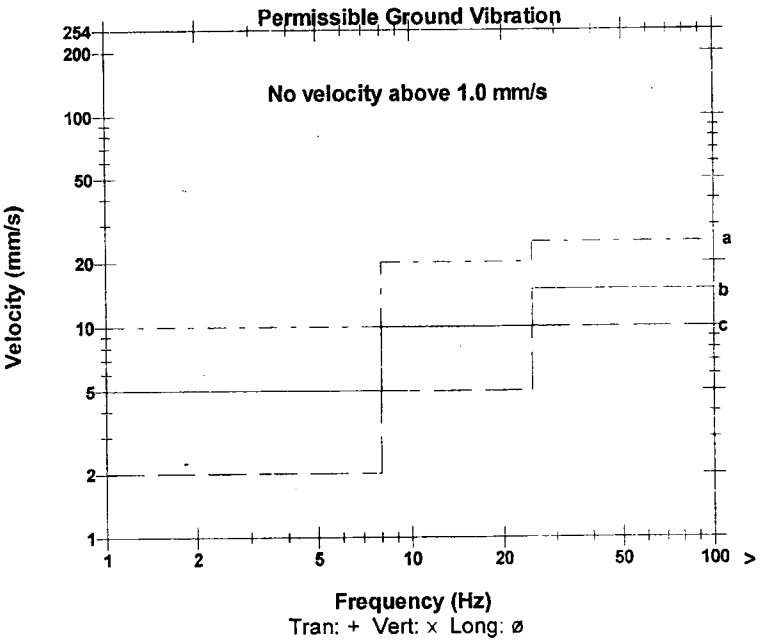
Microphone	Linear Weighting
PSPL	2.500 pa.(L) at 4.441 sec
ZC Freq	4.2 Hz
Channel Test	Passed (Freq = 20.1 Hz Amp = 515 mv)

	Tran	Vert	Long	
PPV	0.603	0.540	0.524	mm/s
ZC Freq	39.4	38.6	44	Hz
Time (Rel. to Trig)	0.035	0.107	0.109	sec
Peak Acceleration	0.040	0.040	0.040	g
Peak Displacement	0.003	0.002	0.002	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 0.714 mm/s at 0.108 sec

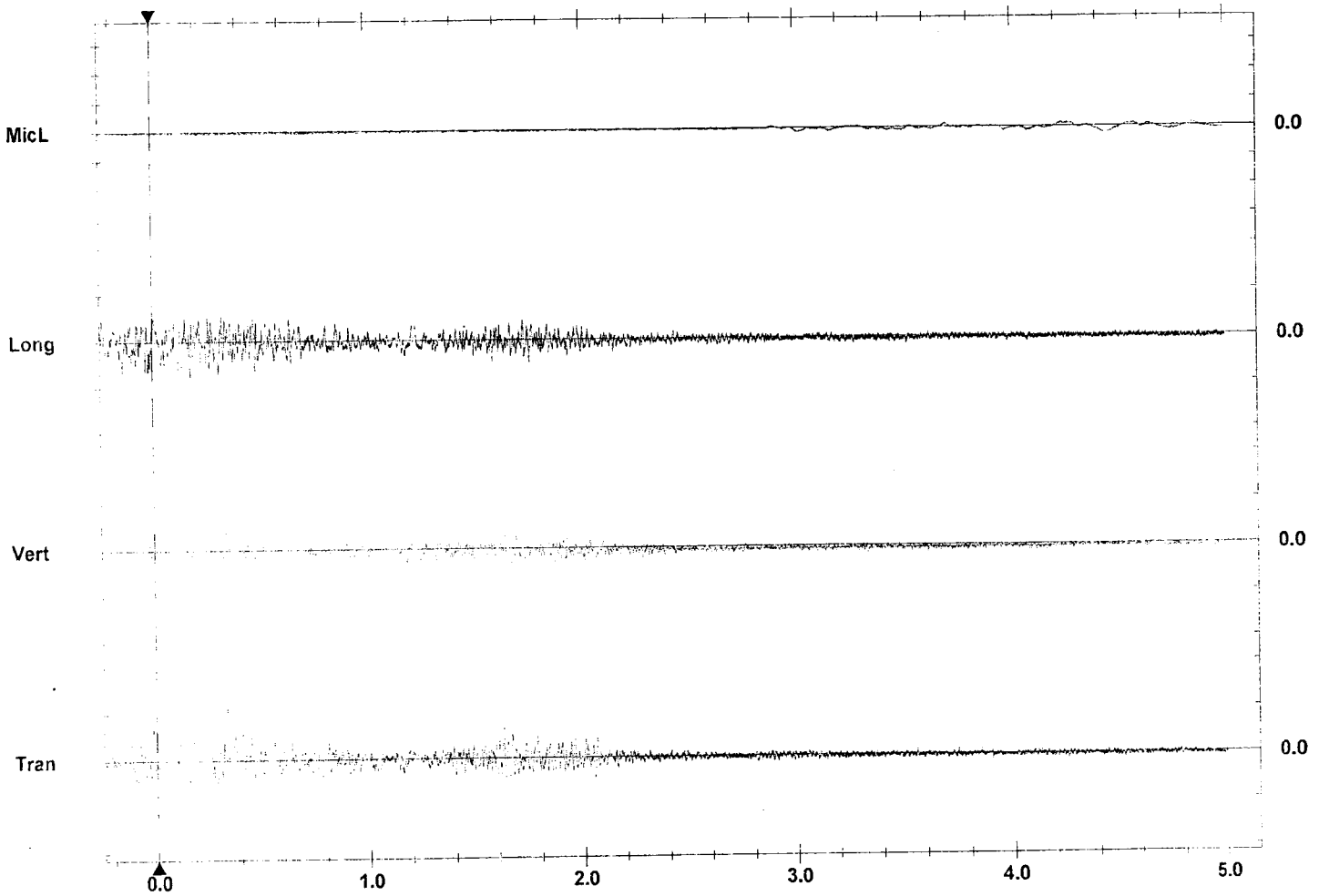
Serial Number	BE16508 V 10.72-1.1 Minimate Blaster
Battery Level	6.4 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	R508IB6M.YI0

DGMS India (A)



Frequency (Hz)
Tran: + Vert: x Long: ø

a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 10.000 pa.(L)/div
Trigger = ▶ ◀

Format © 1995-2015 Xmark Corporation

(78)

Instantel

Event Report

Date/Time	Long at 13:11:23 February 4, 2020
Trigger Source	Geo: 0.510 mm/s
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps

Serial Number	BE13781 V 10.72-8.17 MiniMate Plus
Battery Level	6.3 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	O781IBC7.AZ0

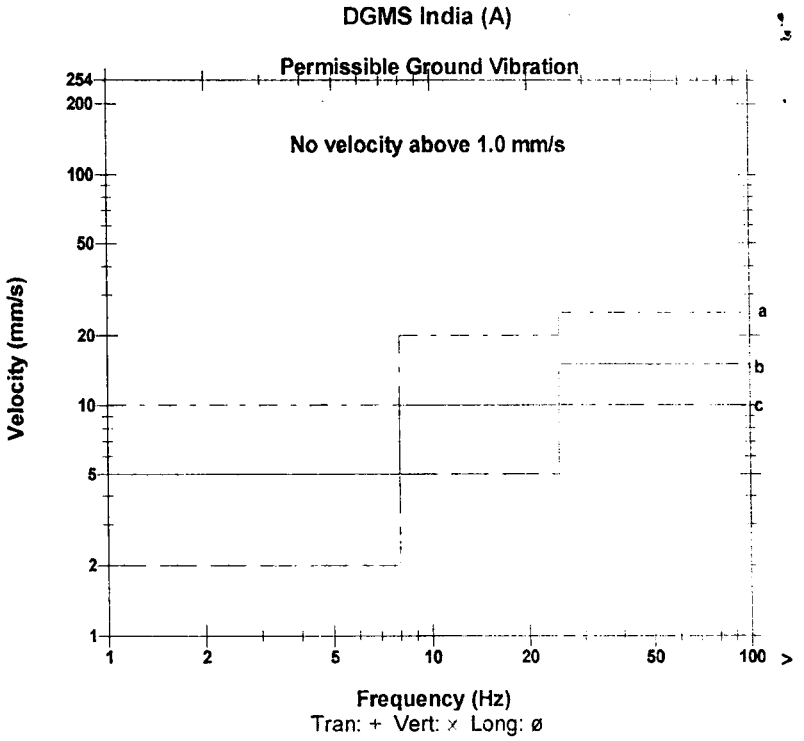
Notes
Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR, Bilaspur Research Centre
General:

Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

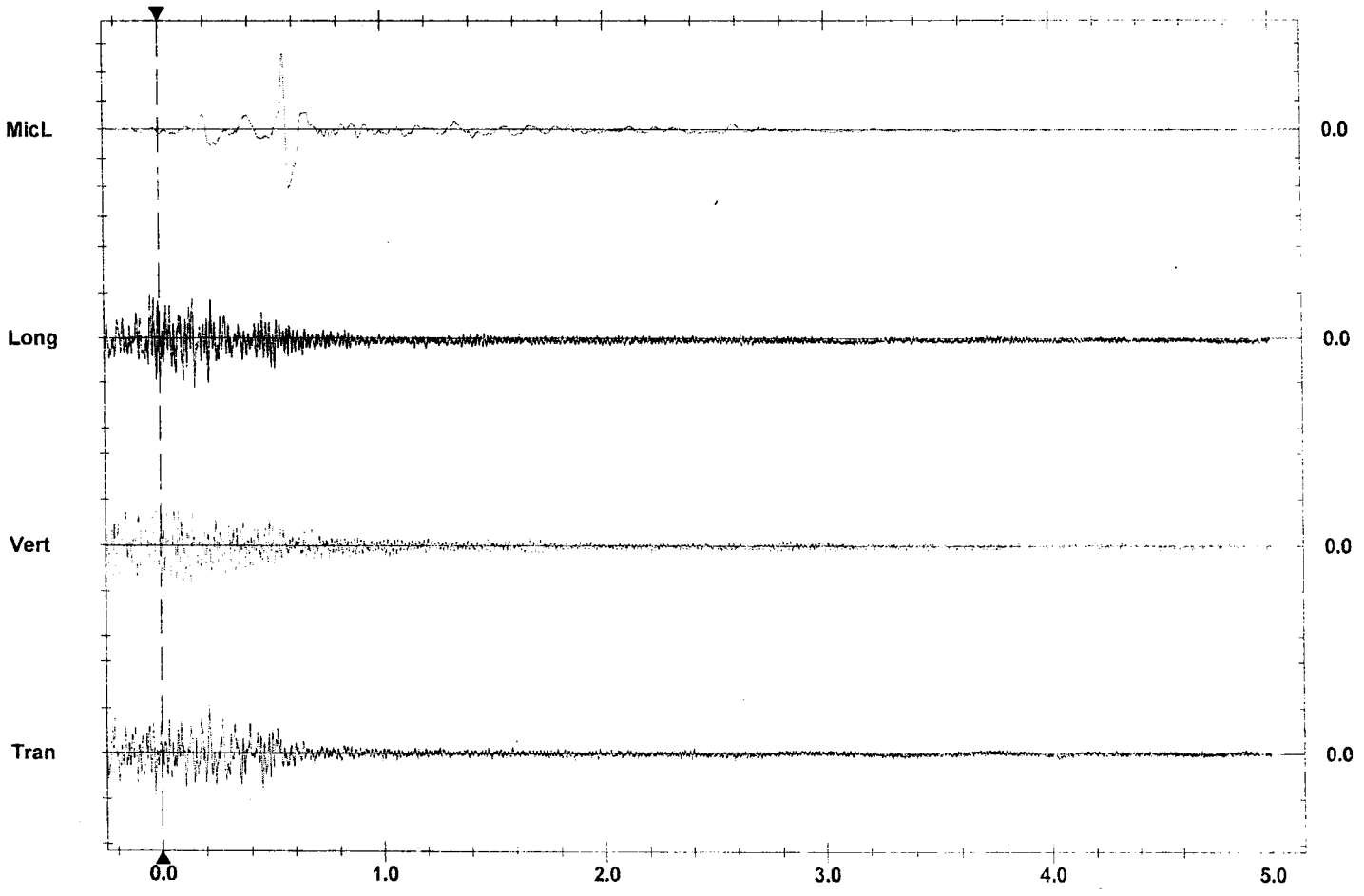
Microphone	Linear Weighting
PSPL	26.75 pa.(L) at 0.558 sec
ZC Freq	9.2 Hz
Channel Test	Passed (Freq = 20.1 Hz Amp = 524 mv)

	Tran	Vert	Long	
PPV	0.540	0.444	0.556	mm/s
ZC Freq	32.0	59	23.8	Hz
Time (Rel. to Trig)	0.211	-0.081	0.155	sec
Peak Acceleration	0.033	0.033	0.033	g
Peak Displacement	0.002	0.002	0.002	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 0.674 mm/s at 0.155 sec



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 10.000 pa.(L)/div
Trigger = ▶—— —— ◀

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Event Report

Date/Time	MicL at 13:11:33 February 4, 2020
Trigger Source	Geo: 0.250 mm/s, Mic: 6.325 pa.(L)
Range	Geo: 254.0 mm/s
Record Time	10.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR BLSPR.mmb

Serial Number	UM12452 V 10-89 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12452_20200204131133.IDFW

Notes

Location:	Pur Village
Client:	Dist. Collector,Bhilwara,Rajasthan Govt.
User Name:	CSIR-CIMFR, Bilaspur Research Centre
General:	

Extended Notes

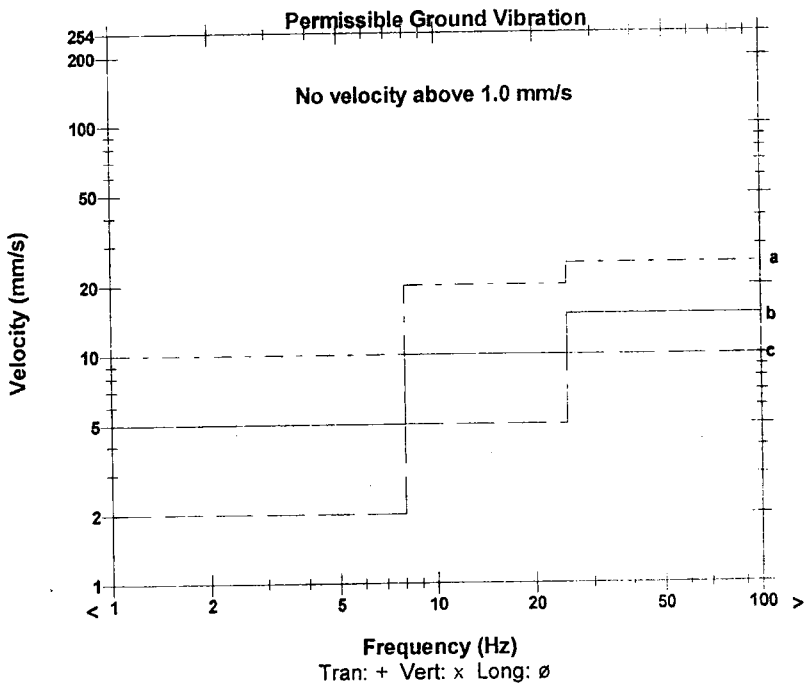
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

Microphone	Linear Weighting
PSPL	9.185 pa.(L) at 0.009 sec
ZC Freq	9.9 Hz
Channel Test	Passed (Freq = 19.7 Hz Amp = 1197 mv)

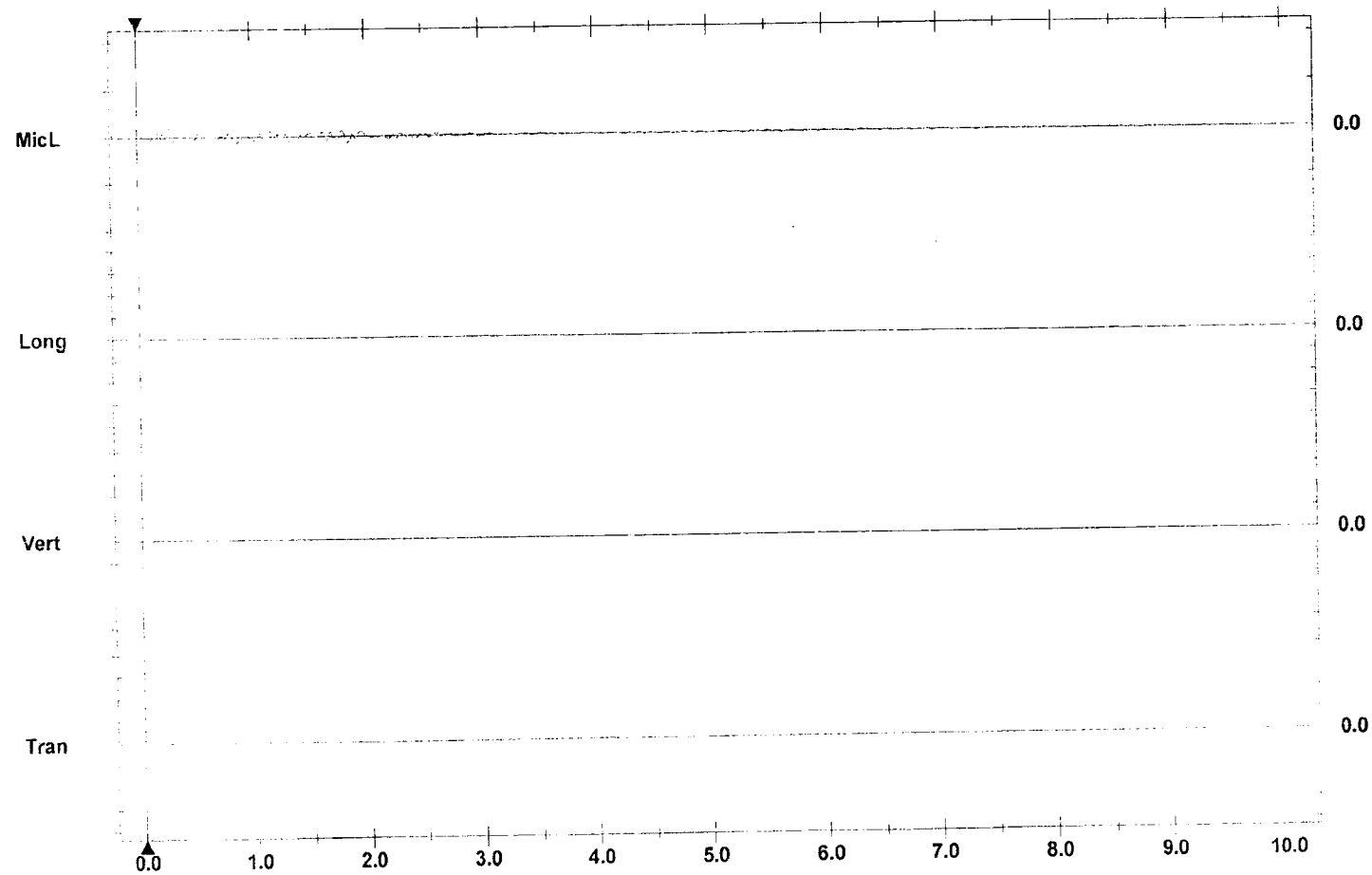
	Tran	Vert	Long	
PPV	0.047	0.087	0.055	mm/s
ZC Freq	186	2.6	50	Hz
Time (Rel. to Trig)	0.777	3.329	0.104	sec
Peak Acceleration	0.016	0.020	0.020	g
Peak Displacement	0.000	0.019	0.000	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 0.090 mm/s at 3.329 sec

DGMS India (A)



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.50 sec/div **Amplitude Scale:** Geo: 2.000 mm/s/div Mic: 5.000 pa.(L)/div
Trigger = ▶---- ---◀

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Instantel Event Report

Date/Time	MicL at 13:11:33 February 4, 2020
Trigger Source	Geo: 0.250 mm/s, Mic: 6.325 pa.(L)
Range	Geo: 254.0 mm/s
Record Time	10.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR BLSPR.mmb

Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200204131133.IDFW

Notes
Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

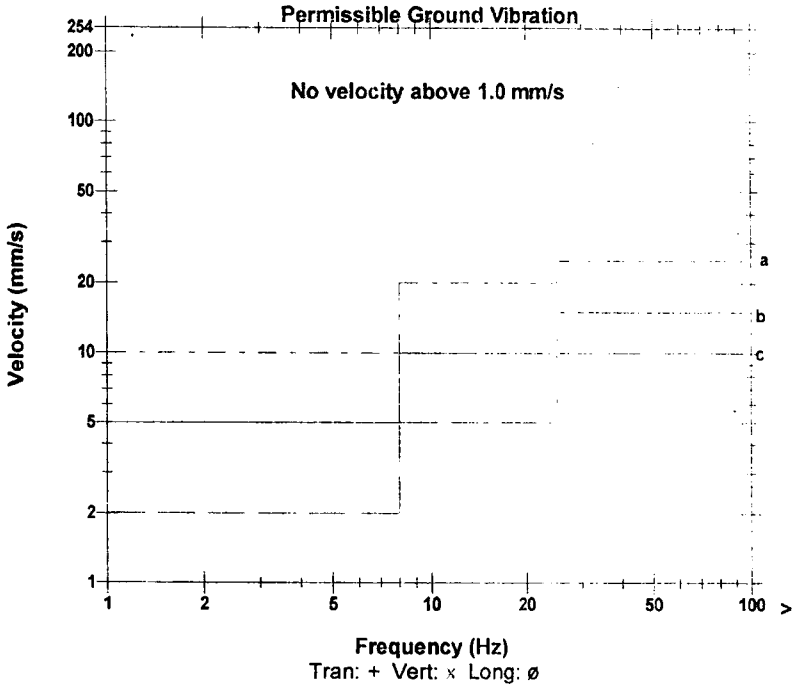
Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

Microphone	Linear Weighting
PSPL	8.689 pa.(L) at 0.045 sec
ZC Freq	8.8 Hz
Channel Test	Passed (Freq = 19.7 Hz Amp = 1280 mv)

	Tran	Vert	Long	
PPV	0.047	0.063	0.047	mm/s
ZC Freq	128	26.6	57	Hz
Time (Rel. to Trig)	1.528	0.019	-0.205	sec
Peak Acceleration	0.020	0.020	0.020	g
Peak Displacement	0.000	0.000	0.000	mm
Sensor Check	Passed	Passed	Passed	

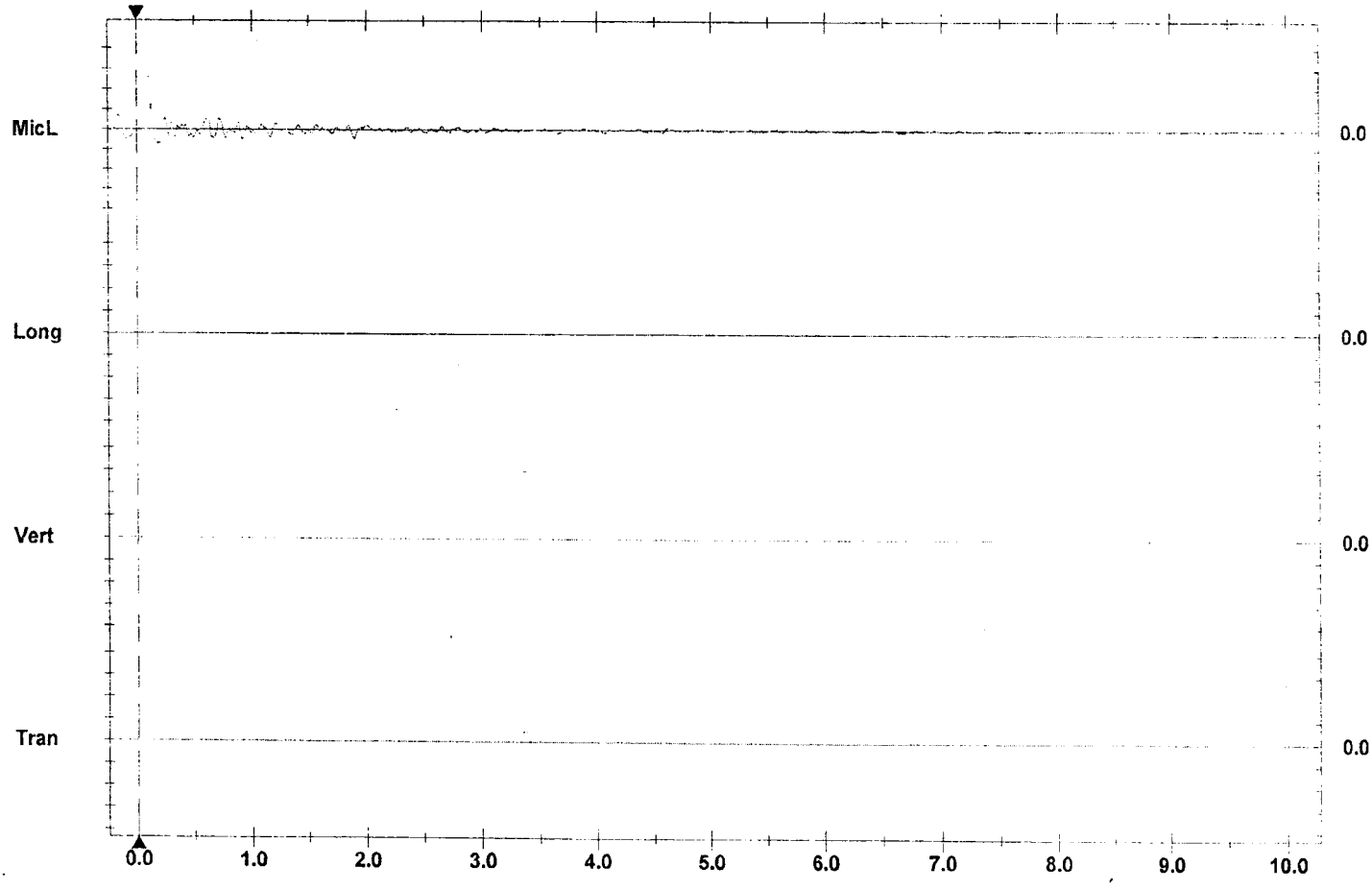
Peak Vector Sum 0.065 mm/s at 0.019 sec

DGMS India (A)



Tran: + Vert: x Long: ø

a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.50 sec/div **Amplitude Scale:** Geo: 2.000 mm/s/div Mic: 2.000 pa.(L)/div
Trigger = ▶— —◀

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Event Report

Date/Time	Long at 13:14:16 February 5, 2020
Trigger Source	Geo: 0.250 mm/s, Mic: 6.325 pa.(L)
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR BLSPR.mmb

Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200205131416.IDFW

Notes

location:	Pur Village
Client:	Dist. Collector,Bhilwara,Rajasthan Govt.
User Name:	CSIR-CIMFR,Bilaspur Research Centre
General:	

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

Microphone	Linear Weighting
PSPL	2.296 pa.(L) at 4.041 sec
ZC Freq	11.4 Hz
Channel Test	Passed (Freq = 19.7 Hz Amp = 1252 mv)

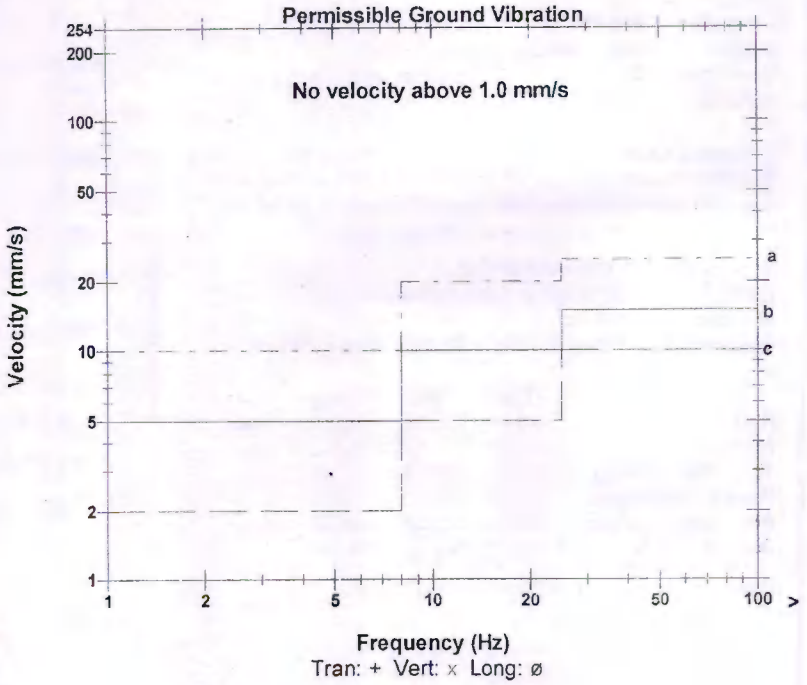
	Tran	Vert	Long	
PPV	0.363	0.189	0.292	mm/s
ZC Freq	14.8	32.0	17.8	Hz
Time (Rel. to Trig)	0.209	0.263	0.525	sec
Peak Acceleration	0.020	0.020	0.020	g
Peak Displacement	0.004	0.001	0.002	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 0.364 mm/s at 0.525 sec

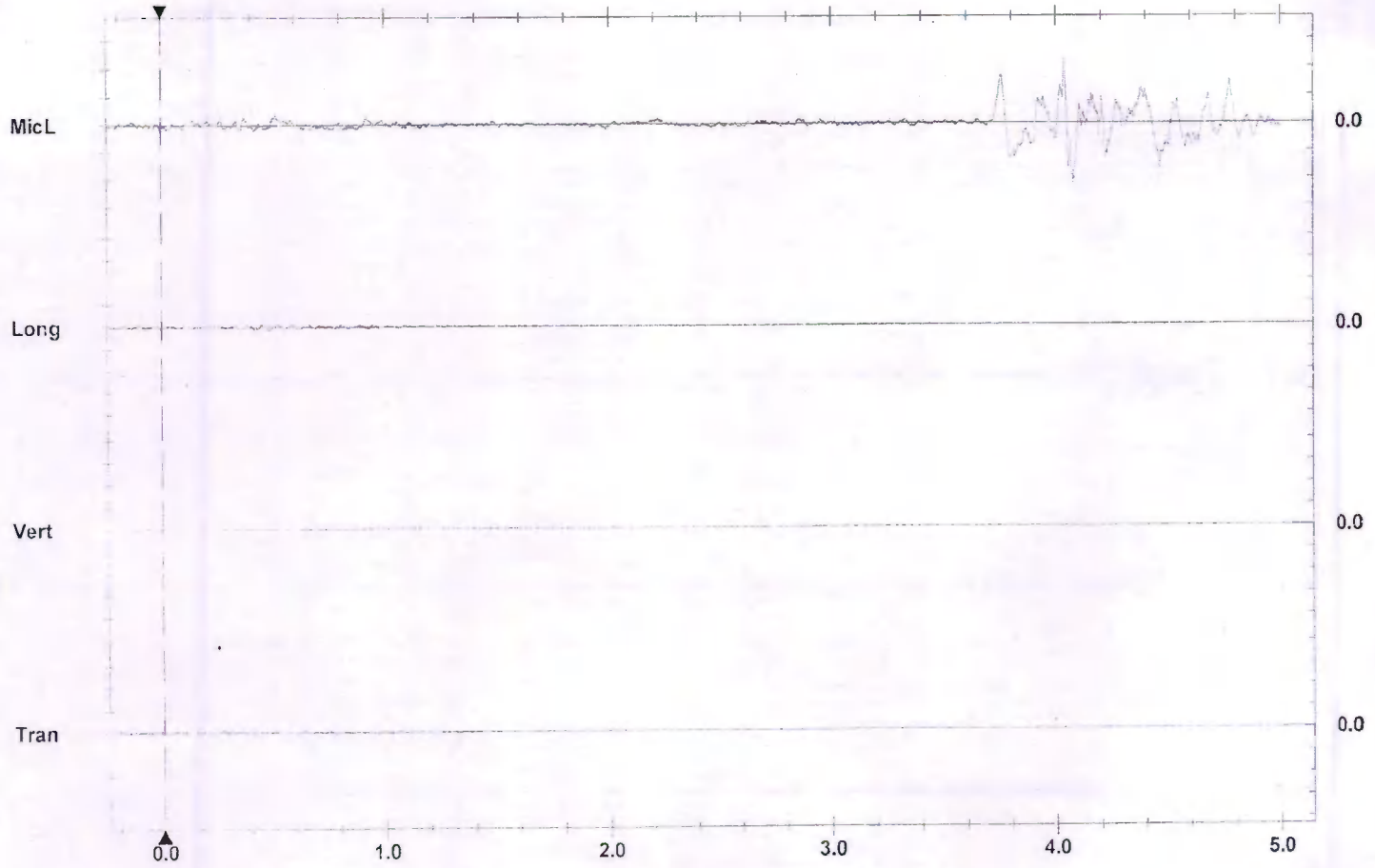
DGMS India (A)

Permissible Ground Vibration

No velocity above 1.0 mm/s



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 2.000 mm/s/div Mic: 1.000 pa.(L)/div
Trigger = ▶---- ---◀

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Instantel Event Report

Date/Time	Long at 13:15:06 February 5, 2020
Trigger Source	Geo: 0.510 mm/s, Mic: 6.325 pa.(L)
Range	Geo: 31.75 mm/s
Record Time	10.0 sec at 4096 sps

Serial Number	BE16508 V 10.72-1.1 Minimate Blaster
Battery Level	6.1 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	R508IBE2.560

Notes
Location: Pur Village
Client: Dist. Collector, Rajasthan Govt.
User Name: CSIR-CIMFR, Bilaspur Research Centre
General:

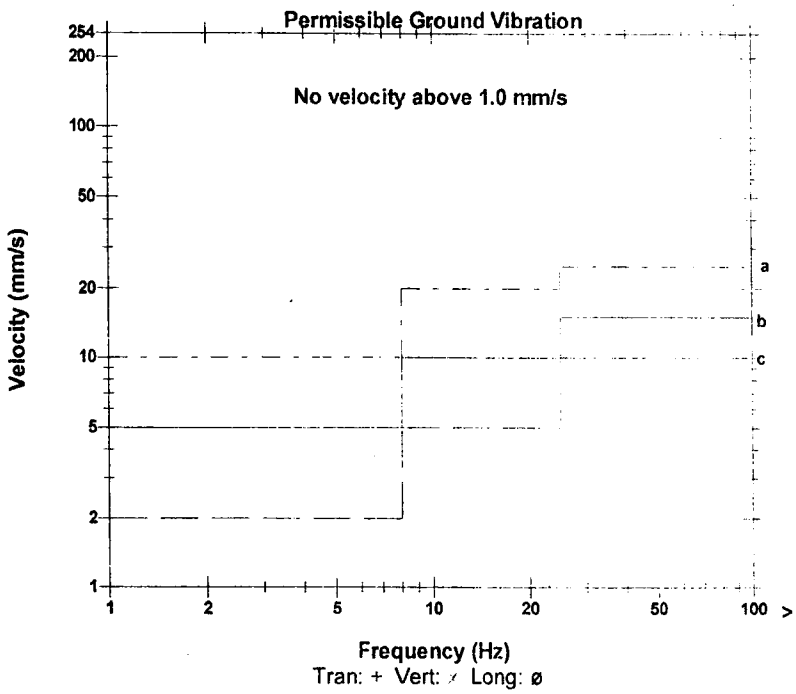
Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

Microphone	Linear Weighting
PSPL	5.000 pa.(L) at 0.725 sec
ZC Freq	6.5 Hz
Channel Test	Passed (Freq = 20.1 Hz Amp = 468 mv)

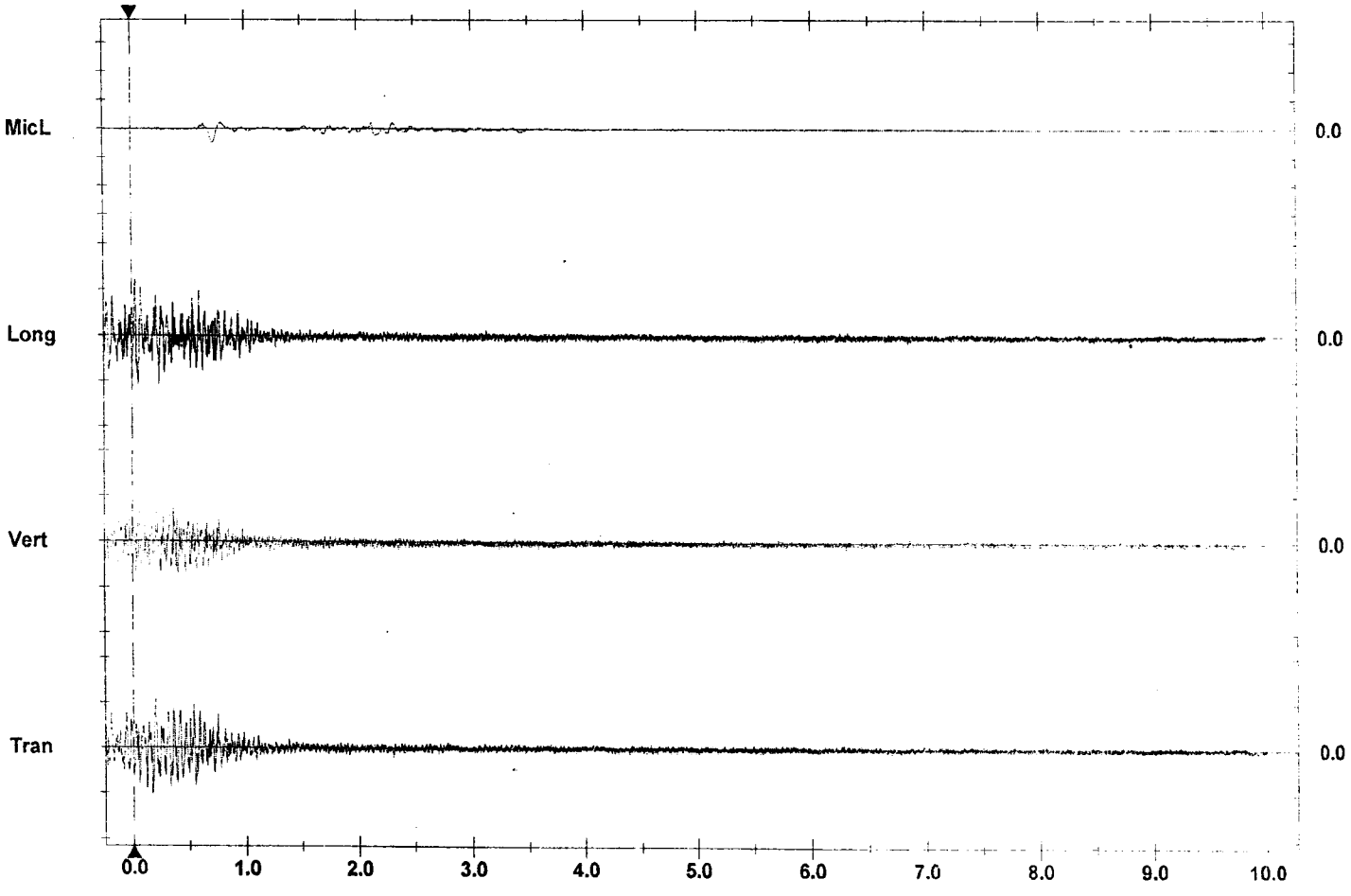
	Tran	Vert	Long	
PPV	0.540	0.381	0.619	mm/s
ZC Freq	18.1	68	22.8	Hz
Time (Rel. to Trig)	0.197	-0.121	0.032	sec
Peak Acceleration	0.033	0.040	0.033	g
Peak Displacement	0.004	0.003	0.005	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 0.696 mm/s at 0.026 sec

DGMS India (A)



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.50 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 10.000 pa.(L)/div
Trigger = ▶— — ◀

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Instantel

Event Report

Date/Time	Tran at 13:15:14 February 5, 2020
Trigger Source	Geo: 0.510 mm/s
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps

Serial Number	BE13781 V 10.72-8.17 MiniMate Plus
Battery Level	6.2 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	O781IBE2.5E0

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR, Bilaspur Research Centre
General:

Extended Notes

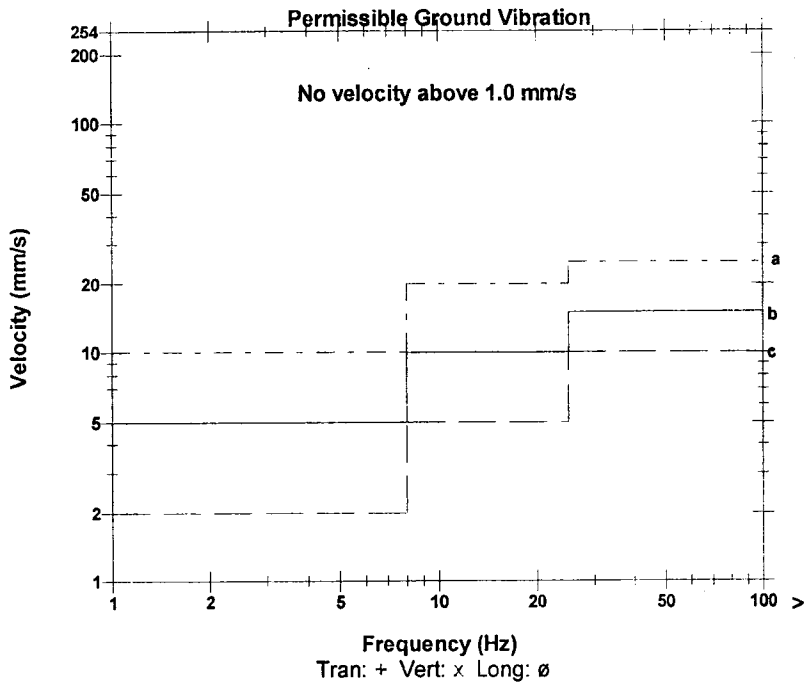
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

Microphone	Linear Weighting
PSPL	7.250 pa.(L) at 0.685 sec
ZC Freq	6.5 Hz
Channel Test	Passed (Freq = 20.1 Hz Amp = 524 mv)

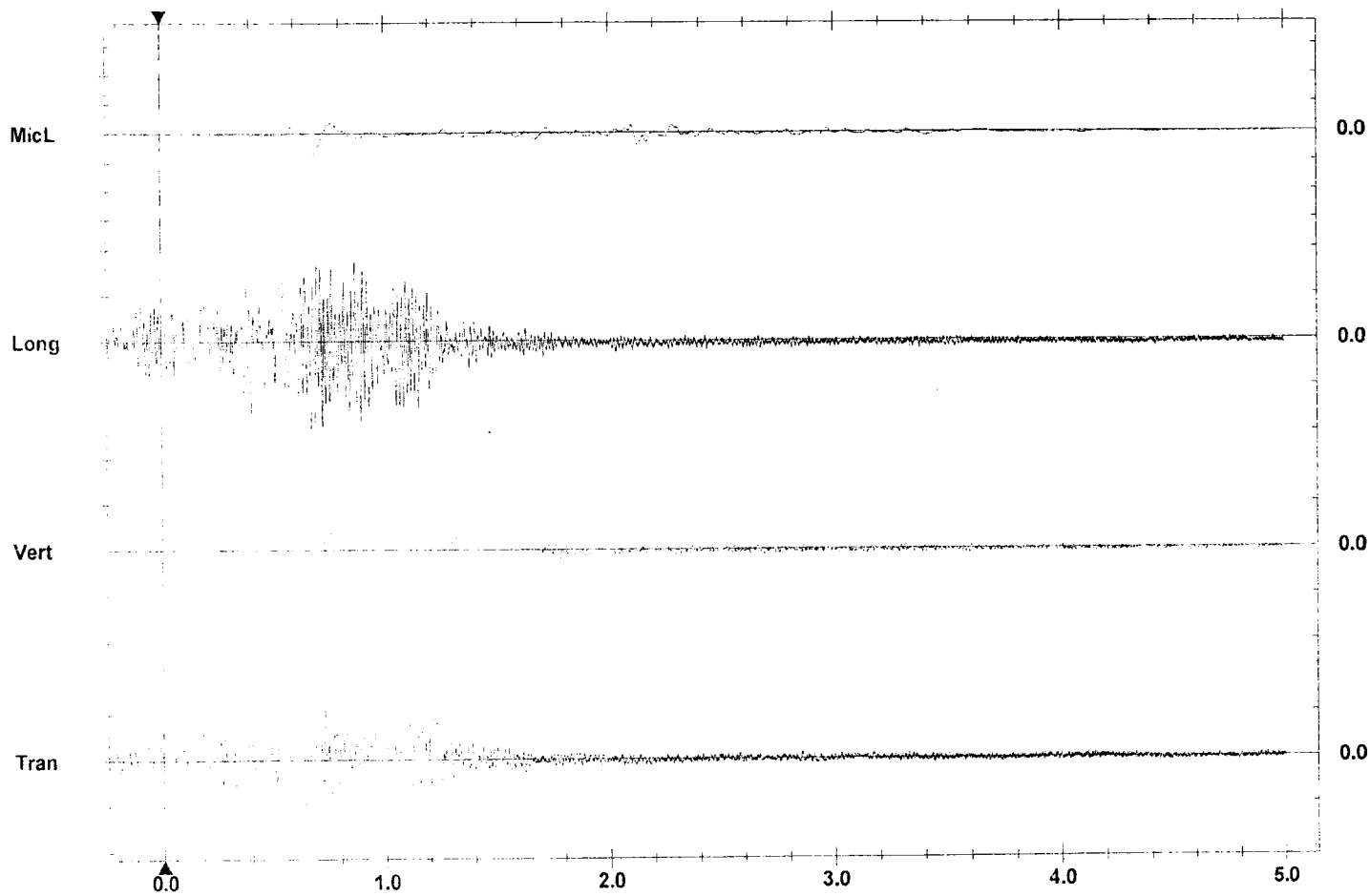
	Tran	Vert	Long	
PPV	0.635	0.683	0.968	mm/s
ZC Freq	39.4	55	57	Hz
Time (Rel. to Trig)	0.670	0.810	0.674	sec
Peak Acceleration	0.033	0.046	0.053	g
Peak Displacement	0.004	0.002	0.003	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 1.088 mm/s at 0.895 sec

DGMS India (A)



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 10.000 pa.(L)/div
Trigger = ▶---◀

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Instantel

Event Report

Date/Time	Long at 13:15:21 February 5, 2020
Trigger Source	Geo: 0.250 mm/s, Mic: 6.325 pa.(L)
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR BLSPR.mmb

Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200205131521.IDFW

Notes
Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

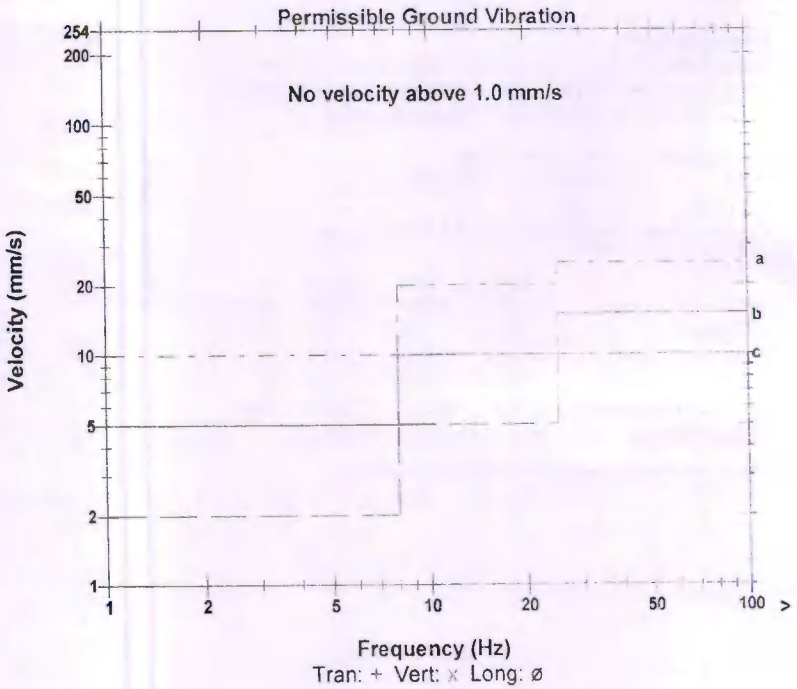
Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

Microphone	Linear Weighting
PSPL	2.669 pa.(L) at 3.500 sec
ZC Freq	6.0 Hz
Channel Test	Passed (Freq = 19.7 Hz Amp = 1252 mv)

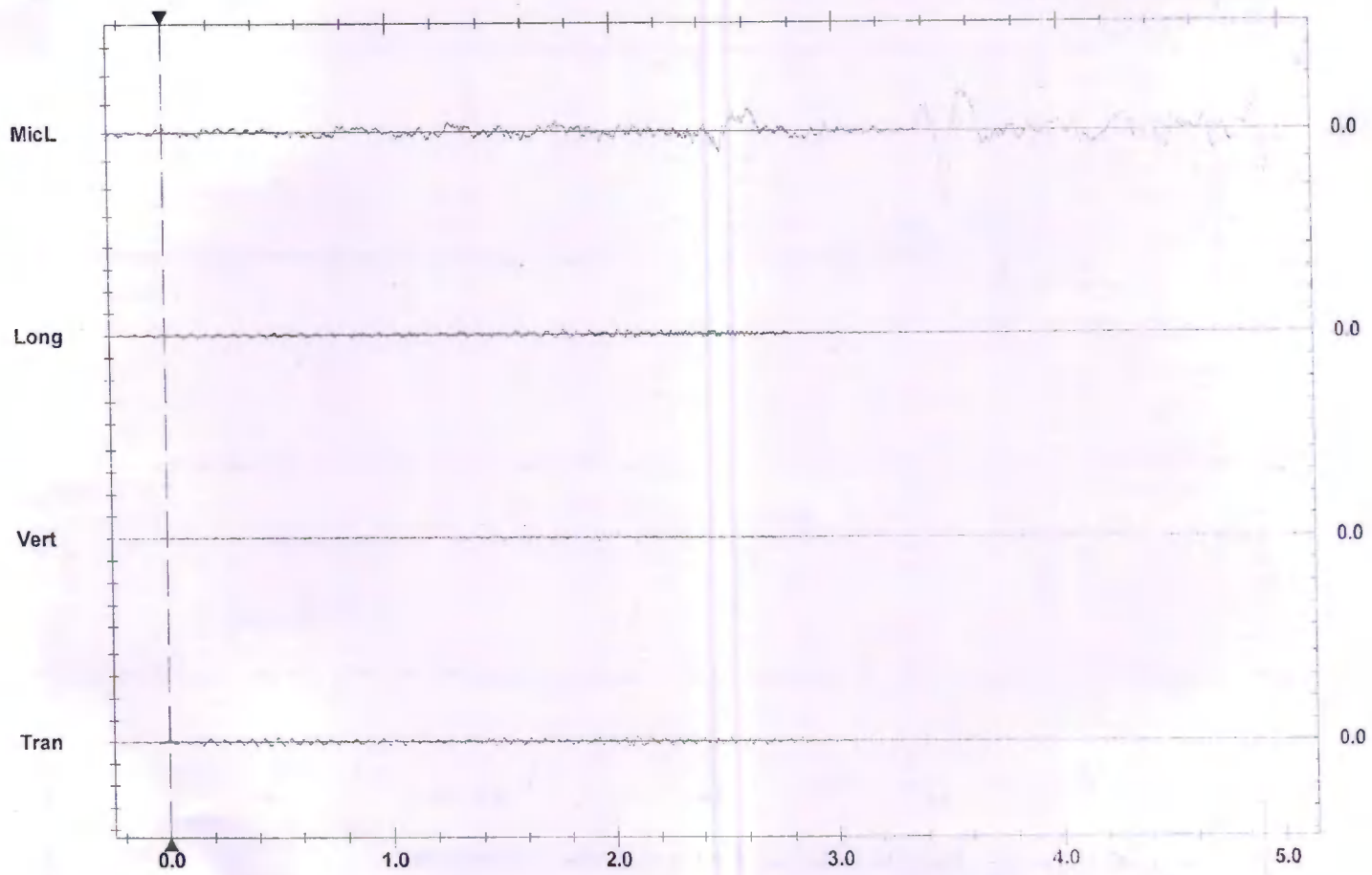
	Tran	Vert	Long	
PPV	0.497	0.323	0.536	mm/s
ZC Freq	16.1	33.0	14.7	Hz
Time (Rel. to Trig)	2.053	1.951	1.777	sec
Peak Acceleration	0.023	0.020	0.026	g
Peak Displacement	0.005	0.002	0.004	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 0.599 mm/s at 2.053 sec

DGMS India (A)



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 2.000 mm/s/div Mic: 1.000 pa.(L)/div
Trigger = ▶—— —— ◀

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Event Report

Date/Time	Tran at 13:12:02 February 6, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR BLSPR.mmb

Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200206131202.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

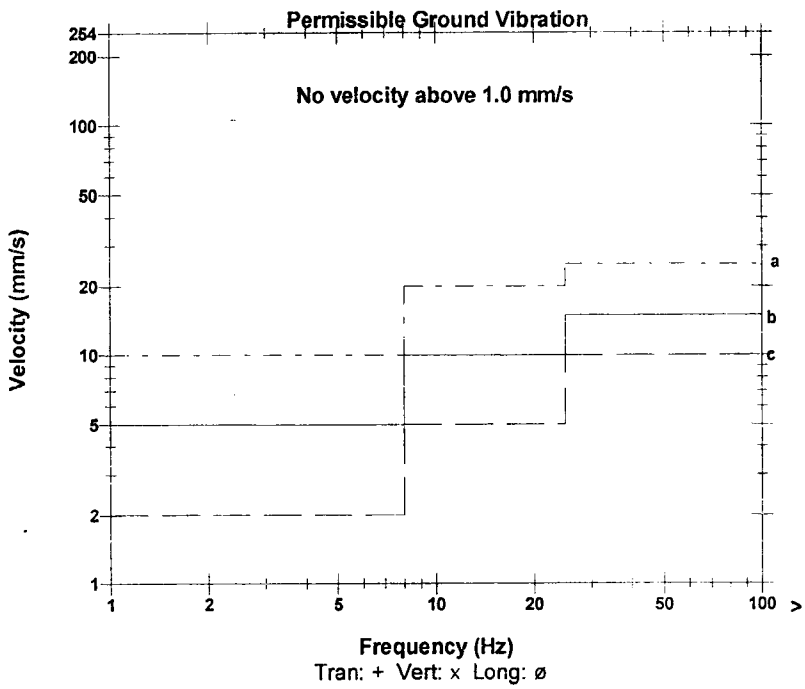
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

Microphone	Linear Weighting
PSPL	0.838 pa.(L) at 4.033 sec
ZC Freq	6.8 Hz
Channel Test	Passed (Freq = 19.7 Hz Amp = 1320 mv)

	Tran	Vert	Long	
PPV	0.410	0.331	0.347	mm/s
ZC Freq	44	35.3	21.8	Hz
Time (Rel. to Trig)	0.876	0.589	0.488	sec
Peak Acceleration	0.020	0.020	0.020	g
Peak Displacement	0.002	0.001	0.002	mm
Sensor Check	Passed	Passed	Passed	

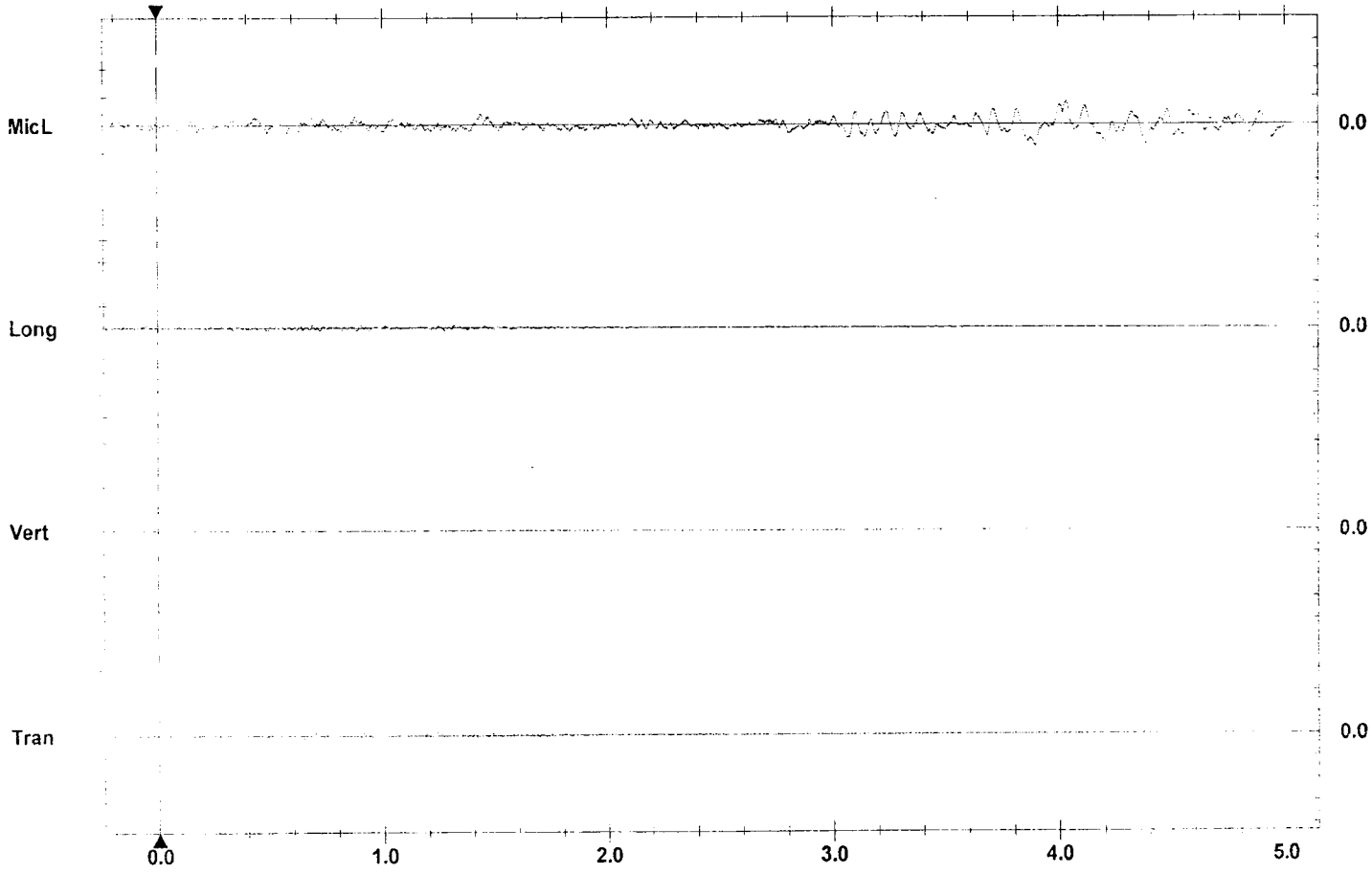
Peak Vector Sum 0.418 mm/s at 0.876 sec

DGMS India (A)



Tran: + Vert: x Long: ø

a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 2.000 mm/s/div Mic: 1.000 pa.(L)/div
Trigger = ▶ ◀

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Instantel Event Report

Date/Time	Tran at 13:14:30 February 6, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR BLSPR.mmb

Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200206131430.IDFW

Notes
Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

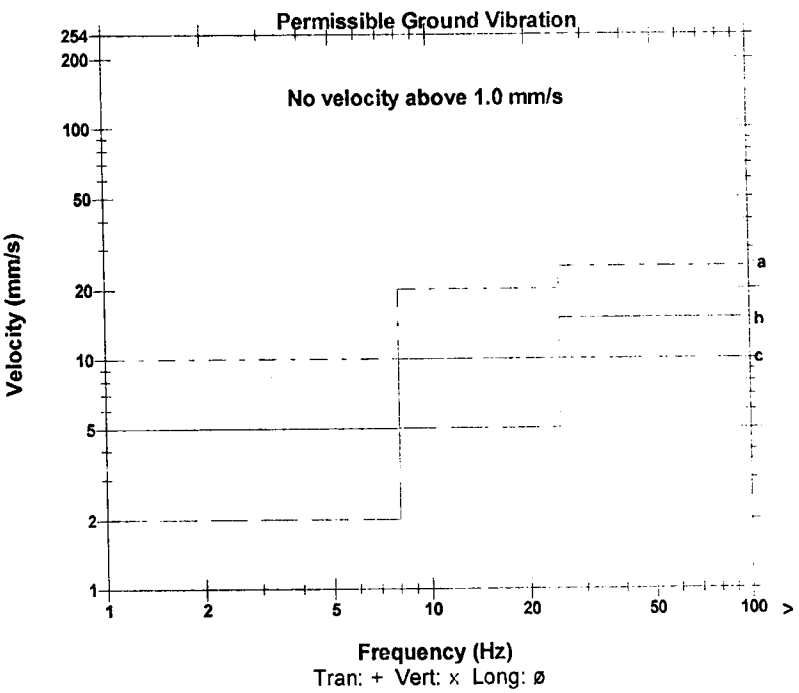
Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

Microphone	Linear Weighting
PSPL	2.048 pa.(L) at 1.063 sec
ZC Freq	4.3 Hz
Channel Test	Passed (Freq = 19.7 Hz Amp = 1320 mv)

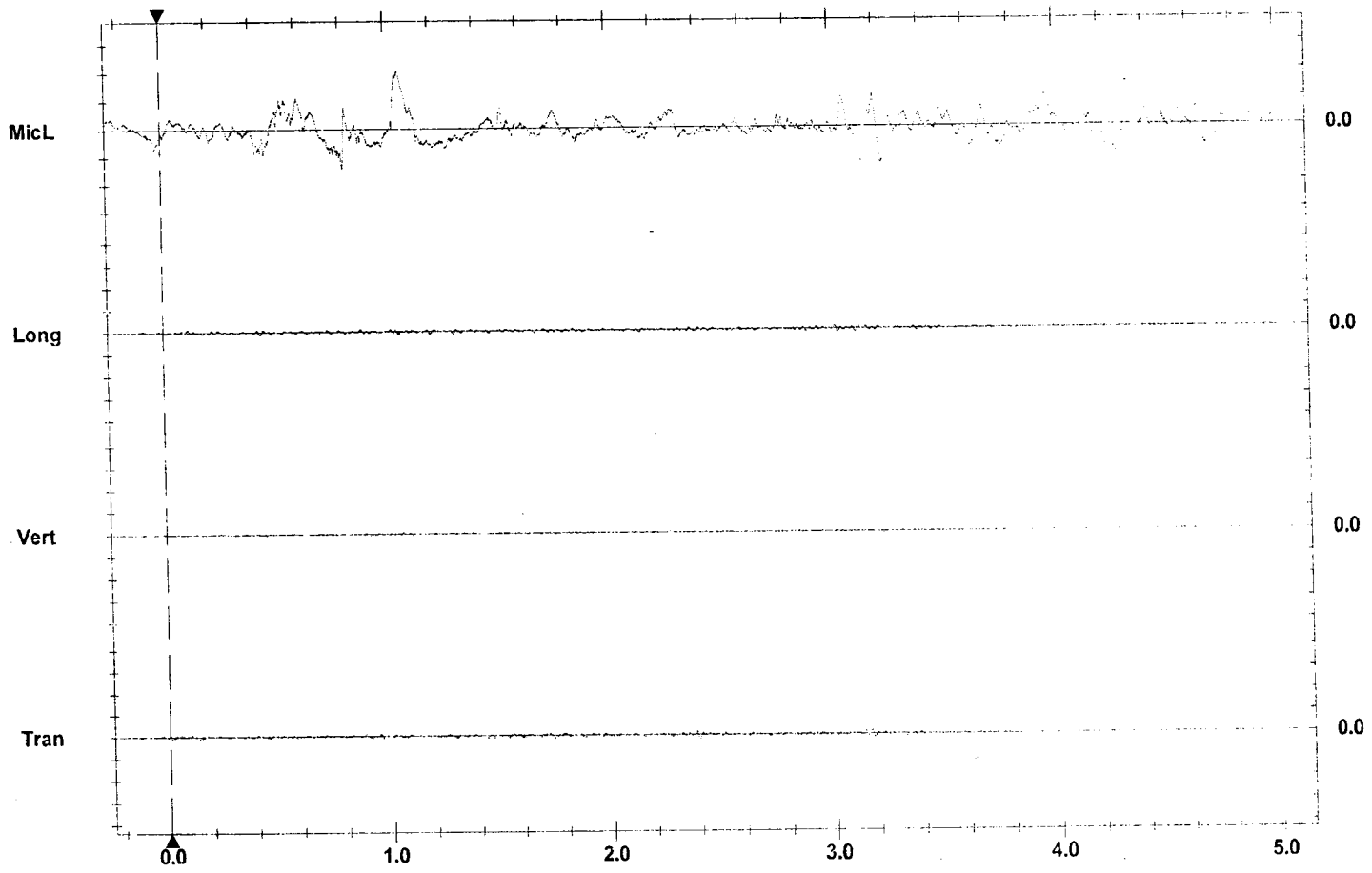
	Tran	Vert	Long	
PPV	0.394	0.236	0.315	mm/s
ZC Freq	35.9	33.6	32.0	Hz
Time (Rel. to Trig)	2.389	3.053	3.107	sec
Peak Acceleration	0.023	0.020	0.020	g
Peak Displacement	0.003	0.001	0.002	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 0.414 mm/s at 2.389 sec

DGMS India (A)



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 2.000 mm/s/div Mic: 1.000 pa.(L)/div
Trigger = ▶—— —— ◀

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Event Report

Date/Time	Long at 13:29:20 March 3, 2020
Trigger Source	Geo: 0.520 mm/s
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps
Job Number:	

Serial Number	BE18062 V 10.72-11 Minimate Blaster
Battery Level	6.2 Volts
Unit Calibration	March 29, 2019 by UES, New Delhi
File Name	T062#CS2.T20

Notes

Location	Pur Village
Client	District collector Bhilwara, Rajasthan
User Name	CIMFR
General:	

Extended Notes

Event: For Investigation of Damage Potential Due to Blast Induced Ground Vibation & Airover Pressure in Domestic Houses inPur Village, Bhilwara, Rajasthan

Microphone	Linear Weighting
PSPL	0.506 pa (L) at 0.250 sec
ZC Freq	N/A
Channel Test	Check (Freq = 0.0 Hz Amp = 0 mv)

	Tran	Vert	Long	
PPV	0.698	0.349	0.571	mm/s
ZC Freq	17.5	35.3	16.9	Hz
Time (Rel. to Trig)	0.029	1.781	0.977	sec
Peak Acceleration	0.027	0.027	0.033	g
Peak Displacement	0.207	0.004	0.005	mm
Sensor Check	Passed	Passed	Passed	

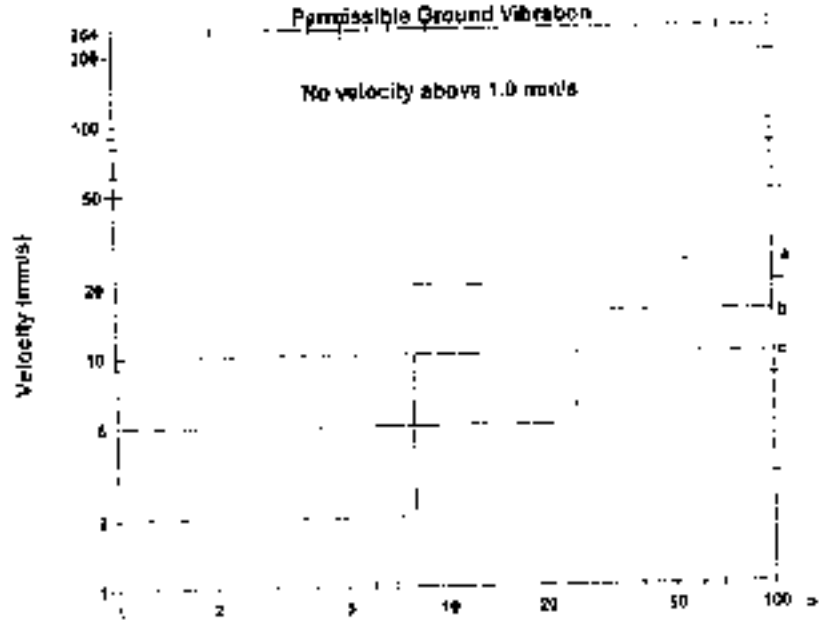
Peak Vector Sum 0.819 mm/s at 0.976 sec

N.A: Not Applicable

DGMS India (A)

Permissible Ground Vibration

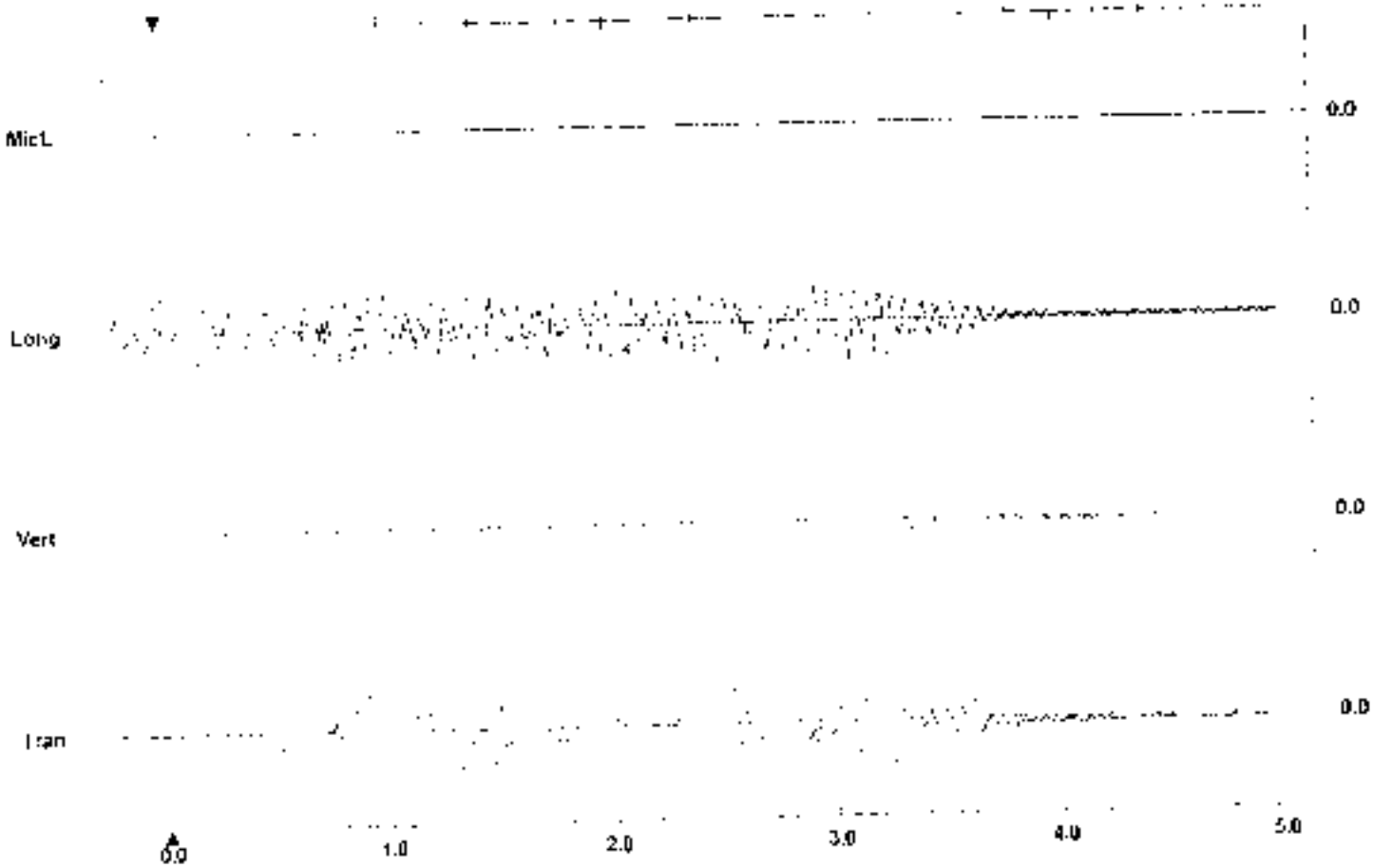
No velocity above 1.0 mm/s



Frequency (Hz)

Tran: + Vert: x Long: 0

a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div Amplitude Scale: Geo: 0.500 mm/s/div Mic: 10.000 pa.(L)/div

Trigger = ▶ —◀

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Instantel Event Report

Date/Time	Long at 13:29:26 March 3, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

Serial Number	UM12452 V 10-89 Micromate ISEE
Battery Level	3.7 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12452_20200303132926.IDFW

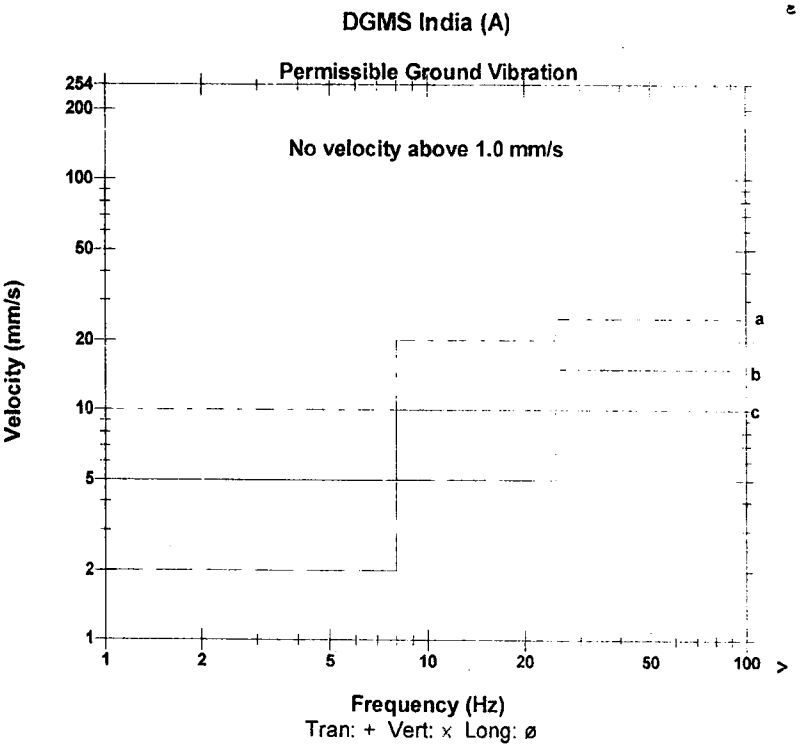
Notes
Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village,-Bhilwara, Rajasthan, India.

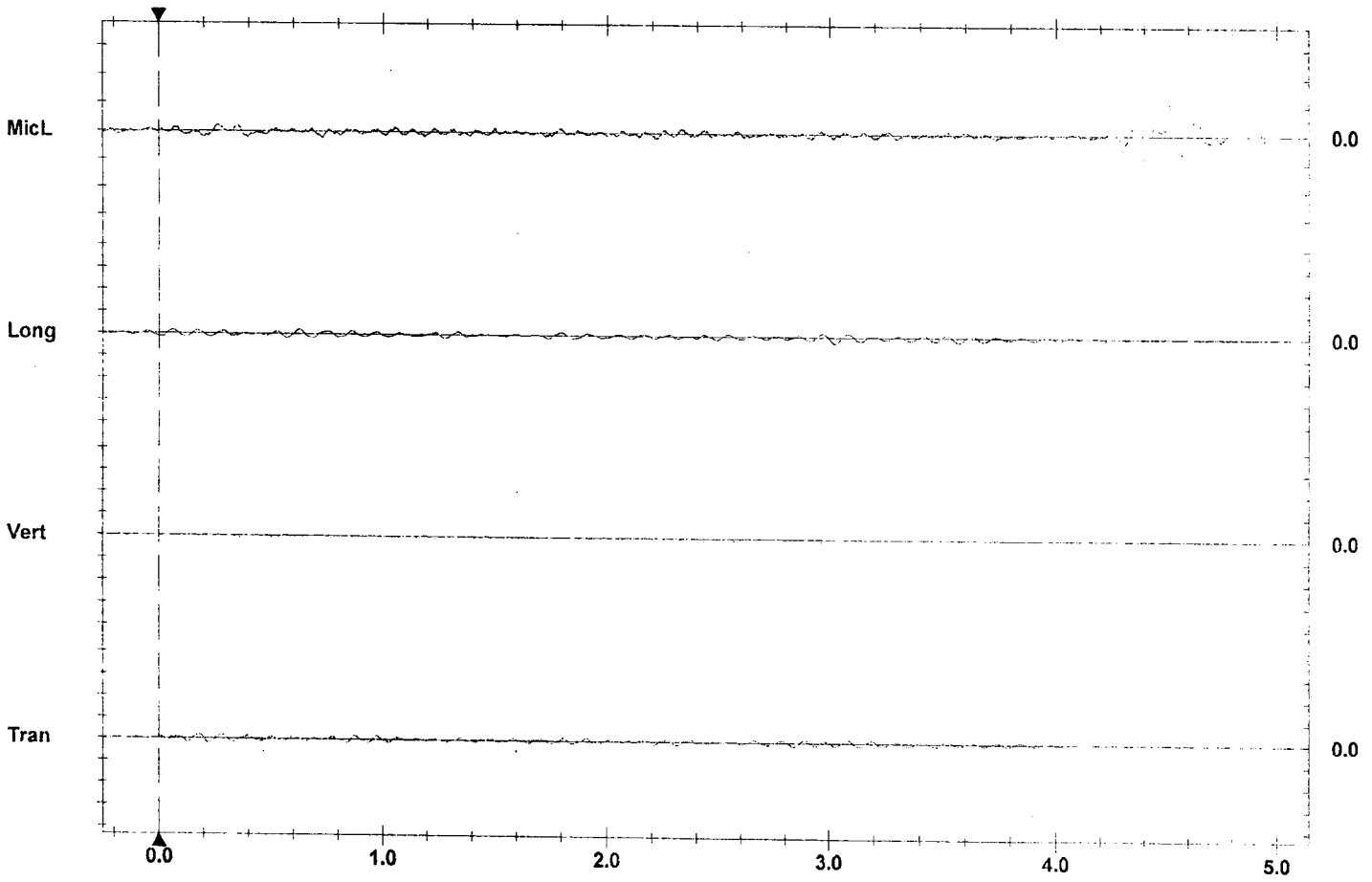
Microphone	Linear Weighting
PSPL	1.536 pa.(L) at 4.862 sec
ZC Freq	6.8 Hz
Channel Test	Passed (Freq = 19.7 Hz Amp = 1185 mv)

	Tran	Vert	Long	
PPV	0.418	0.284	0.544	mm/s
ZC Freq	10.6	8.7	8.4	Hz
Time (Rel. to Trig)	0.222	2.573	3.023	sec
Peak Acceleration	0.020	0.016	0.016	g
Peak Displacement	0.006	0.006	0.010	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 0.612 mm/s at 3.025 sec



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 2.000 mm/s/div Mic: 1.000 pa.(L)/div
Trigger = ▶—— —— ◀

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Event Report

Date/Time	Long at 13:18:28 March 4, 2020
Trigger Source	Geo: 0.500 mm/s, Mic: 6.325 pa.(L)
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

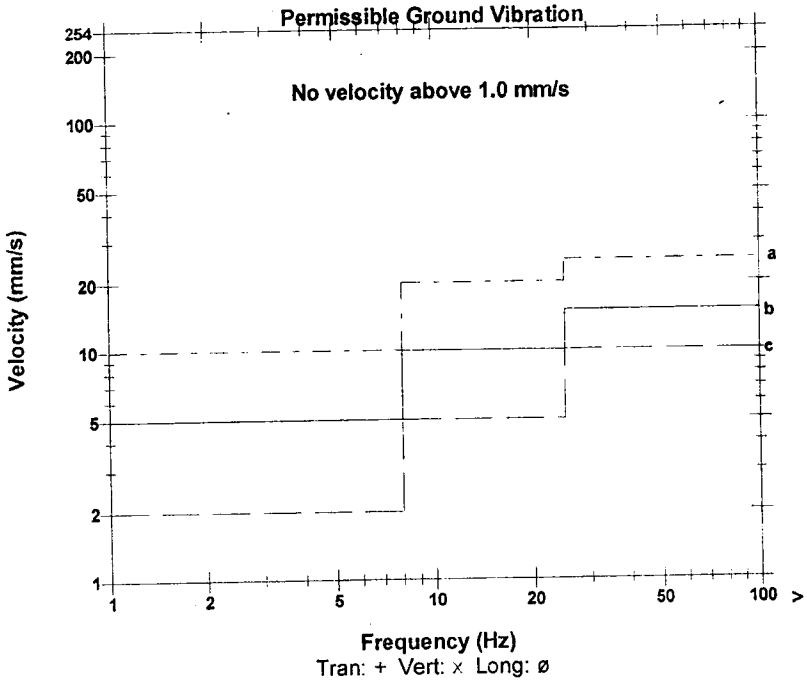
Microphone	Linear Weighting
PSPL	5.250 pa.(L) at 1.506 sec
ZC Freq	5.9 Hz
Channel Test	Passed (Freq = 20.1 Hz Amp = 441 mv)

	Tran	Vert	Long	
PPV	0.587	0.270	0.540	mm/s
ZC Freq	26.6	21.8	20.7	Hz
Time (Rel. to Trig)	0.378	-0.054	0.304	sec
Peak Acceleration	0.027	0.027	0.027	g
Peak Displacement	0.004	0.002	0.004	mm
Sensor Check	Passed	Passed	Passed	

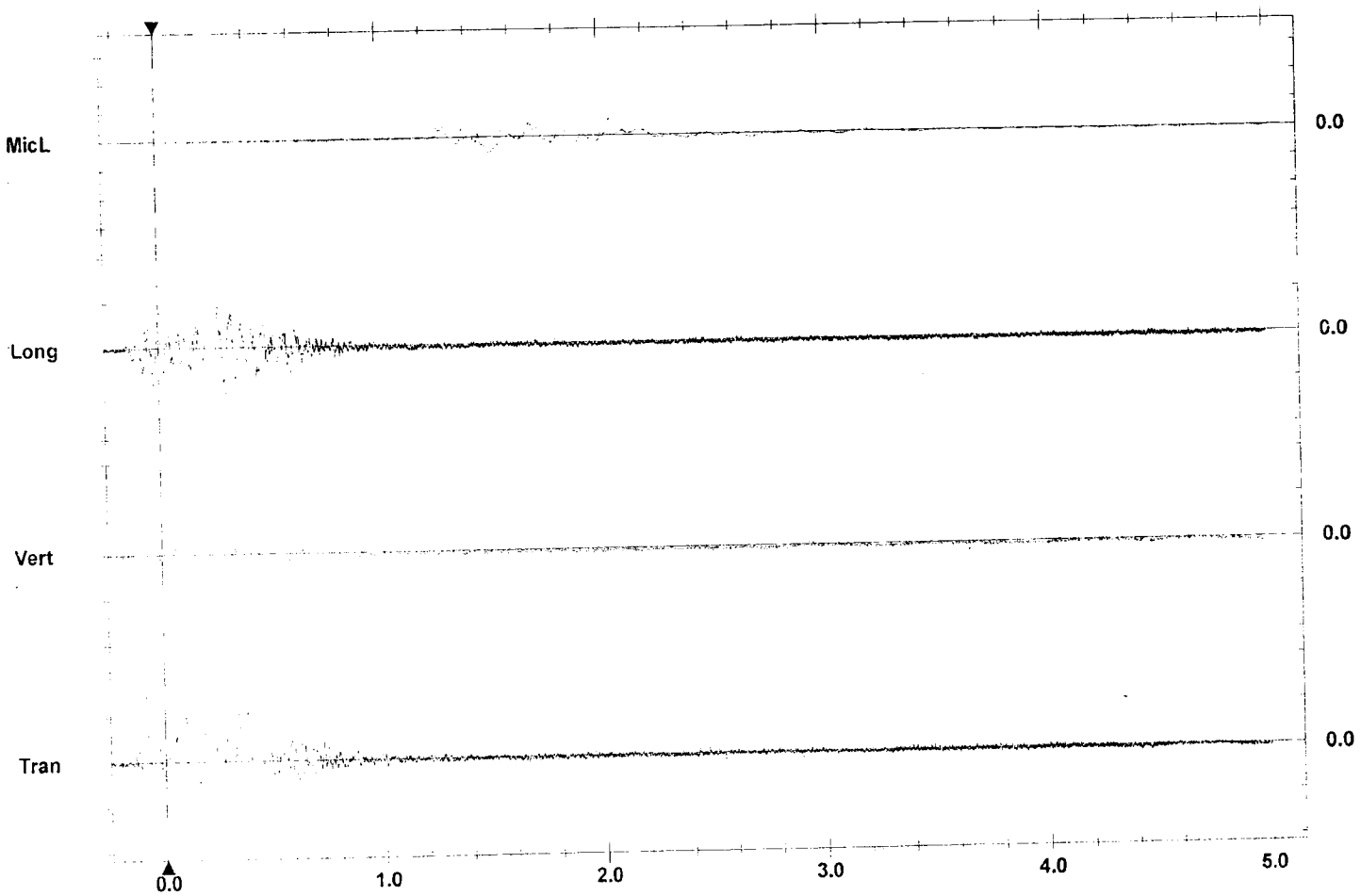
Peak Vector Sum 0.663 mm/s at 0.378 sec

Serial Number	BE16508 V 10.72-1.1 Minimate Blaster
Battery Level	6.2 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	R508ICTW.YS0

DGMS India (A)



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 10.000 pa.(L)/div
Trigger = ▶ ◀

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Instantel Event Report

Date/Time	Long at 13:18:45 March 4, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200304131845.IDFW

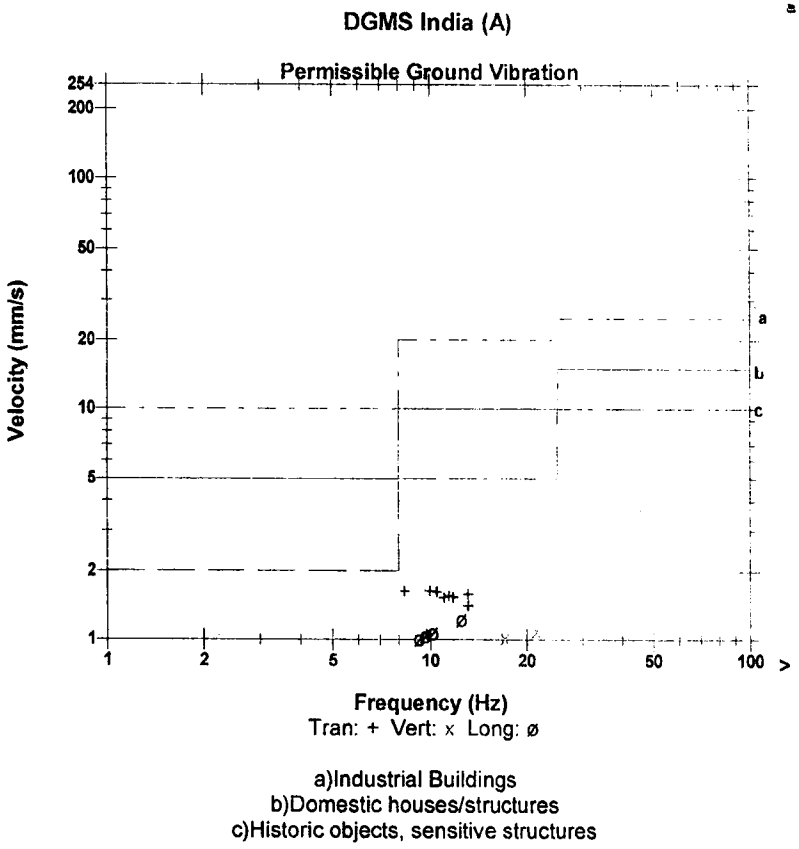
Notes
Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

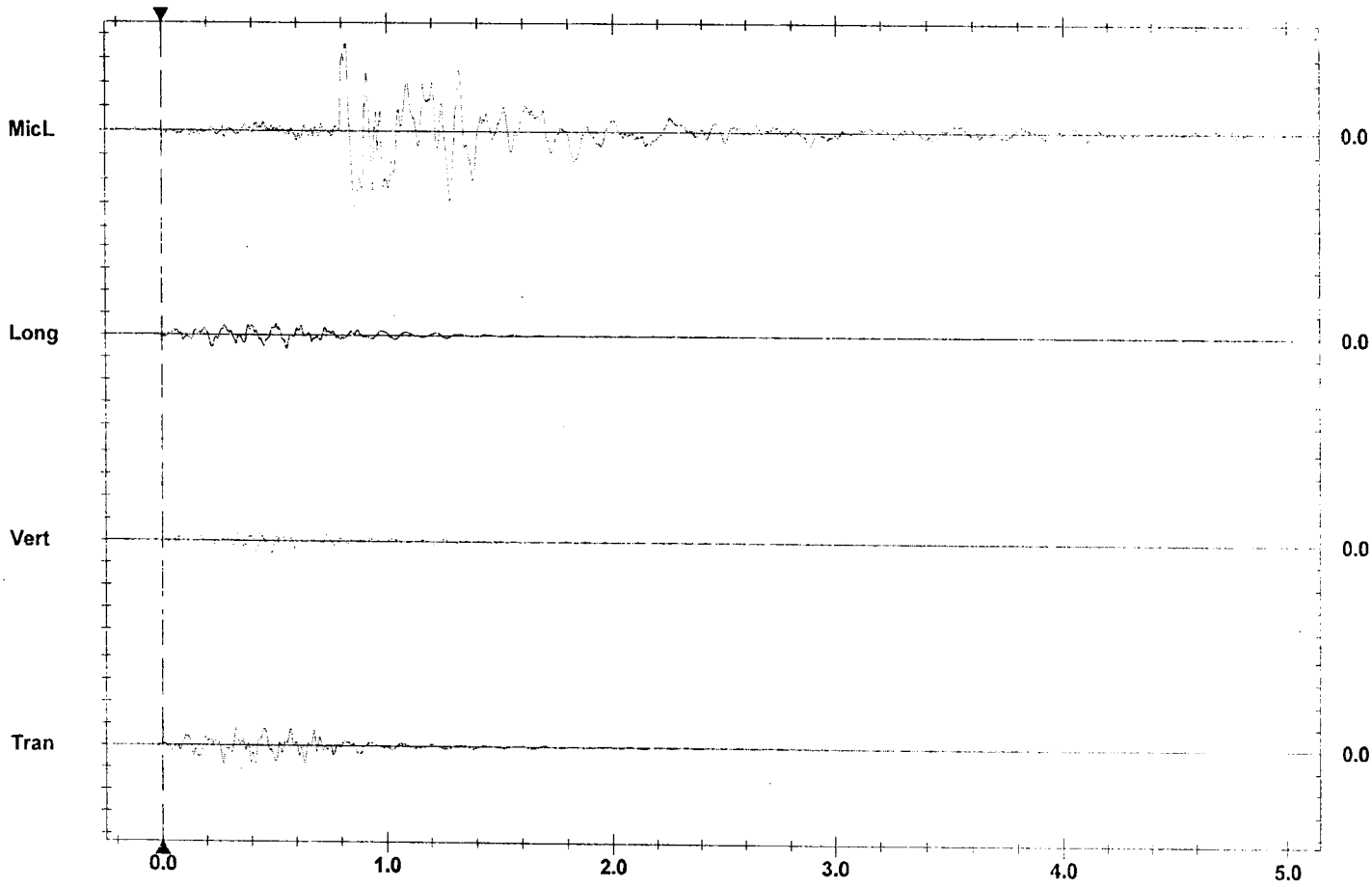
Microphone	Linear Weighting
PSPL	7.308 pa.(L) at 0.822 sec
ZC Freq	6.8 Hz
Channel Test	Passed (Freq = 19.7 Hz Amp = 1197 mv)

	Tran	Vert	Long	
PPV	1.639	1.096	1.230	mm/s
ZC Freq	9.9	21.3	12.5	Hz
Time (Rel. to Trig)	0.327	0.489	0.556	sec
Peak Acceleration	0.046	0.039	0.033	g
Peak Displacement	0.022	0.009	0.016	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 1.878 mm/s at 0.453 sec



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 2.000 mm/s/div Mic: 2.000 pa.(L)/div
Trigger = ▶—— —— ◀

Printed: December 31, 2020 (V 10.74)

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Instantel

Event Report

Date/Time	Vert at 13:18:46 March 4, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

Serial Number	UM12452 V 10-89 Micromate ISEE
Battery Level	3.7 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12452_20200304131846.IDFW

Notes

Location:	Pur Village
Client:	Dist. Collector,Bhilwara,Rajasthan Govt.
User Name:	CSIR-CIMFR,Bilaspur Research Centre
General:	

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

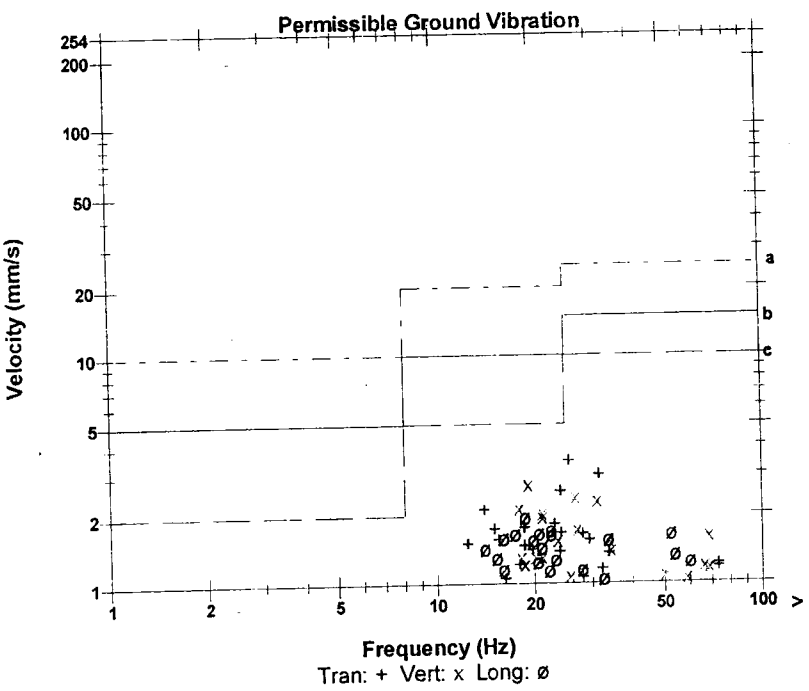
Microphone	Linear Weighting
PSPL	<0.500 pa.(L)
ZC Freq	N/A
Channel Test	Check (Freq = 0.0 Hz Amp = 0 mv)

	Tran	Vert	Long	
PPV	3.460	2.719	1.955	mm/s
ZC Freq	25.6	19.1	18.8	Hz
Time (Rel. to Trig)	0.313	0.502	0.383	sec
Peak Acceleration	0.118	0.112	0.079	g
Peak Displacement	0.018	0.017	0.015	mm
Sensor Check	Passed	Passed	Passed	

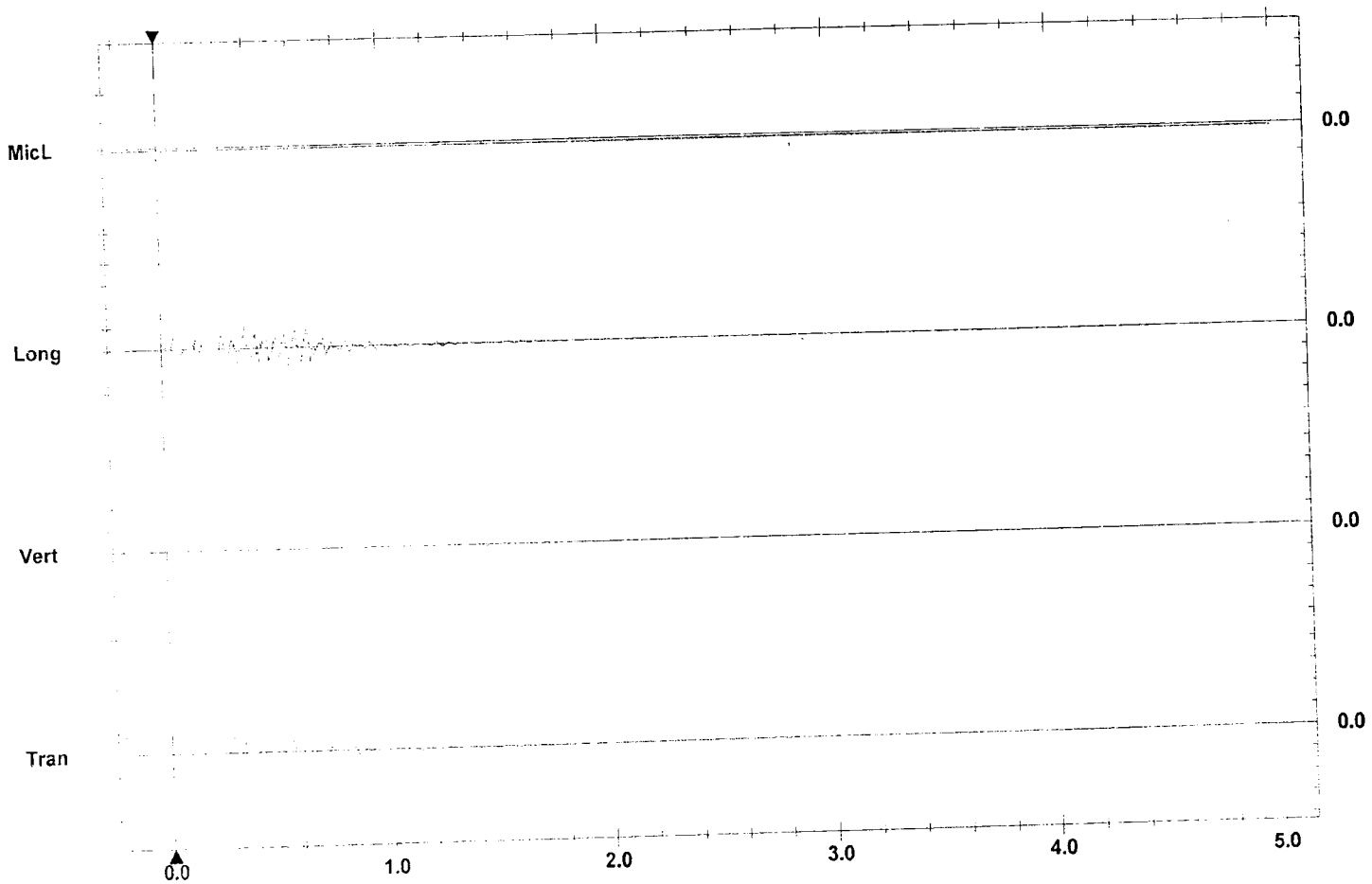
Peak Vector Sum 3.961 mm/s at 0.313 sec

N/A: Not Applicable

DGMS India (A)



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 2.000 mm/s/div Mic: 1.000 pa.(L)/div

Trigger = ▶ ◀

Printed: December 31, 2020 (V 10.74)

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(62)

Instantel Event Report

Date/Time	Tran at 13:20:44 March 4, 2020
Trigger Source	Geo: 0.500 mm/s, Mic: 6.325 pa.(L)
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps

Serial Number	BE16508 V 10.72-1.1 Minimate Blaster
Battery Level	6.2 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	R508ICTX.2K0

Notes
Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

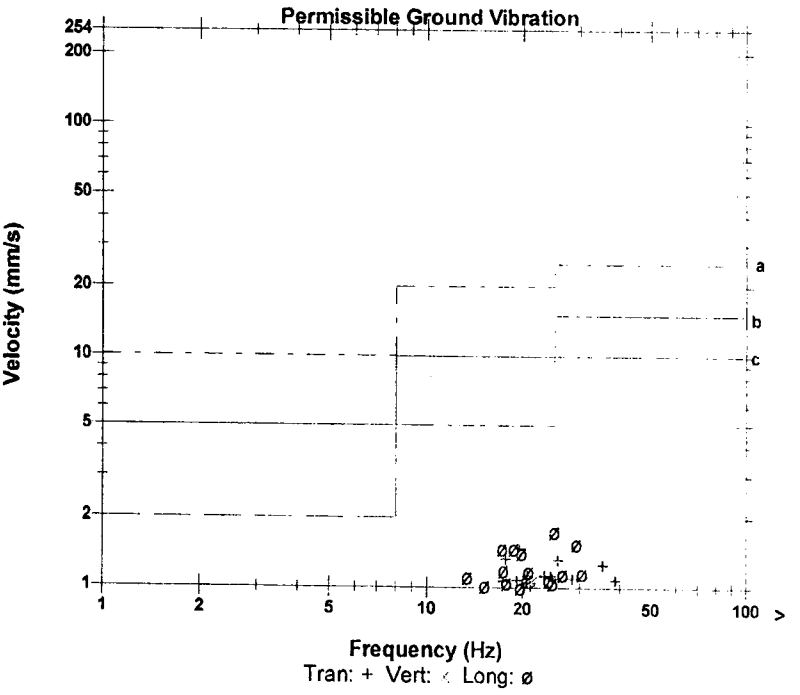
Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

Microphone	Linear Weighting
PSPL	7.500 pa.(L) at 1.309 sec
ZC Freq	9.4 Hz
Channel Test	Passed (Freq = 20.1 Hz Amp = 441 mv)

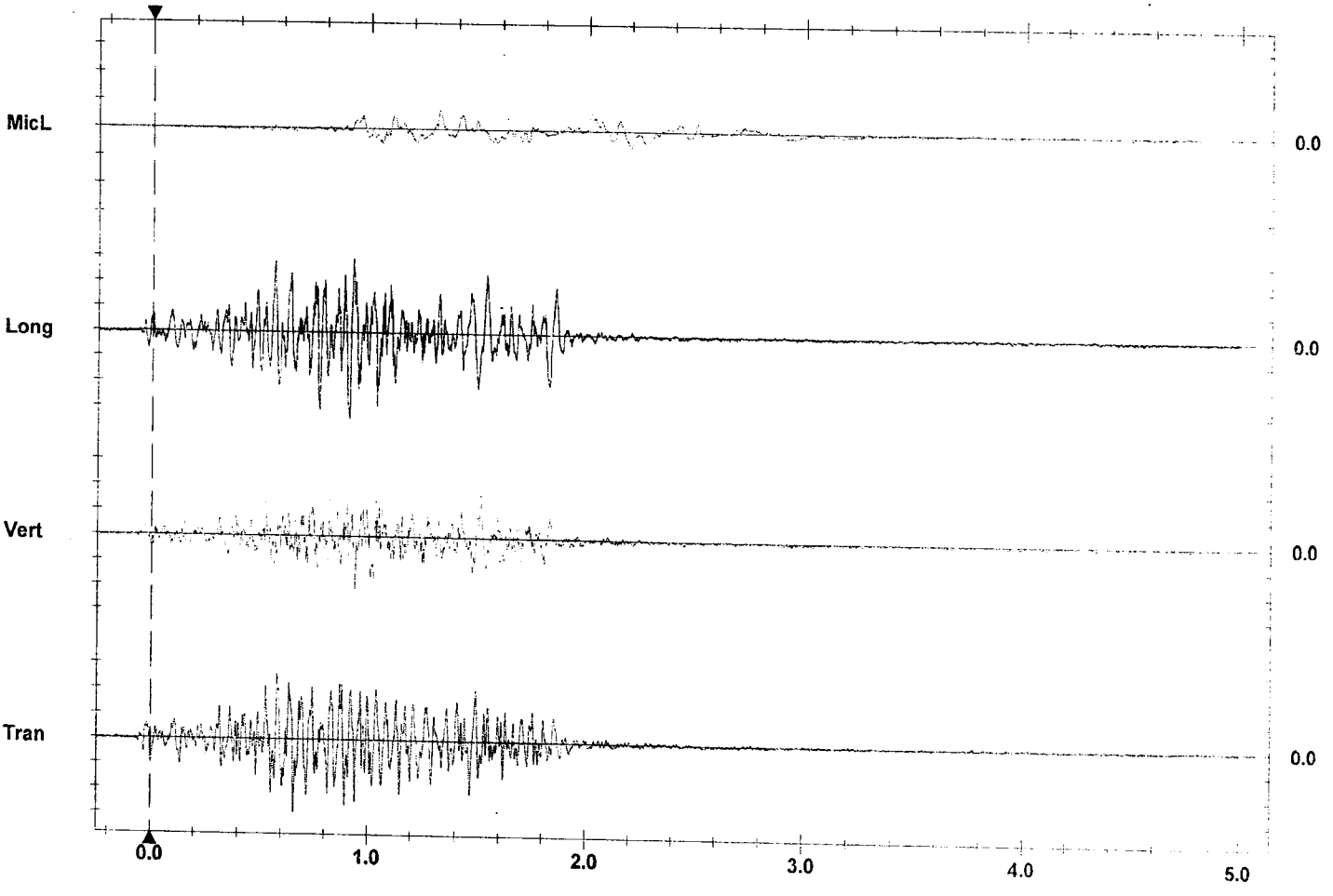
	Tran	Vert	Long	
PPV	1.476	1.079	1.746	mm/s
ZC Freq	19.5	21.3	25.0	Hz
Time (Rel. to Trig)	0.658	0.938	0.908	sec
Peak Acceleration	0.053	0.046	0.060	g
Peak Displacement	0.009	0.007	0.011	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 1.855 mm/s at 0.908 sec

DGMS India (A)



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 10.000 pa.(L)/div
Trigger = ▶—— ——◀

Printed: December 31, 2020 (V 10.74)

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Instantel Event Report

Date/Time	Vert at 13:21:02 March 4, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200304132102.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

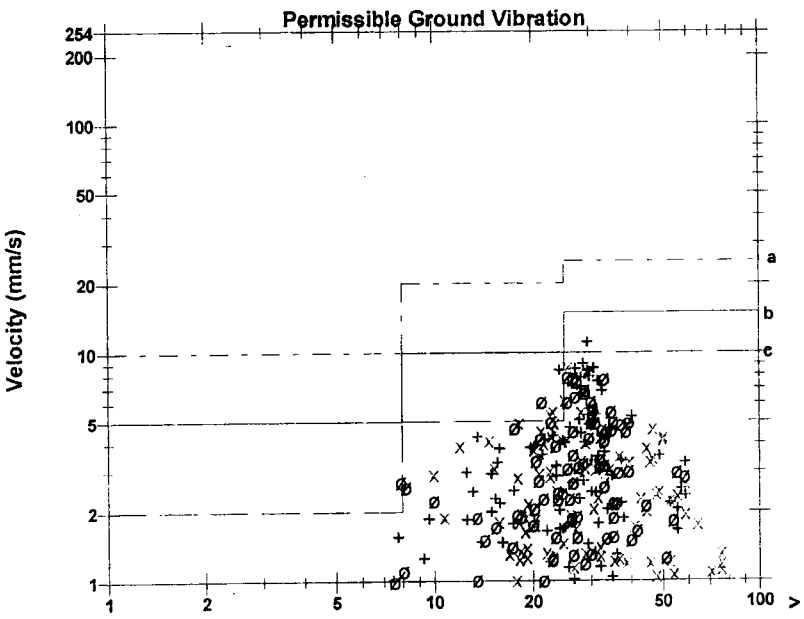
Microphone	Linear Weighting
PSPL	24.00 pa.(L) at 0.678 sec
ZC Freq	5.8 Hz
Channel Test	Passed (Freq = 19.7 Hz Amp = 1197 mv)

	Tran	Vert	Long	
PPV	11.14	8.686	7.850	mm/s
ZC Freq	29.3	25.6	25.6	Hz
Time (Rel. to Trig)	1.017	0.811	0.580	sec
Peak Acceleration	0.434	0.260	0.306	g
Peak Displacement	0.057	0.046	0.049	mm
Sensor Check	Passed	Passed	Passed	

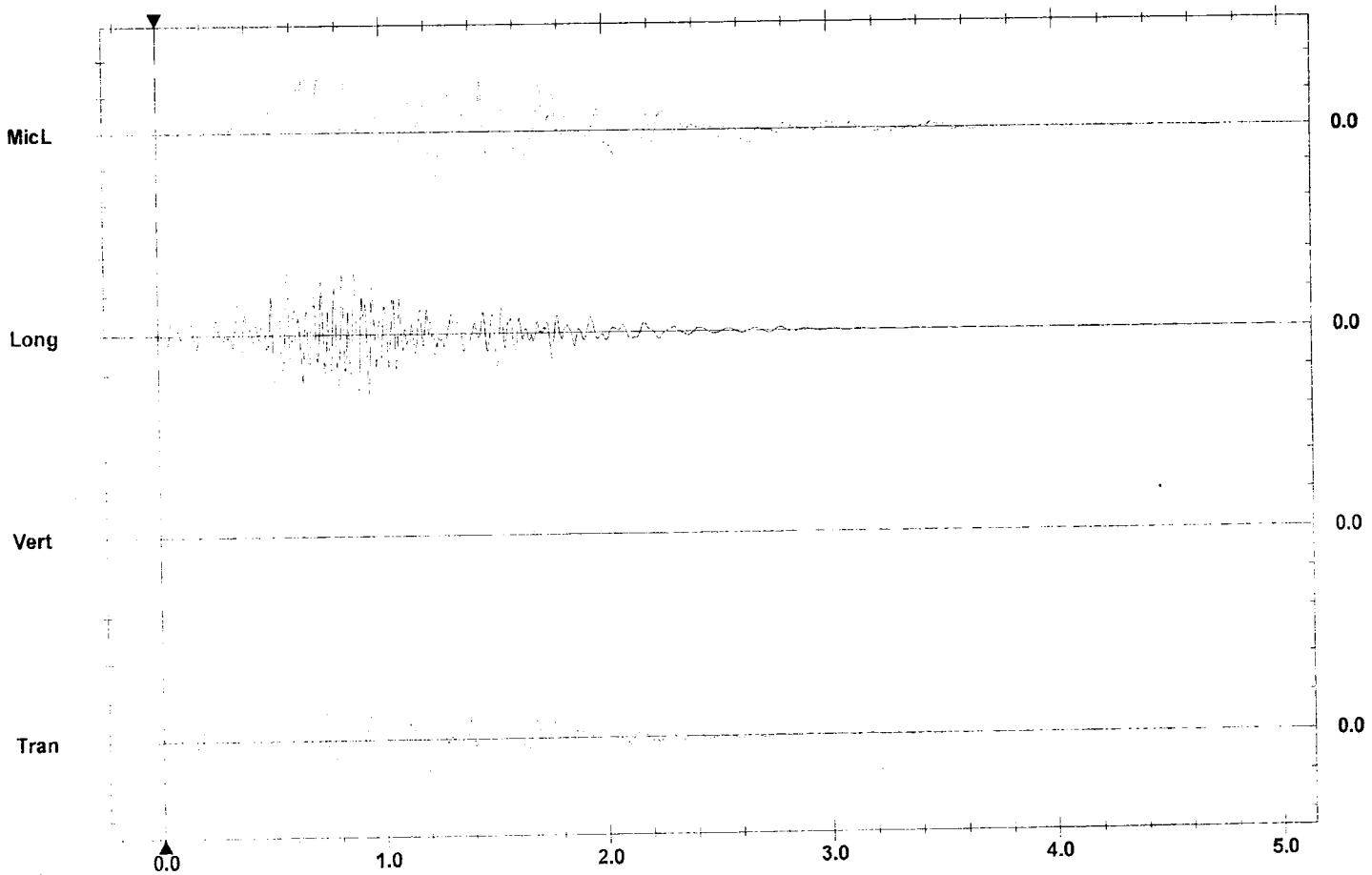
Peak Vector Sum 12.82 mm/s at 0.947 sec

DGMS India (A)

Permissible Ground Vibration



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 5.000 mm/s/div Mic: 10.000 pa.(L)/div
Trigger = ▶---------◀

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Instantel

Event Report

Date/Time	Vert at 13:21:03 March 4, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

Serial Number	UM12452 V 10-89 Micromate ISEE
Battery Level	3.7 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12452_20200304132103.IDFW

Notes
Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

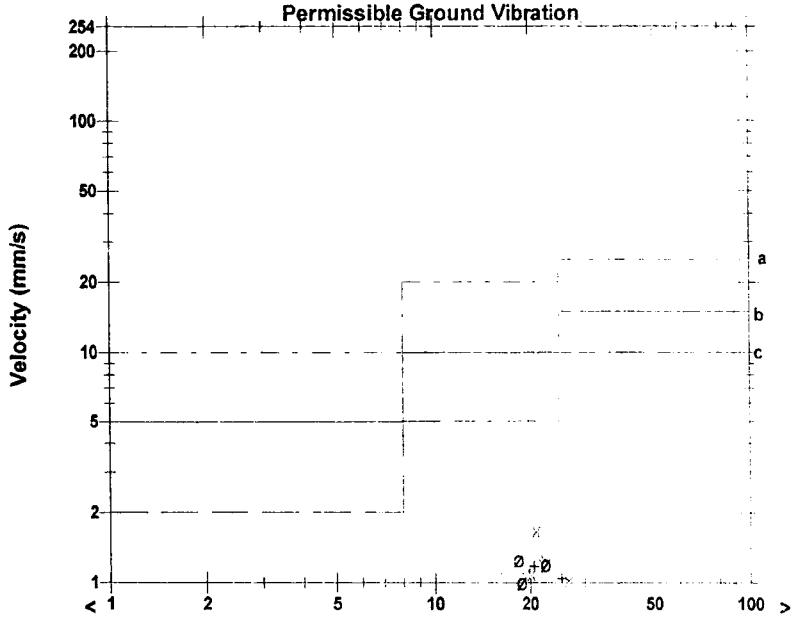
Microphone	Linear Weighting
PSPL	<0.500 pa.(L)
ZC Freq	N/A
Channel Test	Check (Freq = 0.0 Hz Amp = 0 mv)

	Tran	Vert	Long	
PPV	1.174	1.671	1.253	mm/s
ZC Freq	20.5	20.9	18.3	Hz
Time (Rel. to Trig)	0.560	0.495	0.977	sec
Peak Acceleration	0.039	0.030	0.043	g
Peak Displacement	0.010	0.015	0.010	mm
Sensor Check	Passed	Passed	Passed	

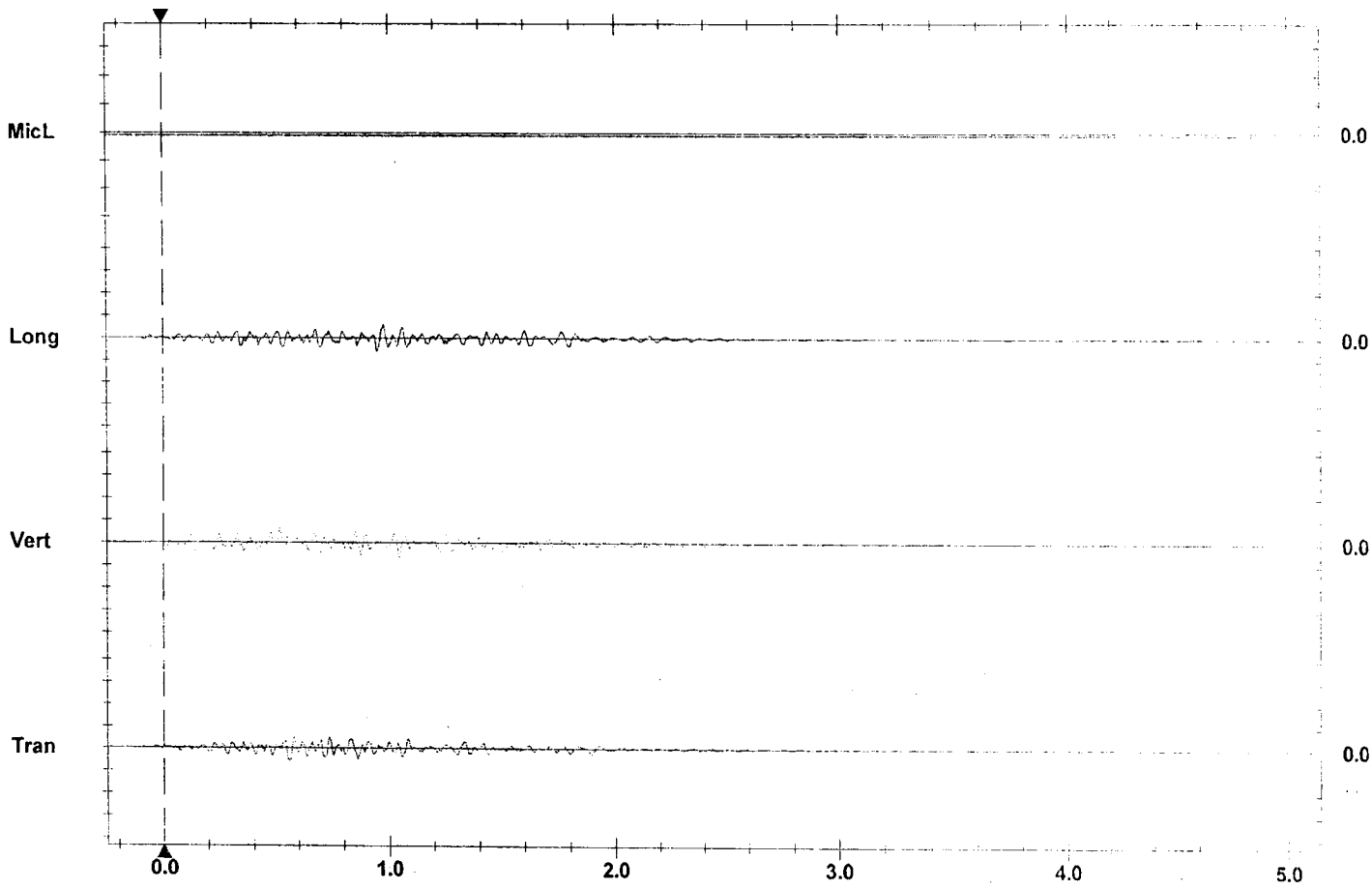
Peak Vector Sum 1.681 mm/s at 0.495 sec
N/A: Not Applicable

DGMS India (A)

Permissible Ground Vibration



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 2.000 mm/s/div Mic: 1.000 pa.(L)/div
Trigger = ▶— — ◀

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Event Report

Date/Time	Tran at 13:17:59 March 5, 2020
Trigger Source	Geo: 0.500 mm/s, Mic: 6.325 pa.(L)
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps

Notes
Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

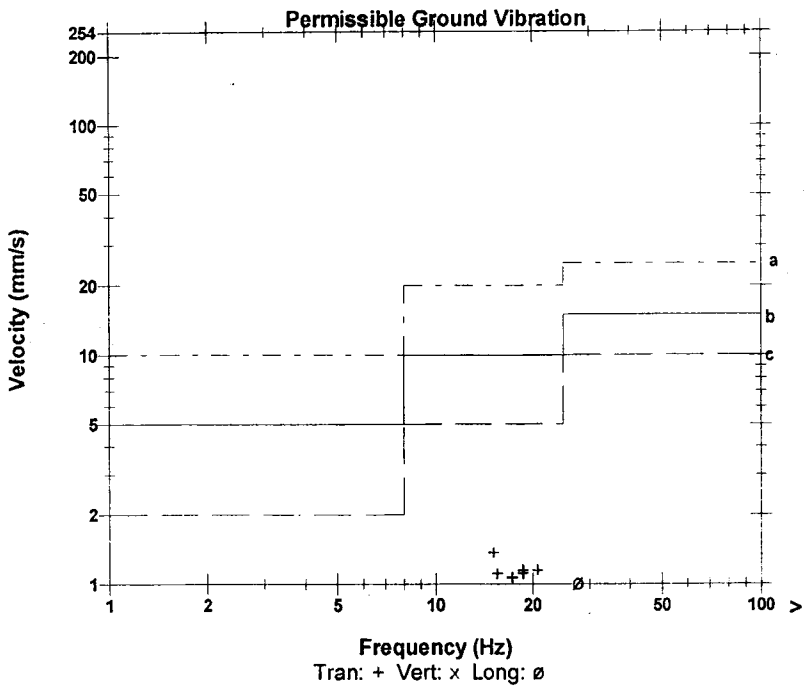
Microphone	Linear Weighting
PSPL	20.75 pa.(L) at 1.104 sec
ZC Freq	6.1 Hz
Channel Test	Passed (Freq = 20.1 Hz Amp = 443 mv)

	Tran	Vert	Long	
PPV	1.365	0.587	1.016	mm/s
ZC Freq	15.2	24.1	27.7	Hz
Time (Rel. to Trig)	1.406	1.378	1.396	sec
Peak Acceleration	0.040	0.033	0.046	g
Peak Displacement	0.011	0.004	0.006	mm
Sensor Check	Passed	Passed	Passed	

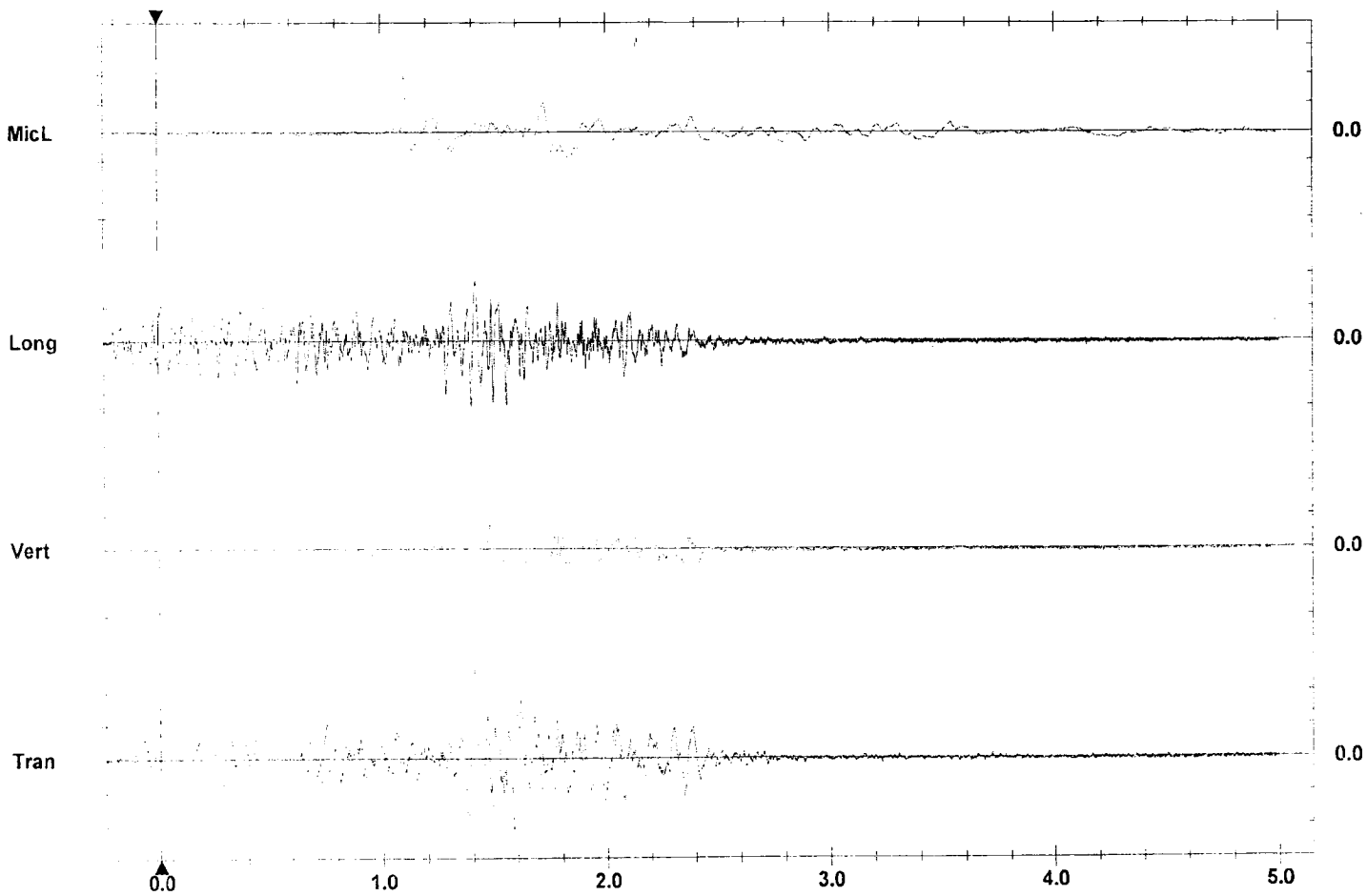
Peak Vector Sum 1.385 mm/s at 1.406 sec

Serial Number	BE16508 V 10.72-1.1 Minimate Blaster
Battery Level	6.3 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	R508ICVR.LZ0

DGMS India (A)



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 0.500 mm/s/div Mic: 10.000 pa.(L)/div
Trigger = ▶---- ◀

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Event Report

Date/Time	Long at 13:18:19 March 5, 2020
Trigger Source	Geo: 0.500 mm/s
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 spa
Job Number	1

Serial Number	BE18062 V 10.72 1 1 Minimate Blaster
Battery Level	6.1 Volts
Unit Calibration	March 29, 2019 by UES, New Delhi
File Name	T062ICVR.MJ0

Notes
Location: Pur Village
Client: District collector Bhilwara, Rajasthan
User Name: CIMFR
General:

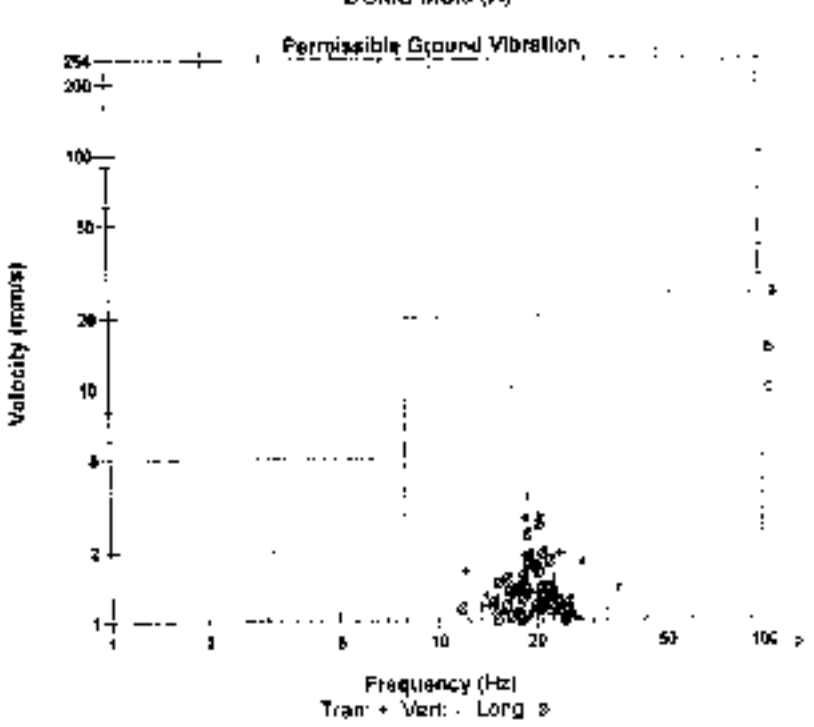
Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration & Airover Pressure in Domestic Houses of Pur Village, Bhilwara, Rajasthan

Microphone	Linear Weighting
PSPL	78.00 pa.(L) at 0.678 sec
ZC Freq	5.8 Hz
Channel Test	Passed (Freq = 20.5 Hz Amp = 473 mv)

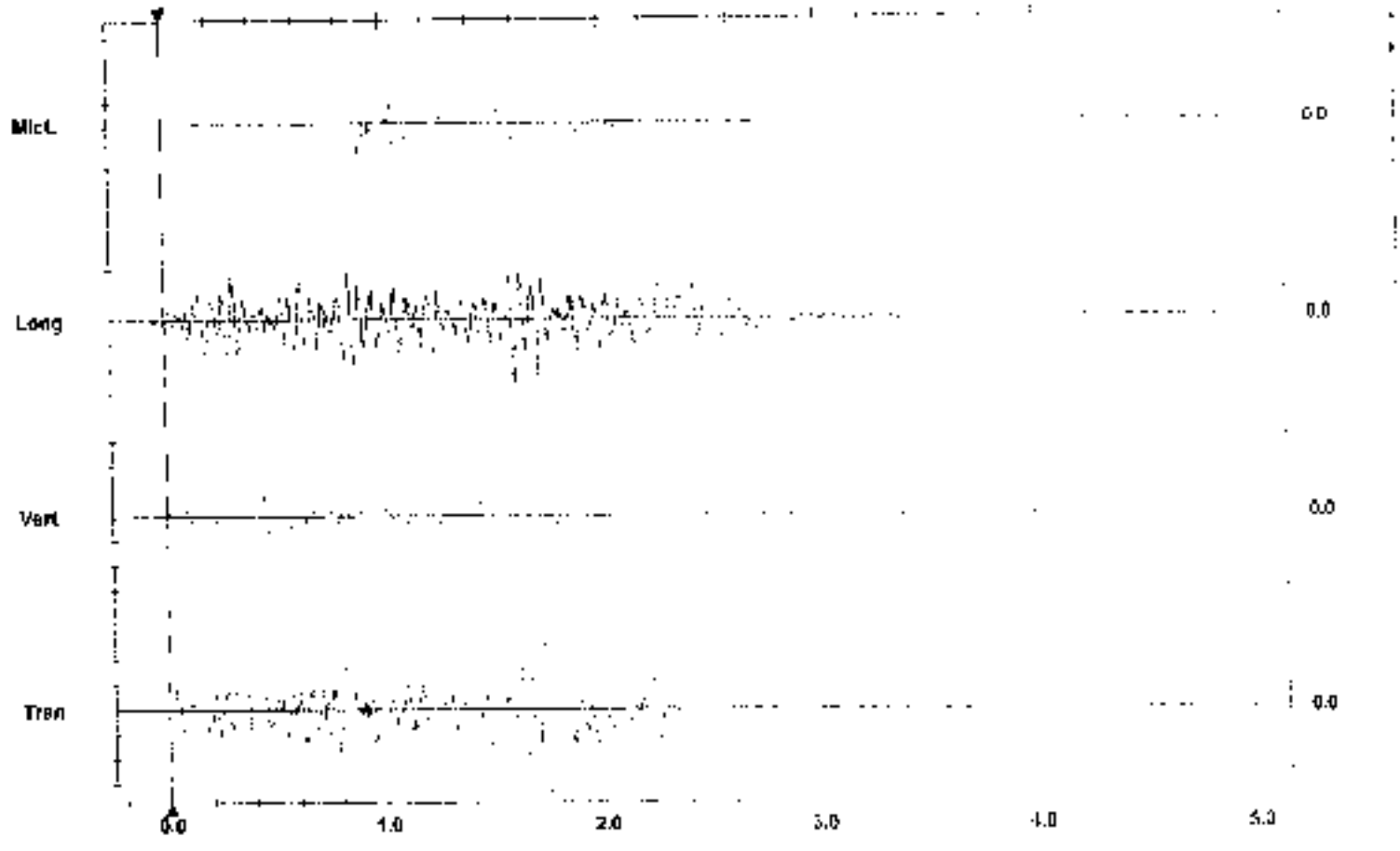
	Tran	Vert	Long	
PPV	3.297	1.556	2.619	mm/s
ZC Freq	19.0	22.8	20.5	Hz
Time (Rel. to Trig)	1.743	1.667	1.803	sec
Peak Acceleration	0.073	0.053	0.046	g
Peak Displacement	0.024	0.009	0.020	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 3.414 mm/s at 1.745 sec

DGMS India (A)



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div Amplitude Scale: Geo: 1.000 mm/s/div Mic: 20.00 pa (L Peak)
Trigger = ▶—— —◀

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Event Report

Date/Time	Vert at 13:18:23 March 5, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200305131823.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

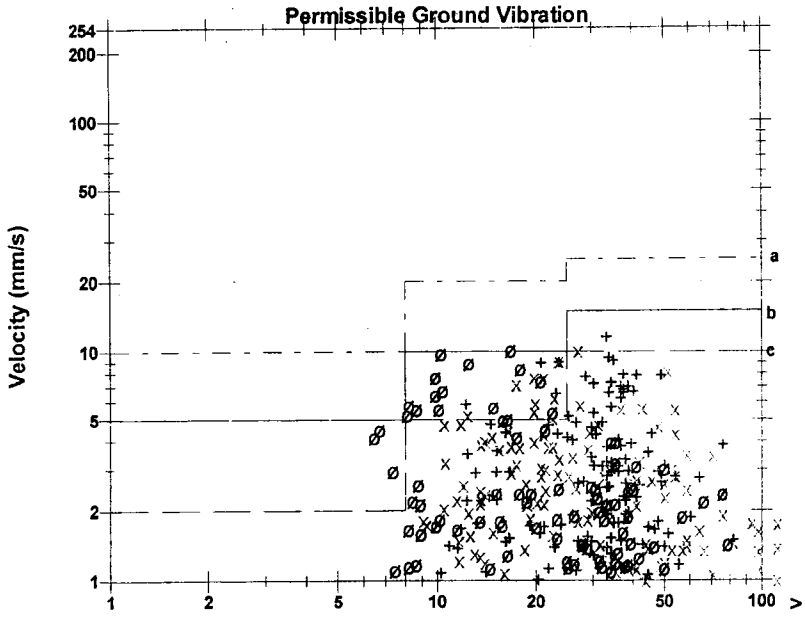
Microphone	Linear Weighting
PSPL	73.77 pa.(L) at 0.507 sec
ZC Freq	22.0 Hz
Channel Test	Passed (Freq = 19.7 Hz Amp = 1188 mv)

	Tran	Vert	Long	
PPV	11.56	10.09	10.17	mm/s
ZC Freq	33.0	26.9	16.8	Hz
Time (Rel. to Trig)	2.001	1.691	1.618	sec
Peak Acceleration	0.477	0.444	0.211	g
Peak Displacement	0.062	0.055	0.108	mm
Sensor Check	Passed	Passed	Passed	

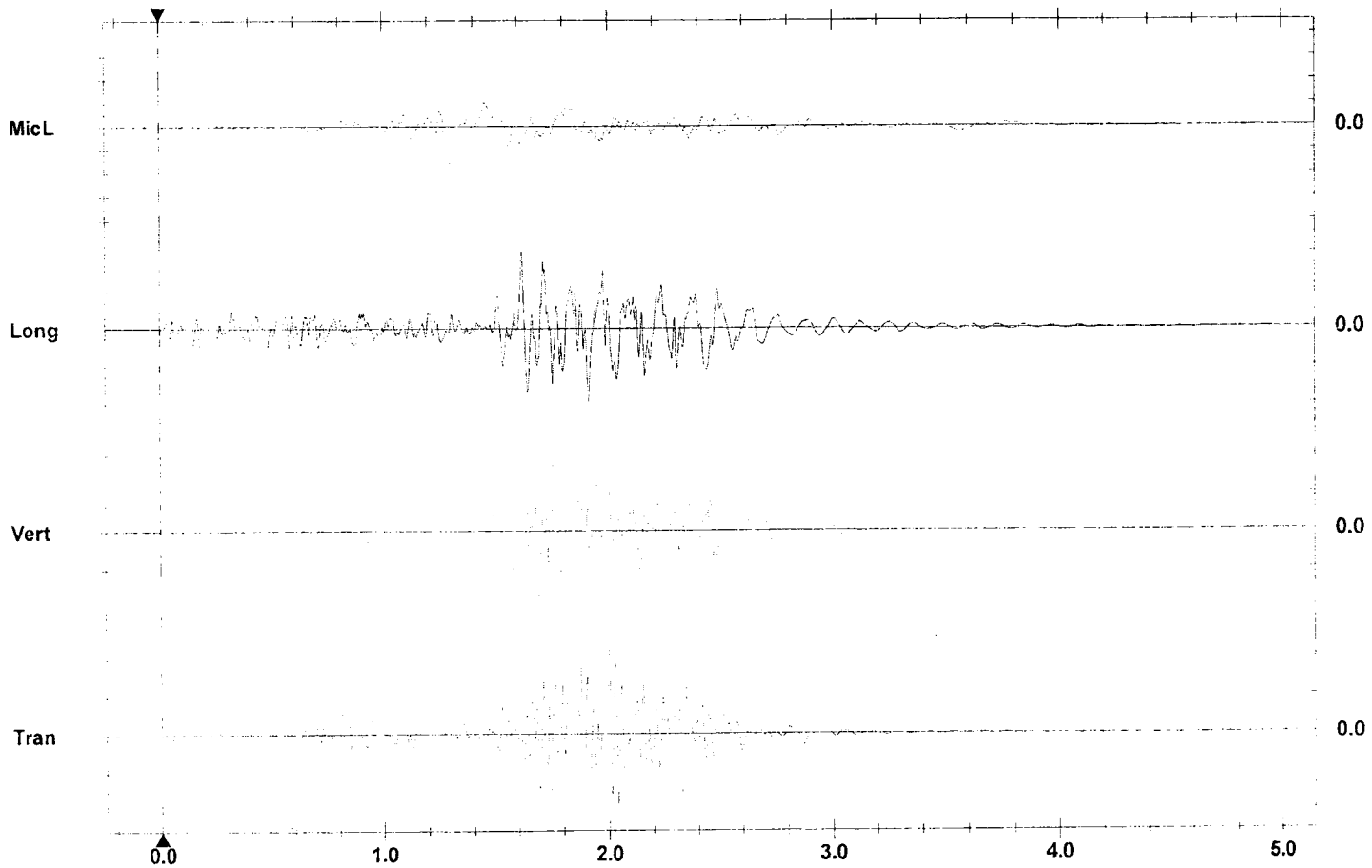
Peak Vector Sum 13.07 mm/s at 1.691 sec

DGMS India (A)

Permissible Ground Vibration



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 5.000 mm/s/div Mic: 20.00 pa.(L)/div
Trigger = ▶— — —◀

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(8)

Instantel

Event Report

Date/Time	Vert at 13:18:24 March 5, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur mmb

Serial Number	UM12452 V 10-99 Micromate ISEE
Battery Level	3.7 Volts
Unit Calibration	January 15, 2020 by UES New Delhi
File Name	UM12452_20200305131824.IDFW

Notes

Location:	Pur Village
Client:	Dist. Collector,Bhilwara,Rajasthan Govt
User Name:	CSIR-CIMFR,Bilaspur Research Centre
General:	

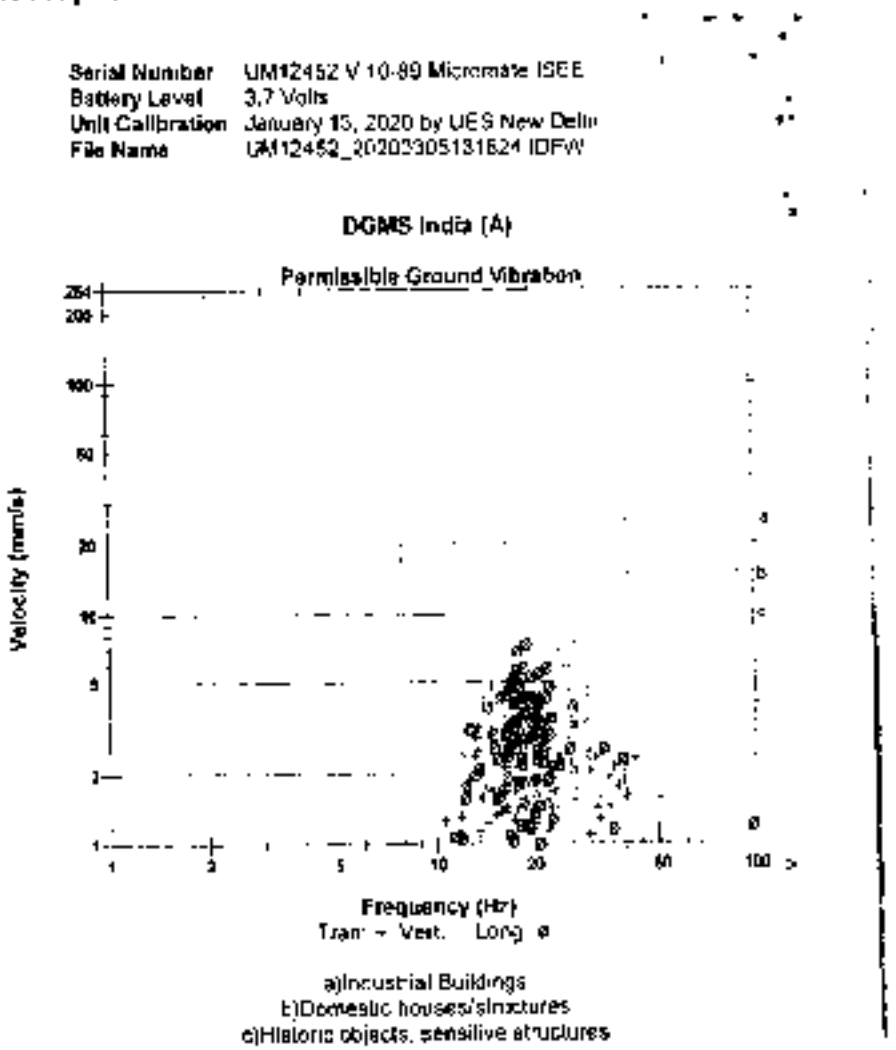
Extended Notes

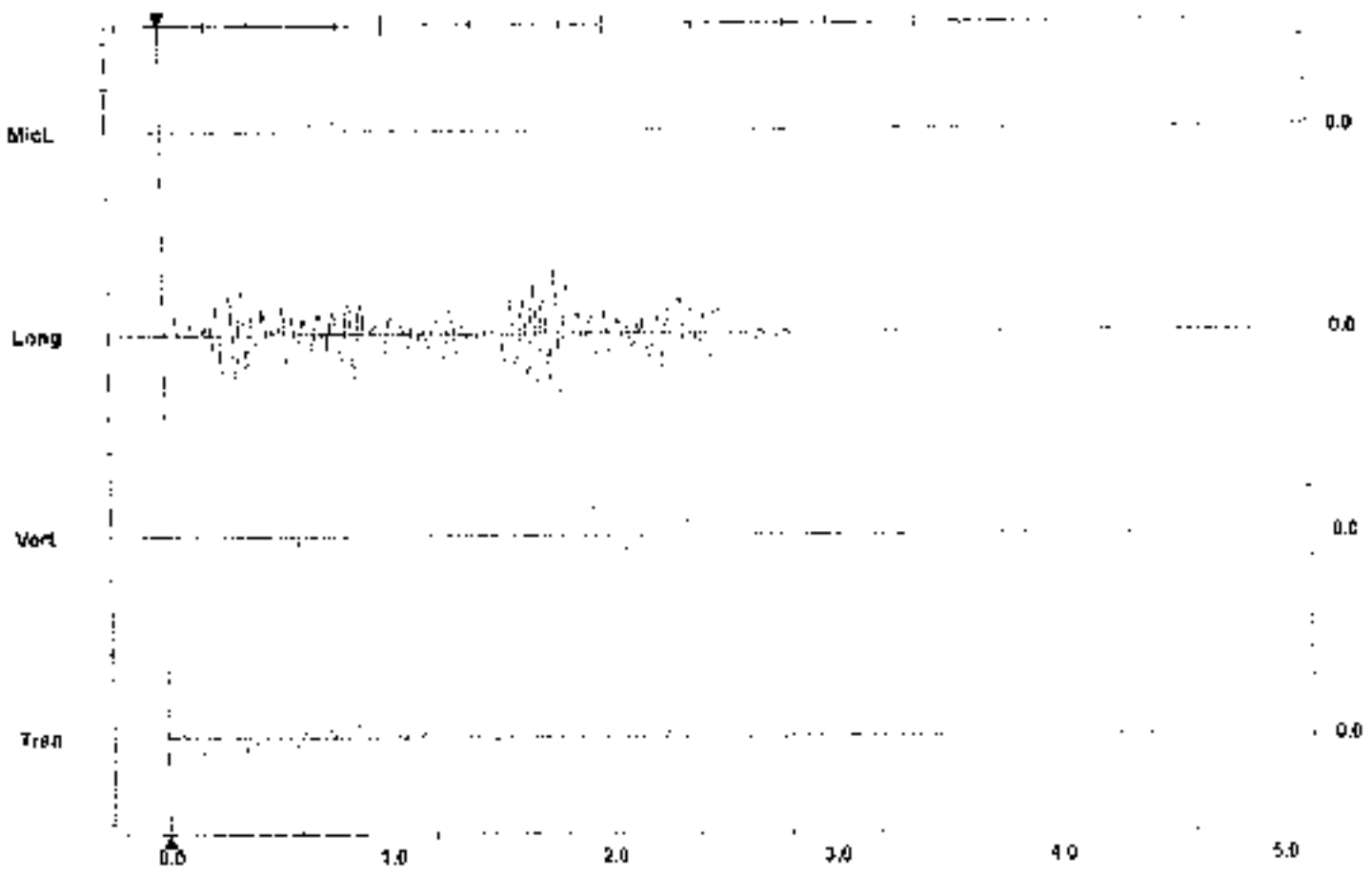
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India

Microphone:	Linear Weighting
PSPL:	96.92 pa.(L) at 0.586 sec
ZC Freq:	21.8 Hz
Channel Test:	Passed (Freq = 19.7 Hz Amp = 1162 mV)

	Tran	Vert	Long	
PPV	5.344	10.16	7.393	mm/s
ZC Freq	20.9	22.6	19.1	Hz
Time (Rel. to Trig)	2.021	1.662	1.755	sec
Peak Acceleration	0.142	0.401	0.174	g
Peak Displacement	0.037	0.074	0.062	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum: 11.32 mm/s at 1.662 sec





Time Scale: 0.20 sec/div Amplitude Scale: Geo: 5.000 mm/s/div M: 50.00 pa-l /div
Trigger =

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Instantel

Event Report

Date/Time	Long at 13:16:33 March 6 2020
Trigger Source	Geo: 0.500 mm/s
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps
Job Number:	1

Serial Number	BE18062 V 10.72-1.1 Minimate Blaster
Battery Level	6.0 Volts
Unit Calibration	March 29, 2019 by UES, New Delhi
File Name	T0621CXM.7K0

Notes

Location	Pur Village
Client	District collector Bhilwara, Rajasthan
User Name	DMG-R
General	

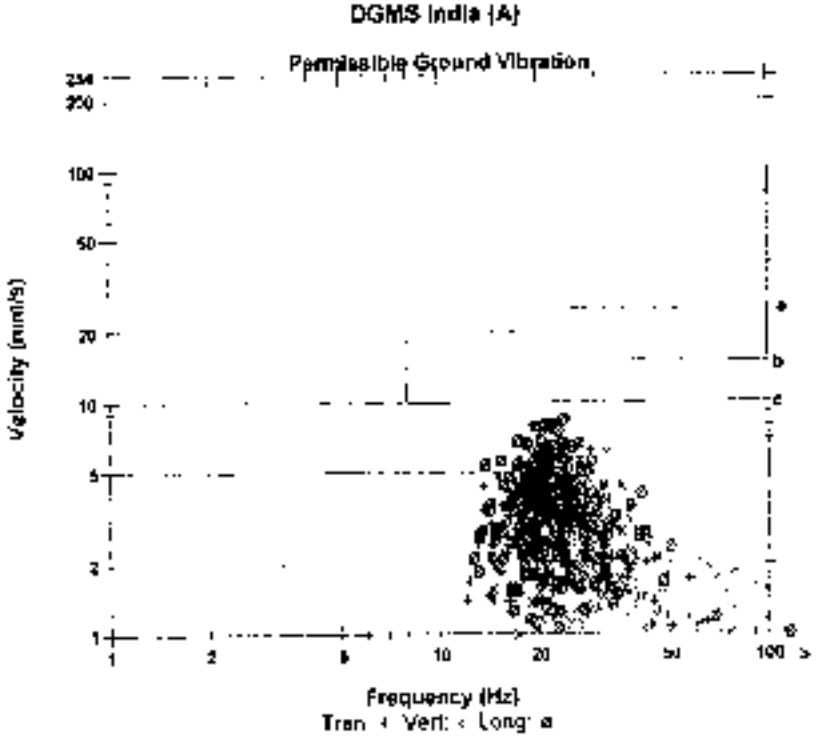
Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration & Airover Pressure in Domestic Houses at Pur Village, Bhilwara Rajasthan

Microphone	Linear Weighting
PSPL	46.25 pa,(L) at 4.245 sec
ZC Freq	17.7 Hz
Channel Test	Passed (Freq = 20.1 Hz Amp = 485 mv)

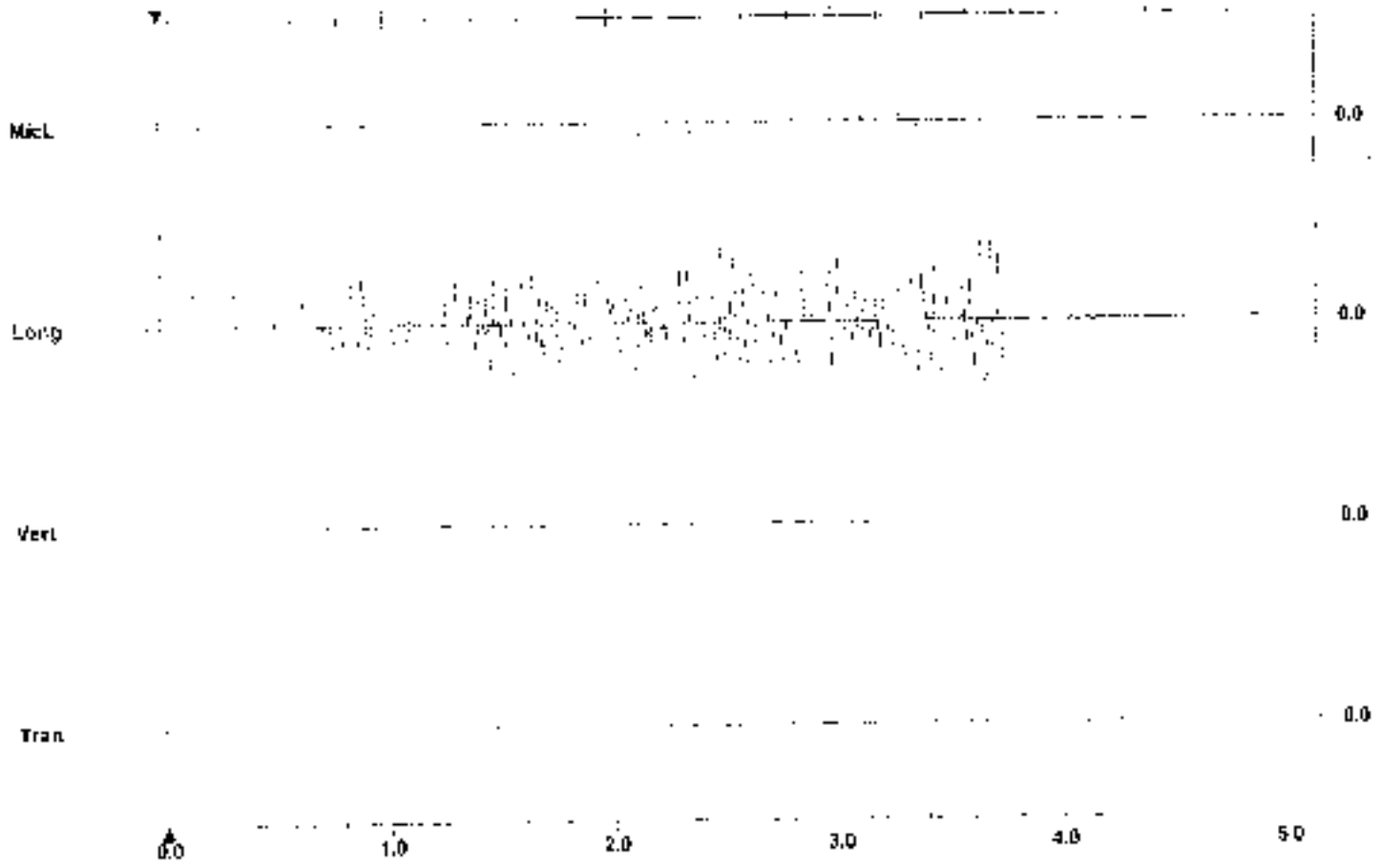
	Tran	Vert	Long	
PPV	6.731	6.525	8.568	mm/s
ZC Freq	16.1	22.3	23.8	Hz
Time (Rel. to Trig)	2.550	2.600	3.603	sec
Peak Acceleration	0.133	0.186	0.159	g
Peak Displacement	0.052	0.042	0.068	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum: 10.15 mm/s at 3.693 sec

DGMS India (A)



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div Amplitude Scale: Geo: 2.000 mm/s/div Mic: 20.00 pa (L)/div
Trigger:

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Event Report

Date/Time	Long at 13:16:32 March 6, 2020
Trigger Source	Geo: 0.500 mm/s
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 spls
Job Number:	1

Serial Number	BE18062 V 10.72-1.1 Minimate Blaster
Battery Level	6.0 Volts
Unit Calibration	March 29, 2019 by UES, New Delhi
File Name	T003:CXM 7K0

Notes

Location:	Pur Village
Client	District collector Bhilwara, Rajasthan
User Name	CIVER
General	

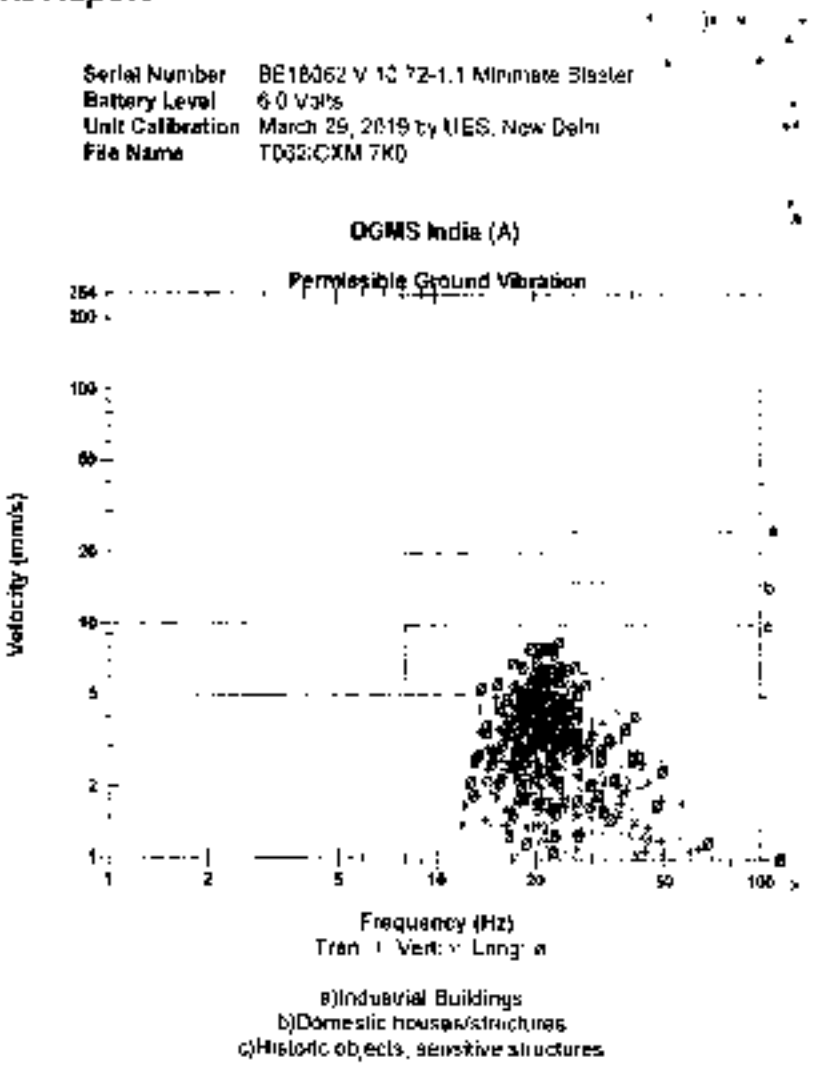
Extended Notes

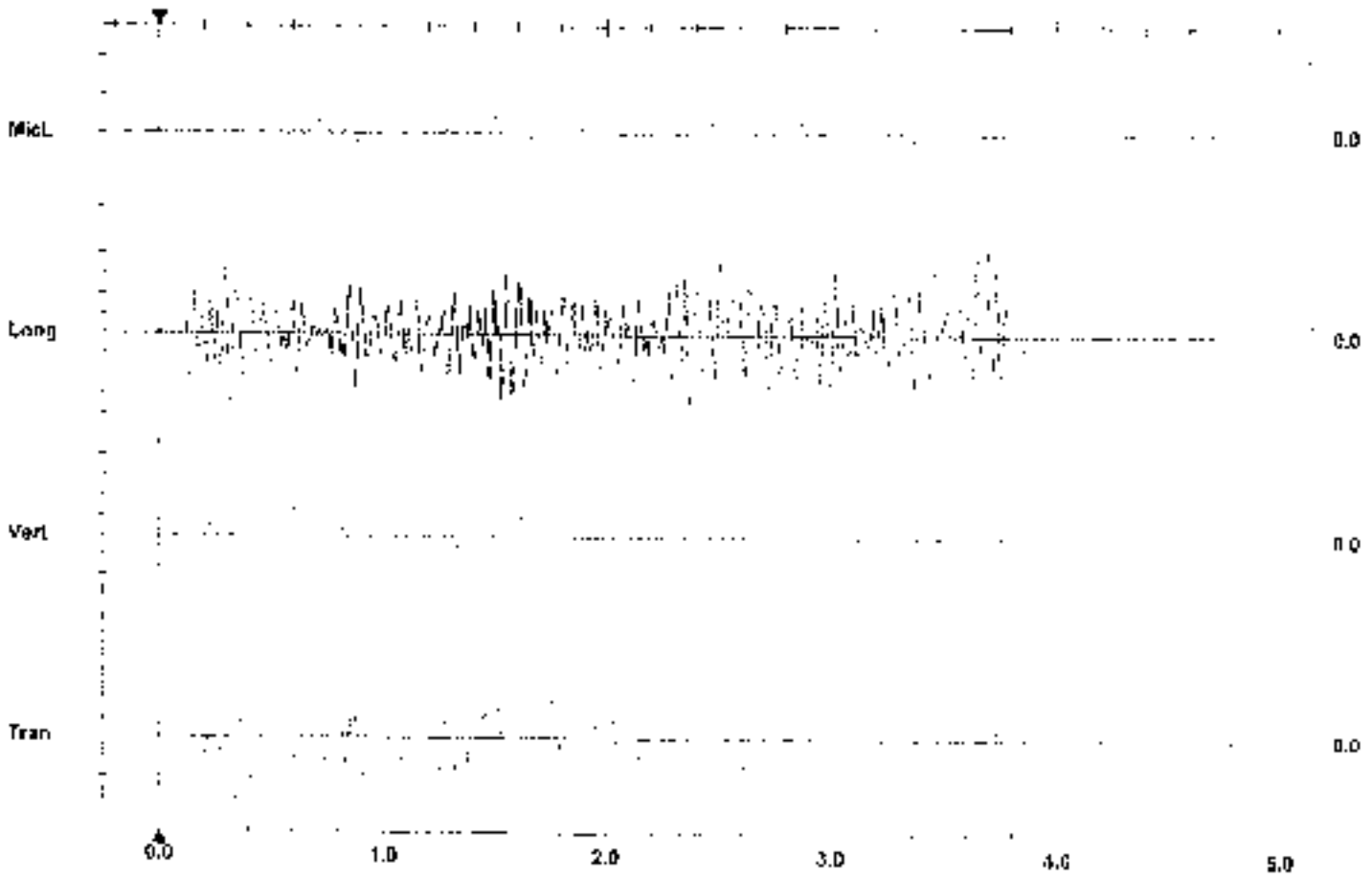
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration & Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan.

Microphone	Linear Weighting
PSPL	46.25 pa.(L) at 4.245 sec
ZC Freq	17.7 Hz
Channel Test	Passed (Freq = 20.1 Hz Amp = 485 mv)

	Tran	Vert	Long	
PPV	6.731	6.525	8.588	mm/s
ZC Freq	18.1	22.3	23.6	Hz
Time (Rel. to Trig)	2.550	2.500	3.693	sec
Peak Acceleration	0.133	0.188	0.159	g
Peak Displacement	0.052	0.042	0.068	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 10.15 mm/s at 3.693 sec





Time Scale: 0.20 sec/div Amplitude Scale: Geo: 2.000 mm/s/div Mic: 20.00 pa (L)/div
Trigger = ▶ - - - ◀

Portions © 1996-2015 Instantel Corporation

Event Report

Date/Time	Long at 13:16:42 March 6, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200306131642.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

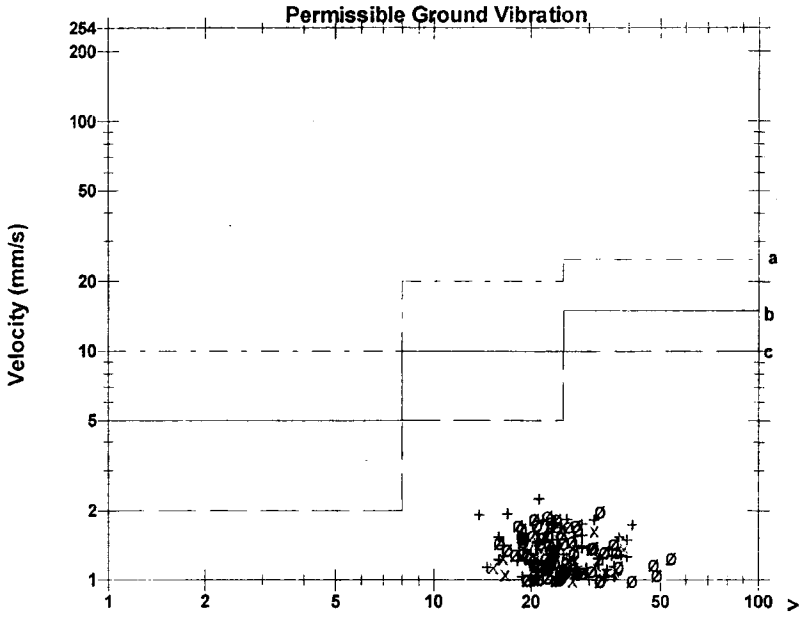
Microphone	Linear Weighting
PSPL	34.75 pa.(L) at 4.779 sec
ZC Freq	18.8 Hz
Channel Test	Passed (Freq = 19.7 Hz Amp = 1275 mv)

	Tran	Vert	Long	
PPV	2.254	1.647	2.002	mm/s
ZC Freq	21.1	31.0	32.5	Hz
Time (Rel. to Trig)	0.367	0.245	2.629	sec
Peak Acceleration	0.076	0.086	0.099	g
Peak Displacement	0.015	0.013	0.014	mm
Sensor Check	Passed	Passed	Passed	

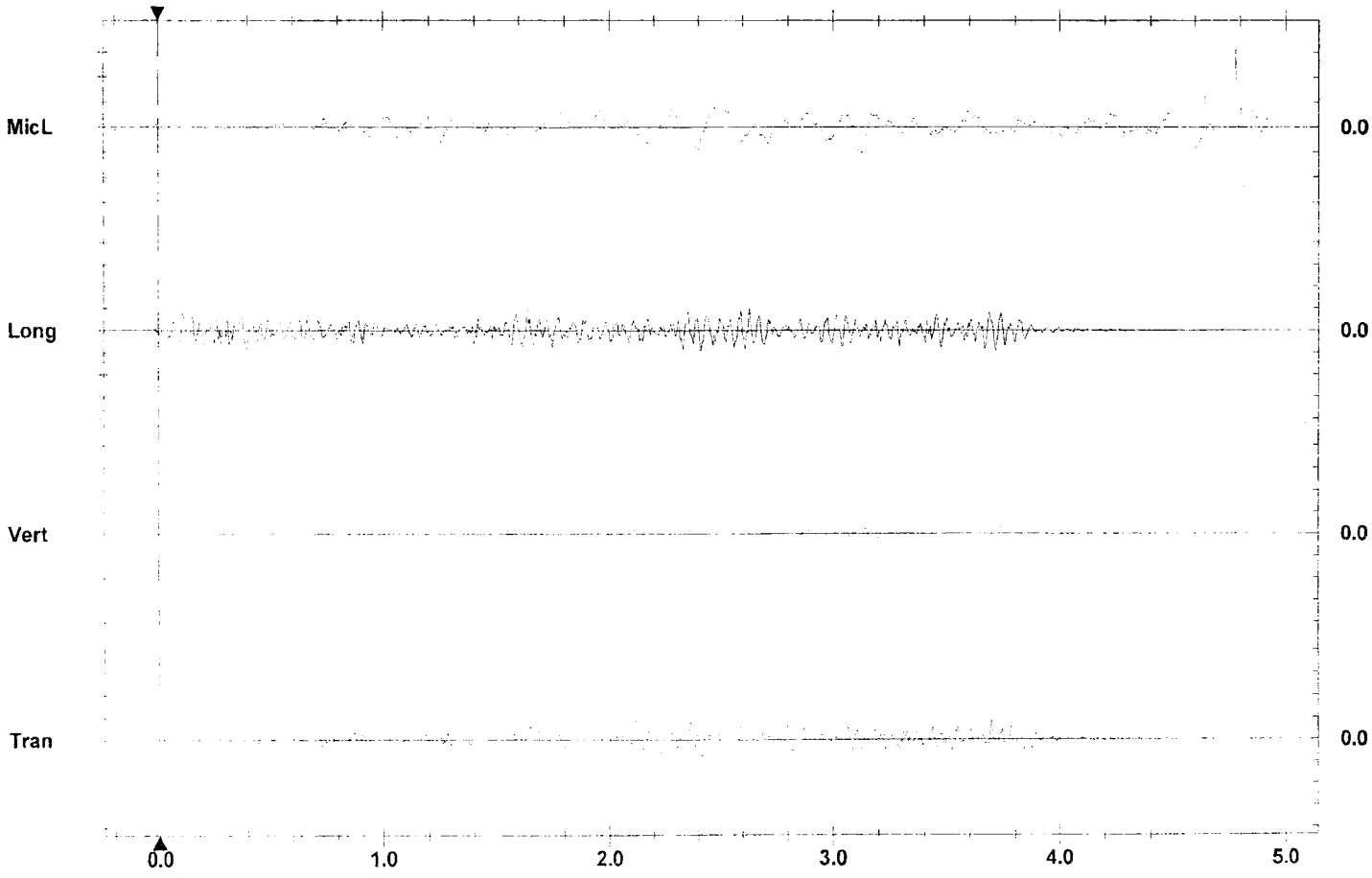
Peak Vector Sum 2.668 mm/s at 2.592 sec

DGMS India (A)

Permissible Ground Vibration



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 2.000 mm/s/div Mic: 10.000 pa.(L)/div
Trigger = ▶ ◀

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(2)

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Event Report

Date/Time	Tran at 13:16:43 March 6, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

Serial Number	UM12452 V 10-89 Micromate ISEE
Battery Level	3.7 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12452_20200306131643.IDFW

Notes
Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

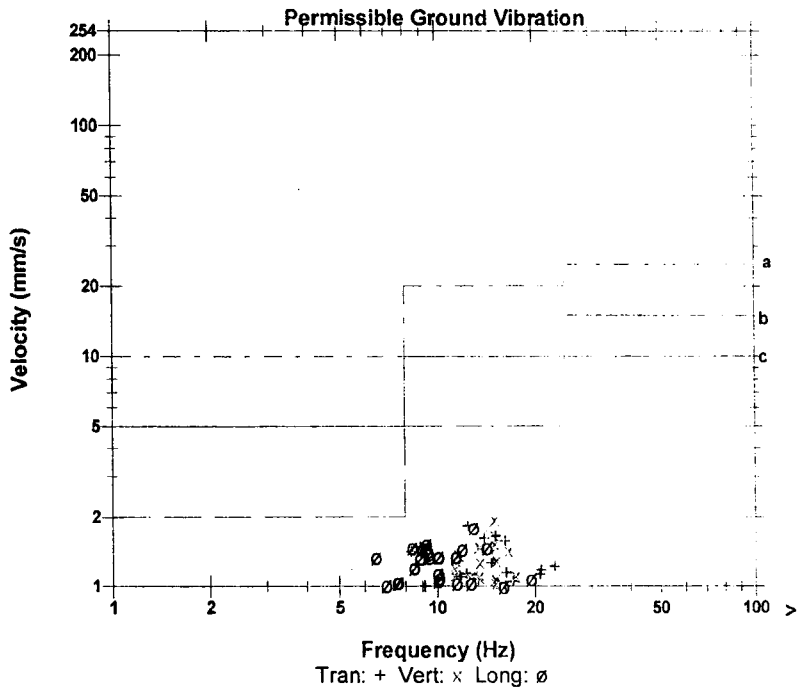
Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

Microphone	Linear Weighting
PSPL	40.01 pa.(L) at 4.445 sec
ZC Freq	7.2 Hz
Channel Test	Passed (Freq = 19.7 Hz Amp = 1272 mv)

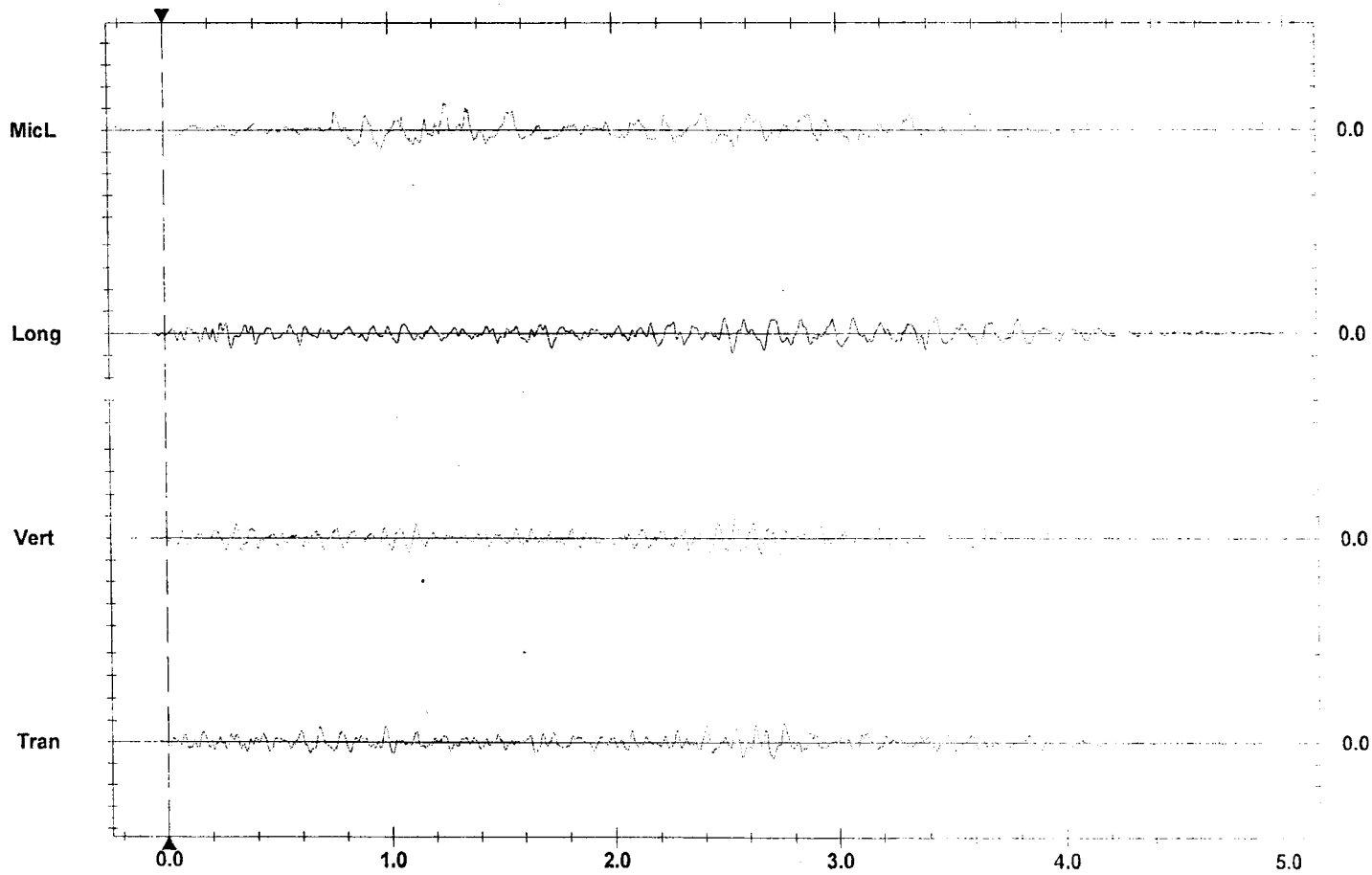
	Tran	Vert	Long	
PPV	1.821	1.947	1.797	mm/s
ZC Freq	12.4	14.9	13.0	Hz
Time (Rel. to Trig)	2.750	2.539	2.531	sec
Peak Acceleration	0.036	0.046	0.043	g
Peak Displacement	0.021	0.020	0.025	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 2.690 mm/s at 2.536 sec

DGMS India (A)



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 2.000 mm/s/div Mic: 10.000 pa.(L)/div
Trigger = ▶—— —— ◀

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Event Report

Date/Time	Long at 13:24:10 March 6, 2020
Trigger Source	Geo: 0.500 mm/s
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps
Job Number:	1

Serial Number	BE18062 V 10.72-1.1 Minimate Blaster
Battery Level	6.0 Volts
Unit Calibration	March 29, 2019 by UES, New Delhi
File Name	T062ICXM.KA0

Notes

Location:	Pur Village
Client:	District collector Bhilwara, Rajasthan
User Name:	CIMFR
General:	

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration & Airover Pressure in Domestic Houses inPur Village, Bhilwara, Rajasthan.

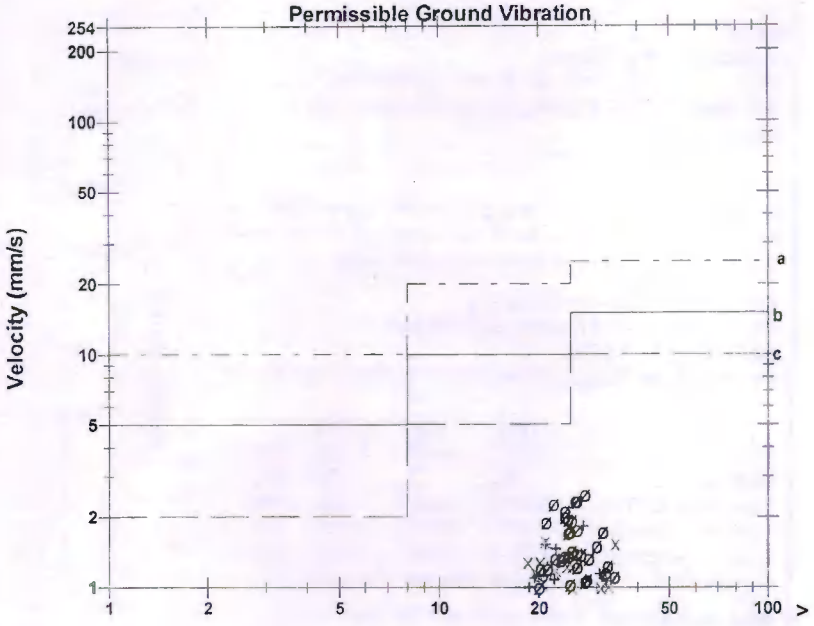
Microphone	Linear Weighting
PSPL	32.25 pa.(L) at 2.254 sec
ZC Freq	10.8 Hz
Channel Test	Passed (Freq = 20.1 Hz Amp = 485 mv)

	Tran	Vert	Long	
PPV	1.826	1.572	2.508	mm/s
ZC Freq	27.3	20.9	27.7	Hz
Time (Rel. to Trig)	0.211	1.250	1.250	sec
Peak Acceleration	0.046	0.066	0.066	g
Peak Displacement	0.011	0.009	0.015	mm
Sensor Check	Passed	Passed	Passed	

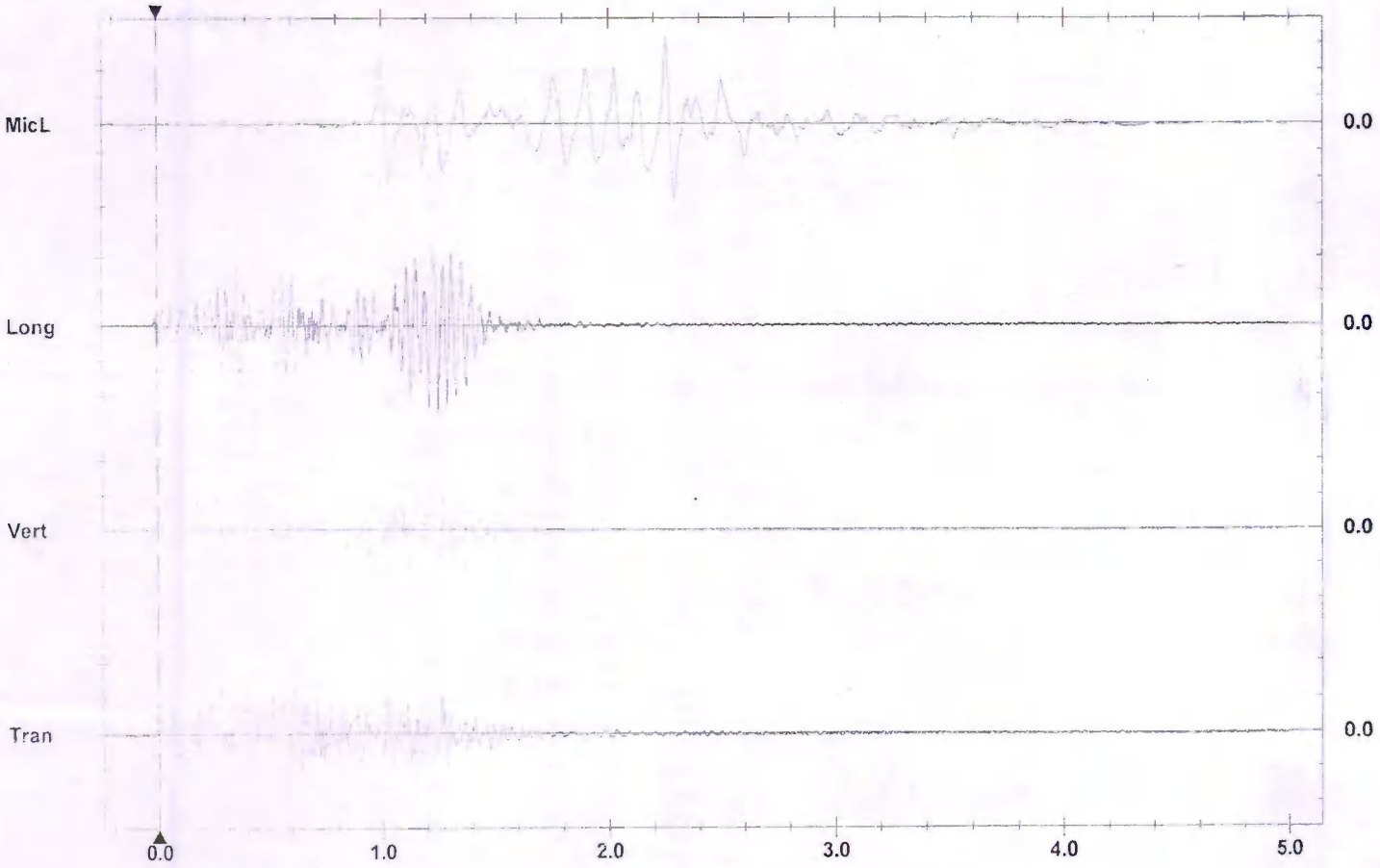
Peak Vector Sum 2.980 mm/s at 1.250 sec

DGMS India (A)

Permissible Ground Vibration



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 1.000 mm/s/div Mic: 10.000 pa.(L)/div
Trigger = ▶ ◀

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Instantel Event Report

Date/Time	Vert at 13:24:20 March 6, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200306132420.IDFW

Notes
Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

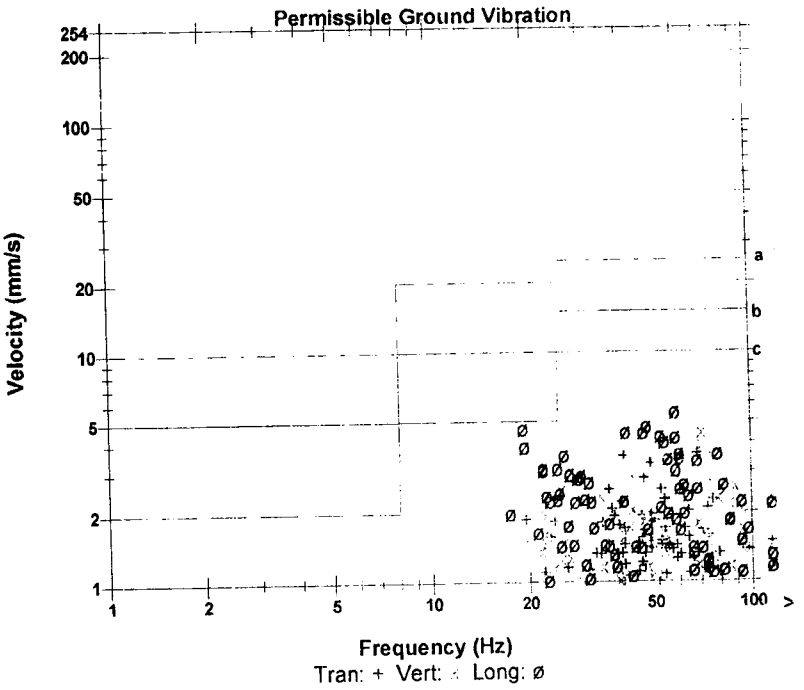
Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

Microphone	Linear Weighting
PSPL	47.57 pa.(L) at 1.694 sec
ZC Freq	13.9 Hz
Channel Test	Passed (Freq = 19.7 Hz Amp = 1275 mv)

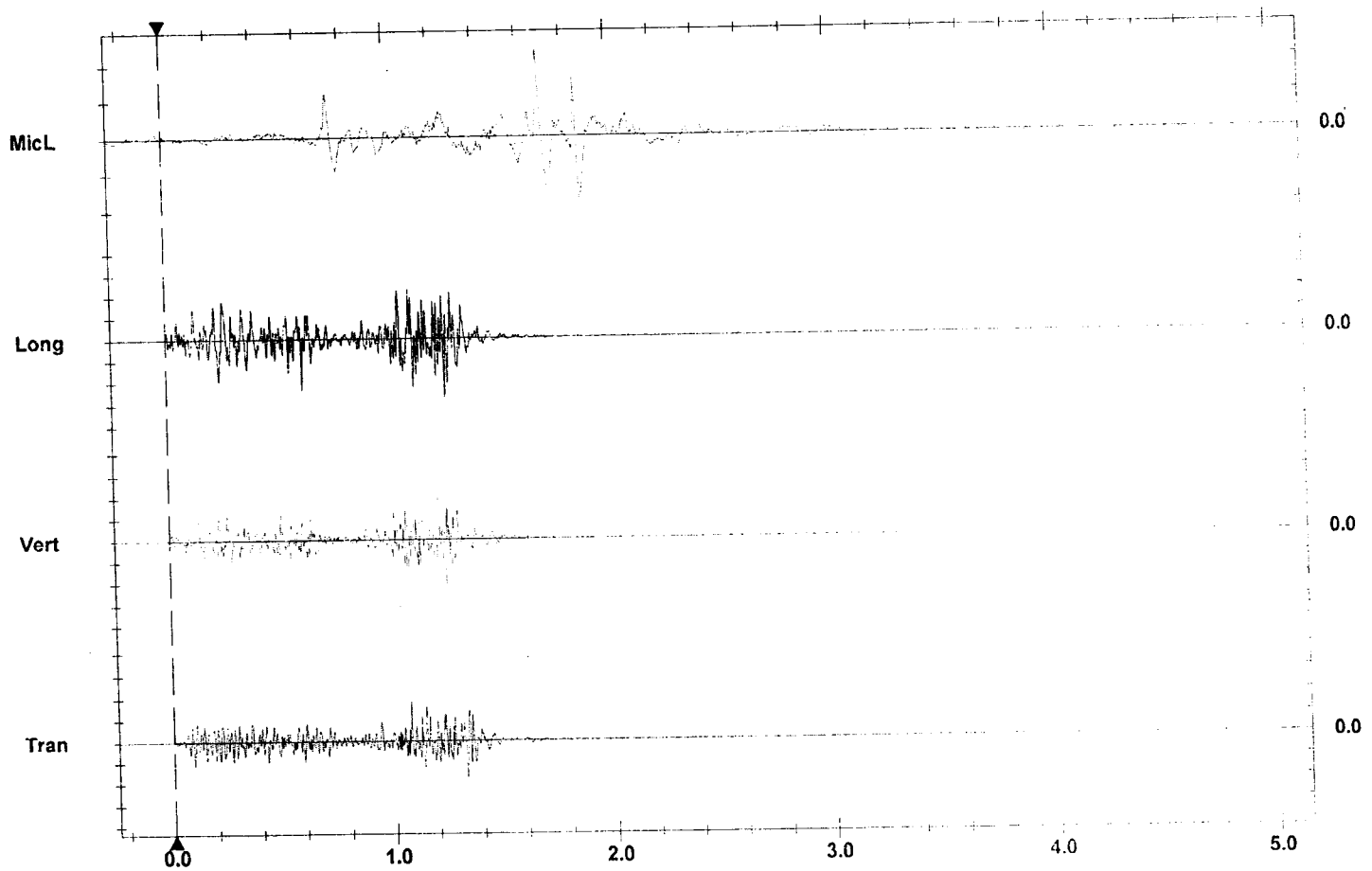
	Tran	Vert	Long	
PPV	3.602	4.461	5.438	mm/s
ZC Freq	68	71	59	Hz
Time (Rel. to Trig)	1.072	1.247	1.256	sec
Peak Acceleration	0.237	0.316	0.329	g
Peak Displacement	0.011	0.010	0.026	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 6.017 mm/s at 1.247 sec

DGMS India (A)



a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 2.000 mm/s/div Mic: 20.00 pa.(L)/div
Trigger = ▶—— —— ◀

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Event Report

Date/Time	Tran at 13:24:21 March 6, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

Serial Number	UM12452 V 10-89 Micromate ISEE
Battery Level	3.7 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12452_20200306132421.IDFW

Notes

Location:	Pur Village
Client:	Dist. Collector,Bhilwara,Rajasthan Govt.
User Name:	CSIR-CIMFR,Bilaspur Research Centre
General:	

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

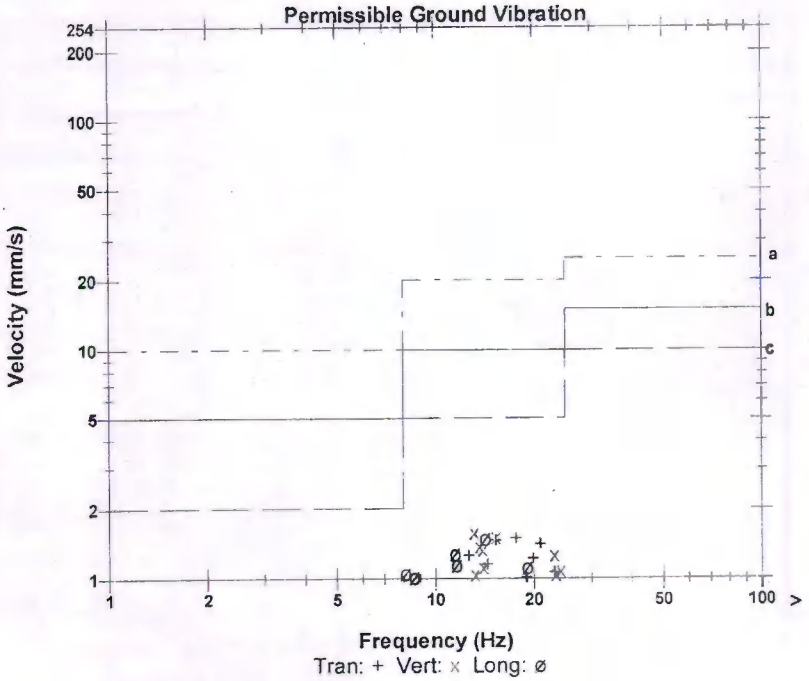
Microphone	Linear Weighting
PSPL	32 94 pa.(L) at 0.787 sec
ZC Freq	12.0 Hz
Channel Test	Passed (Freq = 19.7 Hz Amp = 1272 mv)

	Tran	Vert	Long	
PPV	1.490	1.576	1.490	mm/s
ZC Freq	17.7	13.1	14.2	Hz
Time (Rel. to Trig)	0.439	0.462	0.733	sec
Peak Acceleration	0.033	0.039	0.030	g
Peak Displacement	0.013	0.015	0.017	mm
Sensor Check	Passed	Passed	Passed	

Peak Vector Sum 2.048 mm/s at 0.440 sec

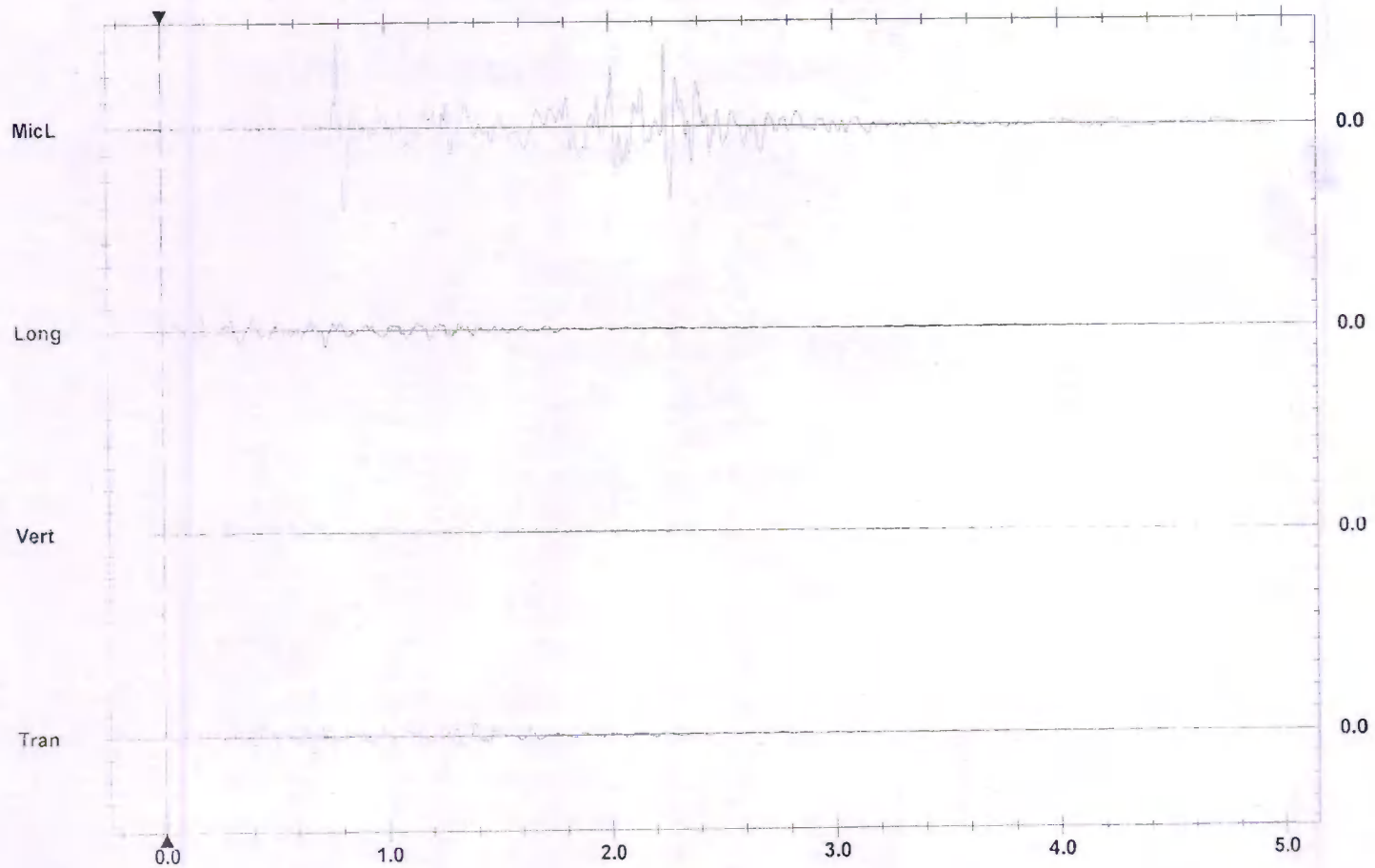
DGMS India (A)

Permissible Ground Vibration



Tran: + Vert: x Long: ø

a)Industrial Buildings
b)Domestic houses/structures
c)Historic objects, sensitive structures



Time Scale: 0.20 sec/div **Amplitude Scale:** Geo: 2.000 mm/s/div Mic: 10.000 pa.(L)/div
Trigger = ▶ ◀

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ANNEXURE – II

(FFT Reports of Observed Vibration)

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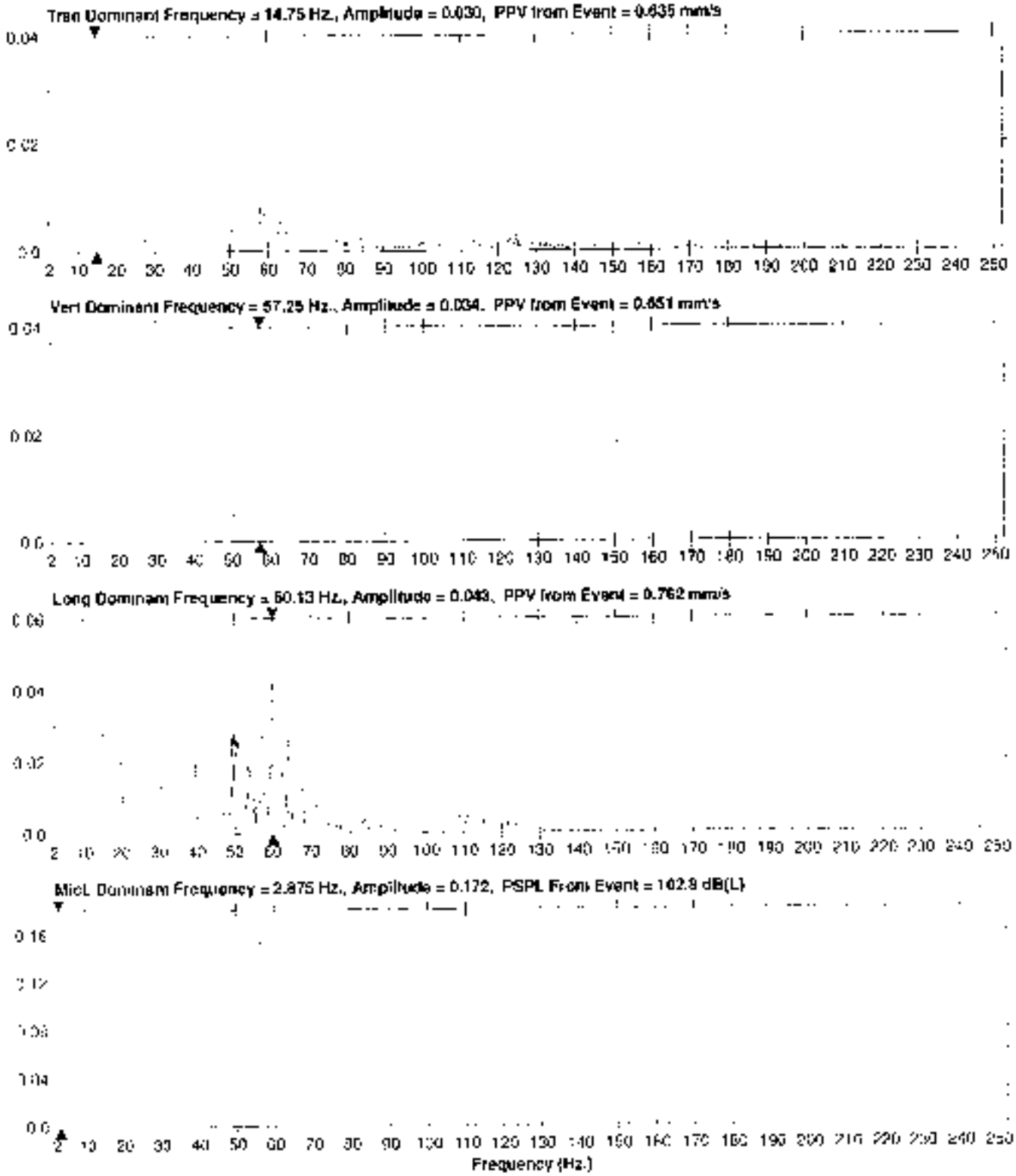
FFT Report

Date/Time: Tran at 1:00:48 PM February 1, 2020
Trigger Source: Geo: 0.510 mm/s, Mic: 100.0 dB(L)
Range: Geo: 30: 75 mm/s
Record Time: 5.0 sec at 4096 sps

Notes
Location: Pur Village
Client:
User Name: Osink CIMFR, Dhanbad Research Centre
General:

Serial Number: BE13781 V 10.72 8.17 MiniMate Plus
Battery Level: 6.1 Volts
Unit Calibration: January 13, 2020 by UES New Delhi
File Name: O781IB8M.TC0

Extended Notes
Scientific investigation of potential damage due to blast-induced ground vibration and air over pressure in domestic houses in Pur Village Bhilwara, Rajasthan, India.



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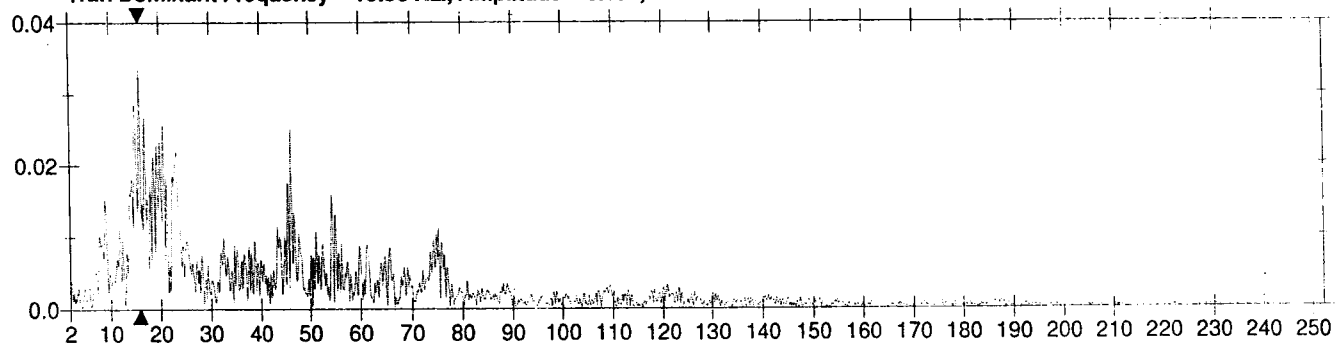
FFT Report

Date/Time	MicL at 1:03:53 PM February 1, 2020
Trigger Source	Geo: 0.510 mm/s, Mic: 100.0 dB(L)
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps
Serial Number	BE13781 V 10.72-8.17 MiniMate Plus
Battery Level	6.1 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	O781IB6M.YH0

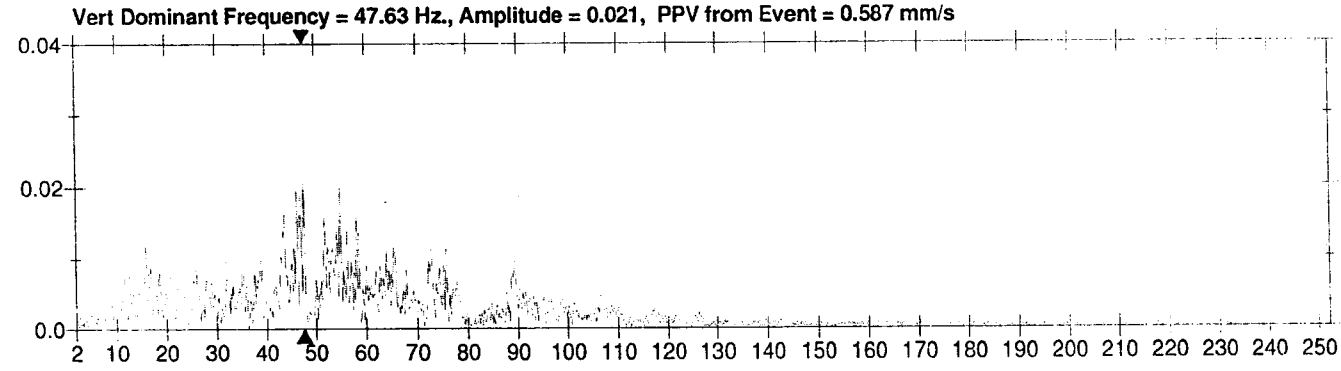
Notes
Location: Pur Village
Client:
User Name: CSIR-CIMFR, Bilaspur Research Centre
General:

Extended Notes
Scientific investigation of potenstial damage due to blast induced ground vibration and air over pressure in domestic houses in Pur Village, Bhilwara, Rajasthan, India.

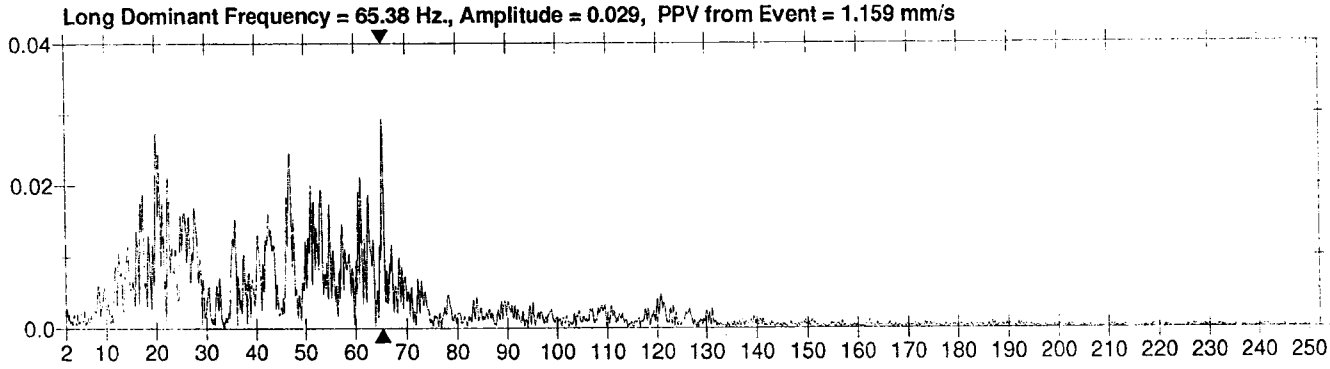
Tran Dominant Frequency = 15.88 Hz., Amplitude = 0.034, PPV from Event = 0.921 mm/s



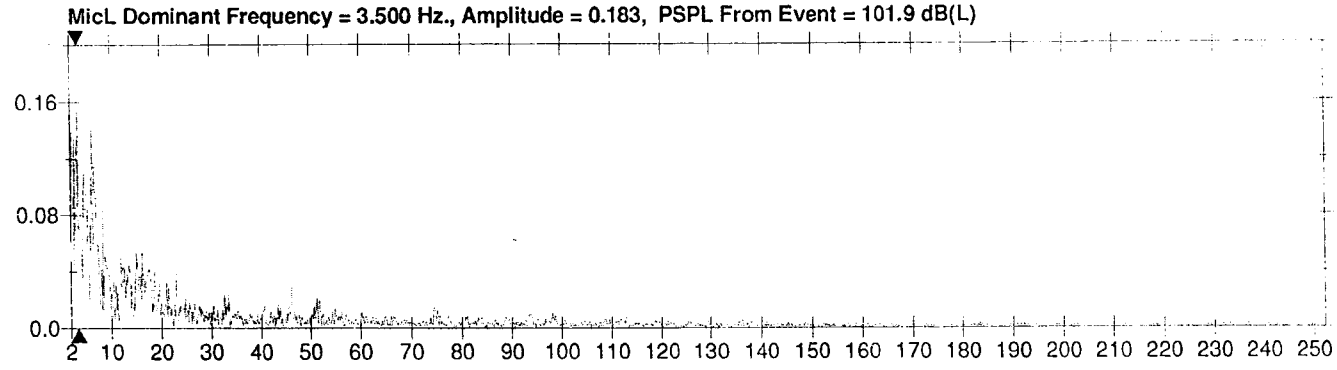
Vert Dominant Frequency = 47.63 Hz., Amplitude = 0.021, PPV from Event = 0.587 mm/s



Long Dominant Frequency = 65.38 Hz., Amplitude = 0.029, PPV from Event = 1.159 mm/s



MicL Dominant Frequency = 3.500 Hz., Amplitude = 0.183, PSPL From Event = 101.9 dB(L)



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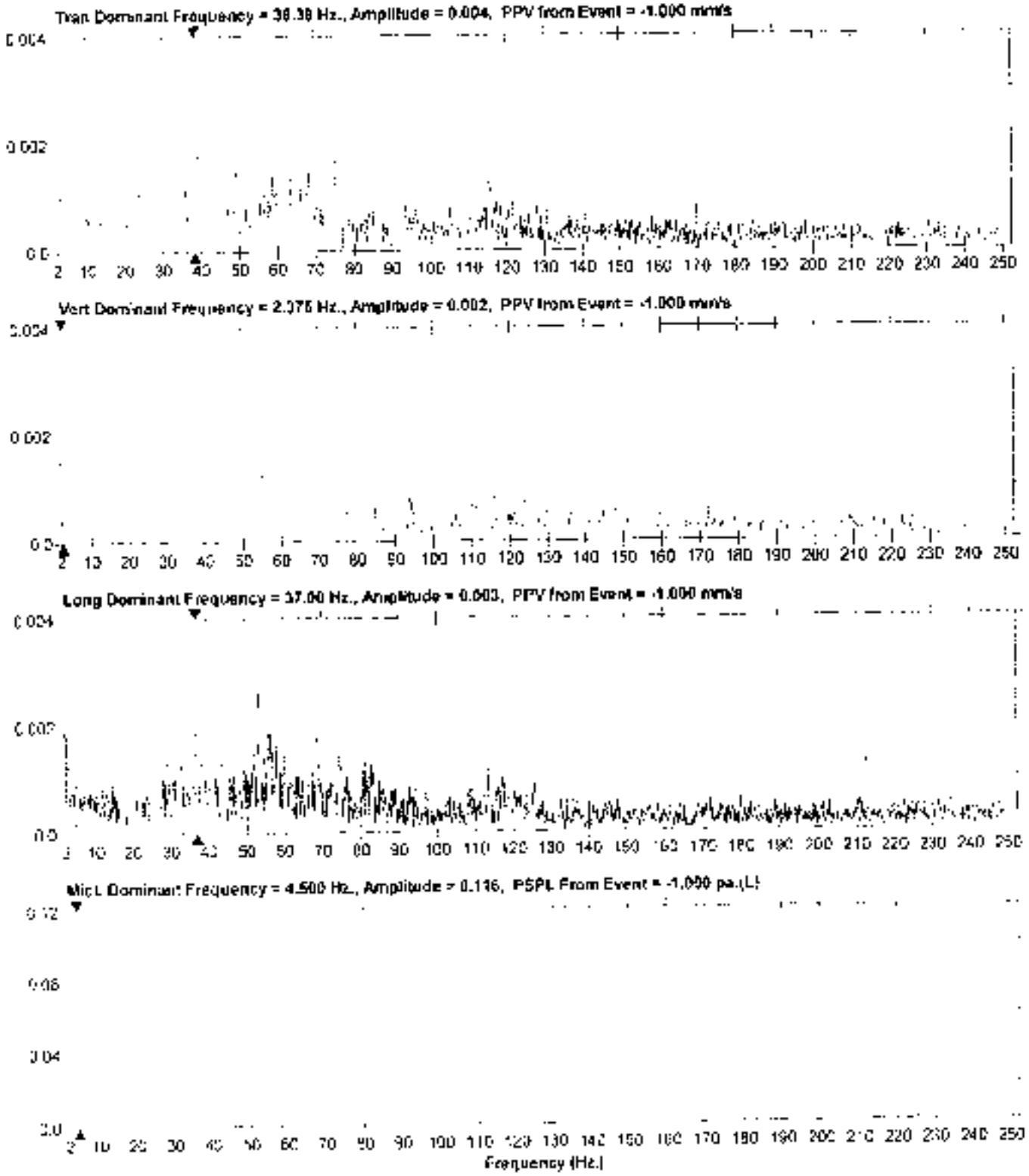
FFT Report

Date/Time	Mon, at 13:00:49 February 1, 2020
Trigger Source	Geo: 0.510 mm/s, Mic: 2.000 pa.(L)
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 spg

Notes
Location: Pur Village
Client:
User Name: CSIR-CIMFR, Bilaspur Research Centre
General

Serial Number	BE16508 V 10.72-1.1 Minimate Blaster
Battery Level	6.4 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	R5081B8M.TC0

Extended Notes
Scientific investigation of potential damage due to blast induced ground vibration and air over pressure on domestic houses in Pur Village, Bhilwara, Rajasthan, India.



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FFT Report

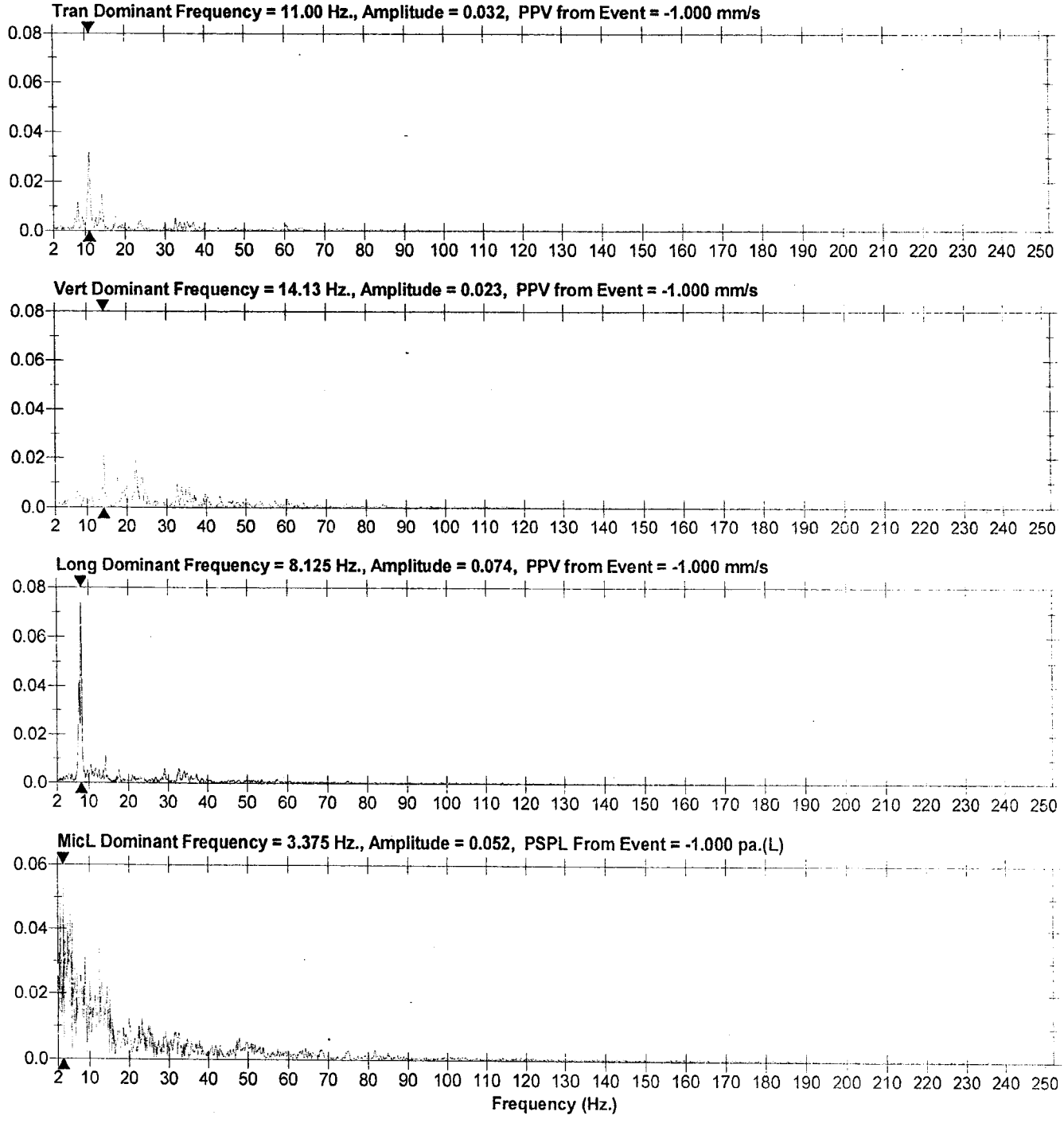
Date/Time	Long at 13:00:51 February 1, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 2048 sps
Operator/Setup:	Operator/CIMFR BLSPR.mmb

Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200201130051.IDFW

Notes
Location: PUR VILLAGE
Client:
User Name: CSIR-CIMFR Bilaspur Research Centre
General:

Extended Notes
Scientific investigation of damage potential due to blast induced ground vibration and airover pressure in domestic houses in Pur Village, Bhilwara, Rajasthan, India.

Post Event Notes
DMG, BHILWARA DIST, RAJASTHAN GOVT.



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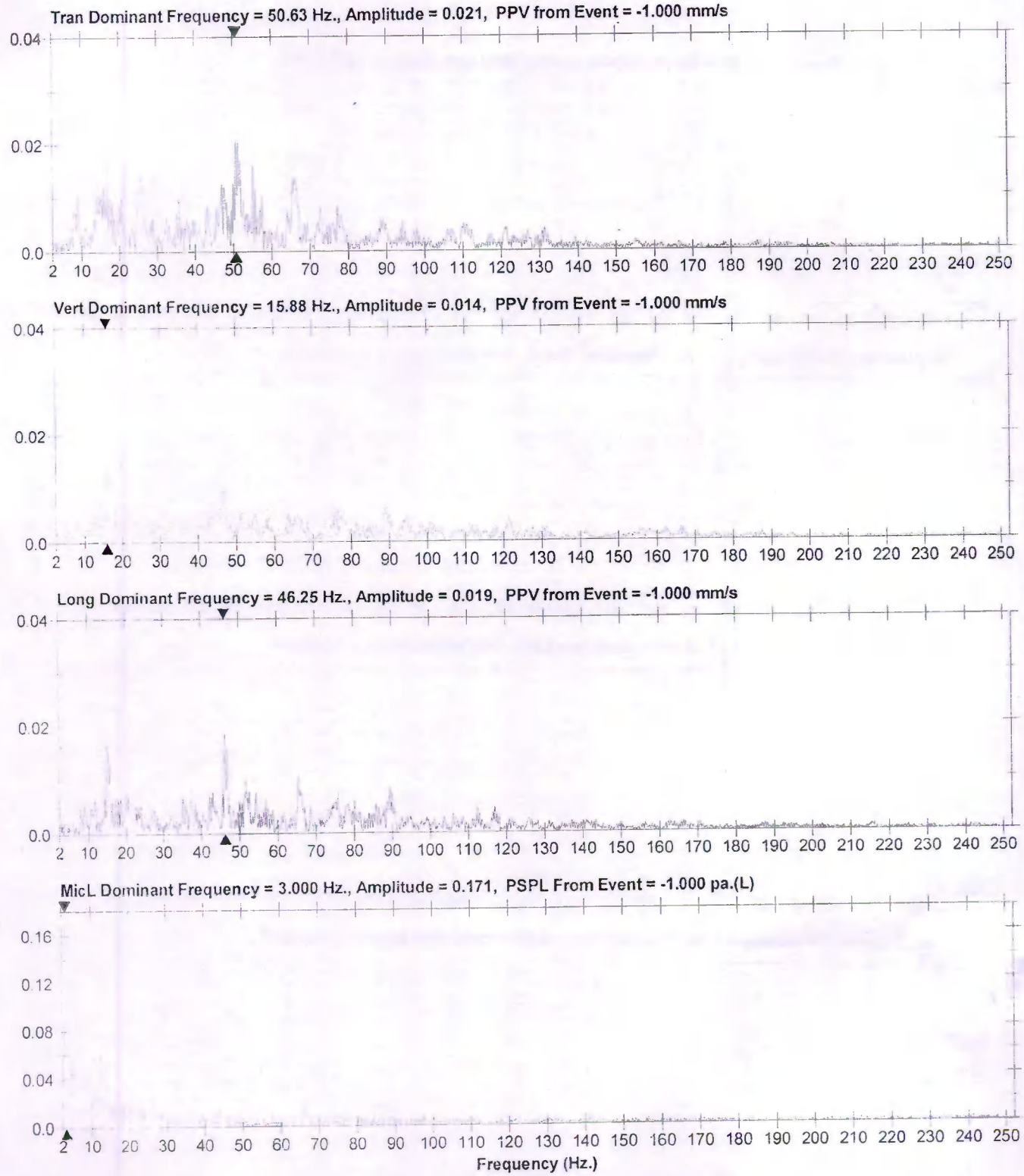
FFT Report

Date/Time	Tran at 13:03:54 February 1, 2020
Trigger Source	Geo: 0.510 mm/s, Mic: 2.000 pa.(L)
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps

Serial Number	BE16508 V 10.72-1.1 Minimate Blaster
Battery Level	6.4 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	R508IB6M.YI0

Notes
Location: Pur Village
Client:
User Name: CSIR-CIMFR, Bilaspur Research Centre
General:

Extended Notes
Scientific investigation of potenstial damage due to blast induced ground vibration and air over pressure in domestic houses in Pur Village, Bhilwara, Rajasthan, India.



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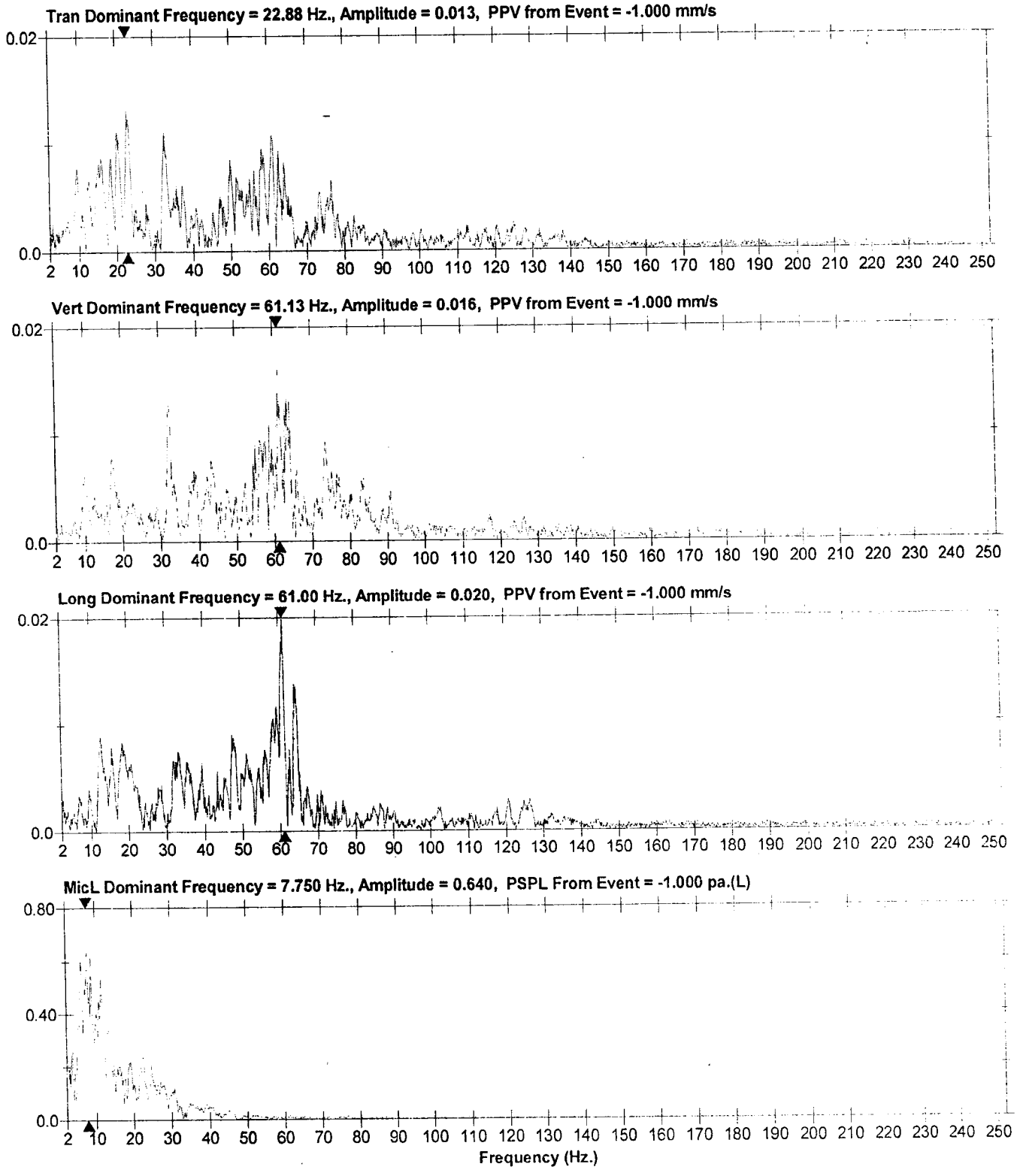
FFT Report

Date/Time	Long at 13:11:23 February 4, 2020
Trigger Source	Geo: 0.510 mm/s
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps

Serial Number	BE13781 V 10.72-8.17 MiniMate Plus
Battery Level	6.3 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	O781IBC7.AZ0

Notes
Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR, Bilaspur Research Centre
General:

Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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FFT Report

Date/Time	MicL at 13:11:33 February 4, 2020
Trigger Source	Geo: 0.250 mm/s, Mic: 6.325 pa.(L)
Range	Geo: 254.0 mm/s
Record Time	10.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR BLSPR.mmb

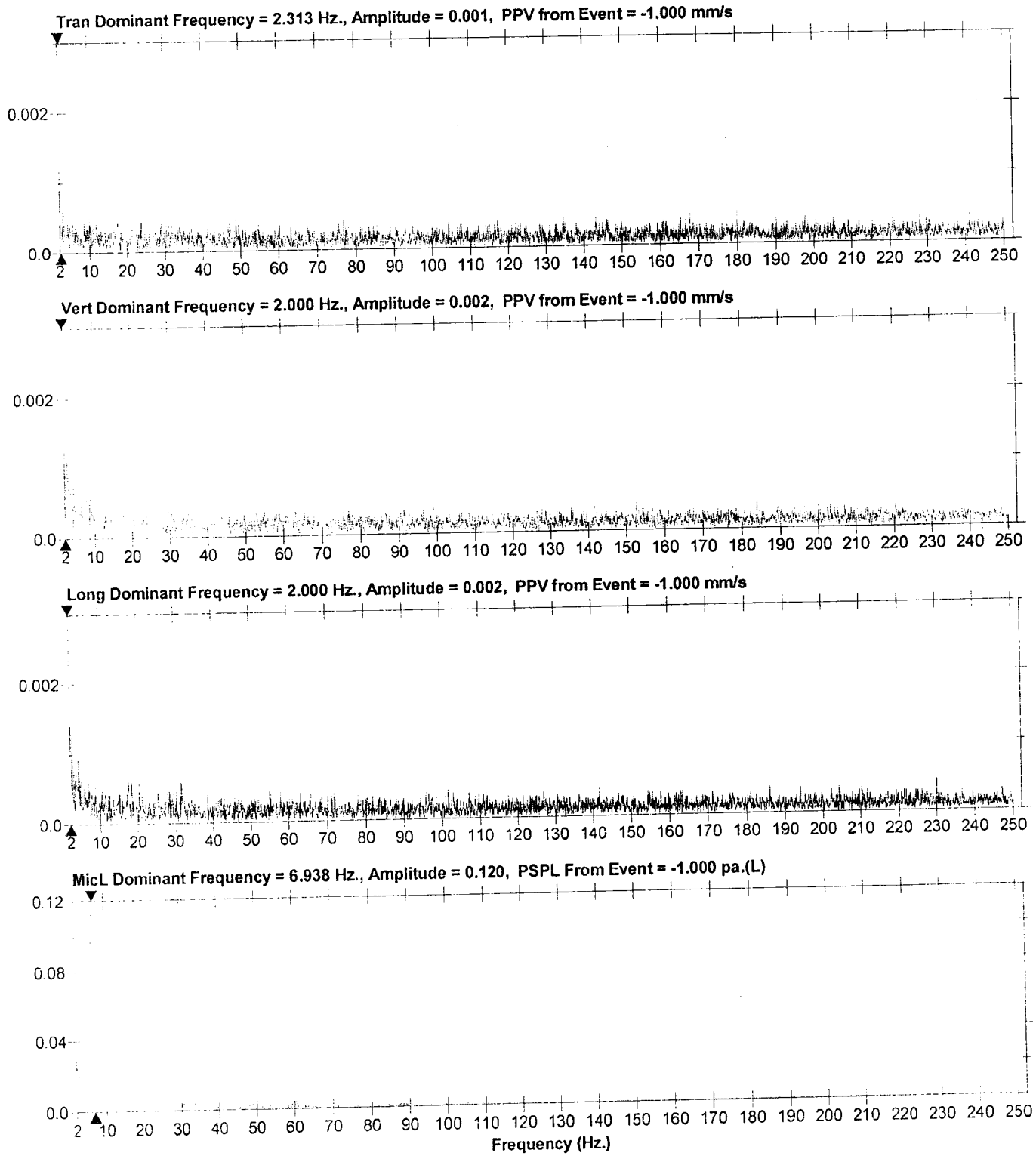
Serial Number	UM12452 V 10-89 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12452_20200204131133.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR, Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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FFT Report

Date/Time	MicL at 13:11:33 February 4, 2020
Trigger Source	Geo: 0.250 mm/s, Mic: 6.325 pa.(L)
Range	Geo: 254.0 mm/s
Record Time	10.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR BLSPR.mmb

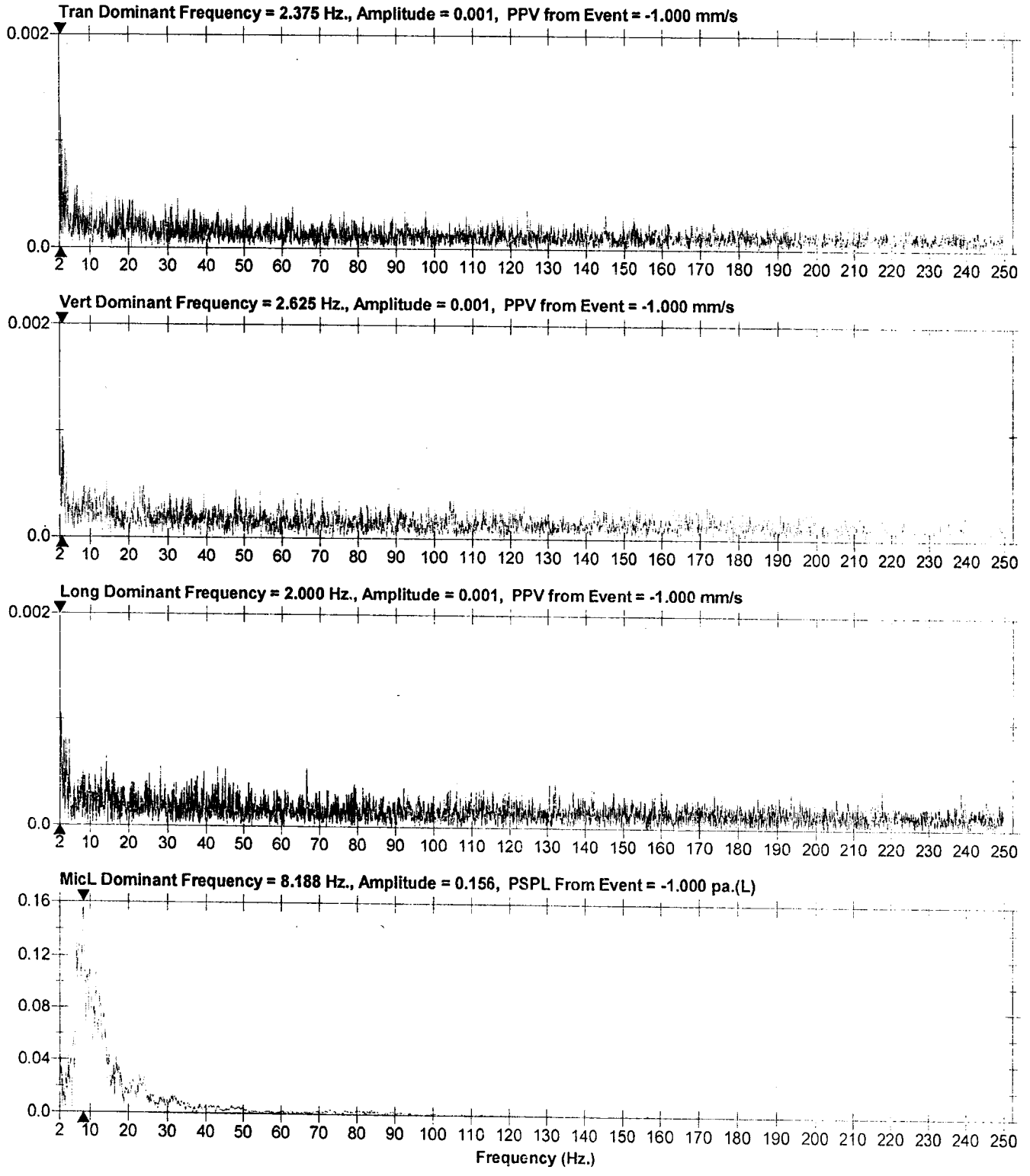
Serial Number	UM12744 V 10-86 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200204131133.IDFW

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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FFT Report

Date/Time	Long at 13:14:16 February 5, 2020
Trigger Source	Geo: 0.250 mm/s, Mic: 6.325 pa.(L)
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR BLSPR.mmb

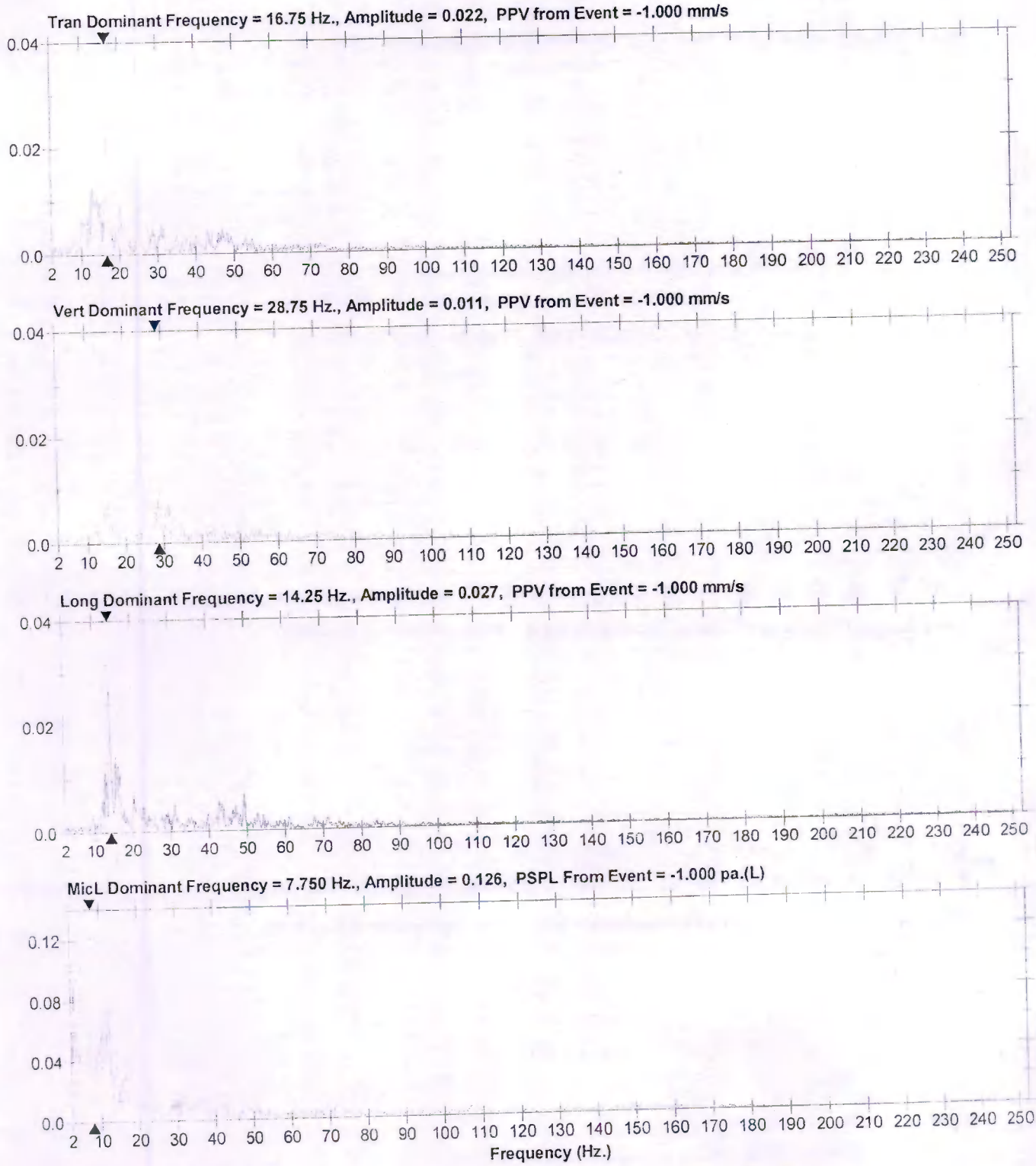
Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200205131416.IDFW

Notes

Location:	Pur Village
Client:	Dist. Collector,Bhilwara,Rajasthan Govt.
User Name:	CSIR-CIMFR,Bilaspur Research Centre
General:	

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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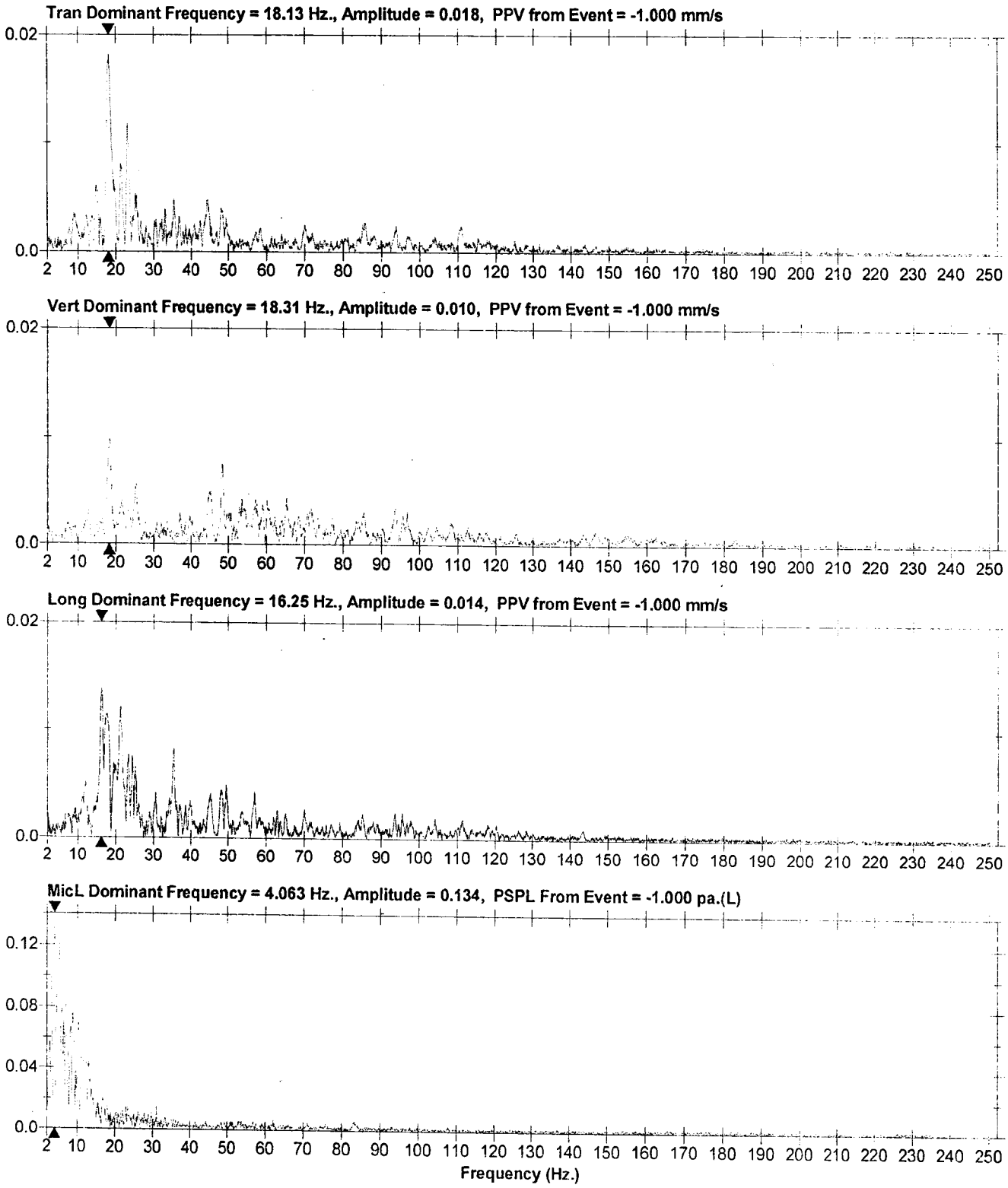
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FFT Report

Date/Time	Long at 13:15:06 February 5, 2020	**Serial Number**	BE16508 V 10.72-1.1 Minimate Blaster
Trigger Source	Geo: 0.510 mm/s, Mic: 6.325 pa.(L)	**Battery Level**	6.1 Volts
Range	Geo: 31.75 mm/s	**Unit Calibration**	January 13, 2020 by UES New Delhi
Record Time	10.0 sec at 4096 sps	**File Name**	R508IBE2.560

Notes
Location: Pur Village
Client: Dist. Collector, Rajasthan Govt.
User Name: CSIR-CIMFR, Bilaspur Research Centre
General:

Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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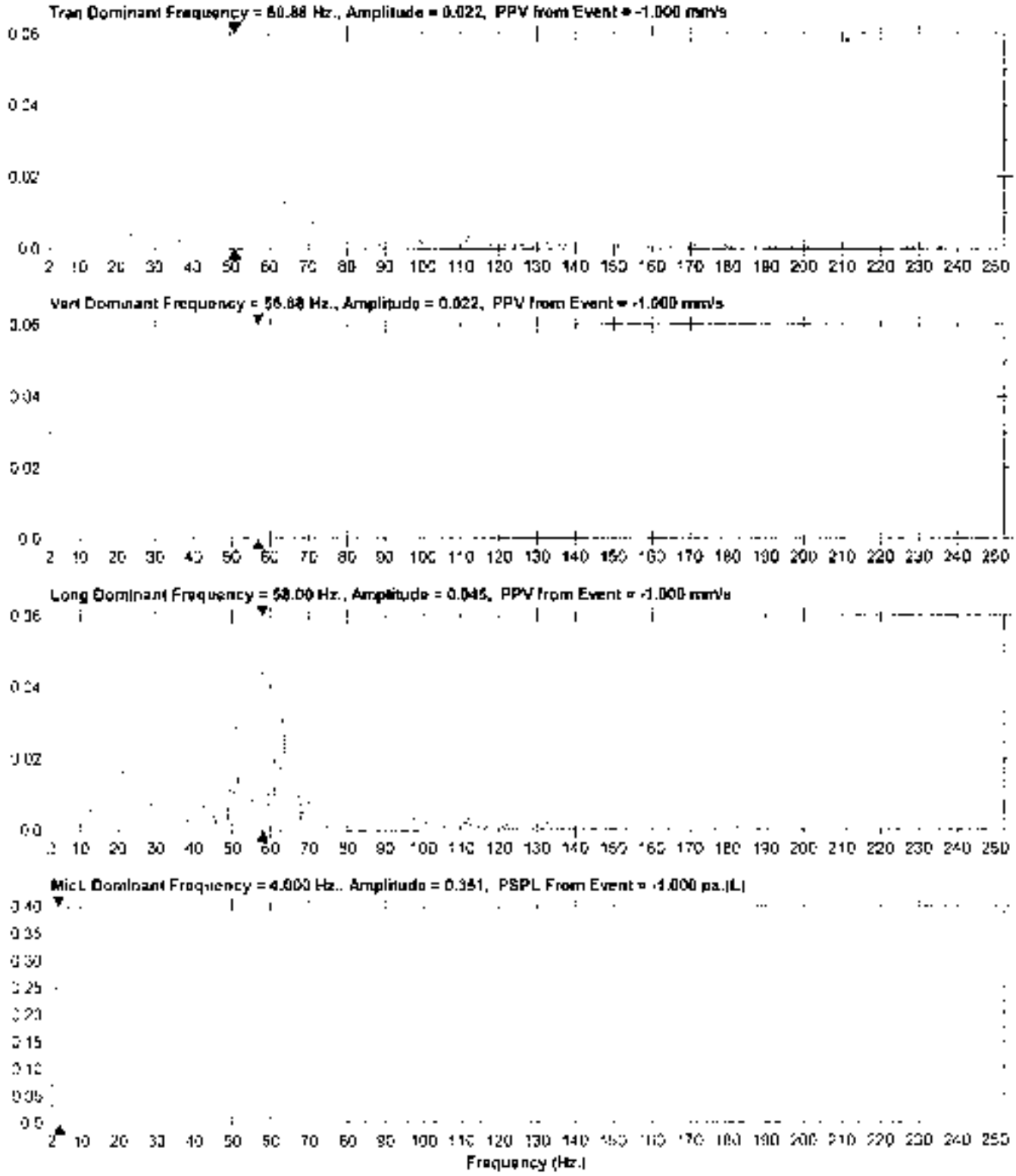
FFT Report

Date/Time	Trig'd at 13:15:14 February 5, 2020
Trigger Source	Geo: 0.510 mm/s
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps

Serial Number	BE13781 V.10.72-8.17 MiniMate Plus
Battery Level	6.2 Volts
Unit Calibration	January 13, 2020 by DES New Delhi
File Name	07811BE2.5EC

Notes
Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR, Bilaspur Research Centre
General:

Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village Bhilwara, Rajasthan, India.



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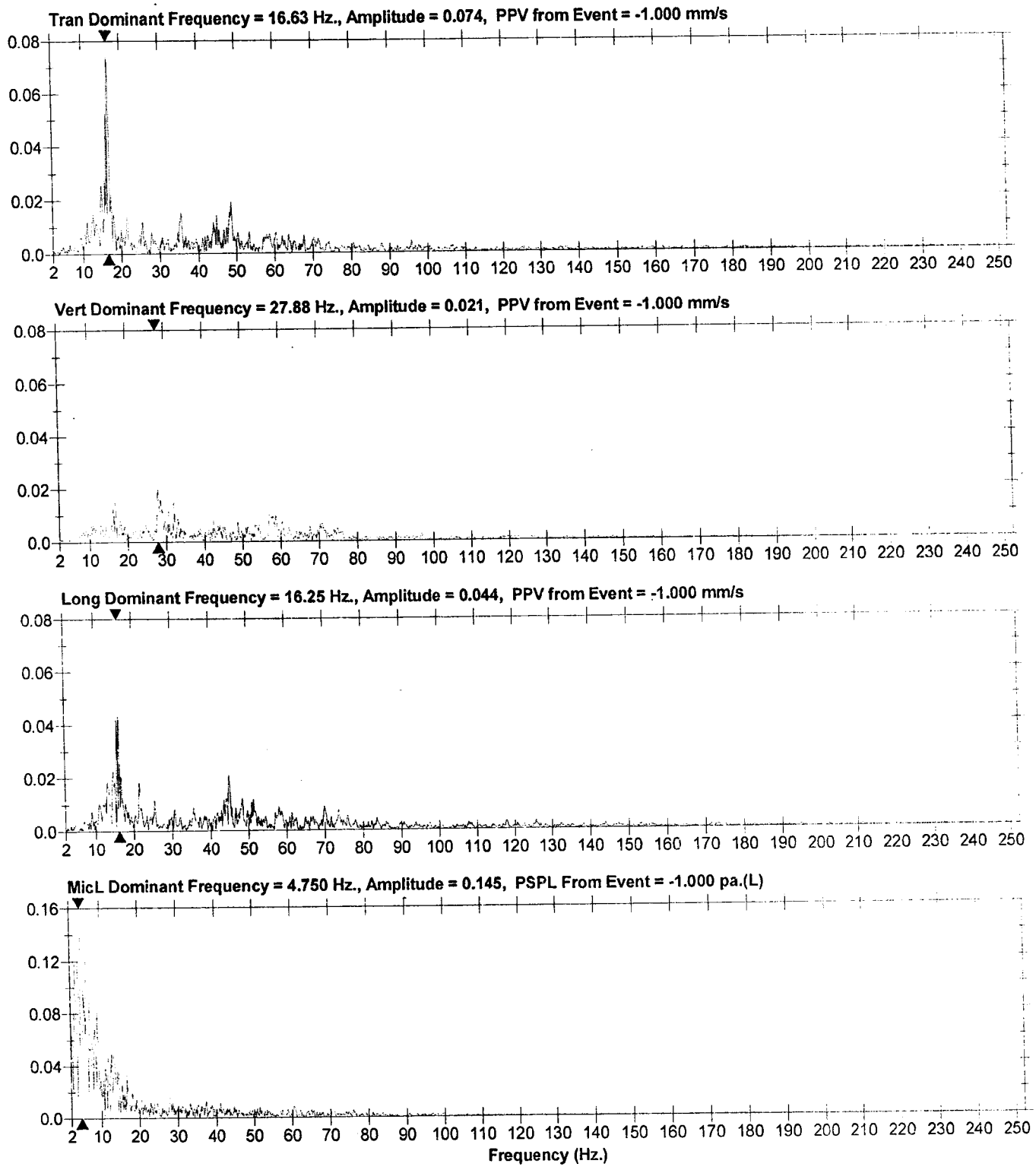
FFT Report

Date/Time	Long at 13:15:21 February 5, 2020
Trigger Source	Geo: 0.250 mm/s, Mic: 6.325 pa.(L)
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR BLSPR.mmb

Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200205131521.IDFW

Notes
Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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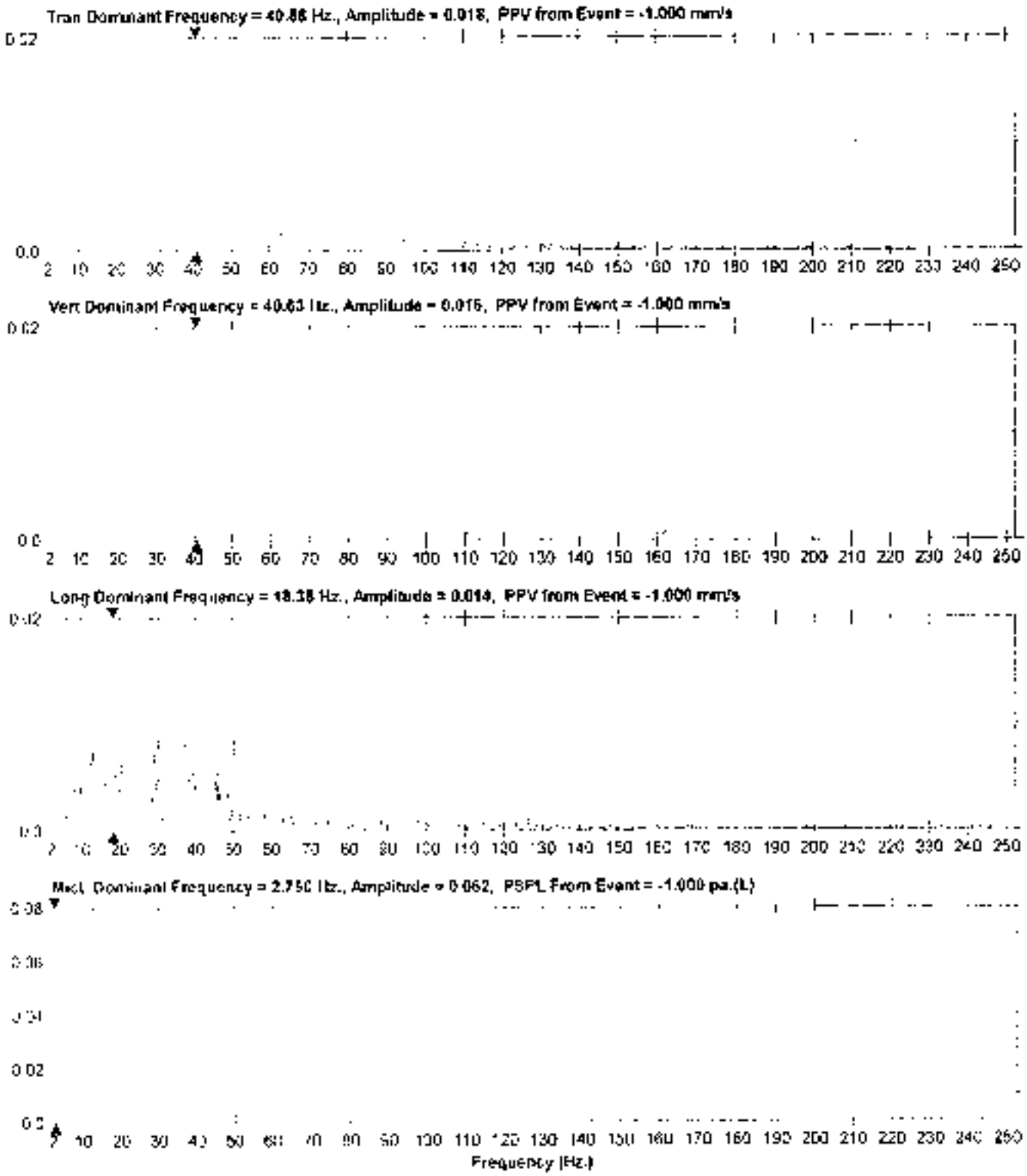
FFT Report

Date/Time	Tran at: 13:12:02 February 6, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR_BLSPR.mnb

Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200206131202.IDFW

Notes
Location: Pur Village
Client: Dist. Collector Bhilwara,Rajasthan Govt
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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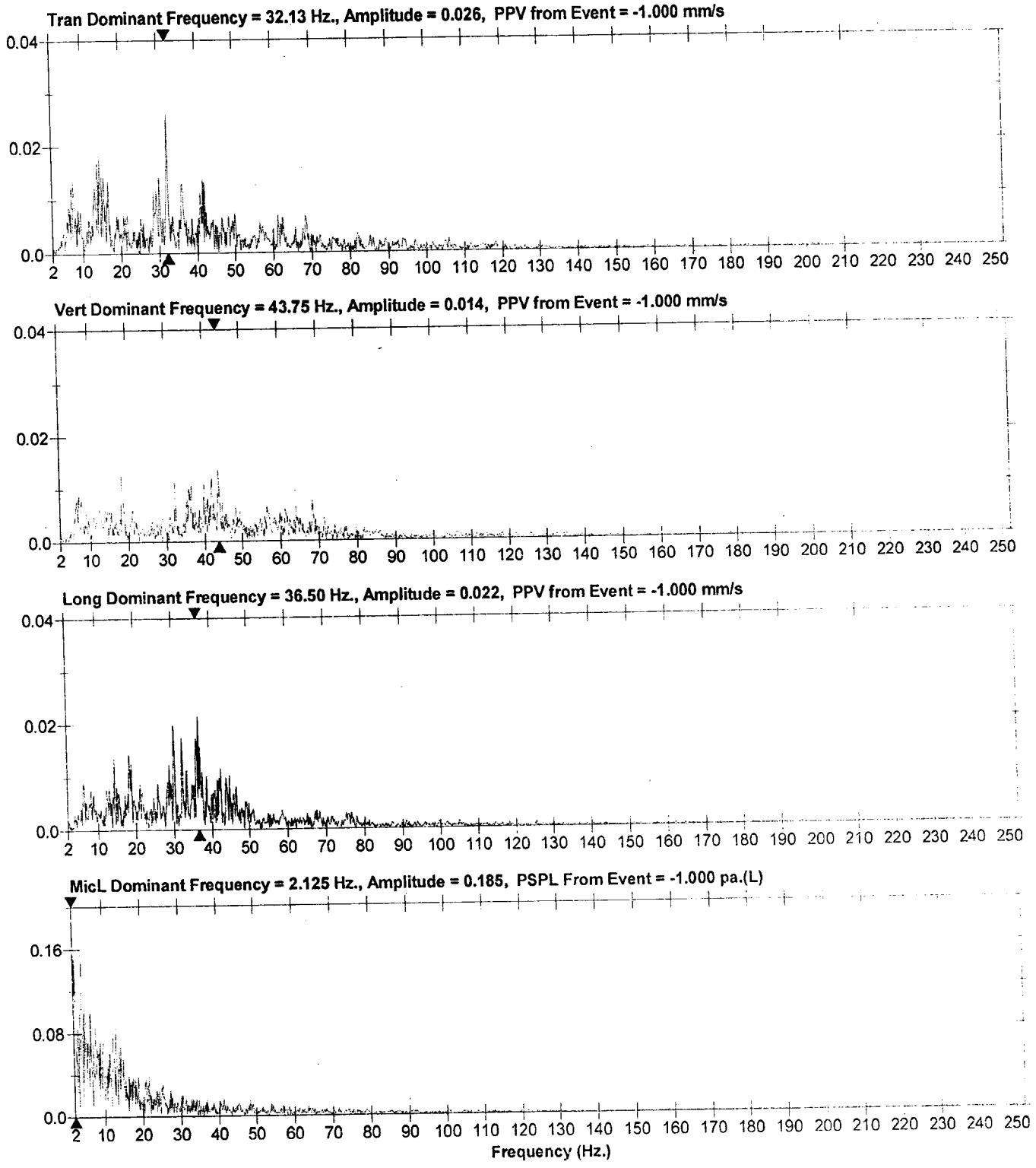
FFT Report

Date/Time	Tran at 13:14:30 February 6, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR BLSPR.mmb

Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200206131430.IDFW

Notes
Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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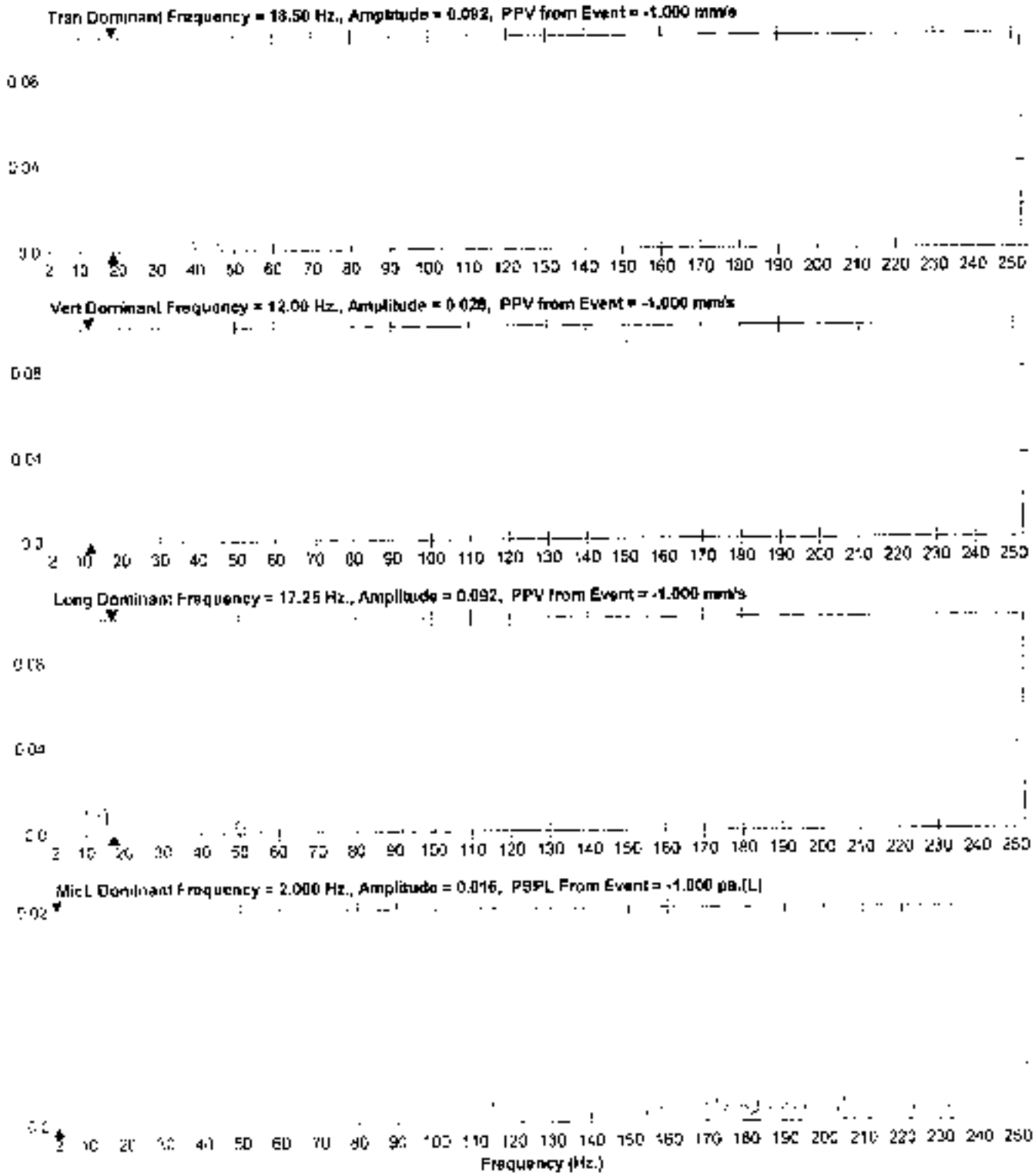
FFT Report

Date/Time	Long at 13:29:26 March 3, 2020
Trigger Source	Geo: 0.500 mm/s
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps
Job Number	1

Serial Number	BE18062 V 10.72-1.1 Minimate Blaster
Battery Level	6.2 Volts
Unit Calibration	March 29, 2019 by UES, New Delhi
File Name	T0S2ICS2.T2D

Notes
Location: Pur Village
Client: District collector Bhilwara, Rajasthan
User Name: CIMFR
General:

Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration & Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan.



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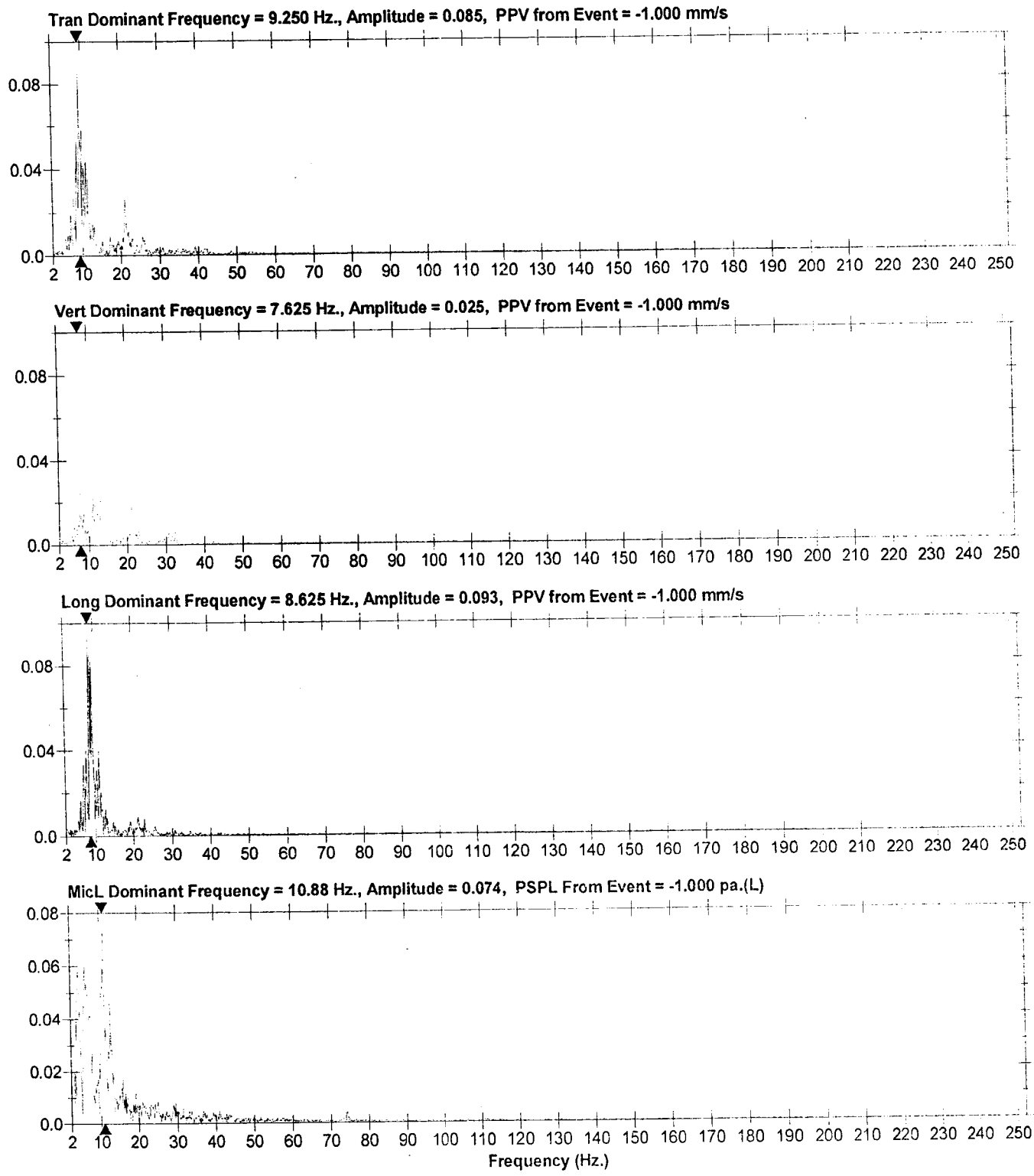
FFT Report

Date/Time	Long at 13:29:26 March 3, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

Serial Number	UM12452 V 10-89 Micromate ISEE
Battery Level	3.7 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12452_20200303132926.IDFW

Notes
Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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FFT Report

Date/Time	Long at 13:18:28 March 4, 2020
Trigger Source	Geo: 0.500 mm/s, Mic: 6.325 pa.(L)
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps

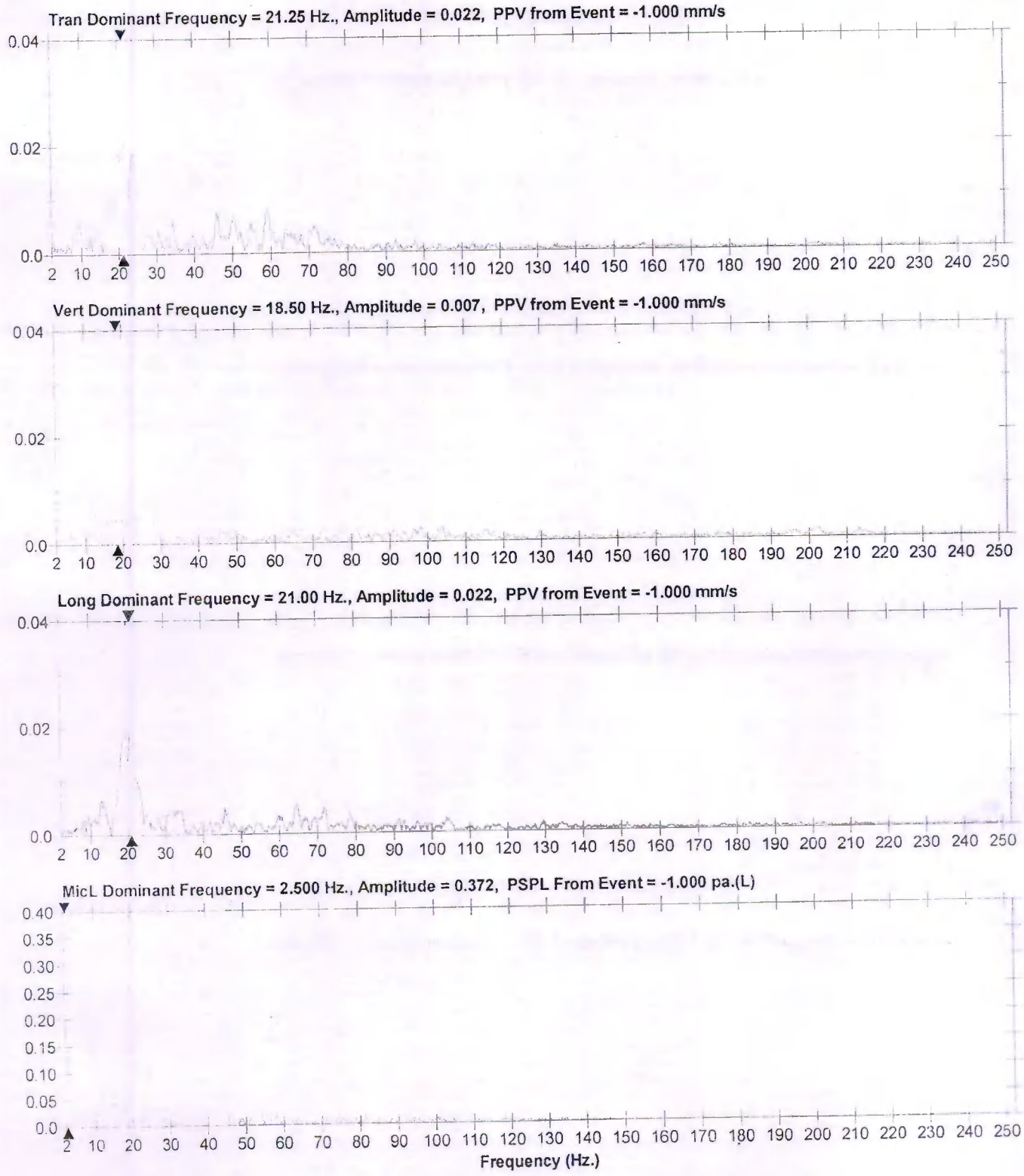
Serial Number	BE16508 V 10.72-1.1 Minimate Blaster
Battery Level	6.2 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	R508ICTW.YS0

Notes

Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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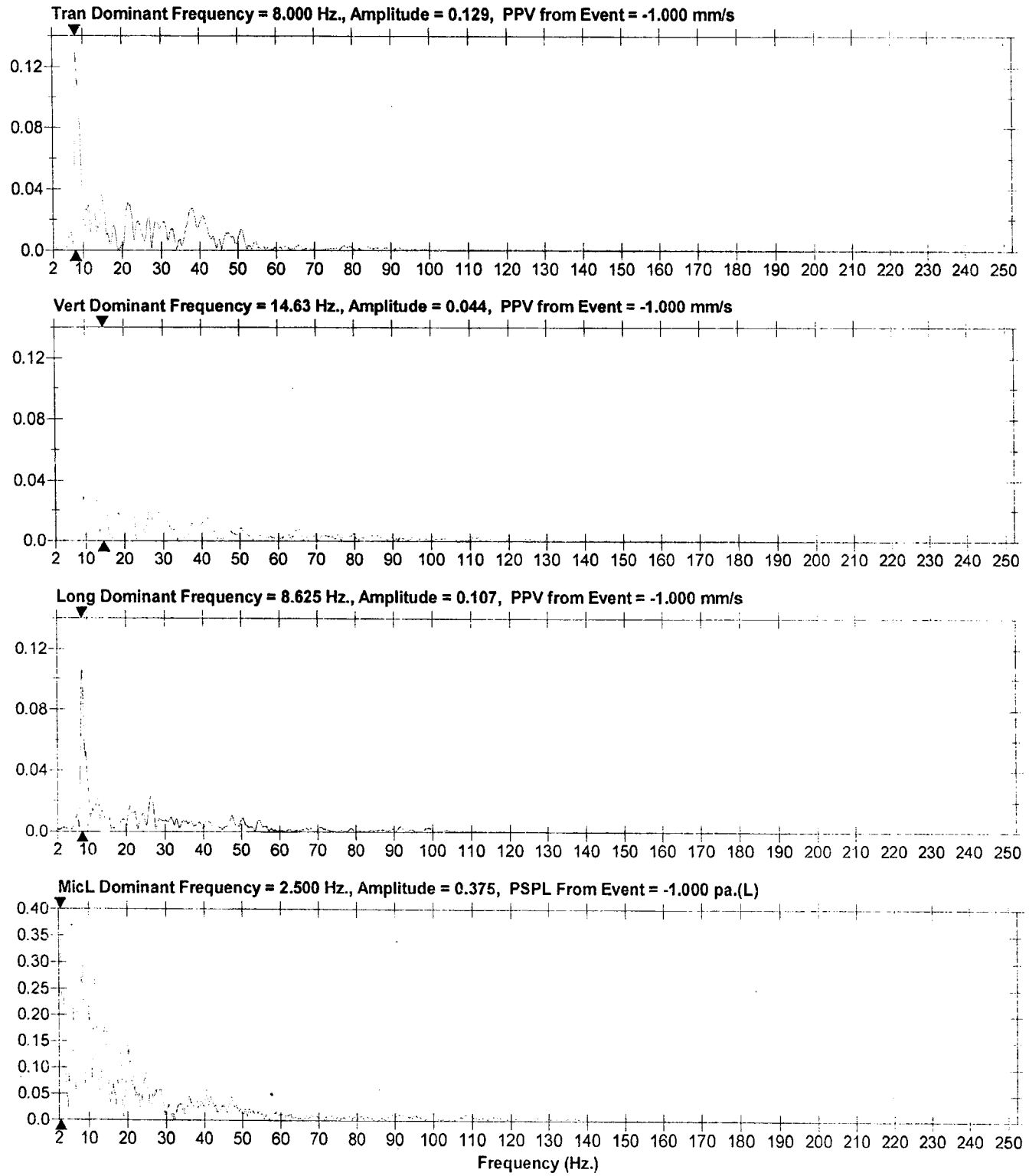
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FFT Report

Date/Time	Long at 13:18:45 March 4, 2020	**Serial Number**	UM12744 V 10-88 Micromate ISEE
Trigger Source	Geo: 0.250 mm/s	**Battery Level**	3.8 Volts
Range	Geo: 254.0 mm/s	**Unit Calibration**	January 13, 2020 by UES New Delhi
Record Time	5.0 sec at 4096 sps	**File Name**	UM12744_20200304131845.IDFW
Operator/Setup:	Operator/CIMFR Bilaspur.mmb		

Notes
Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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FFT Report

Date/Time	Vert at 13:18:46 March 4, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

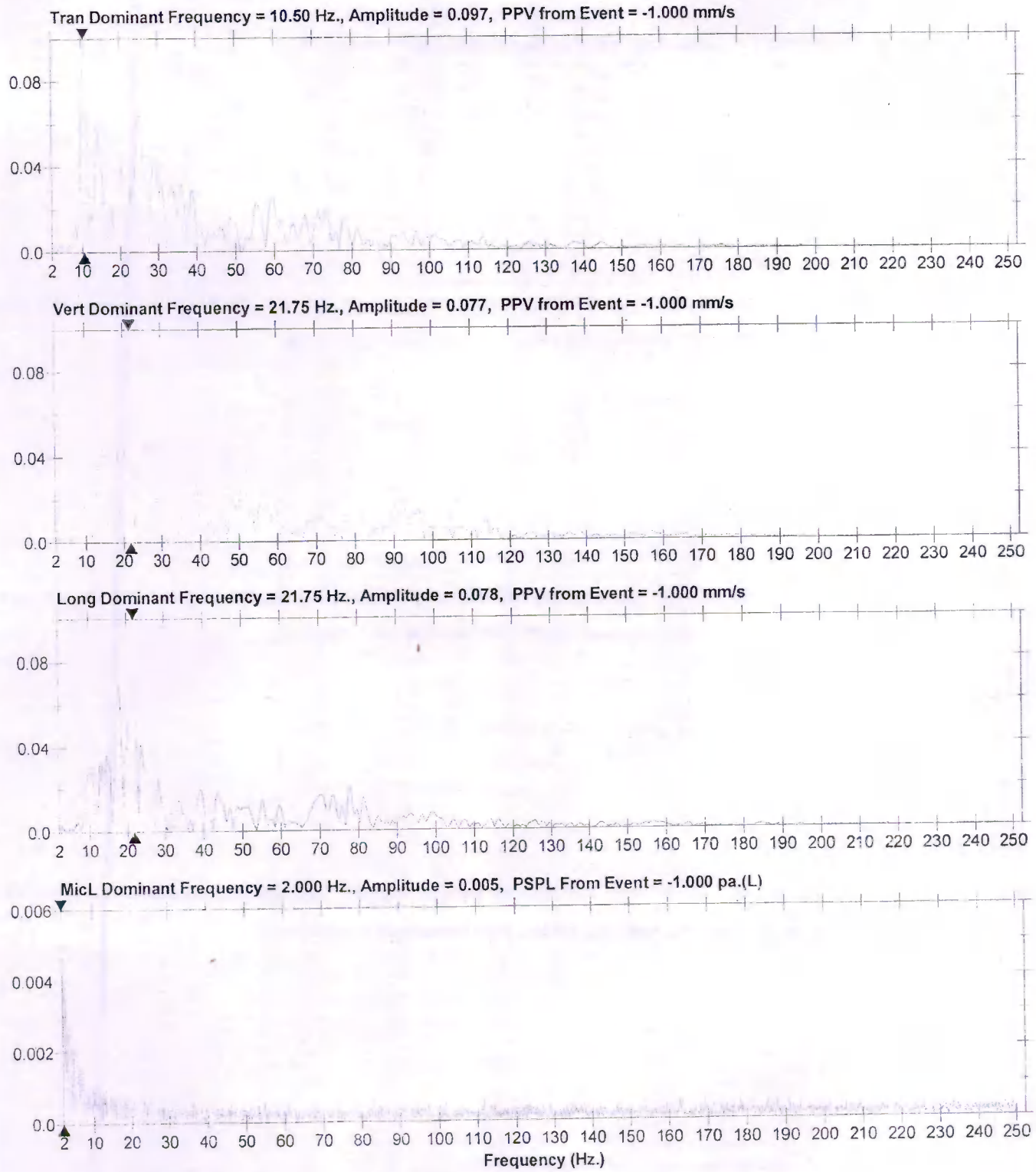
Notes

Location:	Pur Village
Client:	Dist. Collector,Bhilwara,Rajasthan Govt.
User Name:	CSIR-CIMFR,Bilaspur Research Centre
General:	

Serial Number	UM12452 V 10-89 Micromate ISEE
Battery Level	3.7 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12452_20200304131846.IDFW

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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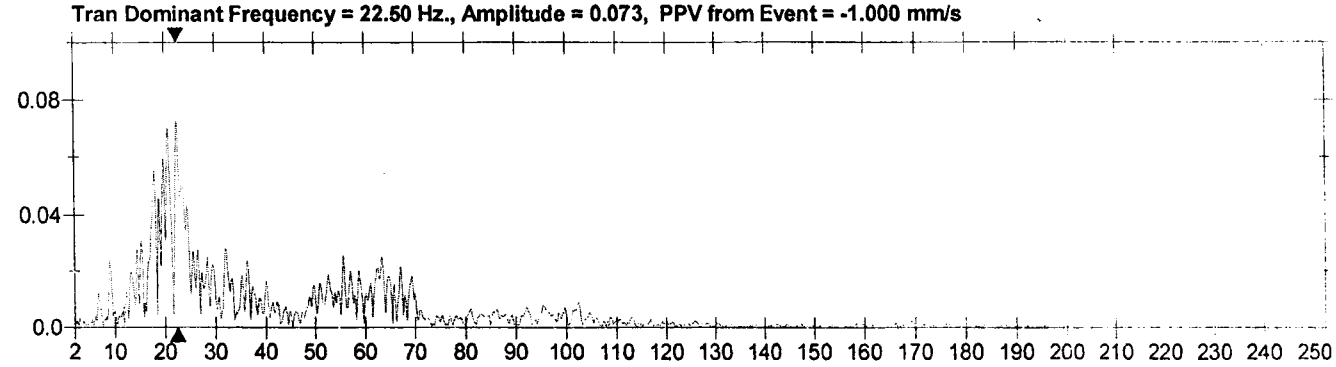
FFT Report

Date/Time	Tran at 13:20:44 March 4, 2020	**Serial Number**	BE16508 V 10.72-1.1 Minimate Blaster
Trigger Source	Geo: 0.500 mm/s, Mic: 6.325 pa.(L)	**Battery Level**	6.2 Volts
Range	Geo: 31.75 mm/s	**Unit Calibration**	January 13, 2020 by UES New Delhi
Record Time	5.0 sec at 4096 sps	**File Name**	R508ICTX.2K0

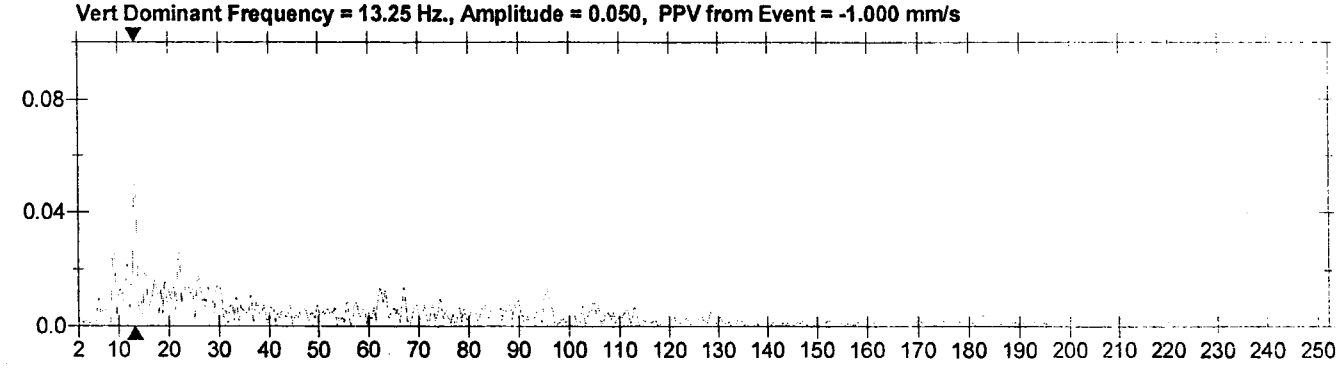
Notes
Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

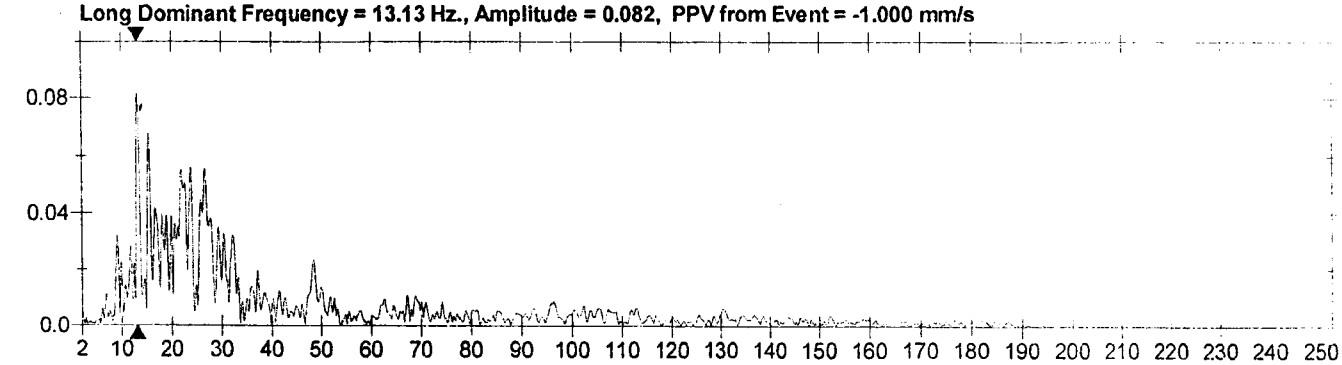
Tran Dominant Frequency = 22.50 Hz., Amplitude = 0.073, PPV from Event = -1.000 mm/s



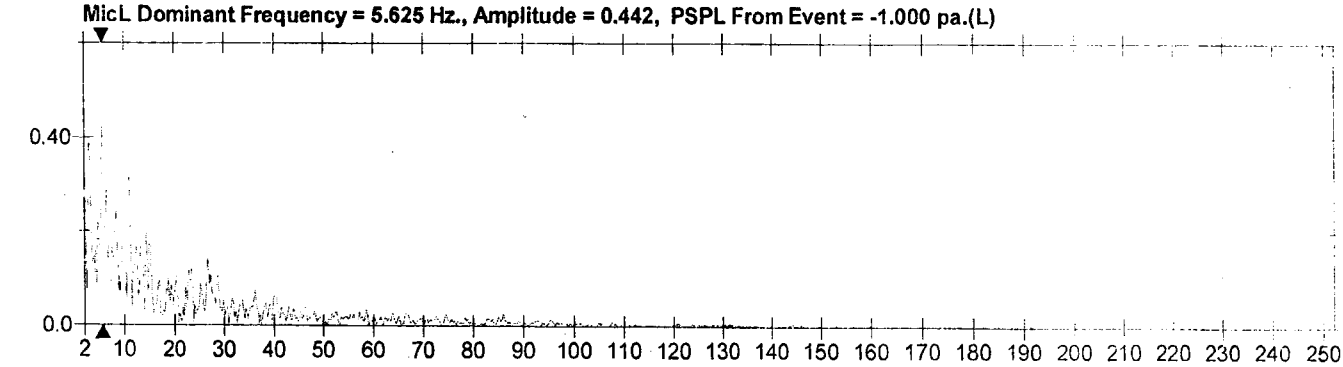
Vert Dominant Frequency = 13.25 Hz., Amplitude = 0.050, PPV from Event = -1.000 mm/s



Long Dominant Frequency = 13.13 Hz., Amplitude = 0.082, PPV from Event = -1.000 mm/s



MicL Dominant Frequency = 5.625 Hz., Amplitude = 0.442, PSPL From Event = -1.000 pa.(L)



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FFT Report

Date/Time	Vert at 13:21:02 March 4, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200304132102.IDFW

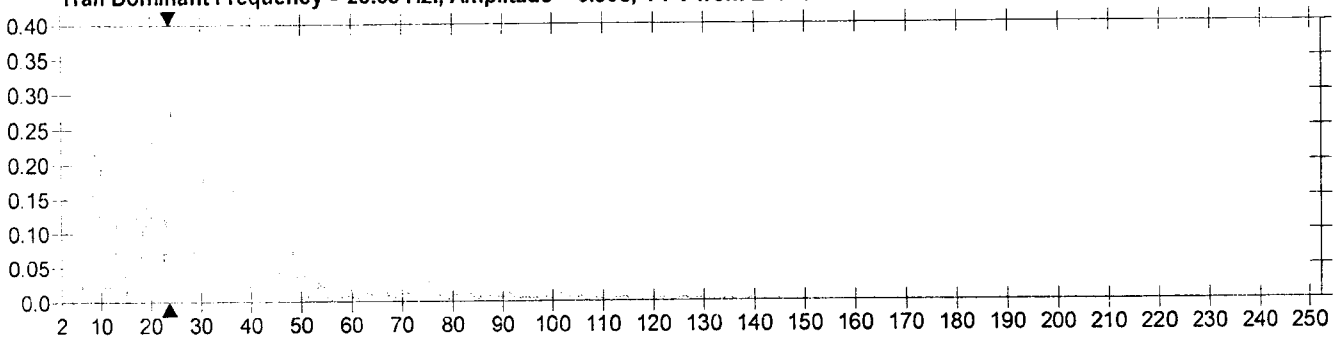
Notes

Location:	Pur Village
Client:	Dist. Collector,Bhilwara,Rajasthan Govt.
User Name:	CSIR-CIMFR,Bilaspur Research Centre
Generai:	

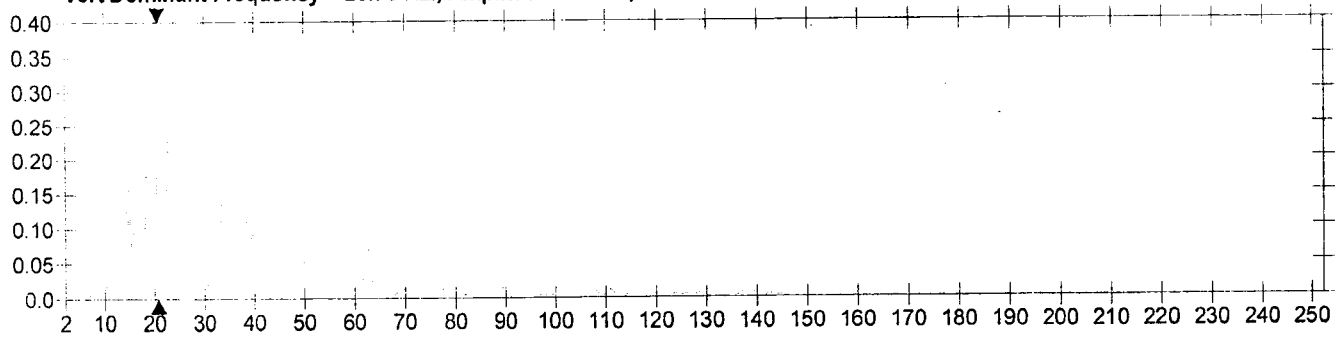
Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

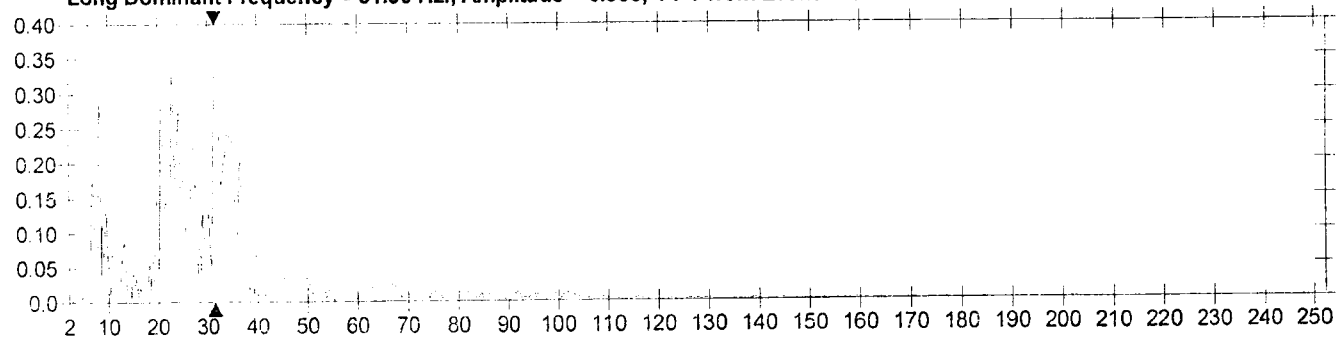
Tran Dominant Frequency = 23.63 Hz., Amplitude = 0.365, PPV from Event = -1.000 mm/s



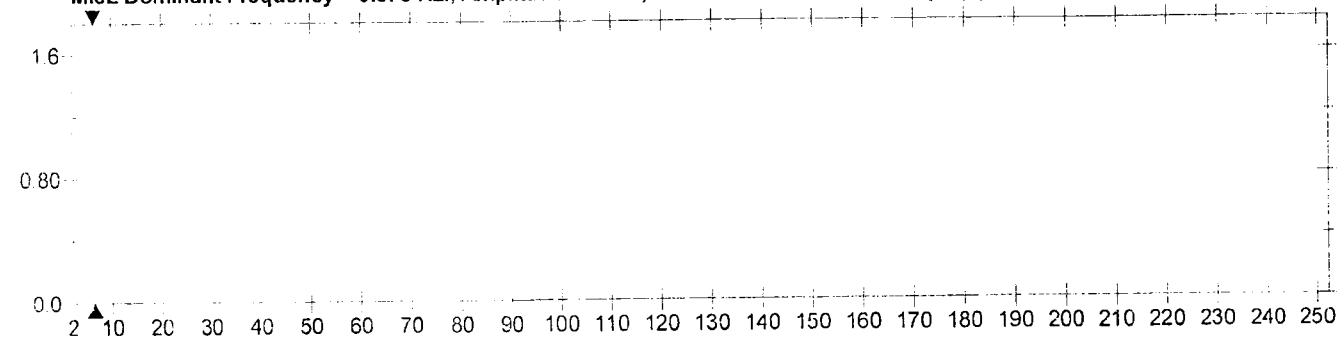
Vert Dominant Frequency = 20.75 Hz., Amplitude = 0.291, PPV from Event = -1.000 mm/s



Long Dominant Frequency = 31.50 Hz., Amplitude = 0.338, PPV from Event = -1.000 mm/s



MicL Dominant Frequency = 6.375 Hz., Amplitude = 1.586, PSPL From Event = -1.000 pa.(L)



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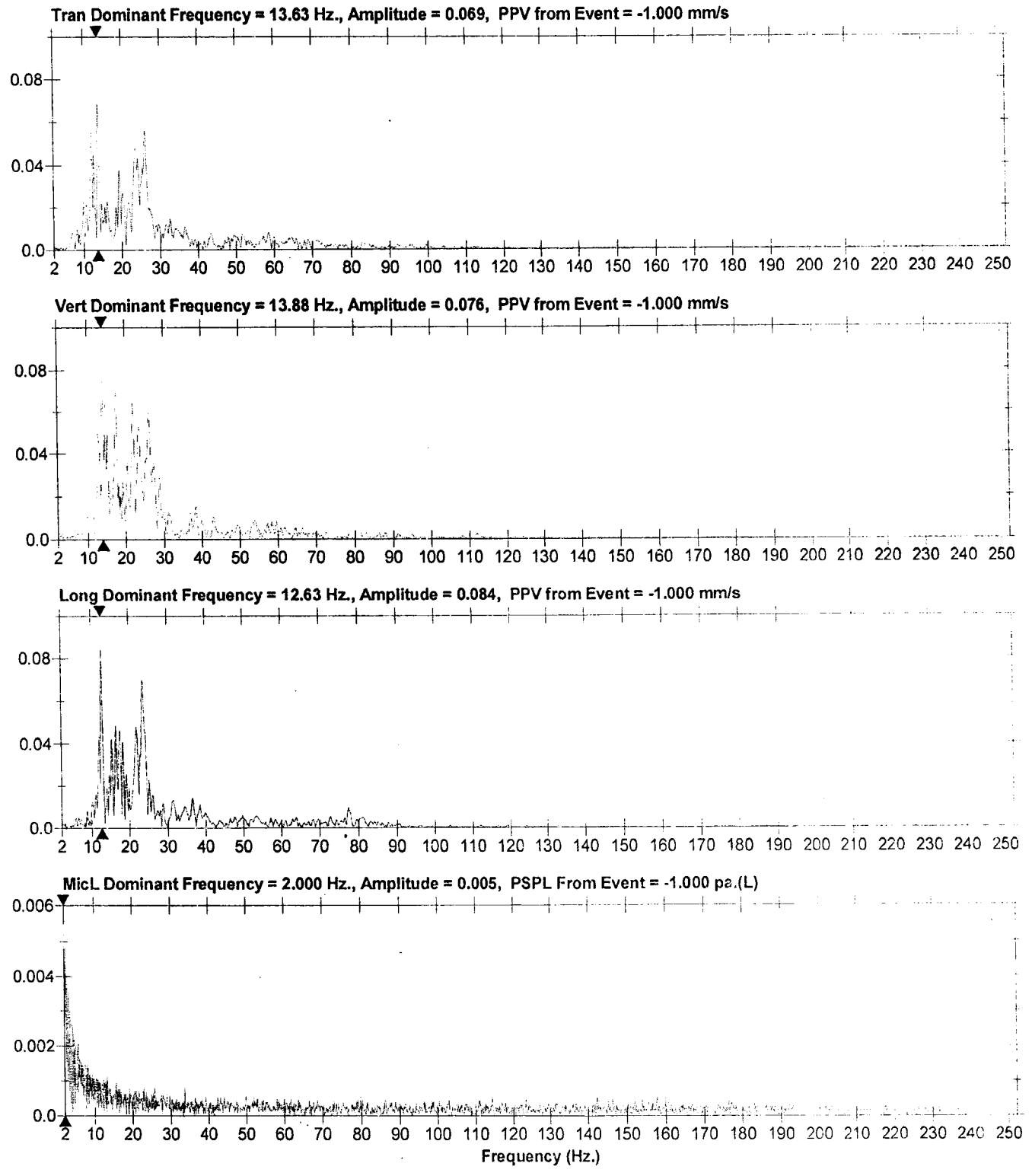
FFT Report

Date/Time	Vert at 13:21:03 March 4, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

Serial Number	UM12452 V 10-89 Micromate ISEE
Battery Level	3.7 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12452_20200304132103.IDFW

Notes
Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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FFT Report

Date/Time	Tran at 13:17:59 March 5, 2020
Trigger Source	Geo: 0.500 mm/s, Mic: 6.325 pa.(L)
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps

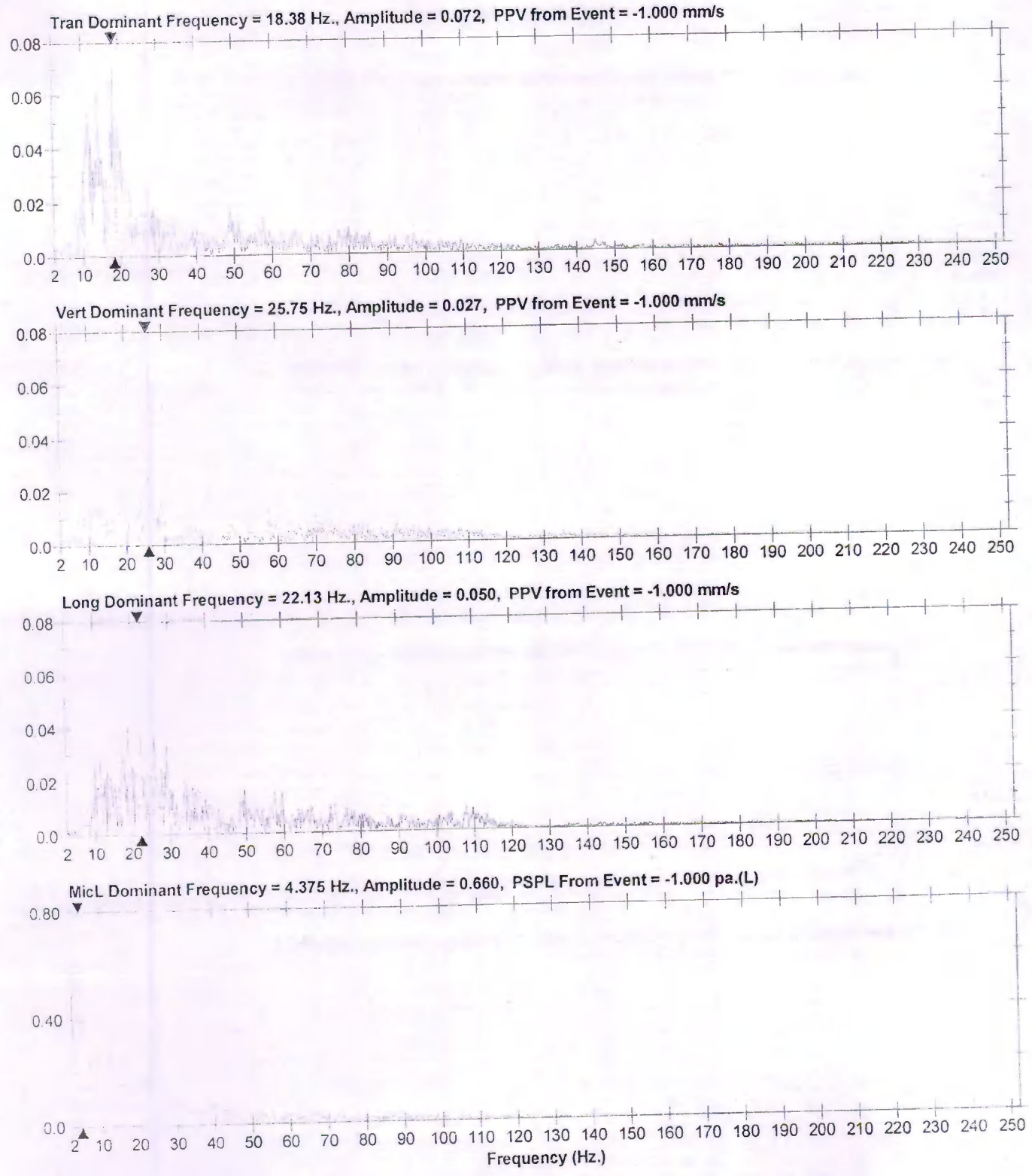
Notes

Location:	Pur Village
Client:	Dist. Collector,Bhilwara,Rajasthan Govt.
User Name:	CSIR-CIMFR,Bilaspur Research Centre
General:	

Serial Number	BE16508 V 10.72-1.1 Minimate Blaster
Battery Level	6.3 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	R508ICVR.LZ0

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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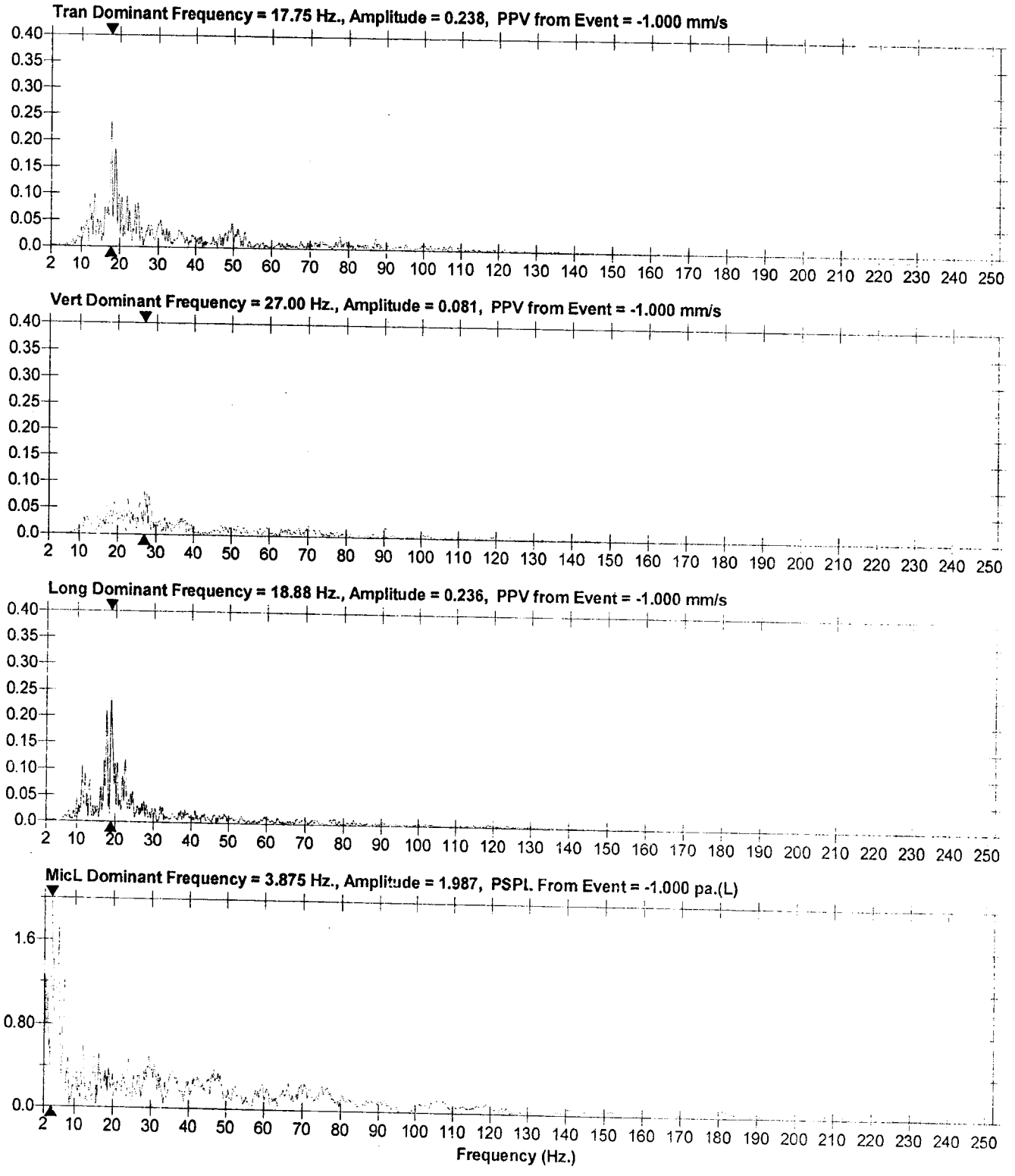
FFT Report

Date/Time	Long at 13:18:19 March 5, 2020
Trigger Source	Geo: 0.500 mm/s
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps
Job Number:	1

Serial Number	BE18062 V 10.72-1.1 Minimate Blaster
Battery Level	6.1 Volts
Unit Calibration	March 29, 2019 by UES, New Delhi
File Name	T062iCVR.MJ0

Notes
Location: Pur Village
Client: District collector Bhilwara, Rajasthan
User Name: CIMFR
General:

Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration & Airover Pressure in Domestic Houses inPur Village, Bhilwara, Rajasthan.



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FFT Report

Date/Time	Vert at 13:18:23 March 5, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

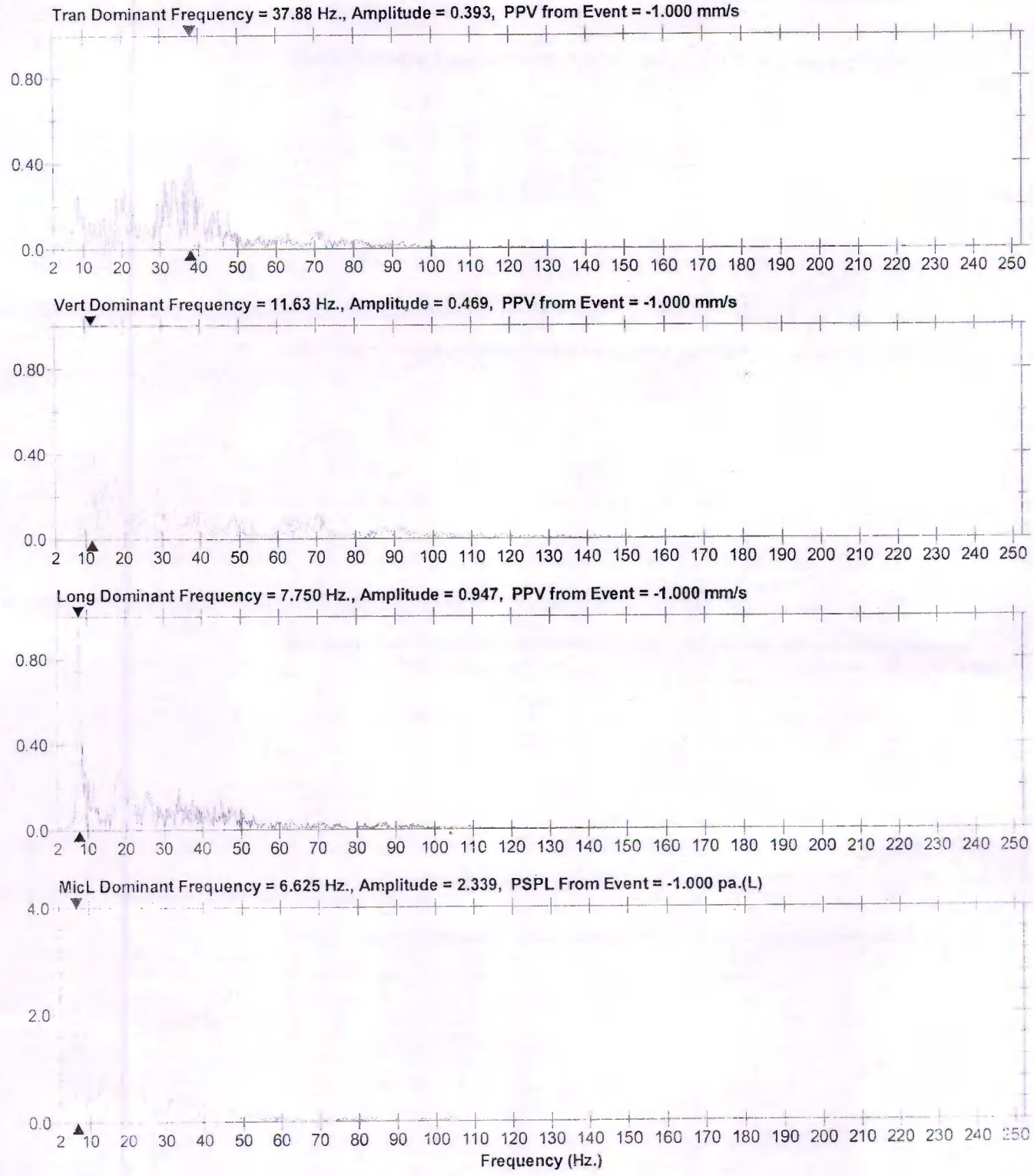
Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200305131823.IDFW

Notes

Location:	Pur Village
Client:	Dist. Collector,Bhilwara,Rajasthan Govt.
User Name:	CSIR-CIMFR,Bilaspur Research Centre
General:	

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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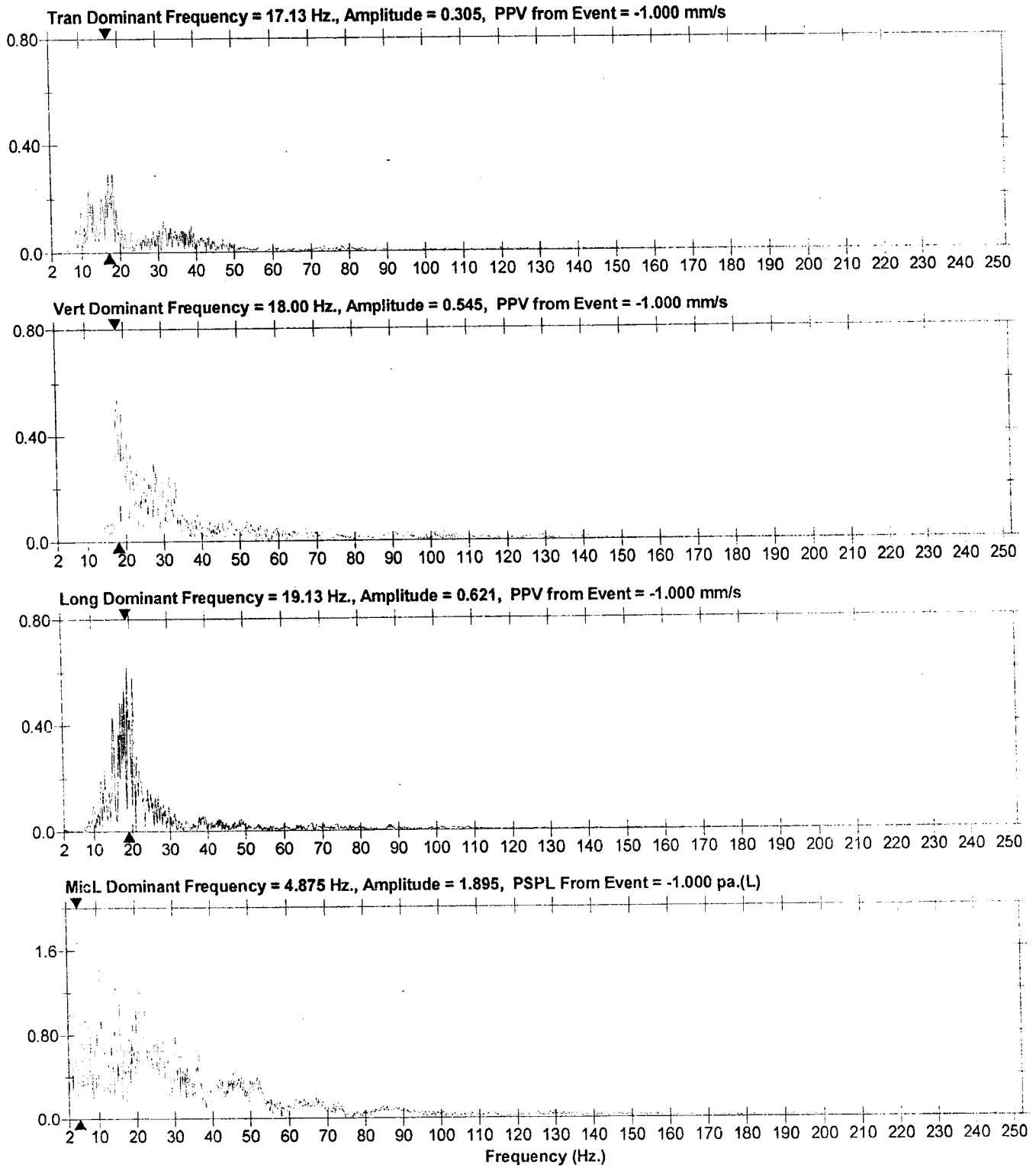
FFT Report

Date/Time	Vert at 13:18:24 March 5, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

Serial Number	UM12452 V 10-89 Micromate ISEE
Battery Level	3.7 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12452_20200305131824.IDFW

Notes
Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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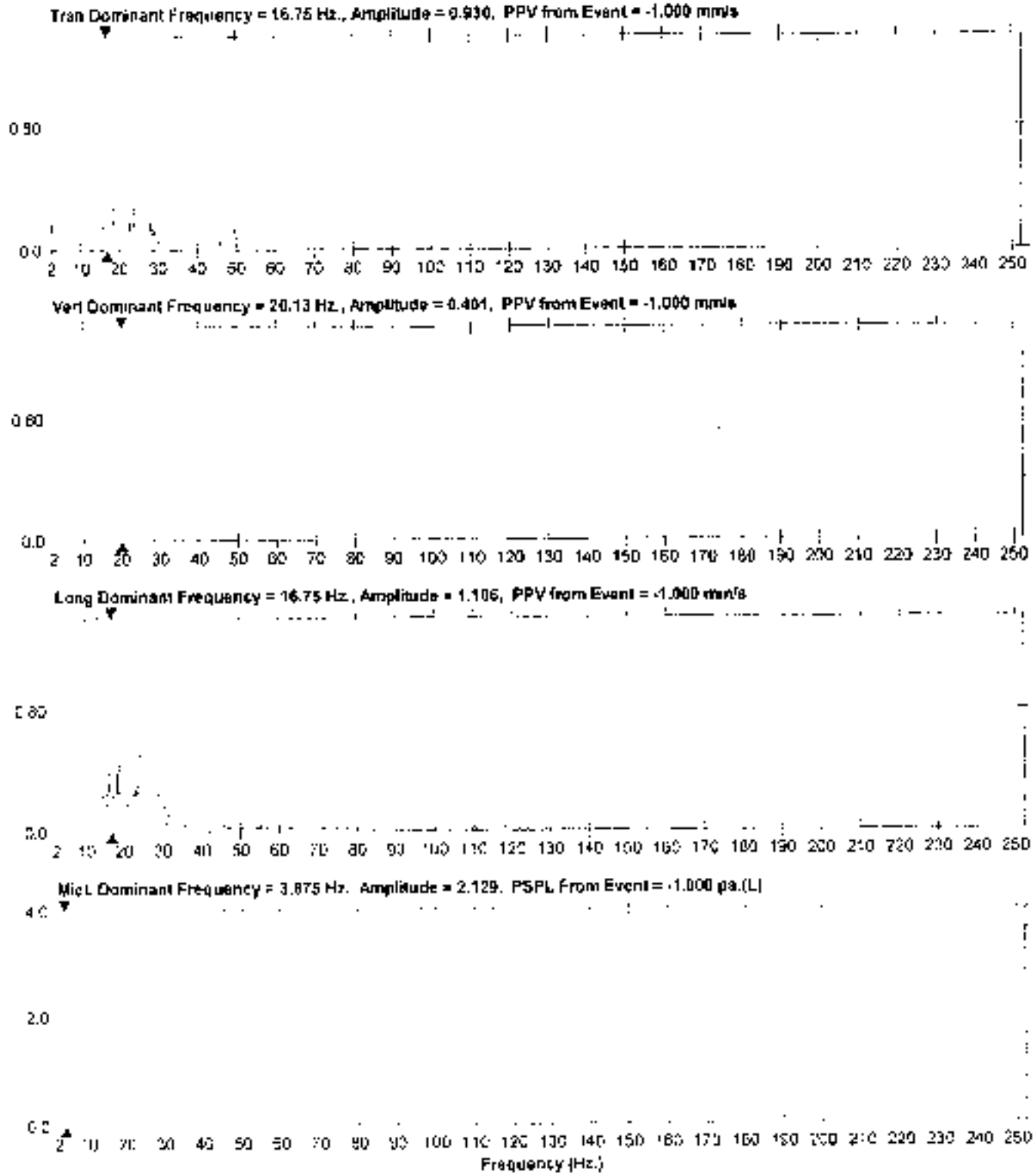
FFT Report

Date/Time	Long at 13:16:32 March 6, 2020
Trigger Source	Geo: 0.500 mm/s
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps
Job Number:	1

Serial Number	BE18062 V 10.72-1 + Minimate Blaste
Battery Level	6.9 Volts
Unit Calibration	March 29, 2019 by USS, New Delhi
File Name	T062ICXM.7K0

Notes
Location: Pur Village
Client: Distt Collector Bhilwara, Rajasthan
User Name: CIMFR
General:

Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration & Airover Pressure in Domestic Houses inPur Village, Bhilwara, Rajasthan.



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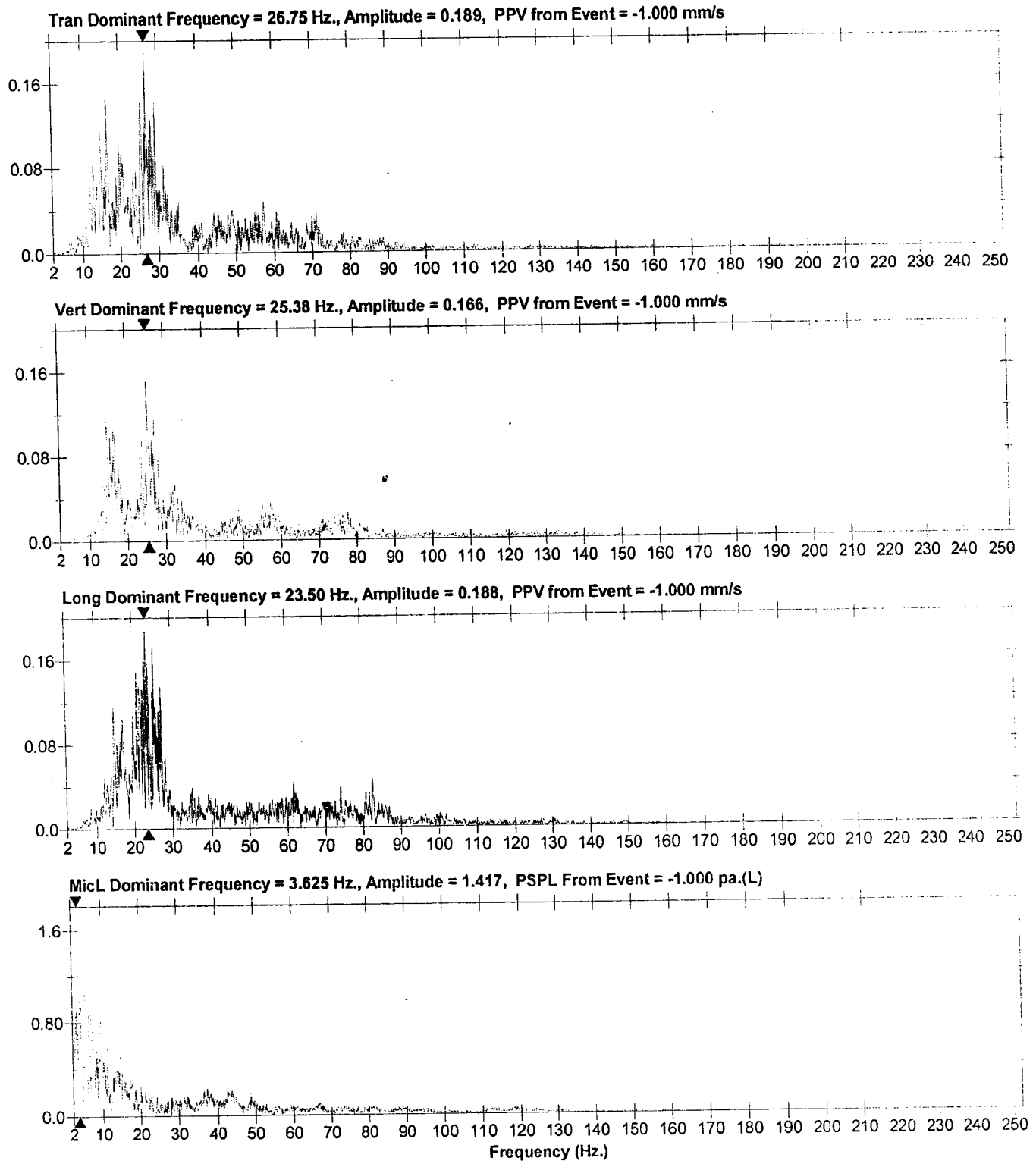
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Date/Time	Long at 13:16:42 March 6, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	3.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200306131642.IDFW

Notes
Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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FFT Report

Date/Time	Tran at 13:16:43 March 6, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator/CIMFR Bilaspur.mmb

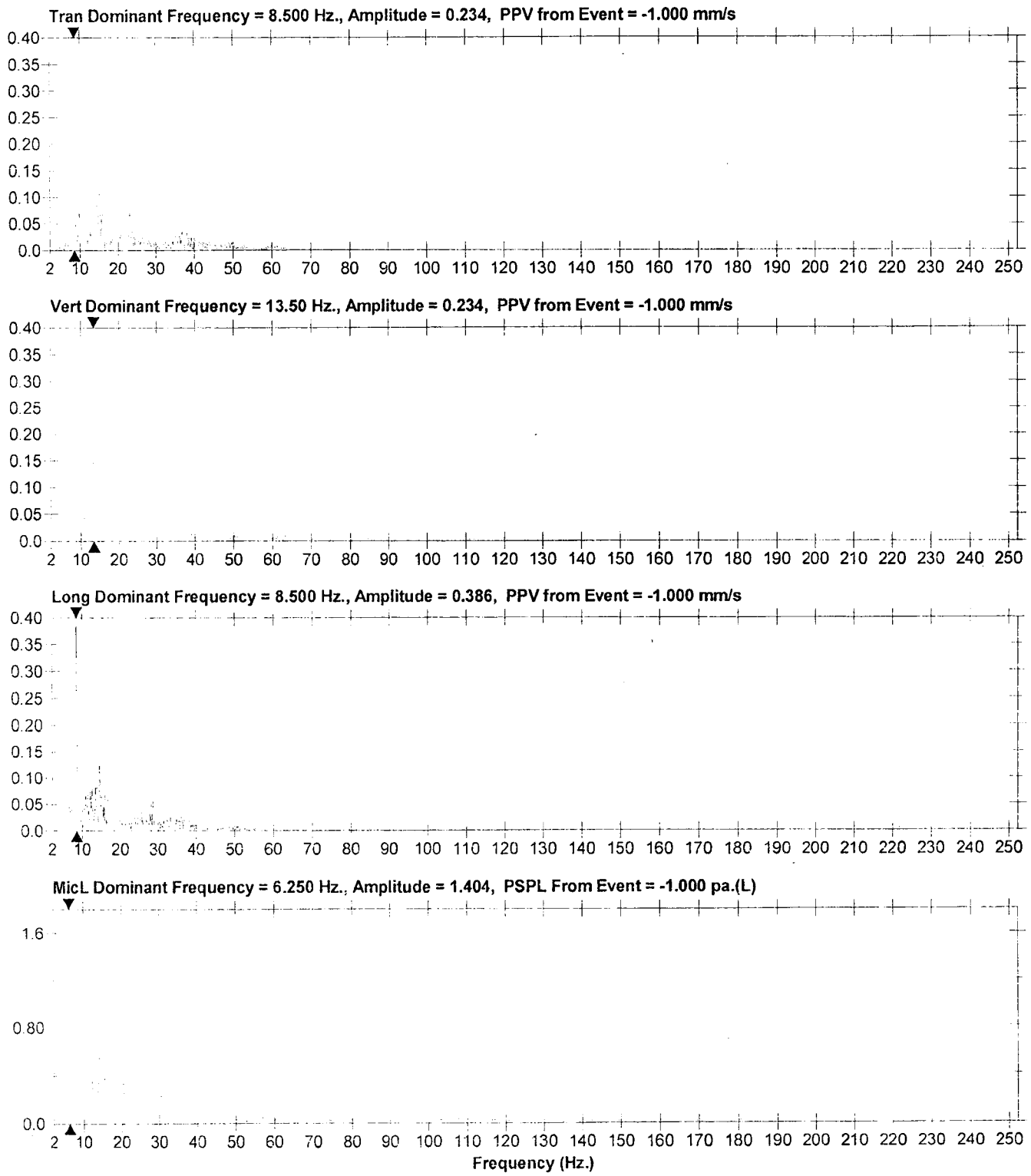
Serial Number	UM12452 V 10-89 Micromate ISEE
Battery Level	3.7 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12452_20200306131643.IDFW

Notes

Location:	Pur Village
Client:	Dist. Collector,Bhilwara,Rajasthan Govt.
User Name:	CSIR-CIMFR,Bilaspur Research Centre
General:	

Extended Notes

Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.



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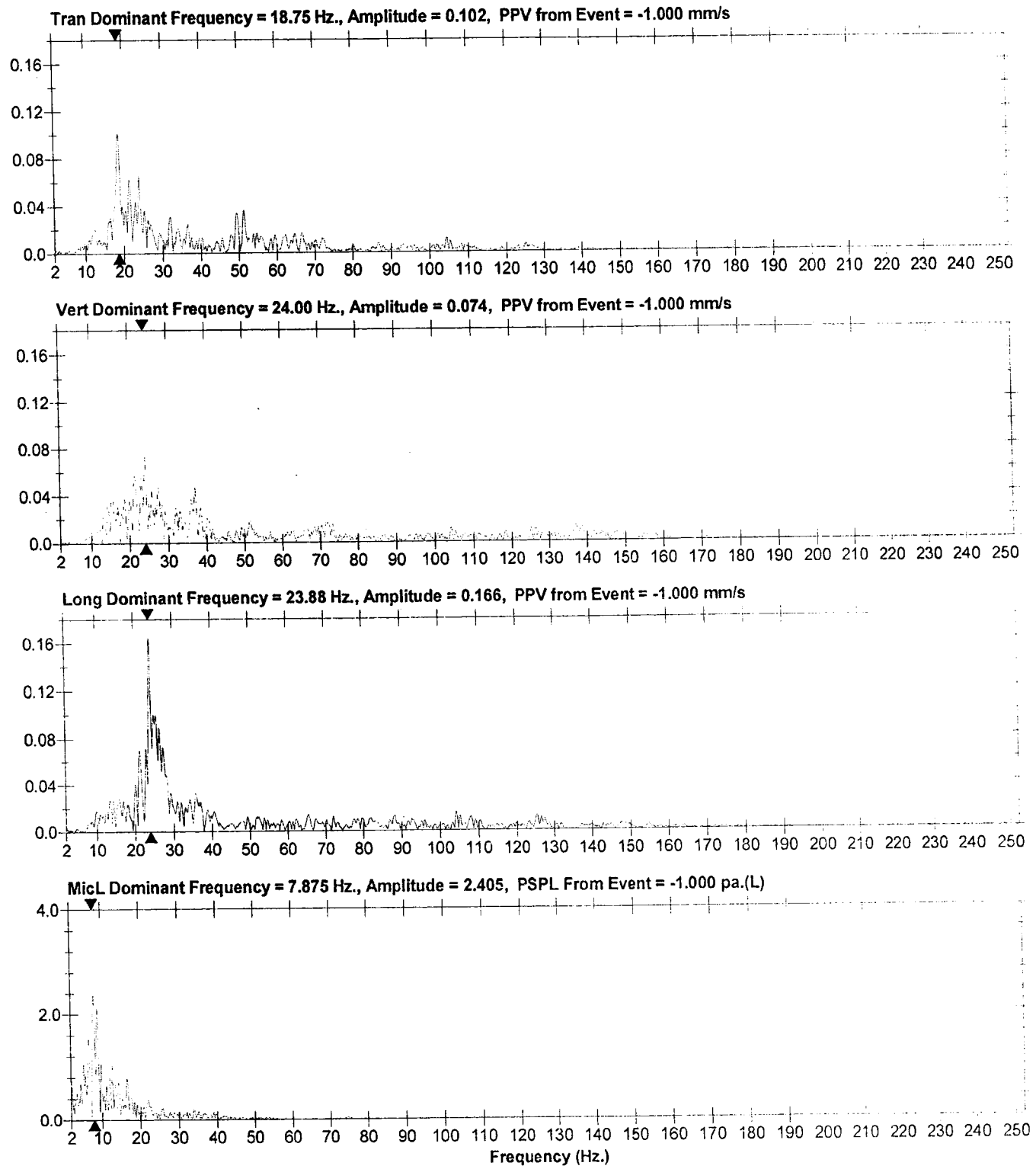
FFT Report

Date/Time	Long at 13:24:10 March 6, 2020
Trigger Source	Geo: 0.500 mm/s
Range	Geo: 31.75 mm/s
Record Time	5.0 sec at 4096 sps
Job Number:	1

Serial Number	BE18062 V 10.72-1.1 Minimate Blaster
Battery Level	6.0 Volts
Unit Calibration	March 29, 2019 by UES, New Delhi
File Name	T062ICXM.KA0

Notes
Location: Pur Village
Client: District collector Bhilwara, Rajasthan
User Name: CIMFR
General:

Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration & Airover Pressure in Domestic Houses inPur Village, Bhilwara, Rajasthan.



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FFT Report

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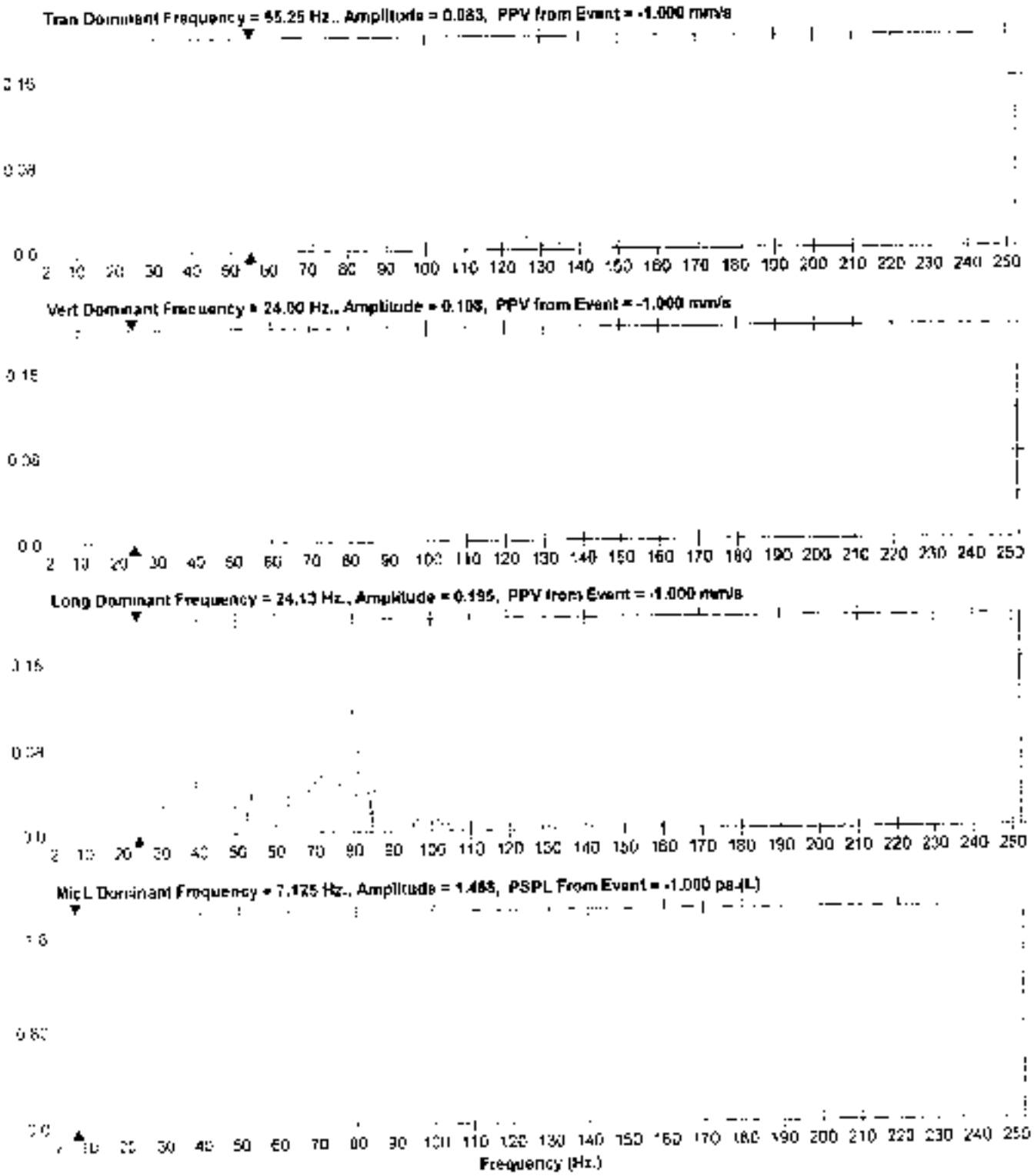
Date/Time	Vert at 13:24:20 March 6, 2020
Trigger Source	Geo: 0.250 mm/s
Range	Geo: 254.0 mm/s
Record Time	5.0 sec at 4096 sps
Operator/Setup:	Operator:CIMFR Bilaspur mmb

Serial Number	UM12744 V 10-88 Micromate ISEE
Battery Level	5.8 Volts
Unit Calibration	January 13, 2020 by UES New Delhi
File Name	UM12744_20200306132420.IDFW

Notes

Location	Pur Village
Client	Dist. Collector,Bhilwara,Rajasthan Govt
User Name	CSIR CIMFR Bilaspur Research Centre
General	

Extended Notes
Scientific investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village Bhilwara, Rajasthan, India



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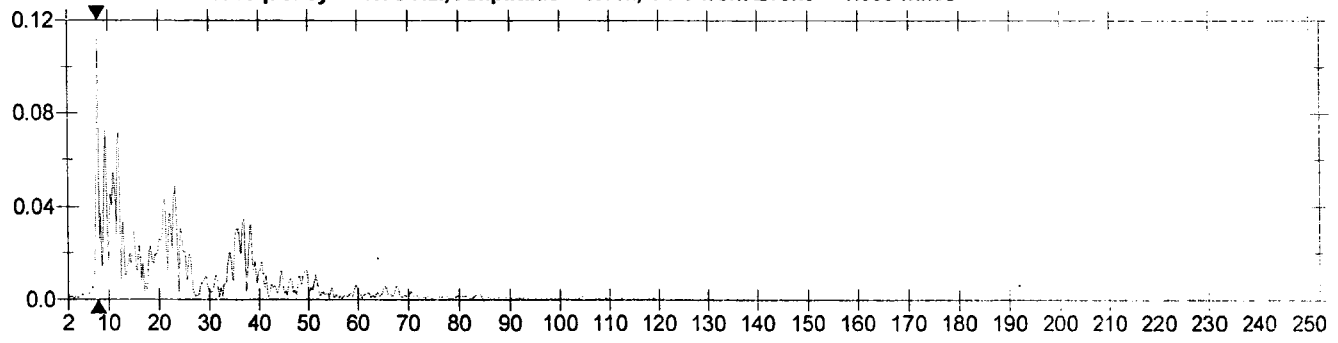
FFT Report

Date/Time	Tran at 13:24:21 March 6, 2020	**Serial Number**	UM12452 V 10-89 Micromate ISEE
Trigger Source	Geo: 0.250 mm/s	**Battery Level**	3.7 Volts
Range	Geo: 254.0 mm/s	**Unit Calibration**	January 13, 2020 by UES New Delhi
Record Time	5.0 sec at 4096 sps	**File Name**	UM12452_20200306132421.IDFW
Operator/Setup:	Operator/CIMFR Bilaspur.mmb		

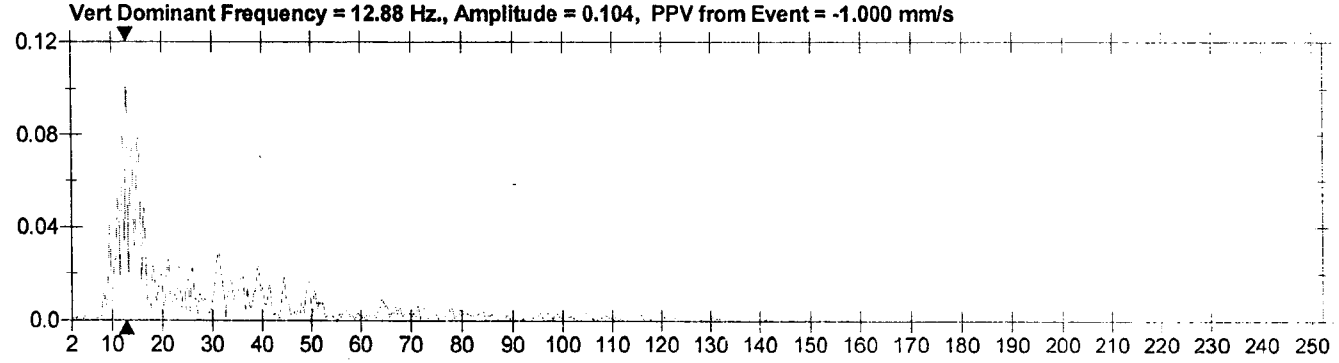
Notes
Location: Pur Village
Client: Dist. Collector,Bhilwara,Rajasthan Govt.
User Name: CSIR-CIMFR,Bilaspur Research Centre
General:

Extended Notes
Scientific Investigation of Damage Potential Due to Blast Induced Ground Vibration and Airover Pressure in Domestic Houses in Pur Village, Bhilwara, Rajasthan, India.

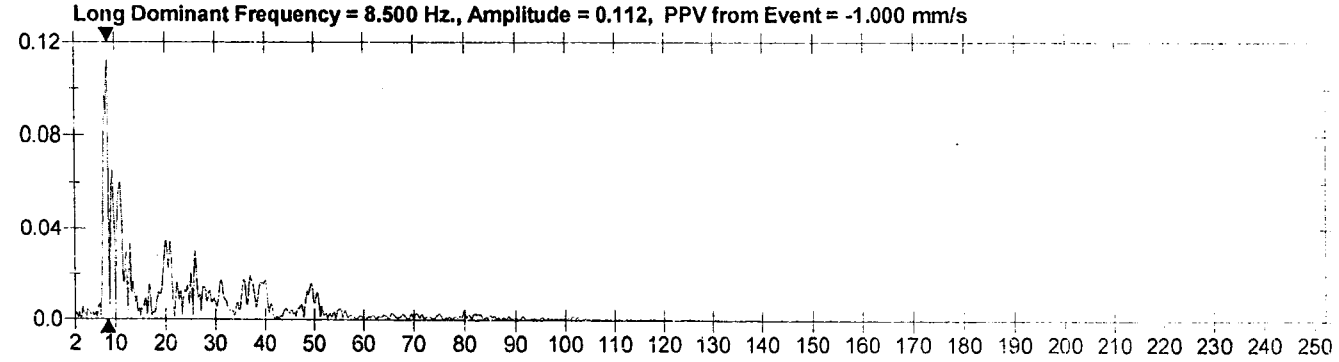
Tran Dominant Frequency = 7.875 Hz., Amplitude = 0.112, PPV from Event = -1.000 mm/s



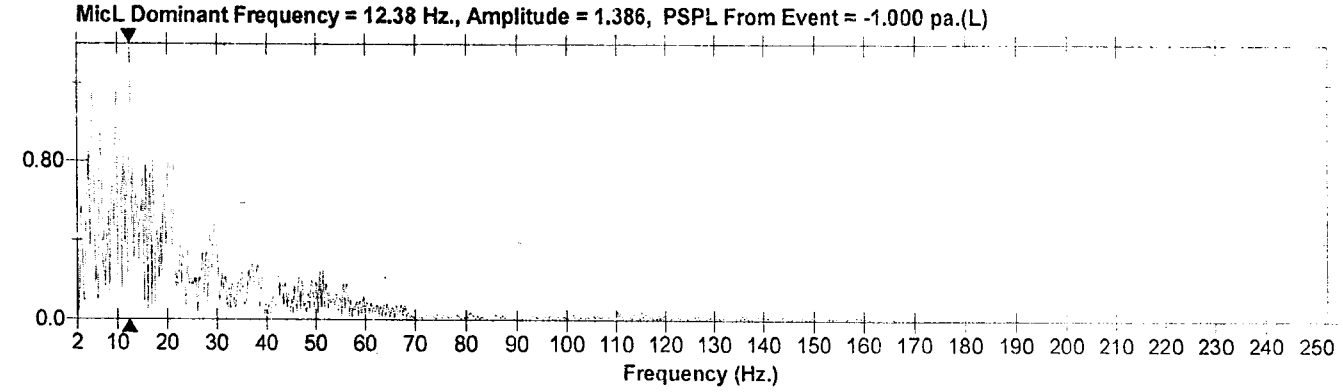
Vert Dominant Frequency = 12.88 Hz., Amplitude = 0.104, PPV from Event = -1.000 mm/s



Long Dominant Frequency = 8.500 Hz., Amplitude = 0.112, PPV from Event = -1.000 mm/s



MicL Dominant Frequency = 12.38 Hz., Amplitude = 1.386, PSPL From Event = -1.000 pa.(L)



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ANNEXURE – III

(DGMS Approval Letter)

(110)

भारत सरकार / Govt of India
श्रम एवं रोजगार मंत्रालय / Ministry of Labour & Employment
खान सुरक्षा महानिदेशालय / Directorate General of Mines Safety
अजमेर क्षेत्र / Ajmer Region

फैक्स नं०- 2429792, दूरभा० 0145-2429139 (डी)

पत्र संख्या: AJR/DMS/Perm -164(1-B)(2):2018/ 5711 दिनांक: 04-10-2018

प्रेषक,
खान सुरक्षा निदेशक
अजमेर क्षेत्र

सेवा में,
प्रतिनिधि
मेसर्स आयरन ओर एवं एसोसिएटेड माइन्स (प्रा०लि० से 531/16)
मेसर्स जिंदल सॉ लिमिटेड
खसरा नम्बर 2697/3811, जिला भीलवाड़ा (राज०)
ग्राम पुरा, तहसील एवं जिला भीलवाड़ा, राजस्थान

विषय: मेसर्स जिंदल सॉ लिमिटेड की डेडवाश उत्खनन ओर व एसोसिएटेड मिनरल्स द्वारा खान स्थली खाने से 300 मीटर के भीतर परंतु 100 मीटर से बाहर एक समय में दो फिलेंगराम से अधिक खान व विस्फोट के साथ खुदाई की अनुमति का अनुमोदन।

संदर्भ:

आपका प्रतिनिधित्व विषय पर आपके पत्र नम्बर JSL/BHL/MINES/2018-19/0152 dated 20.08.2018 एवं अन्य पत्र व्यवहार।

Ref: Your letter No. Dhed/Sur/2018A/Permission dated 20.08.2018 and other correspondence.

The matter has since been considered in the light of what has been stated in your application under reference and shown on the accompanying plans.

The matter has since been considered in the light of what has been stated in your application under reference and plans and sections enclosed therewith. By virtue of the powers conferred on the Chief Inspector of Mines (also designated as Director General of Mines Safety) under Section 5(3)(b) of the Metalliferous Mines Regulations, 1961 and by virtue of the duties entrusted to me by the Chief Inspector of Mines (also designated as Director General of Mines Safety) under Section 4(2) of the Mines Act, 1952, I hereby accord the permission granted vide my this office letter No. AJR/DMS/Perm-B(a)/2005 dated 04.02.2015 to conduct controlled deep hole blasting with more than two kilograms of explosive at one time to extract iron ore within 500 m but beyond 300 m of Dhedans Surface Structures belonging to owner under Regulation 104(1-B)(2) of the Metalliferous Mines Regulations, 1961 at Dhedans Iron Stone Mine of M/s Jindal Saw Ltd situated near village Pur, Taluk and district Bhilwara as depicted on Plan No. Dhed/Sur/2018A/Permission dated 20/09/2018 enclosed with your application under reference and subject to the following conditions being duly complied with:

1.0 No blasting operations shall be conducted within 100 m of structures/dwellings not belonging to the owner and permanent nature without acquiring a separate permission under Regulation 154(1)(b) of the Metalliferous Mines Regulation, 1961.

1.1 The drilling, blasting and blasting operations shall be carried out under direct personal supervision of an Assistant Manager holder of 2nd Class Certificate of Competency with specially trained supervisors and workers.

1.2 The Manager shall fix the time of blasting and the same shall be communicated to all persons including the inhabitants of structures and dwellings, not belonging to the mine/quarry. Timings shall also be conspicuously posted on the mine's notice board. Blasting shall be done in daylight hours.

2.0 Following blast design parameters, as recommended by the scientific institute in the report "Blast Fragmentation studies and Establishment of Controlled Blasting Parameters for Chromite and Associated minerals Mine (M.L No 631/05)", shall be strictly adhered to while carrying out the hole blasting, which are reproduced below:

Bench height (m)	Drill hole Dia(mm)	Min. No. of holes in a round	Toe(m)	Pattern of holes(m)	
				Spacing (m)	Burden (m)
8-10	115	20	9-10	3.0-3.5	2.5-3.0

2.1 (i) No drilling shall be commenced in an area where shots have been fired, until the workmen have made a thorough examination at all places, including remaining butts of the deep holes, for unexploded charges that the drill may strike.

(ii) The position of every deep hole to be drilled shall be distinctly marked so as to be readily seen by the drillers.

(iii) No drill or bore rod or pick shall be inserted in the butts of the deep holes before examination under Clause ( ) has failed to reveal presence of explosives.

2.2 (i) Drilling operators shall not be carried out simultaneously on two benches or platforms one above the other.

(ii) Drilling and logging of deep holes shall not be carried out in the same bench.

2.3 (a) The peak particle velocity of blast-induced ground vibrations, at dwellings not belonging to the owner within 2.0km of the place of blasting and not belonging to the quarry, shall not exceed

(b) To limit the peak particle velocity as mentioned in para 2.3(a) above, the following Controlled Blasting techniques shall be adopted: Short delay detonators with delay period of 25 milliseconds between successive holes in a row, Short delay detonators with delay period of 100 milliseconds between successive rows, Deck charging, Decoupled charging, Millisecond delay detonators in combination with controlled burden and spacing, Presplitting, Cushion blasting, Line drilling, Smooth blasting, Use of mechanical excavators, Use of hydraulic splitters, Use of expansive grouts, Use of non-explosive chemical agents, Use of plasma-blasting, Use of controlled blasting with optimum burden, spacing, stemming and delay between holes and rows.

Tiranga Block

Distance (m)	100	150	200	250	300
Max. Charge per delay (kg.)	16.6	37.3	66.4	104	149

Dhulchera Block

Distance (m)	100	150	200	250	300
Max. Charge per delay (kg.)	44.9	101	179	280	403

Suras Block

Distance (m)	100	150	200	250	300
Max. Charge per delay (kg.)	77.6	175	310	485	698

3.2 Only non-electric down-the-hole detonators of 450 ms in conjuction with detonating fuse shall be used for detonation/initiation of explosive column of deep-holes. The inline detonators of 17/25 ms delay intervals may be used to provide delay interval between holes in a row. Delay interval between the rows of deep-holes shall be 42 ms, as to comply with the charge restrictions stipulated as above.

3.3 In deep-hole blasting, cartridges of explosives shall be lowered down the hole carefully. The stemming length/length of hole left uncharged shall be measured to ascertain the length of explosive column and ensure that the cartridges of explosives/primers are in close contact and there is no air space. In case the measurements indicate presence of air space in the explosives column, the cartridges may be gently pushed down by a wooden rod only. No explosive is being used for this purpose.

4.0 A safe code of blasting practice shall be framed by the manager and shall be circulated to all concerned for its strict compliance.

5.1 Shots shall not be fired beyond day light hours until adequate artificial light is provided. No holes/charges on any one day shall be fired on the same day. Blasting of holes shall not be permitted after specific permission in this regard is obtained.

5.1 During the approach and progress of an electric storm, the following precautions shall be taken:

(i) No explosive/electrically detonators shall be handled.

(ii) If charging operations have begun, the work shall be discontinued until the storm has passed.

(iii) If the blast is to be fired electrically all exposed wires shall be short circuited and placed in the mouth of the holes, or kept covered by a grounded iron plate.

(iv) All wires shall be removed from contact with the shot rails or a bonded track so as to prevent the charge being exploded prematurely by a direct stroke of the lightening.

6.0 The Manager of the mine shall ensure that recommendations made by the scientific agency for control of the controlled blasting are strictly followed.

7.0 To control flying fragments resulting out of blasting from projecting beyond a distance of 10 meters from the place of firing, following precautions shall be taken:

a) [illegible] shall be fired in crushed, broken or fractured ground/strata.

b) Blasting shall be done against a free face only. Blasted material shall be cleared [illegible] commencement of drilling operations for succeeding round.

c) [illegible] shall not be less than the burden.

d) Only such blasting material that is free from pebbles and stone chips shall be used. Moist [illegible] shall be used for stemming of deep-holes.

e) [illegible] shall not be less than 300 mm from the collar of each hole to avoid [illegible] broken stone, and cuttings, debris and other loose material.

f) [illegible] of holes shall be within 5 degrees to avoid variation [illegible]

g) [illegible] shall be adequately and effectively muffled to ensure that no flying fragments [illegible] and a distance of 20.0 m from the place of blasting. Muffling of shot holes shall be done with conveyor belt/wire netting having not more than 25 mm mesh over an adequate [illegible] in such a way that not less than 40 kg by weight.

h) [illegible] shall be used as stemming material and shall be tapped hard into the blast hole [illegible] of explosive from the hole.

5.0 Monitoring of peak particle velocity and of the dominant frequency shall be done with each [illegible] seismograph as directed.

5.1 A complete record of blast parameters i.e. spacing & burden of holes, hole depth, number of holes fired in the round, charge/hole, charge/delay, and charge/round, length of explosive column, stemming column length(s), initiation pattern (with proper sketches wherever called for), [illegible] muffling, results of ground vibration observed (ppv, frequency & air over pressure) and [illegible] upto which flying fragments resulting out of blasting projected, shall also be kept maintained round paged book with each round of deep-hole shots fired. The records shall be duly signed by the Manager of the mine.

5.2 In case when any of the rounds fired, the peak particle velocity of ground vibrations resulting out of blasting is observed to be more than 5mm/sec in case of Tirunga Block, 10mm/sec in case of Dip Side Pit Block (with frequency 8-25 Hz) and 15mm/sec (with frequency >25 Hz) for Surface Block at the R.L. structures not belonging to the management, or the flying fragments [illegible] the [illegible] and 10m from the place of firing, blasting operations shall be discontinued [illegible] Director DGMS shall inform immediately. The blasting operations cannot be resumed [illegible] requirement that a control seismograph recording is recorded by the Directorate [illegible]

6.0 All regulations with regard to blasting, shelter etc., as laid down in Regulation [illegible] Metalliferous Mines Regulations, 1961 shall be complied with.

7.0 (a) Before commencement of any blasting operation, the area of danger as per Regulation 164 of the Metalliferous Mines Regulations, 1961 shall be determined by the competent person in charge of the blasting operations. All persons shall be removed from the area of danger, i.e. within a radius of 400 m from the face or the shot hole where charges are to be fired, before any blast is fired.

(b) Before commencement of any blasting operation, the area of danger as per Regulation 164 of the Metalliferous Mines Regulations, 1961 shall be determined by the competent person in charge of the blasting operations. All persons shall be removed from the area of danger, i.e. within a radius of 400 m from the face or the shot hole where charges are to be fired, before any blast is fired. Adequate precautions shall be taken to prevent entry of persons into the danger zone. Proper guards shall be posted at suitable locations all round the danger zone to prevent accidental entry of persons into the danger zone. Adequate arrangements shall be made to ensure that all persons in the area of danger have been accounted for before firing. Necessary instructions shall be given to each person employed in the mine including the contractor's employees about the area of danger, method of intimation by means of signals, manner in which persons should take shelter in the event of blasting, and the action required to be taken by them after the blasting operations are completed.

(c) The shift in charge of blasting operations shall ensure that all persons working within the danger zone have been withdrawn to the specified distance or to the place of shelter before blasting. Unless the dwelling/adjacent private structures and overburden, etc. have been cleared up to the extent of 500m of the place of blasting, no blasting operation shall be carried out. Adequate/proper shelter from flying fragments of the blast out of blasting shall be provided. Guards shall be posted to ensure that no person inadvertently enters the danger zone, and to ensure that all persons within the danger zone have taken proper shelter.

(y)

(f) Subsequent to blast, at least after 15.0 minutes, all clear signal shall be given. Hooters/siren or other efficient mechanism shall be installed for this purpose.

9.2 Guards shall be posted, one in either direction at the two extreme points of Metaled road which fall within the danger zone to warn passers by and stop vehicular traffic, if any, and intimate the cessation of traffic by an efficient system of communication.

10.0 Owners of structures and dwellings and land, not belonging to the management and habitants/occupants of such dwellings/buildings shall be indemnified against damage to property/ injury to persons, if any, arising out of mining operations.

11.0 In the event of any change in the circumstances connected with this permission which is likely to endanger the life of workmen employed in the mine or endanger the mine, the mining operations for which this permission has been granted shall be stopped forthwith and intimation thereof shall be sent to this Directorate. The said mining operation shall not be resumed without express and fresh permission in writing from this Directorate.

12.0 If at any time any of the conditions subject to which this permission has been granted is violated or not complied with, this permission shall be deemed to have been revoked with immediate effect.

13.0 This permission may be amended or withdrawn at any time if considered necessary in the interest of safety and is being issued under Regulation 15(1)(b) of the Metalliferous Mines Regulations, 1961, only without prejudice to any other provisions of law which may be or may become applicable at any time.

14.0 Unless renewed, this relaxation shall be valid for a period of 3(three) years from the date of issue of this letter.

संलग्न

(अजीत कुमार)
खान सुरक्षा निदेशक
पूर्वी क्षेत्र, धनबाद

NOTE

सीएसआईआर- केंद्रीय भवन अनुसंधान संस्थान
CSIR- CENTRAL BUILDING RESEARCH INSTITUTE
रुड़की – 247 667(उत्तराखंड) भारत/ ROORKEE – 247 667 (UTTARAKHAND) INDIA
दूरभाष / Phone: 01332-283247 , फैक्स 01332-272272, website : http://www.cbri.res.in, ई-मेल/E-mail: sksingh_cbri@yahoo.co.in

Letter No.: CSIR-CBRI/SKS/DMG/2021
Date: 18th January, 2021

To
District Magistrate
Bhilwara (Rjasthan)

Subject: Studies to Investigate the Reasons for Cracks Development in Buildings of Pur Village, Bhilwara, Rajasthan-Submission of report

Dear Sir,

The CSIR-CBRI report on "**Studies to Investigate the Reasons for Cracks Development in Buildings of Pur Village, Bhilwara, Rajasthan**" is attached here along with the consolidated executive summary prepared by investigating teams of CSIR-CIMFR Dhanbad, CSIR-CBRI Roorkee and IIT Roorkee for your kind perusal.

Any query/ information in this regard shall be highly appreciated.

With best regards,

SK Singh
Sr Principal Scientist

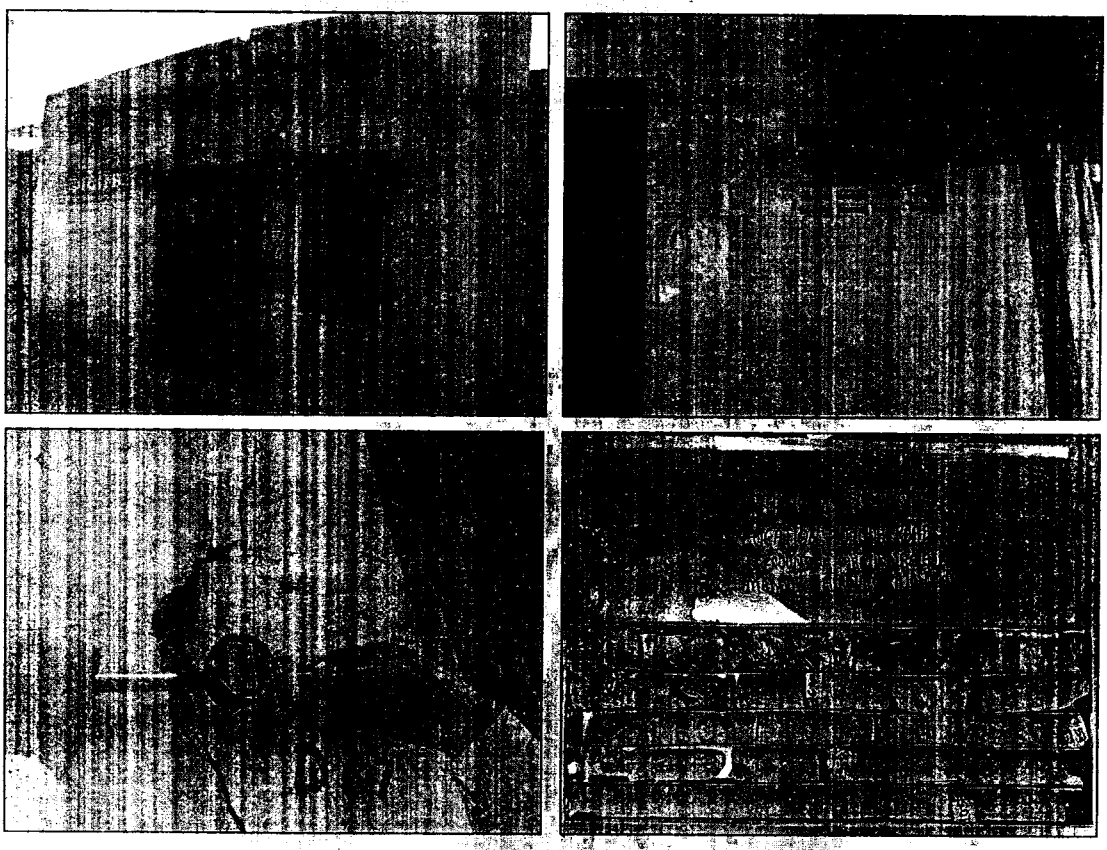


Annexure – D

Report

on

Studies to Investigate the Reasons for Cracks Development in Buildings of Pur Village, Bhilwara, Rajasthan



Submitted to:

Office of District Collector and District Magistrate,
Bhilawara, Rajasthan State Govt.

CSIR-Central Building Research Institute
Roorkee – 247667 Uttarakhand, INDIA

January 2021

Final Report

on

Studies to Investigate the Reasons for Cracks Development in Buildings of Pur Village, Bhilwara, Rajasthan

Team of Consultants:

Dr. S. Sarkar, Chief Scientist
Prof. S. K. Singh, Sr. Pr. Scientist
Er. Manojit Samanta, Sr. Scientist
Er Md. Reyazur Rahman, Scientist
Er. Ajay Dwivedi, Sr. Technical Officer
Er. Rakesh Paswan, Scientist
Er. Koushik Pandit, Scientist
Er. Ashish Barthwal, Project Assistant
Mr Neeraj, Research Scholar
Mr Suvam Das, Research Scholar

CSIR-Central Building Research Institute
Roorkee – 247 667 Uttarakhand, INDIA

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Studies to Investigate the Reasons for Cracks Development in Buildings of Pur Village, Bhilwara, Rajasthan

1. Introduction

Pur village is situated very near to Bhilwara town of Rajasthan around 10.8 km towards South West direction. Bhilwara is a small town in the Mewar region of Rajasthan. Clusters of houses in the Pur village are continuously developing cracks in the buildings. The safety of houses of Pur village are concerning issues. Accordingly, District Administration, Bhilwara, Rajsthan entrusted CSIR-Central Building Research Institute (CBRI), Roorkee to investigate the reasons of cracks development in buildings of Pur village, Bhilwara, Rajasthan. The study mainly involves geotechnical investigations and damage assessment in the buildings based on crack monitoring. The scope of the study was as follows:

- Reconnaissance survey of the Pur village, Bhilwara
- Identification of buildings developing cracks
- Drilling of bore holes at selected location
- Study of sub-surface geological strata
- Laboratory testing of soil and rock samples obtained from the bore holes
- Evaluation of geotechnical properties of soil and rocks
- Monitoring of cracks in selected houses
- Data analysis of crack monitoring to determine the nature of cracks
- Demarcation of houses having severe damage potential
- Possible causes for cracks development in the houses

A reconnaissance survey of the Pur village was conducted to observe the nature of cracks developed in the houses. The cracks were observed mostly in stone masonry buildings. The both types of cracks were observed i.e. non-structural and structural. Fig. 1 to Fig. 3 shows the typically damages in the buildings in the region categorized as severely damaged, moderately damaged and minor damaged structures. About 80 houses were randomly selected for crack monitoring. The damage pattern of buildings were dependant of the type of building structure. The damage patterns in non-engineered buildings (typically stone masonry) were found moderate to severe whereas the damages in reinforced moment-resisting concrete frame structure were negligible.

A detailed geotechnical investigation was carried out to evaluate the soil condition of the village. During investigation, a few bore holes were drilled in the village to investigate the subsurface strata and the geological formation. Laboratory testing was performed on the drilled samples to determine the geotechnical parameters of soil and rocks. Based on the investigation, possible causes for appearance of cracks in the buildings are pointed out.

2. Study Area

Pur village is situated adjacent to Bhilwara town around 10.8 km towards southwest direction. Bhilwara is a small town in the Mewar region of Rajasthan. It is located almost in the centre of the Rajasthan state covering an area of 10,455 km^2. It is bounded by latitudes 25°01' to 25°58' N and longitudes 74°01' to 75°28' E and it is surrounded by other districts, on the north by Ajmer district, on the east by Bundi district, on the south by Chittaurgarh district, and on the west by Rajsamand district. The average elevation of Bhilwara district is 421 metres (1381 feet). It is an elevated plateau. The Bhilwara district is intersected by the Aravali ranges at several places. There is a range of hills in the North-East corner of the district which extends right up to Jahajpur town. These ranges are predominant in the south east in Mandalgarh tehsil and in the north east in Jahajpur tehsil. The soil in this region varies from sandy loam to heavy loams.

Mean annual rainfall (1971-2000) in the district is 635.3 mm whereas normal rainfall (1901-70) is lower than average rainfall and placed at 603.3. Almost 95% of the total annual rainfall is received during the southwest monsoon, which enters the district in the last week of June and withdraws in the middle of September. Probability of average annual rainfall exceeding 900 mm is only 10%. However, there is 90% probability that the average rainfall will be more than 400 mm. The probability of occurrence of mean annual rainfall is 45%. Drought analysis based on agriculture criteria indicates that the district is prone to mild and normal types of droughts. Occurrence of severe and very severe types of droughts is very rare. January is the coldest month with mean maximum and minimum temperatures being lowest at 22.20° C and 7.30° C. Temperature in summer month of June reaches up to 46° C. There is a drop in temperature due to onset of monsoon and rises again in the month of September. Atmosphere is generally dry except during the monsoon period. The humidity is maximum in August with mean daily relative humidity at 80%. The annual potential evapo-transpiration in the district is 1495 mm and is the highest in the month of May (228 mm) (Ministry of Environment, Forest and Climate Change, Dated 15th January, 2016).

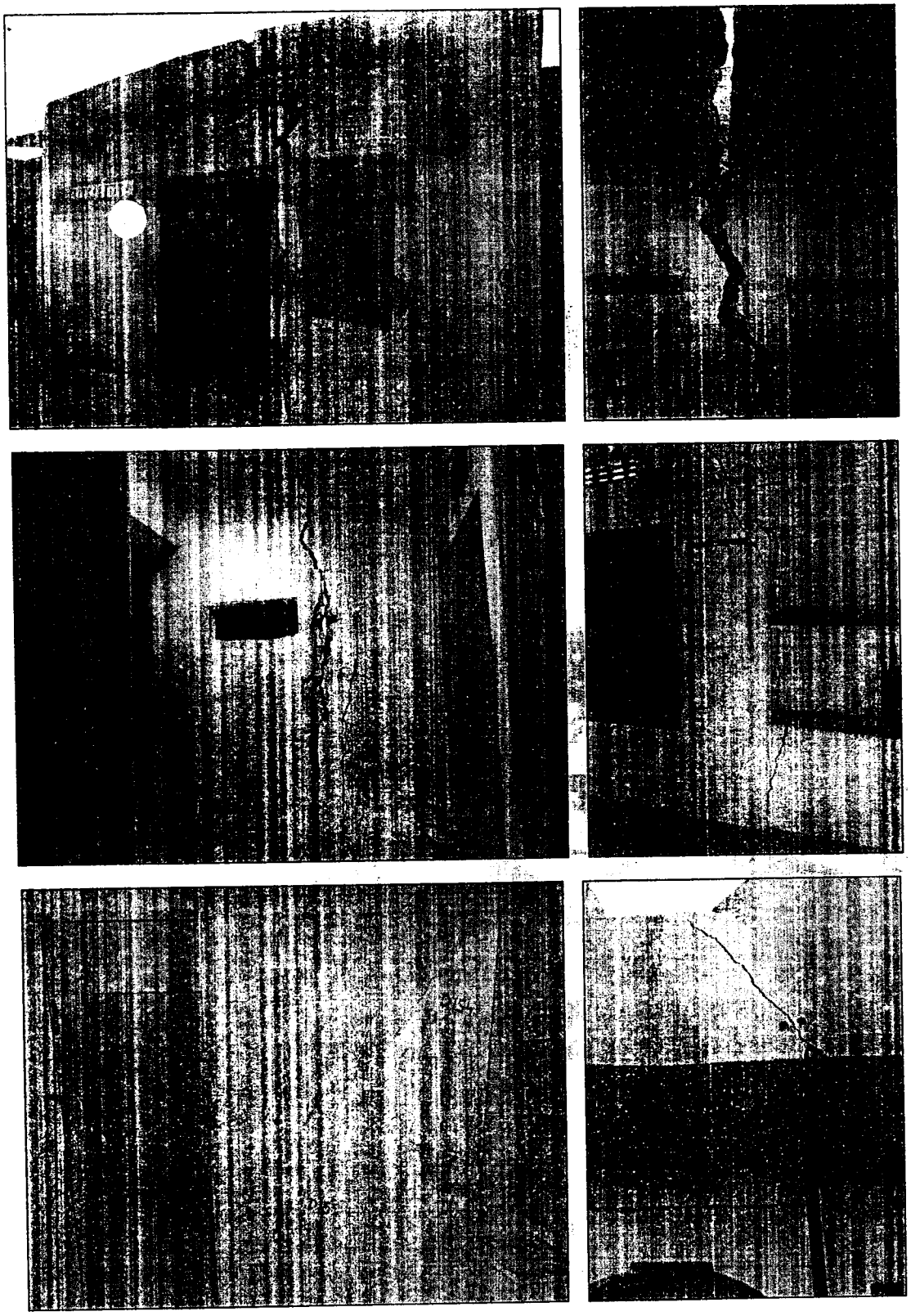


Fig. 1. Severely damaged buildings

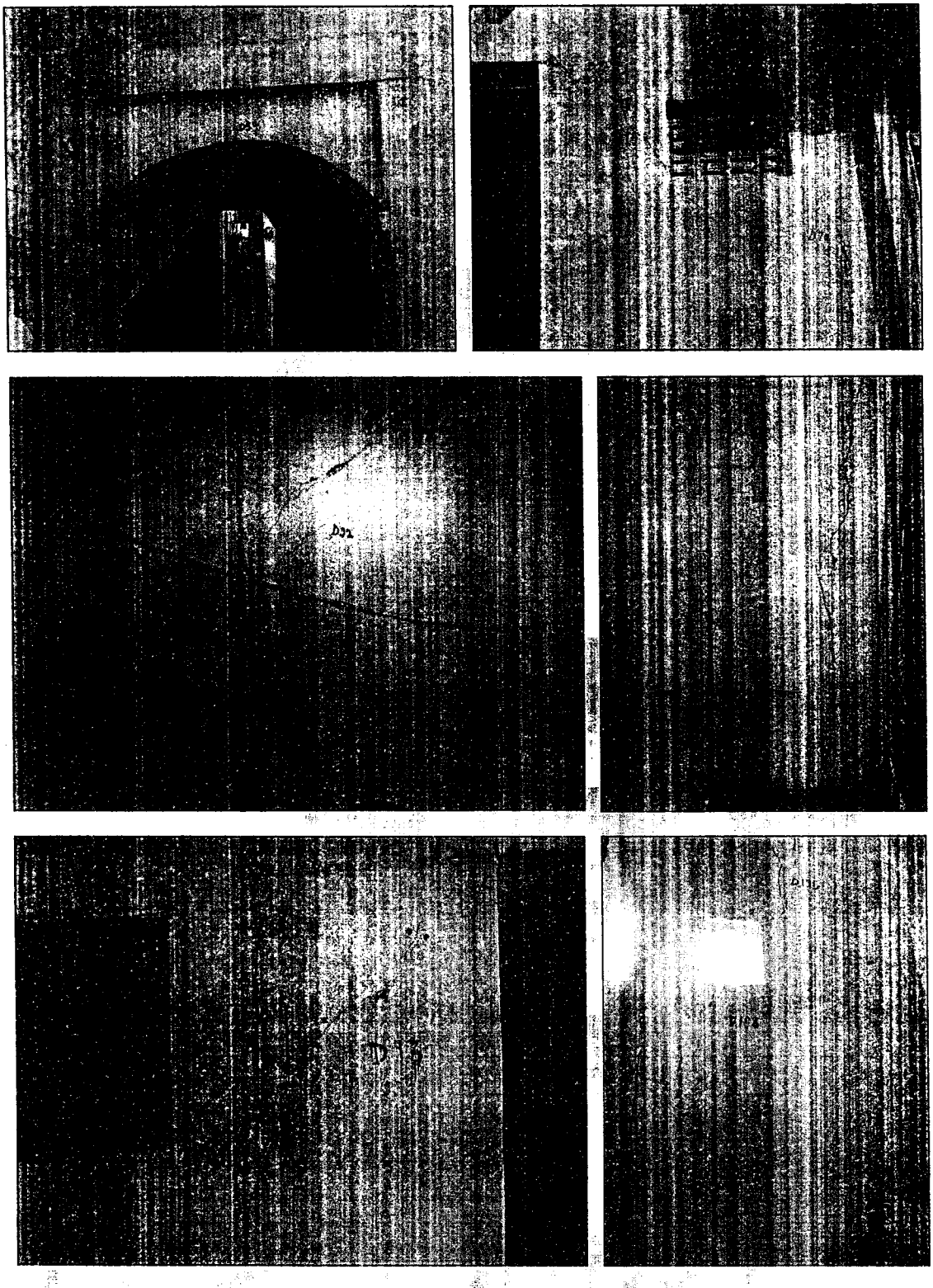


Fig. 2. Moderately damaged buildings

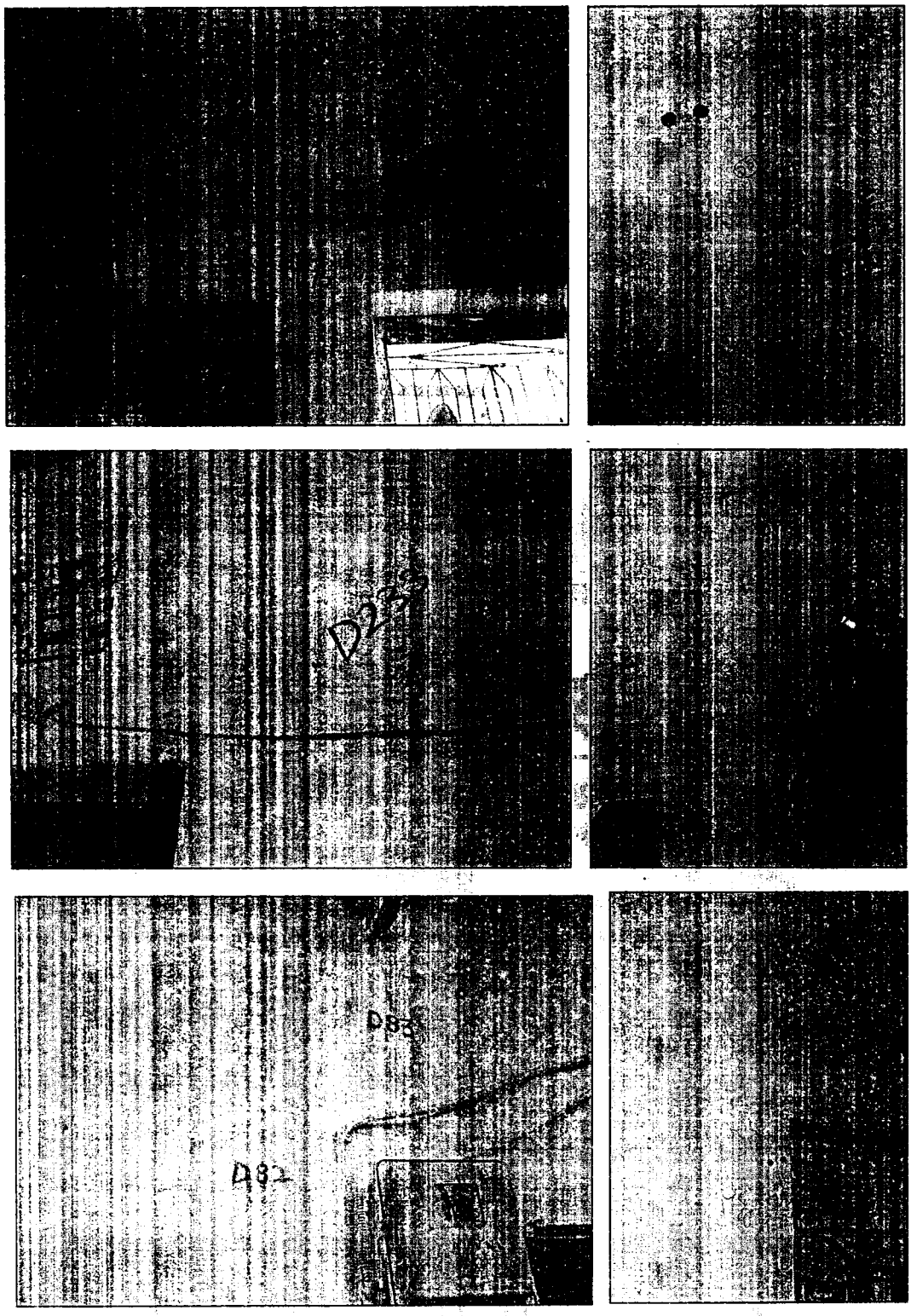


Fig. 3. Minor damaged buildings

PART I: GEOTECHNICAL INVESTIGATIONS

1. Geology of the area

Bhilwara district comes under the Survey of India toposheet no. 45K/11. Geologically the area is covered by Banded Iron Formation (BIF) and associated litho-units i.e. part of Pur-Banera Group of the Bhilwara Supergroup of Archean to Lower Proterozoic in age. The major rock types discernible in the area are banded iron formation including Banded Hematite Quartzite (BHQ) and Banded Magnetite Quartzite (BMQ). Other litho members of the area are conglomerate, garnetiferous mica-schist, calc-schist, amphibolite, calc-gneiss, calc-silicate marble and carbonate rocks with associated sulphide mineralization. Pur-Banera Group rocks un-conformably overlie the rocks of the Mangalwar Complex (Suwana Formation and Potla Formation). The Pur-Banera Group has been subdivided into five formations, Pur, Jansal, Deogarh, Tiranga, and Samodi (Gupta, 1934). The investigated Pur village belongs to Pur formation. A regional geological map of the Bhilwara district is shown in the Figure 1.

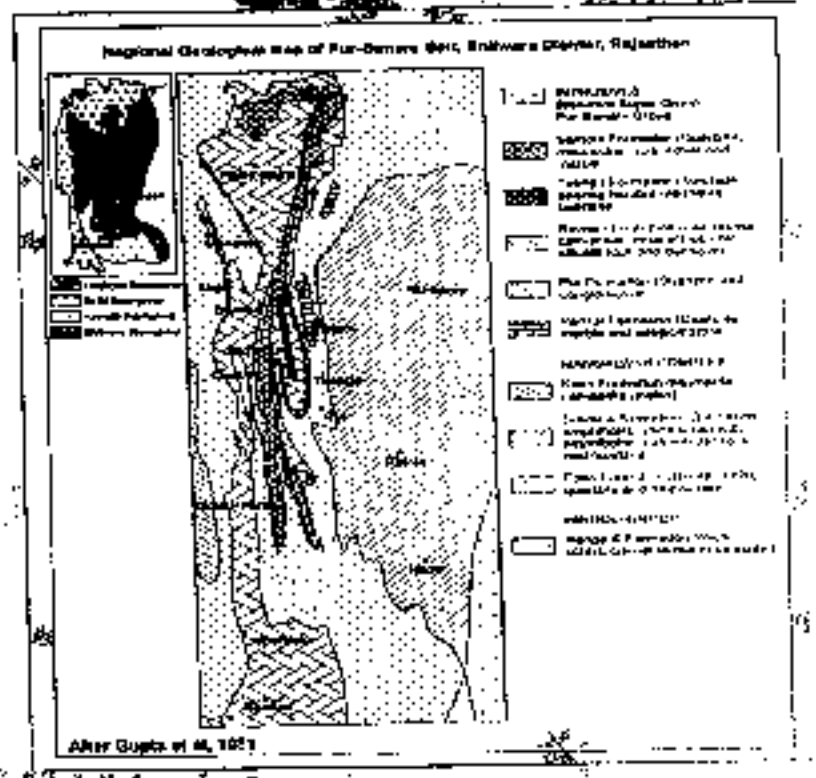


Fig 1 Geological map of the Bhilwara District (after GSI)

Table. 1 Geological stratigraphy of Bhilwara district

Era/ Peiod	Gelogical Cycle	Group	Lithology
Quarternery	-	-	Alluvium, blown sand
Upper Proterozie	Vindhyan Supergroup	Bhander Group	Shale, snadstone and limestone
ARCHEAN PROTHROZOIC	Delhi Super Group	Kumbhalgarh Group	Calc-Schist, gneisses, marble, garnet-boitite schust, migmatites
		Gogunda Group	Quartzite, biotite schist, Calcschist, hornblende schist
	Aravalli Super Group	Dovda Group	Quartzite, dolomite marble, dolomite, amphibolites, cals-sillicates rocks, biotite schist, quartz-biotite gneiss and migmatites
	Igneous activity/Intrusives		Dolerite dykes and sills
	Bhilwara Supergroup	Ranthambor Group	quartzite, shales and slates
		Igneous activity/ Intrusives	Berach granite and gneisses Jahajpur granite
		Pur-Banera Group	Calc-schist, gneisses, banded magnetite-quaratzite, dolomitic marble, quartzite, garnet-mica schist and amphibolites
		Jahajpur Group	Dolomite, Phyllite, Quartzite
		Hindoli Group	Shales, slates, phyllites, metagrawacke, limestone, dolomite, quartzite, mica shist, meta basics, volcanics.
		Mangalwar Complex	Migmatites, gneisses, mica schist, garnetiferous mica schist, para-amphibolites silicified mica schist.
		Sandmata Complex	Para-gneisses, migmatites, pyroxene-granulites, amphibolites, biotite-ultranatic rocks.
		Igneous activity/ Intrusive	Acidic and mafic bodies

1.1 Pur Formation

The Pur Formation is the beginning of Proterozoic age and it unconformable overlies the Potla Formation of the Mangalwar Complex and the formation is overlain by the Pansal Formation of

the Bhilwara Supergroup of Lower Proterozoic age. The iron ore (hematite and magnetite) bands are exposed between the Pur & Samodi Formation. The Pur Formation of the Bhilwara Supergroup is situated within the basement of the Pur-Banera Group of Bhilwara Supergroup. The Pur Formation extends from 5 km north-east direction of village Jasma in southern direction to vlillage Mandal along western limb while village Rasmi in the eastern direction to Banera, along the eastern limb. The name of this formation is after the Pur-village in the district and it comprises mainly of quartzite and conglomerate rocks. The Pur Formation mainly comprises of massive quartzite rock and thinly foliated schist. It shows gradational joining with the overlying calcareous metasedimentary rocks. The conglomerate bands are seen in the south-east direction of the study area and the ferruginous quartzite belt is exposed in the SW direction to the eastern direction of the study area near Pur village. The Pur pebbles are comprised of the veins of quartz & the beds of quartzite rock and are ellipsoidal of many sizes; the pebbles are very overstretched and deformed (Shrivastava, 1970) as shown in Fig. 2. Pebbles are set in a fine-grained matrix which consists of fine size sand particles and the pebbles are cemented by silica content & iron oxides (hematite and magnetite). The quartzite rock is composed essentially of the quartz with submissive amount of mica mineral, iron oxides and feldspars.

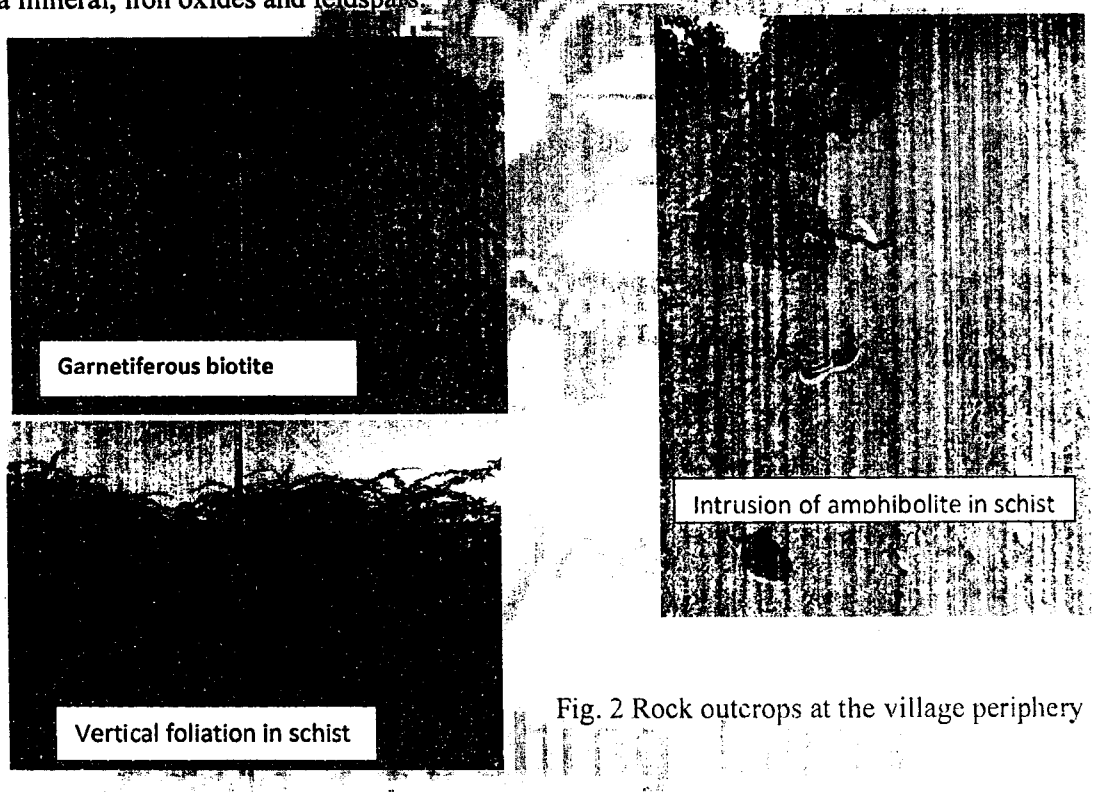


Fig. 2 Rock outcrops at the village periphery

2. Geotechnical Investigations

Geotechnical investigation was carried out by drilling bore holes at selected locations in the village as shown in Fig. 3 followed by laboratory investigation of soil and rock samples obtained from the drill holes. Four bore holes were drilled in different locations in the village. The sites were selected to know the sub-surface lithology of the surrounding region and also the central part of the village. Bore holes 1 and 4 are drilled at the periphery of the village while Bore holes 2 and 3 are drilled at the central part of the village where maximum damages found in the houses. These locations are:

- BH-1: Kaali Baawdi (12m drilling)
- BH-2: Mosque (12m drilling),
- BH-3: Sri Narayan Temple (16m drilling)
- BH-4: College campus of Pur Village (20m drilling)

The drilling locations are shown on the Google image (Fig 3)

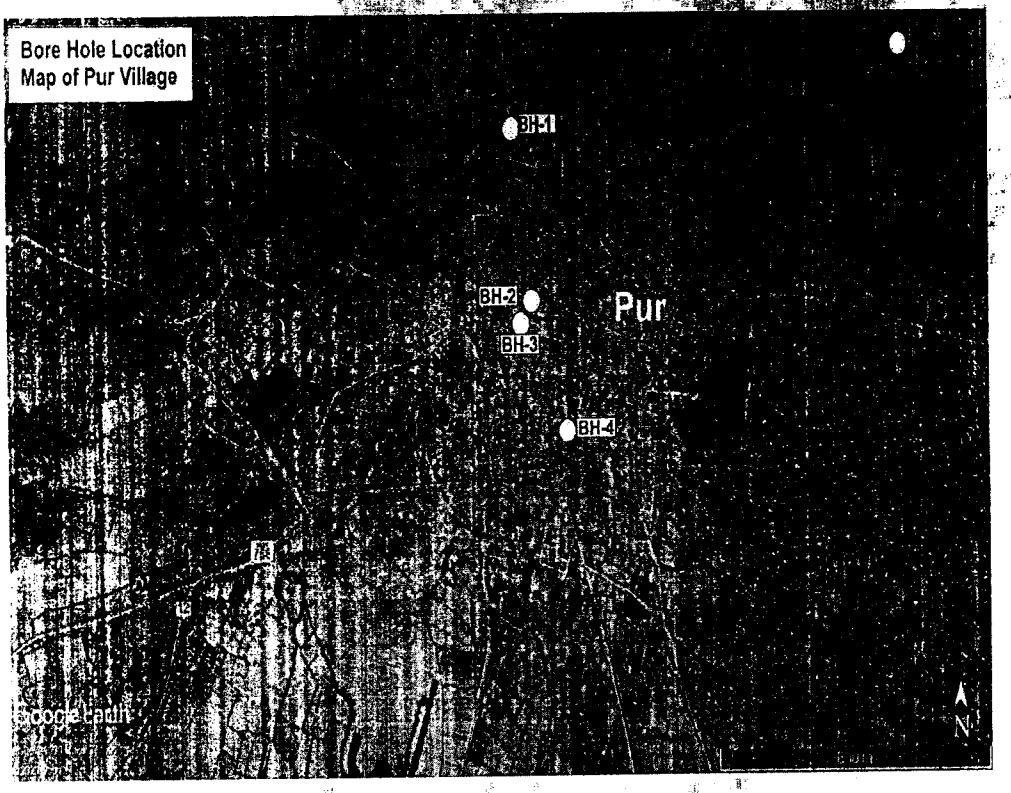


Fig. 3 Borehole locations at the Pur village

2.1 Bore Hole Investigation

Bore Hole 1 (BH-1)

BH-1 was drilled at Kaali Baawdi upto a depth of 12m (Fig.4). The bore hole log is shown in the Fig.5. It was observed that the rock formation started right from the surface. Rock type present here is garnetiferous mica schist. The rocks found from 0 to 1.5m depth are highly weathered and having vertical foliation planes. The Rock Quality Designation (RQD) is varying with depth and reaches to 89.8% upto 7.5m depth. However, between 7.5 to 9.0m slickensides are observed and RQD reduces to 20.33%. The RQD is again observed more than 70% below the depth 9.0m. There are three joint planes observed at deeper depth. The ground water table observed to be at 5.5m. The core samples obtained is shown in the Figure 6.

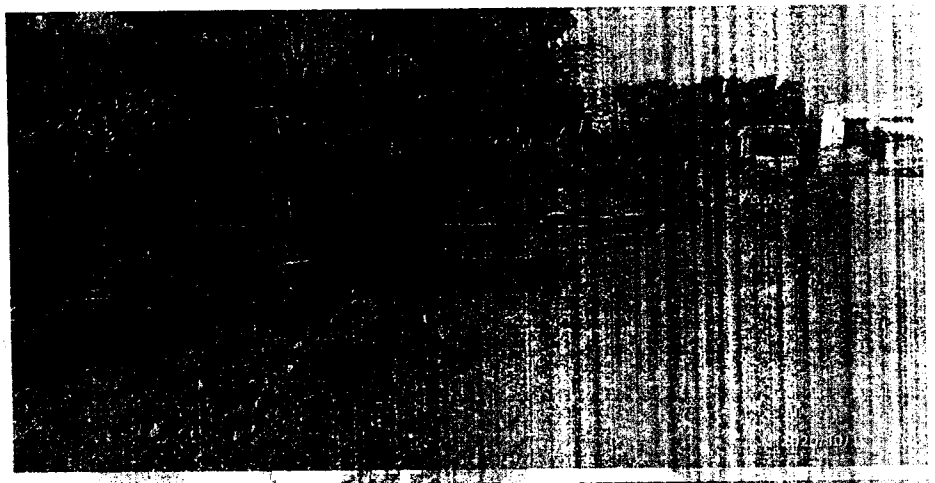
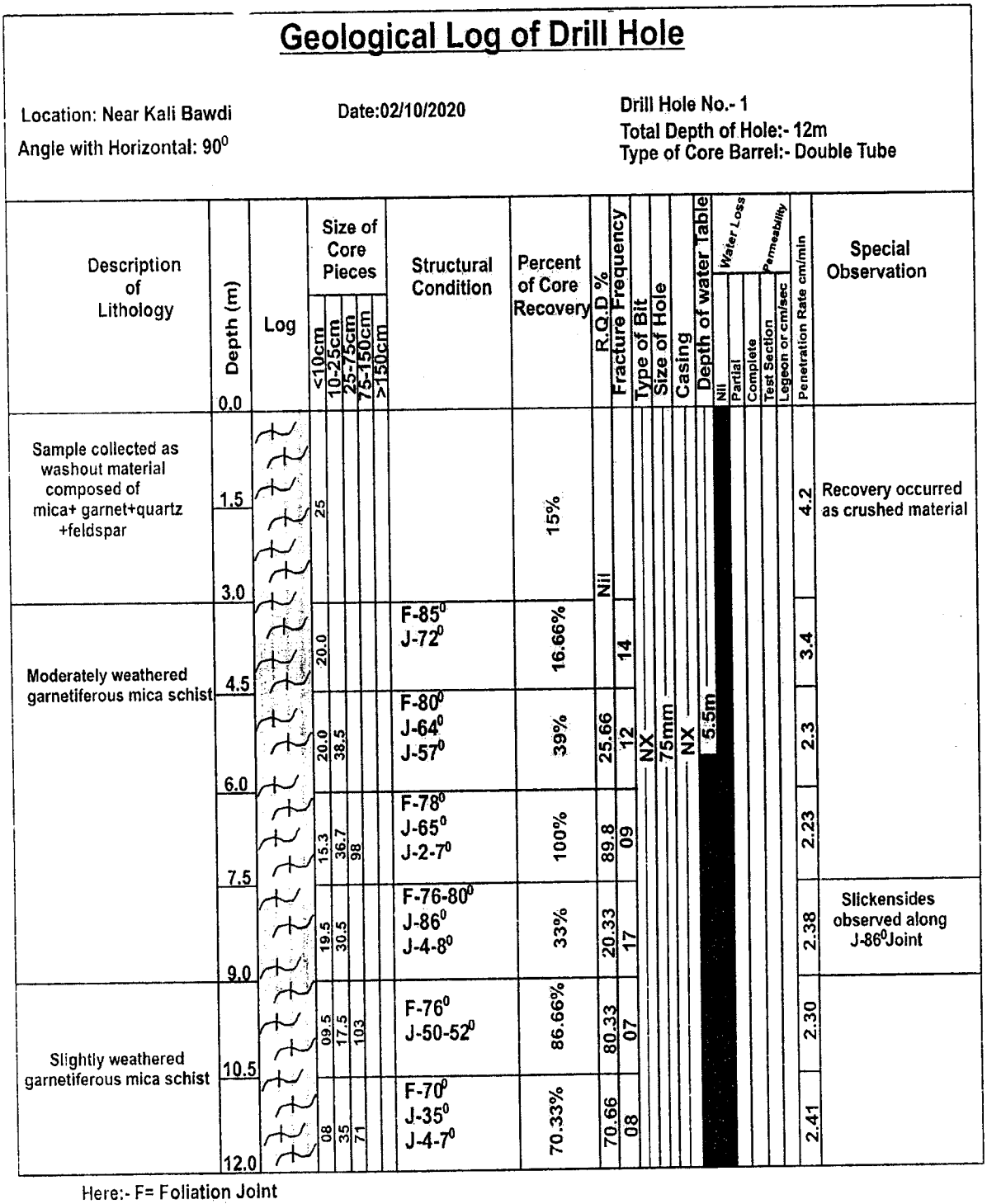


Fig.4 Location of Bore Hole 1



CSIR Tarachi



Here:- F= Foliation Joint
J= Other Joint/ Fracture

Fig. 5 Geological borehole log of BH-1 at Kaali Bawdi

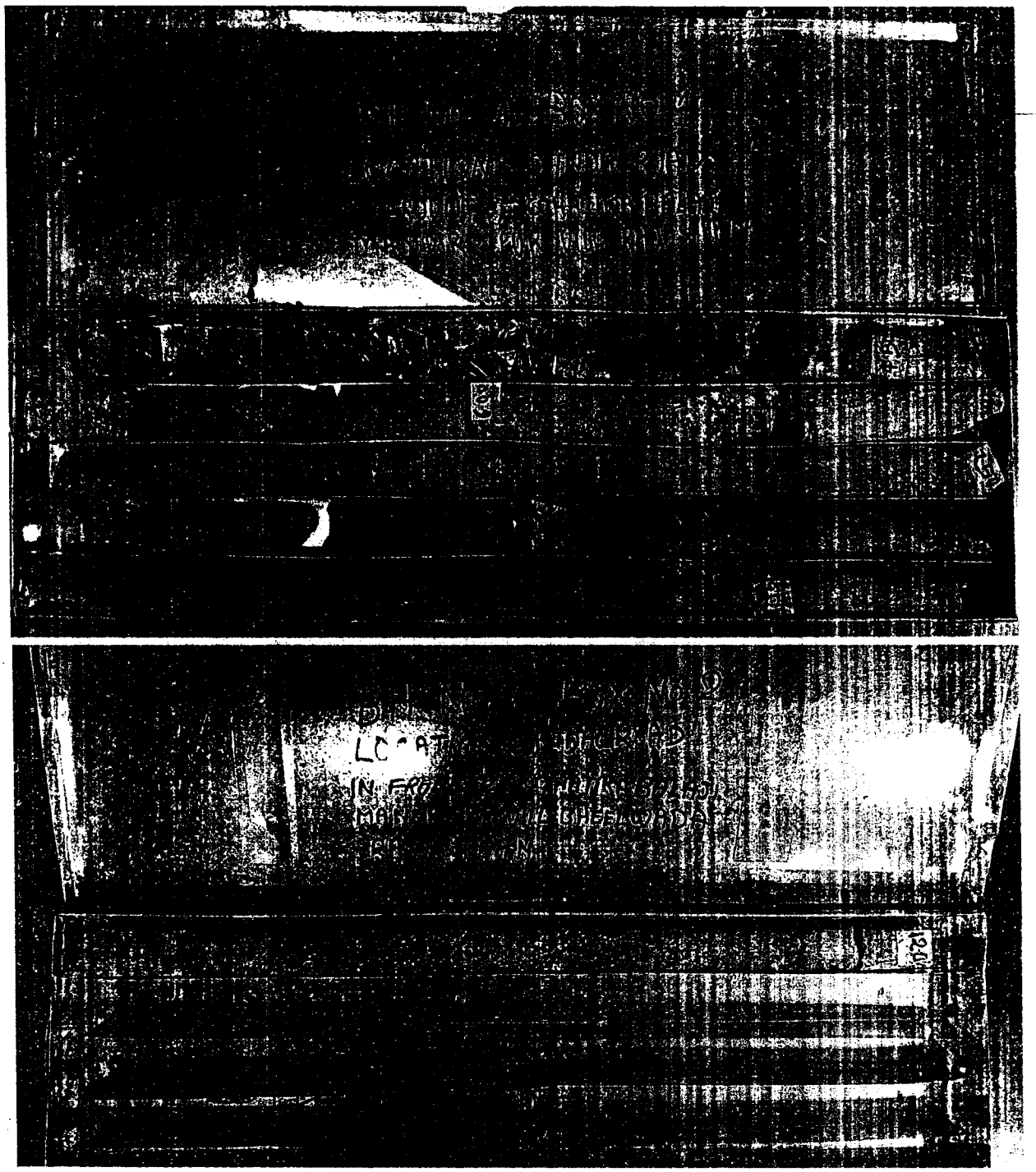


Fig.6 Photograph of core samples obtained from BH-1

Bore Hole 2 (BH-2)

The BH-2 was drilled at Mosque up to a depth of 12m (Fig. 7). The borelog (Fig.8) shows boulders of greyish colour quartzite and brownish colour sand from 0 to 7.5m depth. There after rock cores started from 7.5m. The rock type present here also is garnetiferous mica schist. Three joint planes were observed from the core samples (Fig. 9). The RQD is very low (< 25%) up to a depth of 7.5 m and reaches on an average upto 38% beyond 7.5 m depth. In general, core recovery (C.R.) is very poor due to presence of boulders and pebbles at initial depth followed by fractured and jointed rocks at deeper depth. Ground water table in this borehole was not encountered up to exploration depth. The SPT test could not be carried out beyond 4.5 m due to refusal was observed. Direct shear tests have been carried out on the soil samples collected at 1.5 m and in between 3 and 4.5 m of depth. Undisturbed samples could not be obtained due to presence of pebbles and boulders in the soil matrix.



Fig.7 Location of Bore Hole 2 at Mosque

Geological Log of Drill Hole

Location: Infront of Mosque **Date:08/10/2020** **Drill Hole No.- 2**

Angle with Horizontal: 90⁰ **Total Depth of Hole:- 12m**

Type of Core Barrel:- Double Tube

Description of Lithology	Depth (m)	Log	Size of Core Pieces <10cm	10-25cm	25-75cm	75-150cm	>150cm	Structural Condition	Percent of Core Recovery	R.Q.D %	Fracture Frequency	Type of Bit	Size of Hole	Casing	Depth of water Table	Water Loss: Nil	Water Loss: Partial	Water Loss: Complete	Permeability: Test Section	Permeability: Legeon or cm/sec	Penetration Rate cm/min	Standard Penetration Value: N	Standard Penetration Value: N' Cor	Special Observation
	0.0																							
Brownish colour sand with concrete particles	1.5		25						Recovery occurred as washout material												7.5	13	13	
Boulders and Pebbles of greyish colour quartzite	3.0								13.33%												6.52	14	16	
Brownish colour coarse sand	4.5								Recovery occurred as washout material												6.00			
Boulders and Pebbles of greyish colour quartzite	6.0								16.00%	Nil	NA	NX	75mm	NX	Nil						8.33			
Brownish colour coarse sand	7.5								11.00%												4.28			
Moderately to Slightly weathered garnetiferous mica schist	9.0			15.0	23.0	30.0		F-84⁰ J-45⁰	45.33%	35.33	11										3.33			
	10.5		1.5	18.0	39.5			F-84⁰ J-2-5⁰	39.33%	38.33	10										3.12			Iron stained along joint
	12.0		10		58			F-80-82⁰ J-45⁰	45.33%	38.66	09										2.88			

Here:- F= Foliation Joint
J= Other Joint/ Fracture

Fig.8 Geological borelog of BH-2 at Mosque

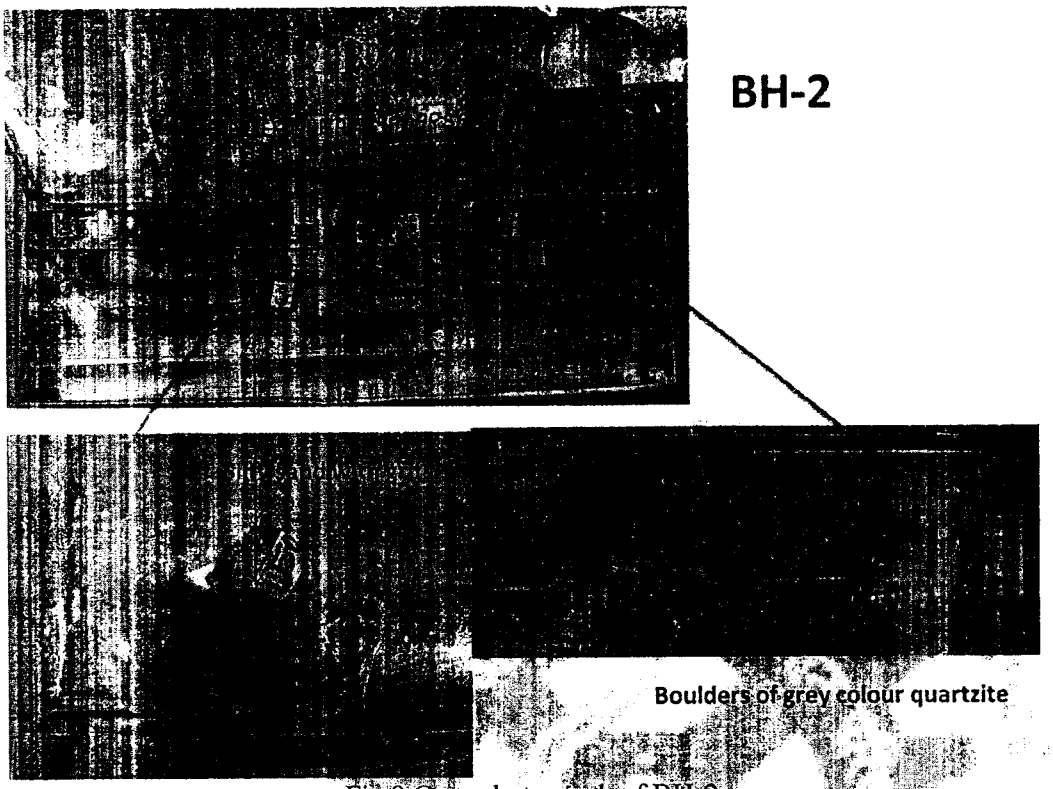


Fig.9 Core photograph of BH-2

Bore Hole 3 (BH-3)

The BH-3 was drilled at Shri Narayan Temple site up to 16m depth (Fig. 10). The borelog is shown in the Fig. 11. Initially, from 0 to 3.0m depth, brownish colour sand was observed and from 3.0m to 12.0m sand mixed with boulders is present. The rock layers start from 13.5m depth. Between 12.0m to 13.5m, clay with pebbles seem was encountered. The rock type is garnetiferous mica schist between 13.5 to 16.0m (Fig. 12) below the quartzite boulders mixed with sand. Ground water table in this borehole was not encountered up to 16m. Iron stained is present along the joints. There are three joint planes observed. RQD varies from 33 to 51.33%. Initially, the core recovery is very poor (ranging from 11 to 24%) up to a depth of 13.5m till the schistose rock layer starts appearing. The direct shear tests were carried out on soil samples collected in between 0 to 3.0 m depth whereas SPT test was terminated at 4.5 m due to refusal as matrix of sand mixed with boulders was observed.

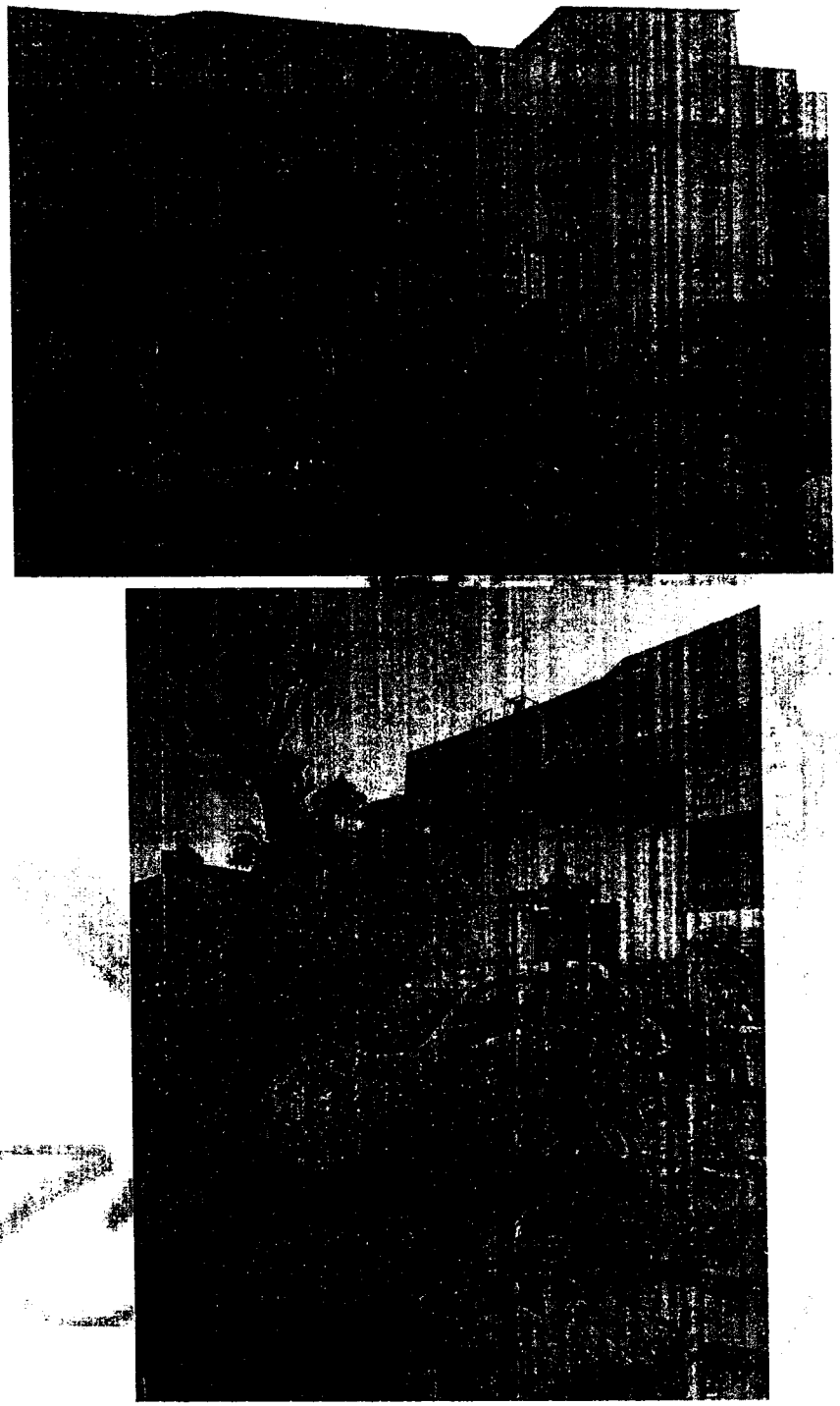


Fig.10 Location of Bore Hole 3 at the temple site

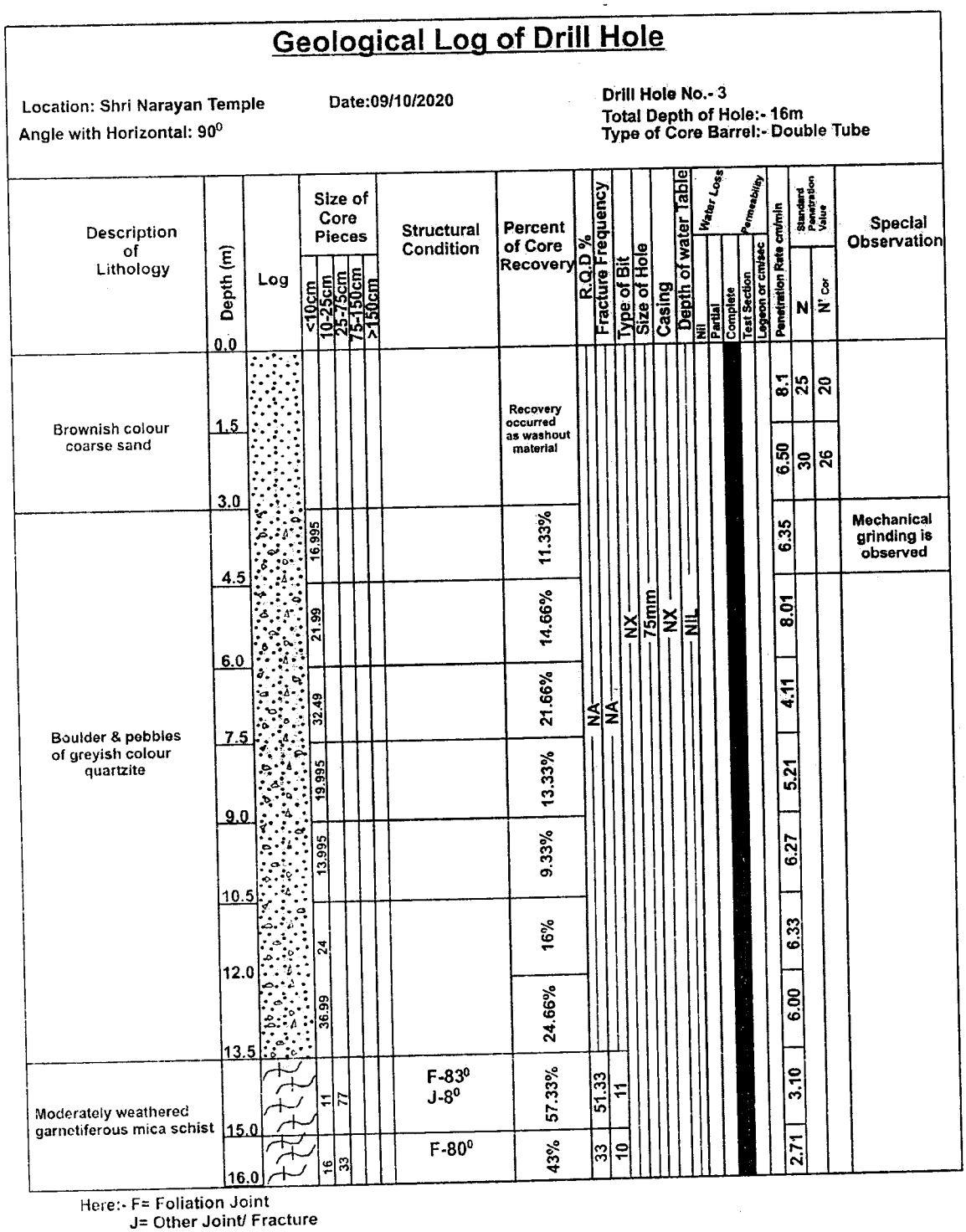


Fig.11 Geological borelog of BH-3 at Shri Narayan Temple

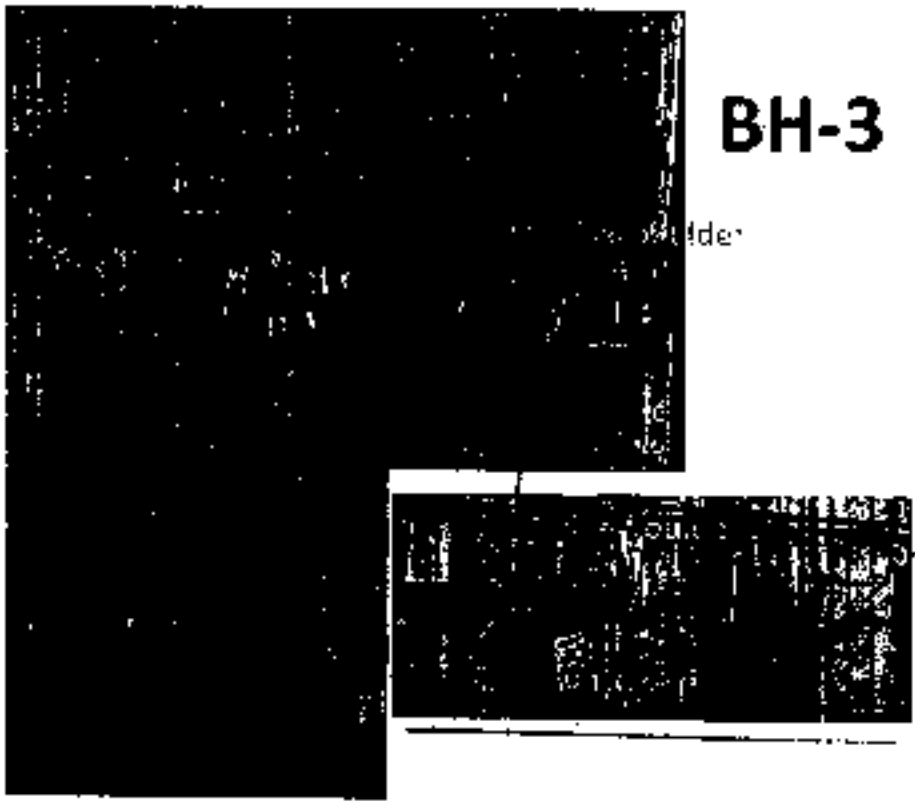


Fig.12 Photographs of cores obtained from BH-3

Bore Hole 4 (BH-4)

The BH-4 was drilled up to a depth of 20m at Inter College campus (Fig. 13). The borelog is shown in the Fig. 14. The initial layer up to 1.5m depth is only concrete and pebbles, filled up zone. The rock layer starts from 1.5m and continues up to 20m. Rock type is garnetiferous mica schist from 1.5 to 20.0m with highly weathered schist having very poor core recovery up to 7.0m depth. After that core recovery is found to be very good and it was 100% at 10.5m depth. The RQD varies from 59.33 to 90%. So, it can be stated here that rock quality is extremely good at this site. The core samples obtained are shown in the Fig. 15. There are three joint planes observed from the drilled cores. Ground water was encountered at 1.0m depth which may be due to the presence of some local water body as water seepage can be seen at the surface also.

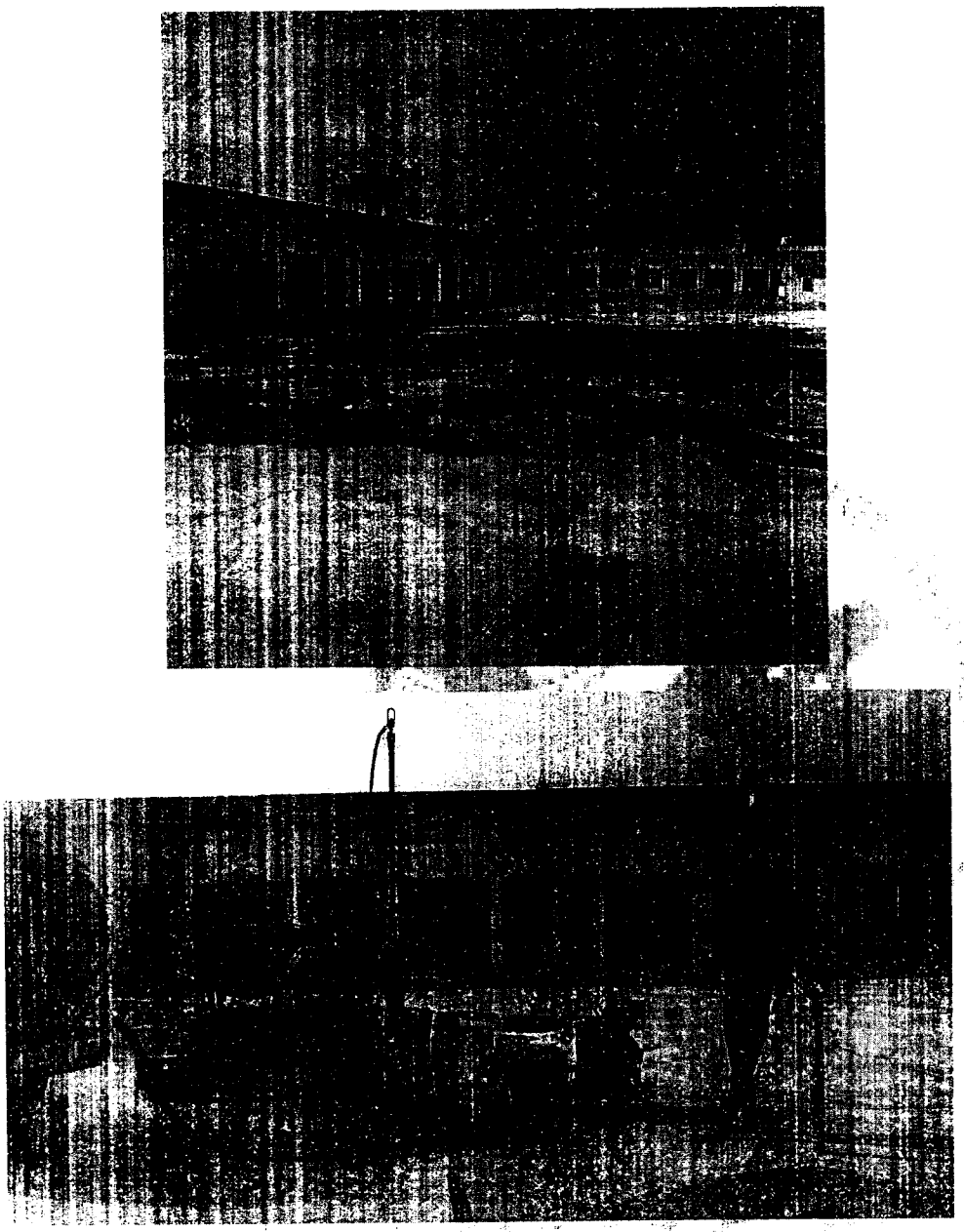


Fig.13 Location of Bore Hole 4 at the Inter College Campus

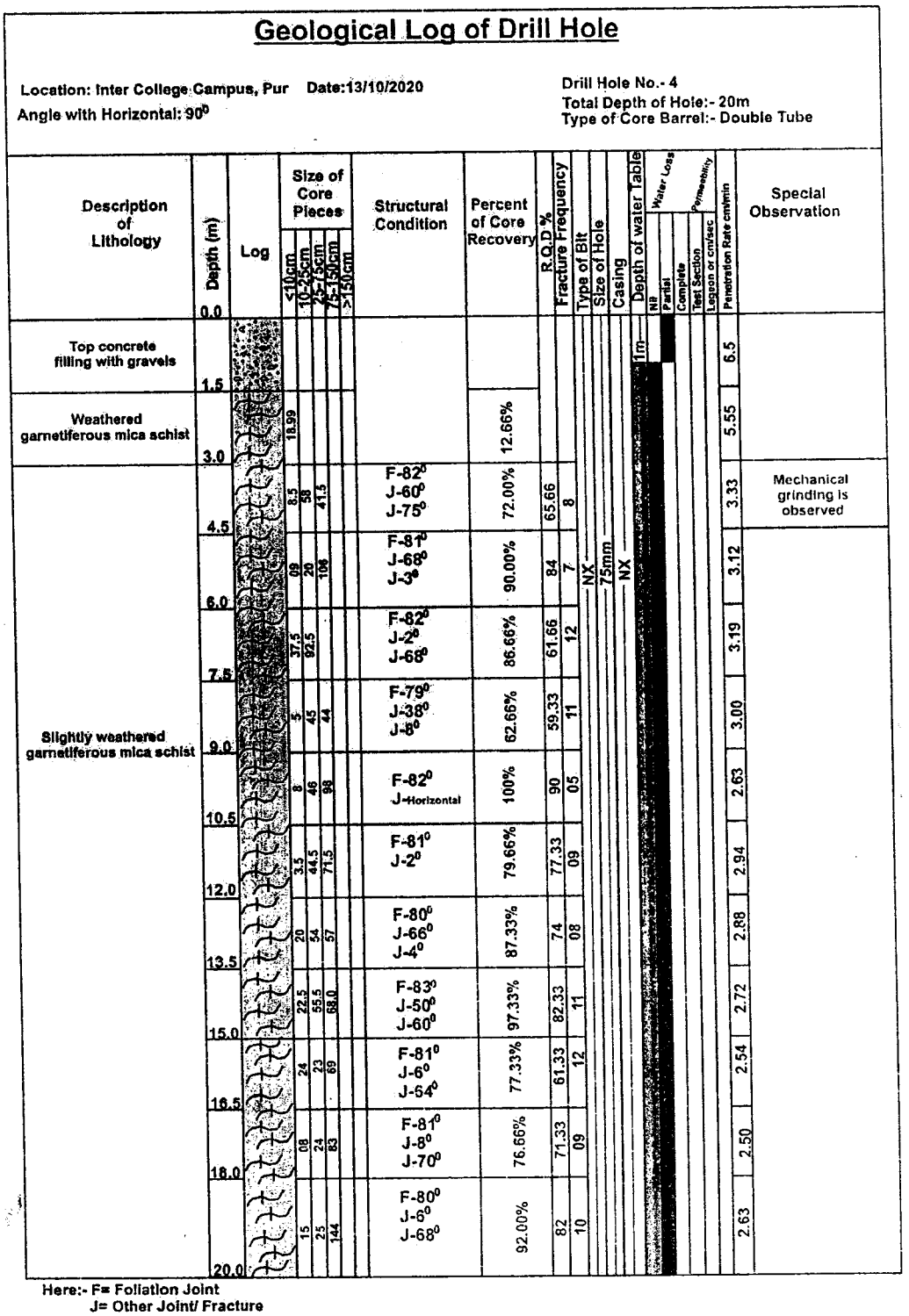


Fig. 14 Geological borelog of BH-4 at Inter College Campus, Pur Village

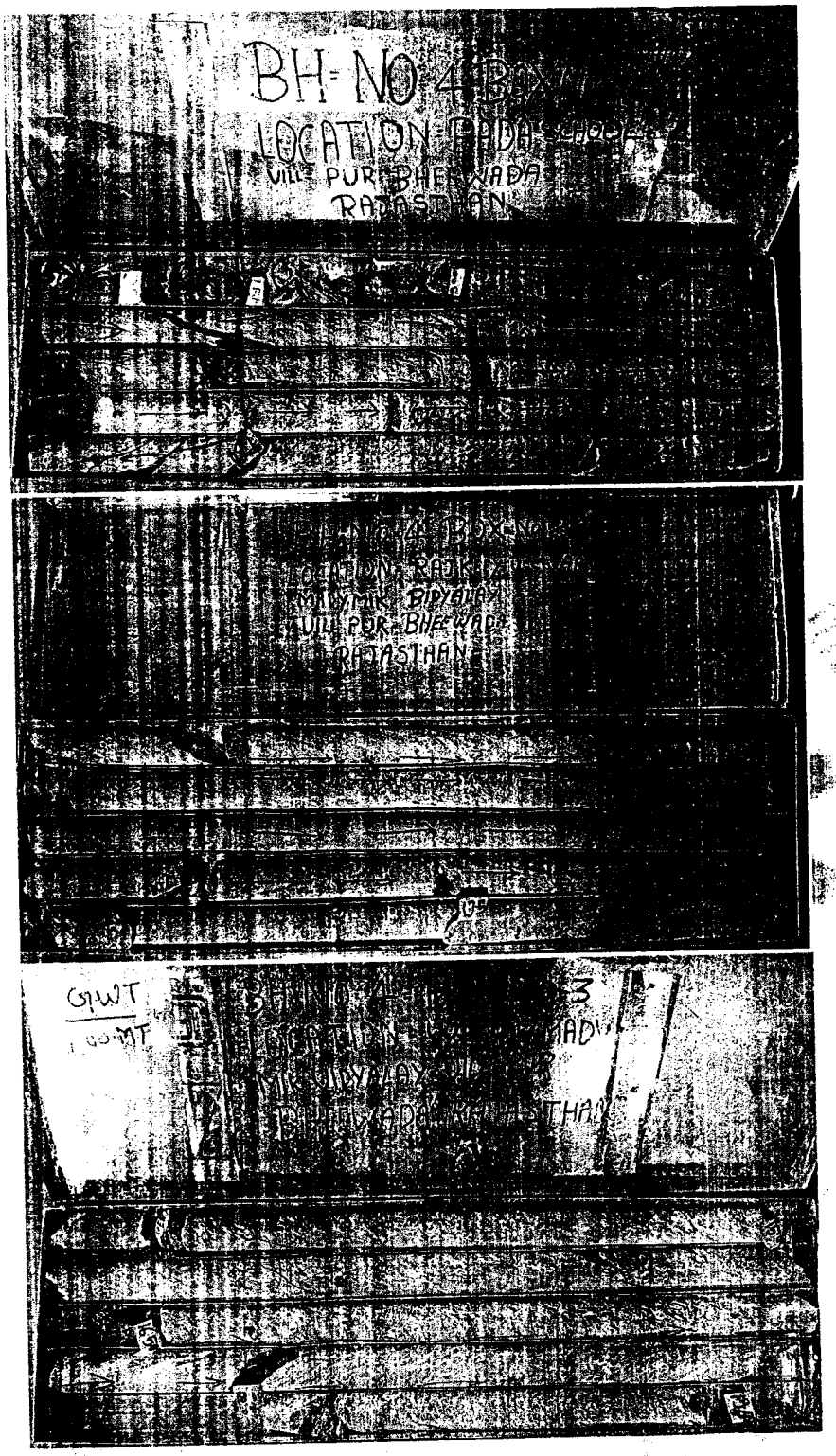


Fig. 15 Core photograph of BH-4

2.2 LABORATORY STUDIES

The rock and soil samples obtained from the boreholes were tested in the laboratory for determination of salient geotechnical properties. All the laboratory tests were carried out following relevant Indian Standards. All the samples were identified and classified as per relevant Indian Standard. The following laboratory tests were conducted on the selected soil samples collected from the boreholes.

2.2.1 Laboratory Tests of Soil Samples

The soil mixed with pebbles present in the top soil layer were tested in the laboratory. The details of the tests and their results are described below.

Grain Size Analysis

Grain size analysis was performed using sieve analysis. The different classes are shown in the Figure 16. The results of the analysis are shown in the Figures 17 and 18.

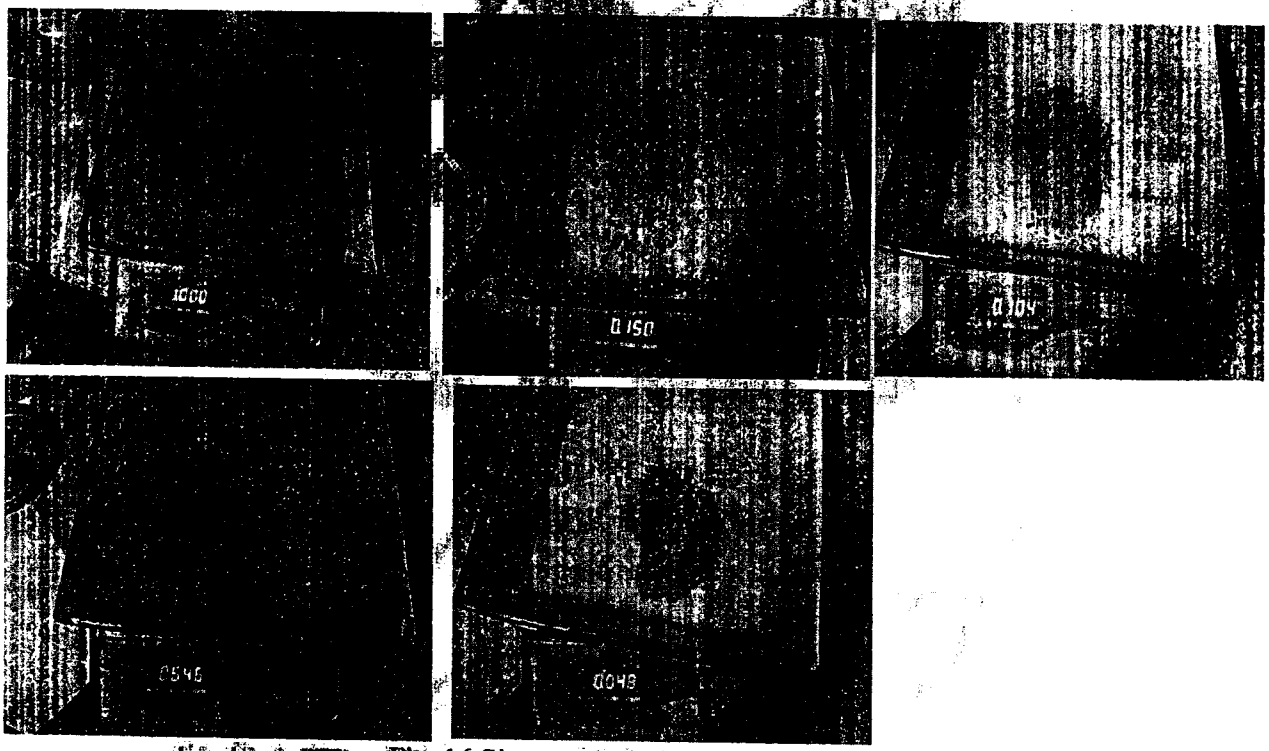


Fig. 16 Sieve analysis for grain size

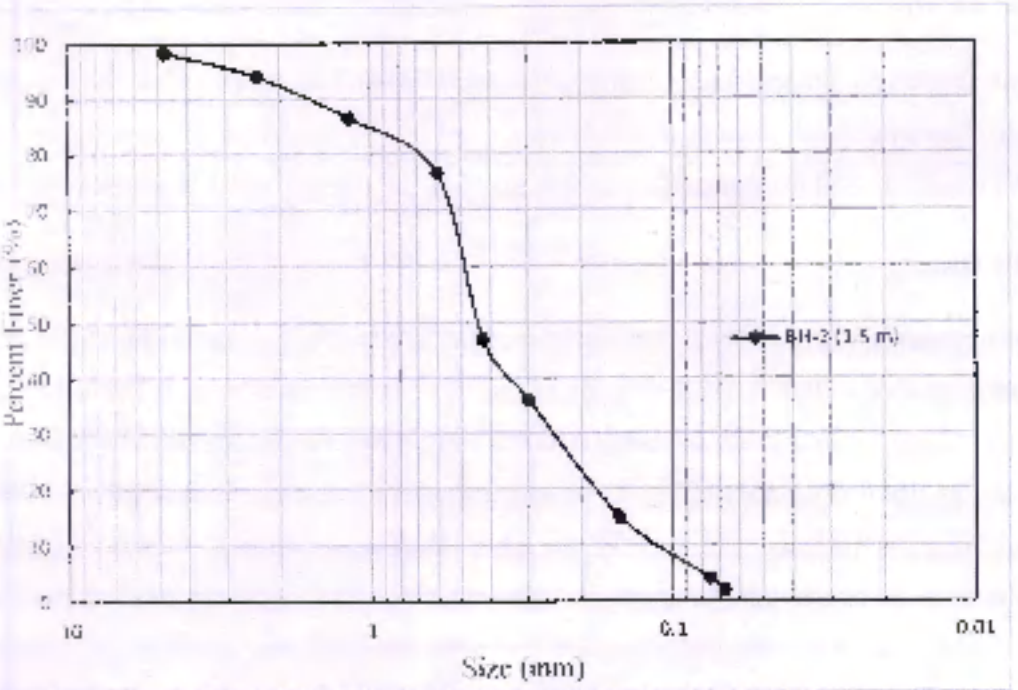


Fig. 17: Grain size distribution curve for BH-2 at depth 1.50 m

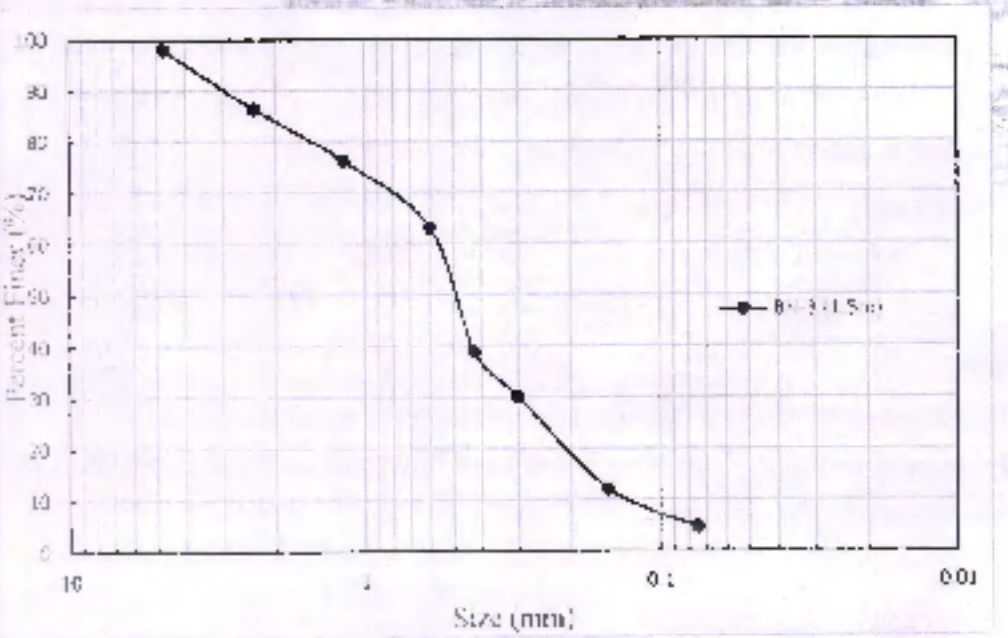


Fig. 18: Grain size distribution curve for BH-3 at depth 1.50 m

The soil samples are predominantly sand type as per the grain size curves. Also, the soil passing through 75-micron sieve is less than 5% and the C_c and C_u values are also not meeting the criteria for SW. Hence, the soil is characterised at both the borehole location as SP (IS code 1498-1970)

Specific Gravity

The Pycnometer was used for determination of specific gravity of soil particles of both fine grained and coarse grained soils. The determination of specific gravity of soil helps in the calculation of void ratio, degree of saturation and other different soil properties. Pycnometer is a glass jar of 1 liter capacity that is fitted at its top by a conical cap made of brass. The Pycnometer was cleaned, dried and cap was tightened. The mass M_1 was taken. The Pycnometer was marked with a vertical line parallel to the axis of the Pycnometer to ensure that the cap is screwed to the same mark each time. The cap was unscrewed and about 200 g of oven dried soil was placed in the Pycnometer. The cap was then tightened and the mass M_2 was taken. The cap was unscrewed and sufficient amount of was water add to the Pycnometer so as to cover the soil. The Pycnometer was then connected to a vacuum pump to remove the entrapped air and after disconnecting the vacuum pump the Pycnometer was filled with water and the mass (M_3) was then taken. The Pycnometer was then emptied, cleaned, dried and filled with water only. The mass (M_4) was taken. The specific gravity of soil is determined using the relation:

$$G = \frac{M_2 - M_1}{(M_2 - M_1) - (M_3 - M_4)}$$

Where,

M_1=mass of empty Pycnometer, M_2= mass of the Pycnometer with dry soil

M_3= mass of the Pycnometer and soil and water, M_4 = mass of Pycnometer filled with water only, G= Specific gravity of soils.

The specific gravity obtained is 2.63

CSIR Toilet

Moisture Content

Table 2 Moisture content test result for BH-2

Moisture Content of Soil (BH-2 depth– 0-1.5m)				
WT. of Container (g)	46	46	44	46
WT. of Container (g)+ Wet Soil (g)	100	88	76	66
WT. of Container+ Dry Soil (g)	98	85	75	64
WT. of Water (g)	2	3	1	2
WT. of Soil (g)	52	39	31	18
MC%	3.84	7.6	3.22	11.11
Mean Moisture content%	6.4425			

Table 3 Moisture content test result table for BH-3

Moisture Content of Soil (BH-3 depth– 0-1.5m)				
WT. of Container (g)	46	48	48	42
WT. of Container (g)+ Wet Soil (g)	100	116	90	86
WT. of Container+ Dry Soil (g)	94	108	90	80
WT. of Water (g)	6	8	4	6
WT. of Soil (g)	48	60	42	38
MC%	12.5	13.5	9.52	15.78
Mean Moisture content%	12.825			

Permeability Tests of Soil Samples

Permeability tests of soil samples obtained from BH-2 and BH-3 were conducted in the laboratory and test results are given in the Tables 4 and 5.

Table 4 Results of permeability tests for the soils obtained from BH-2

Permeability Test for BH-2 (3-4.5m depth)			
Length of Specimen (L) cm	12.7		
Area of Specimen (A) cm²	78.54		
Volume of Specimen (V) cm³	997.458		
Experiment No.	1	2	3
Discharge Q (cm³)	32.4	66	96.3
Time t (sec)	150	300	450
Height of water h (cm)	30	30	30
Temperature (°C)	25	25	25
Coefficient of Permeability at 25°C k = Q.L / (A.h.t) (cm/ sec)	0.001164	0.001186	0.001153
Average Permeability, k (cm/sec)	0.001167841		
Permeability at 25°C: $k_{25} = k \times \eta_t / \eta_{25}$ (cm/sec)	0.001221562		

Table 5 Results of permeability tests for the soils obtained from BH-3

Permeability Test for BH-3 (1.5-3.0m depth)			
Length of specimen (L) cm	12.5		
Area of Specimen (A) cm²	78.69		
Volume of Specimen (V) cm³	983.658 625		
Experiment No.	1	2	3
Discharge Q (cm³)	38	78	159
Time t (sec)	150	300	450
Height of water h (cm)	30	30	30
Temperature (°C)	25	25	25
Coefficient of Permeability at 25°C k = Q.L / (A.h.t) (cm/ sec)	0.001341	0.001377	0.0014
Average Permeability, k (cm/sec)	0.001372788		
Permeability at 25°C: $k_{25} = k \times \eta_t / \eta_{25}$ (cm/sec)	0.001435036		

Direct Shear Test

Direct shear test is performed to determine the shear strength properties i.e. cohesion (c) and friction angle (Ø) of the material. The samples were made from the soil obtained from the bore hole for conducting shear tests. The direct shear test includes the testing of a square prism of soil that is laterally restrained and sheared along a mechanically involved horizontal plane while being subjected to pressure applied along a plane normal to the shearing plane. The soil sample is compacted in mould after bringing it to optimum moisture and dry density condition. Then sample is carefully transferred to the sample shear box. The shearing resistance was measured at regular intervals using data logger and tests were carried out with number of samples using different normal stress until the shearing resistance reached the maximum sustainable value. The relationship between measured shear stress at failure and normal applied stress obtained were noted to determine the shear strength parameters. Graphs were plotted between shear stress and normal stress obtained during the tests and c, Ø values of the soil were obtained (Figures 20 to 23).



Fig. 19 Direct shear test of soil

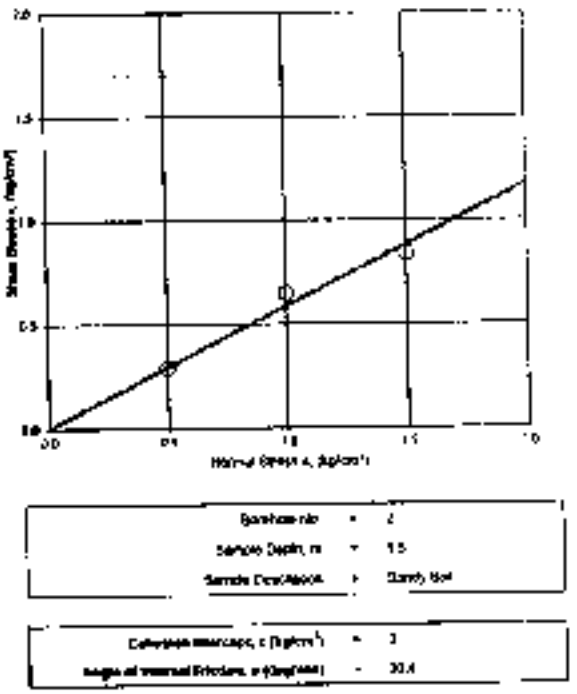


Fig. 20 Shear test of soil sample obtained at 1.5m depth from BH-2

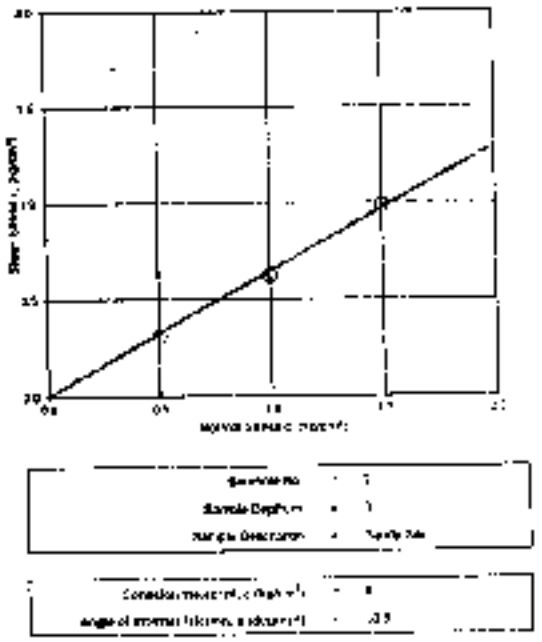


Fig.21 Shear test of soil sample obtained at 3m depth from BH-2

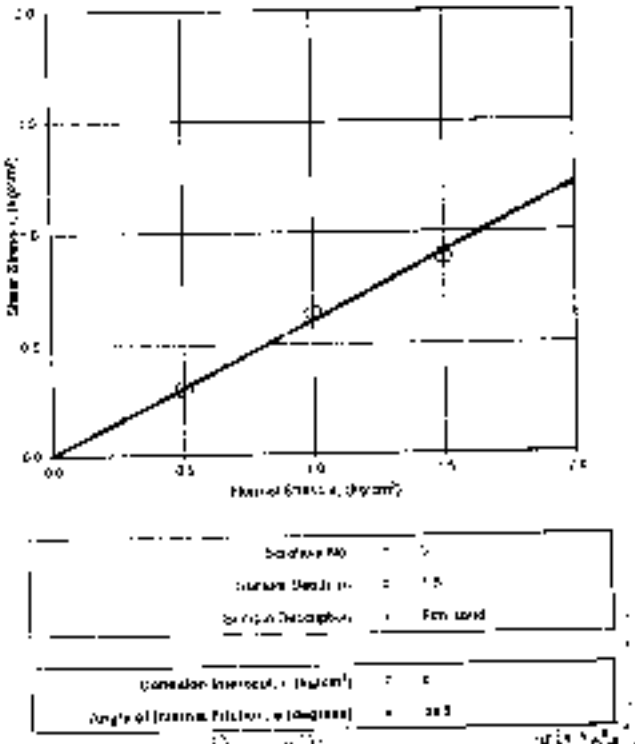


Fig.22 Shear test of soil sample obtained at 1.5m depth from BH-3

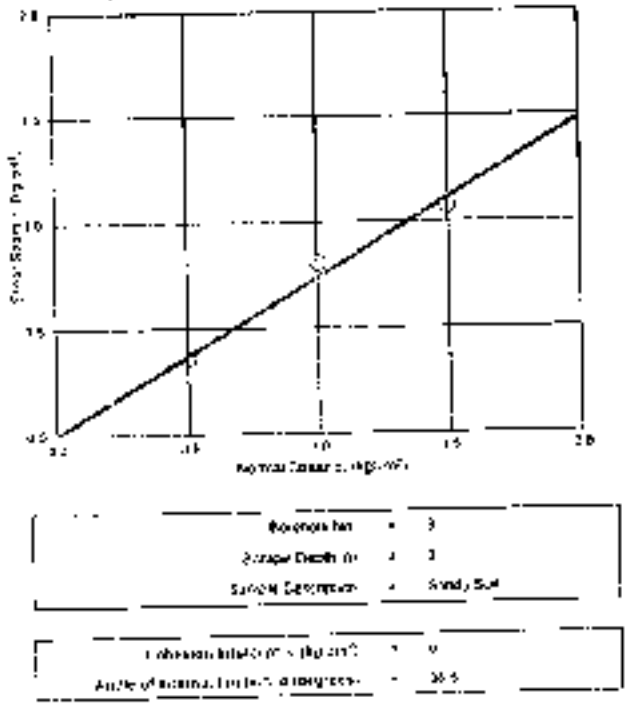


Fig. 23 Shear test of soil sample obtained at 3m depth from BH-3

2.2.2 LABORTORY TESTS OF ROCK SAMPLES

The rock cores obtained from the bore holes were tested for their engineering properties. Laboratory testing comprised of following tests conducted as per procedures given in relevant IS codes.

Slake Durability Tests

This test is done to find out the abrasion resistance offered by a rock sample to weathering and disintegration during wetting and drying cycles. The pebbles and boulders obtained from the bore hole were tested. The results are tabulated in the Tables 6 and 7.

Table 7 Slake durability test of samples of BH-2

Specimen No.	BH-2
Oven-dried weight of drum+ sample, A (gm)	2.434
Oven-dried weight of drum+ retained portion of the sample, after 1st cycle, B (gm)	2.42
Oven-dried weight of drum+ retained portion of the sample, after 2nd cycle, C (gm)	2.416
Weight of drum, D (gm)	1.872
Slake durability Index (%) $I_d = (C-D)/(A-D)*100\%$	96.797153

Table 8 Slake durability test of samples of BH-3

Specimen No.	BH-3
Oven-dried weight of drum+ sample, A (gm)	2.446
Oven-dried weight of drum+ retained portion of the sample, after 1st cycle, B (gm)	2.422
Oven-dried weight of drum+ retained portion of the sample, after 2nd cycle, C (gm)	2.408
Weight of drum, D (gm)	1.874
Slake durability Index (%) $I_d = (C-D)/(A-D)*100\%$	93.35664336

Uniaxial Compressive Strength of Rock Sample

UCS of the rock samples were determined following the relevant methods described in IS 9143 (1979, 2006)

$$UCS = \frac{P}{Change\ in\ area \times Correction\ Factor}$$

Where,

UCS = Unconfined Compressive Strength in MPa

P = Failure Load in N

Correction Factor = 0.77+0.46 (D/L) From IS 516 (1959)

D = Diameter and L = Length of core



Fig. 24 UCS testing of rock core

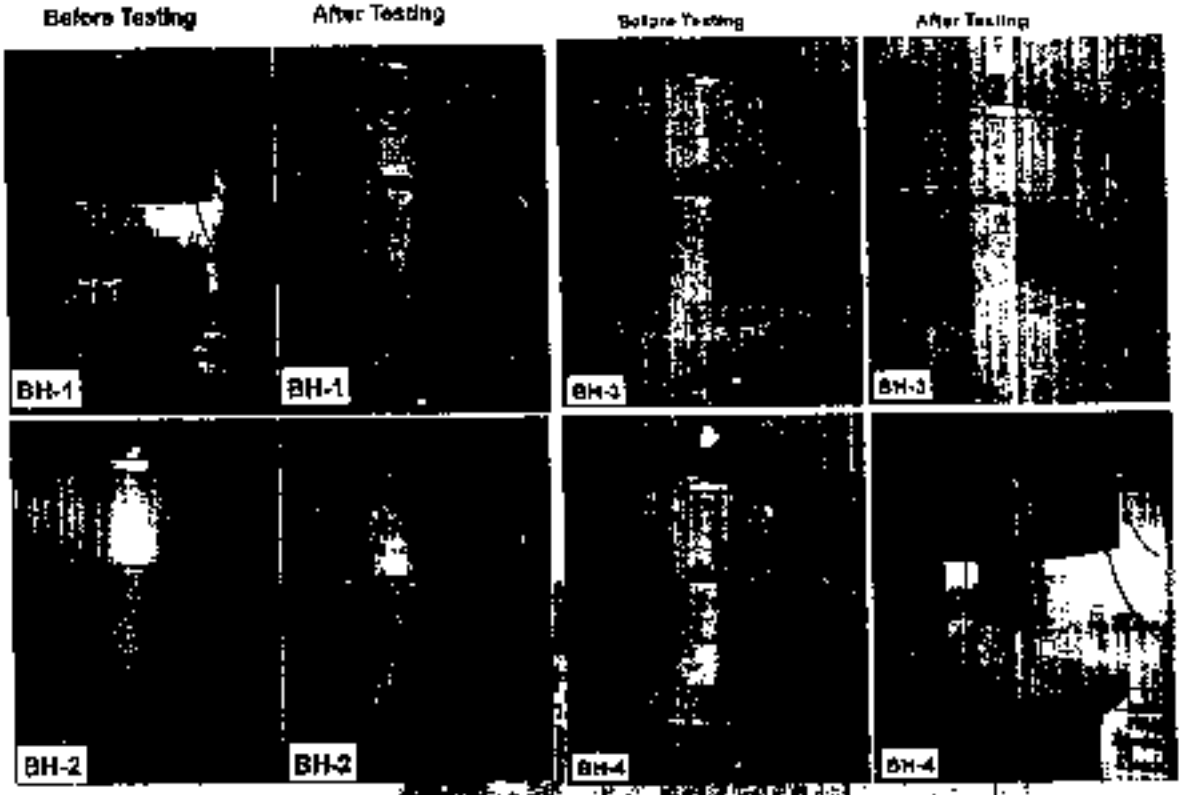


Fig. 25 UCS testing of rock cores showing before and after testing

Porosity and Density of Rock:

Porosity of the rock samples were determined on selected samples as per the relevant methods described in IS: 13030 (1991, 2016).

$$\text{Porosity } (n \text{ in } \%) = (V_v/V) \times 100$$

$V_v = (M_{sat} - M_s) / \rho_w$

ρ_w= density of water at tempreture. t

M_{sat}=Saturated mass of sample

M_s=Mass of solid sample

V_v= Pore volume

V=Bulk volume of sample

$$\text{Dry density } (\rho \text{ in kg/m}^3) = M_s/V$$

Water absorption of Rock

Water content of rock samples were determined on the samples as per the relevant methods described in IS: 13030 (1991, Reaff. 2016).

The water content was calculated from the following formula:

$$w = \frac{(m_2 - m_3)}{(m_3 - m_1)} \times 100$$

Where,

m_1 = Mass of the container with its lid at room temperature

m_2 = Mass of the container with its lid and the sample at room temperature.

m_3 = Mass of the container with its lid and the sample after drying.

Specific gravity of rock is determined as follow.

$$G = Gl \times (m_2 - m_3) / ((m_4 - m_1) - (m_5 - m_3))$$

Where,

Gl = Specific gravity of the liquid used at the constant temperature.

m_1 = Saturated-submerged mass of basket alone, in g

m_2 = Saturated-submerged mass of basket+specimen, in g

m_3 = Mass of container and lid in g

m_4 = Saturated surface dry mass of the sample plus container in g.

m_5 = Dried mass of the container with sample in g.

The summary of the test results of rock cores are given in the Table 9.

Table 9 Results of rock testing

S.No.	Bore Hole No.	Depth (m)	Specimen code	Sample Dimension		Volume of sample in cm³	Air Dry Weight (gm)	Weight of sample in saturated condition (gm)	Saturated weight of sample in water (gm)	Oven Dry weight (gm)	Bulk Density	Specific Gravity	Water absorption %	Porosity %	Void Ratio
				Length (mm)	Diameter (mm)										
1	BH-1	9-10.5	BH-1/1	120	55	284955	783	798	794	778	2.744259036	2.753173778	0.514158852	1.385958561	.05
			BH-1/2	120	55	284955	804	826	822	799	2.821098413	2.85101888	0.501891	1.416036941	.07
2	BH-2	3.50-5.00	BH-2/1	120	55	284955	840	861	857	839	2.947833251	2.969691653	0.519892511	1.532278401	.08
		6.50-8.00	BH-2/2	120	55	284955	856	881	861	856	3.003108174	2.858495344	0.233564 08	0.674661672	.020
		11.00-14.00	BH-2/3	89	56	278819	834	858	836	833	4.221184814	2.98	0.1209498	0.3251 772	.01
3	BH-3	1.50-3.00	BH-3/1	93	55	197045.8	799	803	788	799	4.055255118	3.045012907	0.27353125	0.8342 7615	0.1
		5.00-6.50	BH-3/2	92	55	196999.9	813	825	815	810	4.1 [illegible]	2.78851197	0.2865 [illegible]	0.7971 [illegible]	0.1
		9.00-10.50	BH-3/3	138	55	284955	835	855	837	830	2.919 [illegible]	2.1 [illegible]	0.2499 [illegible]	0.6 [illegible]	.025
4	BH-4	6.00-7.50	BH-4/1	120	55	284955	834	856	836	833	2.92 [illegible]	2.81 [illegible]	0.48 [illegible]	1.3 [illegible]	.07
		7.5 - 9.00	BH-4/2	120	55	284955	848	869	848	848	2.96 [illegible]	2.96 [illegible]	0.5 [illegible]	1.46 [illegible]	.013

3. Computation of Bearing Capacity

Based on Direct Shear Test (Shear Criteria)

a) Site: Near Mo[illegible]

Depth of Foundation considered at 1.5m

Footing width assumed to be 1.5m

The angle of internal friction from direct shear test obtained is 30.4° and apparent cohesion 0.0 kg/cm².

Sc = 1.3 , Sq = 1.2, Sγ = 0.8 (For Square Footing)

Assuming, ic = iq = iγ = 1

Scenario 1: As per the borelog of BH-2, W'= 1 (Since no GWT encountered upto depth of exploration)

1(a) in case of general shear failure

For $\phi = 30.4°$;

Bearing Capacity Factor	IS : 6403 – 1981 R 1997		Interpolated Value for ϕ = 30.4°
	$\phi = 30°$	$\phi = 35°$	
N_c	30.14	46.12	31.42
N_q	18.40	33.30	19.59
N_γ	22.40	48.03	24.45

1(b) in case of Local shear failure

For $\phi = 30.4°$; $\phi' = \tan^{-1}(0.67 \tan 30.4°) = 21.45°$

Bearing Capacity Factor	IS : 6403 – 1981 R 1997		Interpolated Value for ϕ =
	$\phi = 20°$	$\phi = 25°$	
N'_c	14.83	20.72	16.54
N'_q	6.40	10.66	7.64
N'_γ	5.39	10.88	6.98

Table 10 Interpolated values for intermediate shear failure (Cl. 5.2.1.1, IS 6403:1981)

Bearing Capacity Factor	IS : 6403 – 1981 R 1997		Interpolated Values
	$\phi = 30.4°$	$\phi = 21.45°$	
N_c	31.42	16.54	$16.54 + \frac{(31.42 - 16.54)(30.4 - 28.5)}{36 - 28.5} = 20.31$
N_q	19.59	7.64	$7.64 + \frac{(19.59 - 7.64)(30.4 - 28.5)}{36 - 28.5} = 10.67$
N_γ	24.45	6.98	$6.98 + \frac{(24.45 - 6.98)(30.4 - 28.5)}{36 - 28.5} = 11.41$

$N_\phi = \tan^2 (45^\circ + \phi/2) = 3.0488$

$\sqrt{N_\phi} = 1.7461$

$d_c = 1 + 0.2 (1.5/1.5) \times \sqrt{N_\phi} = 1.35$

$d_q = d_\gamma = 1 + [0.1 \times 1.5 \times (\sqrt{N_\phi}/1.5)] = 1.17$

The ultimate bearing capacity for footing resting on soil is calculated using following equation

$q_{ult} = c.N_c.s_c.d_c.i_c + q .(N_q - 1).s_q.d_q.i_q + \frac{1}{2} B.\gamma.N_\gamma.s_\gamma.d_\gamma.i_\gamma.W'$

$q_{ult} = 0$ (since c is zero)$+ (16.5 \times 1.5) \times (10.67-1) \times 1.2 \times 1.17 \times 1$

$+0.5 \times 1.5 \times 16.5 \times 11.41 \times 0.8 \times 1.17 \times 1 \times 1$

$= 0 + 336.02 + 132.16$

$= 468.18 \text{ kN/m}^2$

Using factor of safety 2.5

$q_{safe} = 468.18 / 2.5 = 187.3 \text{ kN/m}^2$

Scenario 2: Assuming total submergence of footing, $W' = 0.5$

The ultimate bearing capacity for footing resting on soil is calculated using following equation

$q_{ult} = c.N_c.s_c.d_c.i_c + q .(N_q - 1).s_q.d_q.i_q + \frac{1}{2} B.\gamma.N_\gamma.s_\gamma.d_\gamma.i_\gamma.W'$

$q_{ult} = 0$ (since c is zero)$+ (16.5 \times 1.5) \times (10.67-1) \times 1.2 \times 1.17 \times 1$

$+0.5 \times 1.5 \times 16.5 \times 11.41 \times 0.8 \times 1.17 \times 1 \times 0.5$

$= 0 + 336.02 + 66.1$

$= 402.12 \text{ kN/m}^2$

Using factor of safety 2.5

$q_{safe} = 402.12 / 2.5 = 161 \text{ kN/m}^2$

Based on Standard Penetration Test (Shear Criteria)

a) Site: Near Mosque (BH-2)

The SPT value corrected for the depth 1.5 is 13. The angle of internal friction $\phi = 31^\circ$

1(a) in case of general shear failure

For $\phi = 31^\circ$

Bearing Capacity Factor	IS : 6403 – 1981 R 1997		Interpolated Value for ϕ = 31°
	ϕ = 30°	ϕ = 35°	
N_c	30.14	46.12	33.34
Nq	18.40	33.30	21.38
$N\gamma$	22.40	48.03	27.53

1(b) in case of Local shear failure

For ϕ = 31°; $\phi' = \tan^{-1}(0.67 \tan 31°) = 21.93°$

Bearing Capacity Factor	IS : 6403 – 1981 R 1997		Interpolated Value for ϕ = 21.93°
	ϕ = 20°	ϕ = 25°	
N'_c	14.83	20.72	17.10
N'_q	6.40	10.66	8.04
N'_γ	5.39	10.88	7.51

Table 11 Interpolated values for intermediate shear failure (Cl. 5.2.1.1, IS 6403:1981)

Bearing Capacity Factor	IS : 6403 – 1981 R 1997		Interpolated Values
	ϕ = 31°	ϕ = 21.93°	
N_c	33.34	17.10	$17.10 + \frac{(33.34 - 17.10)(31 - 28.5)}{36 - 28.5} = 22.51$
N_q	21.38	8.04	$8.04 + \frac{(21.38-8.04)(31-28.5)}{36-28.5} = 12.49$
N_γ	27.53	7.51	$7.51 + \frac{(27.53 - 7.51)(31 - 28.5)}{36 - 28.5} = 14.18$

$N_\phi = \tan^2(45° + \phi/2) = 3.124$

$\sqrt{N_\phi} = 1.767$

$dc = 1 + 0.2\ (1.5/1.5) \times \sqrt{N_\phi} = 1.35$

$dq = d\gamma = 1 + [0.1 \times 1.5 \times \{\sqrt{N_\phi}\}/1.5] = 1.18$

The ultimate bearing capacity for footing resting on soil is calculated using following equation

$q_{ult} = c.N_c.s_c.d_c.i_c + q.(N_q - 1).s_q.d_q.i_q + \frac{1}{2} B.\gamma.N_\gamma.s_\gamma.d_\gamma.i_\gamma.W'$

$q_{ult} = 0$ (since c is zero)+ (16.5x 1.5)x (12.49-1) x 1.2 x 1.18 x 1

+0.5 x 1.5 x 16.5 x 14.18 x 0.8 x 1.18 x 1 x 1

= 0 – 402.68 + 165.65

= 568.33 kN/m^2

Using factor of safety 2.5

q_{safe} = 568.33 / 2.5 = 227.33 kN/m^2

Scenario 2: Assuming **total submergence** of footing, W'= 0.5

The ultimate bearing capacity for footing resting on soil is calculated using following equation

$q_{ult} = c.N_c.s_c.d_c.i_c + q .(N_q - 1).s_q.d_q.i_q + ½ B.\gamma.N_\gamma.s_\gamma.d_\gamma.i_\gamma.W'$

q_{ult} = 0 (since c is zero)+ (16.5x 1.5)x (12.49-1) x 1.2 x 1.18 x 1

+0.5 x 1.5 x 16.5 x 14.18 x 0.8 x 1.18 x 1 x 0.5

= 0 + 402.68 + 82.82

= 485.5 kN/m^2

Using factor of safety 2.5

q_{safe} = 485.5 / 2.5 = 194.2 kN/m^2

Computation of Bearing Capacity

Based on Direct Shear Test (Shear Criteria)

b) Site: Near Mandir (BH-6)

Depth of Foundation considered at 1.5m

Footing width assumed to be 1.5m

The angle of internal friction from direct shear test obtained is 32.9° and apparent cohesion 0.0 kg/cm^2.

Sc = 1.3 , Sq = 1.2, Sγ = 0.8 (For Square Footing)

Assuming, ic = iq = iγ = 1

Scenario 1: As per the borelog of BH-2, W'= 1

1(a) in case of general shear failure

For ϕ = 32.9°;

Bearing Capacity Factor	IS : 6403 – 1981 R 1997		Interpolated Value for ϕ = 32.9°
	ϕ = 30°	ϕ = 35°	
N_c	30.14	46.12	39.41
N_q	18.40	33.30	27.042
N_γ	22.40	48.03	37.26

1(b) In case of Local shear failure

For ϕ = 32.9°; $\phi' = \tan^{-1}(0.67 \tan 32.9°) = 23.43°$

Bearing Capacity Factor	IS : 6403 – 1981 R 1997		Interpolated Value for ϕ = 23.43°
	ϕ = 20°	ϕ = 25°	
N'_c	14.83	20.72	18.87
N'_q	6.40	10.66	9.32
N'_γ	5.39	10.88	9.16

Table 12 Interpolated values for intermediate shear failure (Cl. 5.2.1(2) IS:6403:1981)

Bearing Capacity Factor	IS : 6403 – 1981 R 1997		Interpolated Values
	ϕ = 32.9°	ϕ' = 23.43°	
N_c	39.41	18.87	$18.87 + \frac{(39.41 - 18.87)(32.9 - 28.5)}{36 - 28.5} = 30.92$
N_q	27.042	9.32	$9.32 + \frac{(27.042 - 9.32)(32.9 - 28.5)}{36 - 28.5} = 19.72$
N_γ	37.26	9.16	$9.16 + \frac{(37.26 - 9.16)(32.9 - 28.5)}{36 - 28.5} = 25.65$

$N_\phi = \tan^2(45° + \phi/2) = 3.378$

$\sqrt{N_\phi} = 1.838$

$d_c = [1 + 0.2(1.5/1.5)\sqrt{N_\phi}] = 1.37$

$d_q = d_\gamma = 1 + [0.1 \times 1.5 \times (\sqrt{N_\phi}/1.5)] = 1.18$

The ultimate bearing capacity for footing resting on soil is calculated using following equation

$q_{ult} = c' N_c s_c d_c i_c + q' (N_q - 1) s_q d_q i_q + \frac{1}{2} B \gamma_1 N_\gamma s_\gamma d_\gamma i_\gamma W'$

q_{ult} = 0 (since c is zero)+ (16.5x 1.5)x (19.72-1) x 1.2 x 1.18 x 1

+0.5 x 1.5 x 16.5 x 25.65 x 0.8 x 1.18 x 1 x 1

= 0 + 656.1 + 299.6

= 955.7 kN/m^2

Using factor of safety 2.5

q_{safe} = 955.7 / 2.5 = 382.28 kN/m^2

Scenario 2: Assuming total submergence of footing, W'= 0.5

The ultimate bearing capacity for footing resting on soil is calculated using following equation

$q_{ult} = c.N_c.s_c.d_c.i_c + q_o.(N_q - 1).s_q.d_q.i_q + ½ B.\gamma.N_\gamma.s_\gamma.d_\gamma.i_\gamma.W'$

q_{ult} = 0 (since c is zero)+ (16.5x 1.5)x (19.72-1) x 1.2 x 1.18 x 1

+0.5 x 1.5 x 16.5 x 25.65 x 0.8 x 1.18 x 1 x 0.5

= 0 + 656.1 + 149.8

= 805.9 kN/m^2

Using factor of safety 2.5

q_{safe} = 805.9 / 2.5 = 322.36 kN/m^2

Based on Standard Penetration Test (Shear Criteria)

a) Site: Near Mandir (BH-3)

The SPT value corrected for the depth 1.5 is 20. The corresponding angle of internal friction ϕ = 33.5°.

1(a) in case of general shear failure

For ϕ = 33.5°;

Sc = 1.3 , Sq = 1.2, Sγ = 0.8 (For Square Footing)

Assuming, ic = iq = iγ =1

Scenario 1: As per the boreing of BH-3, W'= 1

1(a) in case of general shear failure

For ϕ = 33.5°;

Bearing Capacity Factor	IS : 6403 – 1981 R 1997		Interpolated Value for ϕ = 33.5°
	ϕ = 30°	ϕ = 35°	
N_c	30.14	46.12	41.33
N_q	18.40	33.30	28.83
N_γ	22.40	48.03	40.34

b)by in case of Local shear failure

For ϕ = 33.5°: $\phi' = \tan^{-1}(0.67 \tan 33.5°) = 23.92°$

Bearing Capacity Factor	IS : 6403 1981 R 1997		Interpolated Value for o = 23.92°
	o = 20°	ϕ = 25°	
N'_c	14.83	20.72	19.45
N'_q	6.40	10.66	9.74
N'_γ	5.39	10.88	9.69

Table 13 Interpolated values for intermediate shear failure (Cl. 5.2.1.1, IS 6403:1981)

Bearing Capacity Factor	IS : 6403 – 1981 R 1997		Interpolated Values
	ϕ = 33.5°	o = 23.92°	
N_c	41.33	19.45	$19.45 + \frac{(41.33-19.45)(33.5-28.5)}{36-28.5} = 34.04$
N_q	28.83	9.74	$9.74 + \frac{(28.83-9.74)(33.5-28.5)}{36-28.5} = 22.47$
N_γ	40.34	9.69	$9.69 + \frac{(40.34-9.69)(33.5-28.5)}{36-28.5} = 30.12$

$N_q = \tan^2(45° + o/2) = 3.464$

$\sqrt{N_q} = 1.861$

$sc = 1 + 0.2 (1.5/1.5) \times \sqrt{N_q} = 1.37$

$dq = dy = 1 + [0.1 \times 1.5 \times \sqrt{N_q}/1.5] = 1.19$

The ultimate bearing capacity for footing resting on soil is calculated using following equation

$q_{ult} = c.N_{cs}.d_c.i_c + q_o(N_q - 1)s_q\, d_q.i_q + \frac{1}{2} B_r \gamma N_\gamma s_\gamma d_\gamma i_\gamma W'$

q_{ult} = 0 (since c is zero)+ (16.5x 1.5)x (22.47-1) x 1.2 x 1.19 x 1

+0.5 x 1.5 x 16.5 x 30.12 x 0.8 x 1.19 x 1 x 1

= 0 + 758.82 + 354.84

= 1113.66 kN/m^2

Using factor of safety 2.5

q_{safe} = 1113.66 / 2.5 = 445.5 kN/m^2

Scenario 2: Assuming total submergence of footing, W'= 0.5

The ultimate bearing capacity for footing resting on soil is calculated using following equation

$q_{ult} = c.N_c.s_c.d_c.i_c + q .(N_q - 1).s_q.d_q.i_q + ½ B.\gamma.N_\gamma.s_\gamma.d_\gamma.i_\gamma.W'$

q_{ult} = 0 (since c is zero)+ (16.5x 1.5)x (22.47-1) x 1.2 x 1.19 x 1

10.5 x 1.5 x 16.5 x 30.12 x 0.8 x 1.19 x 1 x 0.5

= 0 + 758.82 + 177.42

= 936.24 kN/m^2

Using factor of safety 2.5

q_{safe} = 936.24 / 2.5 = 374.5 kN/m^2

Table 1.5 Bearing capacity of soil

Site Location	Bearing capacity based on shear strength parameters obtained			
	From Direct Shear Tests (t/m^2)		From field SPT values (t/m^2)	
	Present Field Condition	Assumed Submerged Condition	Present Field Condition	Assumed Submerged Condition
BH-2	18.73	16.10	22.73	19.42
BH-3	38.23	32.24	44.55	37.45

Considering the lower bearing capacity from the above two criteria, it is found that the net safe bearing capacity at location near Mosque (BH-2) is 18.73 and 16.1 t/m2 for the present scenario and in case of submergence of the foundation respectively. Similarly, at the location near Mandir (BH-3), the net safe bearing capacity is 38.23 and 32.24 t/m2 for the present scenario and in case of submergence of the foundation respectively.

4. Conclusions & Recommendation

The geological and geotechnical investigation were carried out in the Pur village to find out the causes for the development of cracks in the buildings. The study shows that the village is situated on schist, a high grade metamorphic rock with vertical foliation. The rock outcrops are clearly visible in the outer periphery of the village and most of the houses in this area are situated almost on the bedrock. The borelog study was carried out by drilling bore holes at selected sites. It was found that the soil thickness overlying the rocks in this area is very less, around 3m. The houses situated in this locality have not developed any crack. The inner region of the village has sand mixed with pebbles/boulders of rocks overlying the schist rocks. The overburden thickness of these loose rock fragments and soil above the bed rocks vary from 8m to 14m. In this central portion, many houses have developed cracks. The cracks developed on the floors and walls are clearly visible in these houses, temple and the mosque.

The geotechnical properties of the soil and rocks were determined from the laboratory investigation. The borehole investigation revealed that the overburden soil varies from sand particles to rock boulders. The shear strength properties show that the soil has apparently no cohesion (c=0) and friction angle value varies from 30.4° to 36.6°. The bearing capacity of the soil is found to be adequate, however it may decrease if gets saturated with water as the top layer is composed of boulder soil matrix. Also, the bearing capacity determined for the studied borehole locations significantly vary, hence, a lower bearing capacity in nearby areas cannot be ruled out. The uniaxial compressive strength (UCS) of the schist rocks vary from 22 to 38 MPa. This shows very low strength of the rock and this is obvious as schist is a soft rock having dominant mica content. The core recovery found is very low and the RQD% of the rock mass is nil up to a depth of 7m to 15m as no rock strata is present within this depth in the central region. In case of water percolating down to the vertically foliated weathered mica schist, there could be a possibility of weakening of the rock strata because of the swelling of mica minerals.

Based on the above study the following conclusions are made:

I. In general, engineering properties of the soil layer is good and suitable for building foundation.

II. The bedrock below the soil layer at a depth of 8m to 14m is weathered schist having low strength with vertical foliation. This may undergo dilation if gets saturated with water because of dominating mica minerals having swelling property.

III. There is a thick heterogeneous soil layer comprises of sand and pebbles/boulders in the central part of the village where cracks are developed in the clusters of houses. There could be a possibility of washing out of fines due to water seepage in this soil layer creating some void spaces. This may cause settlement of buildings resulting in appearance of cracks. However, saturated zones were not encountered in the overburden soil layer during the drilling.

IV. Another cause of crack development in the buildings could be the thick heterogeneous soil layer subjected any kind of dynamic loading causing loosening of the heterogeneous soil layer and creating void spaces.

V. It is inferred from the geotechnical investigation that the cracks are appeared only in the buildings, which are situated on the considerably thick heterogeneous soil in the central part of the village. The buildings situated at the village periphery having less overburden are less damaged than the buildings in the central part of the village where the loose soil mixed with rock fragments has a thickness varying from 8m to 14m.

VI. As a suggestive measure, it is advised to retrofit and strengthen the building foundations.

VII. The drainage network should be properly investigated and improved if there are any leakages or underground seepage problems.

Part II: STRUCTURAL INVESTIGATIONS

1	Name of work	Studies to investigate the reasons of cracks development in buildings of Pur village, Bhilwara, Rajasthan
2	Institute	CSIR-Central Building Research Institute, Roorkee
3	Site	Pur Village, Bhilwara, Rajasthan
4	Date of visit	28th January 2020 to 3rd February 2020 28th September 2020 to 2nd October 2020
5	Type of work	Condition assessment, cracks mapping and monitoring of various buildings in Pur village, Bhilwara
6	Status of work	• Condition assessment of 6 important structures (3 Schools, 1 Hospital, 1 Temple & 1 Mosque) and more than 80 houses of Pur Village, Bhilwara has been carried out in respect to typology of buildings, structural systems, construction materials, mapping of structural and non-structural cracks and other observations. The buildings were identified and marked for monitoring at different locations in Pur village. • The monitoring of cracks in buildings were carried out after installation of Demec gauges at different locations in the building. • Total of about 237 locations were marked for crack monitoring and readings were taken. • Demec points locations and crack measurements are given in **Annexure A** • During studies, the cracks and other distresses in buildings were properly marked. The plan drawings of few buildings under distressed were prepared. Crack mapping and its pattern for all the structures/houses were carried out. Architectural drawing and crack mapping are provided in **Annexure B.**
7	Observations	• The building stocks in Pur village are mostly non-engineered type with stone masonry wall having thickness varying from 0.35m -0.45 m. • The majority of the houses in the village are single storied or G+1 structure. • The sand stone slabs are used as in roofing elements.

		• Kota stone has been used as flooring material in the most of houses. • Foundations of buildings were constructed with stone masonry with varying depth of about 0.5 m - 2.5 m. At a few places it was even deeper. • The roof slabs were made of sandstone supported with steel girders. A few houses also used wooden beams and I-Section for providing support to stone slabs. • Recently build houses were found to be constructed with RCC roof slab and having brick masonry. In few places both stone masonry and brick masonry were observed along with RCC roof slab and stone slab where new construction was done over/along the old structure. • The diagonal cracks were predominantly observed in walls mostly in non-engineered buildings and old structures. The cracks were also found between wall joints, surface floors, ceiling and skirting of walls. • Stone flooring were found dislocated at a few places causing gaps between stones, which make the surface uneven. • Most of cracks in walls were diagonal in nature and at some places cracks propagated from floor to wall and then to ceiling. • Water leakage problem from cracked underground water tank in various houses were also observed • The damages and cracking in the buildings are mostly due to differential settlements. • The engineered buildings made with reinforced concrete frames or brick masonry load bearing buildings were found negligible damages except a few. • The cracks were found gradually increasing at several locations. The reading were found increase in cracks varying from 0.007 mm to 1.000 mm during 8 months period at most of the locations. However, a few cracks were found widened even about 3.300 mm. The crack widths found to be also decreased at several locations.
8.	Conclusions	• The damages were observed mainly in non-engineered old buildings. The crack pattern in the buildings clearly indicate towards differential settlements in foundation. Several buildings were found severely damaged, which need to be dismantled and reconstructed. • The cracks were found gradually progressing at several locations. It is also due to rearrangement in non-engineered building elements.

		• The foundations were found filled with stones only, where the cracks were observed. • The most water tanks are underground made with stone masonry walls. The tanks were also found damaged at several places. This leads to seepage of water into foundation areas causing settlements.
9.	Recommendations	Buildings in Pur Village, Bhilwara, Rajsthan are mostly affected by differential settlements. This leads to both non-structural and structural damages. These can be clearly differentiated. The severity of the structural damages were carefully studied and found that the damages were more prominent in non-engineered buildings as compared to engineered buildings. Before a decision by competent authority on repair and restoration or demolition of the buildings, a holistic approach is required. Often it has been seen that the recommendations are made in great haste create further problems. Therefore, it is advised that dismantling and reconstruction or repair and rehabilitation of buildings were taken after consultative meetings with affected residents. The proper categorization of the damages are therefore, of basic importance for post damage rehabilitation or reconstruction program. **Non-structural/Architectural repairs** The main purpose of these repairs is to bring back the architectural shape of the building so that all services start working and the functioning of building is resumed quickly. The actions will include the following: a) Patching up of defects such as cracks and fall of plaster. b) Repairing doors, windows, replacement of glass panes. c) Checking and repairing electric wiring. d) Checking and repairing gas pipes, water pipes and plumbing services. e) Rebuilding non-structural walls, smoke chimneys, boundary walls, etc. f) Replastering of walls as required. g) Rearranging disturbed roofing tiles. h) Relaying cracked flooring at ground level i) Redecoration – white washing, painting etc. The architectural repairs as stated above do not restore the original structural strength of cracked walls or columns and may sometimes be very illusive, since the redecorated building will hide all the weaknesses and the building will suffer even more sever damages if shaken again by an equal shock since the original energy absorbing capacity will not be available.

Structural repairs or restoration

The main purpose of restoration is to carry out structure repairs to load bearing elements. It may involve cutting portion of the elements and rebuilding them or simply adding more structure material so that the original strength is more or less restored. The process may involve inserting temporary supports, underpinning etc. After assessing the damage of particular structural elements, suitable repair methods should be adopted component wise depending upon damage intensity. Some of the approaches are stated below:

a) Removal of portions of cracked masonry walls and piers and rebuilding them in richer mortar. Use of non-shrinking mortar will be preferable.

b) Addition of reinforcing mesh on both faces of the cracked wall, holding it to the wall through spikes or bolts and covering it suitably. The strength of the reinforced cover plates should be designed to more than balance the lost strength of the cracked elements.

c) Injecting epoxy, cement grout or like materials, or cement mortar which is strong in tension, into the cracks in columns, beams, walls etc. depending on the width of the crack and lost strength to be restored.

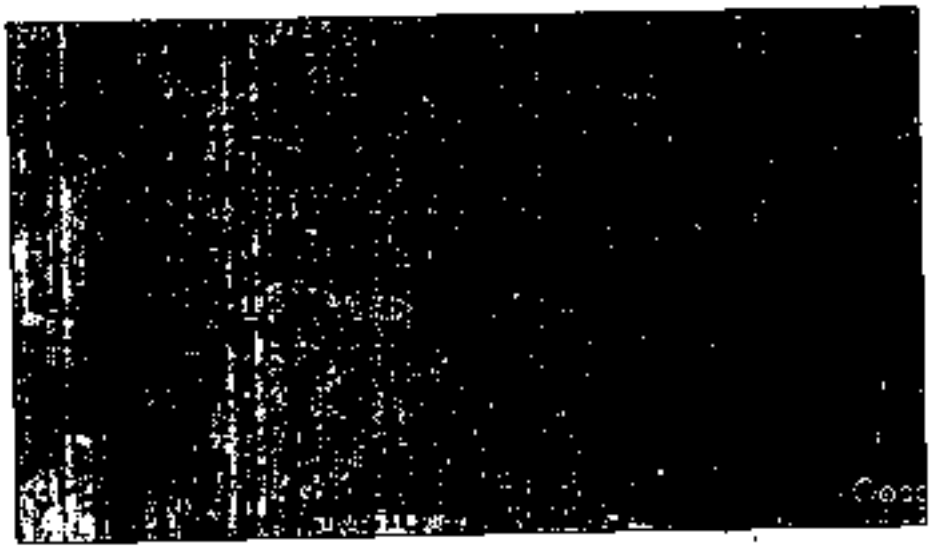
Where structural repairs are considered necessary, these should be carried out prior to or simultaneously with the architectural repairs so that the total planning of work could be done in a coordinated manner and wastage is avoided.

Dismantling and Reconstruction

The main purpose of dismantling and reconstruction is to dismantle the existing building/ structure which is beyond repair. It may involve dismantling of the building and reconstruct them based on geotechnical investigation report in engineered manner. This requires proper planning and implementation.

Resettlements

The survey of building shows that damages in buildings were distributed in particular region near Laxmi Narayan temple and Madina Masjid. The information about damage distribution in this whole region, was prepared by block-by-block basis survey. Therefore, it is advised to resettle the affected people in some other stable locations.



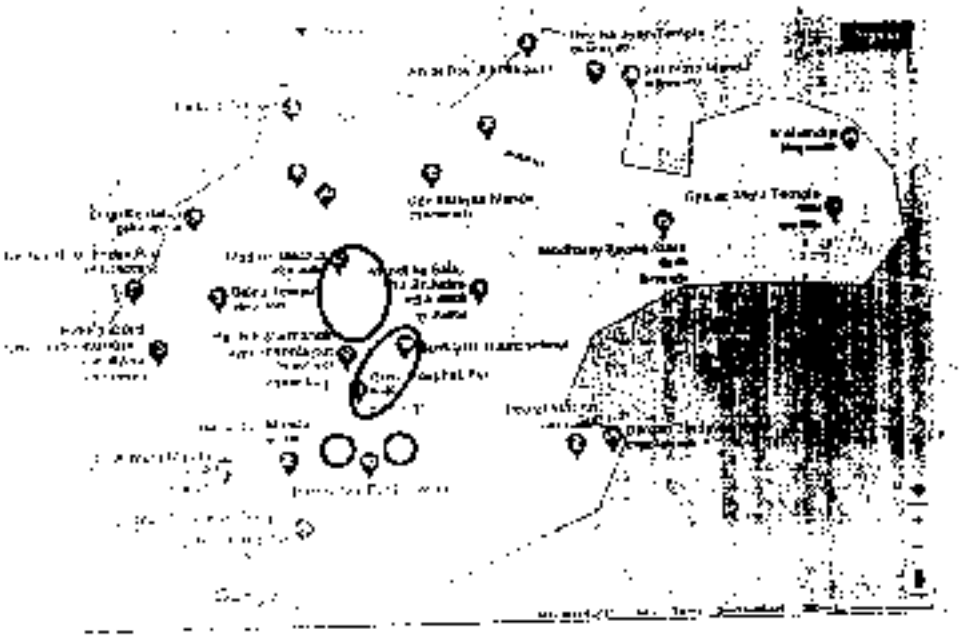


Fig. 1 (a) Satellite image of Pur village (hashed and red circled area)showing locations covered

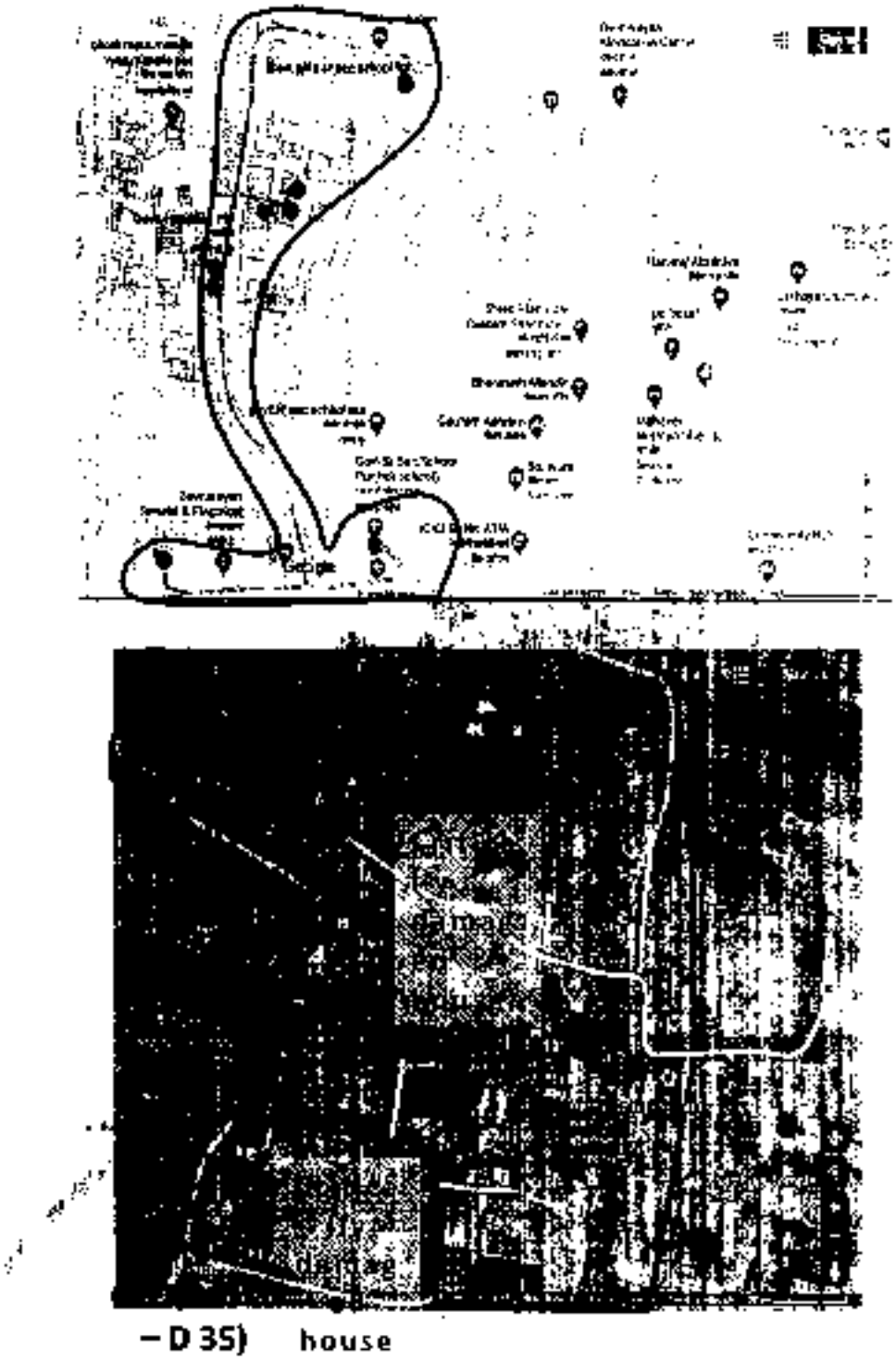


Fig. 1 (b). Locations of houses having demec points (marked red and green dots) installed

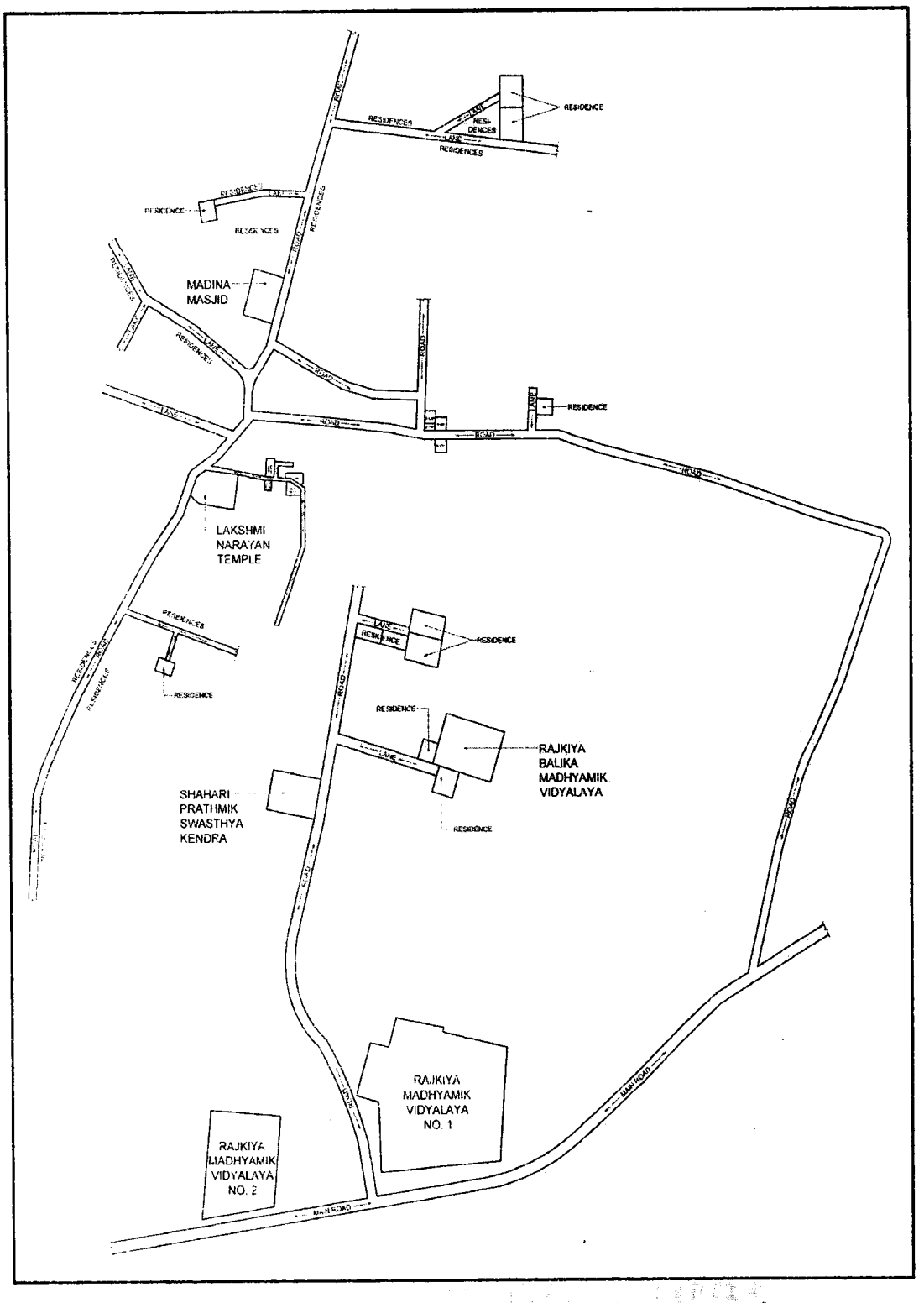


Fig. 2. Key Plan of Pur village

Survey Reports of the Buildings

1. Government Primary School

Observations:

- No. of stories built: Single.
- Occupancy: About 300 students.
- School was built around year 1995.
- Building was load bearing structure as shown in Fig. 3.
- Building walls are made of stone masonry in lime mortar and plastered with cement mortar.
- Cracks observed in middle of walls and near wall corners as shown in Fig. 4.
- Large width cracks observed propagating from walls to the roof slab.

Building type	Foundation type	Masonry type	Flooring	Roof type	Area
Load bearing structure	Stone masonry	Stone masonry	Kota stone	Stone slab	1271 sqm

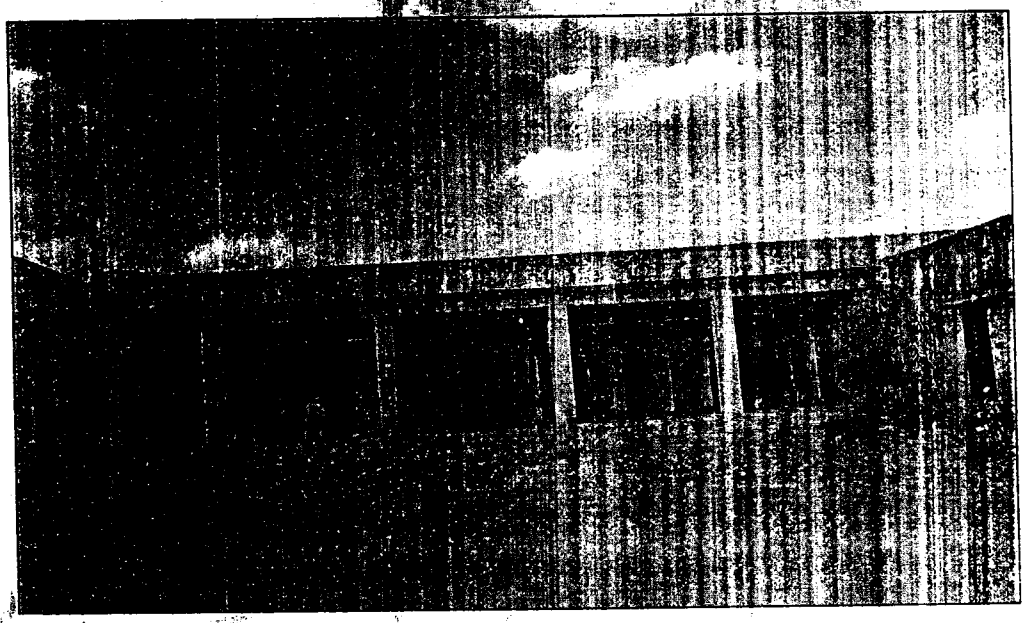


Fig. 3. Govt. primary school building

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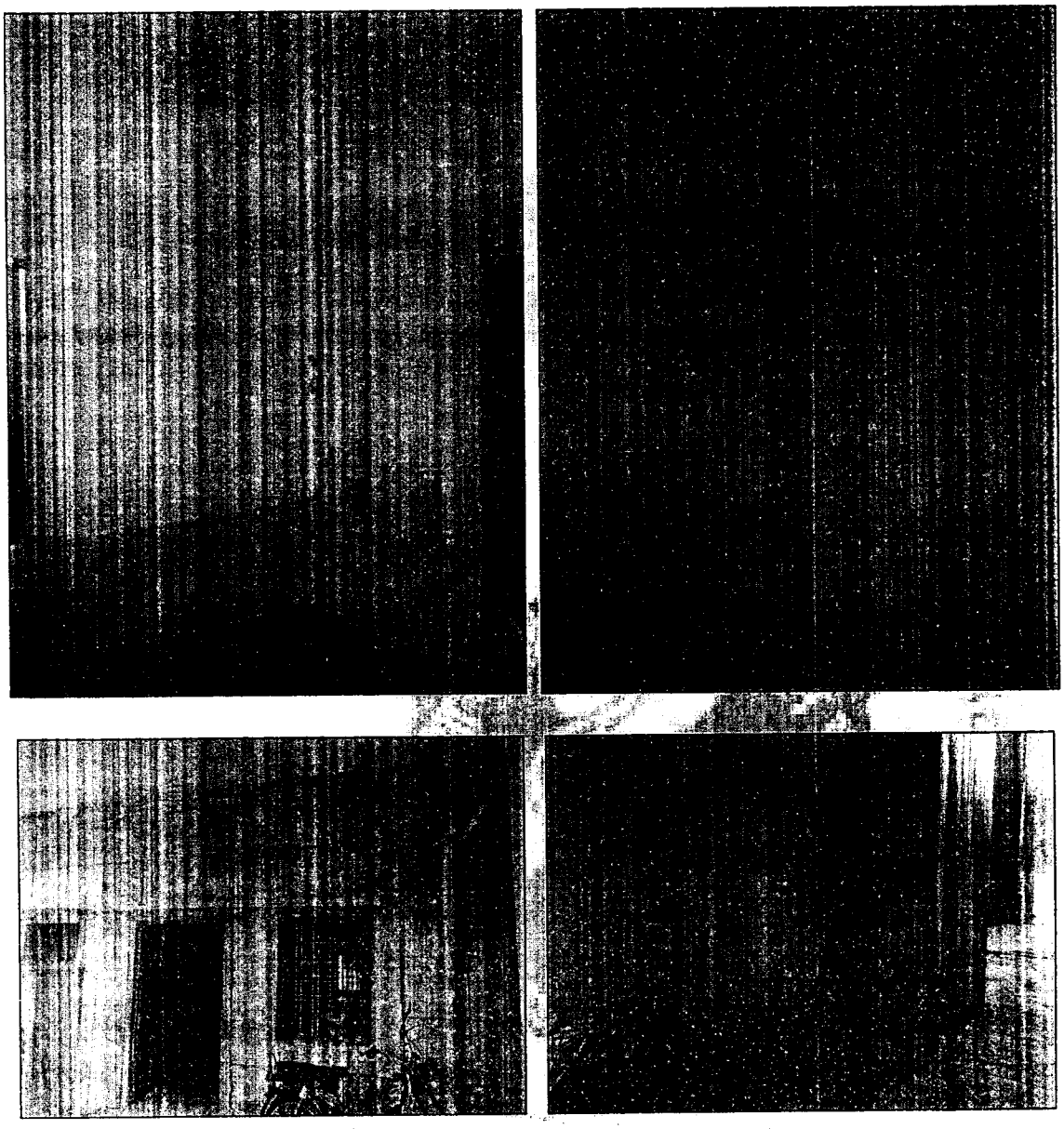


Fig. 4. Vertical and horizontal cracks in school building

2. Government Higher Secondary School

Observations:

- No. of Stories built: Single.
- Occupancy: About 800 students.
- Building was constructed around year 1995.
- Building was constructed in form of load bearing structure on stone masonry wall (Fig.5).
- Walls are made of stone masonry in lime mortar. The cement-sand plaster was carried out.
- Separation horizontal cracks were observed in walls of building particularly at floor level and slab level. Vertical cracks at beam column joints as shown in Fig. 6
- Water seepage was observed from ground at surface of walls as shown in Fig. 7.

Building type	Foundation type	Masonry type	Flooring	Roof type	Area
Load bearing structure	Stone masonry	Stone masonry	Kota stone	Flat stone girder	3180 sqm

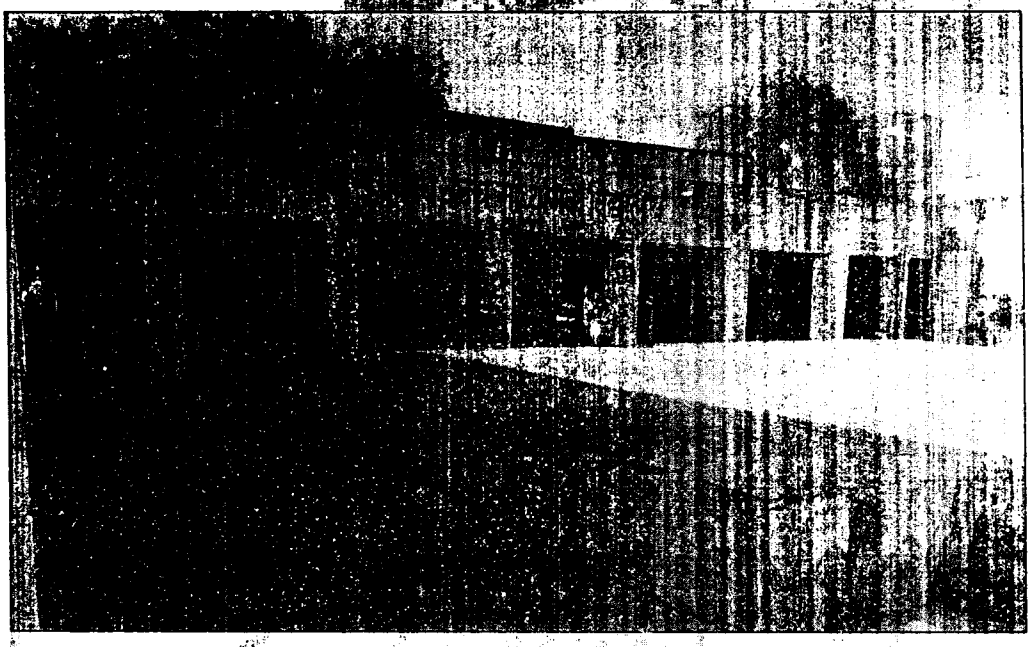


Fig. 5. Govt. higher secondary school building

CSIR Roorkee Library

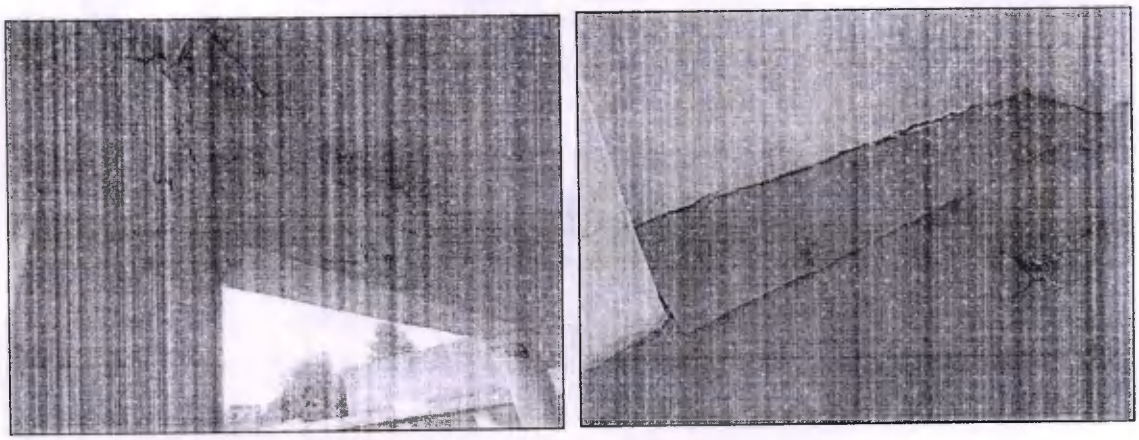


Fig. 6. Vertical and horizontal cracks in beam and near column joint

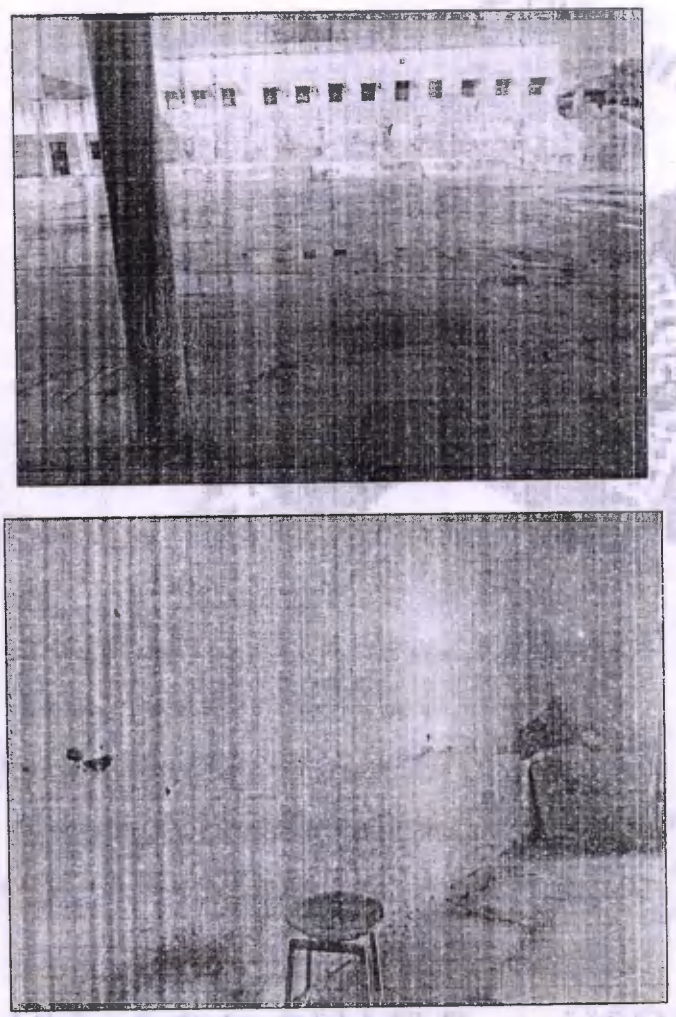


Fig. 7. Water seepage in the premises of school building

3. Government Girls School

Observation:

- No. of stories built: G+1.
- Occupancy: About 370 students.
- Building constructed around year 2005.
- Cracks were found in many locations like walls, columns and floor.
- The building was load bearing structure and made of stone masonry with lime mortar as shown in Fig. 8.
- The surface of walls was finished with cement-sand mortar as plastering material.
- The cracks were both horizontal and vertical in nature.
- Horizontal cracks were found in the joints of roof slab and wall.
- Vertical cracking was observed in the toilet structure of the school as shown in Fig. 9.

Building type	Foundation type	Masonry type	Flooring	Roof type	Area
Load bearing structure	Stone masonry	Stone masonry	Kotastone	Stone slab	1365 sqm



Fig. 8. Government girls school building

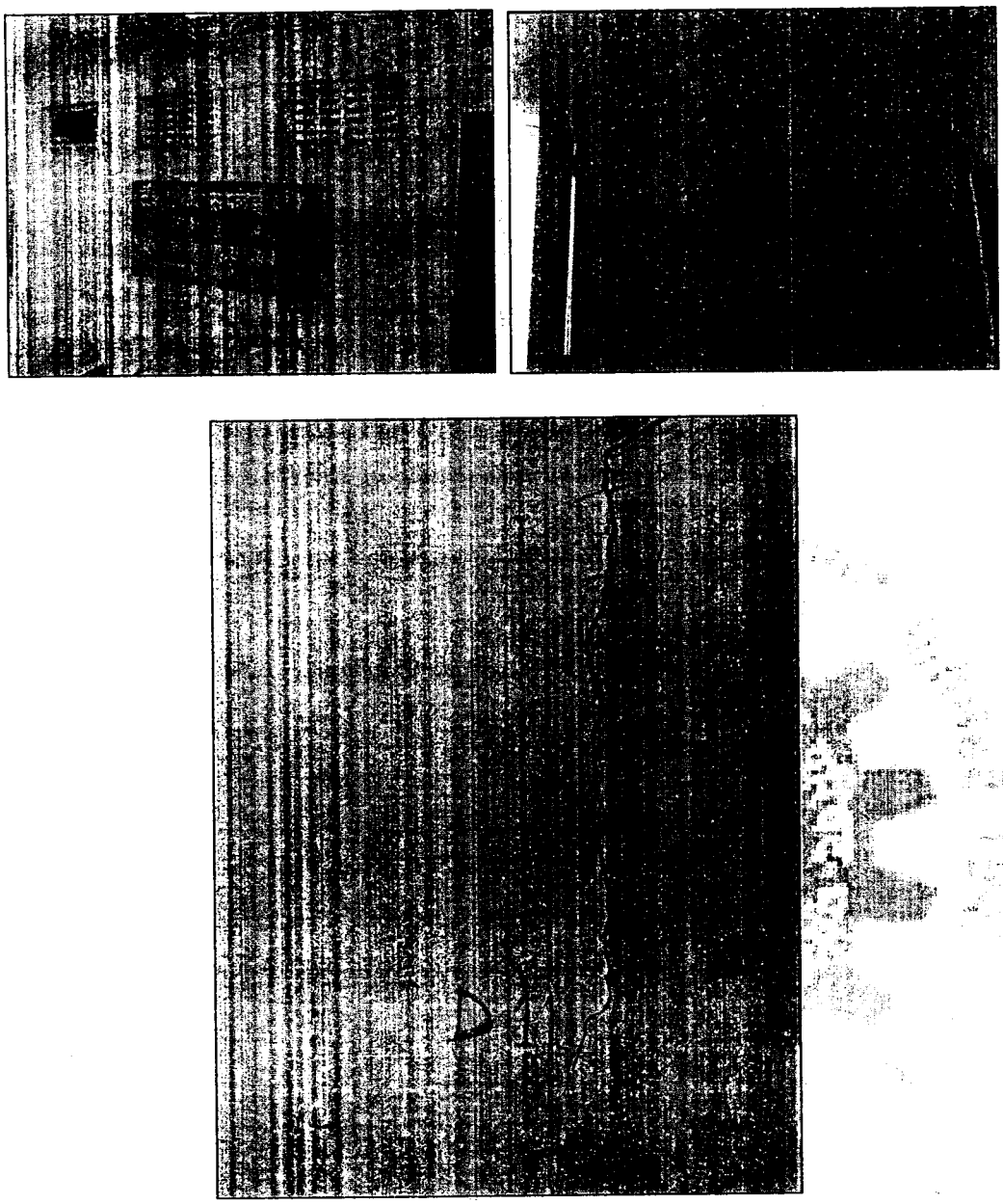


Fig. 9.Vertical crack on external wall and horizontal crack in class room

4. Government General Hospital

Observations:

- No. of Stories built : Single.
- Occupancy: About 200 beds.
- Building constructed around year 1995.
- Building was load bearing structure as shown in Fig. 10.
- Walls were made of stone masonry in lime mortar. The cement-sand mortar was used for plastering.
- Severe cracks were observed in wards of the hospital.
- These were diagonal cracks as shown in Fig. 11, due to settlement of foundation.
- Cracks were also observed in beam-column joints.
- Cracks were observed in floor propagating towards the walls.
- Cracks were found propagating from walls to roof as shown in Fig. 11.
- Roof was of stone slab supported on I girders.

Building type	Foundation type	Masonry type	Flooring	Roof type	Area
Load bearing structure	Stone masonry	Stone masonry	Kota stone	Stone slab with I girder	391 sqm

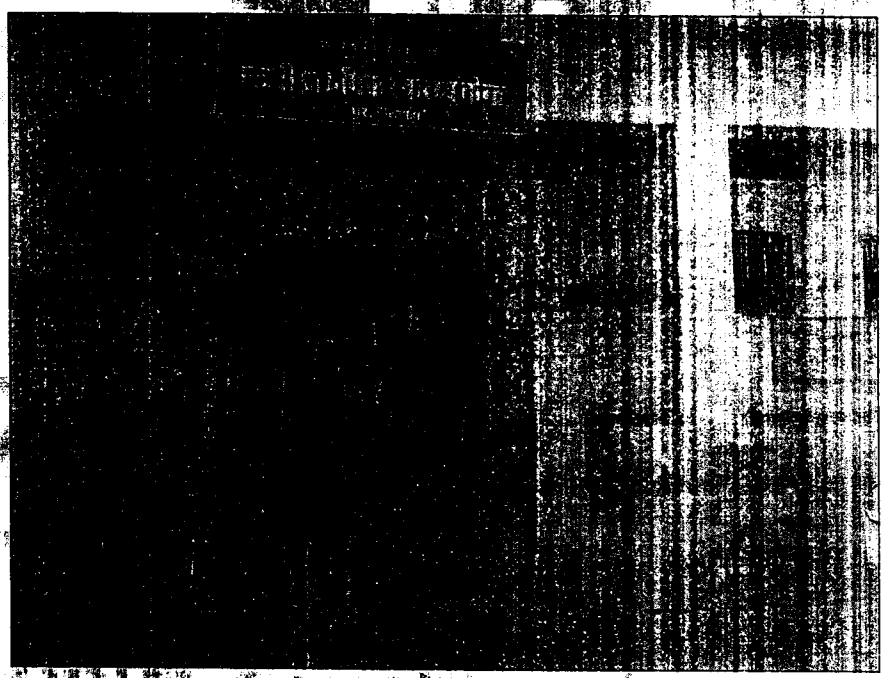


Fig. 10 Village general hospital building

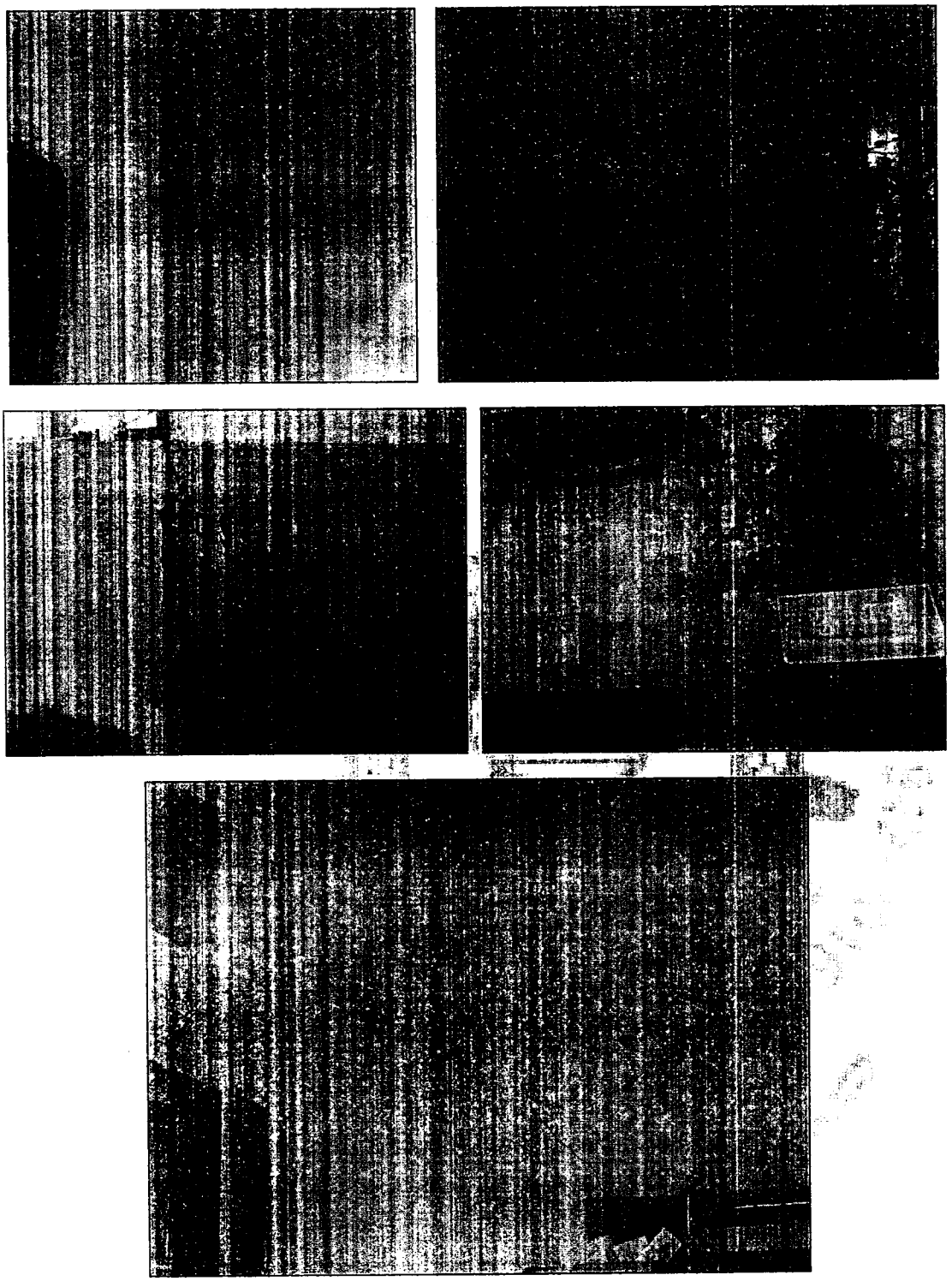


Fig. 11. Vertical and diagonal cracks in walls and near corners

5. Laxmi Narayana Temple

Observation:

- No. of stories built: Single.
- Occupancy: About 150 visitors.
- Temple was about 500 year old (Fig. 12) and a new room constructed inside the temple premises in 2014.
- Walls around the temple were made of rubble stone masonry.
- Lime mortar was found to be used in stone masonry of old structure.
- Major cracks were found inside the new room of temple and it was propagating from walls up to the roof as shown in Fig. 13.
- Cracks were also observed in boundary wall of temple as shown in Fig. 14 and Fig. 15.

Building type	Foundation type	Masonry type	Flooring	Roof type	Area
Load bearing structure	Stone masonry	Stone masonry	Marble stone	Conical and flat stone slab	375 sqm

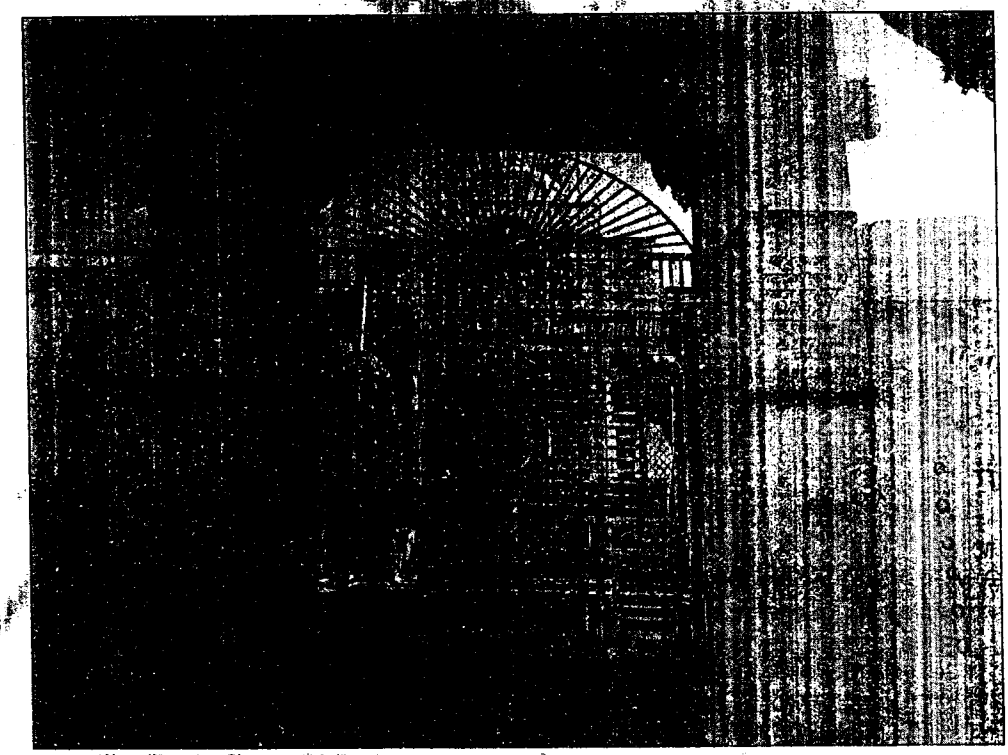


Fig. 12: Laxmi Narayan temple structure

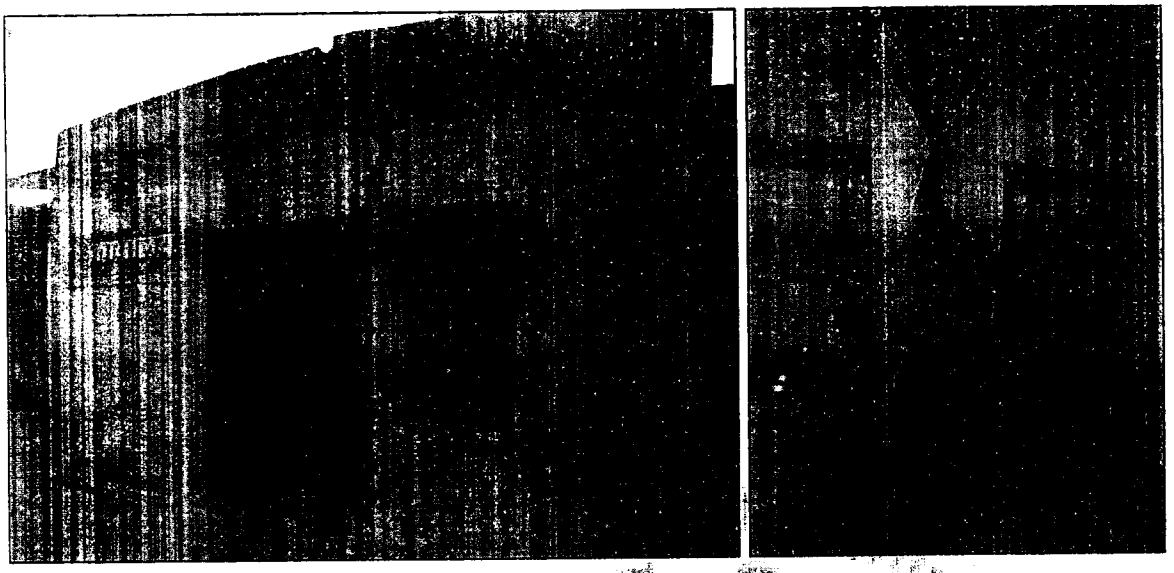


Fig. 13.Cracks on wall upto roof level

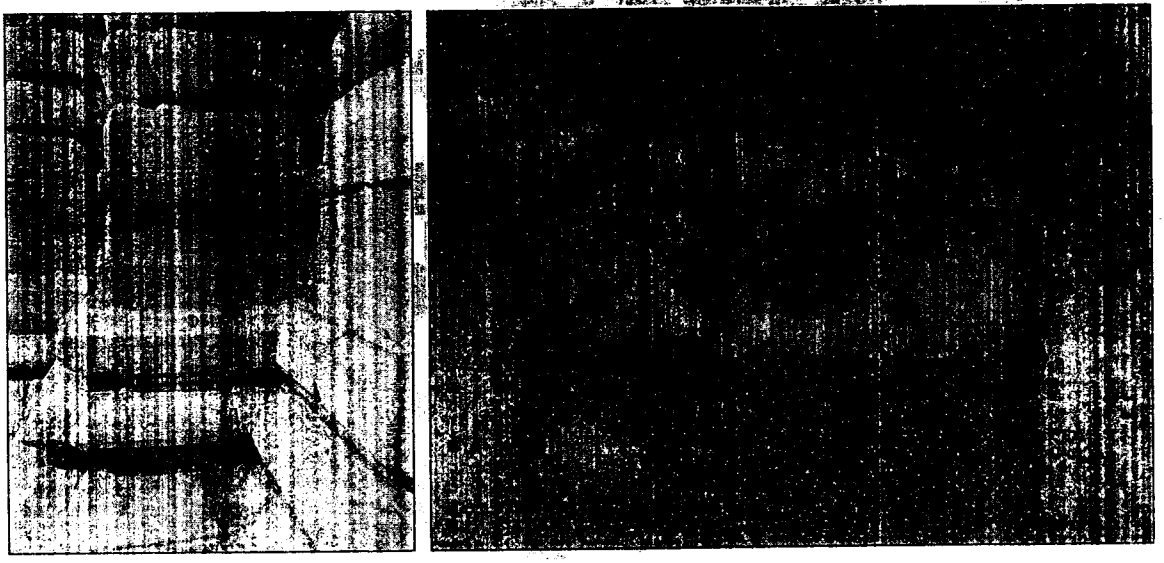


Fig. 14. Cracks on temple structure and periphery wall

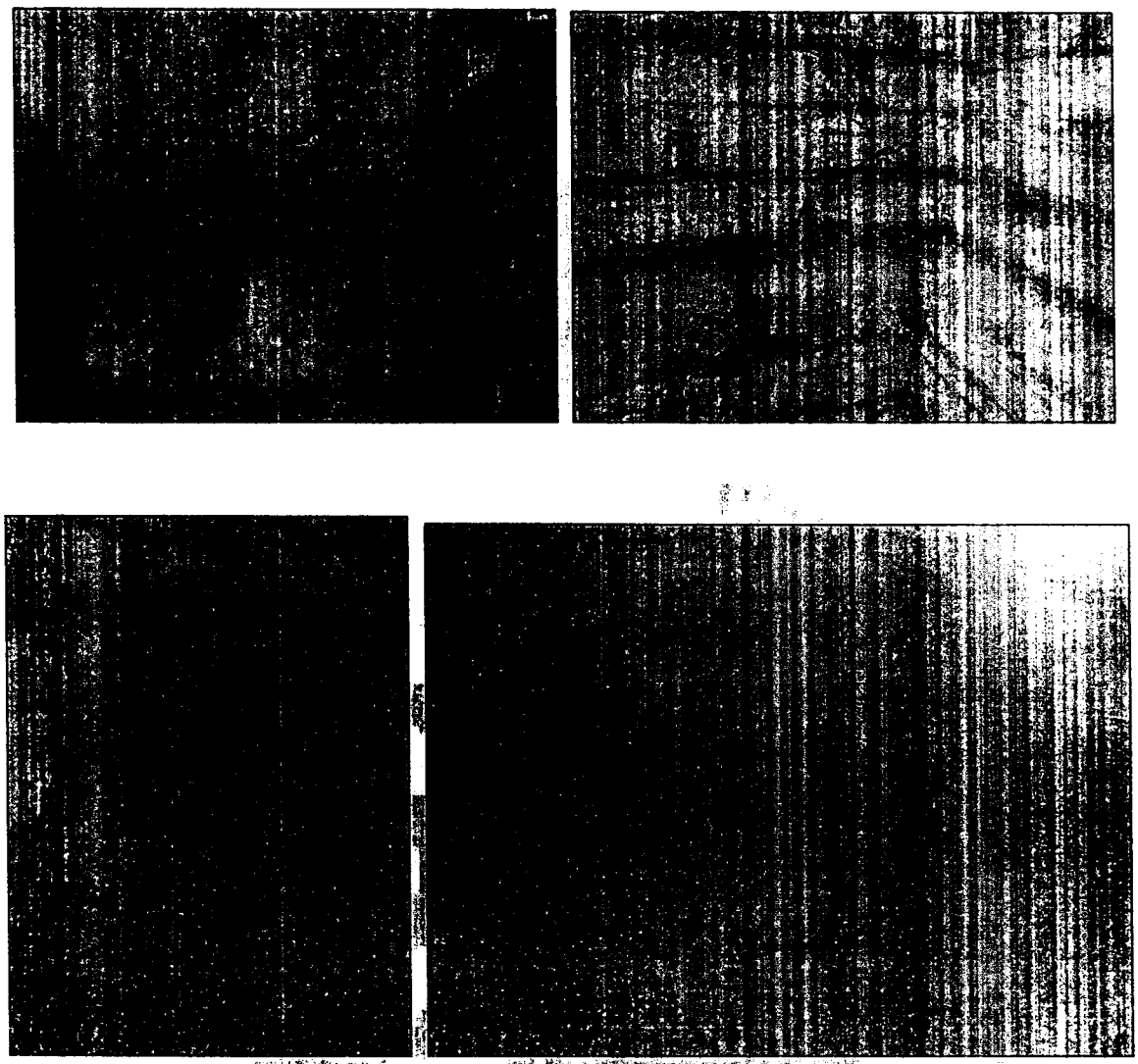


Fig. 15. Cracks on temple structure and periphery walls

6. House no. 2249

Observations:

- No. of Stories built : G+1
- Occupancy: Zero (House is in dilapidated condition, hence vacated from occupants).
- Ground floor of house was built around year 1990 and first floor was built in year 2015.
- Major structural cracks were observed in building occurring diagonally as shown in Fig.16 to Fig. 21.
- The cracks were found propagating from floor to walls.
- Diagonal cracks were observed on parapet walls as shown in Fig. 17.
- The wall joints got seperated as shown in Fig. 18 due to differential settlement.
- First Floor ceiling was found severely damaged. Stone slab was used as roofing element which got separated as shown in Fig.19.
- Overhangs/ projects were also severely damaged at several locations.

Building type	Foundation type	Masonry type	Flooring	Roof type	Area
Load bearing structure	Stone masonry	Stone masonry	Marble	Stone slab	126 sqm

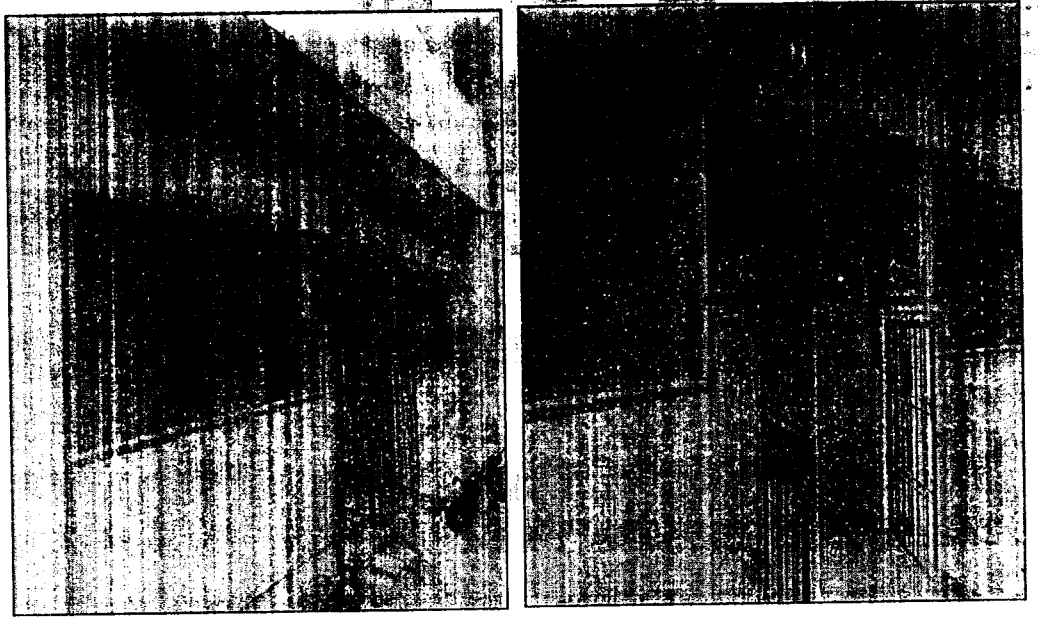


Fig.16. House no. 2249



Fig. 17. Damaged parapet and overhang

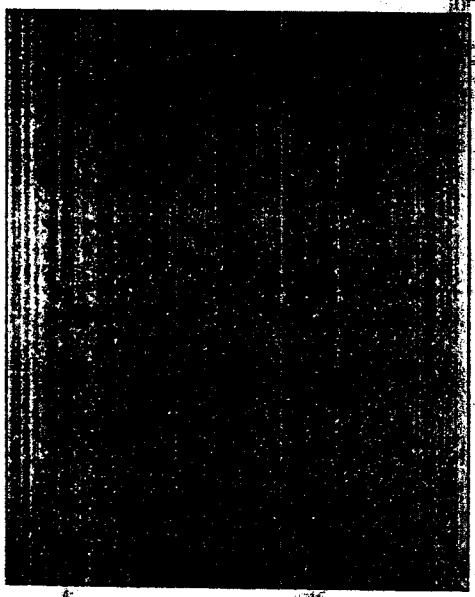


Fig.18. Opened wall joints

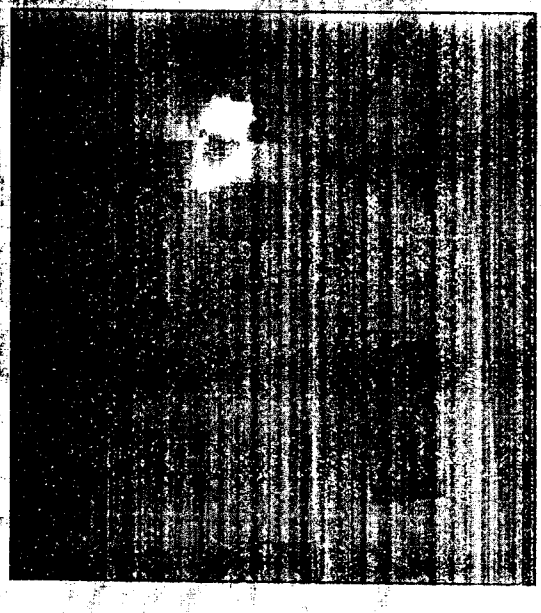


Fig. 19. Damaged First floor ceiling

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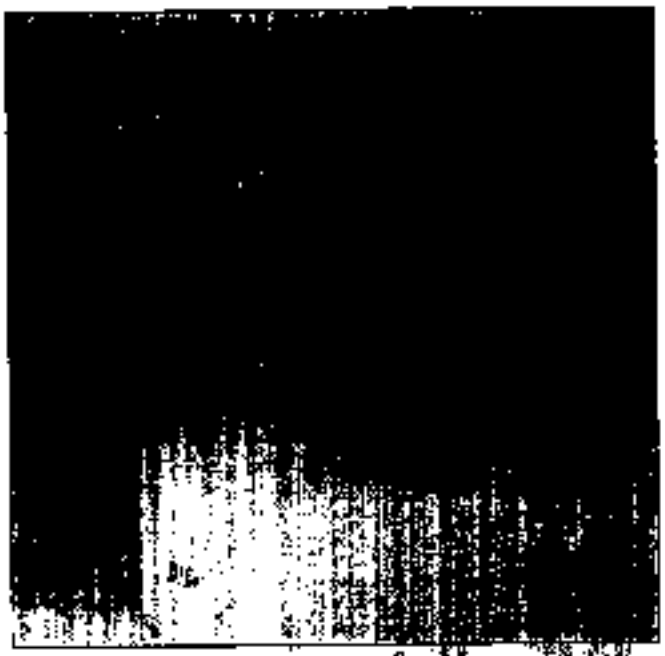


Fig.20. Diagonal cracks in walls with installed demec points (outside)

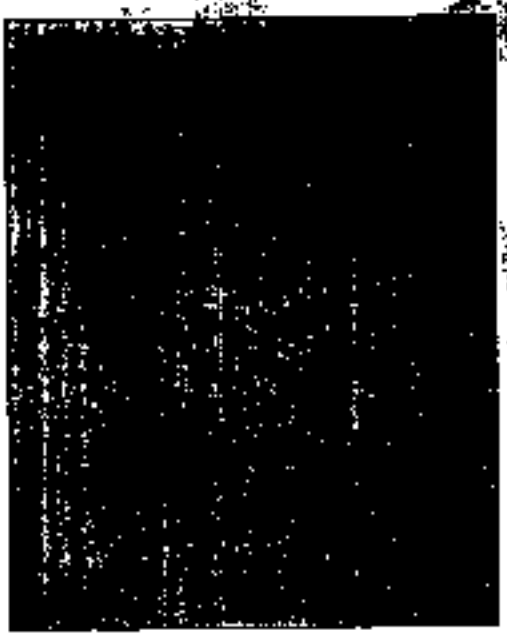


Fig.21 Diagonal cracks in walls with installed demec points (Inside)

7. House no. 2245 (As shown in Fig. 22)

Observations:

- No. of Stories built: G+1.
- Occupancy: 2 people.
- House was constructed around 1980 and renovates in 2008.
- External projects/ balcony was found excessively deflected. The same was supported by temporary support (wooden shoring) as shown in Fig. 23.
- The cracks observed in walls/ roofs of the building as shown in Fig. 24 to Fig. 27.
- Horizontal cracks were observed in roof slabs as shown in Fig 25.
- Major cracks were observed near the joints of orthogonal walls.
- The cracks were found propagating from walls to roof as shown in Fig.24.
- Stone slabs in the roof were found to be displaced and gap was clearly visible between stones.
- Gap was also observed between walls and skirting.
- It was found that walls joint got opened and separated from each other as shown in Fig. 26.

Building type	Foundation type	Masonry type	Flooring	Roof type	Area
Load bearing structure	Stone masonry	Stone masonry	Marble	Stone slab	145 sqm



Fig.22. House no. 2245

CSIR Township



Fig. 23. Temporary support (wooden shoring)

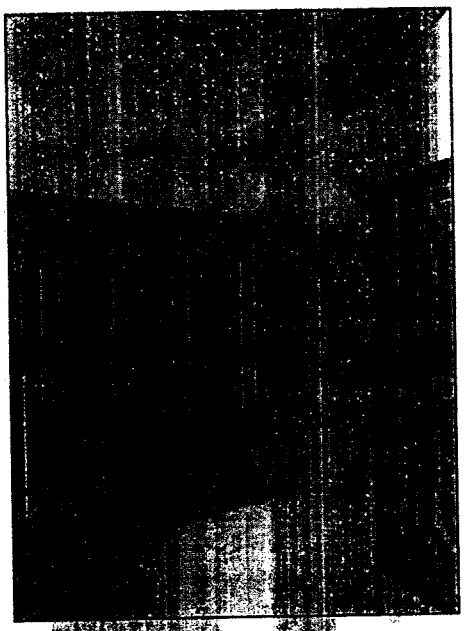


Fig. 24. Opened wall joints

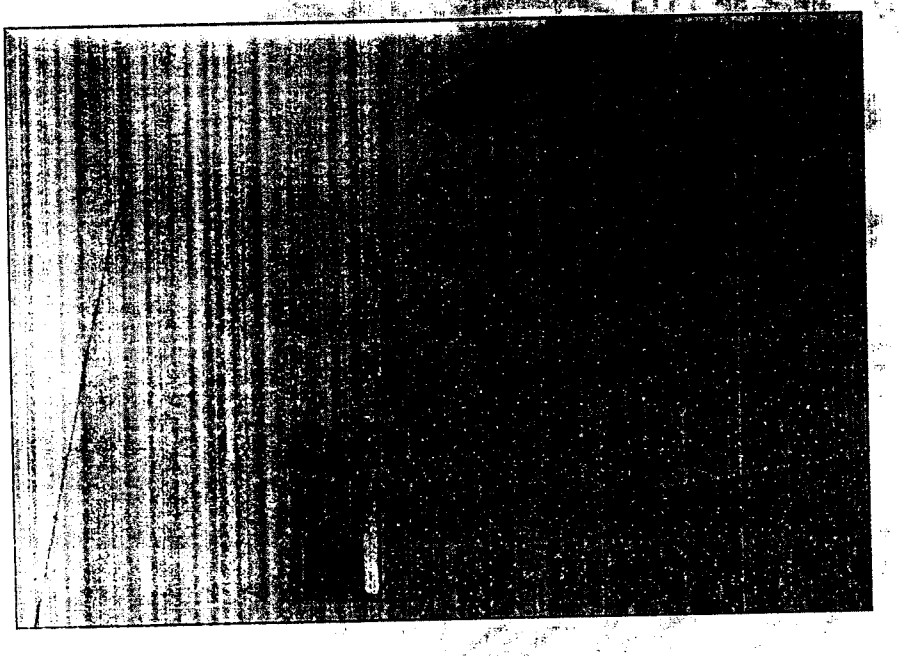


Fig. 25. Horizontal cracks in roof slabs

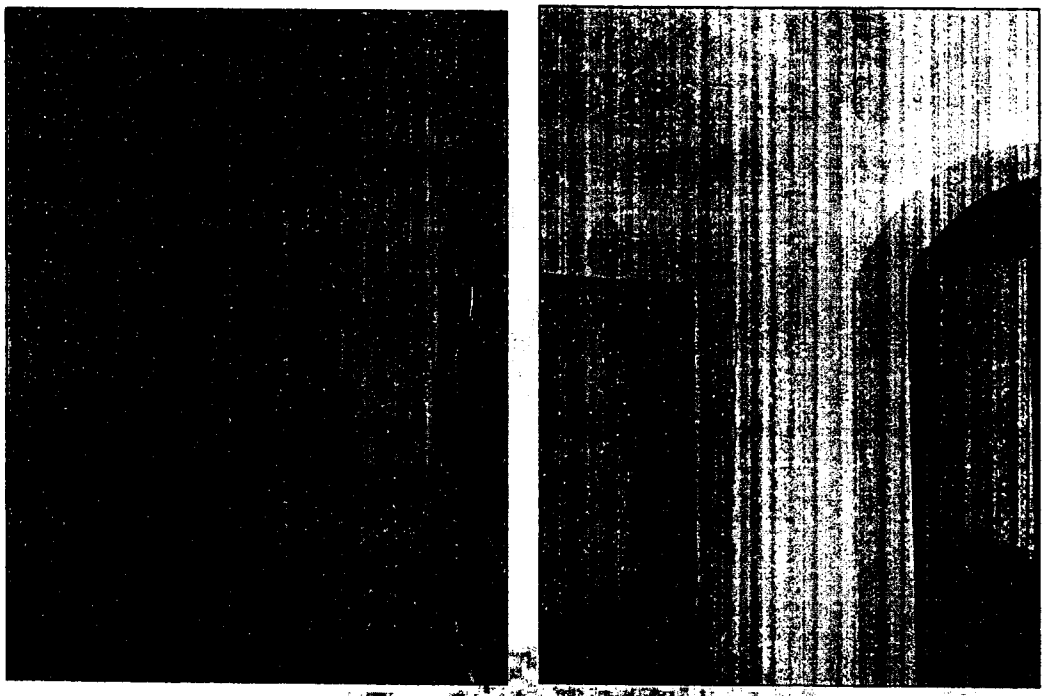


Fig. 26. Cracks in wall and near wall joints



Fig.27.Cracks in wall and installed demec points

8. House no. 1353

Observation:

- No. of stories built: G+1.
- Occupancy: 3 people (House was in dilapidated condition).
- Ground floor structure was built around year 1990 and first floor was built in year 2010.
- The structural cracks were found propagating up to ceiling from wall as shown in Fig. 28 to Fig. 30.
- Diagonal cracks and vertical cracks were observed in the walls of the building.
- Horizontal cracks were also observed in ceiling.
- Joints of wall were found opened as shown in Fig. 29.
- The cracks in walls were observed propagating into floor and ceiling as shown in Fig. 30.

Building type	Foundation type	Masonry type	Flooring	Roof type	Area
Load bearing structure	Stone masonry	Stone masonry	Cement flooring	Stone slab	45 Sq. m.



Fig.28. House no. 1353

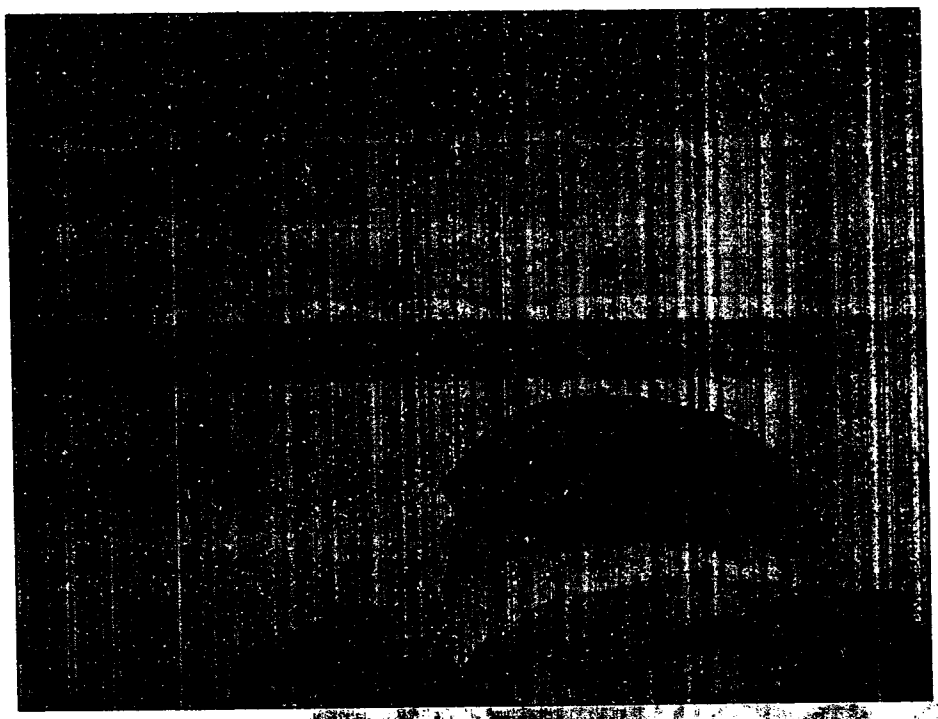


Fig. 29. Opened joints of wall

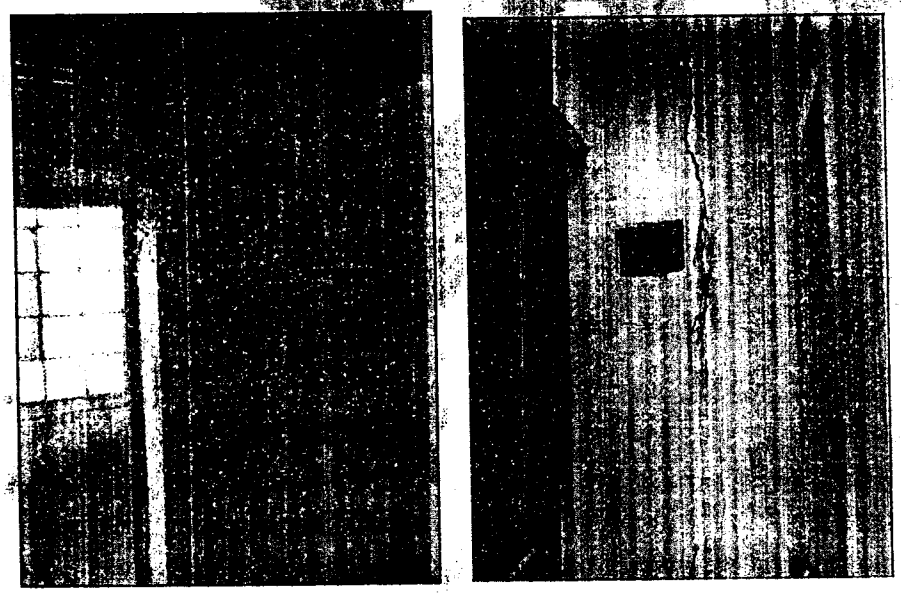


Fig. 30 (a). Structural cracks on ceiling to wall

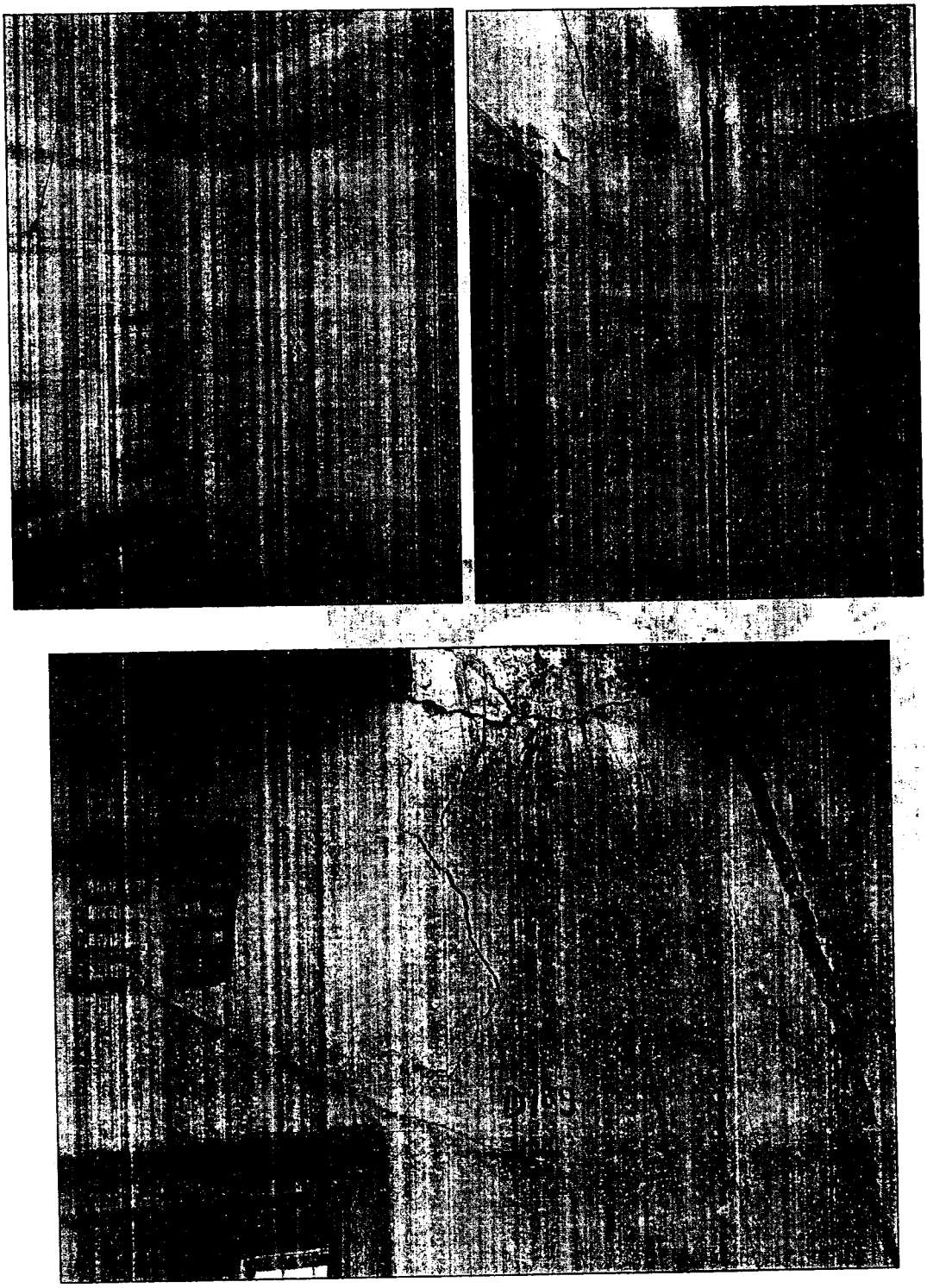


Fig. 30 (b). Joint separation and cracks in wall/ cornor

9. House no. 2246

Observation:

- No. of stories built: G+2.
- Occupancy: Vacated.
- Major structural cracks were found on external walls as shown in Fig. 31.
- Diagonal cracks were observed in wall of the building near window opening as shown in Fig. 31.
- Cracks in walls were propagating up to ground from window level.

Buildingtype	Masonrytype	Flooring	Roof type
Load bearing structure	Stone masonry	Stone flooring	Flat girder

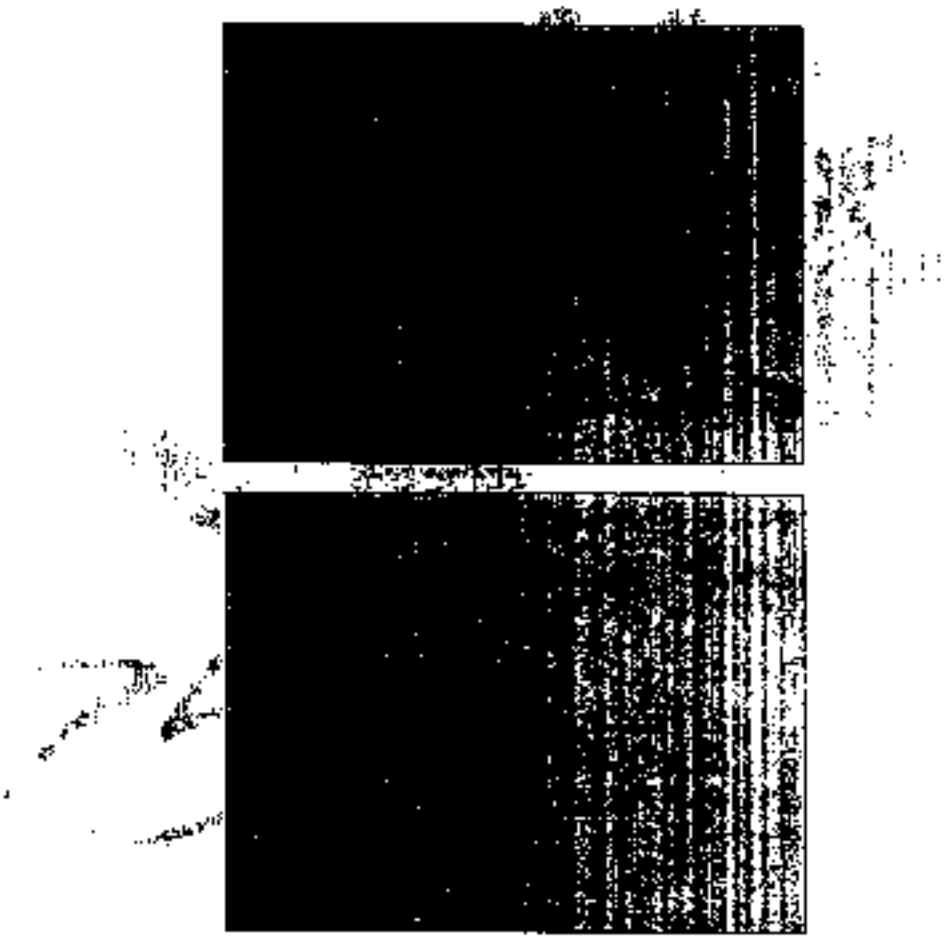


Fig. 31: House no. 1353 (Crack pattern and demec points)

10. House no. 2216

Observations:

- No. of Stories built: G+1.
- Occupancy: 8-10 people.
- House constructed around 1980.
- The building was load bearing structure as shown in Fig. 32.
- Vertical cracks observed in external front walls of the building as shown in Fig. 32 and Fig. 33.
- Most of the cracks were observed in the middle portion of the wall.
- The cracks were observed propagating from wall up to roof as shown in Fig. 32.
- The roof of the house was made of stone slabs supported on I girders.

Building type	Masonry type	Flooring	Roof type
Load bearing structure	Stone masonry	Stone floor	Stone slab with I girder



Fig. 32. House no. 2216

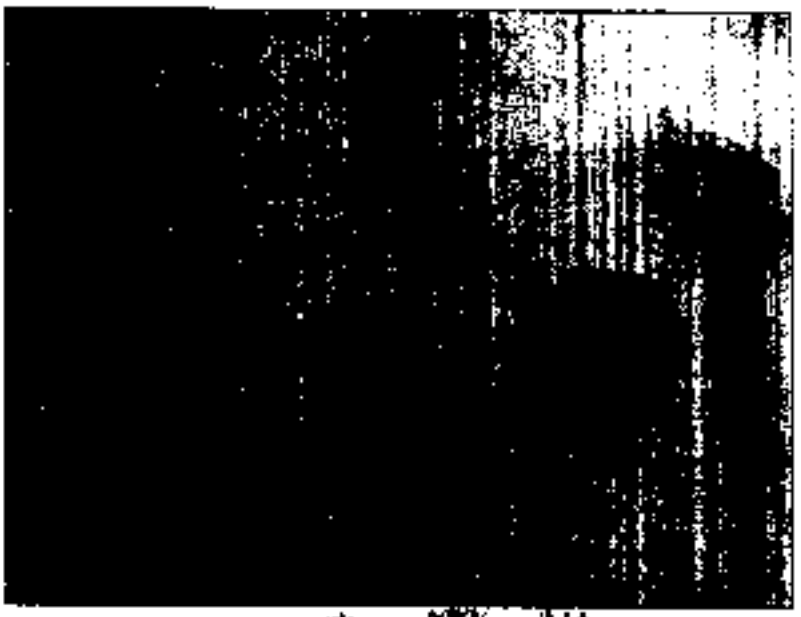


Fig. 33. Vertical crack in external wall and demec points



11. House no. 2226

Observations:

- No. of stories built: G+2.
- Occupancy: 6-8 people.
- The house was found to be load bearing structure. The wall were made of stone masonry and cement mortar was used in plaster as shown in Fig. 34.
- Diagonal cracks were observed in walls of the building propagating up to the roof slab.

Building type	Masonry type	Flooring	Roof type
Load bearing structure	Stone masonry	Marble stone	Stone slab

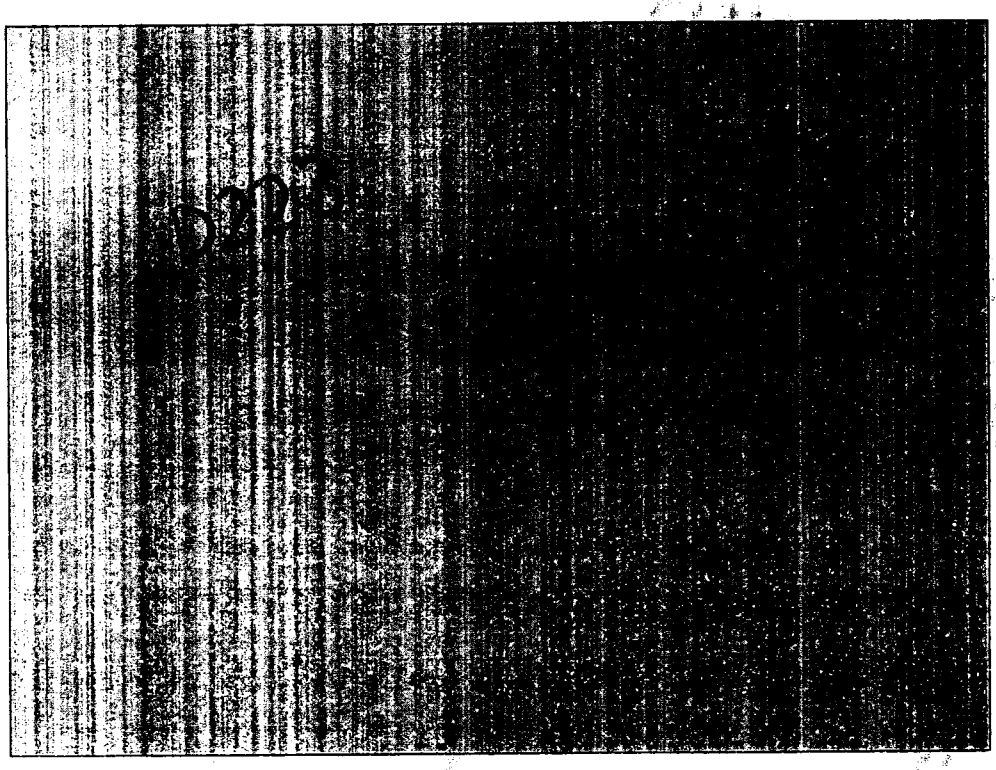


Fig. 34. House no. 2226 (Crack pattern and demec point)

12. House no. 2225

Observations:

- No. of stories built : single.
- Occupancy: vacated.
- The house was found to be load bearing structure. The house is made of stone masonry and plastering work was done using cement-sand mortar as shown in Fig. 35.
- Horizontal cracks were also observed in the wall near window.
- The cracks were observed between entry door and adjacent window of the house as shown in Fig. 35.
- Diagonal cracks observed in walls of the house as shown in Fig. 36.
- Wide crack was found in the back side wall of the house. It was propagating from mid of the window opening up to ground level as shown in Fig. 36.

Building type	Masonry type	Flooring	Roof type
Load bearing structure	Stone masonry	Stone marble floor	Stone slabs



Fig. 35. House no. 2225

CSIR Roorkee

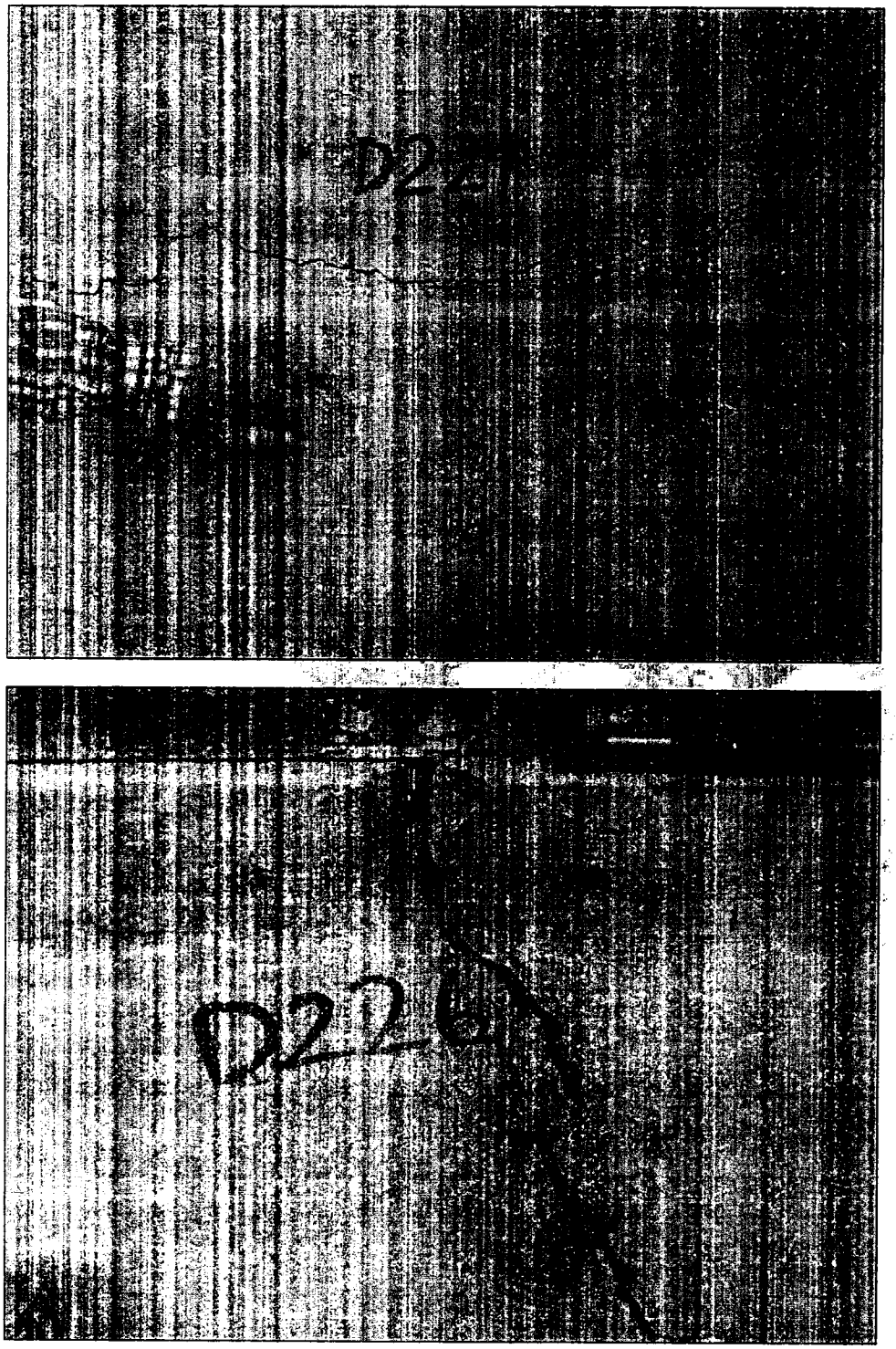


Fig. 36. Horizontal and diagonal cracks and demec points

13. House no. 2223

Observations:

- No. of stories built: Single.
- Occupancy: 10-12 people.
- House was constructed around year 1980.
- The building was load bearing structure. The wall was made of stone masonry as shown in Fig. 37.
- Diagonal cracks were observed in external walls of the building as shown in Fig. 37 and Fig. 38.
- The crack was propagating from walls to the roof level.
- Wide cracks were also observed at few locations as shown in Fig. 38.

Building type	Masonry type	Flooring	Roof type
Load bearing structure	Stone masonry	Stone flooring	Stone slabs



Fig. 37. House no. 2223

CSIR Roorkee

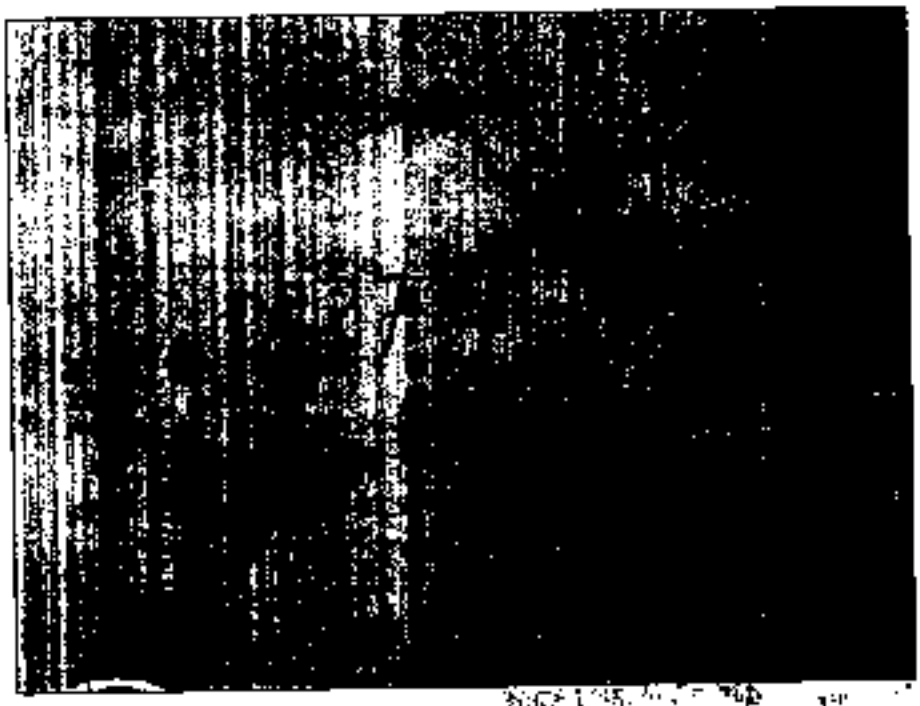


Fig. 38.Wide digonal crack on external wall

14. House no. 544

Observations:

- No. of stories built: Single.
- Occupancy: 18 people.
- House was found to be constructed in two parts – front part was an old structure constructed in 1980 and inside part was newly constructed RCC structure.
- Wall was made of stone masonry in old structure and brick masonry has been used in new structure.
- The roof was found to be made of sandstone slab supported on MS girder in old structure.
- Diagonal cracks were observed in external walls of the old building as well as in new construction as shown in Fig. 39 and Fig. 40.
- The crack was found propagating along the height of walls.

Building type	Masonry type	Flooring	Roof type
Load bearing structure	Stone masonry	Stone floor	Flat girder

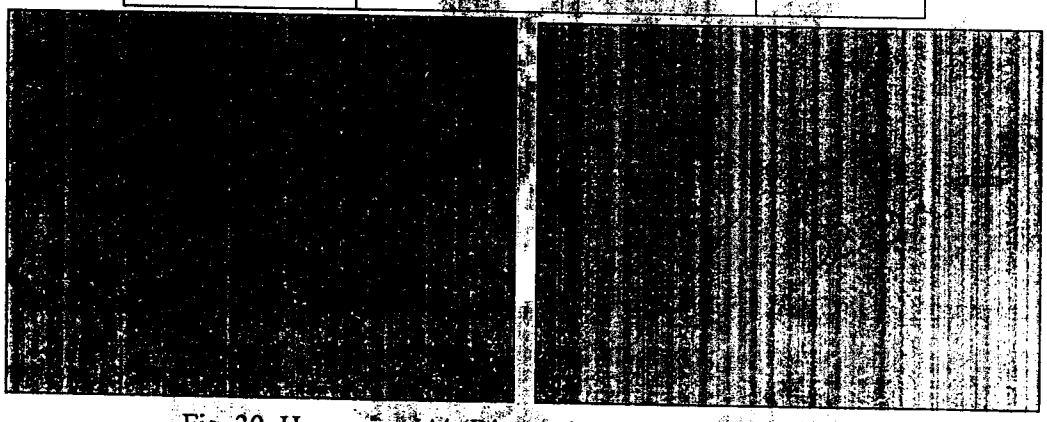


Fig. 39. House no. 544 (Diagonal crack on external wall)

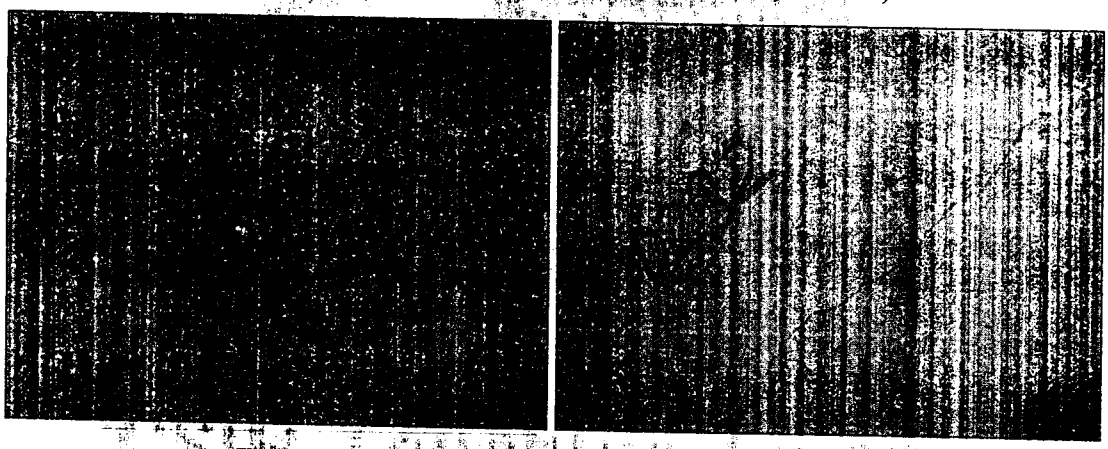


Fig. 40. Diagonal crack on outer wall of inside house

15. House no. 910

Observation:

- No. of stories built: Single.
- Occupancy: 5 people.
- House was built in year around 1970.
- The structural cracks were found in external as well as inside walls.
- Diagonal cracks were observed in inside wall of the building as shown in Fig. 41.
- The building was load bearing structure made of stone masonry with lime mortar.
- The roof of house was made with tin sheds.

Building type	Masonrytype	Flooring	Roof type
Load bearing structure	Stonemasonry	Stone flooring	Tin sheds

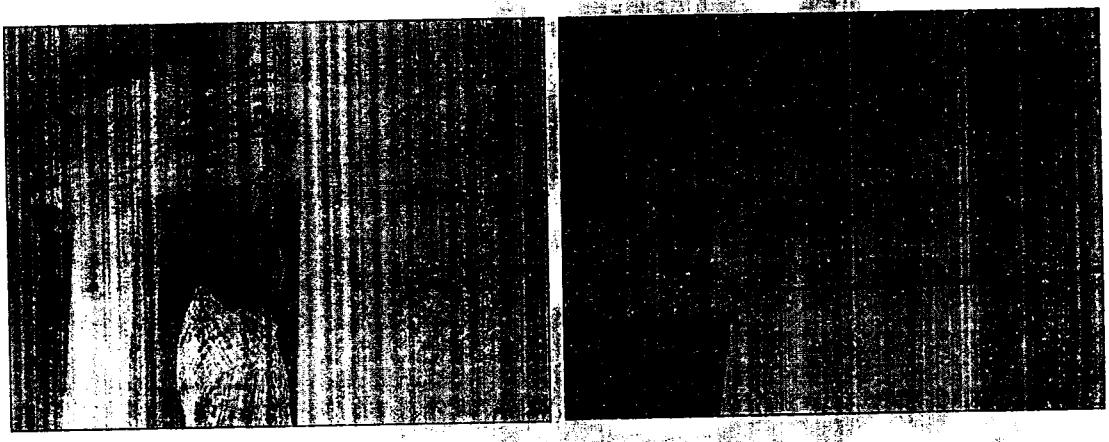


Fig. 41. House no. 910 (crack on wall)

16. House no. 908

Observation:

- No. of stories built: Single.
- Occupancy: 5 people.
- The building was made of stone masonry. The walls were found to be plastered with cement-sand mortar.
- Cracks were observed in external wall of the house as shown in Fig. 42.
- Vertical cracks were also observed propagating along the height of the wall.

Building type	Masonry type	Flooring	Roof type
Load bearing structure	Stone masonry	Stone flooring	Stone slab

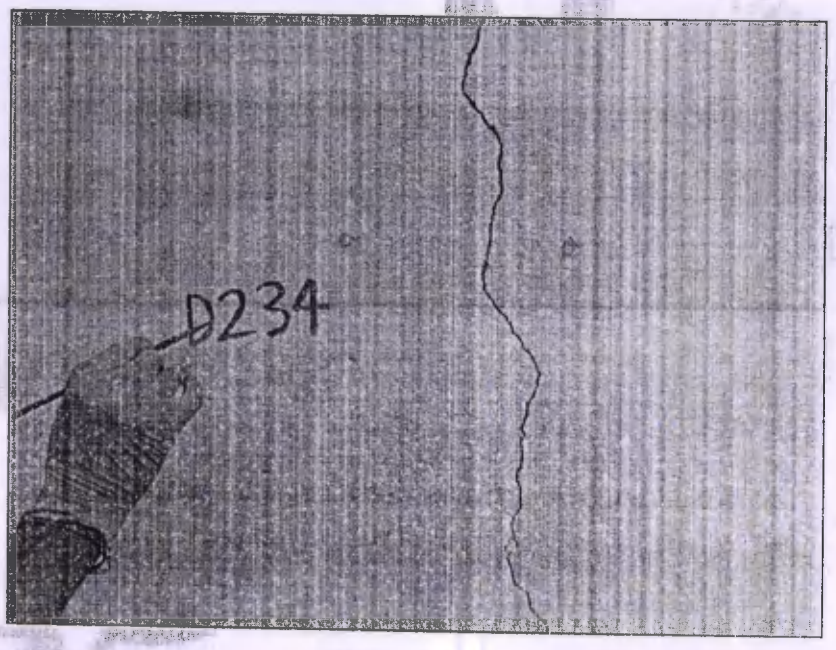


Fig. 42. House no. 908 (Vertical crack on external wall)

CSIR Touching Lives

17. **House no. 885**

Observation:

- No. of stories built: G+1.
- Occupancy: 13 people.
- House was built around year 1980.
- The walls were found to be made of stone and brick masonry and cement-sand mortar has been used for plastering.
- Room on ground floor was found to be vacated due to severe cracking in walls and floor.
- Horizontal cracks were observed near joints and corners of roof in the room at first floor as shown in Fig. 43 and Fig. 44.
- Diagonal cracks were observed in bottom of the walls and at the staircase walls as shown in Fig. 45.
- Cracks were also noticed in the inner and outer walls.
- Cracks in walls were found propagating towards floor and ceiling.

Building type	Masonry type	Flooring	Roof type
Load bearing structure	Stone & brick masonry	Stone flooring	Stone slab

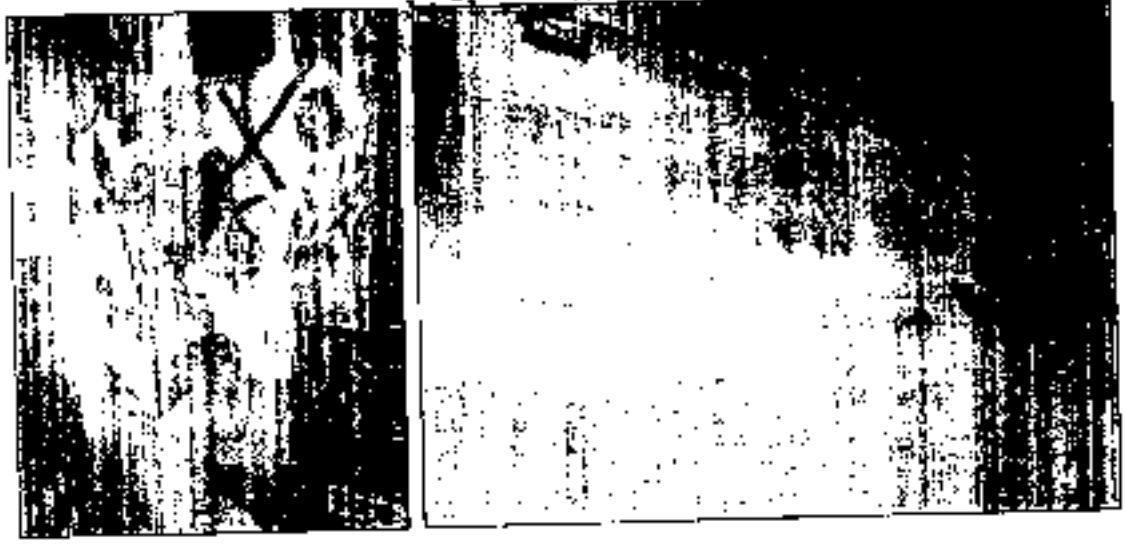


Fig. 43. House no. 885 and horizontal crack inside house

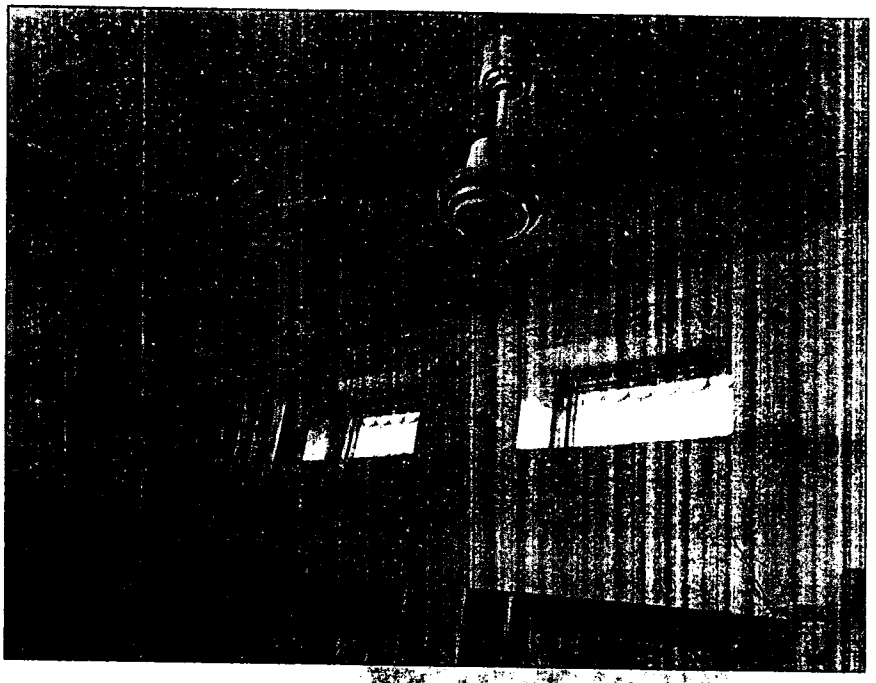


Fig. 44. Horizontal crack along roof and wall joint

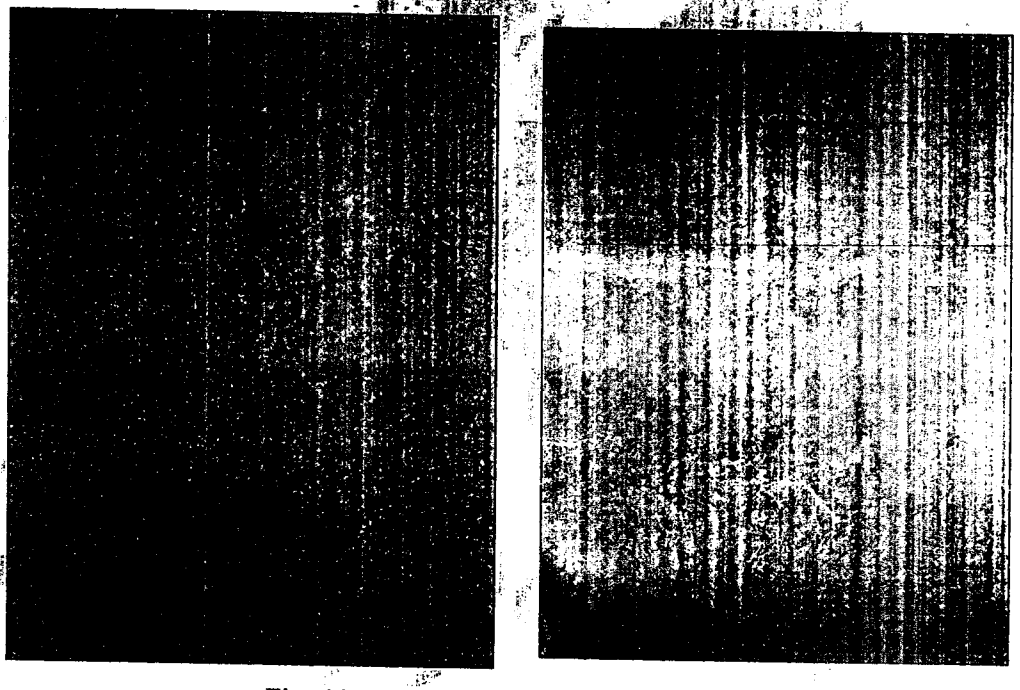


Fig. 45. Diagonal crack and stone floor

CSIR Building

18. House no. 2835

Observation:

- No. of stories built: G+1.
- Occupancy: Vacated.
- Building was about 70-80 year old.
- The house was a load bearing structure as shown in Fig. 46.
- Roof was made of stone slab resting on I girders.
- Walls were found to be of rubble stone masonry and it was plastered using cement sand mortar.
- Cracks were found at several locations inside and outside the house.
- Some new construction using bricks and cement sand mortar was found inside the house to support the damaged portion as shown in Fig. 47.
- Diagonal cracks were observed in walls as shown in Fig. 47 and vertical cracks were found along the wall corners.

Building type	Foundation type	Masonry type	Flooring	Roof type	Area
Load bearing structure	Stone masonry	Stone masonry	Stone flooring	Stone slab and girder	98 sqm



Fig. 46. House no. 2835

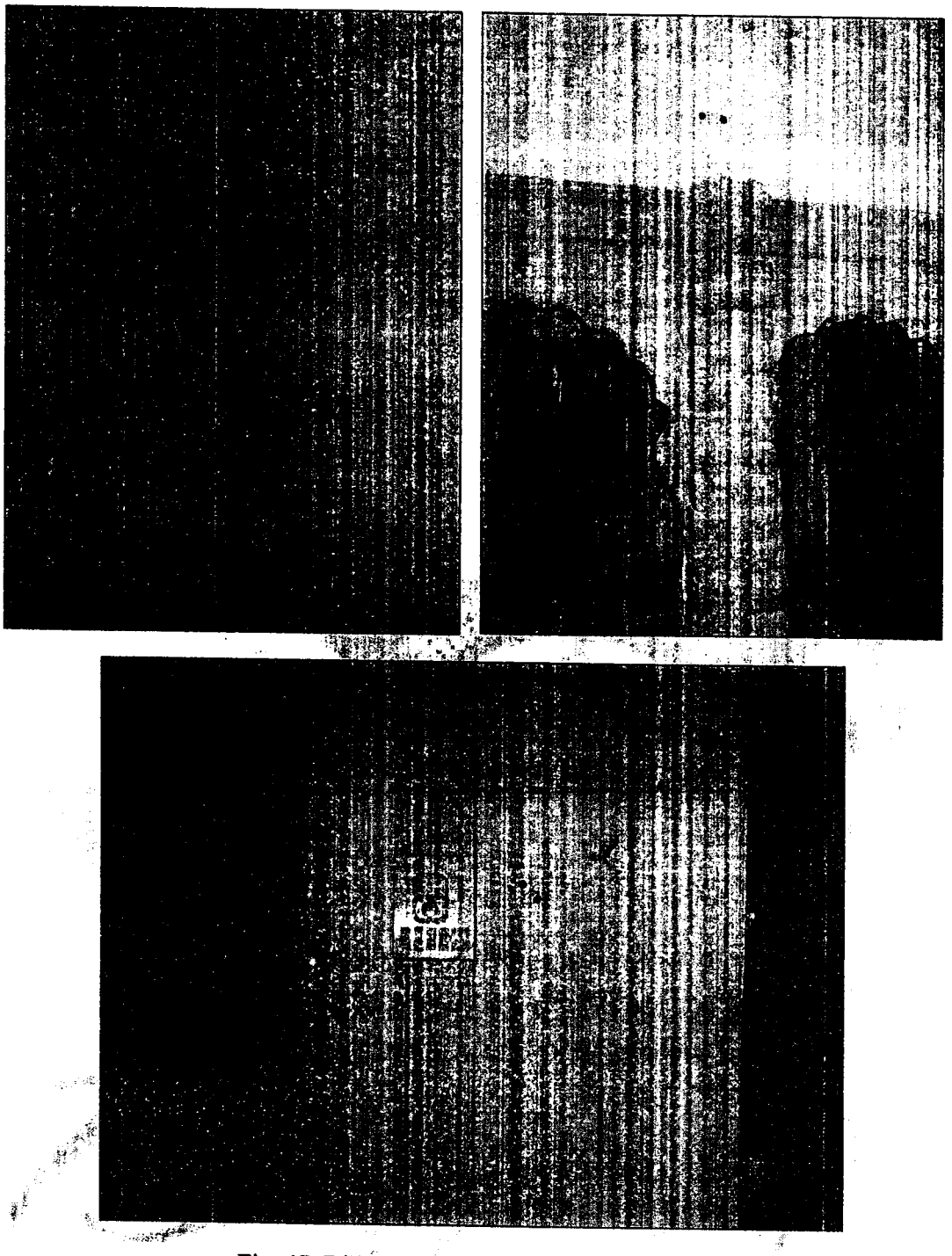


Fig. 47. Diagonal crack on wall inside house

CSIR Publication

19. House no. 2836

Observation:

- No. of stories built: G+1.
- Occupancy: 26 people.
- The house was found to be constructed about 60-80 year before and some new house construction work was done around year 2005.
- Walls of old structure were of stone masonry (Fig. 48) and new construction was done using brick masonry.
- Wooden beams were used to support the stone roof slab in old structure whereas new construction was done with RCC.
- Cracks were found in old structure only as shown in Fig. 49 and Fig. 50.

Building type	Foundation type	Masonry type	Flooring	Roof type	Area
Load bearing structure	Stone masonry	Stone and brick masonry	Kota stone	Stone slab on wood and RCC beams	360 sqm



Fig. 48. House no. 2836

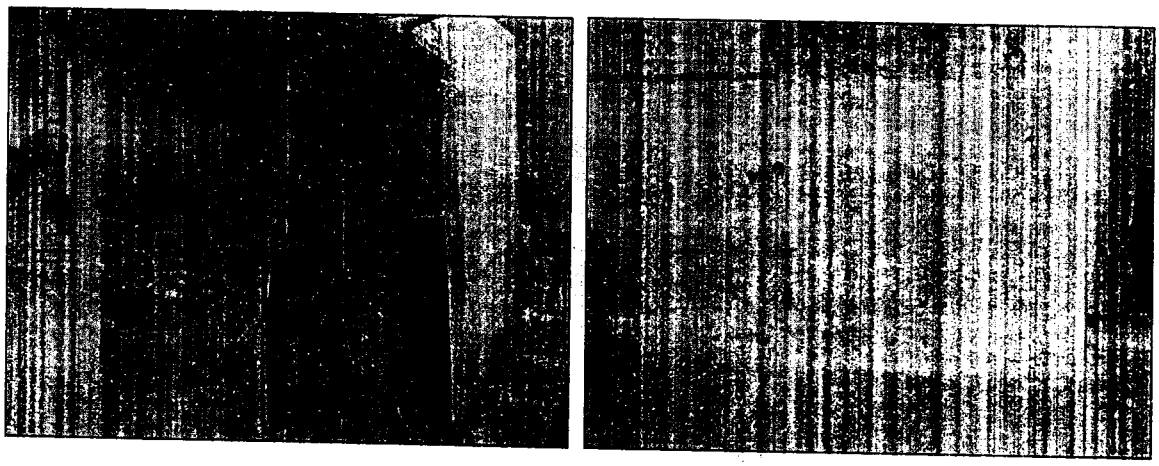


Fig. 49.Cracks on wall and roof joint and at wall bottom

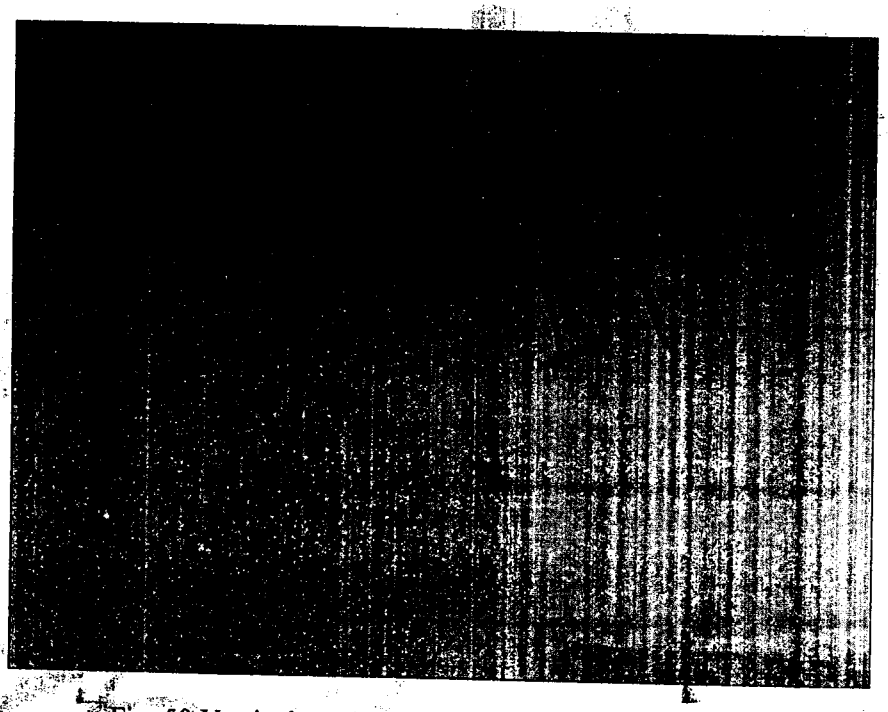


Fig. 50.Vertical cracks on wall inside room above door

CSIR Building

20. House no. 1095

Observations:

- No. of stories built: G+2.
- Occupancy: 8 people.
  - House was found to be constructed as a load bearing structure having walls made of stone as shown in Fig. 51.
- Lime mortar was used in masonry of wall and outside it was finished with cement mortar.
- Major cracks were found extending diagonally at exterior wall of house as shown in Fig. 52.
- Minor cracks have been also observed inside house as shown in Fig. 53.

Building type	Foundation type	Masonry type	Flooring	Roof type	Area
Load bearing structure	Stone masonry	Stone masonry	Kota stone	Stone slab	60 sqm

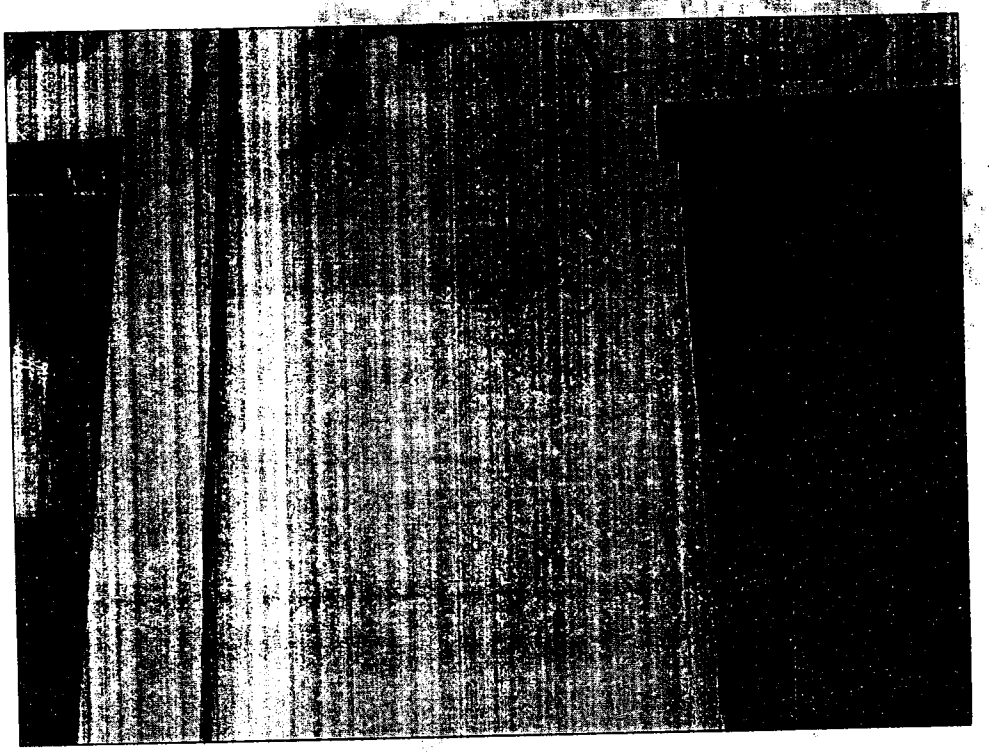


Fig. 51. House no. 1095

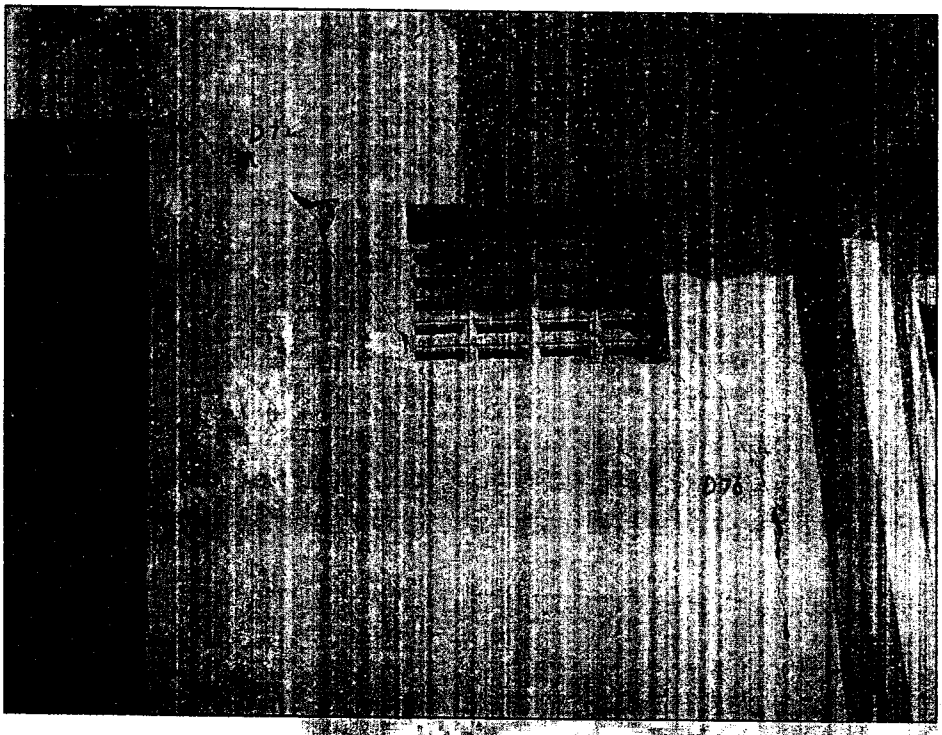


Fig. 52. Diagonal cracks in exterior wall at front side

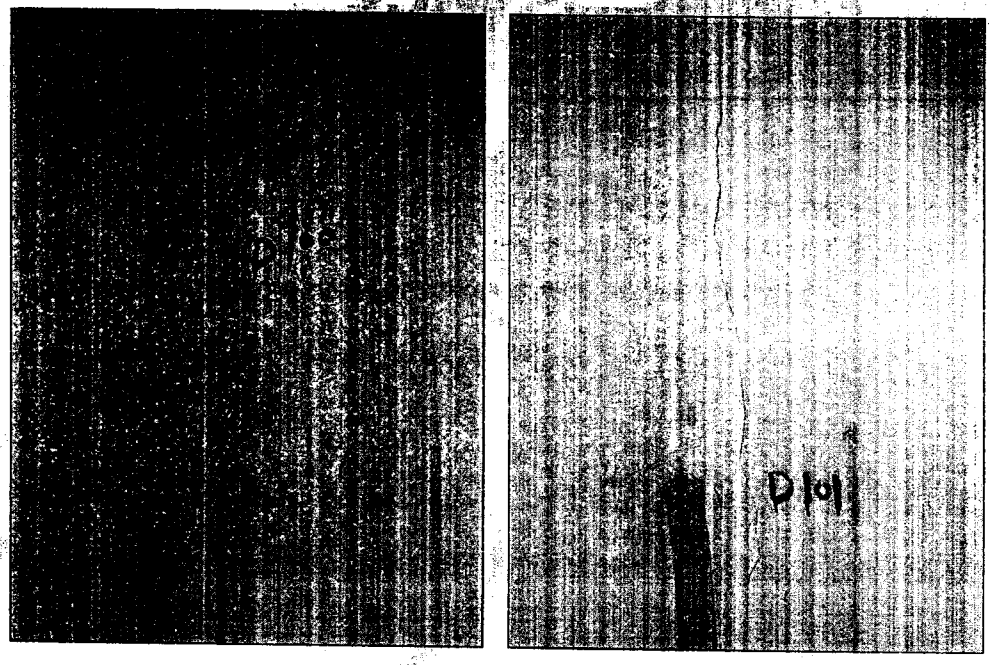


Fig. 53. Vertical cracks in corner of wall

CSIR-Central Building Library

21. House no. 1089

Observations:

- No. of stories built: G+1.
- Occupancy: 8 people.
- Ground floor of the house was built around year 1980 and first floor has been constructed recently in year 2017.
- The house is load bearing structure and the wall were made of stone masonry as shown in Fig. 54.
- The work of stone masonry has been carried out using lime mortar and finished with cement sand mortar.
- The cracks were found in newly constructed septic tank which was built 3 years before.
- Minor vertical cracks were observed at first floor of house as shown in Fig. 55.

Building type	Foundation type	Masonry type	Flooring	Roof type	Area
Load bearing structure	Stone masonry	Stone masonry	Kota stone	Stone slab and GI sheet	46 sqm



Fig. 54. House no. 1089

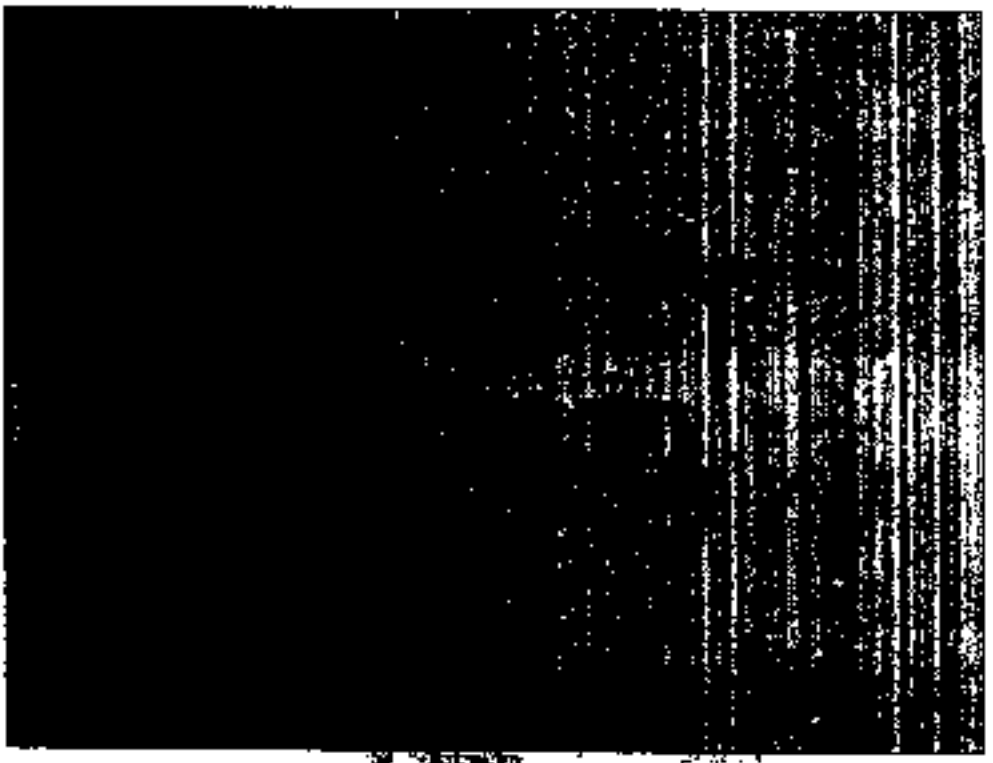


Fig. 5.1 Typical cracks at first floor

CSIR Tower

22. House no. 1093

Observations:

- No. of stories built: Single.
- Occupancy: 5 people.
- House was built around year 2008 and it is a load bearing structure as shown in Fig. 56.
- The walls of house were constructed using stone masonry and thereafter new construction has been done by using brick masonry.
- Vertical cracks were observed in walls inside house as shown in Fig. 57.
- Mud mortar and cement mortar was used in old structure and new construction respectively.

Building type	Foundation type	Masonry type	Flooring	Roof type	Area
Load bearing structure	Stone masonry	Stone and brick masonry	Cement	Stone slab	44 sqm

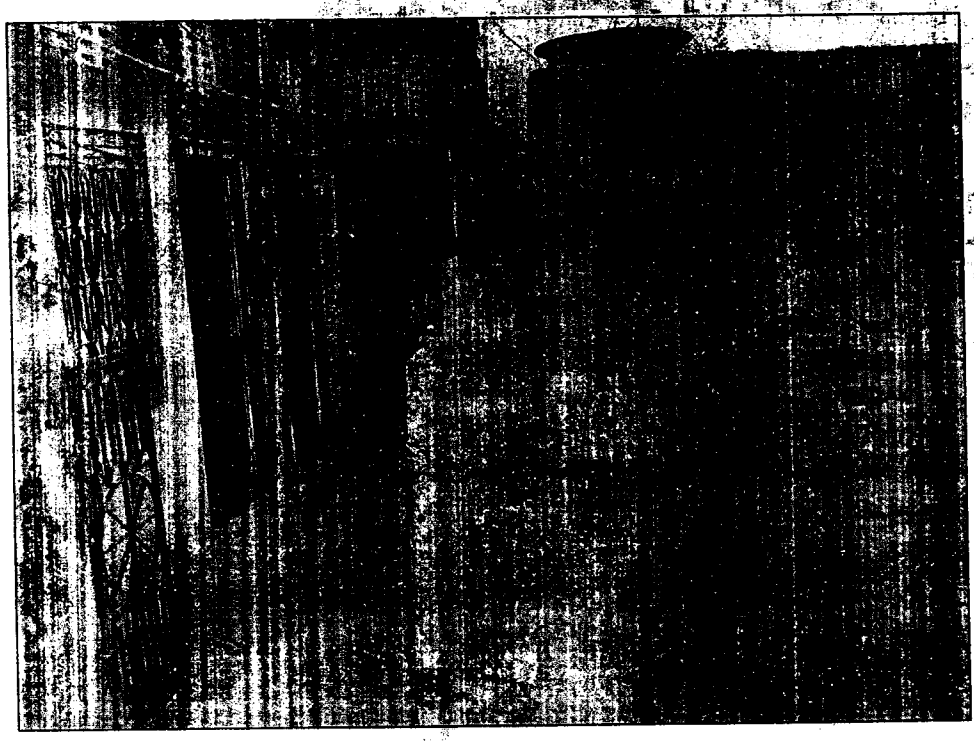


Fig. 56. House no. 1093

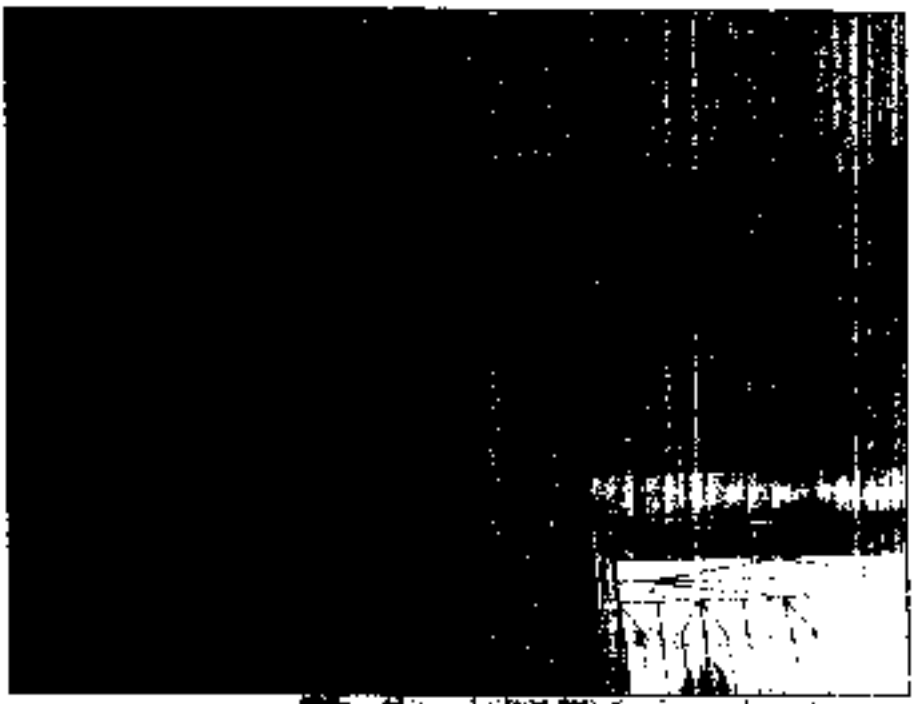


Fig. 57. Vertical crack in wall inside house

23. House no. 841

Observations:

- No. of stories built: G+1.
- Occupancy: 20 people.
- House was built around year 1995
- The building was found to be a partial load bearing structure with stone pillars erected at few locations as shown Fig. 58.
- Stone and brick masonry was used with lime mortar in construction of house.
- Vertical and diagonal cracks were observed in walls and wall corners of house as shown in Fig. 59

Building type	Foundation type	Masonry type	Flooring	Roof type	Area
Load bearing structure	Stone masonry	Stone and brick masonry	Cement	Stone slab with I girders	160 sqm

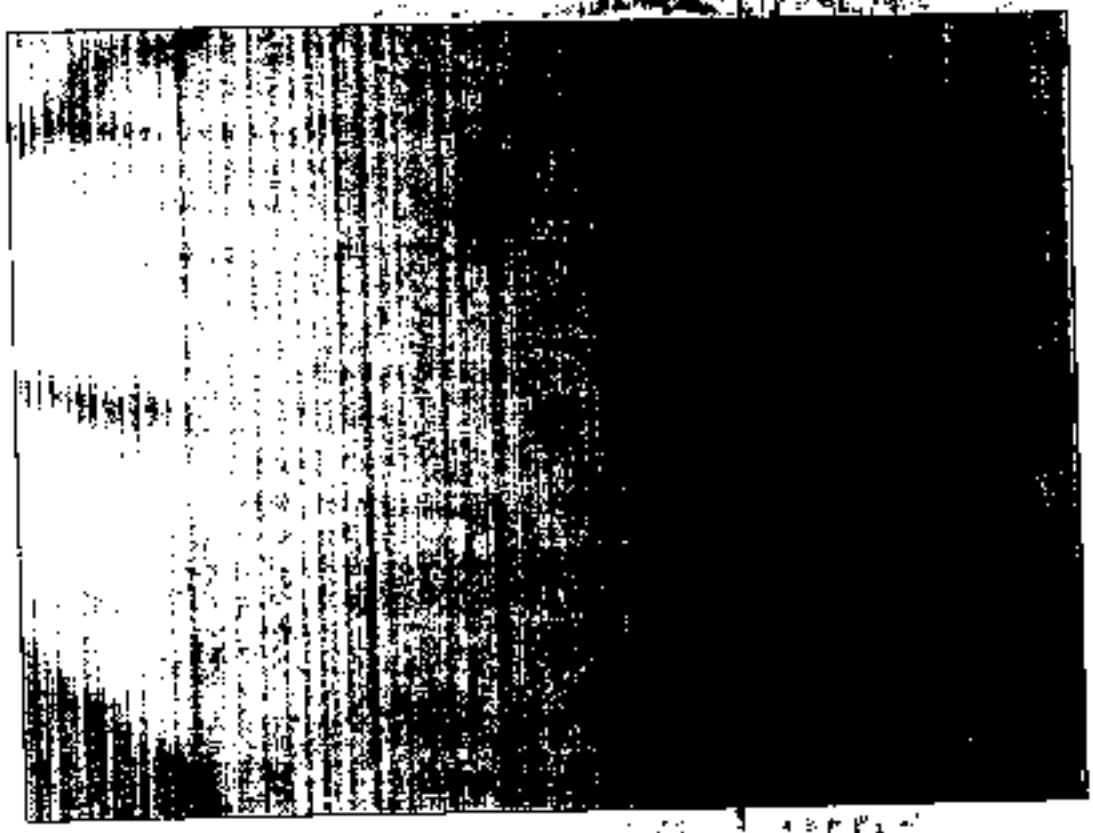


Fig. 58. House no. 841

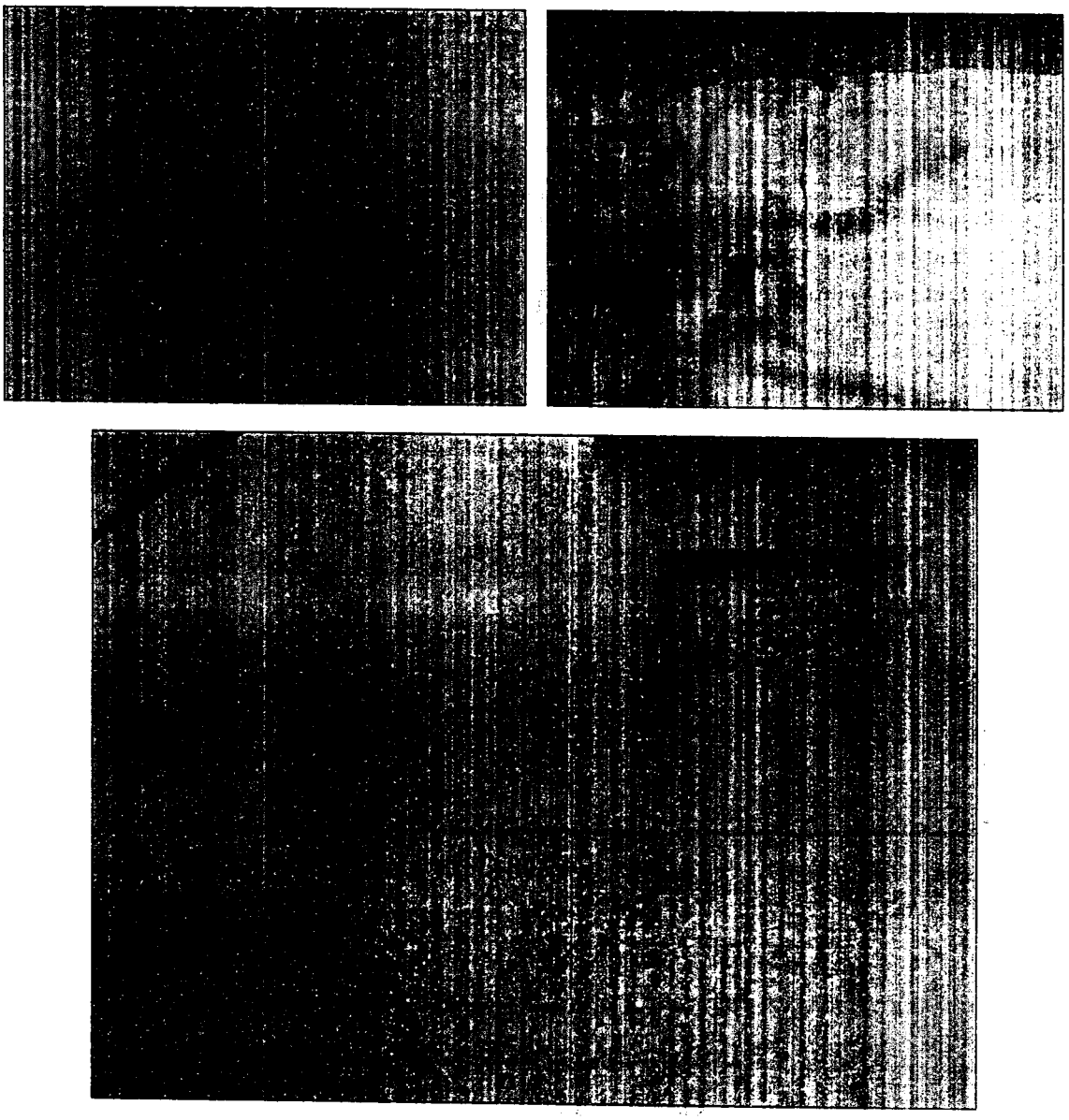


Fig. 59. Diagonal cracks in walls of house

CSIR Building

24. House no. 1112

Observations:

- No. of stories built: G+1.
- Occupancy: 7 people.
- Ground floor of house was built around year 2010 as a partial load bearing structure with stone pillars whereas first floor constructed later in year 2015 as shown Fig. 60 and Fig. 61.
- The RCC columns were found to be constructed at first floor of house.
- The walls were made of stone masonry and it was plastered with cement-sand mortar.
- Diagonal cracks were observed at many locations of house as shown in Fig. 61.

Building type	Foundation type	Masonry type	Flooring	Roof type	Area
Load bearing structure	Stone masonry	Stone and brick masonry	Cement	Stone slab	70 sqm

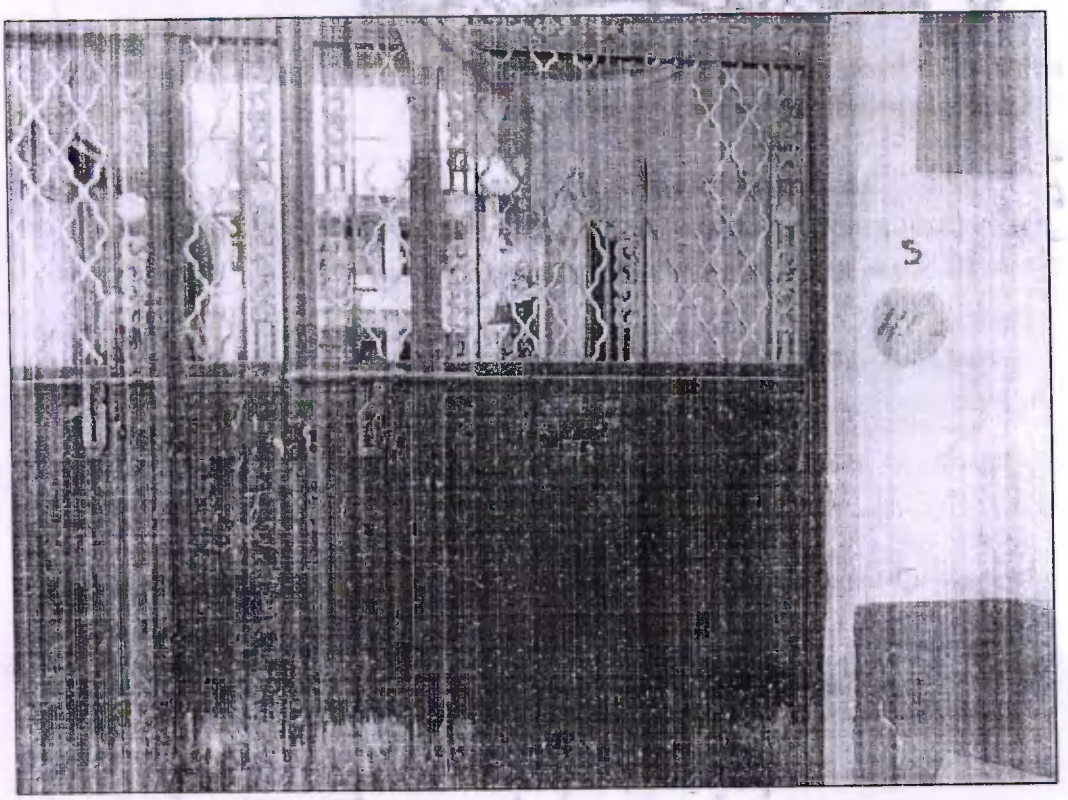


Fig. 60. House no. 1112

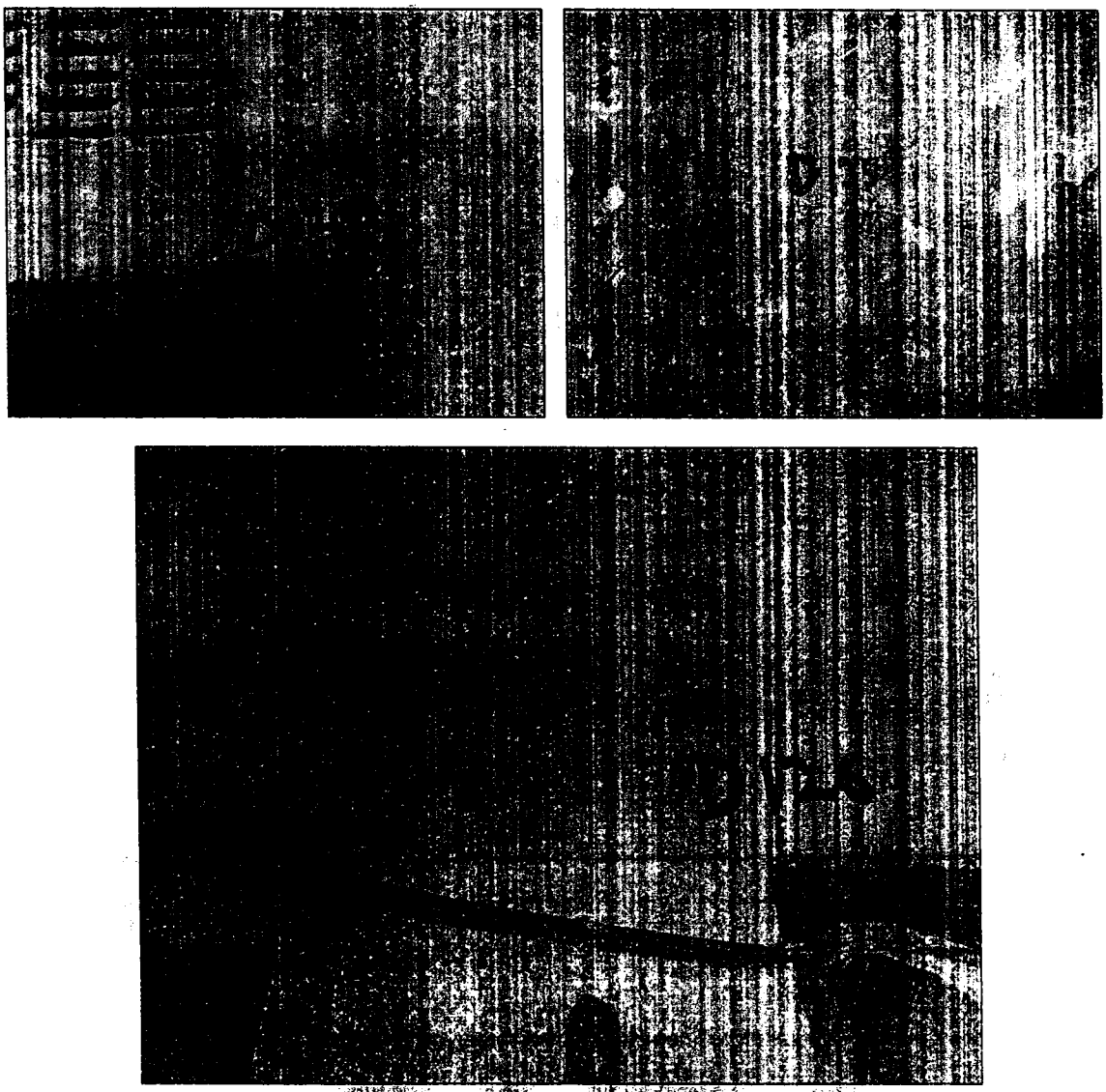


Fig. 61. Diagonal cracks in walls of house

CSIR Toucilla

25. House no. 891

Observation:

- No. of stories built: Single.
- Occupancy: Vacated.
- Building was built around 1980.
- Diagonal cracks were observed in external wall of the building.
- Cracks were found to be located near window and it was propagating to roof level.

Building type	Masonry type	Flooring	Roof type
Load bearing structure	Stone masonry	Stone flooring	Stone slab

26. House no. 886

Observation:

- No. of stories built: Single.
- Occupancy: Vacated.
- House was built around year 1980.
- The wall was observed to be made of stone masonry.
- Vertical cracks were observed between two entry doors in external wall of the building.
- Crack was found to be propagating upto roof level.

Building type	Masonry type	Flooring	Roof type
Load bearing structure	Stone masonry	Stone flooring	Stone slab

27. House no. 880

Observation:

- No. of stories built: G+1.
- Occupancy: 12 people.
- House was built in year 2002.
- The walls were found to be made of both stone and brick masonry.
- Diagonal cracks were observed on side wall of the building.
- Cracks in walls were observed propagating towards roof from window.

Building type	Masonry type	Flooring	Roof type
Load bearing structure	Stone & brick masonry	Marble stone floor	Stone slab



Annexure - A

Table A1: Location of Demec points at various places in Pur village, Bhilwara

Sr. No.	Location	Demic Points
1	Govt. Primary School	D1, D2, D3, D188, D189
2	Govt. Higher Secondary School	D4, D5
3	Village General Hospital	D6, D6, D7, D8, D9, D10, D190, D191, D192, D217
4	Govt. Girls School	D11, D208, D209
5	Laxmi Narayan temple	D23, D24, D25, D26, D27, D28, D29, D30, D31, D32, D33, D34, D35, D184, D185, D186, D187
6	Madina Masjid	D134, D134, D135, D136, D137, D138, D139, D140, D141, D142
7	House no. 2835	D12, D13
8	House no. 2836	D14
9	House no.2249	D15, D16, D17, D18, D19, D20
10	House no. 2251	D21, D22
11	House no. 1936	D36
12	House no. 1952	D37, D38,39
13	House no. 1956	D40, D41, D42, D43, D45, D46
14	House no. 1962	D44
15	House no. 1970	D47
16	House no. 1982	D48
17	House no. 2213	D49
18	House no. 2377	D50, D51
19	House no. 2489	D52
20	House no. 2490	D53, D54, D55
21	House no. 2669	D56, D57
22	House no. 2491	D58
23	House no. 2496	D59, D60
24	House no. 2492	D61
25	House no. 2502	D62, D64
26	House no. 2505	D63, D65
27	Shop no. 1100	D66, D67, D68, D69
28	House no. 1095	D70, D71, D72, D100, D101
29	House no. 1089	D73
30	House no. 1092	D74
31	House no. 1093	D75, D76
32	House no. 841	D77, D78, D79, D80, D81
33	House no. 1064	D82, D83

34	House no. 1066	D84, D85
35	House no. 1068	D86, D87
36	House no. 1077	D88, D89
37	House no. 1073	D90
38	House no. 1067	D91, D92, D93
39	House no. 1079	D94
40	House no. 878	D95, D96
41	House no. 882	D97, D98, D99
42	House no. 1353	D102, D103, D104, D105, D106, D107, D108, D109
43	House no. 1372	D110, D111, D112, D113, D114
44	House no. 1375	D115, D116
45	House no. 1378	D117
46	Shop no. 1582	D118, D119
47	Shop no. 1581	D120, D121
48	Shop no. 1635	D122
49	House no. 1567	D123
50	House no. 112	D124, D125, D126
51	House no. 1126	D127
52	House no. 1122	D128
53	House no. 1132	D129
54	House no. 1135	D130
55	House no. 1141	D131, D132, D133
56	House no. 2245	D143, D144, D145, D146, D147, D148
57	House no.2249	D149, D150, D151, D152, D153, D153, D154, D155, D156, D157
58	House no. 2248	D158, D159, D160, D161, D162, D163, D164, D165, D166, D167
59	House no. 2235	D168, D169, D170, D171, D172
60	House no. 2234	D173, D174, D175, D176, D177
61	House no. 2237	D178, D179
62	House no. 2826	D180, D181, D182, D183
63	House no. 2822	D193, D194, D195, D196,
64	House no. 2824	D197, D198, D199, D200
65	House no. 2823	D201, D202, D203, D204, D205
66	House no. 2835	D206, D207
67	House no. 2324	D210, D211, D212, D213, D214, D215
68	House no. 1374	D216
69	House no. 2246	D218, D219
70	House no. 2216	D220,D221,D222

71	House no. 2226	D223
72	House no. 2225	D224, D225, D226
73	House no. 2223	D227
74	House no. 544	D228, D229, D230, D231, D232
75	House no. 910	D233
76	House no. 908	D234
77	House no. 891	D235
78	House no. 886	D236
79	House no. 880	D237

Platinum Jubilee 1942-2017
Years of
S.R. Touching Lives

Table A2: Crack dimension of demec points installed at various important structures

Sr. No.	Location	Demec point No.	Demec Points ID	Crack widening (mm)
1	Govt. Primary School	1	D1	0.301
		2	D2	1.146
		3	D3	-0.238
		4	D188	Removed
		5	D189	-0.211
2	Govt. Higher Secondary School	6	D4	0.066
		7	D5	0.436
3	Village General Hospital	8	D6	-1.053
		9	D7	0.512
		10	D8	-0.869
		11	D9	-0.850
		12	D10	-0.337
		13	D190	0.181
		14	D191	-0.362
		15	D192	-0.395
		16	D217	-0.265
4	Govt. Girls School	17	D11	Repaired
		18	D208	Repaired
		19	D209	Repaired
5	Laxmi Narayan Temple	20	D23	3.243
		21	D24	2.095
		22	D25	-1.942
		23	D26	2.100
		24	D27	-1.323
		25	D28	0.088
		26	D29	0.755
		27	D30	-0.492
		28	D31	3.193
		29	D32	Removed
		30	D33	0.006
		31	D34	0.650
		32	D35	0.306
		33	D184	-0.216
		34	D185	Removed
		35	D186	0.130
		36	D187	Removed
6	Madina Masjid	37	D134	Repaired

	38	D135	Repaired
	39	D136	-0.092
	40	D137	Removed
	41	D138	0.166
	42	D139	0.295
	43	D140	-0.099
	44	D141	-0.396
	45	D142	0.007

Table A3: Crack dimension of demec points installed at various houses in Pur village

Sr. No.	Location	Demec point No.	Demec points	Cracking
7	House no. 2835	46	D12	0.226
		47	D13	0.081
8	House no. 2836	48	D14	-0.175
9	House no 2249	49	D15	Removed
		50	D16	-2.979
		51	D17	Removed
		52	D18	0.130
		53	D19	0.047
		54	D20	0.184
10	House no. 2251	55	D21	-0.030
		56	D22	0.091
11	House no. 1936	57	D36	0.09
12	House no. 1952	58	D37	-0.001
		59	D38	0.425
		60	D39	0.024
13	House no. 1956	61	D40	0.036
		62	D41	-0.298
		63	D42	-0.034
		64	D43	0.077
		65	D45	Removed
		66	D46	0.321
14	House no. 1962	67	D44	0.145
15	House no. 1970	68	D47	0.151
16	House no. 1982	69	D48	Removed
17	House no. 2213	70	D49	Removed
18	House no. 2377	71	D50	2.984
		72	D51	3.310
19	House no. 2489	73	D52	0.122
20	House no. 2490	74	D53	-2.018

		75	D54	0.165
		76	D55	0.295
21	House no. 2669	77	D56	0.257
		78	D57	0.351
22	House no. 2491	79	D58	0.185
23	House no. 2496	80	D59	0.248
		81	D60	0.843
24	House no. 2492	82	D61	Repaired
25	House no. 2502	83	D62	0.058
		84	D64	-0.174
26	House no. 2505	85	D63	0.641
		86	D65	0.584
27	Shop no. 1100	87	D66	Removed
		88	D67	-0.139
		89	D68	Removed
		90	D69	0.522
28	House no. 1095	91	D70	Removed
		92	D71	Removed
		93	D72	0.878
		94	D100	-0.271
		95	D101	0.047
29	House no. 1089	96	D73	Removed
30	House no. 1092	97	D74	0.846
31	House no. 1093	98	D75	0.036
		99	D76	0.091
32	House no. 841	100	D77	0.446
		101	D78	0.327
		102	D79	0.238
		103	D80	0.241
		104	D81	0.336
33	House no. 1064	105	D82	0.315
		106	D83	-1.498
34	House no. 1066	107	D84	Removed
		108	D85	Removed
35	House no. 1068	109	D86	Repaired
		110	D87	Repaired
36	House no. 1077	111	D88	Removed
		112	D89	0.731
37	House no. 1073	113	D90	-1.227
38	House no. 1067	114	D91	-0.103
		115	D92	0.134
		116	D93	0.229
39	House no. 1079	117	D94	-0.024

40	House no. 878	118	D95	Removed
		119	D96	Removed
41	House no. 882	120	D97	0.180
		121	D98	0.228
		122	D99	0.361
42	House no. 1353	123	D102	Repaired
		124	D103	Repaired
		125	D104	Repaired
		126	D105	Removed
		127	D106	Repaired
		128	D107	Repaired
		129	D108	Repaired
		130	D109	Repaired
43	House no. 1372	131	D110	Removed
		132	D111	2.122
		133	D112	1.024
		134	D113	1.557
		135	D114	1.607
44	House no. 1375	136	D115	-0.856
		137	D116	Removed
45	House no. 1378	138	D117	1.743
46	Shop no. 1582	139	D118	-1.229
		140	D119	2.509
47	Shop no. 1581	141	D120	2.548
		142	D121	1.198
48	Shop no. 1635	143	D122	Removed
49	House no. 1567	144	D123	2.541
50	House no. 112	145	D124	1.889
		146	D125	Removed
		147	D126	-2.440
51	House no. 1126	148	D127	2.539
52	House no. 1122	149	D128	0.955
53	House no. 1132	150	D129	-0.097
54	House no. 1135	151	D130	2.970
55	House no. 1141	152	D131	Removed
		153	D132	Removed
		154	D133	2.900
56	House no. 2245	155	D143	1.570
		156	D144	0.340
		157	D145	2.539
		158	D146	0.076
		159	D147	1.897
		160	D148	0.000

57	House no.2249	161	D149	Removed
		162	D150	0.065
		163	D151	0.463
		164	D152	-0.066
		165	D153	0.050
		166	D154	0.281
		167	D155	1.209
		168	D156	0.042
		169	D157	0.402
58	House no. 2248	170	D158	Removed
		171	D159	Removed
		172	D160	Removed
		173	D161	Removed
		174	D162	-0.988
		175	D163	-0.998
		176	D164	-0.903
		177	D165	0.164
		178	D166	-0.012
		179	D167	0.174
59	House no. 2235	180	D168	0.281
		181	D169	0.184
		182	D170	0.237
		183	D171	Removed
		184	D172	0.090
60	House no. 2234	185	D173	-1.577
		186	D174	-0.773
		187	D175	1.906
		188	D176	-3.144
		189	D177	Removed
61	House no. 2237	190	D178	0.680
		191	D179	-0.057
62	House no. 2826	192	D180	1.801
		193	D181	-1.667
		194	D182	Removed
		195	D183	-3.180
63	House no. 2822	196	D193	0.106
		197	D194	0.019
		198	D195	0.525
		199	D196	0.338
64	House no. 2824	200	D197	0.071
		201	D198	0.080
		202	D199	-0.085
		203	D200	0.004

65	House no. 2823	204	D201	-0.630
		205	D202	-0.72
		206	D203	-0.903
		207	D204	-0.001
		208	D205	0.168
66	House no. 2835	209	D206	-0.014
		210	D207	0.147
67	House no. 2824	211	D210	0.53
		212	D211	2.331
		213	D212	1.277
		214	D213	0.739
		215	D214	0.402
		216	D215	0.283
68	House no. 1374	217	D216	Removed

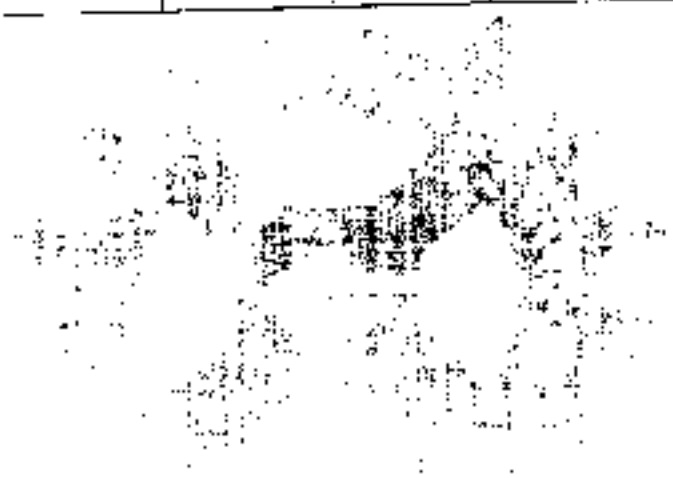


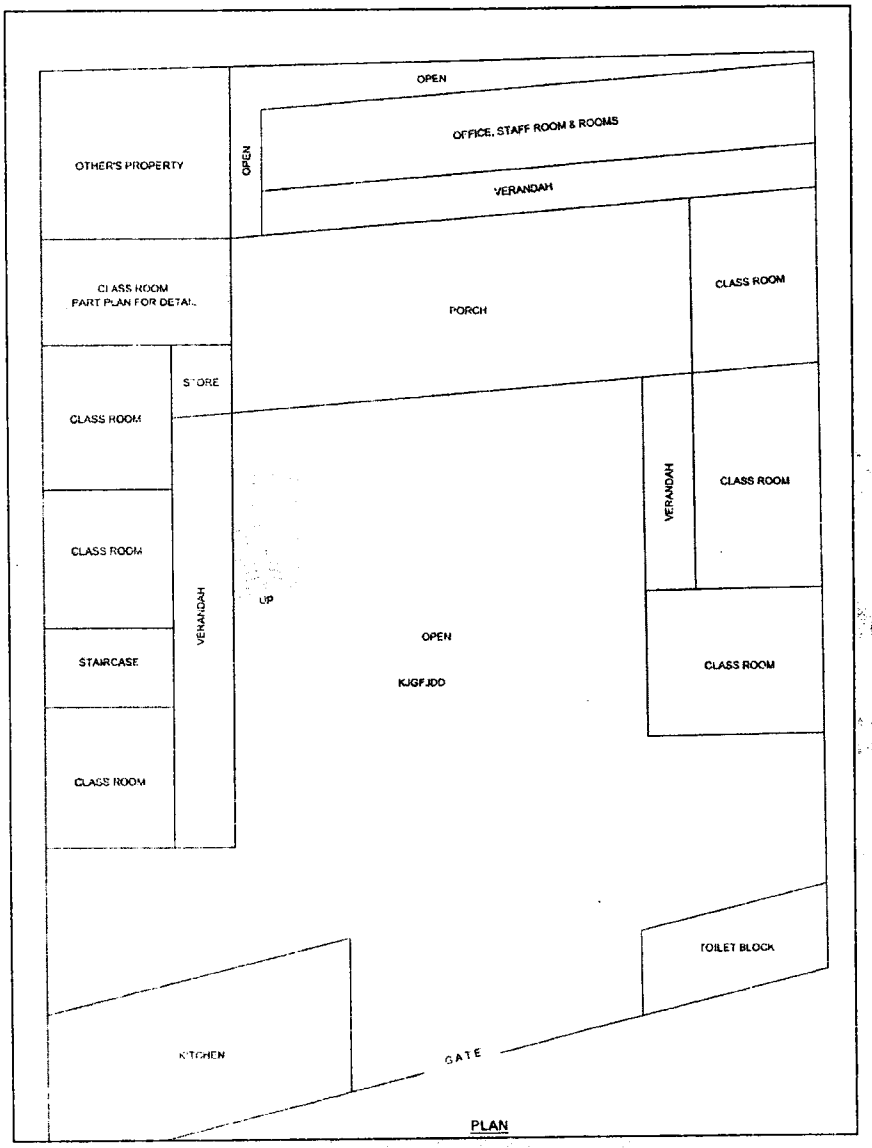
Table A4: Initial readings of demec points installed at additional locations in Pur village

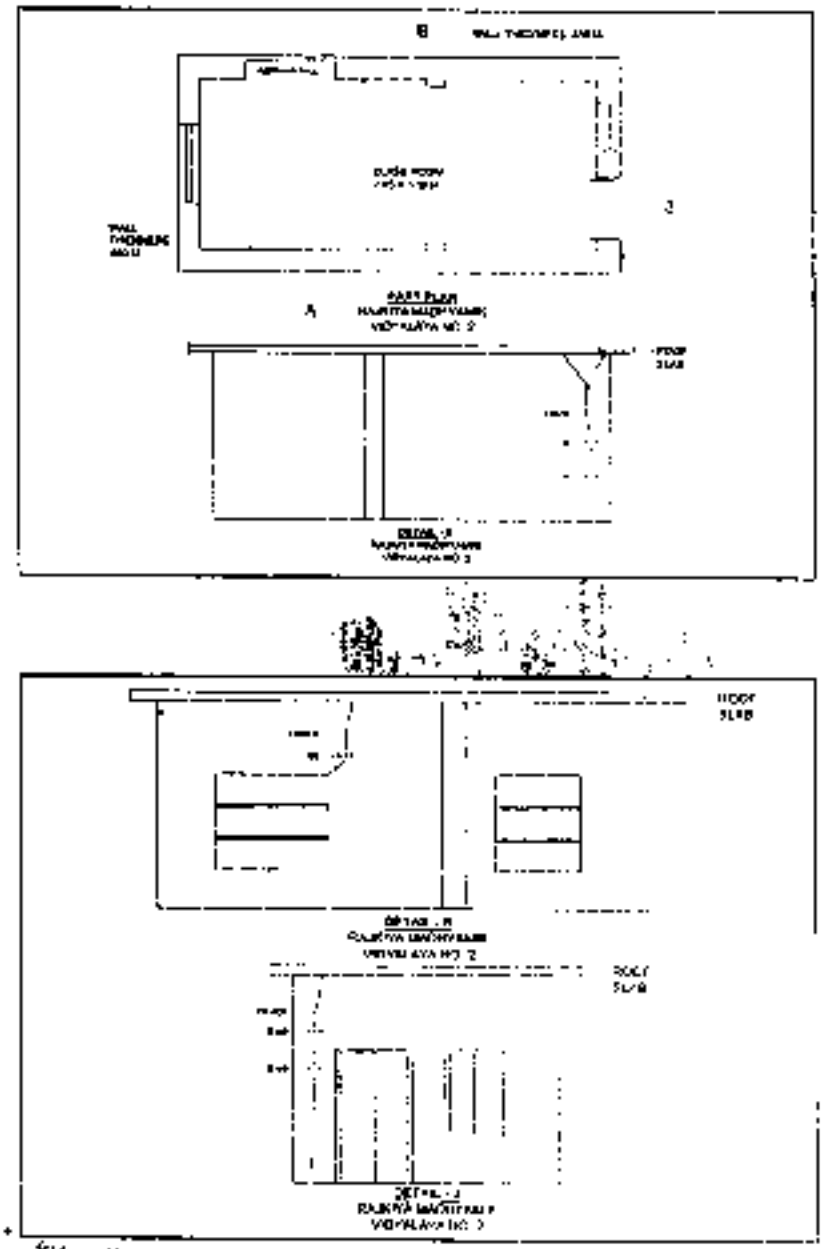
S. No.	Location	Demec point No.	Demec points ID	Initial reading
69	House no. 2246	218	D218	-0.934
		219	D219	0.117
70	House no. 2216	220	D220	1.935
		221	D221	0.341
		222	D222	2.159
71	House no. 2226	223	D223	2.023
72	House no. 2225	224	D224	-0.545
		225	D225	1.734
		226	D226	-0.091
73	House no. 2223	227	D227	2.298
74	House no. 544	228	D228	6.091
		229	D229	-0.650
		230	D230	3.190
		231	D231	5.237
		232	D232	7.538
75	House no. 910	233	D233	2.603
76	House no. 908	234	D234	1.335
77	House no. 89	235	D235	3.870
78	House no. 886	236	D236	6.524
79	House no. 880	237	D237	5.647

Annexure - B

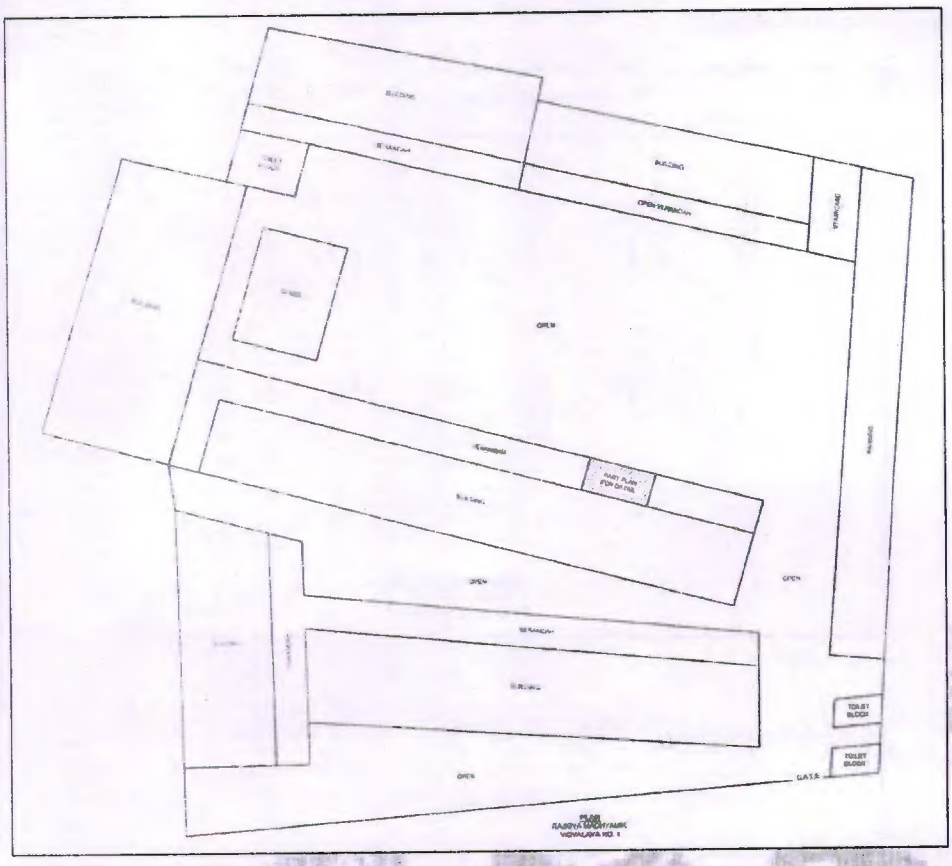
Architectural drawings with crack detailing

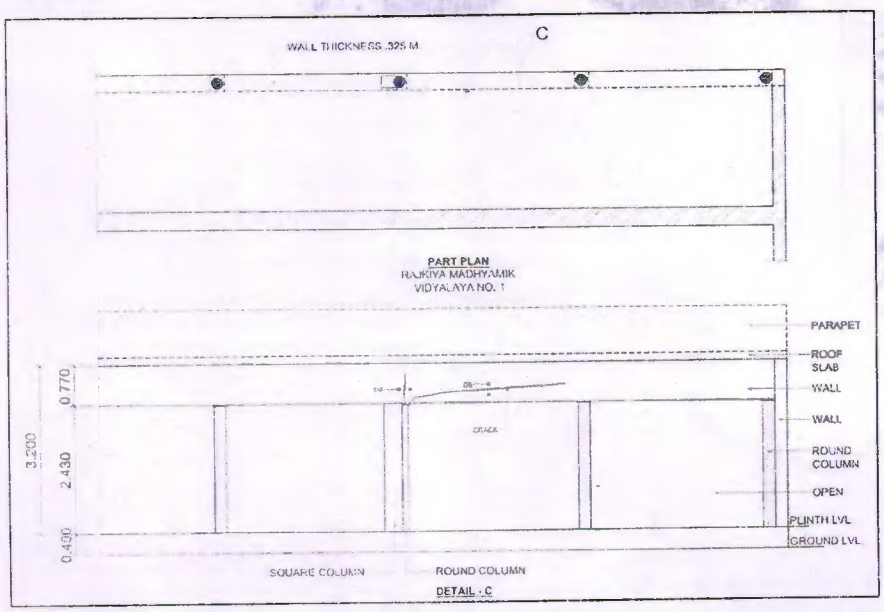
B1. Government Primary School



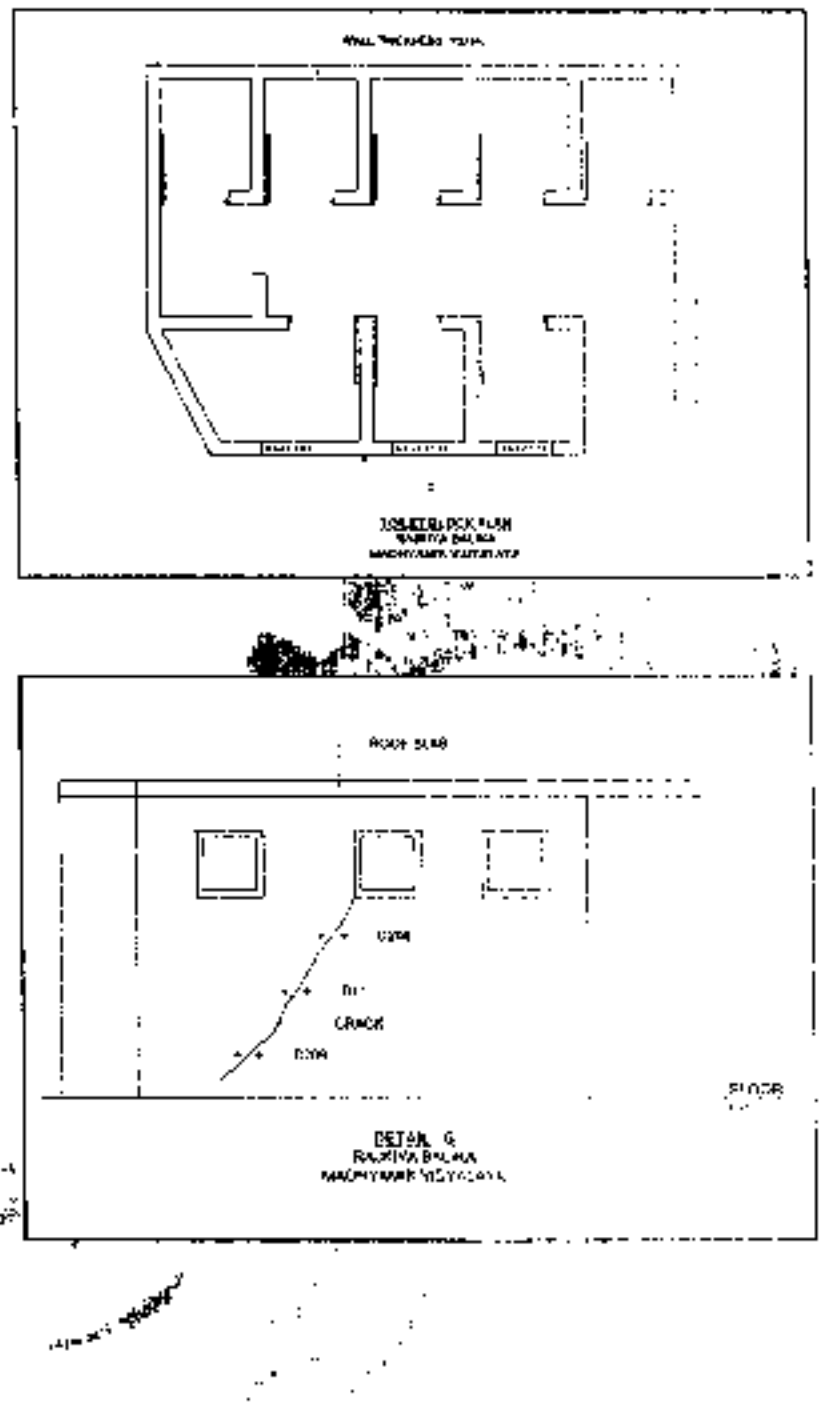


B2. Government Higher Secondary School



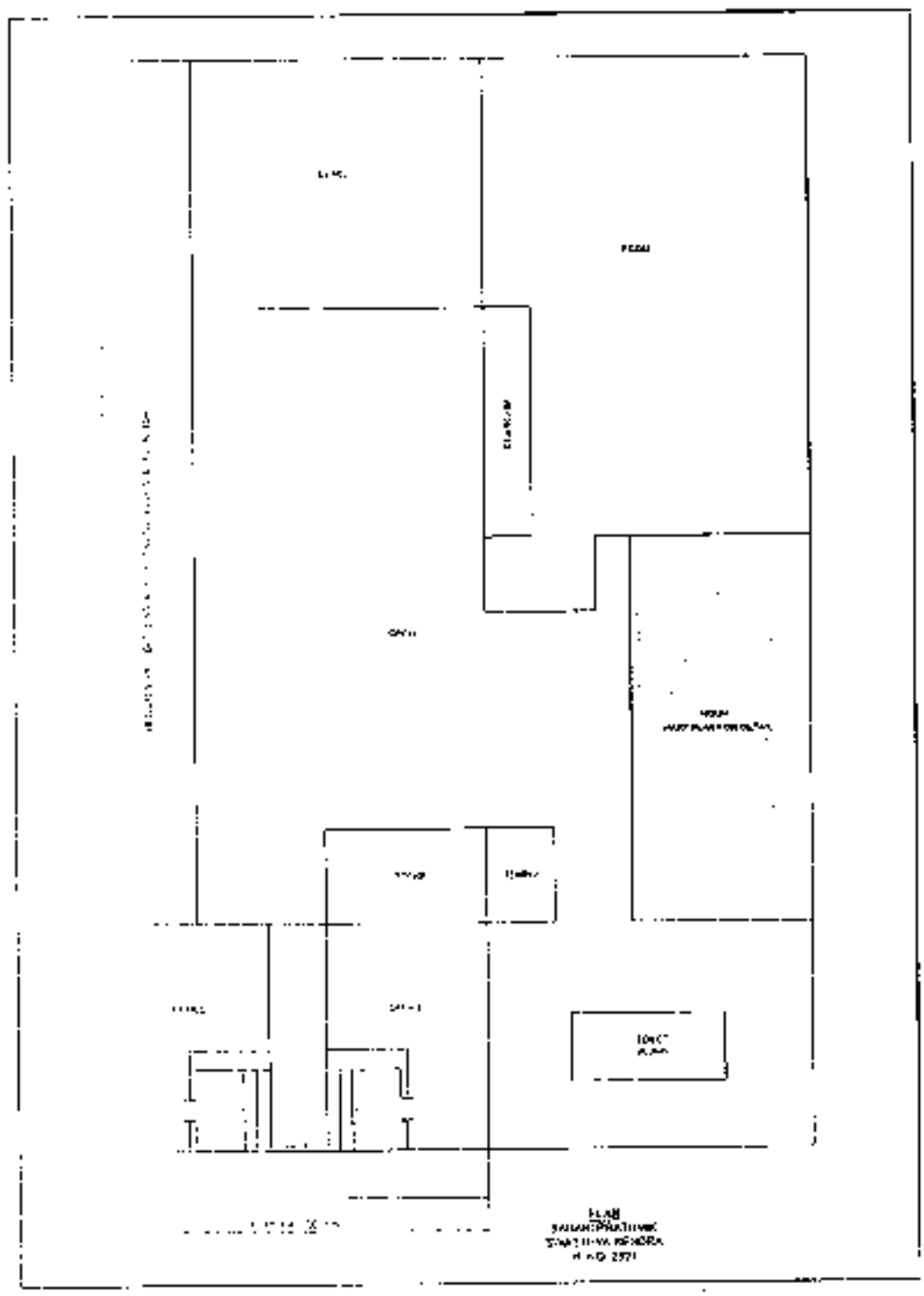


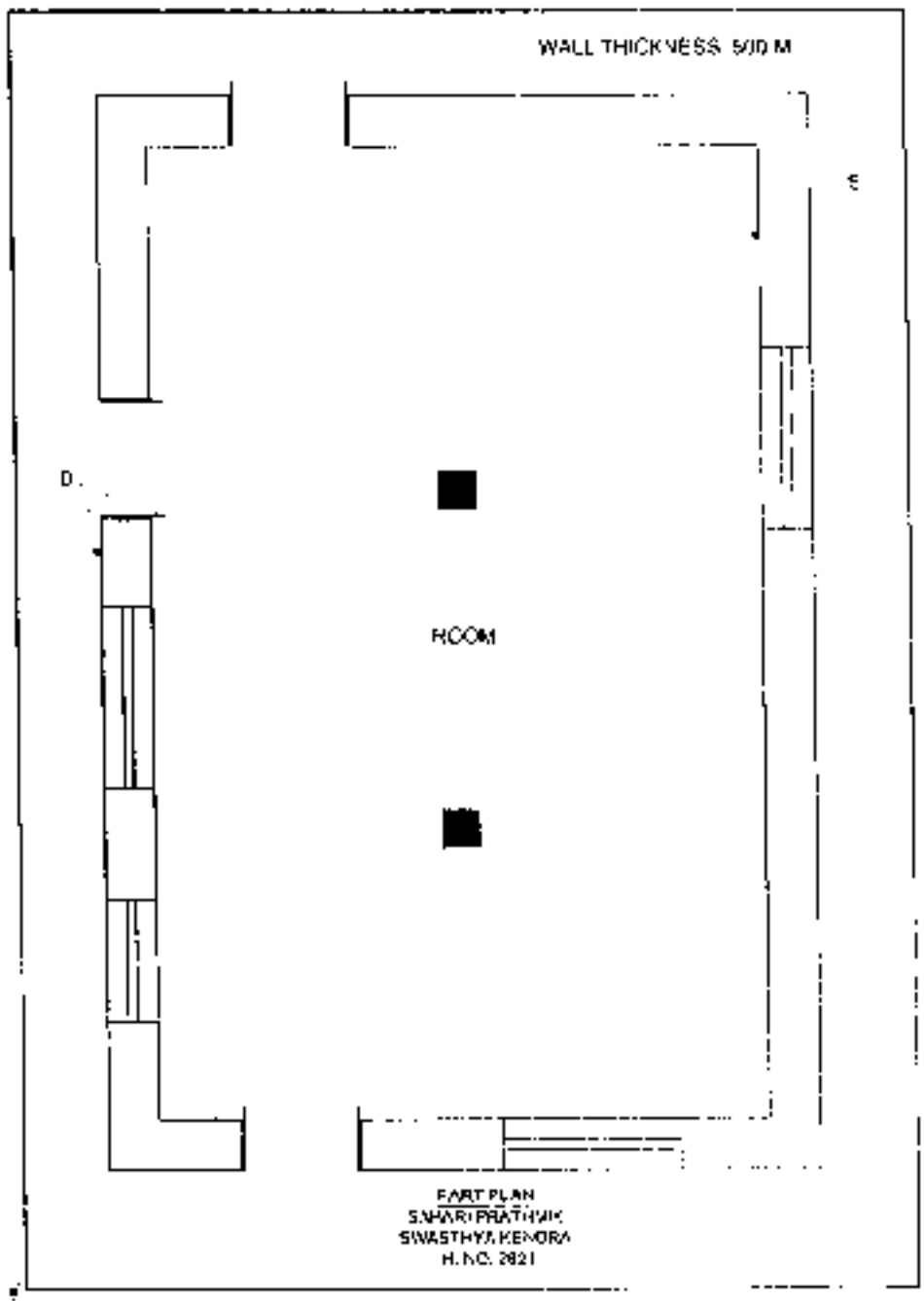
B3. Government Girls School

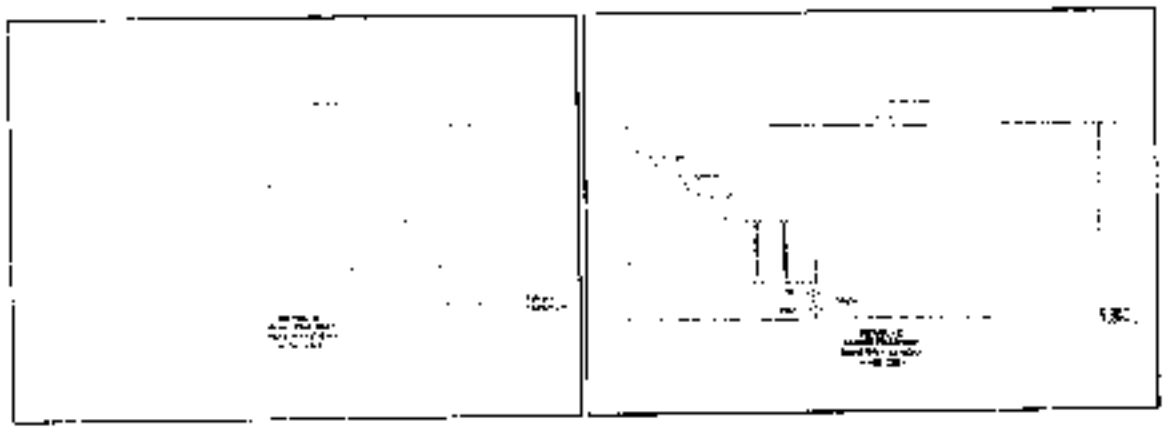


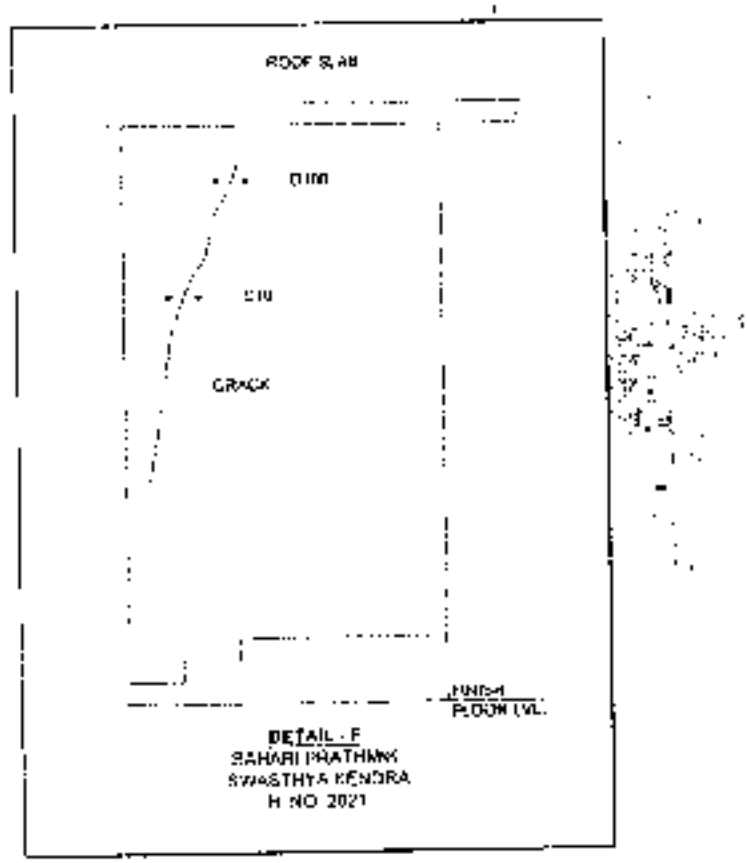
CSIR Tech

B4. Village General Hospital

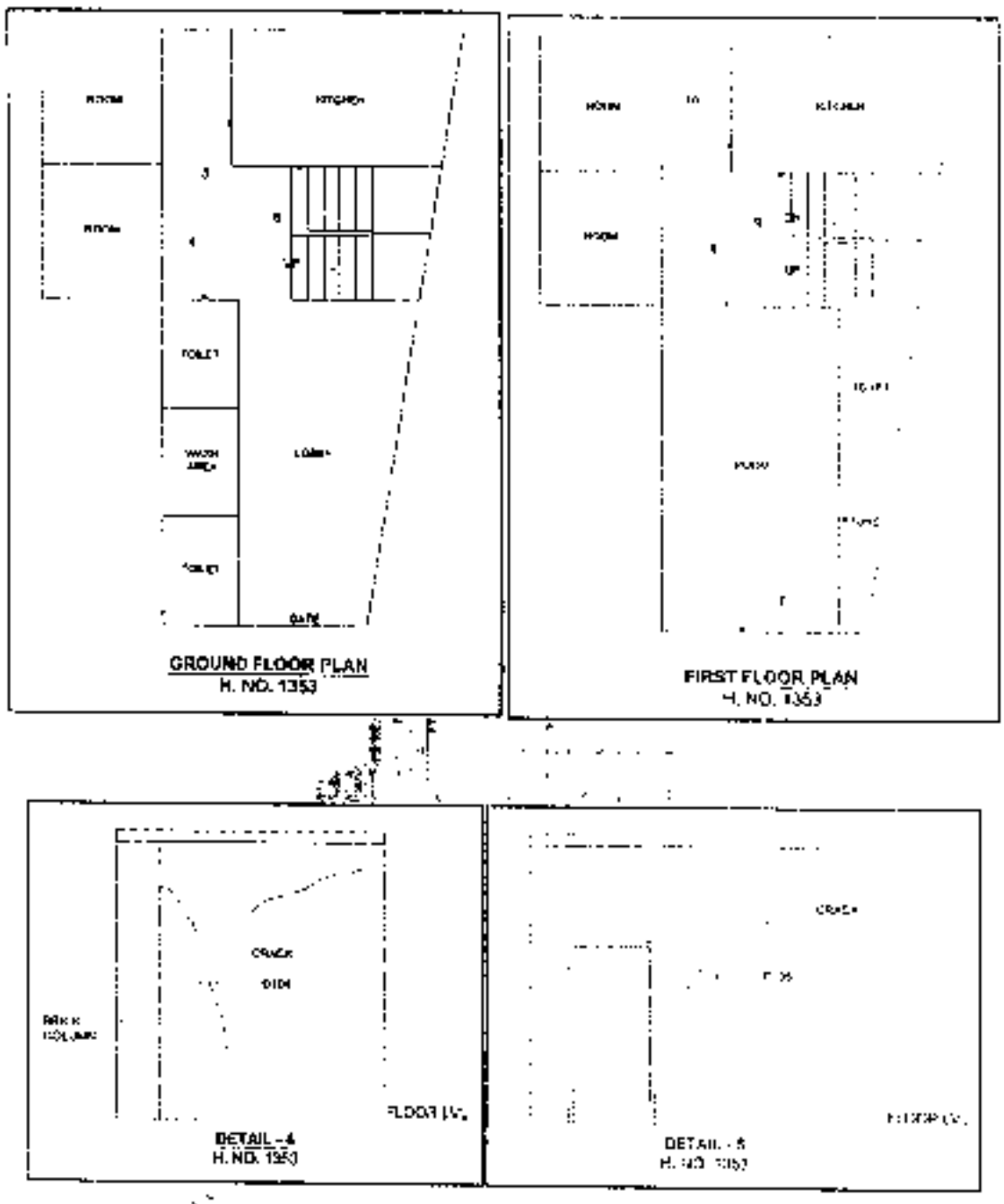


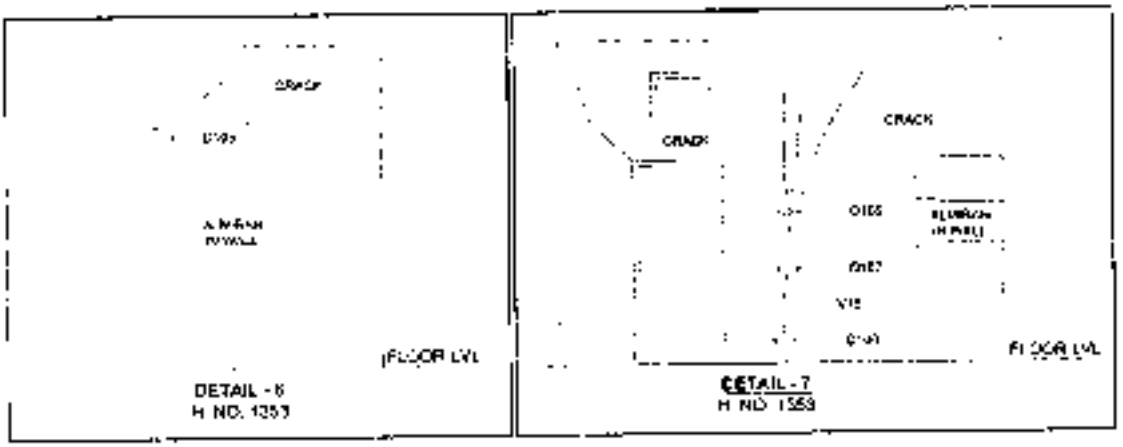

WALL THICKNESS 500 M
ROOM
PART PLAN
SHARI PRATHMIK
SWASTHYA KENDRA
H. NO. 2821

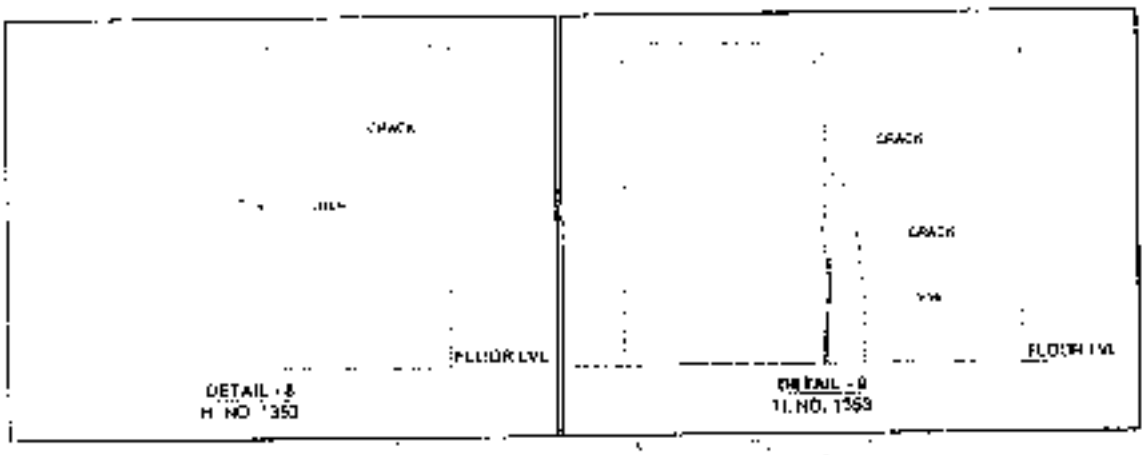


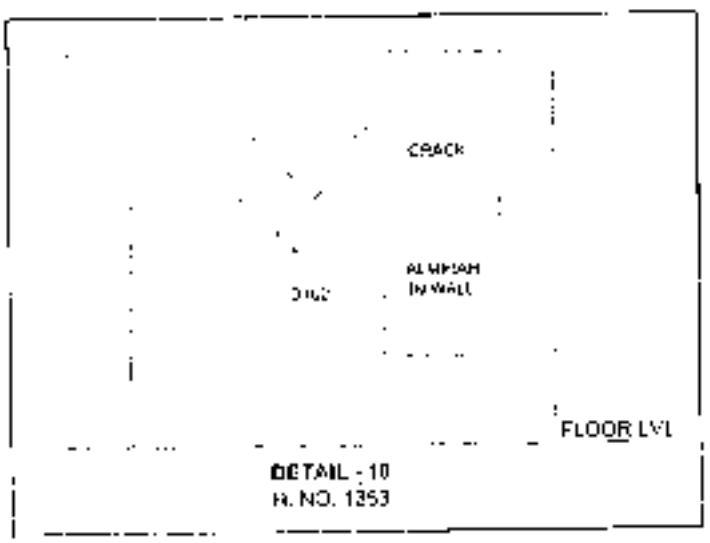

ROOF SLAB
CRACK
CRACK
CRACK
FINISH
FLOOR LVL.
DETAIL - F
SAHARI PRATHMIK
SWASTHYA KENDRA
H NO 2021

BS. House no. 1353

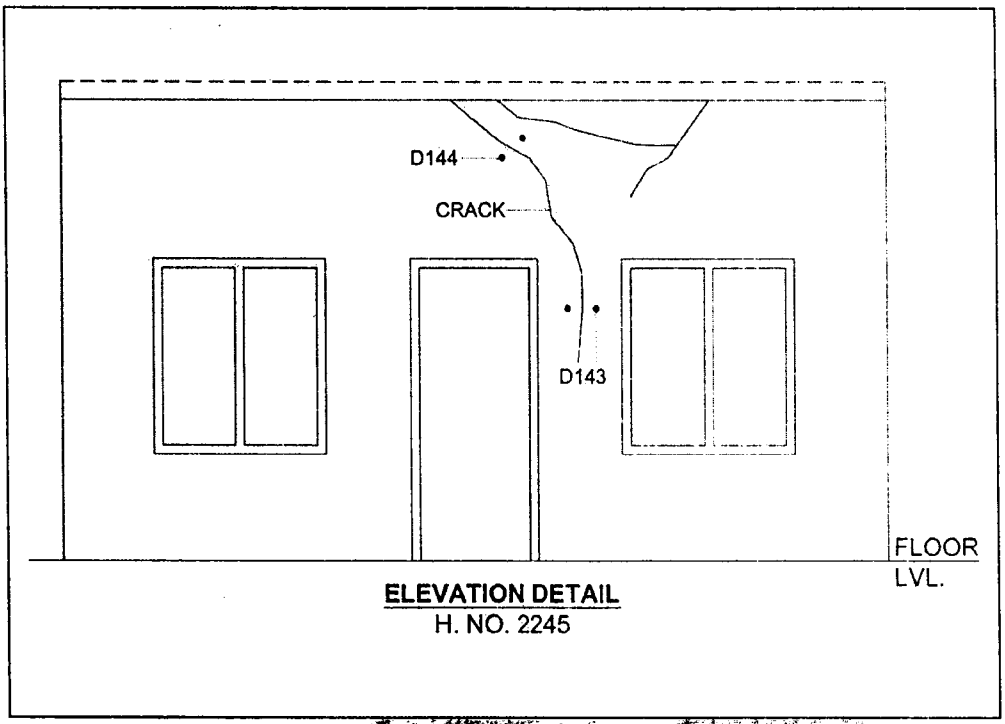



CRACK
FLOOR LVL
DETAIL - 6
H. NO. 1353
CRACK
CRACK
FLOOR LVL
DETAIL - 7
H. NO. 1353

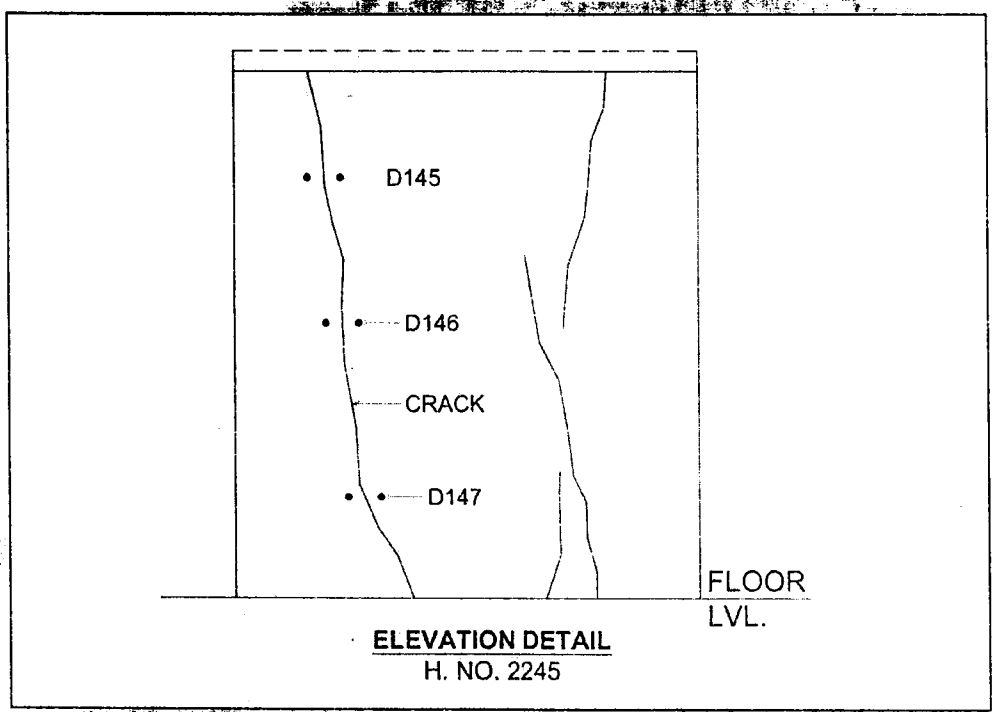

CRACK
FLOOR LVL
DETAIL - 8
H. NO. 1353
CRACK
CRACK
FLOOR LVL
DETAIL - 9
H. NO. 1353


CRACK
FLOOR LVL
DETAIL - 10
H. NO. 1353

B6. House no. 2245



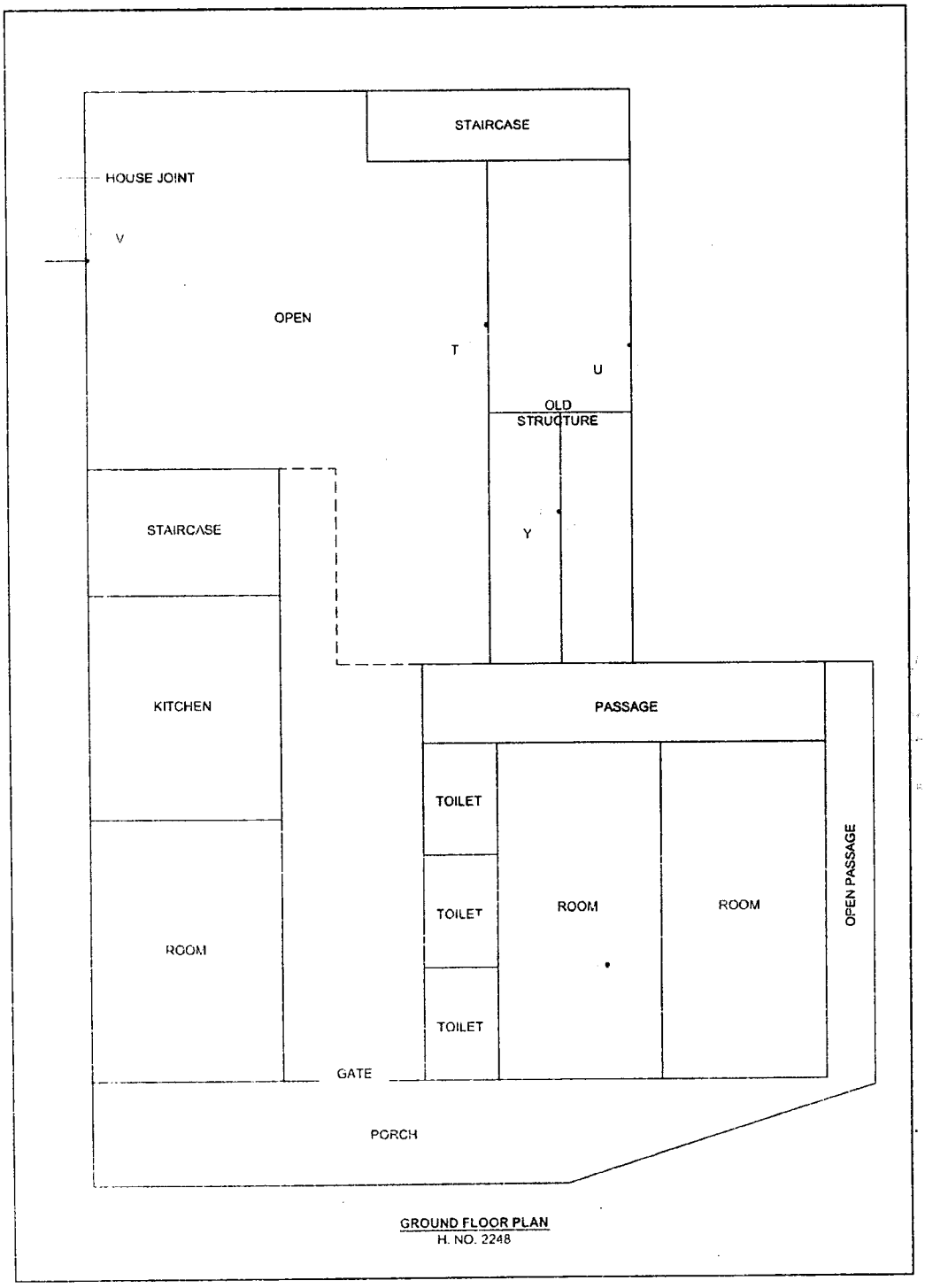
ELEVATION DETAIL
H. NO. 2245

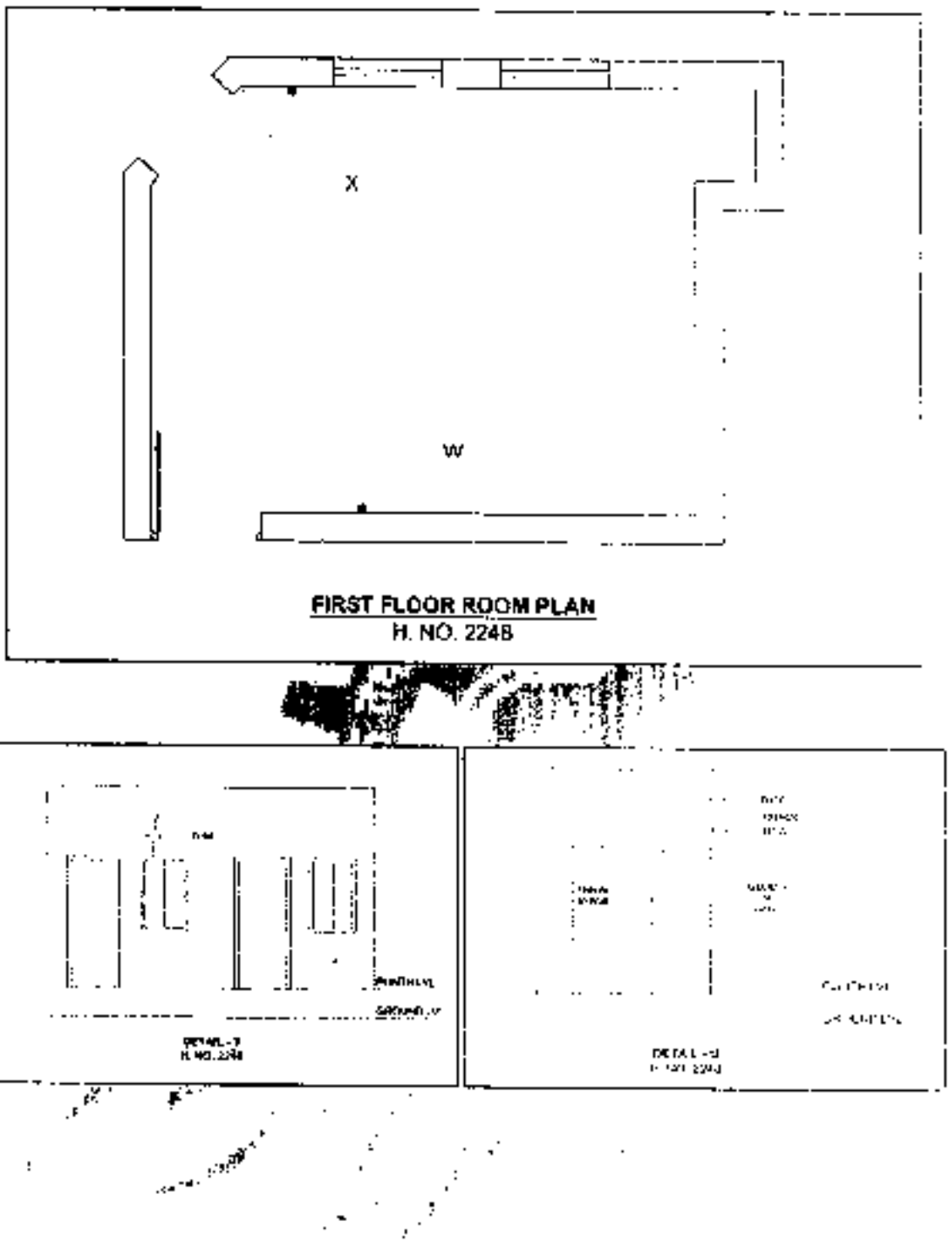


ELEVATION DETAIL
H. NO. 2245

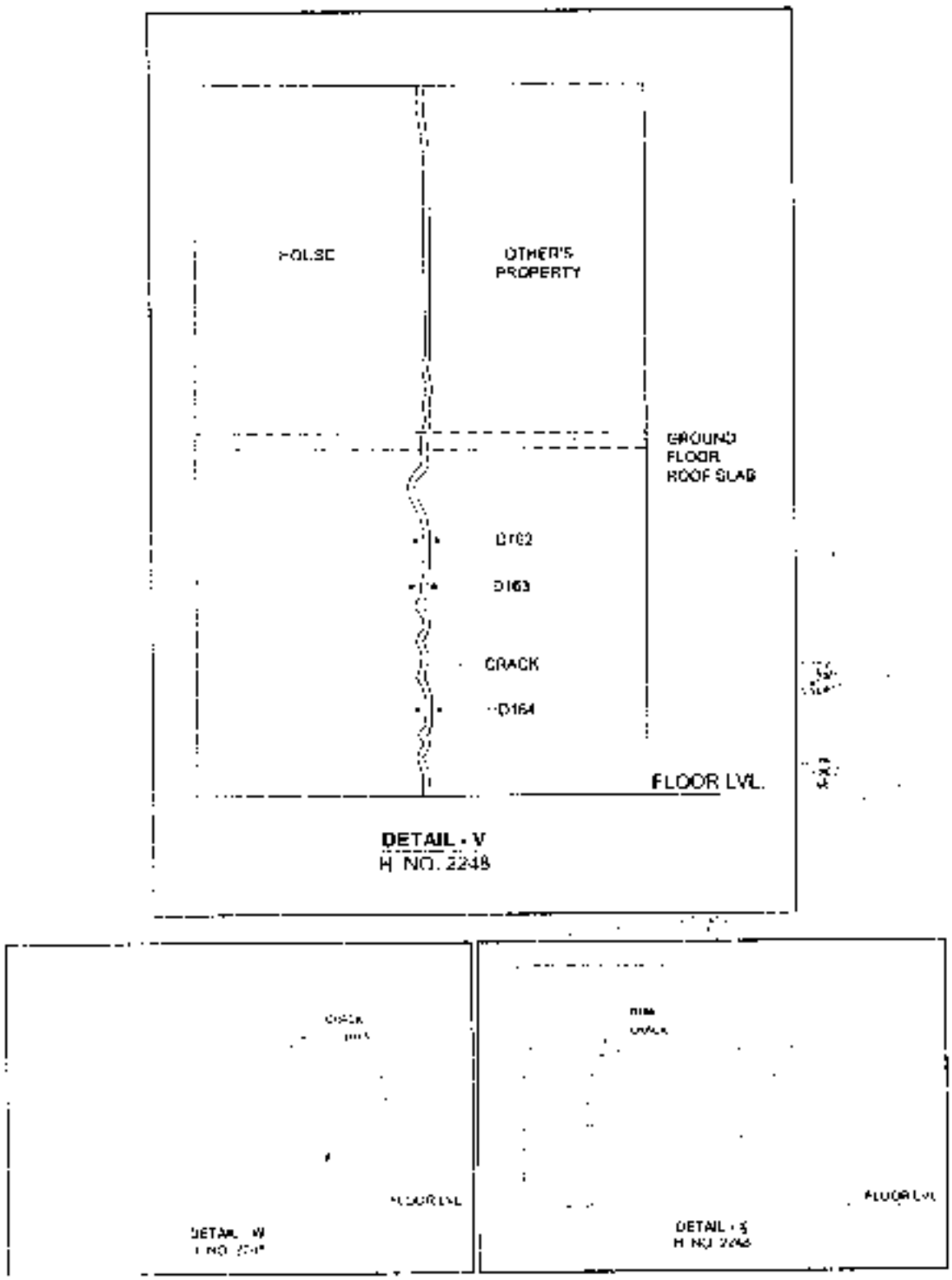
CSIR-Roorkee

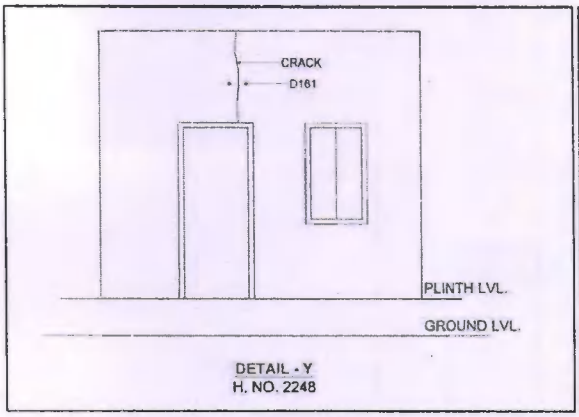
B7. House no. 2248



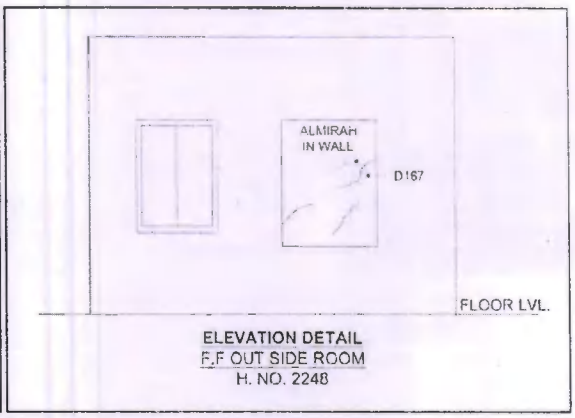


CSIR Tandem


HOUSE
OTHER'S PROPERTY
GROUND FLOOR ROOF SLAB
D162
D163
CRACK
D164
FLOOR LVL.
DETAIL - V
H. NO. 2248
FLOOR LVL
DETAIL - W
FLOOR LVL
DETAIL - S
H. NO. 2248



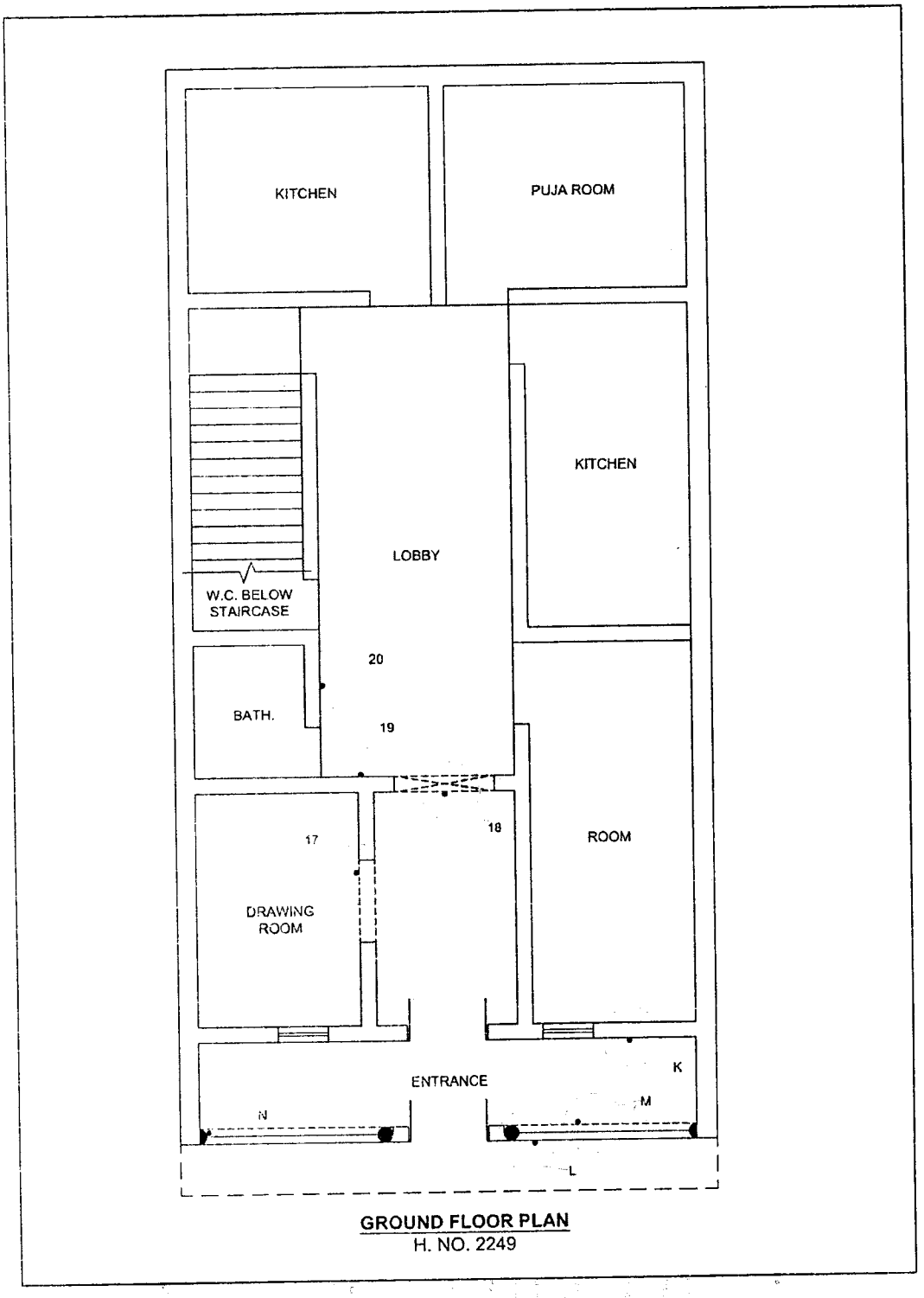
DETAIL - Y
H. NO. 2248



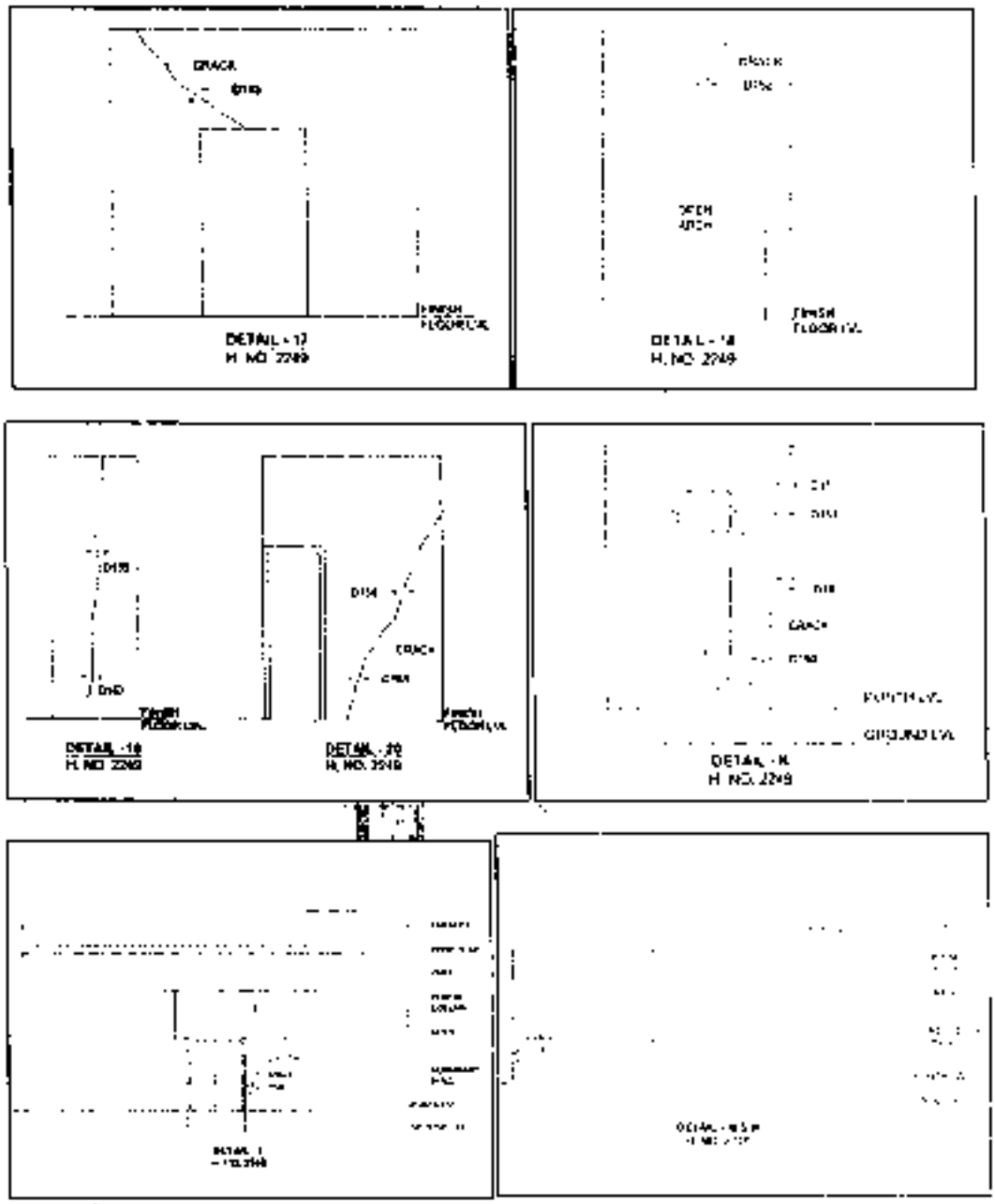
ELEVATION DETAIL
F.F OUT SIDE ROOM
H. NO. 2248

CSIR Touching Lives

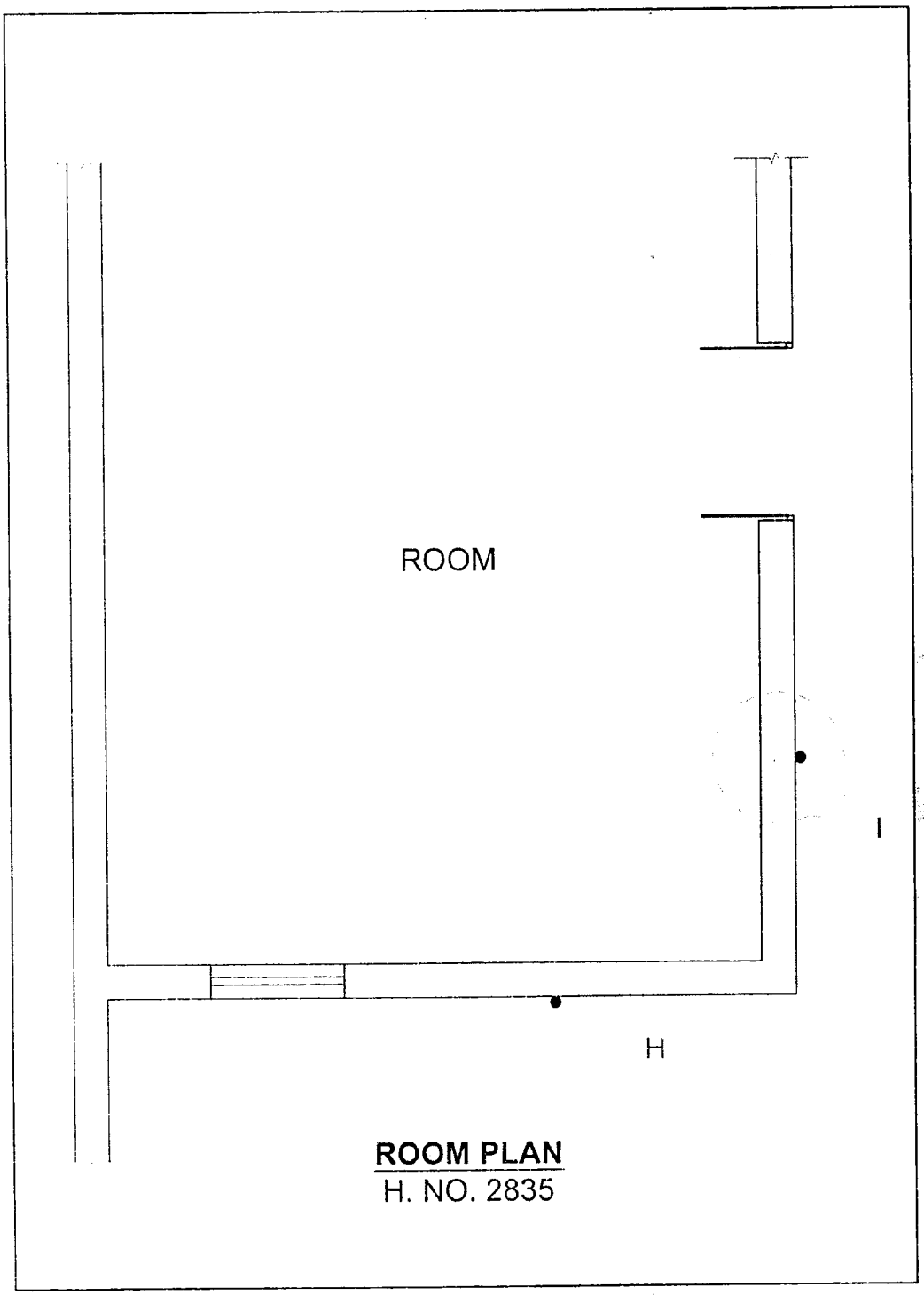
B8. House no. 2249

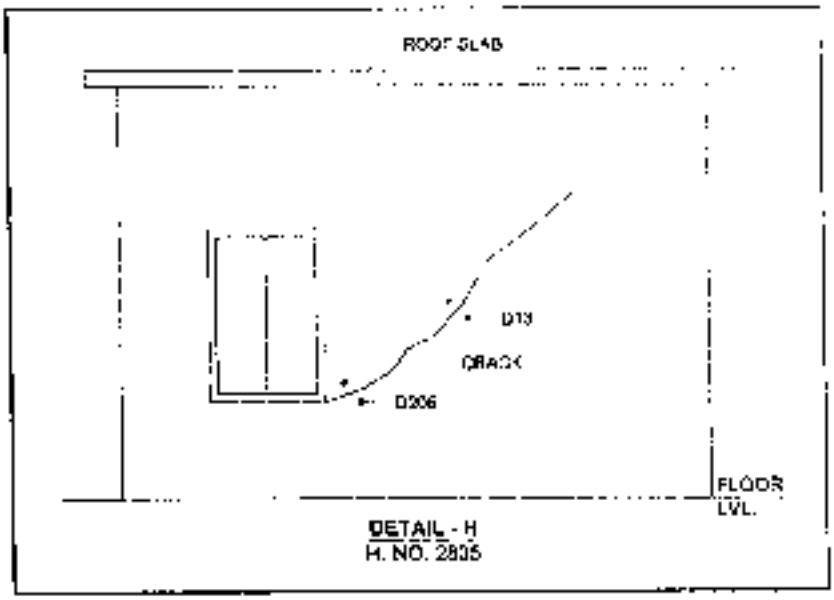


GROUND FLOOR PLAN
H. NO. 2249

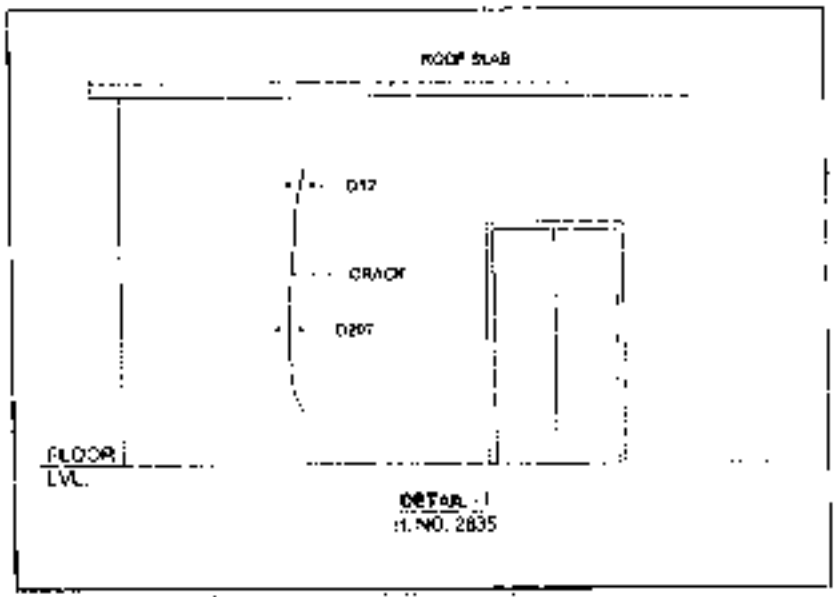

CRACK
DETAIL - 17
H. NO. 2249
DETAIL - 18
H. NO. 2249
DETAIL - 19
H. NO. 2249
DETAIL - 20
H. NO. 2249
DETAIL - K
H. NO. 2249

B9. House no. 2835



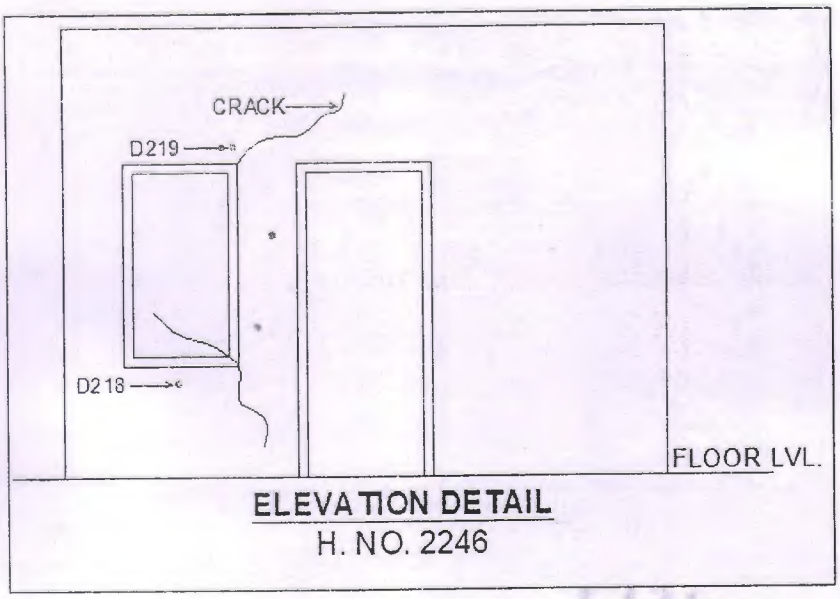


DETAIL - H
H. NO. 2835

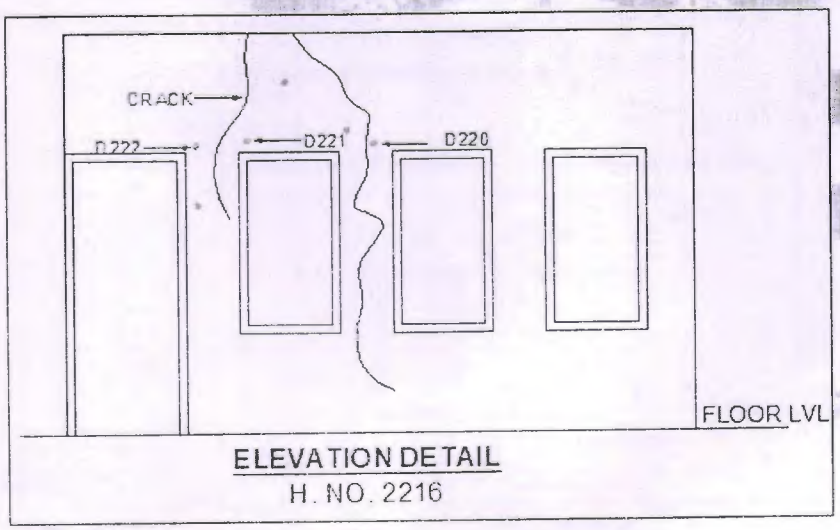


DETAIL - I
H. NO. 2835

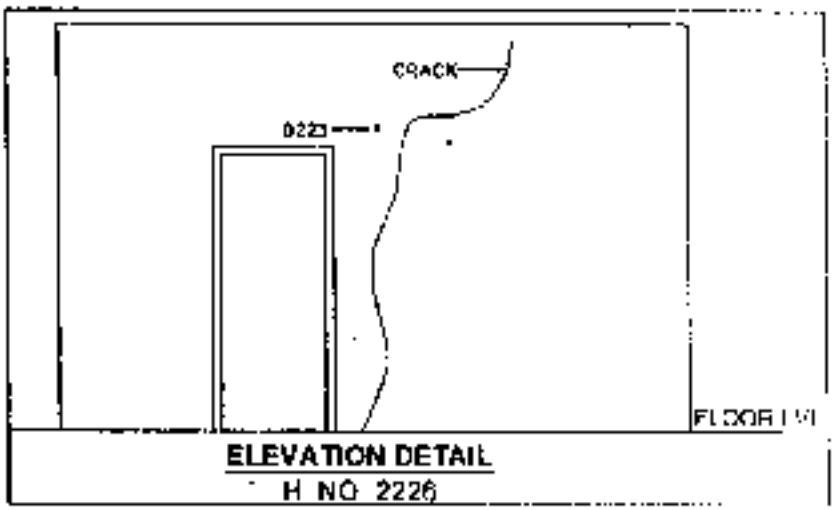
B10. House no. 2246



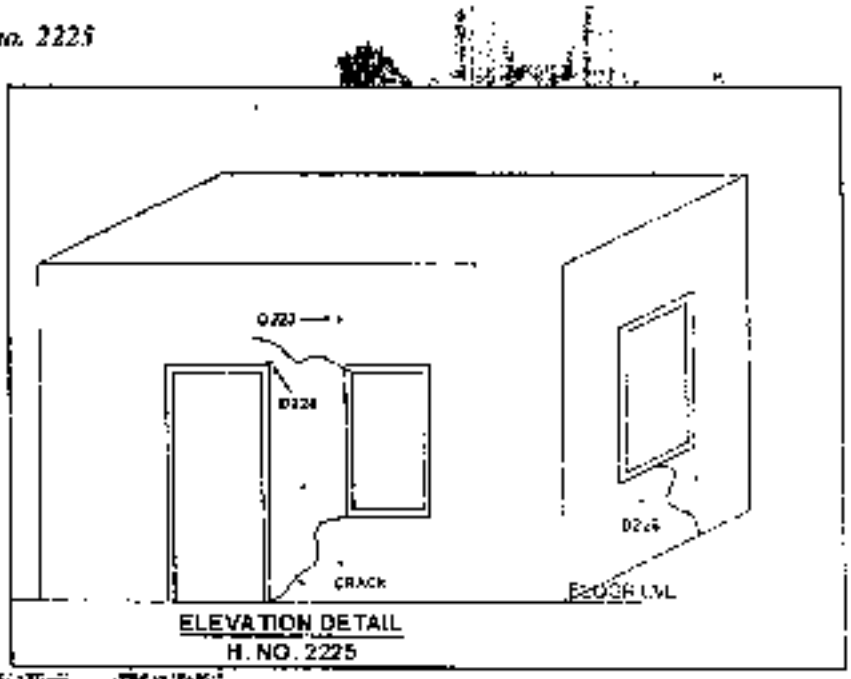
B11. House no. 2216



B12. House no. 2226

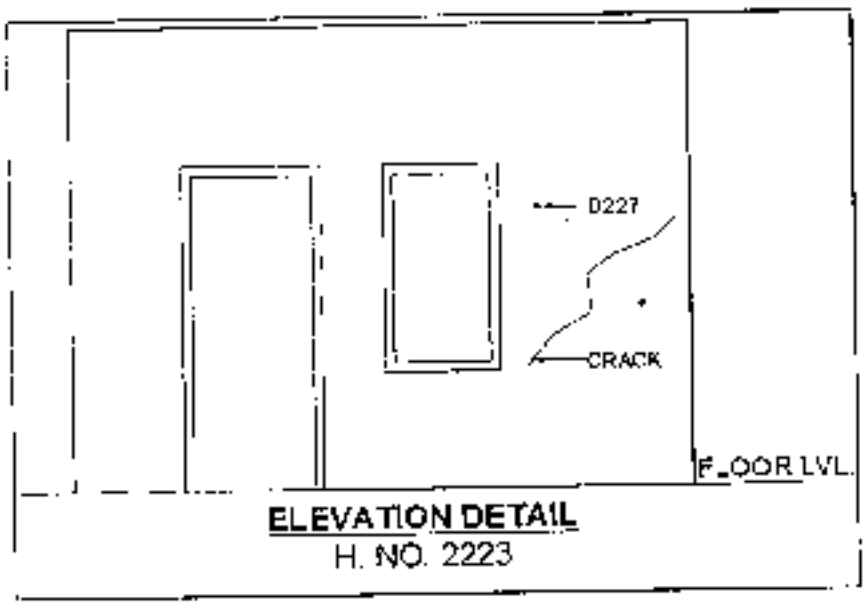


B13. House no. 2225

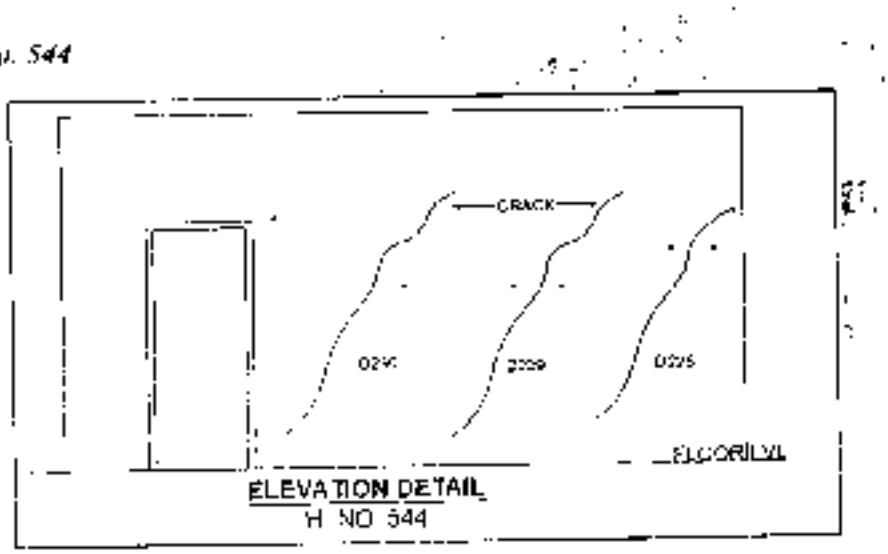


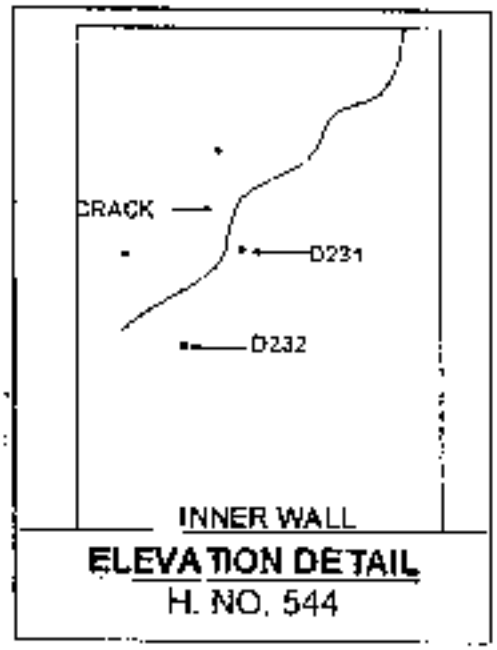
CSIR Tejpur

B14. House no. 2223

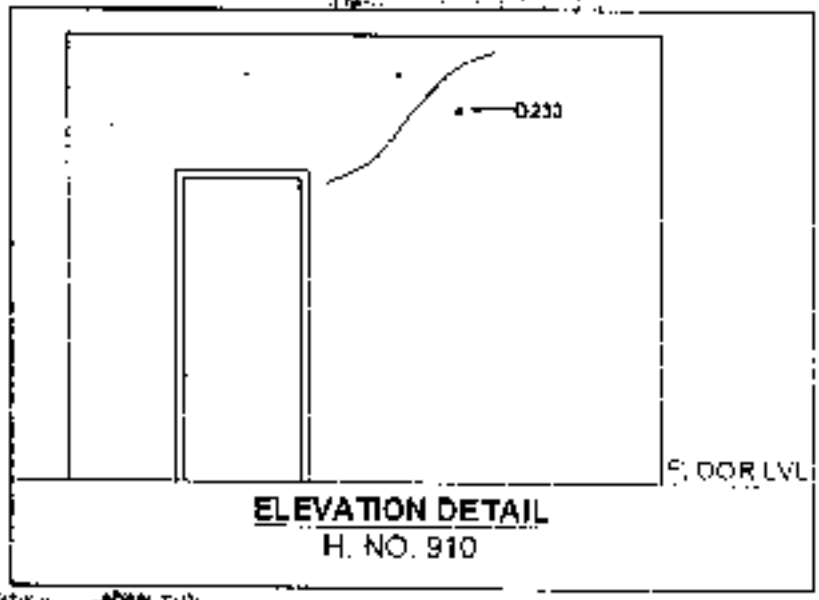


B15. House no. 544

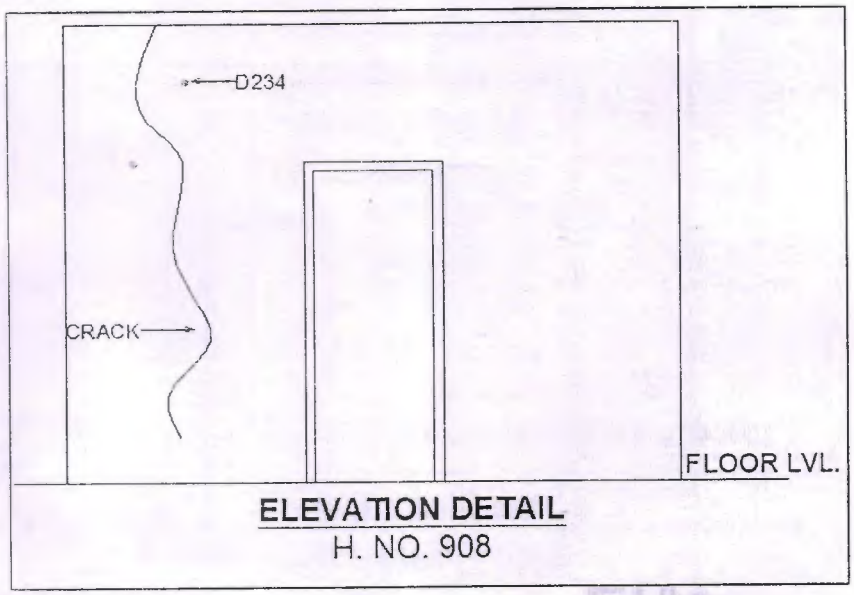




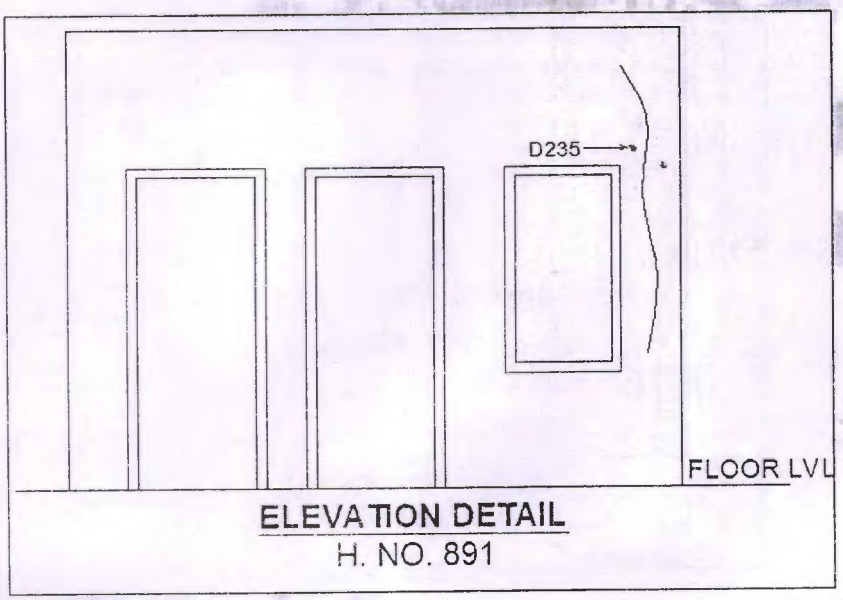
B16. House no. 910



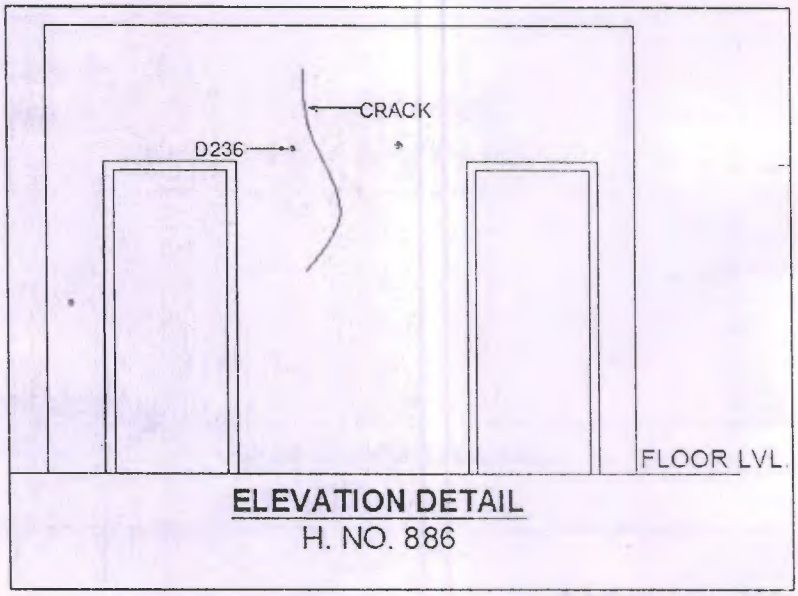
B17. House no. 908



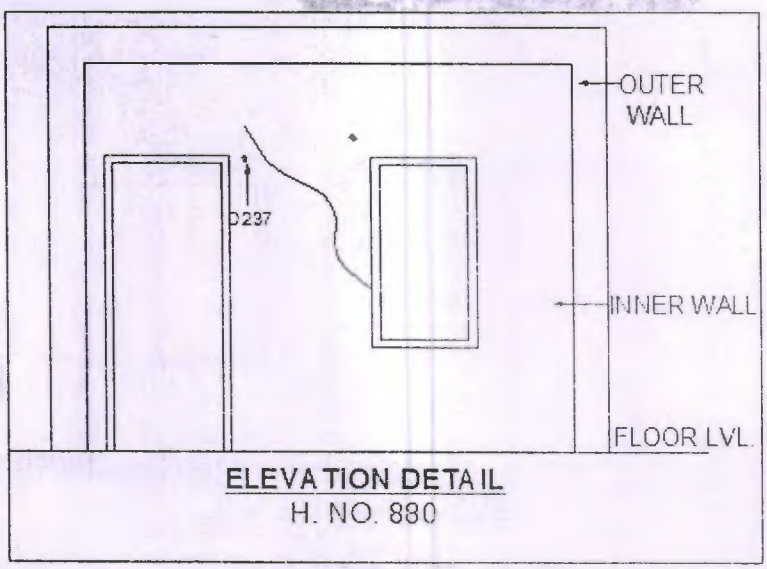
B18. House no. 891



B19. House no. 886

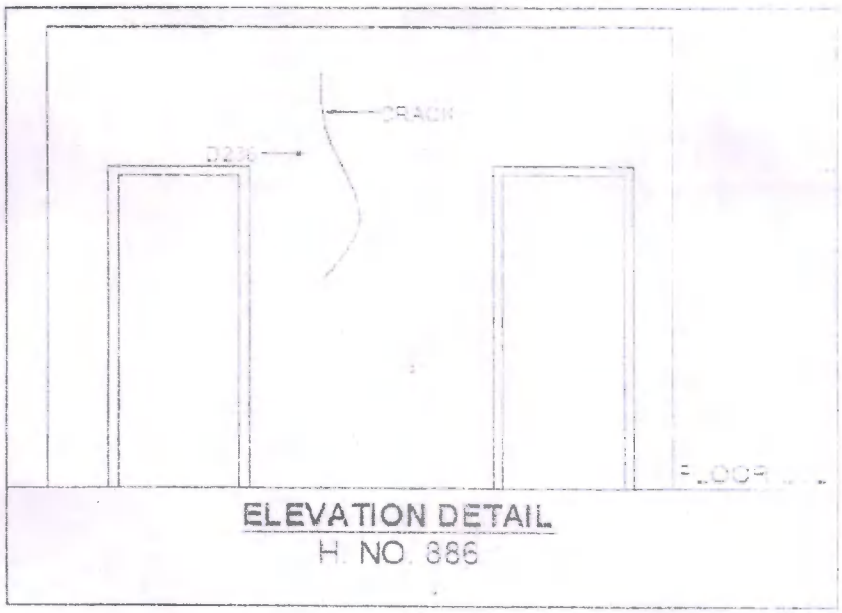


B20. House no. 880

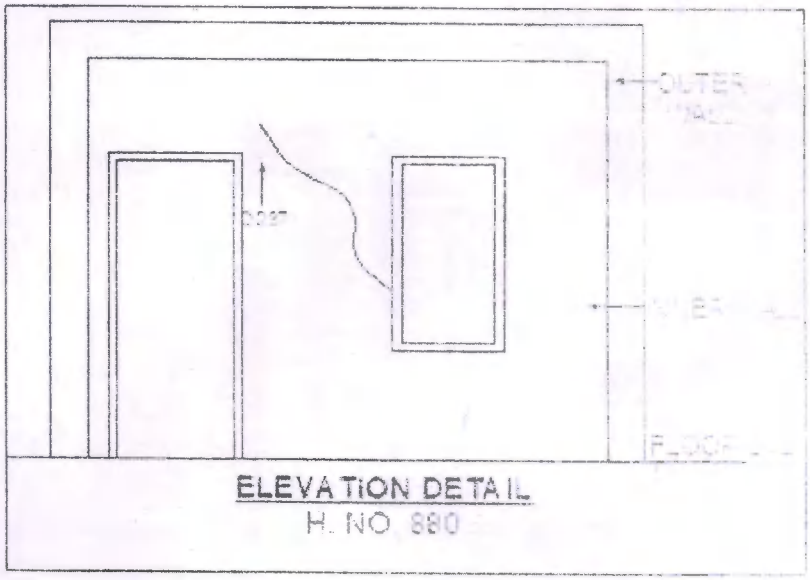


CSIR Touching Lives

B19. House no. 886



B20. House no. 880



REGIONAL OFFICE
RAJASTHAN STATE POLLUTION CONTROL BOARD
18,Near Pannadhaya Circle,Azad Nagar,Bhilwara
Phone : 01482-241159; Email ID:-rorpcb.bhilwara@gmail.com

IV. Report on Studies to investigate the Reasons for Cracks Development in Buildings of Pur Village, Bhilwara, Rajasthan by_CSIR-Central Building Research Institute Roorkee – 247667 Uttarakhand. (Enclosed herewith as **Annexure-D)**

Therefore, reports mentioned above are enclosed herewith and submitted for kind perusal.

Encl: As above.

Yours Sincerely,

(Mahaveer Mehta)
Regional Officer,
RSPCB,Bhilwara

Copy to followings for information:

1. District Collector, Bhilwara in compliance your office letter no.25258 dated 24.12.2020.
2. SDM and Nodal Officer (OA 288/2019),Bhilwara,
3. In charge Legal Cell , RSPCB, Jaipur.

Regional Officer,
RSPCB,Bhilwara

Annexure. C
Draft (1)

REGIONAL OFFICE
RAJASTHAN STATE POLLUTION CONTROL BOARD

18,Near Pannadhaya Circle,Azad Nagar,Bhilwara
Phone : 01482-241159; Email ID:-rorpcb.bhilwara@gmail.com

(Draft Letter)

No. RPCB/RO/BHL/NGT(2019)/L-4/ **Dated :**

Urgent/NGT Matter(O.A. No. 288/2019)
Date of Next Hearing-12.02.2021.

(Through Post/Email)

To,
The Registrar,
National Green Tribunal,
Principal Bench, New Delhi
(Email:-judicial-ngt@gov.in)

Subject:-.Regarding Compliance of directions passed by Hon'ble N.G.T.,Principal Bench,New Delhi in O.A. No. 288/2019, titled as Shri Balkrishan Vyas V/s State of Raj & Others.

Ref:- 1. Hon'ble N.G.T.,Principal Bench,New Delhi's order sheet dated 12.10.2020.
2. Office of the District Collector,Bhilwara's letter no. Nyay/2020/25258,dated 24.12.20.

Sir,

Apropos above, in compliance of directions passed by Hon'ble N.G.T.,Principal Bench,New Delhi, it is submitted that :-

1. Hon'ble N.G.T.,Principal Bench, New Delhi has passed directions in O.A. No. 288/2019, titled as Shri Balkrishan Vyas V/s State of Raj & Others vide order sheet dated 12.10.2020 , interalia reproduced as follows:-

   Accordingly, we grant time for submitting final report by 31.01.2021 by e-mail at judicial-ngt@gov.in preferably in the form of searchable PDF/ OCR Support PDF and not in the form of Image PDF.

2. In compliance of above stated directions, reports have been received from esteemed institutions detailed as :-

I. Consolidated executive summary submitted by Dr. Brijesh K.Yadav,Assosiate Professor ,Dept. of Hydrology ,IIT Roorkee (U.K.),Dr. Harsh Kumar Verma, Sr. Principal Sci. & Head of the section, Mining Science Research group,CSIR-Regional Research Centre CIMFR,Bilaspur (C.G.) and Prof. S.K.Singh , Sr. Principal Sci. & Head of the section, PPC group , CSIR-CBRI, Roorkee (U.K.)- (Enclosed herewith as **Annexure-A.)**

II. Report on Hydro-Geological Study of Pur Village Area, Bhilwara, Rajasthan by Dr. B.K. Yadav and Team,Indian Institute of Technology Roorkee(U.K.)- (Enclosed herewith as **Annexure-B.)**

III. Report on Scientific Studies on Blast Induced Ground Vibration & Air Overpressure and Investigation on its Damage Potential vis-à-vis Housing Structures in Pur Village, Bhilwara, Rajasthan by Central Institute of mining & fuel research (Council of Scientific and Industrial Research, New Delhi, Govt. of India) Regional Research Centre, Bilaspur (CG) 495001 (Enclosed herewith as **Annexure-C.)**