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IIT Indore

From,

Dr. Neelima Satyam

Professor

Department of Civil Engineering

Indian Institute of Technology Indore

28<sup>th</sup> February, 2024

To,

The Superintending Engineer (Civil)

STPS, MPPGCL,

Sarni

Sub: stability report of ash dykes named as 130-hectare ash dykes at Satpura Thermal Power Station, MPPGCL, Sarni (District -Betul) M.P.

Dear Sir,

This letter is to proceed with the submission of recommendations for stability analysis of 2 ash ponds for a 130-hectare site, Satpura Thermal Power Station, MPPGCL, Sarni. The existing ash dykes are used for HCS and bottom ash disposal, and as per the request the site has been visited by Professor Neelima Satyam, IIT Indore on 10<sup>th</sup> April 2025. The findings from field inspection and design and drawing for the embankment are provided in the report. Please find the attached report and make sure that quality is maintained during the execution of work as per the recommendations.

Regards,

*Neelima Satyam*  
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Professor  
Department of Civil Engineering  
Indian Institute of Technology Indore  
Simrol, Indore 453 552, India

(Prof. Neelima Satyam)

**Report on**  
**Inspection of Ash Dyke on 130 hec land**  
**at Satpura Thermal Power Station,**  
**MPPGCL, Sarni**

By  
Prof. Neelima Satyam  
Department of Civil Engineering  
Indian Institute of Technology Indore  
Simrol, Indore – 453552 M.P

## **Introduction**

The Satpura Thermal Power Station (STPS) is located at Sarni town near Ghoradongri railway station in the Betul district of Madhya Pradesh, India. The power plant is one of the coal-based power plants of MPPGCL with an installed capacity of 1330 MW. The Water for the plant has been procured from the nearby Satpura Dam Reservoir and the coal for the plant has been procured by Rail/Road/Belt from Western Coal Field Limited (WCL).

The power plant has recently extended an ash pond dyke of 130 hectares. The Ash Dyke being used for storage of pond ash was analyzed (Fig 1-3).

As per the request from the Superintending Engineer STPS Sarni, Prof Neelima Satyam, IIT Indore visited the site for a field survey on 10/04/2025 (Fig. 4) and investigated the ash dykes at the 130-hectare area of STPS, MPPGCL, Sarni in District-Betul (M.P.). Later after slope stability analysis, it was observed that the bund in the downstream/upstream slope was in stable condition in all critical conditions. After a detailed analysis of the Pond cross-section of STPS Sarni and slope stability analysis of the existing ash dyke considering seepage, conclusions are provided for further scope of improvement.



*Fig 1: Starter dyke for fly ash pond at 130 hec area*



*Fig 2: Starter dyke for bottom ash pond*



*Fig. 3: Toe rock and drain configuration for seepage exit*



*Fig 4: Reconnaissance survey of IIT Indore and STPS officials at 130 hec site*

## **Scope**

- ✓ Checking of structural safety, and stability of the ash dyke in respect of technical soundness, structural strength, and safety.
- ✓ Physical visit at site Sarni.
- ✓ Any other test required to ascertain the above.

**Boundary Conditions:** The upstream and downstream water levels and drainage conditions were taken as the hydraulic boundary conditions. The boundary conditions were varied as per the requirement of the analysis.

**Design Conditions:**

As per IS 7894:1975, the following cases are critical for the stability of the earthen dam.

1. Construction condition (u/s slope and d/s slope)- This condition was not checked as the dyke was raised already.
2. Reservoir pool level (u/s slope)- This condition was not checked as construction of dyke was already done.
3. Sudden drawdown (u/s slope)- Stability was checked for this condition
4. Steady Seepage (d/s slope)- Stability was checked for this condition

5. Rainfall- This condition was not checked as annual rainfall in Betul District was below the threshold level to be considered in the IS code.
6. Earthquake condition (u/s and d/s slope)- Stability was checked considering horizontal peak ground acceleration as 0.1g since Betul falls in Zone-2 as per IS 1893:2016.

## 1. Design Details for Fly ash dyke

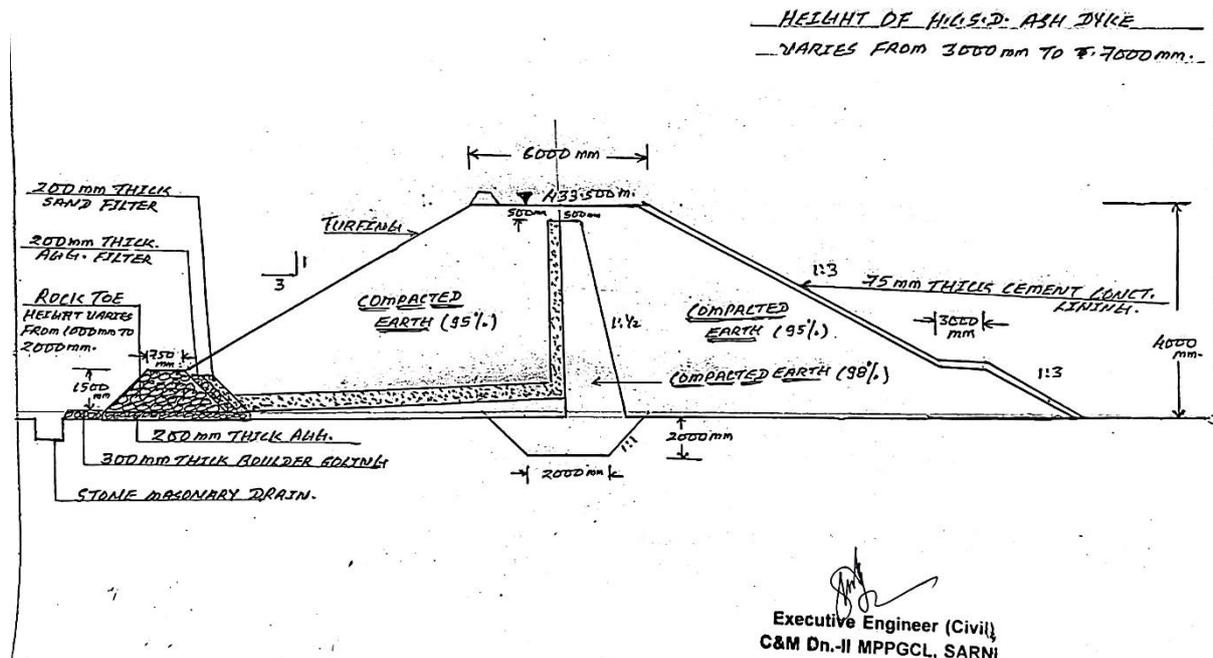


Fig 5: typical cross-section of fly ash dyke at STPS

Table 1: Data considered from CAD design provided by the client

Location	Satpura Thermal Power Station - Power station Sarni, Madhya Pradesh 460447
Gross area	130 hectares (1.30 km <sup>2</sup> )
Latitude	22° 6'3.25"N
Longitude	78° 8'23.02"E
Min. ground level	429m
T.B.L.	433m
F.S.L.	432m
Width of berm	6m
Height of starter dyke	4m

Table 2: Geotechnical properties of materials considered for analysis

Material	Bulk Density (kN/m <sup>3</sup> )	Saturated Density (kg/m <sup>3</sup> )	Cohesion- (kPa)	Angle of Internal friction- <sup>o</sup>	Legend
Dam	18.7		19	22	
Aggregate filter	24		20	10	
Sand filter	18		0.1	35	
Clayey ore	18		20	5	
Cement concrete lining	24		10	10	
Rock toe	30		20	10	

The slope stability analysis for all the conditions has been done by Bishop simplified method, Morgenstern- price method, and Janbu Method which are considered one of the most accurate methods for stability analysis of embankments (Fig. 6-10).

Below mentioned are the results of the analysis carried out for the stability check of the fly ash dyke cross-section compartments of STPS Sarni. The geotechnical properties of Dam material was determined in IIT Indore on the soil sample shared by the client during the visit. Remaining properties were considered based on the previous reports. The FoS obtained after different analyses are listed in Table 3. The comparison with the least factor of safety as per IS code and obtained is mentioned in Table 4.

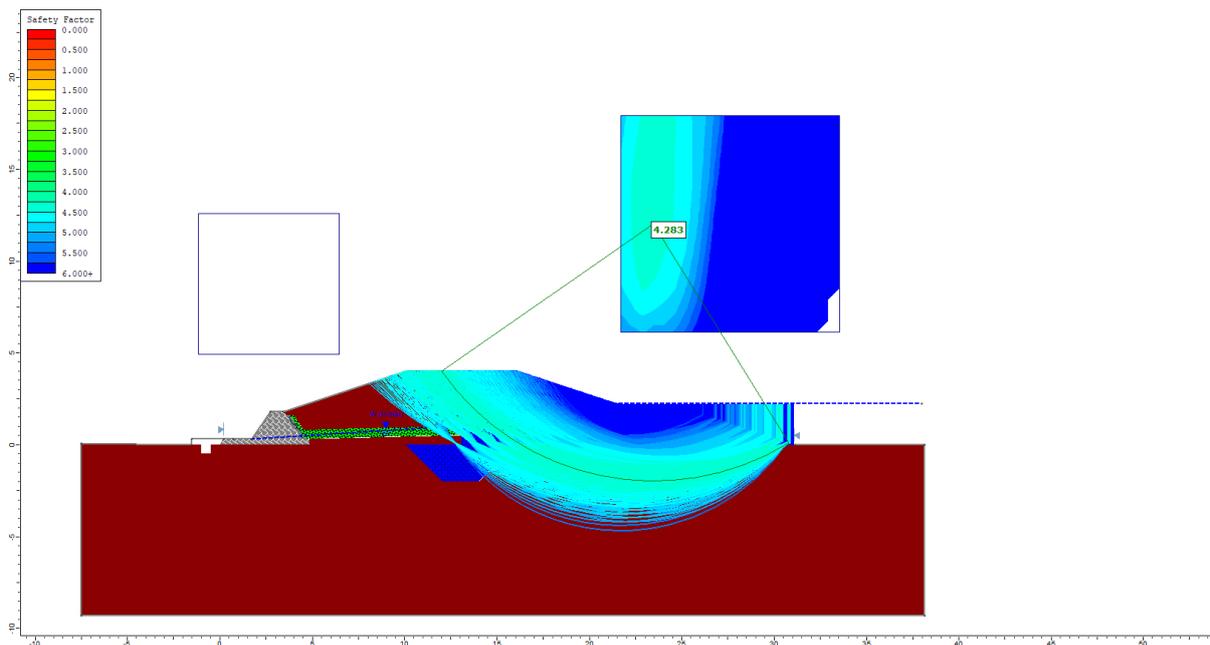


Fig 6: Minimum FOS obtained for sudden draw down at upstream

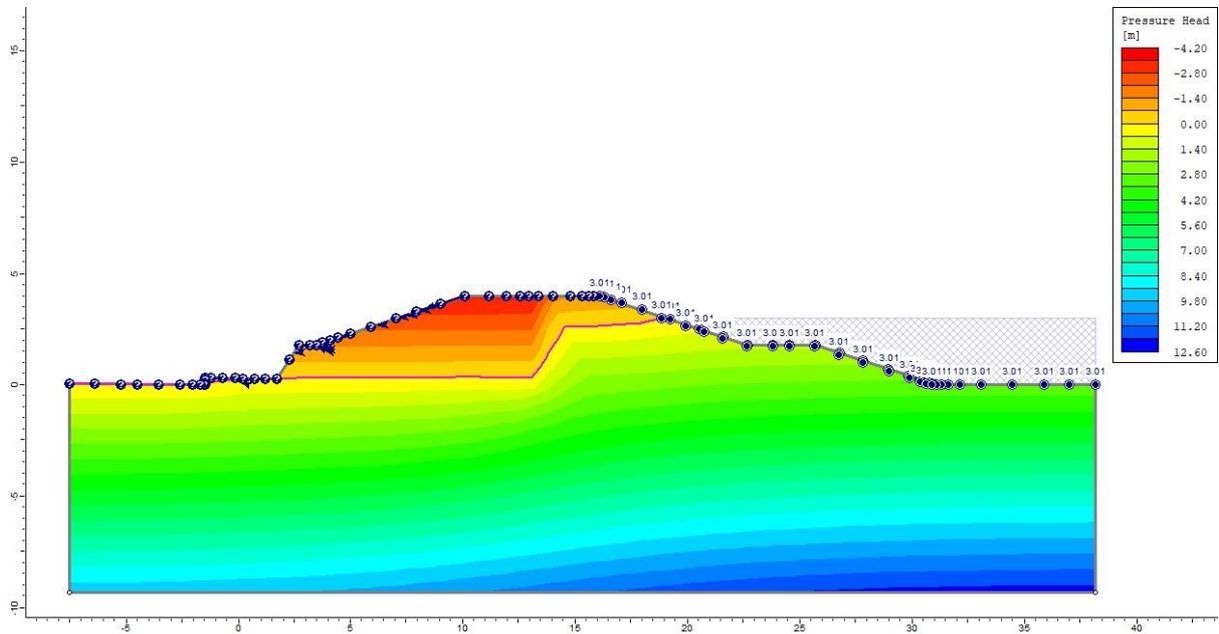


Fig 7: Total Pressure head distribution in steady seepage condition

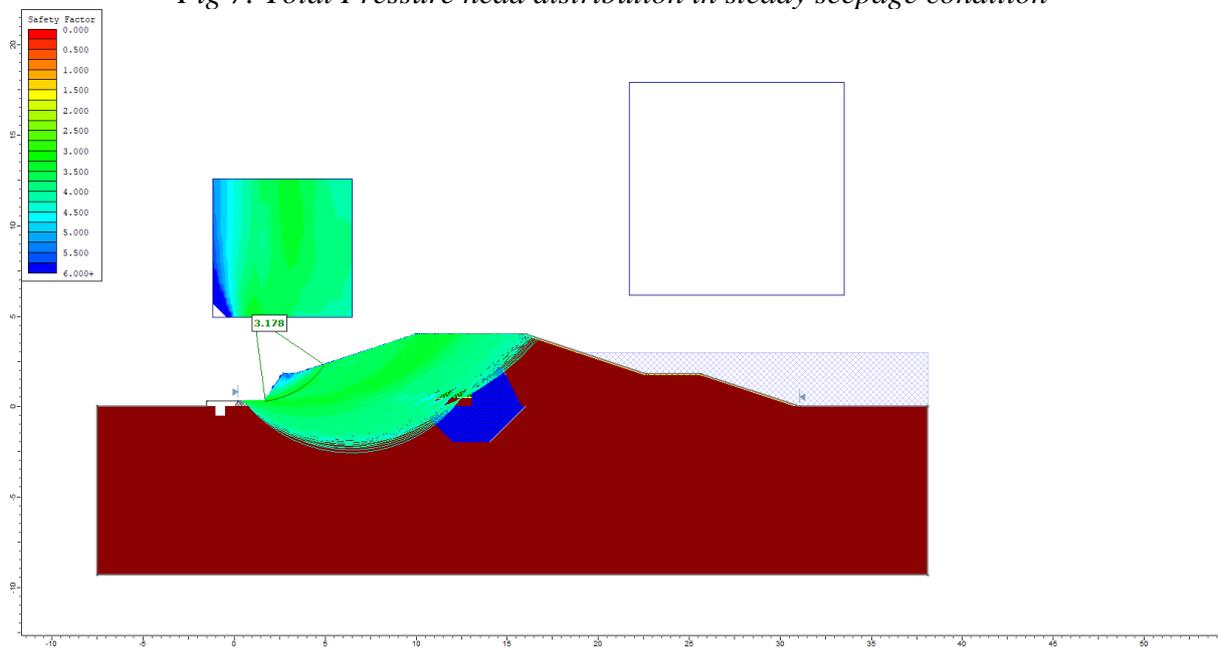
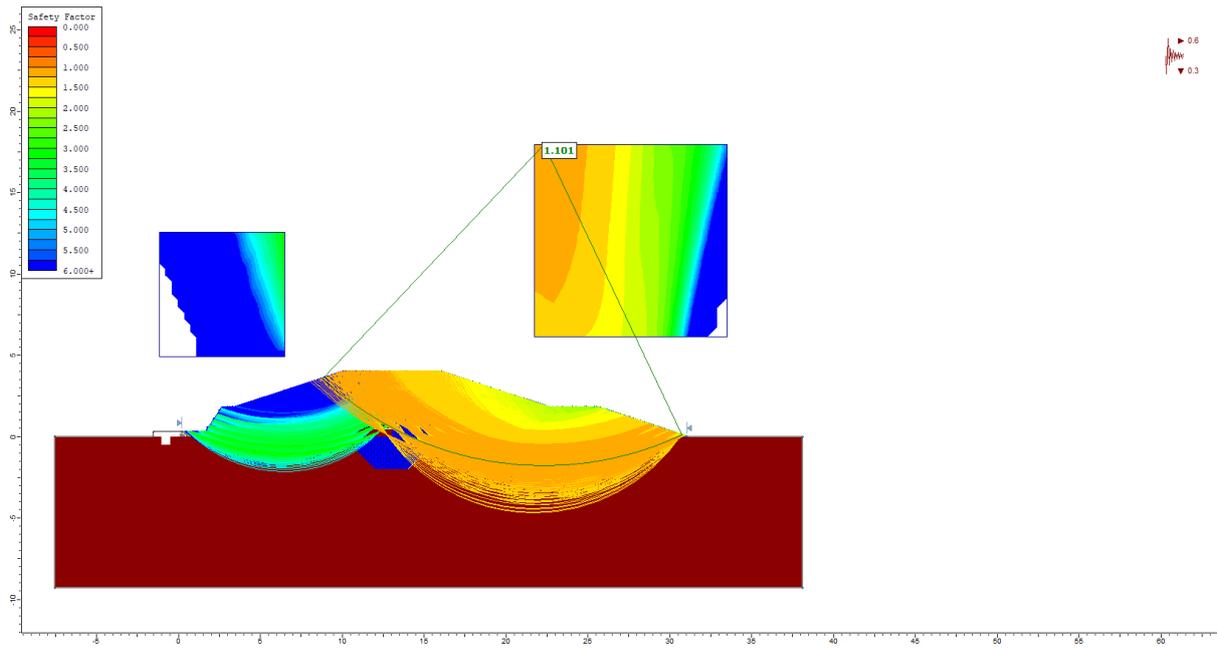
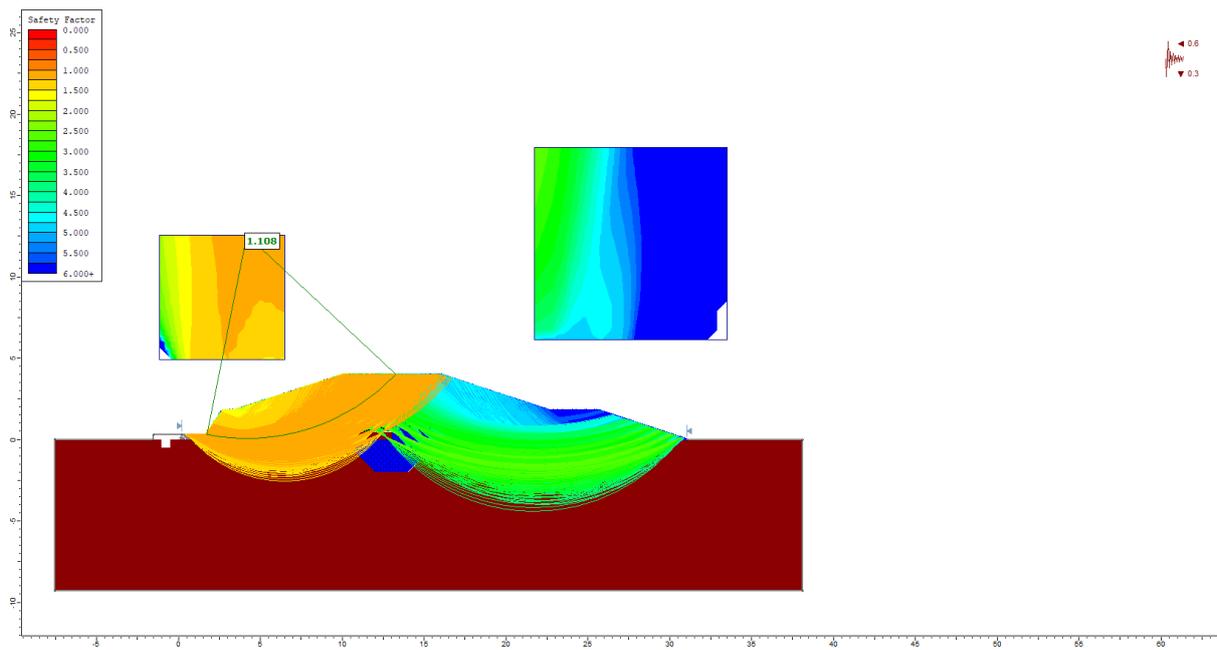


Fig 8: Minimum FOS obtained for steady seepage condition downstream.



*Fig 9: Minimum FOS obtained for Earthquake conditions upstream.*



*Fig 10: Minimum FOS obtained for Earthquake condition downstream.*

Table 3: Results of slope stability analysis for the fly ash dyke cross-section

S. No.	Seepage	Critical slope	Type of Analysis	FOS
1	Sudden drawdown	Upstream	Janbu	4.42
2			Bishop	4.30
3			Morgenstern- price	4.283
1	Steady seepage	Downstream	Janbu	3.50
2			Bishop	3.23
			Morgenstern- price	3.178
1	Rainfall	As per the last ten years' annual rainfall data of Betul District, the average rainfall is less than the required rainfall for slope stability analysis in rainfall condition. <a href="http://mpwrdd.gov.in/tapti-basin/">http://mpwrdd.gov.in/tapti-basin/</a>		
1	Earthquake	Downstream	Janbu	1.10
2			Bishop	1.11
3			Morgenstern- price	1.108
1	Earthquake	Upstream	Janbu	1.05
2			Bishop	1.05
3			Morgenstern- price	1.101

Table 4: Comparison of obtained FOS and required FOS

Sl. No.	Seepage	Critical slope	Min. FOS obtained	Min. FOS required
1	Sudden drawdown	Upstream	<b>4.283</b>	<b>1.3</b>
2	Steady seepage	Downstream	<b>3.178</b>	<b>1.50</b>
3	Rainfall Induced		---	
4	Earthquake	Downstream	<b>1.108</b>	<b>1</b>
5	Earthquake	Upstream	<b>1.101</b>	<b>1</b>

## 2. Design Details for bottom ash dyke

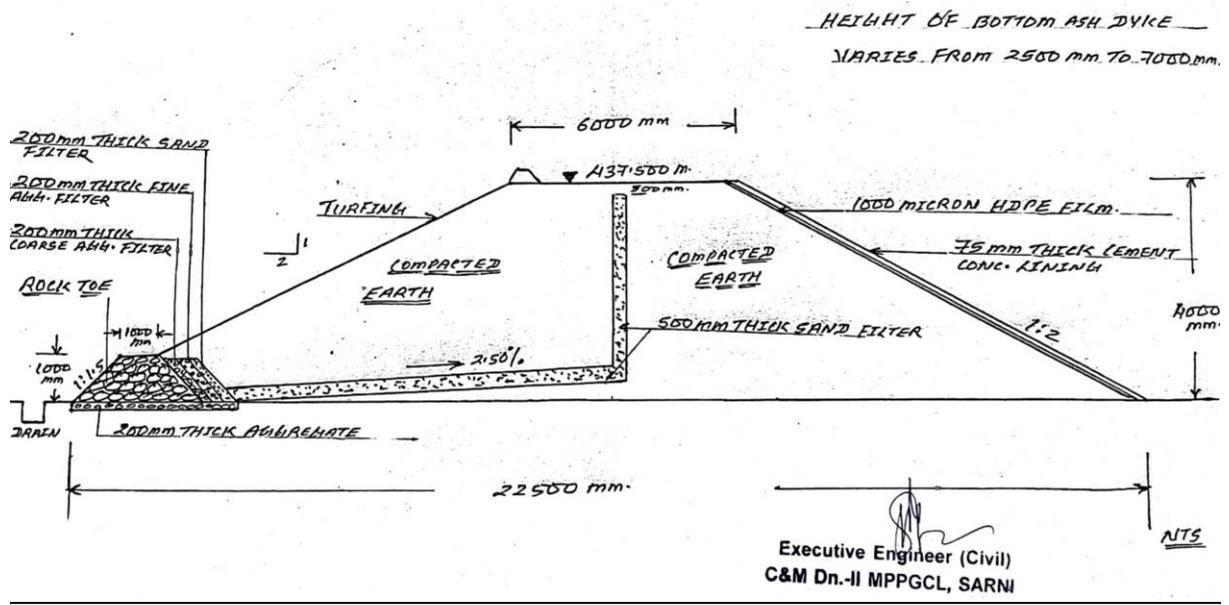


Fig 11: typical cross section of bottom ash dyke at STPS

Table 5: Data considered from CAD design provided by the client

Location	<b>Satpura Thermal Power Station - Power station</b> Sarni, Madhya Pradesh 460447
Gross area	130 hectares (1.30 km <sup>2</sup> )
Latitude	22° 6'3.25"N
Longitude	78° 8'23.02"E
Min. ground level	433m
T.B.L.	437m
F.S.L.	436m
Width of berm	6m
Height of starter dyke	4m

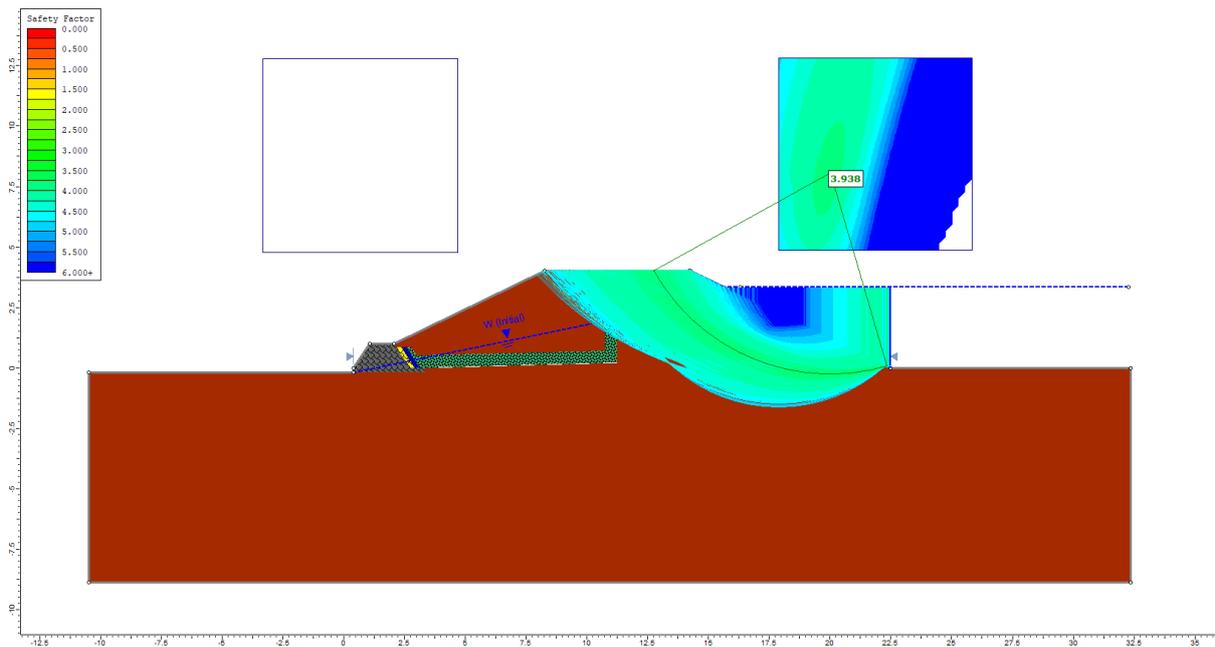
Table 6: Geotechnical properties of materials considered for analysis

Material	Bulk Density (kN/m <sup>3</sup> )	Saturated Density (kg/m <sup>3</sup> )	Cohesion- (kPa)	Angle of Internal friction-°	Legend
Dam	18.7		18	35	
Coarse aggregate filter	24		5	30	
Sand drain	18		0.1	35	

Fine aggregate filter	18		20	5	
Cement concrete lining	24		20	10	
Rock toe	20		20	10	
HDPE lining	0.1		20	1	

The geotechnical properties of the material used in the bottom ash dyke were provided by the client (i.e. STPS) after sample collection from 5 random sites. The slope stability analysis for all the conditions has been done by Bishop simplified method, Morgenstern-Price method, and Janbu Method which are considered one of the most accurate methods for stability analysis of embankments (Fig. 12-16).

Below mentioned are the results of the analysis carried out for the stability check of the fly ash dyke cross-section compartments of STPS Sarni. The FoS obtained after different analyses are listed in Table 7. The comparison with the least factor of safety as per IS code and obtained is mentioned in Table 8.



*Fig 12: Minimum FOS obtained for sudden draw down at upstream.*

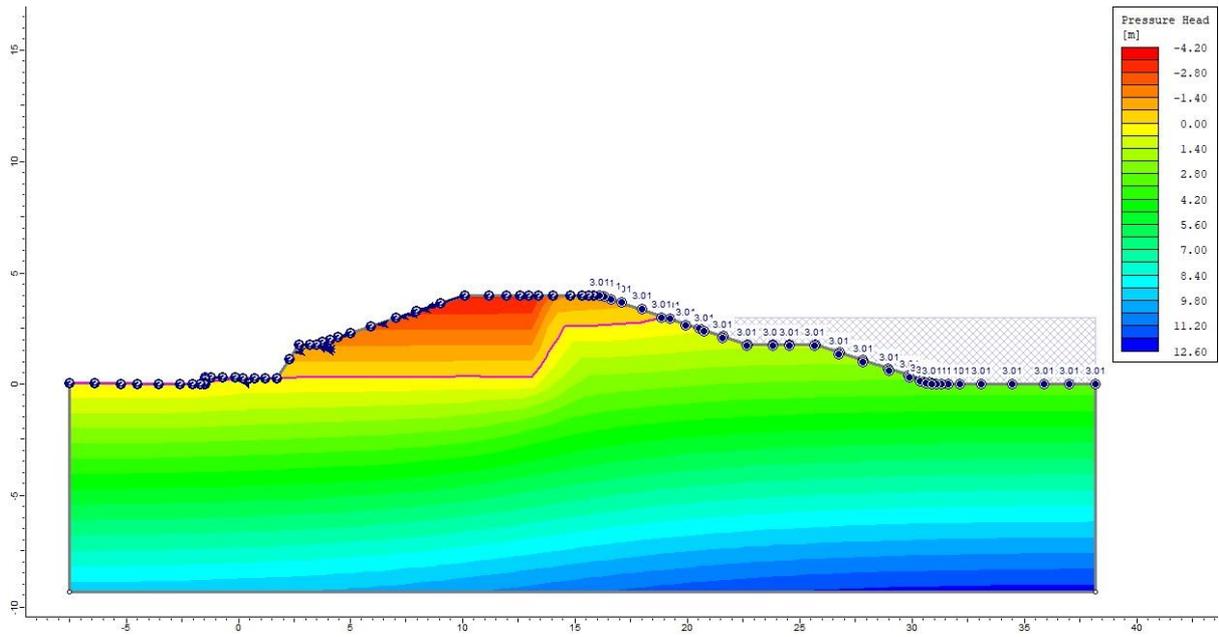


Fig 13: Total Pressure head distribution in steady seepage condition

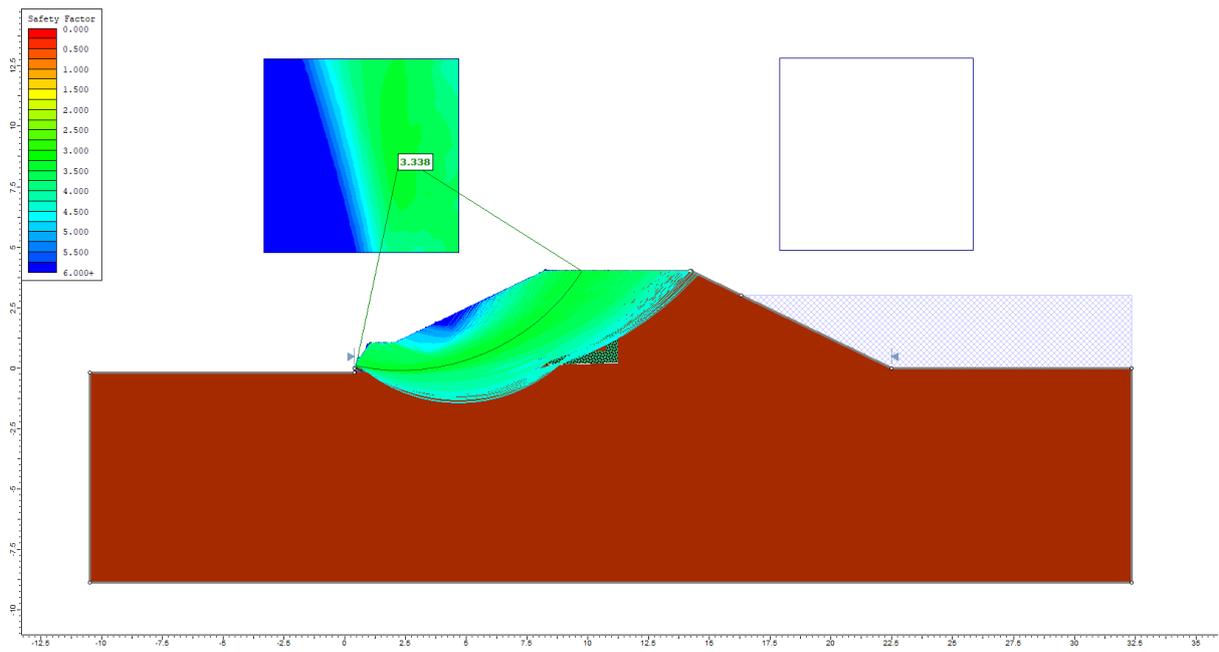


Fig 14 : Minimum FOS obtained for steady seepage condition at downstream.

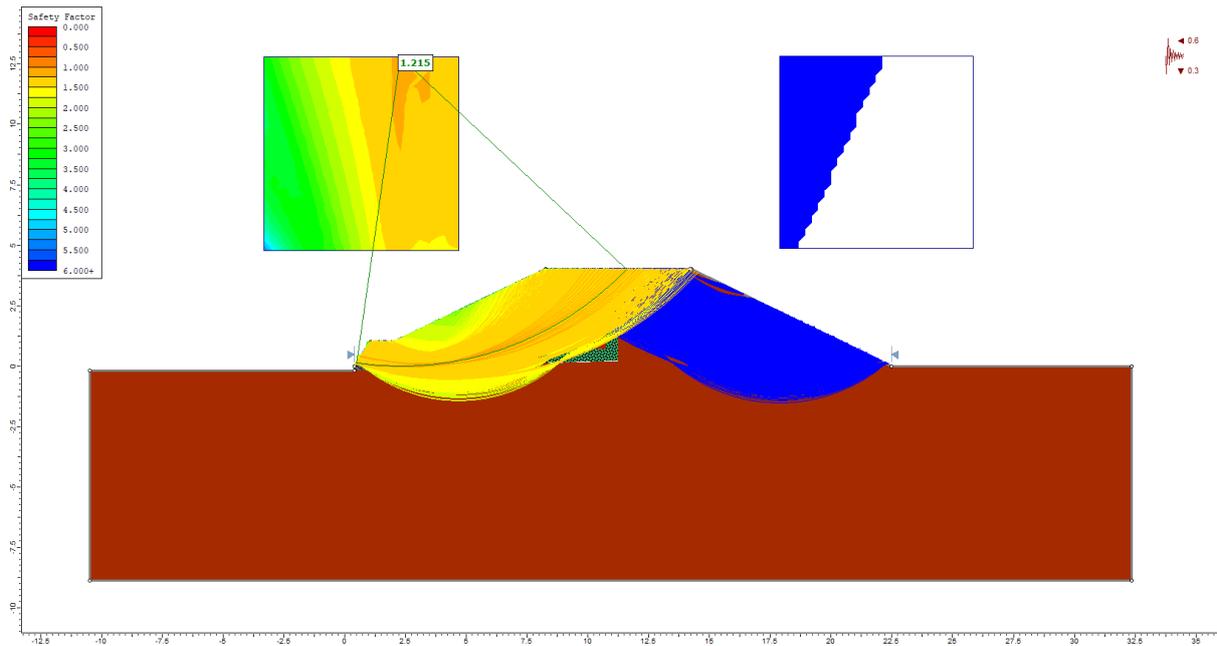


Fig 15 : Minimum FOS obtained for Earthquake condition at downstream.

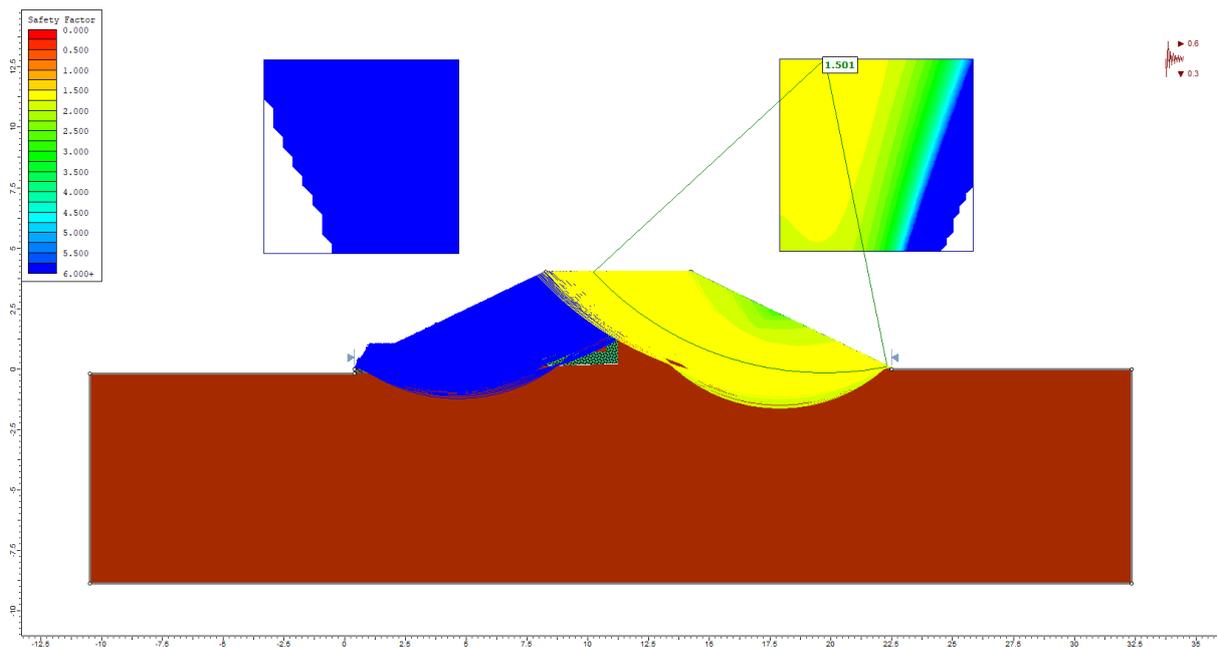


Fig 16 : Minimum FOS obtained for Earthquake condition at upstream.

Table 7: Results of slope stability analysis for the top ash dyke pond cross-section

Sl. No.	Seepage	Critical slope	Type of Analysis	FOS
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1	Sudden draw down	Upstream	Janbu	4.025
2			Bishop	3.955
3			Morgenstern- price	<b>3.938</b>
1	Steady seepage	Downstream	Janbu	3.560
2			Bishop	3.450
			Morgenstern- price	<b>3.338</b>
1	Rainfall	As per last five years annual rainfall data of Betul District, the average rainfall is which is less than the required rainfall for slope stability analysis. <a href="http://mpwrd.gov.in/tapti-basin/">http://mpwrd.gov.in/tapti-basin/</a>		
1	Earthquake	Downstream	Janbu	1.300
2			Bishop	1.300
3			Morgenstern- price	<b>1.215</b>
1	Earthquake	Upstream	Janbu	1.600
2			Bishop	1.525
3			Morgenstern- price	<b>1.501</b>

*Table 8: Comparison of obtained FOS and required FOS*

Sl. No.	Condition	Critical slope	Min. FOS obtained	Min. FOS required
1	Sudden drawdown	Upstream	<b>3.938</b>	<b>1.3</b>
2	Steady seepage	Downstream	<b>3.338</b>	<b>1.50</b>
3	Rainfall Induced		---	
4	Earthquake	Downstream	<b>1.215</b>	<b>1</b>
5	Earthquake	Upstream	<b>1.501</b>	<b>1</b>

### **Inferences from site inspection and slope stability analysis**

- No new gully formations or seepage was observed during the field visit. Prima facie dykes are properly maintained and area 130 hec was inspected for stability analysis.
- All the obtained FOS were above the permissible limit of minimum FOS as per IS 7894:1975 for both embankments.

- Seepage analysis for steady and sudden drawdown conditions indicates water will drain out in 12 hours considering the level to be  $2/3^{\text{rd}}$  of F.R.L.
- The phreatic line goes well below the surface indicating surface and toe drains are well connected.

### **Recommendation for slope stability**

Prima facie it can be inferred that the dykes are in safe and stable in all conditions. A regular inspection for drainage blockage and maintenance of weeds/plants over the bund is suggested as regular maintenance activity.

## **Annexure-1**

### **1. Sudden draw down condition at upstream**

Slice Number	Width (m)	Weight (kN)	Angle of Slice Base	Base Material	Base Cohesion kPa	Base friction Angle	Shear stress kPa	Shear strength kPa	Base normal stress kPa	Pore pressure kPa	Eff. Normal stress kPa	Base vertical stress kPa	Eff. vertical stress kPa
1	0.13944 2	0.148051	-39.1577	Soil	0.388	16	0.51353 1	0.572536	0.643553	-24.6043	0.643553	1.06175	1.06175
2	0.13944 2	0.438666	-38.1026	Soil	0.388	16	0.96291 2	1.07355	2.3908	-23.3143	2.3908	3.14589	3.14589
3	0.13944 2	0.732772	-37.0624	Soil	0.388	16	1.42314	1.58666	4.18022	-22.0648	4.18022	5.2550 6	5.25506
4	0.13944 2	1.03379	-36.0364	Soil	0.388	16	1.8994	2.11764	6.03198	-20.8539	6.03198	7.4138 1	7.41381
5	0.13944 2	1.22413	-35.0235	Soil	0.388	16	2.2079	2.46159	7.23149	-19.6803	7.23149	8.77883	8.77883
6	0.13944 2	1.35339	-34.0231	Soil	0.388	16	2.4235	2.70196	8.06975	-18.5426	8.06975	9.7058 4	9.70584

7	0.13944 2	1.47346	- 33.0343	Soil	0.388	16	2.6265	2.92828	8.85901	-17.4394	8.85901	10.5669	10.5669
8	0.13944 2	1.58465	- 32.0565	Soil	0.388	16	2.8171	3.14079	9.60011	-16.3697	9.60011	11.364 3	11.3643
9	0.13944 2	1.68725	- 31.089	Soil	0.388	16	2.99552	3.3397	10.2938	-15.3322	10.2938	12.1	12.1
10	0.13944 2	1.78151	- 30.1313	Soil	0.388	16	3.16192	3.52523	10.9408	-14.3262	10.9408	12.776	12.776
11	0.13944 2	1.86768	- 29.1828	Soil	0.388	16	3.31649	3.69756	11.5418	-13.3505	11.5418	13.394	13.394
12	0.13944	1.94599	- 28.243	Soil	0.388	16	3.45939	3.85687	12.0974	-12.4045	12.0974	13.9556	13.9556
13	0.13944 2	2.01665	- 27.3114	Soil	0.388	16	3.59074	4.00332	12.6081	-11.4872	12.6081	14.4623	14.4623
14	0.13944 2	2.07985	- 26.3876	Soil	0.388	16	3.71071	4.13707	13.0745	-10.598	13.0745	14.9155	14.9155
15	0.13944 2	2.13577	- 25.4711	Soil	0.388	16	3.81941	4.25826	13.497 2	-9.7362	13.4972	15.3166	15.3166
16	0.13944 2	2.18458	- 24.5615	Soil	0.388	16	3.91696	4.36702	13.8765	-8.90114	13.8765	15.666 6	15.6666
17	0.13944 2	2.22644	- 23.6585	Soil	0.388	16	4.00347	4.46347	14.2128	-8.09223	14.2128	15.9668	15.9668
18	0.13944 2	2.26148	- 22.7616	Soil	0.388	16	4.07905	4.54773	14.5067	-7.30894	14.5067	16.2181	16.2181
19	0.13944 2	2.28986	- 21.8707	Soil	0.388	16	4.14376	4.61988	14.7583	-6.55075	14.7583	16.4216	16.4216
20	0.13944 2	2.31169	- 20.9852	Soil	0.388	16	4.19771	4.68003	14.9681	-5.81718	14.9681	16.5782	16.5782
21	0.13944 2	2.32709	- 20.105	Soil	0.388	16	4.24096	4.72825	15.1363	-5.1078	15.1363	16.6887	16.6887
22	0.13944 2	2.33617	- 19.2297	Soil	0.388	16	4.27359	4.76462	15.2631	-4.42219	15.2631	16.753 8	16.7538
23	0.13944 2	2.33904	- 18.3591	Soil	0.388	16	4.29563	4.7892	15.3488	-3.75996	15.3488	16.7744	16.7744
24	0.13944 2	2.33579	- 17.4928	Soil	0.388	16	4.30715	4.80204	15.3936	-3.12074	15.3936	16.751	16.751
25	0.13944 2	2.32651	- 16.6306	Soil	0.388	16	4.3082	4.80321	15.3976	-2.50422	15.3976	16.6845	16.6845
26	0.13944 2	2.31129	- 15.7723	Soil	0.388	16	4.29879	4.79272	15.3611	-1.91006	15.3611	16.5753	16.5753
27	0.13944 2	2.29019	- 14.9176	Soil	0.388	16	4.27898	4.77063	15.284	-1.33799	15.284	16.424	16.424
28	0.13944 2	2.26329	- 14.0663	Soil	0.388	16	4.24876	4.73694	15.1666	-0.787737	15.1666	16.2311	16.2311
29	0.13944 2	2.23067	- 13.2181	Soil	0.388	16	4.20816	4.69168	15.0087	-0.259042	15.0087	15.9971	15.9971
30	0.14444 7	2.27024	- 12.3578	Soil	0.388	16	4.15609	4.63363	14.8063	0	14.8063	15.7168	15.7168
31	0.14444 7	2.2229	- 11.4852	Soil	0.388	16	4.09216	4.56235	14.5577	0	14.5577	15.3891	15.3891
32	0.14444 7	2.16939	- 10.6152	Soil	0.388	16	4.01709	4.47865	14.2658	0	14.2658	15.0187	15.0187
33	0.14444 7	2.10976	- 9.74775	Soil	0.388	16	3.93086	4.38252	13.9305	0	13.9305	14.6058	14.6058
34	0.14444 7	2.04405	- 8.88253	Soil	0.388	16	3.83346	4.27392	13.5518	0	13.5518	14.1509	14.1509
35	0.14444 7	1.97231	- 8.01935	Soil	0.388	16	3.72484	4.15282	13.1295	0	13.1295	13.6543	13.6543
36	0.14444 7	1.89458	- 7.158	Soil	0.388	16	3.60497	4.01918	12.6635	0	12.6635	13.1162	13.1162
37	0.14444 7	1.8109	- 6.29827	Soil	0.388	16	3.4738	3.87294	12.1534	0	12.1534	12.5368	12.5368
38	0.14444 7	1.7213	- 5.43997	Soil	0.388	16	3.33128	3.71404	11.5992	0	11.5992	11.9165	11.9165
39	0.14444 7	1.6258	- 4.58288	Soil	0.388	16	3.17733	3.5424	11.0007	0	11.0007	11.2554	11.2554
40	0.14444 7	1.52443	- 3.72683	Soil	0.388	16	3.01188	3.35795	10.3575	0	10.3575	10.5536	10.5536
41	0.14444 7	1.41721	- 2.8716	Soil	0.388	16	2.83486	3.16058	9.66914	0	9.66914	9.81134	9.81134
42	0.14444 7	1.30416	- 2.01702	Soil	0.388	16	2.64616	2.9502	8.93549	0	8.93549	9.02868	9.02868
43	0.14444 7	1.18527	- 1.16288	Soil	0.388	16	2.44568	2.72669	8.15601	0	8.15601	8.20566	8.20566
44	0.14444 7	1.06057	- 0.30900 5	Soil	0.388	16	2.23332	2.48993	7.33029	0	7.33029	7.34233	7.34233
45	0.14444	0.930059	0.54480	Soil	0.388	16	2.00894	2.23977	6.4578	0	6.45788	6.43877	6.43877

	7		4						8				
46	0.14444 7	0.793728	1.39873	Soil	0.388	16	1.77241	1.97606	5.53823	0	5.53823	5.49496	5.49496
47	0.14444 7	0.651577	2.25297	Soil	0.388	16	1.52359	1.69865	4.57079	0	4.57079	4.51085	4.51085
48	0.14444 7	0.503597	3.10771	Soil	0.388	16	1.26232	1.40736	3.55493	0	3.55493	3.48639	3.48639
49	0.14444 7	0.349777	3.96315	Soil	0.388	16	0.98842	1.10199	2.48998	0	2.48998	2.4215	2.4215
				cement									
50	0.1868 9	0.175577	4.94546	concrete lining	10	10	9.2445	10.3067	1.73937	0	1.73937	0.939446	0.939446

## 2. Steady seepage condition at downstream

Slice Number	Width (m)	Weight (kN)	Angle of Slice Base	Base Material	Base Cohesion kPa	Base friction Angle	Shear stress kPa	Shear strength kPa	Base normal stress kPa	Pore pressure kPa	Eff. Normal stress kPa	Base vertical stress kPa	Eff. vertical stress kPa
1	0.12646 2	0.071846	-8.40186	Soil	0.388	16	0.55450 7	0.574336	0.6498 3	- 15.8158	0.64983	0.5679 3	0.56793
2	0.12646 2	0.212875	-7.40092	Soil	0.388	16	0.87190 3	0.903082	1.796 3	- 15.6414	1.7963	1.68305	1.68305
3	0.12646 2	0.348598	-6.40225	Soil	0.388	16	1.17413	1.21612	2.8879 8	- 15.4874	2.88798	2.7562 4	2.75624
4	0.12646 2	0.479046	-5.40553	Soil	0.388	16	1.46151	1.51377	3.9260 4	- 15.3539	3.92604	3.78774	3.78774
5	0.12646 2	0.604249	-4.41045	Soil	0.388	16	1.73435	1.79637	4.9115 7	- 15.2418	4.91157	4.777 8	4.7778
6	0.12646 2	0.724231	-3.4167	Soil	0.388	16	1.99292	2.06419	5.8455 8	- 15.1501	5.84558	5.72659	5.72659
7	0.12646 2	0.839009	-2.42398	Soil	0.388	16	2.23749	2.3175	6.7289 8	- 15.0798	6.72898	6.6342 6	6.63426
8	0.12646 2	0.948597	-1.43199	Soil	0.388	16	2.46828	2.55655	7.5626 2	- 15.0308	7.56262	7.50091	7.50091
9	0.12646 2	1.05301	-0.440423	Soil	0.388	16	2.68551	2.78154	8.3472 6	- 15.0025	8.34726	8.3266 2	8.32662
10	0.12646 2	1.15224	0.551009	Soil	0.388	16	2.88937	2.99269	9.083 6	- 14.9957	9.0836	9.11138	9.11138
11	0.12646 2	1.24629	1.54261	Soil	0.388	16	3.08004	3.19018	9.7723 8	- 15.0102	9.77238	9.8553 3	9.85533
12	0.12646 2	1.33517	2.53467	Soil	0.388	16	3.25768	3.37417	10.41 4	- 15.0455	10.414	10.5582	10.5582
13	0.12646 2	1.41885	3.52749	Soil	0.388	16	3.42243	3.54482	11.009 2	- 15.1021	11.0092	11.220 1	11.2201
14	0.12646 2	1.49733	4.52137	Soil	0.388	16	3.57444	3.70226	11.558 2	- 15.1799	11.5582	11.8408	11.8408
15	0.12646 2	1.57058	5.51662	Soil	0.388	16	3.7138	3.84661	12.061 6	- 15.2785	12.0616	12.420 3	12.4203
16	0.12646 2	1.63859	6.51354	Soil	0.388	16	3.84064	3.97798	12.519 7	- 15.3988	12.5197	12.9582	12.9582
17	0.12646 2	1.70132	7.51245	Soil	0.388	16	3.95502	4.09645	12.932 9	- 15.5409	12.9329	13.454 5	13.4545
18	0.12646 2	1.75874	8.51366	Soil	0.388	16	4.05703	4.20211	13.301 4	-15.705	13.3014	13.9087	13.9087
19	0.12646 2	1.8108	9.5175	Soil	0.388	16	4.14673	4.29502	13.625 4	- 15.8929	13.6254	14.3206	14.3206
20	0.12646 2	1.85747	10.5243	Soil	0.388	16	4.22418	4.37524	13.905 2	- 16.1031	13.9052	14.6899	14.6899
21	0.12646 2	1.8987	11.5344	Soil	0.388	16	4.2894	4.44279	14.140 7	-16.336	14.1407	15.016 1	15.0161
22	0.12646 2	1.93442	12.5481	Soil	0.388	16	4.34243	4.49772	14.332 3	- 16.5916	14.3323	15.2988	15.2988
23	0.12646 2	1.96458	13.5659	Soil	0.388	16	4.38328	4.54003	14.479 9	- 16.8704	14.4799	15.537 5	15.5375
24	0.12646 2	1.9891	14.588	Soil	0.388	16	4.41195	4.56972	14.583 4	- 17.1736	14.5834	15.7317	15.7317
25	0.12646 2	2.00792	15.6149	Soil	0.388	16	4.42843	4.58679	14.642 9	- 17.5007	14.6429	15.880 6	15.8806

26	0.12646 2	2.02094	16.647	Soil	0.388	16	4.43271	4.59122	14.658 3	- 17.8517	14.6583	15.9837	15.9837
27	0.12646 2	2.02807	17.6847	Soil	0.388	16	4.42473	4.58296	14.629 6	- 18.2272	14.6296	16.040 4	16.0404
28	0.12646 2	2.02922	18.7284	Soil	0.388	16	4.40448	4.56198	14.556 4	- 18.6274	14.5564	16.0496	16.0496
29	0.12646 2	2.02427	19.7785	Soil	0.388	16	4.37186	4.5282	14.438 6	- 19.0529	14.4386	16.010 7	16.0107
30	0.12646 2	2.01311	20.8357	Soil	0.388	16	4.32684	4.48157	14.27 6	- 19.5043	14.276	15.9227	15.9227
31	0.12646 2	1.99561	21.9003	Soil	0.388	16	4.26931	4.42198	14.068 2	- 19.9818	14.0682	15.784 5	15.7845
32	0.12646 2	1.97163	22.973	Soil	0.388	16	4.19919	4.34935	13.814 9	- 20.4862	13.8149	15.595	15.595
33	0.12646 2	1.94102	24.0542	Soil	0.388	16	4.11635	4.26355	13.515 7	-21.018	13.5157	15.353 1	15.3531
34	0.12646 2	1.90361	25.1447	Soil	0.388	16	4.02068	4.16446	13.170 1	-21.578	13.1701	15.0573	15.0573
35	0.12646 2	1.85922	26.2449	Soil	0.388	16	3.91204	4.05193	12.777 7	- 22.1675	12.7777	14.706 4	14.7064
36	0.12646 2	1.80765	27.3557	Soil	0.388	16	3.79026	3.9258	12.337 7	- 22.7868	12.3377	14.2987	14.2987
37	0.12646 2	1.7487	28.4778	Soil	0.388	16	3.65517	3.78588	11.849 8	- 23.4366	11.8498	13.832 6	13.8326
38	0.12646 2	1.68212	29.6119	Soil	0.388	16	3.50659	3.63199	11.313 2	- 24.1181	11.3132	13.3061	13.3061
39	0.12646 2	1.60766	30.7589	Soil	0.388	16	3.34433	3.46392	10.72 7	- 24.8322	10.727	12.717 3	12.7173
40	0.12646 2	1.52504	31.9197	Soil	0.388	16	3.16812	3.28141	10.090 5	-25.58	10.0905	12.064	12.064
41	0.12646 2	1.43396	33.0954	Soil	0.388	16	2.97774	3.08422	9.4028 7	-26.363	9.40287	11.343 7	11.3437
42	0.12646 2	1.33406	34.2871	Soil	0.388	16	2.77292	2.87208	8.6630 3	- 27.1823	8.66303	10.5537	10.5537
43	0.12646 2	1.22499	35.4959	Soil	0.388	16	2.55336	2.64467	7.8699 1	- 28.0394	7.86991	9.6909 3	9.69093
44	0.12646 2	1.10631	36.7232	Soil	0.388	16	2.31876	2.40168	7.0225 5	- 28.9363	7.02255	8.75236	8.75236
45	0.12646 2	0.977582	37.9704	Soil	0.388	16	2.06877	2.14275	6.1195 3	- 29.8747	6.11953	7.7341 1	7.73411
46	0.12646 2	0.838276	39.2392	Soil	0.388	16	1.80302	1.8675	5.1596 3	- 30.8569	5.15963	6.6322	6.6322
47	0.12646 2	0.687819	40.5315	Soil	0.388	16	1.52113	1.57553	4.1414 3	- 31.8853	4.14143	5.4420 4	5.44204
48	0.12646 2	0.52556	41.8491	Soil	0.388	16	1.22269	1.26641	3.0633 9	- 32.9625	3.06339	4.15849	4.15849
49	0.12646 2	0.350763	43.1945	Soil	0.388	16	0.90723	0.939673	1.9239 1	- 34.0916	1.92391	2.7757	2.7757
50	0.12646 2	0.141332	44.5703	Soil	0.388	16	0.53770 8	0.556936	0.58914 8	- 35.2756	0.589148	1.11885	1.11885

### 3.1 Earthquake condition at downstream

Slice Number	Width (m)	Weight (kN)	Angle of Slice Base	Base Material	Base Cohesion kPa	Base friction Angle	Shear stress kPa	Shear strength kPa	Base normal stress kPa	Pore pressure kPa	Eff. Normal stress kPa	Base vertical stress kPa	Eff. vertical stress kPa
1	0.12800 1	0.071614	-7.67139	Soil	0.388	16	0.74595 3	0.57723 8	0.65995 2	0	0.659952	0.55947 5	0.559475
2	0.12800 1	0.212222	-6.70706	Soil	0.388	16	1.16661	0.90275 3	1.79516	0	1.79516	1.65797	1.65797
3	0.12800 1	0.347608	-5.74463	Soil	0.388	16	1.5660 8	1.21188	2.873 2	0	2.8732	2.71565	2.71565
4	0.12800 1	0.477798	-4.78383	Soil	0.388	16	1.94491	1.50502	3.89551	0	3.89551	3.73275	3.73275
5	0.12800 1	0.602818	-3.82437	Soil	0.388	16	2.3035 8	1.78257	4.8634 5	0	4.86345	4.70946	4.70946
6	0.12800	0.722686	-2.86599	Soil	0.388	16	2.64256	2.04488	5.77821	0	5.77821	5.64592	5.64592

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7	0.12800 1	0.837418	-1.90841	Soil	0.388	16	2.9622 6	2.29227	6.6409 7	0	6.64097	6.54226	6.54226
8	0.12800 1	0.947025	-0.951359	Soil	0.388	16	3.26306	2.52504	7.45274	0	7.45274	7.39856	7.39856
9	0.12800 1	1.05151	0.0054228 4	Soil	0.388	16	3.54534	2.74348	8.21453	0	8.21453	8.21486	8.21486
10	0.12800 1	1.15088	0.962206	Soil	0.388	16	3.80944	2.94784	8.92724	0	8.92724	8.99123	8.99123
11	0.12800 1	1.24514	1.91926	Soil	0.388	16	4.0556 4	3.13836	9.59163	0	9.59163	9.72753	9.72753
12	0.12800 1	1.33426	2.87685	Soil	0.388	16	4.28423	3.31525	10.2086	0	10.2086	10.4239	10.4239
13	0.12800 1	1.41825	3.83524	Soil	0.388	16	4.4954 9	3.47873	10.7787	0	10.7787	11.08	11.08
14	0.12800 1	1.49709	4.79471	Soil	0.388	16	4.68963	3.62896	11.3025	0	11.3025	11.6959	11.6959
15	0.12800 1	1.57076	5.75553	Soil	0.388	16	4.866 9	3.76613	11.7809	0	11.7809	12.2714	12.2714
16	0.12800 1	1.63923	6.71798	Soil	0.388	16	5.02745	3.89037	12.2143	0	12.2143	12.8064	12.8064
17	0.12800 1	1.70248	7.68233	Soil	0.388	16	5.171 5	4.00184	12.60 3	0	12.603	13.3006	13.3006
18	0.12800 1	1.76048	8.64888	Soil	0.388	16	5.29919	4.10065	12.9476	0	12.9476	13.7536	13.7536
19	0.12800 1	1.81317	9.61792	Soil	0.388	16	5.4106 7	4.18692	13.2484	0	13.2484	14.1653	14.1653
20	0.12800 1	1.86053	10.5897	Soil	0.388	16	5.50608	4.26075	13.5058	0	13.5058	14.5353	14.5353
21	0.12800 1	1.9025	11.5647	Soil	0.388	16	5.5855 1	4.32221	13.7202	0	13.7202	14.8632	14.8632
22	0.12800 1	1.93903	12.543	Soil	0.388	16	5.64906	4.37139	13.8918	0	13.8918	15.1486	15.1486
23	0.12800 1	1.97005	13.525	Soil	0.388	16	5.69682	4.40835	14.020 6	0	14.0206	15.391	15.391
24	0.12800 1	1.99551	14.5112	Soil	0.388	16	5.72886	4.43314	14.1071	0	14.1071	15.5899	15.5899
25	0.12800 1	2.01533	15.5017	Soil	0.388	16	5.7452 2	4.4458	14.1512	0	14.1512	15.7447	15.7447
26	0.12800 1	2.02943	16.497	Soil	0.388	16	5.74593	4.44635	14.1532	0	14.1532	15.8549	15.8549
27	0.12800 1	2.03773	17.4975	Soil	0.388	16	5.7310 3	4.43482	14.11 3	0	14.113	15.9197	15.9197
28	0.12800 1	2.04012	18.5035	Soil	0.388	16	5.70053	4.41122	14.0306	0	14.0306	15.9384	15.9384
29	0.12800 1	2.03652	19.5154	Soil	0.388	16	5.6544 1	4.37553	13.9062	0	13.9062	15.9102	15.9102
30	0.12800 1	2.0268	20.5338	Soil	0.388	16	5.59267	4.32775	13.7396	0	13.7396	15.8343	15.8343
31	0.12800 1	2.01085	21.5589	Soil	0.388	16	5.5152 6	4.26785	13.5306	0	13.5306	15.7097	15.7097
32	0.12800 1	1.98855	22.5914	Soil	0.388	16	5.42215	4.1958	13.2794	0	13.2794	15.5355	15.5355
33	0.12800 1	1.95973	23.6316	Soil	0.388	16	5.3132 7	4.11155	12.9855	0	12.9855	15.3103	15.3103
34	0.12800 1	1.92427	24.6802	Soil	0.388	16	5.18856	4.01504	12.649	0	12.649	15.0333	15.0333
35	0.12800 1	1.88198	25.7377	Soil	0.388	16	5.047 9	3.9062	12.2694	0	12.2694	14.7029	14.7029
36	0.12800 1	1.83268	26.8047	Soil	0.388	16	4.89122	3.78495	11.8466	0	11.8466	14.3178	14.3178
37	0.12800 1	1.77619	27.8818	Soil	0.388	16	4.7183 7	3.6512	11.3801	0	11.3801	13.8765	13.8765
38	0.12800 1	1.71229	28.9698	Soil	0.388	16	4.52925	3.50485	10.8697	0	10.8697	13.3772	13.3772
39	0.12800 1	1.64074	30.0693	Soil	0.388	16	4.323 7	3.34579	10.31 5	0	10.315	12.8183	12.8183
40	0.12800 1	1.5613	31.1812	Soil	0.388	16	4.10154	3.17388	9.71549	0	9.71549	12.1976	12.1976
41	0.12800 1	1.47368	32.3063	Soil	0.388	16	3.862 6	2.98898	9.07072	0	9.07072	11.5131	11.5131
42	0.12800 1	1.37759	33.4456	Soil	0.388	16	3.60669	2.79095	8.38006	0	8.38006	10.7624	10.7624
43	0.12800 1	1.27268	34.6	Soil	0.388	16	3.33359	2.57962	7.6430 6	0	7.64306	9.94276	9.94276

44	0.128001	1.15858	35.7707	Soil	0.388	16	3.04307	2.35481	6.85905	0	6.85905	9.05142	9.05142
45	0.128001	1.03491	36.959	Soil	0.388	16	2.73489	2.11633	6.0274	0	6.0274	8.08522	8.08522
46	0.128001	0.901194	38.166	Soil	0.388	16	2.40878	1.86398	5.14737	0	5.14737	7.04059	7.04059
47	0.128001	0.756943	39.3935	Soil	0.388	16	2.0645	1.59756	4.21823	0	4.21823	5.91364	5.91364
48	0.128001	0.601595	40.6429	Soil	0.388	16	1.70171	1.31683	3.23922	0	3.23922	4.69997	4.69997
49	0.128001	0.416809	41.9162	Soil	0.388	16	1.28168	0.99179	2.1057	0	2.1057	3.25634	3.25634
50	0.128001	0.143936	43.2154	Soil	0.388	16	0.681001	0.526976	0.484667	0	0.484667	1.12451	1.12451

### 3.2 Earthquake condition at upstream

Slice Number	Width (m)	Weight (kN)	Angle of Slice Base	Base Material	Base Cohesion kPa	Base friction Angle	Shear stress kPa	Shear strength kPa	Base normal stress kPa	Pore pressure kPa	Eff. Normal stress kPa	Base vertical stress kPa	Eff. vertical stress kPa
1	0.141485	0.152378	-39.15	Soil	0.388	16	0.654033	0.543462	0.542161	0	0.542161	1.07463	1.07463
2	0.141485	0.451407	-38.0796	Soil	0.388	16	1.23306	1.0246	2.22007	0	2.22007	3.1862	3.1862
3	0.141485	0.754863	-37.0247	Soil	0.388	16	1.82972	1.52039	3.94913	0	3.94913	5.32916	5.32916
4	0.141485	1.06252	-35.9842	Soil	0.388	16	2.44347	2.03038	5.72767	0	5.72767	7.50192	7.50192
5	0.141485	1.25096	-34.9572	Soil	0.388	16	2.83187	2.35311	6.85313	0	6.85313	8.83287	8.83287
6	0.141485	1.38334	-33.943	Soil	0.388	16	3.11438	2.58786	7.67184	0	7.67184	9.76801	9.76801
7	0.141485	1.50614	-32.9408	Soil	0.388	16	3.38111	2.8095	8.44479	0	8.44479	10.6355	10.6355
8	0.141485	1.61969	-31.9497	Soil	0.388	16	3.63225	3.01818	9.17249	0	9.17249	11.4377	11.4377
9	0.141485	1.7243	-30.9693	Soil	0.388	16	3.86796	3.21404	9.85555	0	9.85555	12.1768	12.1768
10	0.141485	1.82023	-29.9988	Soil	0.388	16	4.08841	3.39722	10.4944	0	10.4944	12.8547	12.8547
11	0.141485	1.90775	-29.0377	Soil	0.388	16	4.29374	3.56784	11.0894	0	11.0894	13.4732	13.4732
12	0.141485	1.98709	-28.0855	Soil	0.388	16	4.4841	3.72602	11.641	0	11.641	14.0339	14.0339
13	0.141485	2.05847	-27.1417	Soil	0.388	16	4.65963	3.87187	12.1497	0	12.1497	14.5384	14.5384
14	0.141485	2.12209	-26.2058	Soil	0.388	16	4.82042	4.00548	12.6156	0	12.6156	14.9882	14.9882
15	0.141485	2.17815	-25.2773	Soil	0.388	16	4.96659	4.12694	13.0393	0	13.0393	15.3845	15.3845
16	0.141485	2.22681	-24.3559	Soil	0.388	16	5.09824	4.23633	13.4207	0	13.4207	15.7287	15.7287
17	0.141485	2.26825	-23.4412	Soil	0.388	16	5.21543	4.33371	13.7604	0	13.7604	16.0217	16.0217
18	0.141485	2.30261	-22.5327	Soil	0.388	16	5.31828	4.41917	14.0583	0	14.0583	16.2648	16.2648
19	0.141485	2.33003	-21.6302	Soil	0.388	16	5.4068	4.49273	14.3149	0	14.3149	16.4589	16.4589
20	0.141485	2.35065	-20.7333	Soil	0.388	16	5.48109	4.55446	14.5302	0	14.5302	16.6049	16.6049
21	0.141485	2.36459	-19.8417	Soil	0.388	16	5.54119	4.6044	14.7043	0	14.7043	16.7038	16.7038
22	0.141485	2.37197	-18.955	Soil	0.388	16	5.58712	4.64256	14.8374	0	14.8374	16.7563	16.7563
23	0.141485	2.37288	-18.0731	Soil	0.388	16	5.6189	4.66897	14.9295	0	14.9295	16.7631	16.7631
24	0.141485	2.36743	-17.1955	Soil	0.388	16	5.63657	4.68365	14.9807	0	14.9807	16.725	16.725
25	0.141485	2.35572	-16.3221	Soil	0.388	16	5.64012	4.6866	14.99	0	14.991	16.6427	16.6427

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26	0.141485	2.33782	-15.4526	Soil	0.388	16	5.62954	4.67781	14.9604	0	14.9604	16.5166	16.5166
27	0.141485	2.31382	-14.5867	Soil	0.388	16	5.60485	4.65729	14.8888	0	14.8888	16.3474	16.3474
28	0.141485	2.28379	-13.7243	Soil	0.388	16	5.566	4.62501	14.7762	0	14.7762	16.1355	16.1355
29	0.141485	2.2478	-12.8649	Soil	0.388	16	5.51296	4.58094	14.6225	0	14.6225	15.8816	15.8816
30	0.141485	2.20591	-12.0085	Soil	0.388	16	5.44571	4.52506	14.4276	0	14.4276	15.586	15.586
31	0.141485	2.15818	-11.1548	Soil	0.388	16	5.36418	4.45731	14.1913	0	14.1913	15.2491	15.2491
32	0.141485	2.10467	-10.3037	Soil	0.388	16	5.26831	4.37765	13.9136	0	13.9136	14.8713	14.8713
33	0.141485	2.04541	-9.45477	Soil	0.388	16	5.15804	4.28602	13.594	0	13.594	14.453	14.453
34	0.141485	1.98047	-8.60797	Soil	0.388	16	5.03328	4.18235	13.2325	0	13.2325	13.9944	13.9944
35	0.141485	1.90987	-7.76306	Soil	0.388	16	4.89393	4.06656	12.8287	0	12.8287	13.4959	13.4959
36	0.141485	1.83365	-6.91985	Soil	0.388	16	4.73988	3.93856	12.3823	0	12.3823	12.9576	12.9576
37	0.141485	1.75185	-6.07814	Soil	0.388	16	4.57105	3.79827	11.893	0	11.893	12.3797	12.3797
38	0.141485	1.66449	-5.23775	Soil	0.388	16	4.38728	3.64557	11.3605	0	11.3605	11.7627	11.7627
39	0.141485	1.5716	-4.39849	Soil	0.388	16	4.18845	3.48035	10.7843	0	10.7843	11.1065	11.1065
40	0.141485	1.47319	-3.56017	Soil	0.388	16	3.9744	3.30249	10.164	0	10.164	10.4113	10.4113
41	0.141485	1.36929	-2.72261	Soil	0.388	16	3.74496	3.11184	9.49913	0	9.49913	9.67722	9.67722
42	0.141485	1.25991	-1.88564	Soil	0.388	16	3.49995	2.90825	8.7892	0	8.7892	8.90442	8.90442
43	0.141485	1.14505	-1.04906	Soil	0.388	16	3.23919	2.69157	8.03352	0	8.03352	8.09283	8.09283
44	0.141485	1.02472	-0.212715	Soil	0.388	16	2.96246	2.46163	7.23162	0	7.23162	7.24262	7.24262
45	0.141485	0.898934	0.623589	Soil	0.388	16	2.66954	2.21823	6.38277	0	6.38277	6.35371	6.35371
46	0.141485	0.767679	1.46002	Soil	0.388	16	2.36018	1.96117	5.4863	0	5.4863	5.42615	5.42615
47	0.141485	0.630954	2.29677	Soil	0.388	16	2.03414	1.69025	4.54147	0	4.54147	4.45989	4.45989
48	0.141485	0.488751	3.13401	Soil	0.388	16	1.69112	1.40522	3.54745	0	3.54745	3.45486	3.45486
49	0.141485	0.34106	3.97192	Soil	0.388	16	1.33083	1.10584	2.5034	0	2.5034	2.41099	2.41099
				cement									
50	0.18689	0.175577	4.94546	concrete lining	10	10	12.4638	10.3567	2.02275	0	2.02275	0.944264	0.944264

## Annexure-2

### 1. Sudden draw down condition at upstream

Slice Number	Width (m)	Weight (kN)	Angle of Slice Base	Base Material	Base Cohesion kPa	Base friction Angle	Shear stress kPa	Shear strength kPa	Base normal stress kPa	Pore pressure kPa	Eff. Normal stress kPa	Base vertical stress kPa	Eff. vertical stress kPa
1	0.19157	0.444	-52.3022	soil	0.388	16	0.968703	0.693324	1.06479	-9.56015	1.06479	2.31825	2.31825
2	0.19157	1.28388	-50.5168	soil	0.388	16	2.17155	1.55423	4.06714	-6.66318	4.06714	6.70301	6.70301
3	0.19157	1.81224	-48.7967	soil	0.388	16	2.97251	2.1275	6.06635	-3.90884	6.06635	9.46143	9.46143
4	0.19157	2.24104	-47.1338	soil	0.388	16	3.65283	2.61442	7.76447	-1.2827	7.76447	11.7	11.7

5	0.168619	2.29419	-45.6154	soil	0.388	16	4.25295	3.04394	9.26237	0	9.26237	13.6077	13.6077
6	0.168619	2.56678	-44.2314	soil	0.388	16	4.77799	3.41972	10.5729	0	10.5729	15.2243	15.2243
7	0.168619	2.8146	-42.8793	soil	0.388	16	5.26988	3.77178	11.8006	0	11.8006	16.6942	16.6942
8	0.168619	3.03928	-41.5562	soil	0.388	16	5.72944	4.1007	12.9478	0	12.9478	18.0268	18.0268
9	0.168619	3.24224	-40.2597	soil	0.388	16	6.15743	4.40702	14.016	0	14.016	19.2304	19.2304
10	0.168619	3.42471	-38.9876	soil	0.388	16	6.55455	4.69125	15.0072	0	15.0072	20.3126	20.3126
11	0.168619	3.5878	-37.7379	soil	0.388	16	6.92145	4.95385	15.923	0	15.923	21.2798	21.2798
12	0.168619	3.73248	-36.5091	soil	0.388	16	7.25876	5.19527	16.7649	0	16.7649	22.1379	22.1379
13	0.168619	3.85965	-35.2994	soil	0.388	16	7.56704	5.41591	17.5344	0	17.5344	22.8921	22.8921
14	0.168619	3.97007	-34.1076	soil	0.388	16	7.84681	5.61615	18.2327	0	18.2327	23.5469	23.5469
15	0.168619	4.06447	-32.9323	soil	0.388	16	8.09854	5.79632	18.861	0	18.861	24.1067	24.1067
16	0.168619	4.14348	-31.7725	soil	0.388	16	8.32266	5.95673	19.4205	0	19.4205	24.5752	24.5752
17	0.168619	4.20768	-30.6271	soil	0.388	16	8.5196	6.09768	19.912	0	19.912	24.956	24.956
18	0.168619	4.25761	-29.495	soil	0.388	16	8.68969	6.21942	20.3366	0	20.3366	25.252	25.252
19	0.168619	4.29374	-28.3755	soil	0.388	16	8.83327	6.32218	20.6949	0	20.6949	25.4662	25.4662
20	0.168619	4.31651	-27.2677	soil	0.388	16	8.9506	6.40616	20.9878	0	20.9878	25.6012	25.6012
21	0.168619	4.32634	-26.1708	soil	0.388	16	9.04198	6.47156	21.2159	0	21.2159	25.6594	25.6594
22	0.168619	4.32358	-25.0841	soil	0.388	16	9.10762	6.51854	21.3797	0	21.3797	25.6429	25.6429
23	0.168619	4.30858	-24.007	soil	0.388	16	9.14769	6.54722	21.4797	0	21.4797	25.5539	25.5539
24	0.168619	4.28165	-22.9389	soil	0.388	16	9.16239	6.55774	21.5164	0	21.5164	25.3941	25.3941
25	0.168619	4.24308	-21.8791	soil	0.388	16	9.15185	6.5502	21.4901	0	21.4901	25.1653	25.1653
26	0.168619	4.19312	-20.8271	soil	0.388	16	9.11617	6.52466	21.4011	0	21.4011	24.8689	24.8689
27	0.168619	4.13203	-19.7825	soil	0.388	16	9.05543	6.48119	21.2495	0	21.2495	24.5065	24.5065
28	0.168619	4.06002	-18.7446	soil	0.388	16	8.9697	6.41983	21.0355	0	21.0355	24.0794	24.0794
29	0.168619	3.97731	-17.7131	soil	0.388	16	8.85902	6.34061	20.7592	0	20.7592	23.5887	23.5887
30	0.168619	3.88407	-16.6875	soil	0.388	16	8.72336	6.24352	20.4206	0	20.4206	23.0357	23.0357
31	0.168619	3.78048	-15.6674	soil	0.388	16	8.56273	6.12855	20.0197	0	20.0197	22.4213	22.4213
32	0.168619	3.66671	-14.6523	soil	0.388	16	8.37706	5.99566	19.5563	0	19.5563	21.7465	21.7465
33	0.168619	3.5429	-13.6419	soil	0.388	16	8.16628	5.8448	19.0301	0	19.0301	21.0121	21.0121
34	0.168619	3.40918	-12.6358	soil	0.388	16	7.93031	5.67591	18.4411	0	18.4411	20.219	20.219
35	0.168619	3.26567	-11.6337	soil	0.388	16	7.66899	5.48888	17.7889	0	17.7889	19.3678	19.3678
36	0.168619	3.11248	-10.6352	soil	0.388	16	7.38219	5.28361	17.073	0	17.073	18.4593	18.4593
37	0.168619	2.94972	-9.63991	soil	0.388	16	7.06971	5.05996	16.293	0	16.293	17.4939	17.4939
38	0.168619	2.77746	-8.64757	soil	0.388	16	6.73135	4.81779	15.4485	0	15.4485	16.4722	16.4722
39	0.168619	2.5958	-7.65783	soil	0.388	16	6.36687	4.55692	14.5387	0	14.5387	15.3948	15.3948
40	0.168619	2.40479	-6.67039	soil	0.388	16	5.97598	4.27715	13.5631	0	13.5631	14.262	14.262
41	0.168619	2.20451	-5.68494	soil	0.388	16	5.5584	3.97828	12.5208	0	12.5208	13.0741	13.0741
42	0.168619	1.99499	-4.70117	soil	0.388	16	5.11377	3.66005	11.411	0	11.411	11.8315	11.8315
43	0.168619	1.77629	-3.71879	soil	0.388	16	4.64173	3.3222	10.2328	0	10.2328	10.5345	10.5345
44	0.168619	1.54845	-2.7375	soil	0.388	16	4.14188	2.96444	8.98514	0	8.98514	9.18319	9.18319
45	0.168619	1.31147	-1.75701	soil	0.388	16	3.61375	2.58645	7.66692	0	7.66692	7.77778	7.77778
46	0.168619	1.06539	-0.777045	soil	0.388	16	3.05686	2.18787	6.27688	0	6.27688	6.31833	6.31833
47	0.168619	0.810217	0.202697	soil	0.388	16	2.47067	1.76832	4.81375	0	4.81375	4.80501	4.80501
48	0.168619	0.54595	1.1825	soil	0.388	16	1.85461	1.32739	3.27603	0	3.27603	3.23775	3.23775
49	0.168619	0.272584	2.16265	soil	0.388	16	1.20803	0.864617	1.66216	0	1.66216	1.61654	1.61654
				Cement									
50	0.0626824	0.0251959	2.83516	concrete lining	20	10	28.389	20.3187	1.80726	0	1.80726	0.401341	0.401341

## 2. Steady seepage condition at downstream

Slice Number	Width (m)	Weight (kN)	Angle of Slice Base	Base Material	Base Cohesion kPa	Base friction Angle	Shear stress kPa	Shear strength kPa	Base normal stress kPa	Pore pressure kPa	Eff. Normal stress kPa	Base vertical stress kPa	Eff. vertical stress kPa
1	0.125333	0.0731165	-0.736299	soil	0.388	16	0.780789	0.558157	0.593406	-11.9496	0.593406	0.583372	0.583372

2	0.12533 3	0.216973	0.19064 1	soil	0.388	16	1.23552	0.88322 6	1.7270 6	-11.933	1.72706	1.73117	1.73117
3	0.12533 3	0.356077	1.11763	soil	0.388	16	1.6693	1.19332	2.80848	- 11.9281	2.80848	2.84105	2.84105
4	0.12533 3	0.490426	2.04491	soil	0.388	16	2.08251	1.48871	3.83864	- 11.9369	3.83864	3.913	3.913
5	0.12533 3	0.620012	2.97273	soil	0.388	16	2.47551	1.76965	4.8184	- 11.9757	4.8184	4.9469 5	4.9469 5
6	0.12533 3	0.744827	3.90133	soil	0.388	16	2.84863	2.03638	5.74857	- 12.0302	5.74857	5.94284	5.94284
7	0.12533 3	0.864855	4.83096	soil	0.388	16	3.20215	2.2891	6.62991	- 12.1016	6.62991	6.90055	6.90055
8	0.12533 3	0.980079	5.76187	soil	0.388	16	3.53636	2.52801	7.4631	-12.188	7.4631	7.81993	7.81993
9	0.12533 3	1.09048	6.6943	soil	0.388	16	3.85149	2.75329	8.24874	- 12.2916	8.24874	8.7008	8.7008
10	0.12533 3	1.19603	7.62852	soil	0.388	16	4.1478	2.96511	8.9874 8	- 12.4141	8.98748	9.54302	9.54302
11	0.12533 3	1.29669	8.56478	soil	0.388	16	4.42548	3.16361	9.67969	-12.555	9.67969	10.3462	10.3462
12	0.12533 3	1.39244	9.50336	soil	0.388	16	4.68472	3.34893	10.326	- 12.7103	10.326	11.1102	11.1102
13	0.12533 3	1.48324	10.4445	soil	0.388	16	4.92569	3.52119	10.9267	- 12.8861	10.9267	11.8347	11.8347
14	0.12533 3	1.56904	11.3885	soil	0.388	16	5.14852	3.68049	11.4823	- 13.0823	11.4823	12.5194	12.5194
15	0.12533 3	1.64979	12.3357	soil	0.388	16	5.35339	3.82694	11.993	- 13.2997	11.993	13.1637	13.1637
16	0.12533 3	1.72545	13.2863	soil	0.388	16	5.54036	3.9606	12.4591	- 13.5356	12.4591	13.7674	13.7674
17	0.12533 3	1.79595	14.2406	soil	0.388	16	5.70954	4.08154	12.8809	- 13.7925	12.8809	14.33	14.33
18	0.12533 3	1.86123	15.199	soil	0.388	16	5.86104	4.18984	13.2586	- 14.0709	13.2586	14.8509	14.8509
19	0.12533 3	1.92122	16.1618	soil	0.388	16	5.99488	4.28552	13.5923	- 14.3711	13.5923	15.3296	15.3296
20	0.12533 3	1.97585	17.1293	soil	0.388	16	6.11113	4.36862	13.8821	- 14.6934	13.8821	15.7655	15.7655
21	0.12533 3	2.02503	18.1018	soil	0.388	16	6.20981	4.43916	14.128	- 15.0381	14.128	16.1579	16.1579
22	0.12533 3	2.06867	19.0798	soil	0.388	16	6.29093	4.49715	14.3303	- 15.4065	14.3303	16.5062	16.5062
23	0.12533 3	2.10668	20.0636	soil	0.388	16	6.35449	4.54259	14.4888	- 15.7982	14.4888	16.8096	16.8096
24	0.12533 3	2.13896	21.0536	soil	0.388	16	6.40049	4.57547	14.6034	- 16.2135	14.6034	17.0672	17.0672
25	0.12533 3	2.16539	22.0502	soil	0.388	16	6.42885	4.59575	14.6742	- 16.6529	14.6742	17.2782	17.2782
26	0.12533 3	2.18585	23.0539	soil	0.388	16	6.43957	4.60341	14.7009	- 17.1169	14.7009	17.4415	17.4415
27	0.12533 3	2.20021	24.0651	soil	0.388	16	6.43253	4.59838	14.6834	- 17.6061	14.6834	17.5561	17.5561
28	0.12533 3	2.20832	25.0844	soil	0.388	16	6.40769	4.58062	14.6214	- 18.1212	14.6214	17.6209	17.6209
29	0.12533 3	2.21004	26.1123	soil	0.388	16	6.36491	4.55004	14.5148	- 18.6636	14.5148	17.6346	17.6346
30	0.12533 3	2.20519	27.1492	soil	0.388	16	6.30409	4.50656	14.363 1	- 19.2335	14.3631	17.5959	17.5959
31	0.12533 3	2.19358	28.1959	soil	0.388	16	6.22507	4.45007	14.1661	- 19.8313	14.1661	17.5034	17.5034
32	0.12533 3	2.17504	29.2529	soil	0.388	16	6.12771	4.38047	13.9234	- 20.4578	13.9234	17.3555	17.3555
33	0.12533 3	2.14934	30.321	soil	0.388	16	6.0118	4.29761	13.6345	- 21.1137	13.6345	17.1504	17.1504
34	0.12533 3	2.11624	31.4009	soil	0.388	16	5.87717	4.20137	13.2988	- 21.7994	13.2988	16.8864	16.8864
35	0.12533 3	2.0755	32.4933	soil	0.388	16	5.7236	4.09159	12.9159	-22.516	12.9159	16.5613	16.5613
36	0.12533 3	2.02683	33.5992	soil	0.388	16	5.55081	3.96807	12.4852	- 23.2654	12.4852	16.1731	16.1731
37	0.12533 3	1.96993	34.7195	soil	0.388	16	5.35858	3.83065	12.0059	- 24.0491	12.0059	15.7191	15.7191
38	0.12533 3	1.90447	35.8551	soil	0.388	16	5.14658	3.6791	11.4775	- 24.8682	11.4775	15.1968	15.1968
39	0.12533 3	1.83008	37.0073	soil	0.388	16	4.91452	3.51321	10.898 9	- 25.7242	10.8989	14.6033	14.6033

40	0.12533 3	1.74635	38.1772	soil	0.388	16	4.66204	3.33272	10.2695	-26.6186	10.2695	13.9351	13.9351
41	0.12533 3	1.65282	39.3663	soil	0.388	16	4.38878	3.13738	9.58823	-27.5543	9.58823	13.1889	13.1889
42	0.12533 3	1.549	40.5759	soil	0.388	16	4.09436	2.92691	8.85419	-28.5337	8.85419	12.3605	12.3605
43	0.12533 3	1.43432	41.8078	soil	0.388	16	3.77833	2.70099	8.06633	-29.5579	8.06633	11.4455	11.4455
44	0.12533 3	1.30815	43.0639	soil	0.388	16	3.44024	2.4593	7.22347	-30.6334	7.22347	10.4387	10.4387
45	0.12533 3	1.16978	44.3464	soil	0.388	16	3.07963	2.20151	6.32448	-31.7609	6.32448	9.33463	9.33463
46	0.12533 3	1.0184	45.6575	soil	0.388	16	2.696	1.92727	5.36806	-32.9422	5.36806	8.12666	8.12666
47	0.12533 3	0.853065	47.0002	soil	0.388	16	2.2888	1.63618	4.35294	-34.1811	4.35294	6.80739	6.80739
48	0.12533 3	0.672721	48.3775	soil	0.388	16	1.85755	1.32789	3.27779	-35.4821	3.27779	5.36833	5.36833
49	0.12533 3	0.475921	49.7931	soil	0.388	16	1.40124	1.00169	2.1402	-36.8478	2.1402	3.79794	3.79794
50	0.12533 3	0.183011	51.2515	soil	0.388	16	0.752516	0.537946	0.522926	-38.2863	0.522926	1.46059	1.46059

### 3.1 Earthquake condition at downstream

Slice Number	Width (m)	Weight (kN)	Angle of Slice Base	Base Material	Base Cohesion kPa	Base Friction Angle	Shear stress kPa	Shear strength kPa	Base normal stress kPa	Pore pressure kPa	Eff. Normal stress kPa	Base vertical stress kPa	Eff. vertical stress kPa
1	0.12533 3	0.0731165	-0.736299	soil	0.388	16	0.983069	0.558903	0.596008	0	0.596008	0.583374	0.583374
2	0.12533 3	0.216973	0.190641	soil	0.388	16	1.553	0.882923	1.726	0	1.726	1.73117	1.73117
3	0.12533 3	0.356077	1.11763	soil	0.388	16	2.09477	1.19094	2.80018	0	2.80018	2.84105	2.84105
4	0.12533 3	0.490426	2.04491	soil	0.388	16	2.60905	1.48332	3.81983	0	3.81983	3.91298	3.91298
5	0.12533 3	0.620012	2.97273	soil	0.388	16	3.09641	1.7604	4.78613	0	4.78613	4.94693	4.94693
6	0.12533 3	0.744827	3.90133	soil	0.388	16	3.55743	2.0225	5.70019	0	5.70019	5.9428	5.9428
7	0.12533 3	0.864855	4.83096	soil	0.388	16	3.99262	2.26992	6.56304	0	6.56304	6.90048	6.90048
8	0.12533 3	0.980079	5.76187	soil	0.388	16	4.40245	2.50292	7.37561	0	7.37561	7.81984	7.81984
9	0.12533 3	1.09048	6.6943	soil	0.388	16	4.78737	2.72176	8.13883	0	8.13883	8.70074	8.70074
10	0.12533 3	1.19603	7.62852	soil	0.388	16	5.14779	2.92667	8.85336	0	8.85336	9.54283	9.54283
11	0.12533 3	1.29669	8.56478	soil	0.388	16	5.48407	3.11785	9.52015	0	9.52015	10.3461	10.3461
12	0.12533 3	1.39244	9.50336	soil	0.388	16	5.79656	3.29551	10.1397	0	10.1397	11.1101	11.1101
13	0.12533 3	1.48324	10.4445	soil	0.388	16	6.08556	3.45982	10.7127	0	10.7127	11.8345	11.8345
14	0.12533 3	1.56904	11.3885	soil	0.388	16	6.35139	3.61095	11.2398	0	11.2398	12.5191	12.5191
15	0.12533 3	1.64979	12.3357	soil	0.388	16	6.59428	3.74904	11.7213	0	11.7213	13.1634	13.1634
16	0.12533 3	1.72545	13.2863	soil	0.388	16	6.81448	3.87423	12.1579	0	12.1579	13.7671	13.7671
17	0.12533 3	1.79595	14.2406	soil	0.388	16	7.0122	3.98664	12.55	0	12.55	14.3296	14.3296
18	0.12533 3	1.86123	15.199	soil	0.388	16	7.18764	4.08638	12.8978	0	12.8978	14.8505	14.8505
19	0.12533 3	1.92122	16.1618	soil	0.388	16	7.34094	4.17354	13.2017	0	13.2017	15.3292	15.3292
20	0.12533 3	1.97585	17.1293	soil	0.388	16	7.47227	4.2482	13.4621	0	13.4621	15.7651	15.7651
21	0.12533	2.02503	18.1018	soil	0.388	16	7.58171	4.31042	13.6791	0	13.6791	16.1574	16.1574

	3												
22	0.12533 3	2.06867	19.0798	soil	0.388	16	7.66941	4.36028	13.853	0	13.853	16.5057	16.5057
23	0.12533 3	2.10668	20.0636	soil	0.388	16	7.73542	4.39781	13.9839	0	13.9839	16.809	16.809
24	0.12533 3	2.13896	21.0536	soil	0.388	16	7.77981	4.42305	14.0719	0	14.0719	17.0666	17.0666
25	0.12533 3	2.16539	22.0502	soil	0.388	16	7.80261	4.43601	14.1171	0	14.1171	17.2775	17.2775
26	0.12533 3	2.18585	23.0539	soil	0.388	16	7.80386	4.43672	14.1196	0	14.1196	17.4408	17.4408
27	0.12533 3	2.20021	24.0651	soil	0.388	16	7.78354	4.42517	14.079 3	0	14.0793	17.5553	17.5553
28	0.12533 3	2.20832	25.0844	soil	0.388	16	7.74165	4.40135	13.9962	0	13.9962	17.6201	17.6201
29	0.12533 3	2.21004	26.1123	soil	0.388	16	7.67813	4.36524	13.8703	0	13.8703	17.6338	17.6338
30	0.12533 3	2.20519	27.1492	soil	0.388	16	7.59295	4.31681	13.7014	0	13.7014	17.5951	17.5951
31	0.12533 3	2.19358	28.1959	soil	0.388	16	7.48599	4.256	13.4893	0	13.4893	17.5026	17.5026
32	0.12533 3	2.17504	29.2529	soil	0.388	16	7.35716	4.18276	13.2339	0	13.2339	17.3546	17.3546
33	0.12533 3	2.14934	30.321	soil	0.388	16	7.20637	4.09703	12.9349	0	12.9349	17.1495	17.1495
34	0.12533 3	2.11624	31.4009	soil	0.388	16	7.03347	3.99873	12.5921	0	12.5921	16.8855	16.8855
35	0.12533 3	2.0755	32.4933	soil	0.388	16	6.8382 6	3.88775	12.2051	0	12.2051	16.5604	16.5604
36	0.12533 3	2.02683	33.5992	soil	0.388	16	6.62061	3.76401	11.7735	0	11.7735	16.1721	16.1721
37	0.12533 3	1.96993	34.7195	soil	0.388	16	6.38029	3.62738	11.2971	0	11.2971	15.7182	15.7182
38	0.12533 3	1.90447	35.8551	soil	0.388	16	6.11707	3.47773	10.7752	0	10.7752	15.1959	15.1959
39	0.12533 3	1.83008	37.0073	soil	0.388	16	5.8307 1	3.31493	10.207 4	0	10.2074	14.6023	14.6023
40	0.12533 3	1.74635	38.1772	soil	0.388	16	5.52095	3.13882	9.59323	0	9.59323	13.9342	13.9342
41	0.12533 3	1.65282	39.3663	soil	0.388	16	5.1874 8	2.94923	8.9321	0	8.9321	13.188	13.188
42	0.12533 3	1.549	40.5759	soil	0.388	16	4.83001	2.746	8.22332	0	8.22332	12.3596	12.3596
43	0.12533 3	1.43432	41.8078	soil	0.388	16	4.44823	2.52895	7.46637	0	7.46637	11.4446	11.4446
44	0.12533 3	1.30815	43.0639	soil	0.388	16	4.04176	2.29786	6.66049	0	6.66049	10.4379	10.4379
45	0.12533 3	1.16978	44.3464	soil	0.388	16	3.6103	2.05256	5.80502	0	5.80502	9.33388	9.33388
46	0.12533 3	1.0184	45.6575	soil	0.388	16	3.15347	1.79284	4.89926	0	4.89926	8.12596	8.12596
47	0.12533 3	0.853065	47.0002	soil	0.388	16	2.6709 3	1.5185	3.94254	0	3.94254	6.80677	6.80677
48	0.12533 3	0.672721	48.3775	soil	0.388	16	2.16237	1.22937	2.9342	0	2.9342	5.36781	5.36781
49	0.12533 3	0.475921	49.7931	soil	0.388	16	1.62699	0.92499	1.8727 1	0	1.87271	3.79752	3.79752
50	0.12533 3	0.183011	51.2515	soil	0.388	16	0.871384	0.49540 7	0.374573	0	0.37457 3	1.46035	1.46035

### 3.2 Earthquake condition at upstream

Slice Number	Width (m)	Weight (kN)	Angle of Slice Base	Base Material	Base Cohesion kPa	Base friction Angle	Shear stress kPa	Shear strength kPa	Base normal stress kPa	Pore pressure kPa	Eff. Normal stress kPa	Base vertical stress kPa	Eff. vertical stress kPa
1	0.170493	0.352925	-52.4005	soil	0.388	16	1.0422	0.59357 7	0.716933	0	0.71693 3	2.07028	2.07028
2	0.170493	1.04001	-50.805	soil	0.388	16	2.32015	1.32143	3.25526	0	3.25526	6.1005 4	6.10054
3	0.170493	1.50187	-49.2623	soil	0.388	16	3.22905	1.83909	5.06054	0	5.06054	8.80966	8.80966

4	0.170493	1.85321	-47.7664	soil	0.388	16	3.9587	2.25466	6.5098	0	6.5098	10.8705	10.8705	
5	0.170493	2.17352	-46.3125	soil	0.388	16	4.64947	2.64808	7.88185	0	7.88185	12.7494	12.7494	
6	0.170493	2.46525	-44.8962	soil	0.388	16	5.30192	3.01968	9.17775	0	9.17775	14.4605	14.4605	
7	0.170493	2.73049	-43.5141	soil	0.388	16	5.91667	3.36981	10.3988	0	10.3988	16.0163	16.0163	
8	0.170493	2.97105	-42.1629	soil	0.388	16	6.49436	3.69883	11.5462	0	11.5462	17.4273	17.4273	
9	0.170493	3.18849	-40.84	soil	0.388	16	7.03556	4.00707	12.6212	0	12.6212	18.7027	18.7027	
10	0.170493	3.38421	-39.543	soil	0.388	16	7.5409	4.29488	13.6249	0	13.6249	19.8507	19.8507	
11	0.170493	3.5594	-38.2699	soil	0.388	16	8.0109	4.56257	14.5585	0	14.5585	20.8783	20.8783	
12	0.170493	3.71515	-37.0187	soil	0.388	16	8.44611	4.81044	15.4229	0	15.4229	21.7918	21.7918	
13	0.170493	3.85242	-35.7878	soil	0.388	16	8.84701	5.03877	16.2192	0	16.2192	22.597	22.597	
14	0.170493	3.97207	-34.5757	soil	0.388	16	9.21404	5.24781	16.9482	0	16.9482	23.2988	23.2988	
15	0.170493	4.07487	-33.381	soil	0.388	16	9.54762	5.4378	17.6107	0	17.6107	23.9017	23.9017	
16	0.170493	4.16152	-32.2025	soil	0.388	16	9.84811	5.60894	18.2076	0	18.2076	24.4099	24.4099	
17	0.170493	4.23264	-31.0391	soil	0.388	16	10.1158	5.76143	18.7394	0	18.7394	24.827	24.827	
18	0.170493	4.28882	-29.8898	soil	0.388	16	10.3512	5.89545	19.2067	0	19.2067	25.1565	25.1565	
19	0.170493	4.33056	-28.7536	soil	0.388	16	10.5543	6.01113	19.6102	0	19.6102	25.4013	25.4013	
20	0.170493	4.35835	-27.6296	soil	0.388	16	10.7254	6.1086	19.9501	0	19.9501	25.5643	25.5643	
21	0.170493	4.37262	-26.517	soil	0.388	16	10.8648	6.18798	20.2269	0	20.2269	25.6479	25.6479	
22	0.170493	4.37377	-25.4151	soil	0.388	16	10.9725	6.24934	20.441	0	20.441	25.6546	25.6546	
23	0.170493	4.36215	-24.3232	soil	0.388	16	11.0488	6.29277	20.5923	0	20.5923	25.5864	25.5864	
24	0.170493	4.33812	-23.2407	soil	0.388	16	11.0936	6.31829	20.6814	0	20.6814	25.4454	25.4454	
25	0.170493	4.30196	-22.1668	soil	0.388	16	11.107	6.32596	20.7081	0	20.7081	25.2333	25.2333	
26	0.170493	4.25397	-21.1011	soil	0.388	16	11.0892	6.31577	20.6726	0	20.6726	24.9517	24.9517	
27	0.170493	4.1944	-20.043	soil	0.388	16	11.0399	6.28772	20.5747	0	20.5747	24.6023	24.6023	
28	0.170493	4.12349	-18.992	soil	0.388	16	10.9592	6.24177	20.4145	0	20.4145	24.1863	24.1863	
29	0.170493	4.04146	-17.9475	soil	0.388	16	10.8471	6.17789	20.1918	0	20.1918	23.7052	23.7052	
30	0.170493	3.94851	-16.9092	soil	0.388	16	10.7033	6.09601	19.9062	0	19.9062	23.16	23.16	
31	0.170493	3.84483	-15.8766	soil	0.388	16	10.5278	5.99604	19.5576	0	19.5576	22.5518	22.5518	
32	0.170493	3.73059	-14.8493	soil	0.388	16	10.3203	5.87788	19.1455	0	19.1455	21.8817	21.8817	
33	0.170493	3.60594	-13.8268	soil	0.388	16	10.0807	5.74139	18.6695	0	18.6695	21.1505	21.1505	
34	0.170493	3.47102	-12.8088	soil	0.388	16	9.8086	5.58644	18.1291	0	18.1291	20.3591	20.3591	
35	0.170493	3.32597	-11.7949	soil	0.388	16	9.50381	5.41285	17.5238	0	17.5238	19.5083	19.5083	
36	0.170493	3.17089	-10.7847	soil	0.388	16	9.16598	5.22044	16.8527	0	16.8527	18.5987	18.5987	
37	0.170493	3.0059	-9.77796	soil	0.388	16	8.7947	5.00898	16.1153	0	16.1153	17.6309	17.6309	
38	0.170493	2.83108	-8.77422	soil	0.388	16	8.38959	4.77825	15.3106	0	15.3106	16.6055	16.6055	
39	0.170493	2.64653	-7.77318	soil	0.388	16	7.95015	4.52797	14.4378	0	14.4378	15.523	15.523	
40	0.170493	2.45232	-6.77452	soil	0.388	16	7.47588	4.25785	13.4958	0	13.4958	14.3838	14.3838	
41	0.170493	2.2485	-5.77793	soil	0.388	16	6.96623	3.96758	12.4835	0	12.4835	13.1884	13.1884	
42	0.170493	2.03514	-4.78309	soil	0.388	16	6.42056	3.6568	11.3996	0	11.3996	11.9369	11.9369	
43	0.170493	1.81229	-3.7897	soil	0.388	16	5.83824	3.32514	10.243	0	10.243	10.6297	10.6297	
44	0.170493	1.57997	-2.79744	soil	0.388	16	5.21852	2.97218	9.01209	0	9.01209	9.26708	9.26708	
45	0.170493	1.33822	-1.80602	soil	0.388	16	4.56061	2.59747	7.70535	0	7.70535	7.84915	7.84915	
46	0.170493	1.08705	-0.815149	soil	0.388	16	3.86363	2.20051	6.32097	0	6.32097	6.37595	6.37595	
47	0.170493	0.826485	0.175483	soil	0.388	16	3.12667	1.78078	4.8572	0	4.8572	4.84762	4.84762	
48	0.170493	0.556519	1.16617	soil	0.388	16	2.34871	1.3377	3.31198	0	3.31198	3.26417	3.26417	
49	0.170493	0.277147	2.1572	soil	0.388	16	1.52864	0.870632	1.68313	0	1.68313	1.62555	1.62555	
				Cement										
50	0.0626824	0.0251959	2.83516	concrete lining		20	10	35.7888	20.3833	2.17402	0	2.17402	0.401643	0.401643

**Report on**  
**Inspection of Ash Dyke on 111 hec land**  
**at Satpura Thermal Power Station,**  
**MPPGCL, Sarni**

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## **Introduction**

Satpura Thermal Power Plant is located at Sarni town near Ghoradongri Railway station in the Betul district of Madhya Pradesh, India. The power plant is one of the coal-based power plants of MPPGCL with an installed capacity of 1330 MW. The Water for the plant has been procured from the nearby Tawa Dam Lake area and the coal for the plant has been procured by Rail/Road/Belt from Western Coal Fields.

The powerplant has an ash pond constructed on 111 hectare land which is being used for storage of pond ash was inspected (Fig 1). The pond has earthen starter dykes with external berms at every 4 mts height or part thereof and provided with vertical chimney, chimney drains and downstream toe drains etc.

As per the request from the Superintending Engineer (civil), STPS Sarni, Prof Neelima Satyam, IIT Indore visited the site on 10<sup>th</sup> April 2025. During the visit, it was observed that the surface of the downstream slope was in stable condition. There were no seepage issues and gully formations. The loose surface material looked constrained, and the seepage has been controlled by providing drains at regular lengths along the periphery of the raising (Fig 2a and 2 b). After a detailed inspection of the ash dyke no. 111 of STPS Sarni and slope stability analysis of the existing ash dyke considering seepage, the following recommendations are provided.



Fig 1: Side view of Ash dyke no 111



Fig 2(a) Site Visit on 10<sup>th</sup> April 2025



Fig 2 (b): Draining across the ash dyke no. 111 using Plain cement concrete (PCC) pipes

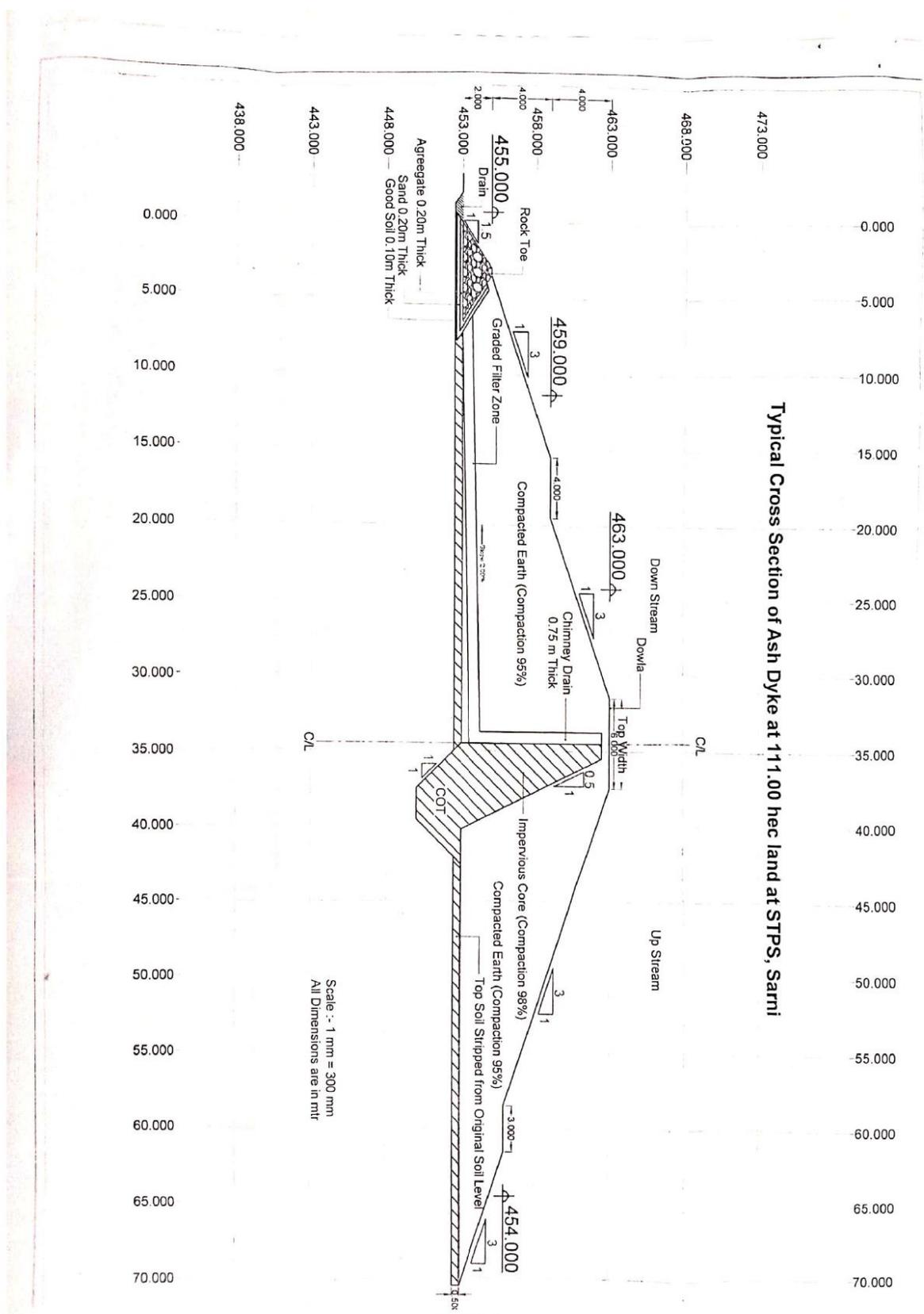
## **Scope**

To carry-out the slope stability analysis for the ash dyke no. 111 hectare at STPS Sarni and provide necessary recommendations for the probable raising of dyke in future

## **Design Consideration**

*Table 1: Data considered from CAD design provided by the client*

Downstream toe level	453 m
Top level of ash dyke	463 m
RL of foundation	450 m
Width of dyke	70 m



Scanned with CamScanner

Fig 3: Plan view of ash dyke no. 111 under inspection (provided by client)

Two staged analysis was conducted for slope stability, the first stage is used to develop the hydraulic conditions and the second stage was for slope stability analysis.

Boundary Conditions: The upstream and downstream water levels and drainage conditions were taken as the hydraulic boundary conditions. The boundary conditions were varied as per the requirement of the analysis.

Design Conditions:

As per IS 7894:1975, the following cases are critical for the stability of the earthen dam.

1. Construction with or without a partial pool (u/s and d/s slope)
2. Reservoir pool level (u/s slope)
3. Sudden drawdown (u/s slope)
4. Steady Seepage (d/s slope)
5. Steady Seepage with sustained rainfall (d/s slope)
6. Earthquake condition (u/s and d/s slope)

Since the dyke is constrained completely and with no sign of any leakage or failure, only condition no. (3) sudden drawdown for the upstream slope and (4) steady seepage for the downstream slope has been considered for the analysis. Since there are no issues of seepage, the possible infiltration during rainfall is not considered. District Betul falls under seismic zone 3 as per IS 1893(1)-2016 with a low to moderate chance of earthquake hence condition (6) has been considered for both upstream and downstream slope.

The material properties provided by the client are tabulated below in Table 2.

*Table 2: Physical properties of soil materials considered for analysis (provided by client)*

Material	Specific Gravity	Unit Weight (kg/m <sup>3</sup> )	Cohesion (KPa)	Angle of Internal friction	Permeability (cm/s)
Dam	2.54	2079	100	10	1.0395 * 10 <sup>-5</sup>

The dyke has 3 layers of soil embankment (Fig 4) which stores the pond ash with the provision of a chimney drain adjacent to the impervious core of the dam. The limit equilibrium analysis for both the conditions (steady state and rapid drawdown) has been done by Morgenstern-price method which is considered one of the most accurate method for stability analysis of embankments.

Below mentioned are the results of the analysis carried out for the stability check of the ash dyke at 111 compartments of STPS Sarni. The FoS obtained after different analyses are listed in Table 3.



Fig 4: Soil embankment is raised in three zones for ash dyke at 111 hec land

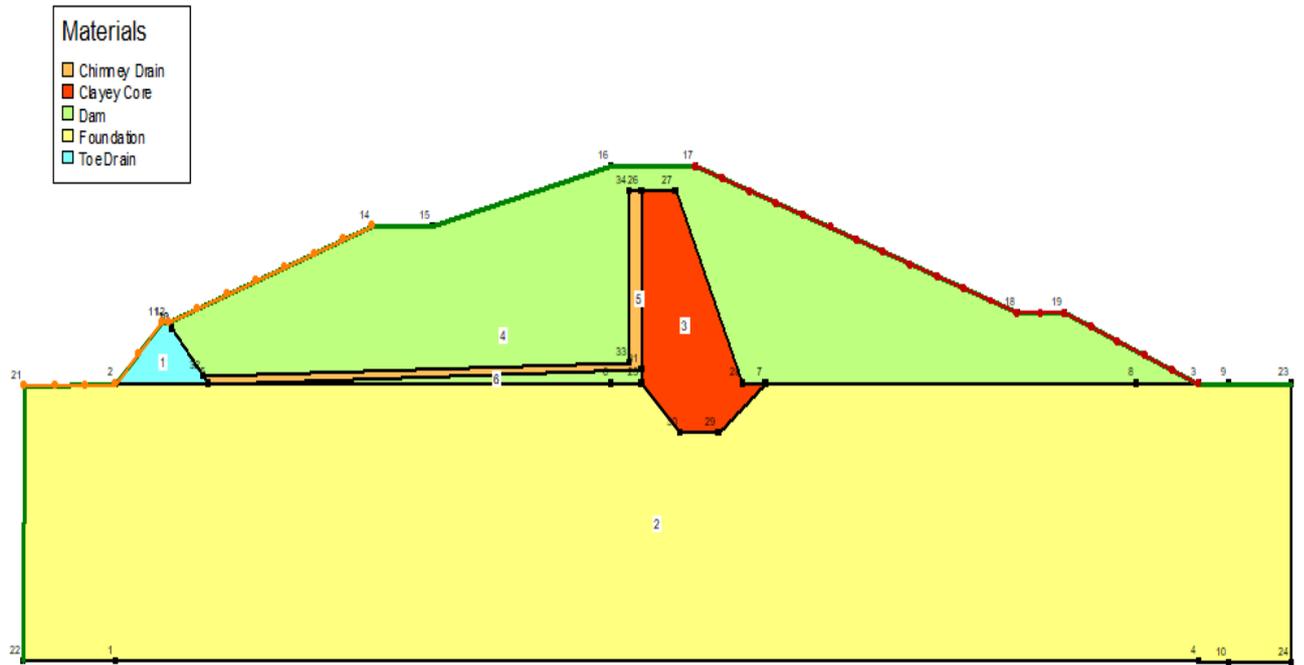


Fig 5 – Cross-section of ash dyke used for analysis

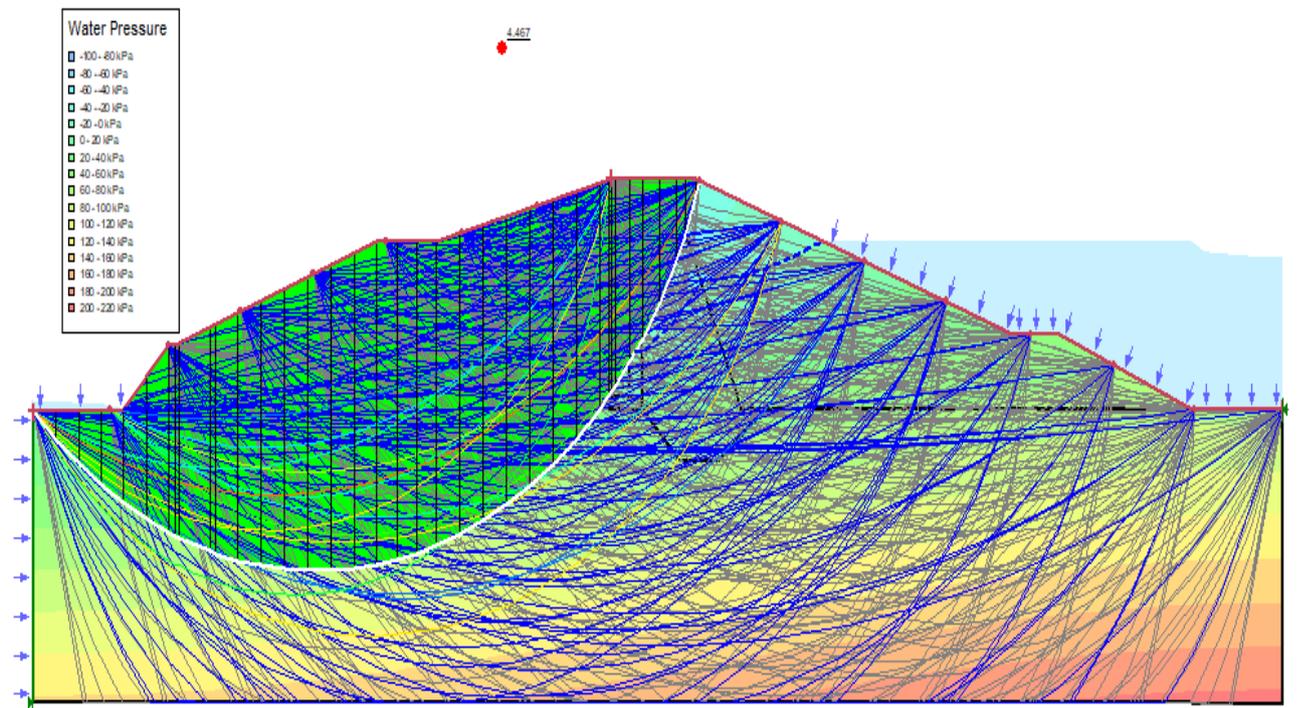


Fig 6 – Slip surfaces considered for analysis for steady-state seepage for downstream slope

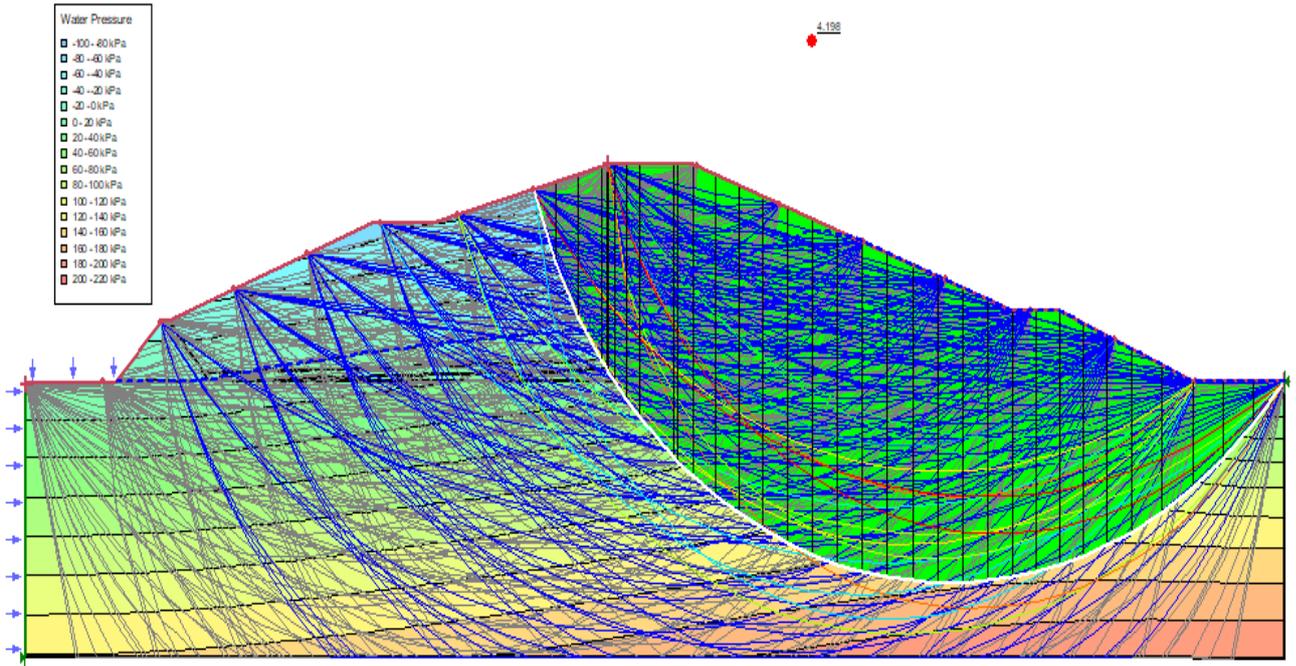


Fig 7 – Slip surfaces considered for analysis of sudden drawdown in Upstream slope

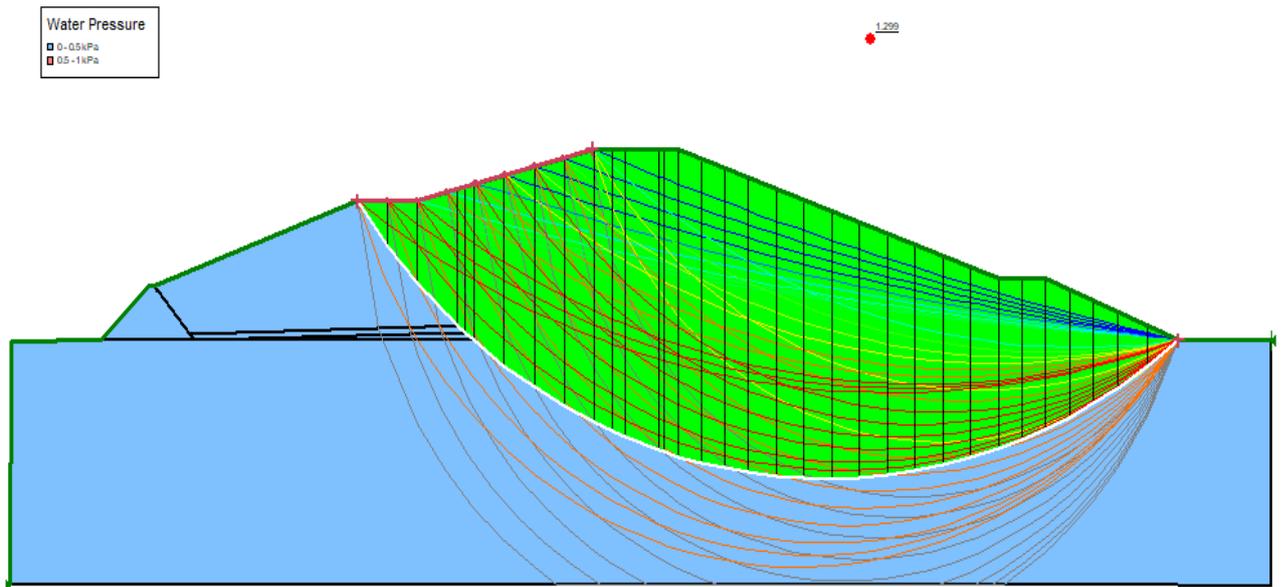


Fig 8 – Slip surfaces considered for analysis of upstream of slope in earthquake condition

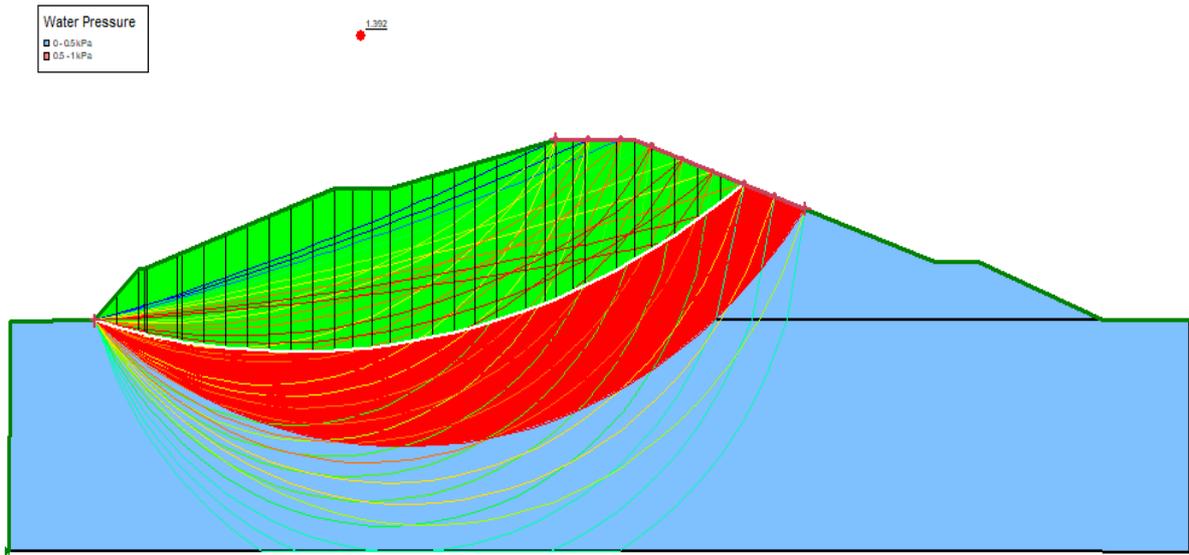


Fig 8 – Slip surfaces considered for analysis of downstream of slope in earthquake condition

Table 3: Results of slope stability analysis for the ash dyke 111

Condition	Method	Minimum required FoS	Obtained FoS	Safe/ Unsafe
Steady seepage (for d/s slope)	Morgenstern-price	1.5	4.450	<b>Safe</b>
Sudden drawdown (for u/s slope)	Morgenstern-price	1.3	3.980	<b>Safe</b>
Earthquake condition (for u/s slope)	Morgenstern-price	1	1.209	<b>Safe</b>
Earthquake condition (for d/s slope)	Morgenstern-price	1	1.245	<b>Safe</b>

## **Inferences from site inspection and slope stability analysis**

- No new gully formations or seepage was observed during the field visit. Prima facie dykes are properly maintained and no. 111 was inspected for stability analysis.
- Samples from embankment portion of 111 hec land was used to calculate geotechnical properties to be used in the analysis. For rest of the sections data was assumed based on literature
- Seepage analysis for both steady and sudden drawdown conditions indicates water will drain out in 12 hours' time considering the level to be 2/3<sup>rd</sup> of F.R.L.
- The phreatic line goes well below the surface indicating surface and toe drains are well connected.

## **Recommendation for slope stability**

Though the ash dyke is stable, safe and sound in all the conditions, however regular inspection of dykes is recommended. The surface and toe drains need to be maintained regularly. The focus should be given to the deaccumulation of water near the slopes

## **Annexure**

### **Details of critical slip surface: Steady seepage (for d/s slope)**

Slip Surface: 9  
Factor of Safety: 4.467  
Volume: 450.04439 m<sup>3</sup>  
Weight: 9,305.3314 kN

Resisting Moment: 2,05,526.7 kN-m  
 Activating Moment: 46,013.34 kN-m  
 Resisting Force: 6,526.6816 kN  
 Activating Force: 1,461.153 kN  
 Slip Rank: 1 of 405 slip surfaces  
 Exit: (37.729842, 24.918229) m  
 Entry: (-5.884278, 13.900266) m  
 Radius: 26.267607 m  
 Center: (12.599586, 32.563974) m

### Slip Columns

Column	X	Y	PWP	Base Normal Stress	Frictional Strength	Cohesive Strength	Suction Strength
Column 1	37.614921 m	24.559099 m	-29.357127 kPa	- 53.979955 kPa	-10.49264 kPa	100 kPa	0 kPa
Column 2	37.158879 m	23.296028 m	-33.605076 kPa	- 20.903391 kPa	-4.0632075 kPa	100 kPa	0 kPa
Column 3	36.508879 m	21.711583 m	-29.542171 kPa	7.2065601 kPa	0.63049231 kPa	125 kPa	0 kPa
Column 4	35.650000 m	20.020386 m	-19.343963 kPa	49.925712 kPa	4.3679338 kPa	125 kPa	0 kPa
Column 5	34.550000 m	18.170904 m	-10.276793 kPa	92.983024 kPa	8.1349605 kPa	125 kPa	0 kPa
Column 6	33.600000 m	16.799270 m	- 0.67914903 kPa	145.66086 kPa	53.016218 kPa	0 kPa	0 kPa
Column 7	32.699113 m	15.670479 m	10.222119 kPa	145.42455 kPa	26.28069 kPa	100 kPa	0 kPa
Column 8	32.099113 m	14.964719 m	17.015528 kPa	175.21977 kPa	57.581635 kPa	0 kPa	0 kPa
Column 9	31.903221 m	14.750033 m	19.062321 kPa	178.7313 kPa	58.114755 kPa	0 kPa	0 kPa
Column 10	31.495028 m	14.322581 m	24.484521 kPa	170.54382 kPa	28.391052 kPa	100 kPa	0 kPa
Column 11	30.420498 m	13.294260 m	35.257166 kPa	182.42045 kPa	28.605644 kPa	125 kPa	0 kPa
Column 12	28.894267 m	11.984297 m	47.031319 kPa	203.45029 kPa	30.404768 kPa	125 kPa	0 kPa

Column 13	27.368037 m	10.860793 m	56.798792 kPa	221.1295 kPa	31.942654 kPa	125 kPa	0 kPa
Column 14	25.841807 m	9.895721 m	64.912251 kPa	236.23419 kPa	33.301611 kPa	125 kPa	0 kPa
Column 15	24.315576 m	9.069387 m	71.611449 kPa	249.24959 kPa	34.529356 kPa	125 kPa	0 kPa
Column 16	22.789346 m	8.367479 m	77.061299 kPa	260.47005 kPa	35.65105 kPa	125 kPa	0 kPa
Column 17	21.263115 m	7.779363 m	81.385665 kPa	270.05472 kPa	36.673549 kPa	125 kPa	0 kPa
Column 18	19.850000 m	7.325881 m	84.496977 kPa	280.88245 kPa	38.173469 kPa	125 kPa	0 kPa
Column 19	18.550000 m	6.987923 m	86.590233 kPa	293.22722 kPa	40.166161 kPa	125 kPa	0 kPa
Column 20	17.250000 m	6.719735 m	88.007579 kPa	304.49968 kPa	42.081801 kPa	125 kPa	0 kPa
Column 21	15.842857 m	6.508528 m	88.782962 kPa	309.71978 kPa	42.945766 kPa	125 kPa	0 kPa
Column 22	14.328571 m	6.364317 m	88.828473 kPa	308.36185 kPa	42.672966 kPa	125 kPa	0 kPa
Column 23	12.814286 m	6.308159 m	88.040055 kPa	304.84343 kPa	42.142306 kPa	125 kPa	0 kPa
Column 24	11.300000 m	6.339489 m	86.431489 kPa	298.94829 kPa	41.309082 kPa	125 kPa	0 kPa
Column 25	9.785714 m	6.458622 m	84.004849 kPa	290.45768 kPa	40.130366 kPa	125 kPa	0 kPa
Column 26	8.271429 m	6.666774 m	80.761069 kPa	279.16367 kPa	38.565559 kPa	125 kPa	0 kPa
Column 27	6.757143 m	6.966124 m	76.694078 kPa	264.88271 kPa	36.580164 kPa	125 kPa	0 kPa
Column 28	5.832258 m	7.183660 m	73.904455 kPa	254.90414 kPa	35.182776 kPa	125 kPa	0 kPa
Column 29	4.632258 m	7.557272 m	69.433235 kPa	240.04477 kPa	33.163524 kPa	125 kPa	0 kPa
Column 30	3.500000 m	7.923086 m	65.175259 kPa	224.7013 kPa	31.008721 kPa	125 kPa	0 kPa
Column 31	3.200000 m	8.036660 m	63.887374 kPa	222.47632 kPa	30.826568 kPa	125 kPa	0 kPa
Column 32	2.250000 m	8.435002 m	59.460081 kPa	197.22068 kPa	26.777948 kPa	125 kPa	0 kPa

Column 33	0.750000 m	9.136039 m	51.908436 kPa	147.94995 kPa	18.668578 kPa	125 kPa	0 kPa
Column 34	-0.735535 m	9.949097 m	43.43492 kPa	114.65123 kPa	13.843049 kPa	125 kPa	0 kPa
Column 35	-2.206604 m	10.885169 m	33.95774 kPa	95.578956 kPa	11.977951 kPa	125 kPa	0 kPa
Column 36	-3.677674 m	11.968852 m	23.244721 kPa	72.79995 kPa	9.6325607 kPa	125 kPa	0 kPa
Column 37	-5.148743 m	13.225222 m	10.939327 kPa	46.867992 kPa	6.9838249 kPa	125 kPa	0 kPa

### Details of critical slip surface: Sudden drawdown (for u/s slope)

Slip Surface: 359  
 Factor of Safety: 4.198  
 Volume: 576.71238 m<sup>3</sup>  
 Weight: 11,957.818 kN  
 Resisting Moment: 2,47,616.77 kN-m  
 Activating Moment: 58,983.09 kN-m  
 Resisting Force: 7,216.5681 kN  
 Activating Force: 1,718.9889 kN  
 Slip Rank: 1 of 405 slip surfaces  
 Exit: (75.959087, 14) m  
 Entry: (27.09632, 23.720779) m  
 Radius: 28.344227 m  
 Center: (54.166324, 32.12376) m

### Slip Columns

Column	X	Y	PWP	Base Normal Stress	Frictional Strength	Cohesive Strength	Suction Strength
Column 1	27.836219 m	21.828491 m	- 53.044183 kPa	- 15.777396 kPa	- 3.0668151 kPa	100 kPa	0 kPa
Column 2	29.316018 m	18.578749 m	- 20.334013 kPa	65.877076 kPa	12.805206 kPa	100 kPa	0 kPa

Column 3	30.795816 m	16.139493 m	4.3201393 kPa	125.45034 kPa	23.545327 kPa	100 kPa	0 kPa
Column 4	31.693808 m	14.851994 m	17.379409 kPa	177.12919 kPa	58.144166 kPa	0 kPa	0 kPa
Column 5	31.925950 m	14.552571 m	20.849644 kPa	164.76884 kPa	27.975059 kPa	100 kPa	0 kPa
Column 6	32.186781 m	14.229422 m	25.708656 kPa	171.96014 kPa	28.428408 kPa	100 kPa	0 kPa
Column 7	32.786781 m	13.524998 m	34.468331 kPa	180.97881 kPa	28.478752 kPa	125 kPa	0 kPa
Column 8	33.600000 m	12.628031 m	44.5042 kPa	205.39893 kPa	31.274768 kPa	125 kPa	0 kPa
Column 9	35.100000 m	11.203544 m	61.231481 kPa	236.96033 kPa	34.158228 kPa	125 kPa	0 kPa
Column 10	36.350000 m	10.079791 m	74.869064 kPa	261.50077 kPa	36.277528 kPa	125 kPa	0 kPa
Column 11	37.000000 m	9.577861 m	81.063866 kPa	271.879 kPa	37.090704 kPa	125 kPa	0 kPa
Column 12	38.250000 m	8.687807 m	91.869643 kPa	285.48652 kPa	37.635308 kPa	125 kPa	0 kPa
Column 13	39.750000 m	7.735120 m	103.33764 kPa	295.80514 kPa	37.411893 kPa	125 kPa	0 kPa
Column 14	41.250000 m	6.907621 m	113.35439 kPa	304.99344 kPa	37.250856 kPa	125 kPa	0 kPa
Column 15	42.815000 m	6.167039 m	122.44788 kPa	313.68319 kPa	37.17238 kPa	125 kPa	0 kPa
Column 16	44.445000 m	5.512894 m	130.68421 kPa	320.93585 kPa	36.981172 kPa	125 kPa	0 kPa
Column 17	46.075000 m	4.972288 m	137.72572 kPa	326.35387 kPa	36.665598 kPa	125 kPa	0 kPa
Column 18	47.705000 m	4.538514 m	143.64599 kPa	329.95589 kPa	36.214977 kPa	125 kPa	0 kPa
Column 19	49.335000 m	4.206572 m	148.48671 kPa	331.69942 kPa	35.612943 kPa	125 kPa	0 kPa
Column 20	50.965000 m	3.972847 m	152.28087 kPa	331.49392 kPa	34.835489 kPa	125 kPa	0 kPa
Column 21	52.595000 m	3.834895 m	155.03172 kPa	329.21168 kPa	33.857154 kPa	125 kPa	0 kPa
Column 22	54.225000 m	3.791314 m	156.74926 kPa	324.69762 kPa	32.645856 kPa	125 kPa	0 kPa
Column 23	55.855000 m	3.841664 m	157.4142 kPa	317.77883 kPa	31.171727 kPa	125 kPa	0 kPa
Column 24	57.485000 m	3.986452 m	156.99184 kPa	308.27401 kPa	29.406276 kPa	125 kPa	0 kPa
Column 25	59.050000 m	4.213812 m	155.55344 kPa	302.21143 kPa	28.507426 kPa	125 kPa	0 kPa
Column 26	60.550000 m	4.518483 m	153.10344 kPa	299.79201 kPa	28.513371 kPa	125 kPa	0 kPa
Column 27	62.083333 m	4.919889 m	149.46854 kPa	287.79783 kPa	26.888491 kPa	125 kPa	0 kPa
Column 28	63.650000 m	5.426119 m	144.41147 kPa	265.84347 kPa	23.60399 kPa	125 kPa	0 kPa
Column 29	65.216667 m	6.036188 m	137.82667 kPa	240.7883 kPa	20.013713 kPa	125 kPa	0 kPa

Column 30	67.000000 m	6.876313 m	127.89571 kPa	208.21859 kPa	15.613188 kPa	125 kPa	0 kPa
Column 31	69.000000 m	7.999516 m	113.01264 kPa	167.0279 kPa	10.499502 kPa	125 kPa	0 kPa
Column 32	71.000000 m	9.353692 m	92.220732 kPa	129.69726 kPa	7.2846996 kPa	125 kPa	0 kPa
Column 33	72.989772 m	10.973881 m	63.840616 kPa	96.335506 kPa	6.3163667 kPa	125 kPa	0 kPa
Column 34	74.969315 m	12.927390 m	24.541531 kPa	57.88438 kPa	6.4811932 kPa	125 kPa	0 kPa

### Details of critical slip surface: Earthquake condition (for u/s slope)

Slip Surface: 3

Factor of Safety: 1.299

Volume: 598.69287 m<sup>3</sup>

Weight: 12,374.561 kN

Resisting Moment: 3,62,956.72 kN-m

Activating Moment: 2,79,390.62 kN-m

Resisting Force: 8,822.3578 kN

Activating Force: 6,788.9799 kN

Slip Rank: 1 of 45 slip surfaces

Exit: (70, 14) m

Entry: (16.6, 22) m

Radius: 37.157543 m

Center: (47.082543, 43.248472) m

Horizontal Seismic Coef.: 0.5886

Verticle Seismic Coef.: 0.2943

Column	X	Y	PWP	Base Normal Stress	Frictional Strength	Cohesive Strength
Column 1	17.575000 m	20.722797 m	0 kPa	-56.982354 kPa	0 kPa	100.94716 kPa
Column 2	19.525000 m	18.365783 m	0 kPa	16.431756 kPa	0 kPa	110.41245 kPa
Column 3	21.813533 m	16.064950 m	0 kPa	77.21311 kPa	0 kPa	120.70938 kPa
Column 4	23.370506 m	14.642139 m	0 kPa	137.37113 kPa	0 kPa	55.236547 kPa
Column 5	23.889516 m	14.220174 m	0 kPa	121.45193 kPa	0 kPa	129.91967 kPa
Column 6	25.144450 m	13.282995 m	0 kPa	137.43491 kPa	0 kPa	159.33854 kPa
Column 7	27.103178 m	11.940994 m	0 kPa	170.88394 kPa	0 kPa	166.7061 kPa
Column 8	29.061907 m	10.772555 m	0 kPa	200.54061 kPa	0 kPa	173.47198 kPa
Column 9	31.020636 m	9.759394 m	0 kPa	228.60671 kPa	0 kPa	179.74362 kPa

Column 10	32.600000 m	9.035691 m	0 kPa	248.93087 kPa	0 kPa	183.93883 kPa
Column 11	33.600000 m	8.625940 m	0 kPa	263.73369 kPa	0 kPa	186.82512 kPa
Column 12	35.100000 m	8.095221 m	0 kPa	280.8746 kPa	0 kPa	189.50697 kPa
Column 13	36.350000 m	7.675014 m	0 kPa	296.21924 kPa	0 kPa	191.60348 kPa
Column 14	37.000000 m	7.488782 m	0 kPa	303.92245 kPa	0 kPa	192.43168 kPa
Column 15	38.250000 m	7.164224 m	0 kPa	315.32159 kPa	0 kPa	192.89017 kPa
Column 16	39.750000 m	6.829638 m	0 kPa	327.04792 kPa	0 kPa	192.42194 kPa
Column 17	41.250000 m	6.559404 m	0 kPa	341.23698 kPa	0 kPa	191.90575 kPa
Column 18	42.905556 m	6.337698 m	0 kPa	359.55012 kPa	0 kPa	191.26603 kPa
Column 19	44.716667 m	6.177429 m	0 kPa	381.12866 kPa	0 kPa	190.23087 kPa
Column 20	46.527778 m	6.106111 m	0 kPa	403.33515 kPa	0 kPa	188.79719 kPa
Column 21	48.338889 m	6.123230 m	0 kPa	424.86424 kPa	0 kPa	186.94059 kPa
Column 22	50.150000 m	6.228910 m	0 kPa	444.01373 kPa	0 kPa	184.63662 kPa
Column 23	51.961111 m	6.423913 m	0 kPa	458.71852 kPa	0 kPa	181.86205 kPa
Column 24	53.772222 m	6.709676 m	0 kPa	466.66246 kPa	0 kPa	178.59603 kPa
Column 25	55.583333 m	7.088353 m	0 kPa	465.48708 kPa	0 kPa	174.82108 kPa
Column 26	57.394444 m	7.562913 m	0 kPa	453.09473 kPa	0 kPa	170.52391 kPa
Column 27	59.050000 m	8.079803 m	0 kPa	438.29426 kPa	0 kPa	167.24185 kPa
Column 28	60.550000 m	8.626760 m	0 kPa	423.75425 kPa	0 kPa	165.06262 kPa
Column 29	62.083333 m	9.264269 m	0 kPa	390.78276 kPa	0 kPa	161.11457 kPa
Column 30	63.650000 m	10.000369 m	0 kPa	339.12119 kPa	0 kPa	155.3799 kPa
Column 31	65.216667 m	10.828865 m	0 kPa	280.03772 kPa	0 kPa	149.24499 kPa
Column 32	67.000000 m	11.902434 m	0 kPa	206.29807 kPa	0 kPa	141.74731 kPa
Column 33	69.000000 m	13.268920 m	0 kPa	120.07896 kPa	0 kPa	132.76925 kPa

**Details of critical slip surface: Earthquake condition (for d/s slope)**

Slip Surface: 32

Factor of Safety: 1.392  
 Volume: 327.5005 m<sup>3</sup>  
 Weight: 6,727.2016 kN  
 Resisting Moment: 3,64,661.03 kN-m  
 Activating Moment: 2,61,876.78 kN-m  
 Resisting Force: 6,645.9911 kN  
 Activating Force: 4,773.4024 kN  
 Slip Rank: 1 of 45 slip surfaces  
 Exit: (45.058596, 22.310884) m  
 Entry: (0, 14) m  
 Radius: 52.660862 m  
 Center: (13.928574, 64.785443) m  
 Horizontal Seismic Coef.: 0.5886  
 Vertical Seismic Coef.: 0.2943

Column	X	Y	PWP	Base Normal Stress	Frictional Strength	Cohesive Strength
Column 1	44.254334 m	21.744221 m	0 kPa	-19.178668 kPa	-3.7279554 kPa	100 kPa
Column 2	42.645810 m	20.654207 m	0 kPa	29.100438 kPa	5.6565522 kPa	100 kPa
Column 3	41.037286 m	19.647831 m	0 kPa	66.344373 kPa	12.89604 kPa	100 kPa
Column 4	39.428762 m	18.719601 m	0 kPa	95.565478 kPa	18.576047 kPa	100 kPa
Column 5	38.062250 m	17.984461 m	0 kPa	116.16685 kPa	10.163282 kPa	125 kPa
Column 6	36.850000 m	17.380239 m	0 kPa	130.36605 kPa	11.405552 kPa	125 kPa
Column 7	35.100000 m	16.582811 m	0 kPa	142.15668 kPa	12.437098 kPa	125 kPa
Column 8	33.600000 m	15.938586 m	0 kPa	139.18703 kPa	50.659936 kPa	0 kPa
Column 9	32.600000 m	15.549963 m	0 kPa	149.8778 kPa	29.133294 kPa	100 kPa
Column 10	31.618191 m	15.186254 m	0 kPa	153.78457 kPa	29.892693 kPa	100 kPa
Column 11	30.555445 m	14.823472 m	0 kPa	136.41285 kPa	49.650216 kPa	0 kPa
Column 12	28.865828 m	14.298431 m	0 kPa	159.38706 kPa	30.981705 kPa	100 kPa
Column 13	27.121434 m	13.809593 m	0 kPa	175.9596 kPa	34.203081 kPa	125 kPa
Column 14	25.650004 m	13.451195 m	0 kPa	185.35538 kPa	36.029436 kPa	125 kPa
Column 15	24.178574 m	13.137197 m	0 kPa	195.94813 kPa	38.088459 kPa	125 kPa
Column 16	22.707145 m	12.866792 m	0 kPa	207.59154 kPa	40.351707 kPa	125 kPa
Column 17	21.235715 m	12.639300 m	0 kPa	220.00669 kPa	42.764968 kPa	125 kPa
Column 18	19.850000 m	12.462645 m	0 kPa	234.81712 kPa	45.643824 kPa	125 kPa

Column 19	18.550000 m	12.331815 m	0 kPa	251.86587 kPa	48.957765 kPa	125 kPa
Column 20	17.250000 m	12.233465 m	0 kPa	268.90439 kPa	52.269719 kPa	125 kPa
Column 21	15.842857 m	12.164840 m	0 kPa	281.50535 kPa	54.719097 kPa	125 kPa
Column 22	14.328571 m	12.131544 m	0 kPa	287.78844 kPa	55.940406 kPa	125 kPa
Column 23	12.814286 m	12.141818 m	0 kPa	289.97591 kPa	56.365607 kPa	125 kPa
Column 24	11.300000 m	12.195688 m	0 kPa	286.92268 kPa	55.77212 kPa	125 kPa
Column 25	9.785714 m	12.293289 m	0 kPa	277.71684 kPa	53.982686 kPa	125 kPa
Column 26	8.271429 m	12.434864 m	0 kPa	261.81856 kPa	50.892372 kPa	125 kPa
Column 27	6.757143 m	12.620772 m	0 kPa	239.16171 kPa	46.488328 kPa	125 kPa
Column 28	5.832258 m	12.750962 m	0 kPa	222.45301 kPa	43.240485 kPa	125 kPa
Column 29	4.632258 m	12.962233 m	0 kPa	197.62215 kPa	38.413854 kPa	125 kPa
Column 30	3.500000 m	13.167609 m	0 kPa	171.66919 kPa	33.369111 kPa	125 kPa
Column 31	3.200000 m	13.229431 m	0 kPa	167.11441 kPa	32.48375 kPa	125 kPa
Column 32	2.250000 m	13.441644 m	0 kPa	130.39051 kPa	25.345349 kPa	125 kPa
Column 33	0.750000 m	13.806119 m	0 kPa	60.959028 kPa	11.849235 kPa	125 kPa



M.P. POWER GENERATING COMPANY LIMITED  
(Govt of MP Undertaking)  
SATPURA THERMAL POWER STATION  
OFFICE OF THE CHIEF ENGINEER (GEN):STPS:SARNI  
P.O.SARNI:DISTRICT-BETUL(MP) 460447, Fax (07146), 278466 Phone : 278422  
E-mail:- stps1@rediffmail.com Website:- mppgcl.mp.gov.in

No. 08-004/Gen-194A /640

Sarni, dt. 28/5/25

To,

1. The Scientist-E, Ministry of Environment, Forest and Climate Change, Regional office (wz), E-5, Kendriya Paryavaran Bhawan, E-5, Arera Colony, Link Road-3, Ravishankar Nagar, Bhopal-462016 E-mail: rowz.bpl-mef@nic.in
2. The Scientist-E, Central Pollution Control Board, Regional Directorate-Bhopal, 3rd Floor, Sahkar Bhawan, North TT Nagar, Bhopal, M.P.-462003 E-mail: cpcb.bhopal@gmail.com
3. The Regional Officer, M.P. Pollution Control Board, in front of Mullaji Petrol pump, Parasia road, Chhindwara-480001 E-mail: romppcbcwh@gmail.com

Sub:- Hon'ble NGT Central Zone Bench Bhopal's order for hearing dated 12.08.2024 in Original Application No. 115/2024-compliance of directions regarding.

Ref:- 1. The Joint Committee report filed in O.A. 115/2024(CZ)

2. NGT Central Zone Bench Bhopal's order for hearing dated 12.08.2024 in O.A. 115/2024(CZ)

3. The Dy Registrar, NGT Central Zone Bench Bhopal's letter no. NGT- CZB/ Jud./2024/332, Bhopal Dtd. 29.08.2024

4. T.O. Letter no. 08-004/Gen-194-A/2380, Sarni Dtd. 22.10.2024

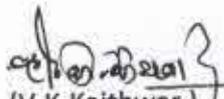
5. Letter No.08-004/Gen-194 A/3449 Sarni dt.01.01.2025

Respected Sir,

In context with subject above, the Central Zone Bench of NGT at Bhopal has passed an order on 27.12.2024 for hearing dated 12.08.2024 in Original Application no. 115/2024 titled as Rashid Noor Khan Vs MoEF&CC and others. Hon'ble NGT has directed in its order for securing compliance of directions given in paragraph 35 of the order.

In the above- mentioned order, the Hon'ble NGT directed to award a fresh study to IIT, indore for the fresh investigation of the 130 hectare ash dyke w.r.t. its stability issue. Accordingly ash dyke stability tests for 130 hectare ash pond as well as another live ash pond of Satpura Thermal Power Station Sarni on 111 hecatre land have been carried out by IIT, Indore providing the result that both ash ponds are in safe and sound conditions. Stability reports are enclosed herewith for your kind information please.

Encl.: As above

  
(V.K. Kaithwar)  
C.E.(GEN),STPS,MPPGCL,SARNI

Copy to:-

1. The Deputy Registrar, NGT Central Zone Bench, III Floor, State Information Commission Building, Arera Hills, Bhopal-462011 (ngtczbbho-mp@gov.in)
2. The Executive Director (O&M: Gen.), MPPGCL, Jabalpur
3. The Addl. CE 2X250 MW, MPPGCL, Sami
4. The Chief Chemist, MPPGCL, Sarni
5. The S.E. (Civil), MPPGCL, Sarni
6. The S.E. (Opn)/(ET&I)-IV, MPPGCL, Sarni
7. The E.E. (Fly Ash Utilization) & Nodal Officer (NGT Case O.A. 115/2024), MPPGCL, Sarni