ISSN 2063-5346

SLOPE STABILITY ANALYSIS OF FLY ASH DYKE

Paruti Bhardwaj[1], Mr. Nikhil Ghodichore [2], Mr. Kishor Kumar Bhardwaj[3]

Article History: Received: 10.05.2023 Revised: 29.05.2023 Accepted: 09.06.2023

Abstract

The stability of the slope must be taken into account while planning and constructing retaining structures such as an earth dam and dyke. Slope failure can lead to disastrous consequences such as damage to life and property. The slope stability analysis using different available techniques, in which the finite element method is the best. In this study, the slope stability of an ash dyke is examined using finite element technique, using PLAXIS 2D model, under various construction and operational conditions namely, dry condition, submerged condition and earthquake condition. The evaluation employs the Mohr-Coulomb method to calculate the safety factor. The results of the model indicate that the displacement and deformation for the dry and submerged loading scenario is 0.4207 m and 0.2880 m respectively. According to the model's findings, the downstream faces and rock toes are the most vulnerable locations for failure of the dyke. The factor of safety is found to be 2.4 in the dry condition, while in submerged conditions, the factor of safety is observed to be 1.56. The results of the study show that since the FOS for both dry and submerged conditions are less than 1.5, the dyke is considered to be safe.

Keywords— stability analysis, dry conditions, fly ash, dyke, Factor Of Safety.

[1]M. Tech, Research Scholar) Environment & Water Resources Engineering, University Teaching Department Under C.S.V.T.U, Newai, P.O.-Newai, Bhilai.
Email Id: parutibhardwaj@gmail.com

[2]Assistant Professor, Environmental & Water Resources Engg, University Teaching Department Under C.S.V.T.U, Newai, P.O.-Newai, Bhilai.

[3]Adviser under Chhattisgarh Swami Vivekananda Technical University Newai, Bhilai (C.G.), India

DOI:10.48047/ecb/2023.12.9.102

I. INTRODUCTION

The stability of earth and rock-fill dams, embankments, excavated slopes, and naturally occurring slopes in soil and rock can be assessed using slope stability analysis, which can be static or dynamic, analytical or empirical. The ability of inclined soil or rock slopes to withstand or experience movement is referred to as slope stability. In the fields of engineering geology, geotechnical engineering, and soil mechanics, the stability condition of slopes is a topic of study and inquiry (Salunkhe 2017). Slope stability is an important factor to take into account while managing various mining operations or civil engineering projects. As an illustration, consider landfills, tailings dams, embankments, surface/open pit mines, some underground mines, and major excavations carried out as part of major construction projects. the depth of open pit mines is increasing (Sungkar et al., 2020; Wolters et al. 2005; Chen et al. 2016; Vaverková, 2019). Due to rising demand as well as more effective procedures and machinery, heap leach facilities, waste rock embankments, and tailings dams are becoming larger, deeper, and steeper. (Lai et al., 2006; Kossoff et al., 2014; Oxley et al., 2016). Due to this, evaluating and monitoring slope stability is crucial, and all mines and other big excavations should include this activity as part of their overall productivity and safety management strategy (Collins 2008).

Slope stability is determined by the ratio of active shear stress to available shear strength, which can be expressed as a safety factor when integrated over a possible (or real) sliding surface. Globally stable systems have a safety factor consistently greater than one along every potential sliding surface. (Ahmed 2017). The overall stability condition of the slope will be assumed to be represented by the safety factor's lowest value. Similarly, if it is estimated that a safety factor greater than one exists along any potential sliding surface traversing a constrained portion of the slope, the slope may be locally stable (for instance, only just inside its toe) (Berilgen 2007). If a slope is marginally stable, it requires monitoring, care, and/or slope stabilization engineering interventions to improve safety and reduce the likelihood of slope movement. Values of global or local safety factors close to 1 indicate this (usually between 1 and 1.3, depending on standards) (Cruikshank & Johnson, 2002). A number of variables or processes can cause a previously stable slope to fail, either by increasing shear stress or decreasing shear strength. A slope can fail due to heavy rain, rapid snowmelt, progressive soil saturation, or an increase in water pressure within the slope, as well as earthquakes (including aftershocks), internal erosion (piping), surface erosion, artificial slope loading (due to building construction), slope cutting (to make room for roads, railways, or buildings), and slope flooding (Huang et al. 2021) (For example, by adding water to a man-made lake after damming a river) (Rodrigues,Coutinho, and Cardoso 2013).

Previous studies have focused on the slope stability analysis using different available techniques (Greenwood, 2006; Charan et al. 2018; Sungkar et al. 2020). In order to evaluate the safety factor of homogenous cohesive-frictional soil slopes with simple profiles, researchers have created an analytical formulation that takes both horizontal and vertical seismic stresses into consideration (Sahoo & Shukla 2019; Rabie et al. 2015; Yang et al., 2016). Yadav et al. (2012) Bishop Method and PLAXIS 2D software were used to analyze slope stability on the Meulaboh-Geumpang road stretch in the Sungai Mas District. The safety factor following reinforcement calculation yielded a score of 1.57.

The limit equilibrium methods of slices and the boundary element methods are two of the current analytical techniques (Siddiqui et al. 2017). M. Abbas (2014) Assessment has been made for slope system with different slope for both cohesive and cohesion less soil. the failure observations and field conditions in order to understand the failure mechanism, which chooses the slope stability method that should be applied to the analysis. Due to their simplicity, two-dimensional slope stability methods are most frequently utilized by engineers. Today, software based on the (FEM) is frequently utilized in geotechnical simulations (Vinod et al. 2017). The Bishop technique, which assumes a circular failure surface, was used to perform the safety factor analysis for the present condition ash dyke. The computation was further validated by FEM using 2D Plaxis software. The computation of the safety factor circular failure yielded a result of 1.56 (Sungkar et al. 2020). Shivamanth et al. (2015) used PLAXIS 2D in their study and determined that the dyke was stable under three different scenarios and that the design is adequate for the intended use because the factor of safety in each case was found to be larger than 1.5. Parekar et al. (2019) carried out a numerical study of slope stability using PLAXIS 2D. The finding of this study shows the different values of factor of safety for different sequence with various frequency and acceleration. . Hammouri et al. (2008) attempted a study to determine the factor of safety for a given angle and displacement of a vertical as well as horizontal soil slope. The stability analysis of slope is carried out by FEM using Plaxis-2D**.** The finding obtained from the calculation of the safety factor 1.5.

Based on the above literature review, it is observed that finite element based methods are widely used for slope stability analysis all over the globe. In this study, we attempt to analyse the stability of slope of a fly ash dyke for different loading conditions.

1.2 Objective

The main objective of this study is to use finite element models for different conditions of ash dyke:

(a) To analyze the stability of ash dykes on slope in dry condition under Gravity loading/self-weight loading conditions.

(b) To analyze the stability of ash dykes on slope in fully saturated condition.

(c) To analysis the stability of ash dykes under earthquake loading condition.

II. Study area and Data used

Chhattisgarh state of India, Korba Thermal Power Station Power House (KTPS P. H.) of Chhattisgarh state power generation company (CSPGCL), which is located in Korba East and is about 120 km from Bilaspur in the state of Chhattisgarh, had a total installed capacity of 620MW (4x50 MW + 2x210 MW). Since December 31, 2020, power generation from this P. H. has been totally halted. Phased construction was used to build the Podimar Ash Dyke. The Podimar Phase-I ash dyke, which is currently elevated to R. L. 322.00 M [Starter dyke + six stage raising], is part of the Phase-I construction, and the Podimar Phase-II ash dyke is part of the Phase-II construction. The Podimar Phase-II ash dyke's part "A" has been elevated to R. L. 316.50 M [Starter dyke + four stage raising], while part B has been raised to R. L. 320.50 M [Starter dyke + five stage raising]. Podimar Ash Dyke covers a total area of 78.25 Hectare. Similar to this, Podimar Phase-I ash dyke is directly adjacent to a section of the ancient ash dyke known as PAB Pond No. 2, Risda. R. L. 322.50 M [Starter dyke + two stage raisings + three stage dry ash mounds] is the current location of this old dyke. Podimar Phase I & II Ash Dyke & PAB Pond-2, Risda, therefore, cover a total area of approximately 108.25 Hectare.

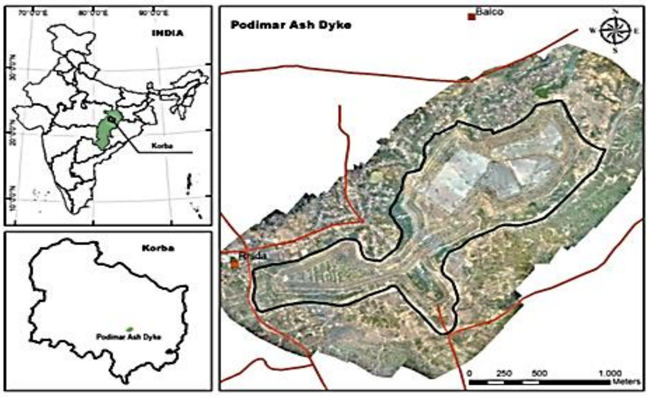


Figure 2.1: Salient feature of the PODIMAR ash dyke

Table 2.1 Salient feature of the PODIMAR ash dyke is given as below Name

S No.	Name of the Project	PODIMAR ash dyke, HTPS, CSPGCL		
1	Location	Korba, Chhattisgarh.		
2	Total area	108.25 Hectare		
3	Details	<u>Section</u>	<u>Details</u>	<u>Reduced levels</u>
		Phase-I	Starter dyke + 6 raisings	322 m.
		Phase-II Pond A	Starter dyke + 4 raisings	316.50 m.
		Phase-II Pond B	Starter dyke + 5 raisings	320.50 m.
		PAB Pond No. 2	Starter dyke + Two stage raisings + Three stage dry ash mound	322.50 m.

Characteristics of Podimar ash dyke

In the current work, Finite Element Methods (FEM) is used to analyses the stability of the ash dyke while taking the upstream construction approach into account. In a scenario-based approach, the FEM-based model is utilized to analyze the slope stability of the existing ash dyke. The materials obtained during sample collection are tested in a lab to determine their material qualities. To get the field parameter values for FEM model input, the following lab tests were carried out on the starter dyke's core and soil fill material, raising's sand filter, and raising's ash fill.

Table 2.2: List of lab tests performed for determination of soil Parameter as a model input.

S. No.	Name of Parameters	Name of Tests
1	Moisture content	Oven drying method
2	Wet density	Vibratory table apparatus
3	Dry density	
4	C value of soil	Unconfined compression test
5	Phi value of soil	
6	safe bearing capacity (net)	
7	Liquid limit	Cone penetration method
8	Plasticity index	
9	Plastic limit	Plastic limit test
10	Unit weight (saturated)	As per IS:2720 part III
11	Unit weight (unsaturated)	
12	Young's modulus	As per IS:2720 part VIII
13	Permeability, Kx	As per IS:2720 part XVII
14	Permeability, Ky	
15	Void ratio	
16	Porosity	
17	Specific gravity	As per IS:2720 part III

Table 2.3: Results of laboratory tests on soil samples from the PODIMAR ash dyke

S No.	**Name of parameter**	**Results**				**Unit**
		Soil (core)	**Soil (fill)**	**Ash fill**	**Sand (fill)**	
1	**Moisture content**	8.30	7.89	6.88	7.40	%
2	**Wet density**	2.18	2.20	2.12	1.94	Gm/cc
3	**Dry density**	2.01	2.04	1.98	1.81	
4	**C value of soil**	0.27	0.24	0.26	0.15	Kg/cm2
5	**Phi value of soil**	25	22	23.5	26	Degree
6	**safe bearing capacity**	14.39	7.63	9.86	6.66	T/m2
7	**Plastic limit**	27.60	28.30	26.50	NP	Unitless

8	**Plasticity index**	18.70	18.60	17.70	NP	
9	**Unit weight (saturated)**	18.00	18.50	17.80	10.4	KN/m3
10	**Unit weight (unsaturated)**	17.60	17.80	17.20	9.40	
11	**Young's modulus**	32.00	34.00	31.00	22.90	MPa
12	**Permeability, Kx**	1.65e-5	1.7e-5	1.68e-5	1.61e-4	m/day
13	**Permeability, Ky**	4.3e-6	4.5e-6	4.1e-6	2.2e-5	
14	**Void ratio**	0.57	0.58	0.57	0.63	
15	**Porosity**	0.23	0.25	0.22	0.21	Unitless
16	**Specific gravity**	2.68	2.7	2.69	2.10	

2.1 Fundamentals of finite element analysis:

Using soil models to simulate soil behavior, PLAXIS 2D is a finite element programme for geotechnical applications. In 1974, Pieter Vermeer launched this finite element program at Delft University of technology in the Netherlands (Burd, 1999). The phrase was taken from the name of a computer programme called plasticity axisymmetric that Pieter Vermeer and de borst created to address the cone penetrometer issue. In 1987, the brand-new edition of it was released. PLAXIS 2D earlier iterations utilized a dos user interface. Automated mesh generation was introduced with the release of PLAXIS 2D v-7 for windows. Three stages make up an analysis utilizing PLAXIS 2D: input, calculation, and post processing (curves). Model design, assigning material parameters, setting boundary conditions, loading, and meshing are all included in the input stage. In the analysis at hand, a triangle element with 15 nodes and 12 stress points is used. As opposed to individual nodes, individual Gaussian integration points are used in PLAXIS 2D to determine stresses and strains. Choosing an analysis type, such as plastic, dynamic, consolidation, or Ø-c reduction, is necessary during the calculation stage. The specified loads are triggered and analyzed here. Plotting of curves between various estimated parameters, such as load and displacement, is done during the post-processing stage. The stiffness and Poisson's ratio of the soil, two input parameters, affect how the slope moves. The Ø-c reduction technique is used to calculate the FOS for slope stability. The soil's strength characteristics (c) are steadily reduced using this technique until the system breaks down. The total multiplier Msf provides the value of the soil strength parameters at a specific stage of the analysis.

$\Sigma Msf = (\tan\emptyset)/(\tan\emptyset r)$ ……………… (1)

Where: Msf = total multiplier factor of safety Ø= friction of angle

2.2 Mohr-coulomb material model

The Mohr-Coulomb equation is the shear strength designation most frequently used for saturated soils in geotechnical engineering.

$\tau f = c' + (\sigma n - uw) \tan\emptyset'$ …………………… (2)

Where: τf = Shear strength, c= Cohesive soil, σn = Normal stress, Ø = Friction of angle, uw = Pore-water pressure

The shear strength parameters and the Mohr-Coulomb failure envelope will take the shape depicted in Figure 2.2.

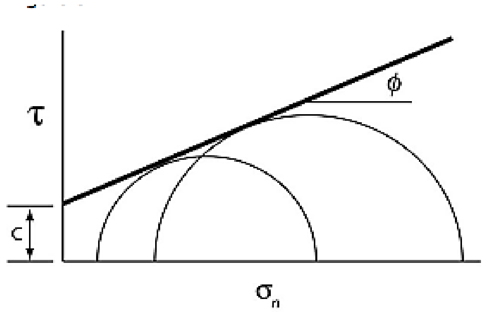


Figure2.2: Mohr-Coulomb failure envelope written in terms of effective stresses

Total stress conditions can also be used to express the Mohr-Coulomb equation (Figure 2.3). Pore-water pressures are not taken into account in a total stress analysis, and the cohesion and friction angle are described in terms of total stress circumstances. The Mohr-Coulomb formula appears as follows:

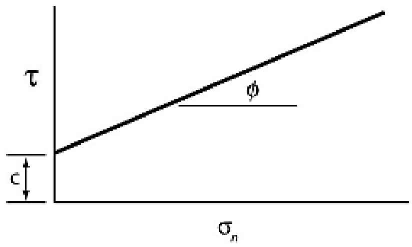
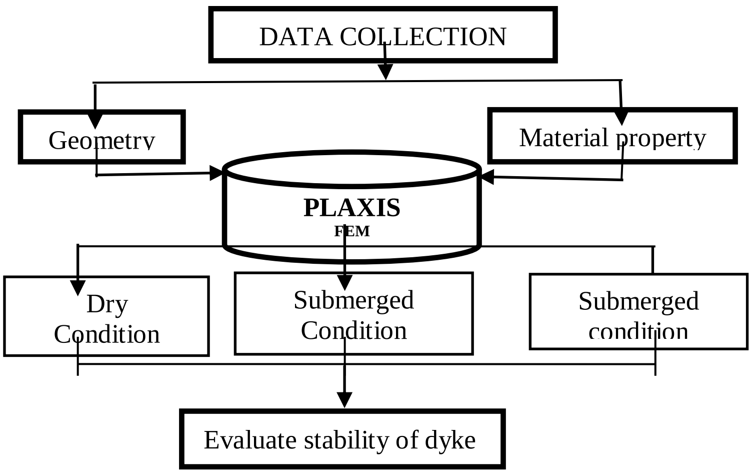


Figure 2.3: The relationship between shear strength and total normal stress

Methodology in flow chart



III. Methodology

In the initial phase of the study, a number of parameters were gathered, such as (C) cohesion, (Ø) angle of internal friction, (Y) unit weight of soil (KN/m^3), angle of dilatancy, |u| total hypothetical displacement, (K) coefficient of permeability (m/day), (E) Young's modulus (KPa), (ϑ) Poisson's ratio, (FS) factor of safety, and (Ko) rigidity factor. A geometry model ought to contain in structural elements, construction stages, loadings, and a representative separation of the subsoil into various soil layers. In order for the borders of the model to have no impact on the conclusions of the problem being examined, it must be sufficiently large. A dyke with a slope of 1V:2.5H and dimensions of 3 m in height, 2 m in height, and 7 m in height, as well as six raisings is conceptualized. The beginning dyke has a slope of 1V:2.5H and a height of 2 m on both the upstream and downstream sides. PLAXIS 2D model was run for different case scenarios including dry, submerged and earthquake conditions.

Scenario

Dry condition

The compressibility of the fluid and the level of saturation are frequently ignored in the dry situation, since it is assumed that the pores are empty. Keep the phreatic level at ground level. The self-weight exerted on the structure is fully responsible for the ash dyke's overall displacement.

In using extremely low or extremely high K0-values, the K0 process may fail to satisfy the Mohr-Coulomb failure criterion. In this case, PLAXIS 2D automatically reduces the lateral loads to ensure adherence to the failure condition. As a result, these stress points are considered to be plastic. Even if the rectified stress state meets the failure condition, an unbalanced stress field may result. It is frequently preferred to create an initial stress field devoid of Mohr-Coulomb plastic points.

If the K0 technique is used, the initial horizontal effective stress to vertical effective stress ratio for each layer must be specified.

Submerged condition

In the submerged situation, it is assumed that the phreatic line is present at the top of the ash-fill. As a result, in this case, both the weight of the water and the ash dike contribute. The ash dike is generally displaced as a result of the combined impacts of the self-weight and water loading on the structure. In using extremely low or extremely high K0-values, the Mohr-Coulomb failure criterion may not be met by the K0 process. PLAXIS 2D automatically reduces the lateral strains in this case to ensure conformance to the failure condition. Therefore, it is thought that these stress sites are in a plastic condition. Even if the rectified stress state meets the criteria for failure, it could nevertheless result in an unbalanced stress field. It is usually desired to have an initial stress field without any Mohr-Coulomb plastic points.

Earthquake condition

An earthquake is a sudden shaking or trembling of the earth which last for a very short period of time. Earthquake is cause by a disturbance deep inside the earth’s crust. Due to the collision of plats, a disturbance is caused. The boundaries of the plates are the week zones where earthquake are more likely to occur, they are called seismic zone or fault zones.

A free vibration analysis can be used to determine the potential vibrations that might occur in a system when a static load is relieved. Finding the intrinsic frequencies of a soil block or structure can be done using a dynamic calculation and a free vibration research. A plastic study employing specified loads or displacements must first be completed before performing a free vibration analysis. The active static external load from the previous compute phase is discharged during the following dynamic phase (deactivated). With the help of the power spectral density map that is generated as an output, natural frequencies can be estimated. Additionally, there is a sudden increase in pore water pressure, which lowers the amount of available shear strength. In earthquake issues, the dynamic loading source is often applied along the bottom of the model, pushing shear waves upward.

IV. Result and Discussions

A. Stability Analysis of the slope of ash dyke in dry condition under gravity loading/self-weight loading conditions.

The dry condition to drain water pressure from a layer of soil, there will be no pressure created in the layer since the pore pressure at the top and bottom levels of the layer (top and bottom, respectively) will both be zero. Un-drained materials subjected to gravity force will experience unreasonable excess pore pressures. For instance, stresses resulting from the soil's own weight are based on a gradual process in which the pore pressure buildup is unimportant.

The principal stresses are vertical for the major stress and horizontal for the minor stress. The Cartesian shear stress in this situation is zero (for example, the initial stress generated by the K0 procedure). It's comparable to an active stress condition right now. It is equivalent to +90 or -90 to be in a passive stress state. Discontinuous color shadings are displayed when zones of positive stress exhibit jumps from = +90 to =-90. If the Cartesian shear stress is positive, the primary stress will rotate clockwise (α > 0), and if the cartesian shear stress is negative, the primary stress will rotate counterclockwise (α<0).

Factor of safety is defined as the factor by which the shear strength must be lowered to get a material mass into a state of limit equilibrium along a particular slip surface. The failure criterion for any particular slice can be used to express the shear force applied to a saturated soil.

SF = (available strength)/ (strength at failure) = value of ΣMsf at failure …………………………….. (4)

The Total Displacement for Gravity Loading in Dry Conditions is shown in Figure 4.1. (Self-Weight) and the maximum displacement (0.4207m) occurs at the upstream side of the top rise. Figure 4.2 shows the result for the total displacement and the mesh deformation in the case of a (1.559×10^-3m) (deformation state). The toe of the starter dyke is displaced by a maximum of (9.239×10^ -3m) as seen in figure 4.2. In the case of the ultimate failure condition, it is observed that the slip circle covers the entire ash dyke, including the starter dyke and all raisings. The maximum displacement (56.61×10^6m) is seen at the toe of the starter dyke, as shown in figure 4.3.

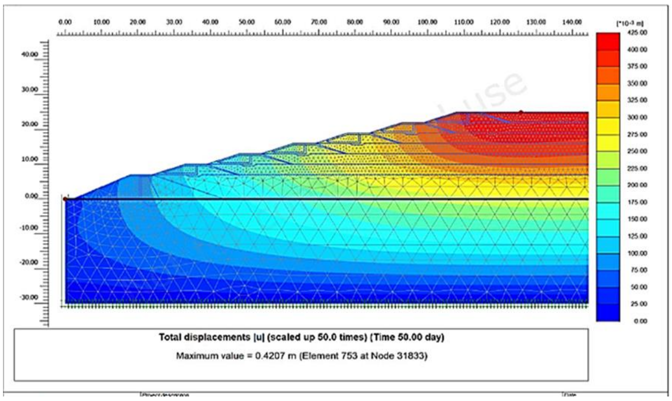


Figure4.1: Total displacement result for Dry Condition- Gravity Loading (Self Weight)

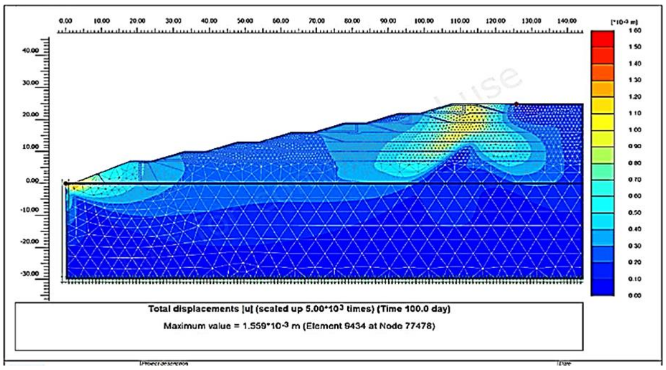


Figure 4.2: Total displacements result for Dry Condition- Deformation in plastic state

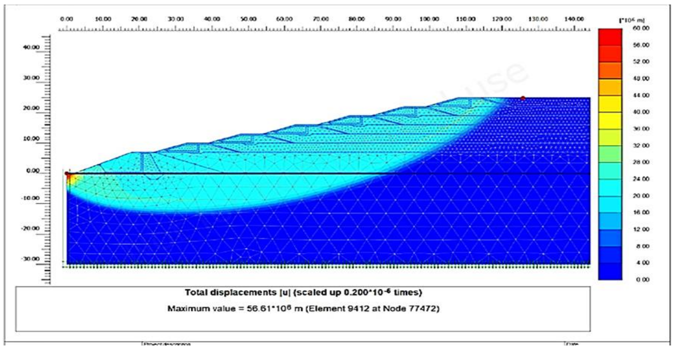


Figure4.3: Total displacement result for Dry Condition- Ultimate failure condition

B. Stability Analysis of slope of ash dykes in submerged conditions.

For both confined and unconfined flow issues, a pore pressure distribution may be calculated using the Flow module in PLAXIS 2D. One of the primary goals of a calculation of unconfined groundwater flow is to locate the free phreatic and measure the length of the seepage surface that corresponds. In this instance, a correlation between pore pressure and saturation level is applied. Both statistics are provided in the Output programme and arrived at by a calculation of groundwater flow. Under phreatic conditions, the degree of saturation is normally 100%, and it decreases to residual saturation within a finite zone above phreatic conditions. When suction occurs, the residual saturation value equals zero and is ignored. Only the saturation can be displayed.

Shear failures are the most common type of structural failure and result in soil masses rolling down a dam's slopes. The soil mass with a slope at one end has shear forces on internal surfaces or failure planes in the soil mass along the slope. Gravitational forces cause the soil mass near to the slope to go downhill, which results in this. To pinpoint the crucial slip surface and the associated safety factor, numerous analytical techniques and models have been created. The safety factor in PLAXIS 2D is computed using the Ø /c reduction approach. The friction angle and cohesiveness of the soil are decreased by PLAXIS 2D to the point of soil collapse. The safety factor must be calculated during this phase.

The Total Displacement for Gravity Loading in submerged Conditions is shown in Figure 4.4. (Self-Weight) and the maximum displacement (0.2880 m.) occurs at the upstream side of the top rise. Figure 4.5 shows the result for the total displacement and the mesh deformation in the case of a plastic state (deformation state). The toe of the starter dyke is displaced by a maximum of (9.239×10^-3) m as seen in figure 4.5. In the case of the ultimate failure condition, it is observed that the slip circle covers the entire ash dyke, including the starter dyke and all raisings. The maximum displacement (106.5×10^3m) is seen at the toe of the starter dyke, as shown in figure 4.6.

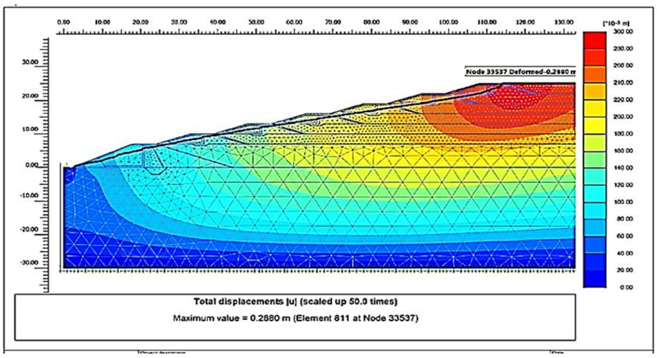


Figure 4.4: Total displacement result for Submerged Condition- Gravity Loading (Self Weight**)**

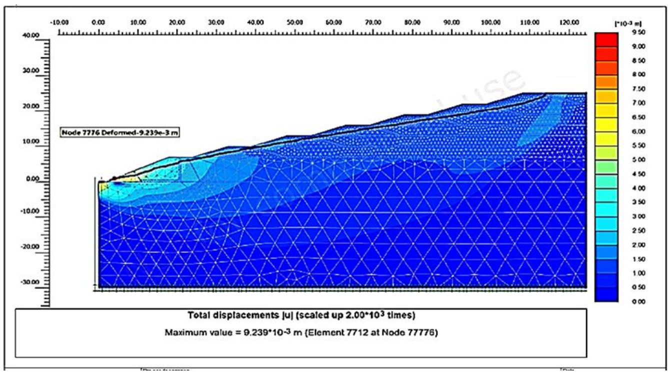


Figure4.5: Total displacement result for Submerged Condition-Deformation State (Self-weight in plastic state**)**

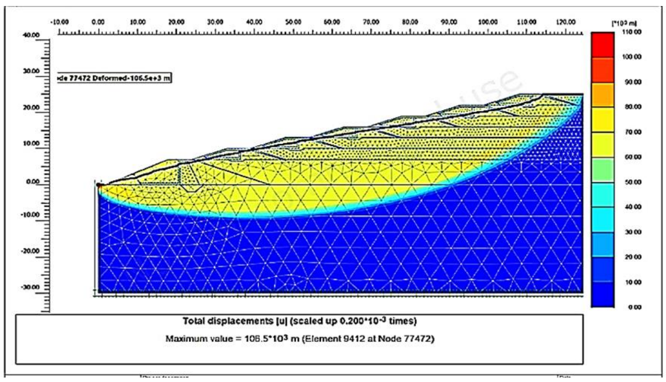


Figure 4.6: Total displacement for Submerged Condition-- Ultimate failure condition

C. Analysis of slope stability and ash dykes under earthquake loading condition.

An earthquake is the shaking of the earth's surface caused by a sudden release of energy in the earth's lithosphere, which generates seismic waves. It is also referred to as a quake, tremor, or temblor. A tectonic plate moving along a fault line in the earth's crust results in an earthquake, which is a powerful and sudden shaking of the ground. Ground tremors, soil liquefaction, landslides, cracks, avalanches, fires, and tsunamis can all be caused by earthquakes. The magnitude, severity, and length of an earthquake all affect the amount of damage and destruction it causes.

There are many different types of earthquakes, ranging in size from those that are so small that no one can feel them to those that are so strong that they may completely upend towns and launch people and items into the air. Seismic activity refers to a region's frequency, kind, and size of earthquakes over a given time period. The seismicity of a given area on Earth is defined as the typical rate of seismic energy release per unit volume. Seismic rumbling is another name for tremors, which are not earthquakes.

A free vibration analysis can be used to determine the potential vibrations that might occur in a system when a static load is relaxed. To ascertain the inherent frequencies of a soil block or building, a dynamics computation can be employed to do a free vibration analysis. In order to do a free vibration analysis, a plastic analysis using predetermined loads or displacements is first performed. The active static external load from the preceding calculation phase is released during the dynamics phase that follows. An output-generated power spectral density map can be used to estimate natural frequencies.

Dynamic analyses typically measure time in seconds rather than the standard unit days. In a dynamic analysis, the time interval is always the dynamic time, and PLAXIS 2D always measures the dynamic time in seconds [s]. The impacts of an earthquake are calculated using two variables, the kh & kV factors, for horizontal and vertical acceleration, respectively. A dimensionless number called the factor of acceleration is used to express the seismic acceleration as a percentage of the acceleration caused by gravity. The acceleration factor, or seismic force S, is what generates an earthquake's impacts. When assuming that earthquake effects only occur in the horizontal plane. Equivalent inertial forces, roughly described as constant body forces with magnitudes proportional to the horizontal and vertical accelerations imposed by the dynamic loading, are used to model the consequences of a dynamic loading.

The total displacement for gravity loading in earthquake conditions is shown in Figure 4.7. (Self-Weight) and the maximum displacement (1.043 m.) occurs at the upstream side of the top rising. Figure 4.8 shows the result for the total displacement and the mesh deformation in the case of a free vibration condition. In this case, the subsoil below the ash dyke is displaced by a maximum of 1.110 m, as seen in figure 4.8. In the case of the dynamic condition (20 seconds), it is observed that the slip circle covers the entire ash dyke, including the starter dyke and all raisings. The maximum displacement (1848 m) is seen below the toe of the starter dyke, as shown in figure 4.9.

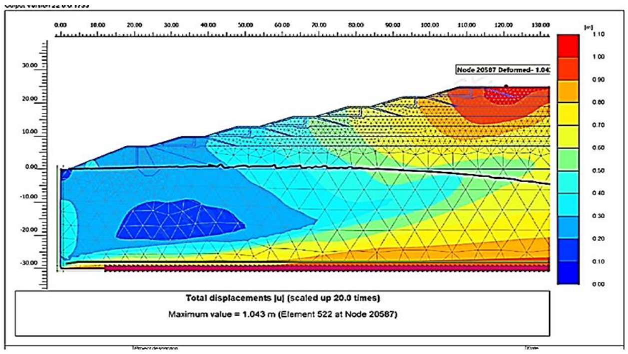


Figure4.7: Total displacement result for Earthquake Condition- Gravity Loading (Self weight)

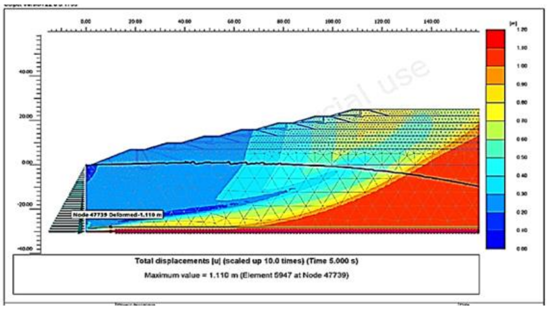


Figure 4.8: Total displacement result for Earthquake Condition-Free vibration Condition

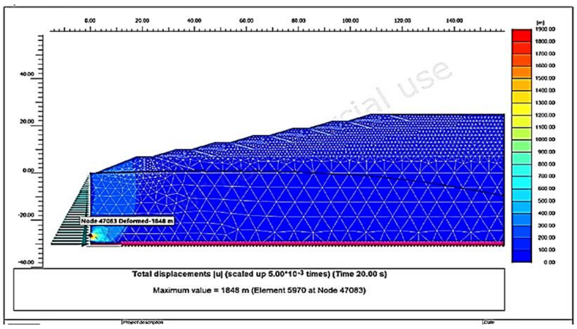


Figure 4.9: Total displacement result for Earthquake Condition-dynamic condition

Factor of safety

Figure 4.10: factor of safety in submerged and dry condition

V. CONCLUSION

In this study, the finite element-based software PLAXIS 2D analyses the stability of the Podimar ash dyke at Korba Thermal Power Station, Korba, under various situations. Model results indicate that the study gives a safety factor of about 2.4 in dry conditions. As seen in Figure 4.10, the FOS slightly drops in the situation of entirely immersed ash but is still far above 1.65. Similar to this, the results of the model indicate that the maximum displacement and deformation for the earthquake loading scenario is 1848 m. According to the model's findings, the downstream faces and rock toes are the dyke's most vulnerable locations for failure. These findings will also be helpful for designing and building new ash dikes, where seepage analysis should be taken into consideration because it seems to be one of the main causes of ash dike failure. The factor of safety under both dry and submerged conditions falls above 1.5, which implies that the dam is safe. The finite element method used for slope stability analysis in this study can be applied to all similar structures around the globe. The three types of failures, as discussed earlier, can be observed in the model results. Mostly toe failure is observed in the case of failure in a plastic state, and base failure is observed in the case of an ultimate failure condition.

VI. REFERENCES

1) Salunkhe, D. P., Bartakke, R. N., Chvan, G., & Kothavale, P. R. (2017). An overview on methods for slope stability analysis. International Journal of Engineering Research & Technology (IJERT), 6(03), 2278-0181.

2) Sungkar, M., Munirwansyah, M., Munirwan, R. P., & Safrina, D. (2020, September). Slope stability analysis using Bishop and finite element methods. In IOP conference series: materials science and engineering (Vol. 933, No. 1, p. 012035). IOP Publishing**.**

3) Wolters, M., Garbutt, A., & Bakker, J. P. (2005). Salt-marsh restoration: evaluating the success of de-embankments in north-west Europe.

Biological Conservation, 123(2), 249-268.

4) Chen, R., Meng, F., Li, Z., Ye, Y., & Ye, J. (2016). Investigation of response of metro tunnels due to adjacent large excavation and protective measures in soft soils. Tunnelling and Underground Space Technology, 58, 224-235.

5) Vaverková, M. D. (2019). Landfill impacts on the environment. Geosciences, 9(10), 431.

6) Kossoff, D., Dubbin, W. E., Alfredsson, M., Edwards, S. J., Macklin, M. G., & Hudson-Edwards, K. A. (2014). Mine tailings dams: Characteristics, failure, environmental impacts, and remediation. Applied Geochemistry, 51, 229-245.

7) Oxley, A., Smith, M. E., & Caceres, O. (2016). Why heap leach nickel laterites?. Minerals Engineering, 88, 53-60.

8) Collins, T. K. (2008). Debris flows caused by failure of fill slopes: early detection, warning, and loss prevention. Landslides, 5(1), 107-120.

9) Ahmed, A., Gariepy, Y., & Raghavan, V. (2017). Influence of wood-derived biochar on the compactibility and strength of silt loam soil. International Agrophysics, 31(2), 149.

10) Berilgen, M. M. (2007). Investigation of stability of slopes under drawdown conditions. *Computers and Geotechnics*, *34*(2), 81-91.

11) Cruikshank, K. M., & Johnson, A. (2002). Theory of slope stability.

12) Huang, Shuai, Shufeng Zhai, Yingjie Liu, Chuanzheng Liu, Katsuichiro Goda, and Ben Mou. "Seismic behavior analysis of the bank slope considering the effect of earthquake-induced excess pore water pressure." Frontiers in Earth Science 9 (2021): 799612.

13) Copana Paucara, J. (2020). Seismic Slope Stability: A Comparison Study of Empirical Predictive Methods with the Finite Element Method (Doctoral dissertation, Virginia Tech).

14) Greenwood, J. R. (2006). SLIP4EX–A program for routine slope stability analysis to include the effects of vegetation, reinforcement and hydrological changes. Geotechnical & Geological Engineering, 24(3), 449-465.

15) Munaga, T., Sai Charan, P., Sai Kiran Raju, M., Yerra, L., Kothakota, B., & Kalyan Kumar, G. (2020). Suitability of Fly ash in Raising the Embankments. In Construction in Geotechnical Engineering (pp. 483-492). Springer, Singapore.

16) Younus, S., Vinod Chandra, S. S., Ibrahim, J., & Nair, A. S. S. (2022). A new approach used in docking study for predicting the combination drug efficacy in EML4-ALK target of NSCLC. Journal of Biomolecular Structure and Dynamics, 1-17.

17) Hazari, S., Sharma, R. P., & Ghosh, S. (2020). Swedish circle method for pseudo-dynamic analysis of slope considering circular failure mechanism. *Geotechnical and Geological Engineering*, *38*(3), 2573-2589.

18) Amin, M. N., Ahmad, I., Iqbal, M., Abbas, A., Khan, K., Faraz, M. I.& Ullah, S. (2022). Computational AI Models for Investigating the Radiation Shielding Potential of High-Density Concrete. Materials, 15(13), 4573.

19) Vinod, V. M., Mekala, V., Abinaya, S., Srinivas, A., & Arun, S. (2020). A Customizable Cartographic Air Pollution Monitoring System. International Journal Of Scientific & Technology Research (IJSTR), 9, 1675-1678.

20) Shivamanth, A., Athani, S. S., Desai, M. K., & Dodagoudar, G. R. (2015). Stability analysis of dyke using limit equilibrium and finite element methods. Aquatic Procedia, 4, 884-891.

21) Parekar, R., Chelani, N., Dhankute, V., Mirza, S., Sauarkar, A., & Ghutke, V. Numerical study of stability of slope by plaxis 2d.

22) Hammouri, N. A., Malkawi, A. I. H., & Yamin, M. (2008). Stability analysis of slopes using the finite element method and limiting equilibrium approach. Bulletin of Engineering Geology and the Environment, 67(4), 471-478.

23) Chakrabarti, B., & Shivananda, P. (2017). Two-Dimensional Slope Stability Analysis with Varying Slope Angle and Slope Height by Plaxis-2D. *SAFETY*, *1*(1.684), 1-512.