SLOPE STABILITY ANALYSIS BY FINITE ELEMENT METHOD USING GEO-STUDIO

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Abstract: The Current Study is designed to model slope stability analysis of earthen dam using finite element method by GEOSTUDIO 2012 Software. The Earthen dam is an important civil engineering structure that is multifunctional and used throughout the world. Slope Stability Investigation is very important issues that should be considered at designing. This paper describes the slope stability of earthen slopes by limit Equilibrium method in the Geo studio Software it is mainly Geotechnical Software. For Slope stability problem Slope/w tool was used from the software and it is completely based on the limit equilibrium principles. This Analysis is mainly carried out to describe the factor of safety for different slope values (H: V). The minimum factor of safety and the critical slip surface are determined using Morgenstern–Price method and Mohr's Coulombs Expression. For the minimum factor of safety, the material properties are carried out such as unit weight, cohesion, angle of friction and the piezometric line for slope stability analysis

Index Terms – Limit Equilibrium, Cohesion, Angle of internal friction, Factor of safety, Slope/W, slope stability, Geo Studio.

I. INTRODUCTION

Slope Stability Analysis is performed to assess the safe design of natural slopes and Equilibrium conditions. The Stability of a slope is of critical importance in geotechnical engineering applications. The minimum required factor of safety in earth dam never exceeds 1.5. it was found that the factor of safety of 1.5 provided sufficient contingency and was generally considered acceptable. A Factor pf safety of 1 means that the structure will fail exactly when it reaches the design load, and cannot support any additional load. To derive the factor of safety, slope stability analysis of the embankment The analysis has been performed using mohr's coulomb failure envelope, there are many methods of analysis such as method of slices, bishop's method, Anbu's method and Morgenstern's method etc., using any of the method one can determine the stability analysis. SLOPE/W is a tool have been used with "Morgenstern method" to do the stability Analysis .it uses the theory of limit Equilibrium of force to compute the factor of safety against failure. Geo-studio is analysis-based software in which we can perform various types of analysis related to geotechnical studies it is user friendly software which is available free for using finite element method of analysis.

II. REVIEW OF LITERATURE

Analysis of an earthen dam, especially its slopes, is very important these days as its failure may cause huge loss of lives and properties. The factor of safety is increased on downstream section after providing the berm on the d/s side. The factor of safety is increased on downstream section after providing the toe drain. Out of four cases, the best case to improve the factor of safety of the slope is the fourth case i.e. earthen dam with berm and with a toe drain [1].

Earthen dams are mostly prone to failures. Seepage failure accounts for 40% of the total failures. So, it is necessary to minimize the seepage within the embankment to increase the stability and thereby increasing the life of structure It is observed that dam is safe against sliding failure at downstream side for steady seepage conditions. Hence there is no internal erosion due to seepage. The provision of rock toe and horizontal filter reduces the pore pressure in the downstream portion of the dam and thus increases stability of structure, permitting steep slopes and thus effecting economy in construction [2].

In this Journal They compared two software's to calculate seepage through dam. They also attempted soil stability of Dam using Ansys. Firstly, Dam was studied by using analysis method, then seepage is predicated the seepage Rate in Ansys, 18% percent is lower than Geo-studio results. Besides, Slope Stability is studied and different behaviour of dam is simulated. The obtained results of Ansys and Geo studio Software were compared [3].

In this paper the computer base analysis is comparatively easy to compute and check stability analysis. Variation in width of berm on upstream and downstream side of dam section is directly affected on factor of safety. It is concluded that by changing the berm width of earth dam the factor of safety can be restored by anchoring and nailing. The effect of anchoring factor of safety is as shown in graph [4].

III. PROPOSED METHODOLOGY

The stability of slope is characterized by the term factor of safety. The first commercial version was installed on mainframe computers and users could access the software through software bureaus. The software was again renamed as SLOPE/W to reflect the Microsoft Windows environment and that it now had a graphical user interface. SLOPE/W was the very first geotechnical software product available commercially for analyzing slope stability based on Limit Equilibrium Principles.

Morgenstern-Price Method

Morgenstern-price method is a general method of slices developed on the basis of limit equilibrium.it requires satisfying equilibrium forces and moments and mainly used in the stability analysis. The interslice functions available and Slope/W for use with the Morgenstern price method are constant, Half sine, Trapezoidal etc. The minimum factor of safety and the critical slip surface have been determined in this method.

The Conditions included are:

(i) Stability analysis for Different slopes (H: V)
(ii) Stability Analysis with varying unit weight (ɣ)
(iii) Stability analysis with different cohesion and angle of internal friction
(iv) Stability analysis with different Piezometric line

3.1 Stability analysis for Different slopes (H: V)

The aim of the analysis was to compute the minimum factor of safety and locate the critical slip surface. Fig.1 presents the schematic diagram of the slope with piezometric line considered 2m below the toe level for the current study. The slope (1.6-horizontal: 1-vertical) is having total height of 20m over rock at 6m below the base of the cut.

Fig. 1 Schematic diagram of a slope

The problem was first designed in SLOPE/W using a Mohr-Coulomb soil model without tension cracks and solved using M-PM with half-sine inter-slice force function. The problem was solved with same cohesion, angle of internal friction and unit weight but with different slopes. The corresponding Factors of Safety(FS) were computed (Table I). The Critical Slip Surface corresponding to lowest FS obtained is shown in Fig.2.The Free body diagram and force polygon of a slice is shown in Fig 3.

3.2 Stability Analysis with varying unit weight (ɣ)

Analysis is done with a slope 1.6:1(H: V) and keeping theslope, cohesion and angle of internal friction as same andpiezometric line constant we have changed the values of unit weight. Entry and exit values of the slope were kept as same. The corresponding *FS* was computed (Table 2). The Critical Slip Surface corresponding to lowest *FS* obtained is shown in Fig. 4.

3.2.1 Stability Analysis with varying unit weight (ɣ)

Analysis is done with a slope 1.8:1(H: V) and keeping theslope, cohesion and angle of internal friction as same andpiezometric line constant we have changed the values of unit weight. Entry and exit values of the slope were kept as same. The corresponding *FS* was computed (Table 3). The Critical Slip Surface corresponding to lowest *FS* obtained is shown in Fig.5.

3.2.2 Stability Analysis with varying unit weight (ɣ)

Analysis is done with a slope 2:1(H: V) and keeping the slope, cohesion and angle of internal friction as same andpiezometric line constant we have changed the values of unit weight. Entry and exit values of the slope were kept as same. The corresponding *FS* was computed (Table 4). The Critical Slip Surface corresponding to lowest *FS* obtained is shown in Fig.6.

3.3 Stability Analysis with varying cohesion (C) and angle of internal friction (ϕ)

Analysis is carried out with a slope of 1.6:1(H: V), keeping the unit weight same and piezometric line constant. The values of cohesion and angle of internal friction are varied. Unit weight for the upper layer is taken as 18 kN/m^3 and that for the lower layer is taken as21 kN/m^3. The entry and exit values of the slope are keptthe same. The corresponding *FS* was computed (Table 5). The Critical Slip Surface corresponding to lowest *FS* obtained is shown in Fig. 7.

3.3.1 Stability Analysis with varying cohesion (C) and angle of internal friction (ϕ)

Analysis is carried out with a slope of 1.8:1(H: V), keeping the unit weight same and piezometric line constant. The values of cohesion and angle of internal friction are varied. Unit weight for the upper layer is taken as 18 kN/m^3 and that for the lower layer is taken as21 kN/m^3. The entry and exit values of the slope are keptthe same. The corresponding *FS* was computed (Table 6). The Critical Slip Surface corresponding to lowest *FS* obtained is shown in Fig. 8.

3.3.2 Stability Analysis with varying cohesion (C) and angle of internal friction (ϕ)

Analysis is carried out with a slope of 2:1(H: V), keeping the unit weight same and piezometric line constant. The values of cohesion and angle of internal friction are varied. Unit weight for the upper layer is taken as 18 kN/m^3 and that for the lower layer is taken as 21 kN/m^3. The entry and exit values of the slope are kept the same. The corresponding *FS* was computed (Table 7). The Critical Slip Surface corresponding to lowest *FS* obtained is shown in Fig. 9.

3.4 Stability Analysis with different piezometric level

Analysis is done with a slope 1.6:1(H: V) and keeping theslope, unit weight cohesion and angle of internal friction as constant every time we have changed the water level. Unit weight for the upper layer is taken as 18KN/m^3 and for the lower layer is taken as 21 kN/m^3. Cohesion forthe upper layer and lower layer is taken as 5 and 10 and angle of internal friction for upper and lower layer was taken 25 and 30 respectively. The corresponding *FOS*s were computed (Table 8). The Critical Slip Surface corresponding to highest *FS* obtained is shown in Fig.10

IV. RESULT & DISCUSION

The problem was first designed in SLOPE/W using a Mohr-Coulomb soil model without tension cracks and solved using M-PM with half-sine inter-slice force function. Analysis is done for the above methods.

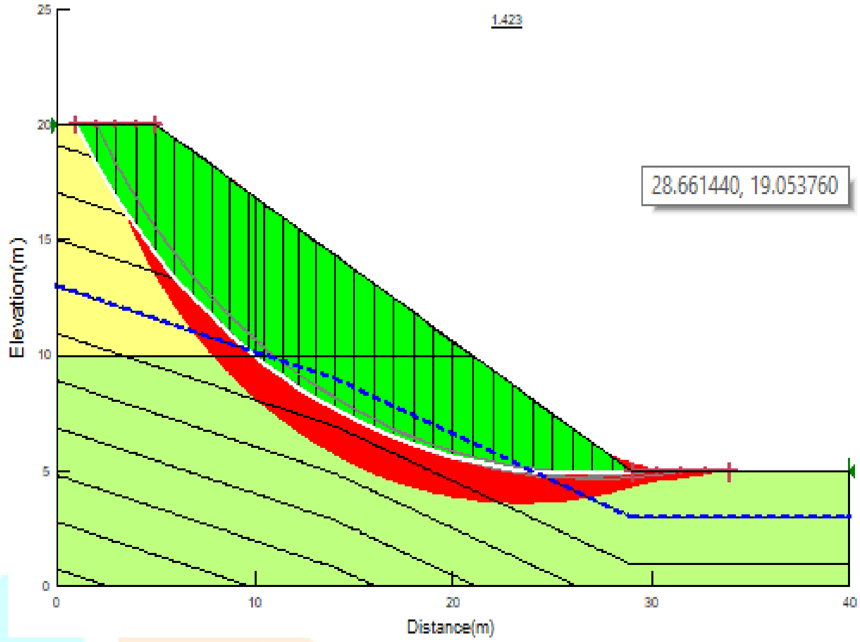

Fig. 2 ***Critical Slip Surface*** **for** ***SLOPE/W*** **Analysis using M-P*M* with a slope of 1.6H: 1V**

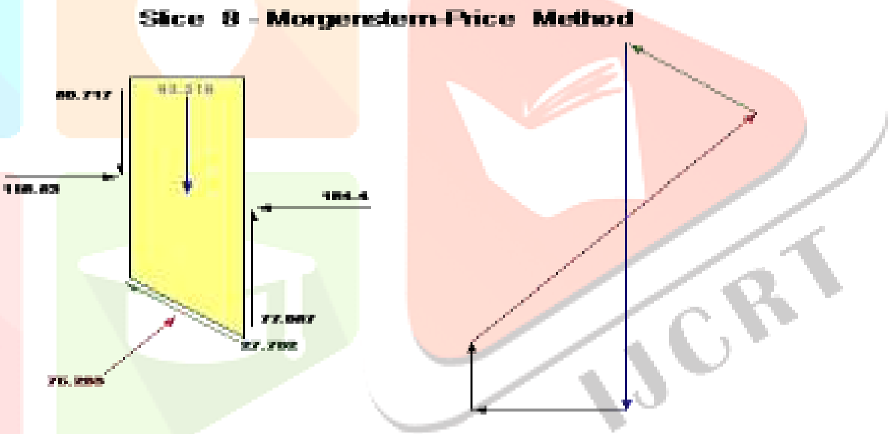

Fig. 3 Free body diagram and force polygon of a slice

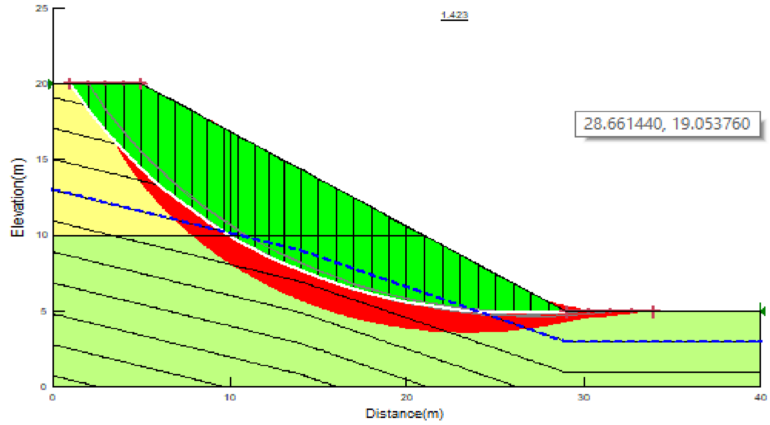

Fig. 4 ***Critical Slip Surface*** **for** ***SLOPE/W*** **Analysis using M-P*M* with varying unit weight**

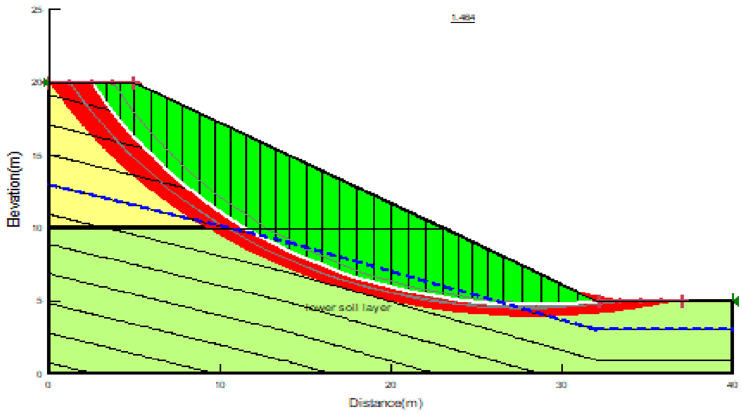

Fig. 5 ***Critical Slip Surface*** **for** ***SLOPE/W*** **Analysis using M-P*M* with varying unit weight**

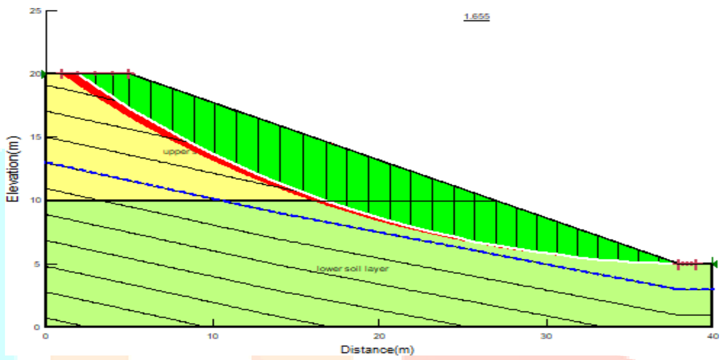

Fig. 6 ***Critical Slip Surface*** **for** ***SLOPE/W*** **Analysis using M-P*M* with varying unit weight**

Fig. 7 ***Critical Slip Surface*** **for** ***SLOPE/W*** **Analysis using M-P*M* with changing C and Φ for a dry slope**

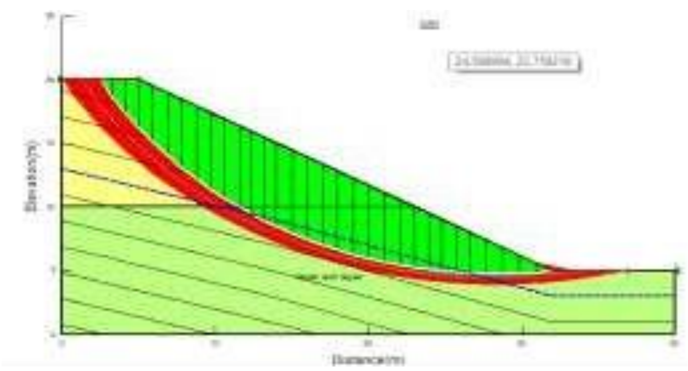

Fig. 8 ***Critical Slip Surface*** **for** ***SLOPE/W*** **Analysis using M-P*M* with changing C and Φ for a dry slope**

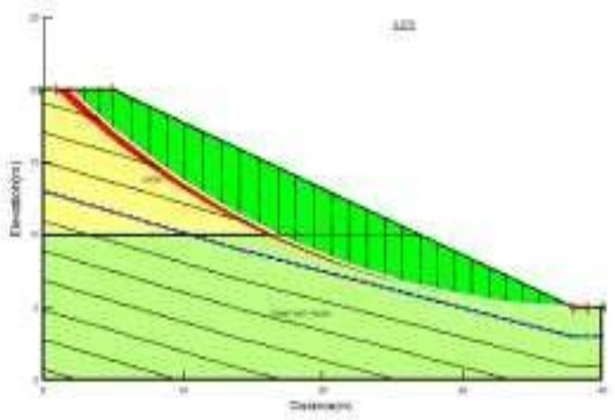

Fig. 9 ***Critical Slip Surface*** **for** ***SLOPE/W*** **Analysis using M-P*M* with changing C and Φ for a dry slope**

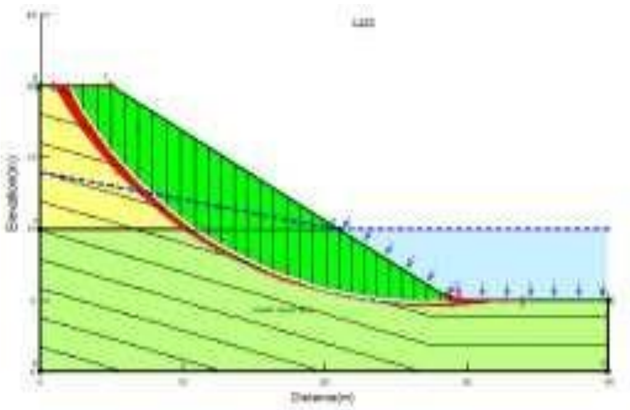

Fig. 10 ***Critical Slip Surface*** **for** ***SLOPE/W*** **Analysis using M-P*M* with Water level 5m above toe**

Table 1: ***Factor of Safety*** **with changing slopes**

GEOSLOPE (SLOPE/W)		
Slope stability method used	H:V	FS
M-PM	1.6:1.0 1.8:1.0 2.0:1.0	1.423 1.559 1.803

Table 2 : *Factor of Safety* with changing unit weight

GEOSLOPE (SLOPE/W)			
Slope stability method used	**Unit weight** (kN/m^3)		FS
	Upper layer	**Lower layer**	
M-PM	15.0	18.0	1.423
	18 .0	21.0	1.370
	21 .0	24.0	1.327

Table 3 : *Factor of Safety* with changing unit weight

GEOSLOPE (SLOPE/W)			
Slope stability method used	**Unit weight** (kN/m^3)		FS
	Upper layer	**Lower layer**	
M-PM	15.0	18.0	1.559
	18 .0	21.0	1.507
	21 .0	24.0	1.464

Table 4 : *Factor of Safety* with changing unit weight

GEOSLOPE (SLOPE/W)			
Slope stability method used	**Unit weight** (kN/m^3)		FS
	Upper layer	**Lower layer**	
M-PM	15.0	18.0	1.803
	18 .0	21.0	1.725
	21 .0	24.0	1.655

Table 5: *Factor of Safety* with changing C and Φ

GEOSLOPE (SLOPE/W)			
Slope stability method used	**C (in kN/m^2) and Φ (in degrees)**		FS
	Upper layer	**Lower layer**	
M-PM	5 & 10	5 & 20	0.794
	10 & 20	10 & 25	1.202
	10 & 25	10 & 30	1.423

Table 6: ***Factor of Safety*** **with changing C and Φ**

GEOSLOPE (SLOPE/W)			
Slope stability method used	**C (in kN/m²) and Φ (in degrees)**		FS
	Upper layer	**Lower layer**	
M-PM	5 & 10	5 & 20	0.861
	10 & 20	10 & 25	1.312
	10 & 25	10 & 30	1.559

Table 7: ***Factor of Safety*** **with changing C and Φ**

GEOSLOPE (SLOPE/W)			
Slope stability method used	**C (in kN/m²) and Φ (in degrees)**		FS
	Upper layer	**Lower layer**	
M-PM	5 & 10	5 & 20	0.978
	10 & 20	10 & 25	1.515
	10 & 25	10 & 30	1.809

Table 8: ***Factor of Safety*** **with changing piezometric level**

GEOSLOPE (SLOPE/W)		
Slope stability method used	Water level above the toe ofthe slope	FS
M-PM	1 m	1.277
	2 m	1.261
	3 m	1.253
	4 m	1.260
	5 m	1.279

V. CONCLUSION

In this study the factor of safety is calculated using Morgenstern Price method. The Problem is modeled in Slope/W using a Mohr-coulomb method, Firstly the problem was solved with same cohesion, Angle of internal friction and unit weight with different slopes. The factor of safety is increased with increasing in slope value. Then for Three different slopes the factor of safety is calculated with constant cohesion and angle of internal friction values with changing unit weight. Factor of safety is decreased with increasing unit weight. Again, for Three different slopes the factor of safety is calculated with constant Unit weight and changing the cohesion and angle of internal friction. Factor of safety is increased with increasing cohesion and angle of internal friction. For the Slope 1.6:1(H:V) keeping the cohesion unit weight and angle of internal friction as constant with changing the different piezometric level. Factor of safety is decreased with increasing with piezometric level up to 3m later the factor of safety is increased with increasing the piezometric level because of lateral pressure present in the side wall of the dam.

On the Basis of work done in this paper later we can do the analysis with different soil layers and with increased or decreased the cohesion and angle of internal friction values and for different piezometric levels.

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