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Slope Stability Analysis of Kashyapi Dam Using Geostudio Software

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Abstract: The increasing demand for slopes on construction for slopes on construction projects has increased the need to understand analytical methods, investigate tools and stabilization methods to solve slope stability problems. There are number of methods and also software available for the calculation of factor of safety. GEOSTUDIO software is used in various civil engineering applications and their problem analysis is done by considering different consideration. Generally it's widely used for finite element analysis, slope stability, seepage analysis and so on other applications. SLOPE/W is a component of a complete suite of geotechnical products called Geo-Studio. SLOPE/W is the leading slope stability CAD software product for computing the factor of safety of earth and rock slopes. SLOPE/W can effectively analyse both simple and complex problems.

***Index Terms* - Slope stability, sudden drawdown, Berm, Drain, Earthen dam, GEOSTUDIO software, Factor of safety.**

I. INTRODUCTION

Slope stability is an important aspect of geotechnical engineering. In general, linear problems such as the prediction of settlements and deformations, the calculation of flow quantities due to steady and transient seepage are all highly amenable to solution by finite elements. The uses offinite element analysis of slope stability and seepage have gained popularity in recent years dueto its capability to handle complex problems. The primary focus of this research was to study the influence of various water levels to the dam slope by using finite element analysis, and to investigate failure mechanism. Geostudio enables you to combine analyses using different products into a single modeling project, using the results from one as the starting point for another. Multiple geometries, including 1D, 2D, and 3D geometries, may also be included in a single file. Draw geometry directly or import CAD files. Geostudio provides many tools to define the model domain including coordinate import, geometric item copy-paste, length and angle feedback, region merge and split, and DWG/DXF file import. BUILD 3D, geostudio & 3D geometry creation tool, offers acomprehensive suite of sketch features. Solve multiple analyses simultaneously. Geostudioruns each analysis solver in parallel, allowing multiple analyses to be solved efficiently on computers with modern, multi-core processors. This saves substantial solve time especiallyfor large 3D analyses. Interpret results with visualization & amp; graphics. Geostudio provides powerful visualization tools, including graphing, contour plots, isolines or isosurfaces, animations, interactive data queries and data exports to spread sheets for further analysis.

To derive factor of safety, slope stability analysis of the embankment may be carried out for the homogeneous dam. The analysis has been performed using Morgenstern Price Method. There are many analysis methods such as Method of Slices, Bishop’s method, Janbu’s method and Mohr Coulumb model etc. using any of the methods we can determine the stability analysis. GEOSLOPE is developed by GEO-SLOPE International, Canada, based on the principle of limit equilibrium which incorporates a finite element method which is developed specially for the deformation and stability of embankment structures. It includes modelling of stability with (SLOPE/W), modelling of seepage with (SEEP/W), modelling of stress and deformation with (SIGMA/W), modelling of dynamic with (QUAKE/W), modelling of thermal with (TEMP/W), modelling of containment with (CTRAN/W) and modelling of vadose zone with (VADOSE/W). SLOPE/W has been used with “Morgenstern Price method” to do the stability analysis. It is designed and developed to be a general software tool for the stability analysis of earth structures for the proposed project of the raw water reservoir.

II. OBJECTIVES OF THE STUDY

In Geotechnical Engineering various methods are useful for calculating factor of safety of earth dam. Since many assumptions are made for the same, but with the help of software earth dams are shown only with eye observation. So, in future I will work upon comparisonof five methods of slope stability of Kashypi Dam, Nashik.

1. To compare an earthen dam for safety, by analyzing the dam section using finite elementmethod (FEM). Analyzed using FEM based software, GEOSTUDIO, using the material properties to be determined from the laboratory investigation.

2.To study the optimum design for an earthen dam by considering factor of safety with Morgenstern-price method. Slope stability analysis is carried to find the factor of safety byusing numerical modeling software GEOSTUDIO for steady seepage and sudden drawdown conditions, considering typical case such as: Earthen embankment with berm with drained blanket.

III. SCOPE OF THE STUDY:

Scope of present study confined to identifying that stability of slopes of embankment damsobtaining the factor of safety of all cases using GEOSTUDIO 2019 software. Study of thesecases gives factor of safety that explains the slope stability of the structure. Further the earthen dam study can be done for seismic behaviour based on QUAKE/W analysis. The emphasis will be on QUAKE/W, because the cases involving earthquake shaking can be solved by taking into consideration different aspects.

IV. LITERATURE REVIEW:This chapter provides a brief literature review about assessment of slope stability analysis of earthen embankment dams. It alsodiscusses about changing different parametersto find out the factor of safety to stabilize the earthen dams.

Bishop A.W. (1954) studied about the errors that may be introduced into the estimate of stability not only by the use of approximate methods of stability analysis, but also by the use ofsampling and testing methods which do not reproduce sufficiently accurately the soil conditions and state of stress in the natural ground or compacted fill under consideration. Unless equal attention is paid to each factor, an elaborate mathematical treatment may lead to afictitious impression of accuracy. However, in a number of cases the uniformity of the soil conditions or the importance of the problem will justify a more accurate analysis, particularly ifthis is coupled with field measurements of pore pressure, which is the factor most difficult to assess from laboratory data alone. [1]

Yu Zhao et al. (2014) analysed limitation of the definition of factor of safety in traditional slice methods, the authors introduce the concept of slice-wise factor of safety and propose a new limit equilibrium method based on it. In the method, an assumption that the inter slice force ratio λ is the same between any two slices is first made to ease the solution process. Theratio reflects the exertion degree of the anti-sliding forces of slip mass. In addition, the eccentric moment is considered in the analysis. [2]

Dhananjai Verma et al. (2014) studied a comprehensive study is necessitated to ensure stable slopes which are aided by numerical, analytical, physical, kinematic and empirical analyses. Inthe present study four cut slopes from a coal mine in Wardha Valley Coal field have been analyzed using empirical and kinematic tools. The study has involved the classification and prediction the probable failure mode of the slope mass using slope mass rating and kinematic analysis. The analysis results have matched well with the field observations and can help to protect the slope and ensure the safety for better productivity. [3]

Hymavathi Jampani (2017) studied the effect of surcharge, water table and seismic load on the slope‟s stability is analyzed. Stability analysis is performed using SLOPE/W (Geostudio 2007). Stabilization techniques used in the present study are berming, soil nailing and combination of both. The effect of berm angle, berm width, soil nail angle, length and spacing along with surcharge and water table is analyzed in the study. Seismic analysis is performed using Pseudo-static approach with horizontal and vertical seismic coefficients of 0.18 and 0.09respectively. The results indicate that the effect of surcharge on slope stability is negligible in comparison with water table and seismic load. Effect of water table & seismic was more pronounced in gravel. Based on the results it can also be concluded that soil nailing is an appropriate slope stabilization technique for gravelly soil and combination of berming and soilnailing technique is advisable in clayey soil. [4]

Durganaga Laxmi Devi (2017) explained about slope stability of earthen dams using GEOSTUDIO software. Generally, in earthen dams, the factors included in this analysis are thespecific site, foundation conditions, construction material characteristics and hazard potential associated with the particular site. To control the slope failures it is important to analyse the factor of safety of the slopes. To derive factor of safety, the tests are carried out by using numerical modelling of SLOPE/W and SEEP/W tools of GEOSTUDIO software for steady state seepage and sudden drawdown conditions. In this paper factor of safeties are analysed for four cases, such as (i) without berm without a drained blanket (ii) with berm without a drainedblanket (iii) without berm with a drained blanket and (iv) with berm with a drained blanket. Out of four cases, the best case to improve the factor of safety of the slope is (IV) with berm with a drained blanket of the earthen dam. [5]

Indra Gunawan et al. (2017) studied data simulation to calculate the safety factor of the slope with soil nailing reinforcement. The results indicate that safety factor of slope stability increases with the increase of length and diameter ratio of the nail. At any angle of friction and steepness of the slope, certain effective length and diameter ratio was obtained. These results may be considered as a preliminary design for slope stabilization. [6]

Alsubal Shamsan et al. (2017) studied about the common issue in construction industry, such that engineers have to avoid its risk on human lives and properties by an appropriate technical design of stabilizing methods. Soil nail is one of such stabilization methods. In this paper,soil-nailing system was studied in terms of inclination, spacing and length to determine the most appropriate values for effective stabilization of soil slope. To find the optimum soil nail system, different soil nail inclination, length and spacing were applied to a hypothetical homogenous soil slope and the Factor of Safety (FOS) was evaluated in each case. [7]

Ravindra Budania et al. (2016) explained about the soil nail walls are relatively flexible and can accommodate comparatively large total and differential movements. The measured deflectionsof soil nail walls are usually withintolerable limits in roadway projects when the construction is properly controlled. Soil nail walls have performed well during seismic events. Soil nailwalls have more redundancy than anchored walls because the number of reinforcing elementsper unit areaof wall is larger than for anchored walls. [8]

Shaw-Shong L. (2005) stated that there are still many misconception and myth in the design and construction of soil nails. Various design and construction practices have been adopted inthe local industry of soil nailing works. This paper present s some of the common conventionaldesign and construction practices in detail. [9]

Javia V. et al. (2013) analysed the results indicate that safety factor of slope stability increaseswith the increase of length and diameter ratio of the nail. At any angle of friction and steepness of the slope, certain effective length and diameter ratio was obtained. These results may be considered as a preliminary design for slope stabilization. [10]

V. REASEARCH GAP

This Literature review explains about various research works done on slope stability analysis of earthen dams to control the failures of the slopes, it needs to be analyzed the factorof safety. From the above literature reviews, it is understood that for slope stability analysis different methods are available in GEO-STUDIO Software.

Finite element modelling of the stability and seepage analyses of the earth dam using GEOSTUDIO software. The analysis has incorporated the fully coupled effects and mainly considers the interaction between the surface water and groundwater which forms the essentialcomponent of the coupled analysis. The two main parameters which were varied in the study toidentify the changes in the stability of the earth dam are the Young's modulus (E) and angle ofinternal friction (φ).

In order to achieve the objectives of this study, Geo-studio software is used. The Geo- studio software is mainly based on finite element method that can be used for evaluate the performance of dams. The Geo-studio software is suitable for eight products. SLOPE/W for slope stability, SEEP/W for ground water seepage, SIGMA/W for stress-deformation, QUAKE/W for dynamic earthquake, on this research SLOPE/W is used. The product SLPOE/W is calculate the analysis of slope stability and pore-water pressure conditions, soil properties, analysis of methods and loading conditions. For analysis of slope stability having a several methods such as Bishop, Ordinary, Janbu, Morgenstern-price method, Spencer method.

VI. REASEARCH METHODOLOGY:

Kashypi Dam, is an earthfill dam on Kashyapi river near Rajapur, Nashik district in the state of Maharashtra in India. The height of the dam above lowest foundation is 41.75 m (137.0 ft) while the length is 1,380 m (4,530 ft). The volume content is 0.05174 km^3 (0.01241 cu mi) and gross storage capacity is0.05269 km^3 (0.01264 cu mi). Downstream of this dam is the Gangapur Dam whichopened in 1965. Due to silt deposition in the reservoir area, the storage capacity of the Gangapur Dam has gradually reduced. The right side canal running towards Nashik is also closed due to the high civilization in the area. For these two reasons, the Kashypi Dam was constructed. The purpose of this dam is for irrigation purpose.

Software analysis is done on Kashypi Dam. The analysis is done by Morgenstern-price method. The data which is required for analysis is collected from Irrigation Department (MERI) for soil. For solving the analysis literature is used with Geostudio help.

The student version of SLOPE/W only allows analysis of materials with the Mohr-Coulombproperties

1. Unit Weight (kN/m')
2. Cohesion (kPa)
3. Friction Angle (Degree).

The student version limits the analysis to 3 materials only.

Table No 1: Properties of Embankment

Type of Soil	Symbol	Units	Property	Values
Fissured Clay	ϕ	KN/m3	Unit weight of soil	18
	C	kPa	Cohesion of Soil	1.62
	Ꞁ	Degree	Angle of internal friction	0.15

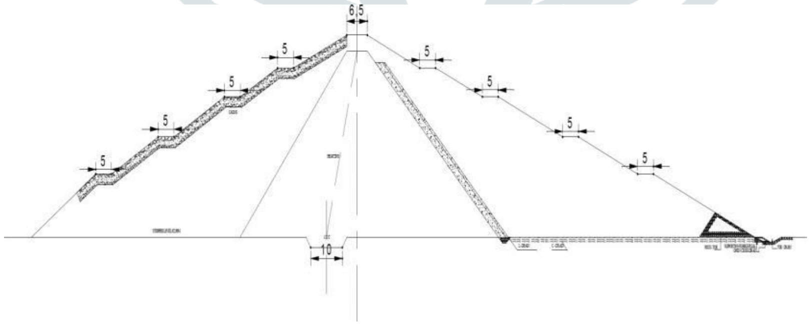

Fig 1: CAD Drawing of Kashyapi Dam

Following steps are used for Geo-studio 2019 software.

1. For slope stability open the Geo Studio SLOPE/W Define module.
2. Identify the individual toolbars available.

3. Set the working area.
4. To set the working page size.
5. Set the scale.
6. Sketch a picture.
7. Set and display the grid.
8. To save the data to a file.
9. To sketch an axis.
10. Sketch the slope stability problem.
11. Specify the options used in the analysis.
12. Define the soil properties.
13. Draw the first region of the problem.
14. Draw entry and exit location.
15. Turn off the points and the point numbers.
16. Display soil properties.
17. Verify the problem.
18. Save and analyse the problem.
19. Viewing the results.

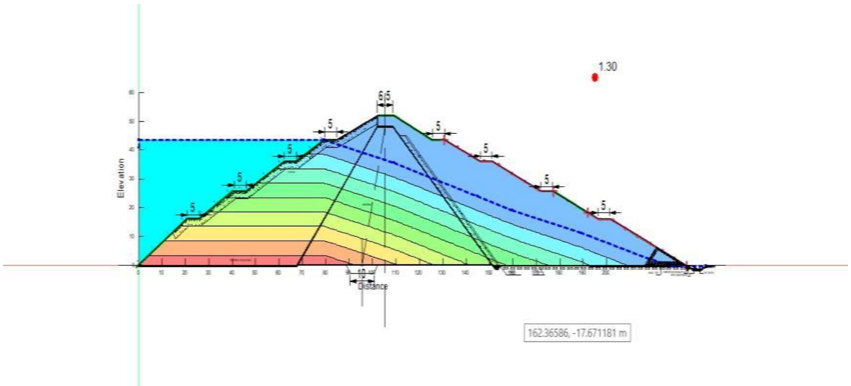

Fig.2 SLOPE/W Model Showing FOS

Therefore, process done to simulate the critical slip surfaces for all the cases which are mentioned above in methodology. The stage involves computing F_m and F_f for a range of trial lambda λ values. These results are used to create a plot such as in Figure 3. The curve with the red, closed-square symbols is the factor of safety with respect to moment equilibrium; that is F_m. The curve with the blue, open-squares is the factor of safety with respect to horizontal force equilibrium; that is, F_f.

where, F_m-moment equilibrium
F_f-horizontal force equilibrium

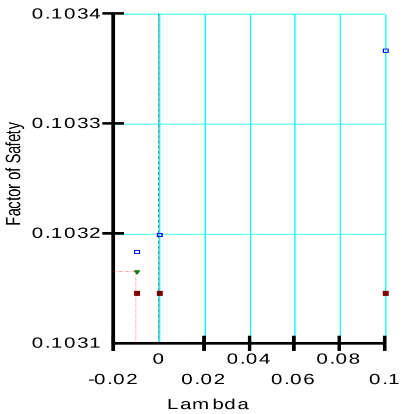

Fig.3 Lambda Vs Factor of Safety

Figure 4 compares the shear strength along the slip surface with and without any seismic forces. Applying the seismic forces alters the shear strength profile. This is primarily due to a change in normal stress distribution along the slip surface. SLOPE/W first does an analysis without any seismic forces, to establish the strength along the slip surface. The shear strength at the base of each slice is then converted into an equivalent undrained (cohesive) strength. The analysis is then repeated with the seismic loading. The undrained shear strength is not a function of the normal stress and, consequently, the seismic loads do not alter the shear strength. This is illustrated in Figure 4. The graph shows that the strength was converted into an equivalent cohesive strength.

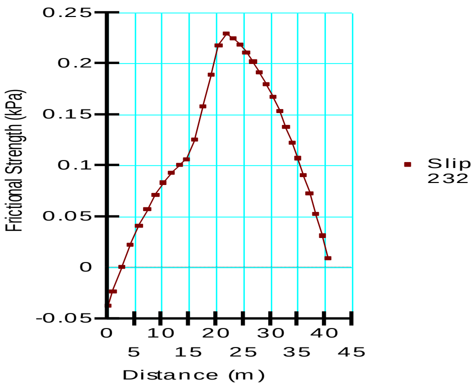

Fig.4 Distance Vs Frictional Strength

Figure 5 shows the piezometric line is used to define the pore-water pressure in the stratigraphic units, while the phreatic line is used for the deepest layer. This would be typical of an artesian aquifer in a field case. It should be noted in the graph or pore-water pressure verses slice base that the use of multiple piezometric lines can result in sharp changes in pore-water pressure. This can be avoided by using the pore-water pressures from a finite element analysis

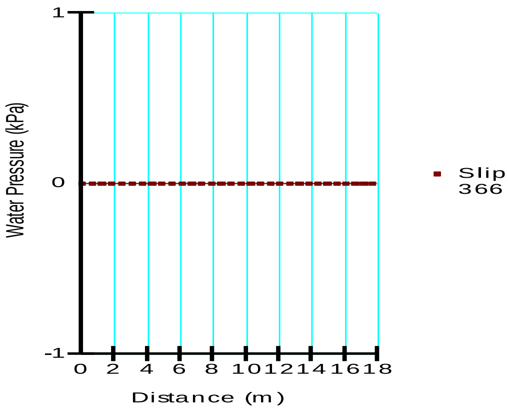

Fig.5 Distance Vs Water Pressure

In fig.6 it represents the relationship between the distance between particles and the cohesive strength of the material. As the distance between particles decreases, the cohesive strength tends to increase, reflecting the material's ability to resist shearing forces. This

+graph helps in understanding how changes in particle arrangement affect the overall stability and behavior of the material, which is crucial for geotechnical analysis and engineering design.

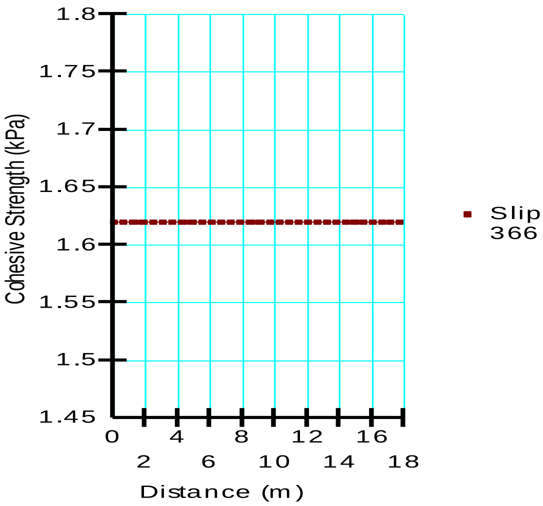

Fig.6 Distance Vs Cohesive Strength

VII. RESULT AND DISCUSSION:

Earthen dams are used to reserve the water on upstream side to facilitate for multi purposes. The slope of the earthen dam may fail due to seepage, during the construction. The ies are needed to be checked for the both upstream and downstream sides. The objective of the analysis was to compute the minimum factor of safety and locate the critical slip surface. The problem was first modeled in SEEP/W and has been applied together with SLOPE/W using a Mohr-Coulomb soil model. It was solved using M-PM with half-sine inter-slice force function.

The stability of slopes of an earthen dam is tested under the following loading conditions:

a) Stability of downstream slope during steady seepage.

b) Stability of upstream slope during sudden drawdown.

571 Stability of downstream slope during Sudden Draw Down analysis: "Entry and Exit" (Case: With berm with drain)

7.1.1 Morgenstern-Price Method

Morgenstern and Price (1965) developed a method similar to the Spencer method, but they allowed for various user-specified interslice force functions. In summary, the Morgenstern-Price method:

1. Considers both shear and normal interslice forces.

2. Satisfies both moment and force equilibrium.

3. Allows for a variety of user-selected interslice force function.

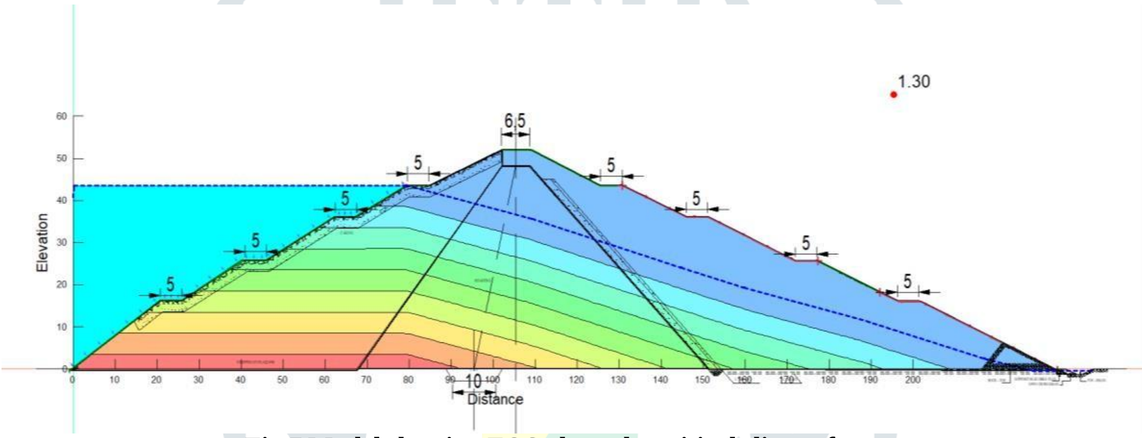

Fig.7 Model showing FOS along the critical slip surface

Figure 8 shows the variation of pore water pressure corresponding to distance along the critical slip circle on downstream slope, the graph depicts that the pore water pressure is negative at the feel of downstream slope due to suction and it increases upto the maxímum ordinate of slices (slice 1to 16) and it decreases further from (slice 17 to31) upto the toe of downstream slope.

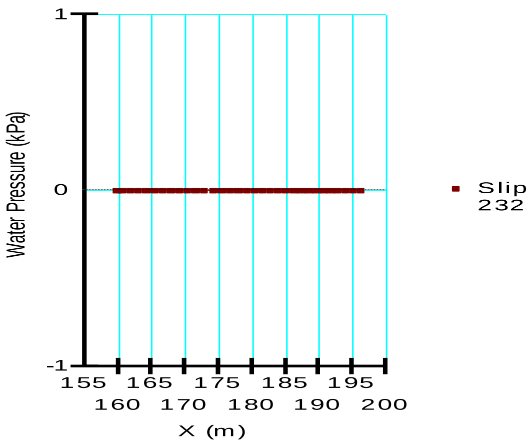

Fig.8 Distance along the critical slip surface Vs Pore-Water Pressure

Figure 9 shows the frictional strength increases corresponding to distance along the critical slip surface from heel to the phreatic line upto slice 17 then maintains constant from slice 4 to 14.Again strength decreases from slice 17 to 31 i.e. upto the last slice of critical slip surface.

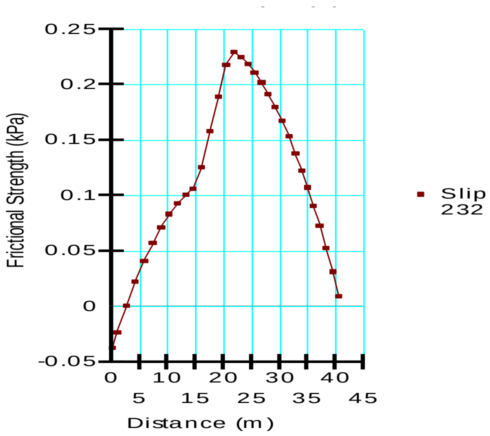

Fig.9 Distance along the critical slip surface Vs Frictional Strength

VIII. CONCLUSION:

1. The value of FOS evaluated using Geo-Studio are more reliable as compared to the limit equilibrium method. In Geo-Studio, it is easy to undertake the parametric sensitivity studies.

2. Provision of drain increases the factor of safety on downstream side.

3. Steady state sudden drawdown stability analysis on downstream side is necessary for homogeneous earthen dam.

4. In this analysis, the factor of safety values form Morgenstern-Price method have been analysed to find out stability of earthen dam, which are analysed with berm with drain case at Entry and Exit.

5. As per IS Code 7894 (1975) for determining the FOS of earth dam minimum FOS should be considered i.e. 1.3 to 1.5.

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