Design and Analysis of Earth Slopes Using Geosynthetics

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Abstract. In the aspect of geotechnical engineering problems, slope stability is a condition of inclined soil, waste heaps to withstand or undergo movement. Slope is an unprotected ground surface that can be necessitated at an angle of horizontal. Slopes are necessitates in the construction of railway embankments and highways, levees, bridges, earth dams, reservoirs and canals etc., and are generally less expensive. Failures of natural and man- made slopes have demise and demolition. Analysis and stability slopes consist of determining and comparing the shear stress developed along the potential rupture surface with the shear strength of the soil. The awareness of the surface drainage is very important factor. Slope stability can be evaluating the ground water, shear strength of the soil. For a secure slope factor of safety should not be less than 1. In recent times electronic computers made it feasible to more easily repetitious mechanism and the use of OASYS GE software has simplified the analysis to a great extent. In this present study OASYS GE Slope software has been to analyze the homogeneous earth slopes for different cohesive strengths, and also we study the improvement of stability of slopes using geo membrane and we also consider the effect of ground water table on stability of slopes.

Keywords: OASYS GE, Slope, Slip surface, Ground water table, Geo membrane, Black cotton soil.

1 Introduction

A slope is an unsupported, inclined surface of a like soil mass. Slopes can be natural or man-made. These may be above ground level as embankments or below ground level as cuttings. Earth slopes are formed for railway embankments, earth dams, canal banks, levees at many locations. Instability related problems in engineered as well as natural slopes are common challenges to both research scholars and professional. Instability results may be due to sudden rain, sudden increasing water table and also

sudden change in stress conditions. The natural slopes are very strong but due to geometry and external forces there is sudden fall and loss of shear strength. In addition, the long-term stability is associated with the weathering and chemical influences that may decrease the shear strength. In such circumstances, the evaluation of slope stability conditions becomes a primary concern everywhere. When a mass of soil has an inclined surface the potential of slope to slide from higher level to lower level always exist. The sliding will occur if shear stress developed in the soil exceeds corresponding shear strength of soil. However certain practical considerations make precise stability analyses of slope difficult in practices. The engineering solutions to slope instability problems require good understanding of analytical methods, investigative tools and stabilization measures. Bishop A W [1955] says, "The primary aim of slope stability analyses is to contribute to the safe and economic design of excavation, embankment and earth slopes".

Objectives of the study:

- By using Oasys slope 19.0 Software, to determine the minimum factor of safety values of the slopes.
- Determining the critical failure of slope's surface and application of engineering judgment in determining, whether the slopes will be stable or not stable as recommended by BS8006:1995.
- Design and implementation of solutions for detection, control, remediation and prevention of subsurface contamination.

2 Literature Review

Abramson, L. W. et al., (2002) have worked on the slice models for evaluating slopes. It has been realized that new slice model predicts the minimum factor of safety. They have said that cutting into existing ground disturbs the mechanics of the surrounding area, which can result in slope failure. This particular information gives the comprehensive data about slope stability analysis. It includes detailed discussions of methods used in slope stability analysis, including the ordinary method of slices such as simplified Bishop's method, Janbu's method, Spencer's method and limit equilibrium method and use of computer programs to solve problems. **Swedish (1950)** developed the Swedish method and he neglected all the internal forces acting on the slices. Iteration analysis is not necessary during the calculation of Factor of Safety. When comparing to other strict methods, the processing of computer calculations is very easy and simple. The assumptions of boundary conditions make Classical Swedish Methods results more conservative. Using this method a Factor of Safety can be estimated quicker than other methods of design in practice. **Bishop A W (1955)** Bishop's method of slope stability analysis is the most common methods. It is the most talk able method in all kinds of geo technology book and throughout the world. Circular failure surface slope stability will be analyzed using this method. In case of undrained condition Swedish method and Bishop's method are more identical to each other. **Janbu (1957)** simplified method will completely satisfy the equilibrium of force even though the moment equilibrium was not satisfied. This method is also used

worldwide. The Janbu method is used for non-circular critical surface that appears in sand. After a rigorous change in formula moment equilibrium is also taken into an account. The value of factor of safety using the simplified method comes very close to the rigorous method results. **Bozana Bacicn (2014)** "Slope stability analysis" in that paper they conclude a methodology of slope stability analysis and provide an insight into the basic of landslides and their general terms. Natural process of constant affected by change in relationship for shearing stress and resistance.

3 Study Area, Materials Preparation and Methodology

3.1 Study Area

Slope is taken at Dundigal area in Hyderabad. The soil sample is also taken at Dundigal village dump area it is located at a distance of nearly 15km kompally, A trench is made at embankment at a depth of 1m to fix the HDPE sheet. To the below mentioned leachate pond reinforced material i.e., Geo membrane is placed to avoid soil pollution and ground water pollution because when a solid waste is dumped into a landfill, that land fill produces liquid i.e. leachate and that leachate is discharged in a pond with the help of a HDPE sheet it does not allow on the surface. HDPE sheet is known as protection of leachate not to flow on the surface or ground. Geo-membrane which gives tensile nature to the ground surface. Leachate which is coming from landfill is collected as shown in figure 1.

Fig. 1. Preparation of slope for leachate pond and placing of geo membrane at slope

Table-1 Tensile Properties of Geo-membrane ASTM D6693

Property	**GM2.0**
Thickness	2.00mm
Density	0.940g/cc
Strength at break KN/m	26
Strength at yield KN/m	40
Elongation at Break (%)	11%
Elongation at yield (%)	600

Physical properties: Thickness -500 micron, density-0.94 g/cm3, mass per unit area 6.4 kg/m2, UV radiation2%, compressive strength-2200 Mpa, type -HDPE virgin, color-black.

Chemical properties: HDPE-35%, LLDPE-25%, PVC-25%, Flexible polypropylene-10%, chlorosulfonated Polyethylene-2%, ethylenepropylenedine+polymer-3%.

3.2 Materials Preparation

The Black cotton (BC) soil has a high percentage of clay, which is predominantly montmorillonite in structure and black Colour. An essentially impermeable geo synthetic composed of one or more synthetic sheets is known as geo membrane. Geo membranes are giant impermeable membranes made of unreinforced polymeric materials and used to stabilize earth and to secure landfills ensuring containment of hazardous or municipal wastes and their leachates. The sample preparation and the laboratory testing have been done as shown in the figure 2. Understand the soil properties of the existing site have been taken into account. Testing of soil sample, mainly we consider the angle of internal friction and cohesion values. These values will be used in the Oasys slope software, and then finally we get the output as factor of safety regarding the slope.

Fig. 2. Sample preparation and laboratory tests

Table- 2 Geotechnical Properties of soil sample at Dundigal Village

Soil sample	*Water Content (%)*	*Bulk Density (KN/m^3)*	*Cohesion (KN/m^2)*	*c*	*Angle of internal friction (φ°)*
1	14.30	19.60	2.5		8.2
2	8.90	18.30	4.6		26.7
3	6.70	17.066	5.2		24.50
4	11.0	16.90	6.5		22.6
1	5.72	16.50	4.9		25.70

These samples were collected to determine the shear parameters cohesion, c and φ using direct shear test. Table II shows the water content, bulk density, cohesion, angle of internal friction.

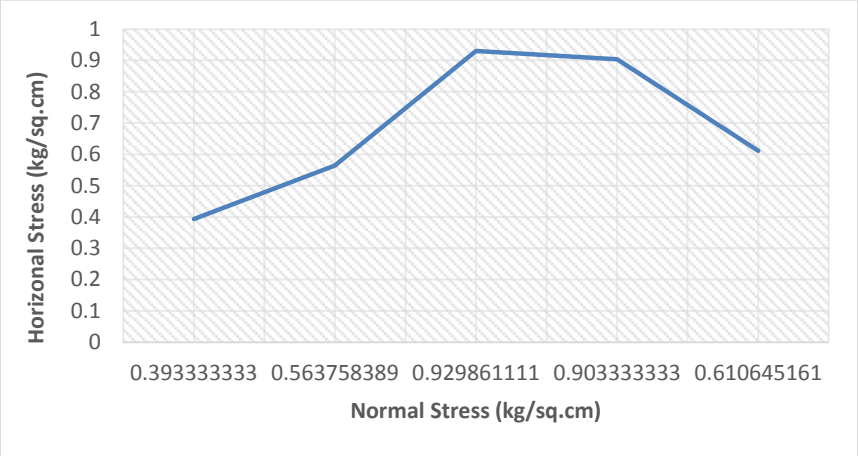

Figure.3 shows a typical effective stress failure envelope of soil sample for calculation of shear parameters.

3.3 Analysis

A. Limit Equilibrium Methods

The various limit equilibrium methods are 1. Swedish circle method, 2. Friction circle method and 3.Bishop's method.

B. Bishop's Method

The analysis has been performed using Bishop's method of slices. In this method, the failure section is divided into a series of vertical slices. The slice width is sufficiently small that the actual shape can be replaced with a rectangular.. It is assumed that the slice weight W acts through the midpoint of the area.

$$FS = \frac{1}{\sum_{i=1}^{i=\infty} W \sin\theta} \sum_{i=1}^{i=\infty} \left[\frac{c'b + W(1 - ru) \tan \emptyset'}{m\theta} \right]$$

Where, F = Factor of safety

w = weight of slice
c = cohesion
b = width of slice
Φ = angle of internal friction
U = pore pressure at each slice

An iterative analysis is necessary to obtain the factor of safety. Since this is trial and error method, this section is deals with the method of slope stability analysis using Oasys slope Software tool. Slope is a system which is utilized for investigating the stability of slopes. The system is additionally pertinent to earth weight and bearing limit issues. The systems are relevant likewise to shake slopes and waste stacks. There are three methods of analysis can be performed using slope software tool they are as both circular and non-circular slip surfaces might be examined. Circular surfaces are characterized by a rectangular matrix of centers and either various diverse radii, a regular point through which all rounds pass or a digression surface which the loop practically touches. Non-circular slip surfaces are characterized separately. The segment to be examined is spoken to by an arrangement of soil or rock strata with limits characterized via Cartesian co-ordinates. The pore water weight appropriation could be changed in every stratum.

4 Slope Stability Analysis Using OASYS Software

4.1 Data Input in Oasys Slope 19.1

Oasys software was established in 1976, Oasys is now recognized as a leading commercial developer of engineering for structural and geo technical, crowd analysis and pedestrian modeling solutions. Oasys slope is the perfect choice for two dimensional slope stability analyses and quick and easy to use for a wide range of slope stability analysis. Analyze reinforcing elements including soil nails, rock bolts, ground anchors and geotextiles. Oasys software innovative solutions are characterized by attractive, intuitive interfaces and the speed and power with which they allow users to test ideas quickly and cost effectively. Enabling engineers to define and solve the most complex of design problems accurately, with complete confidence in their compliance with international standards and compatibility with other leading packages. The following data can be entered in the software with different soil strata and in the presences of ground water table. The data can be entered in both tabular and graphical form. The

methods are fully interchangeable and will update automatically. Before the analysis the input and after the analysis output data has been shown in Figure 3 and 4.

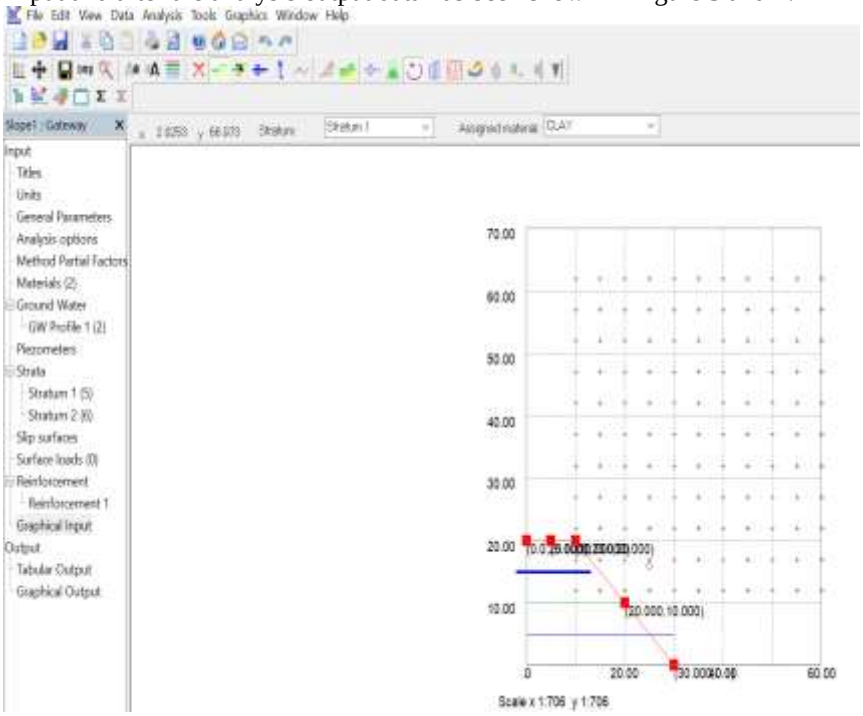

Fig.4. Graphically represented input data in Oasys software (data entry screens)

4.2 Graphical Output

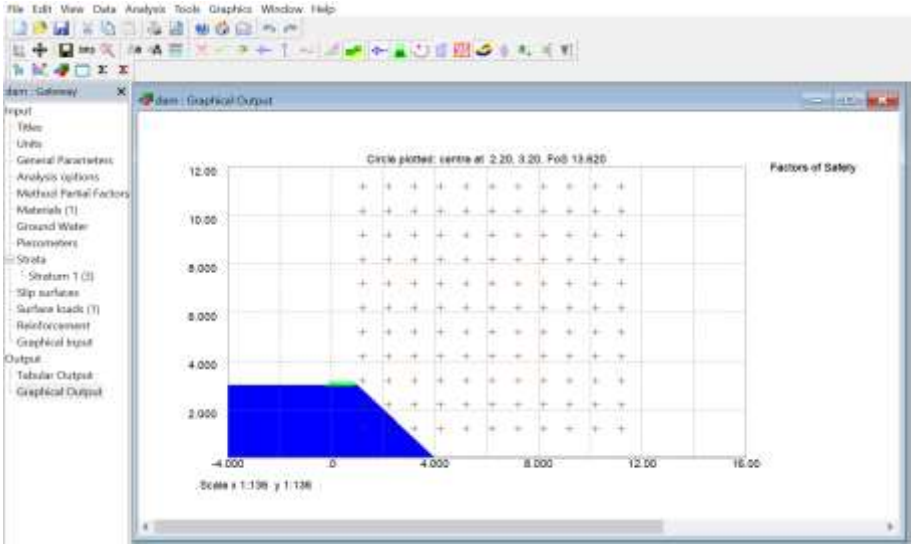

Fig.5. Graphically represented output data in Oasys software (data entry screens)

5 Result and Analysis

The factor of safety (FS) against pullout is required because of uncertainty in the maximum mobilized shear strength. Selection of the safety factor, therefore, depends on the designer's confidence in the value of this strength and how critical the slope is with respect to a potential failure. The soil-geosynthetics friction is influenced by both the soil with geosynthetics and without geosynthetics. The Bishop's method is experimented use of in the evaluation of factor of safety. The factor of safety obtained was 1.32 without geosynthetics as shown in figure 5. In the case of with geosynthetics the factor of safety obtained is 1.36, which is giving around 4% more than as compared to FS obtained as shown in figure 6.

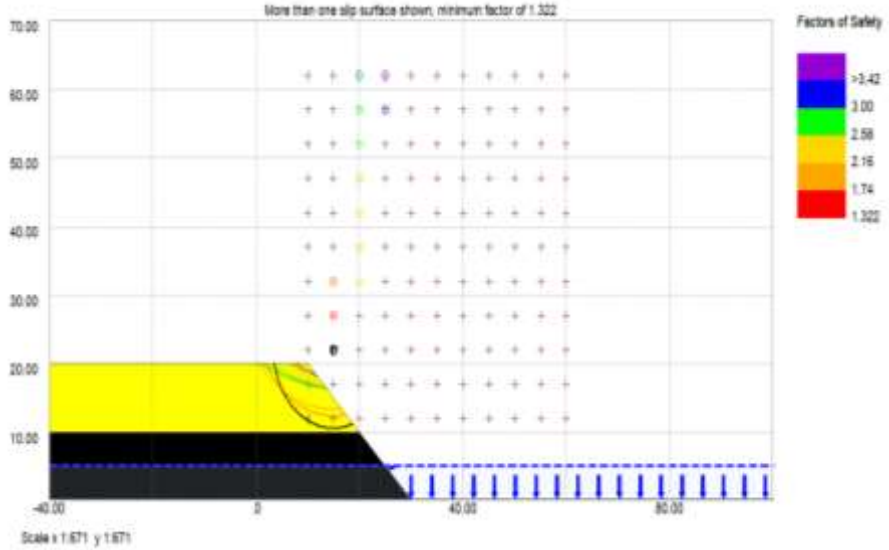

Fig.6. Graphical output without geo synthetics section-I

Table 3 Reinforcement Results

Description	***Possible Capacity KN/m***	***Actual Capacity KN/m***	***Governing Criterion***	***Applied Pre-stress KN/m***	***Additional Capacity KN/m***
Geo-membrane Reinforcement	15.00	50.00	50.00	Tensile	50.00

Table 3 Reinforcement Results

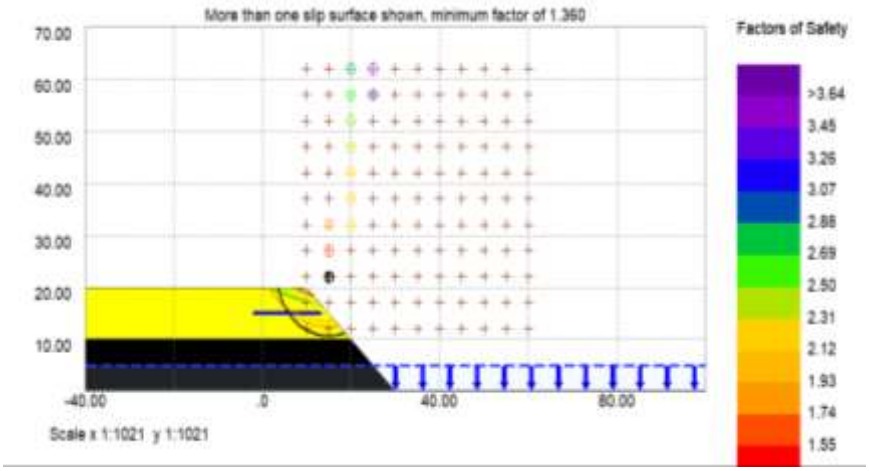

Fig.7. Graphical output with geo synthetics section-II

Note: The applied pre-stress force is the lesser of the specified pre-stress and the actual capacity for this slip surface. The additional capacity is the actual capacity minus the applied pre-stress force. If the angle of reinforcement is greater than the angle from the circle center to the point of intersection with the slip surface, only the applied pre-stress force is taken into account.

6 Conclusions

1. Factor of safety obtained for the section I without geo-synthetic material yield values less than 1.5, which indicates that the slope is unsafe against failure , which is from the slip that have occurred during monsoons.
2. Factor of safety obtained for the section II with geosynthetics material yield stress greater than 1.5 which indicate slope is safe conditions.
3. Results of software analysis are within 0-4 % for both sections without geo-membrane and with geo-membrane. Hence, the Bishop's method can effectively be used to determine the factor of safety of the slope.
4. The 0-4 % difference in FOS can be attributed to capability of Oasys software to optimize the number of slices in Bishop's method and selection of ideal trial slip circle.

5. Factor of safety values less than 1.5 indicate the susceptibility of slope to failure. At present the sites show signs of erosion and slips and if ignored they may develop into major landslides in the near future due to excessive rainfalls,
6. From this study it conclude that the factor safety values increases when we are introducing the geo-membrane as a liner material which is given better values and slope also safe.

This project aims study of limit equilibrium method in various slope stability analyses based on significant works with regards to stability of slopes. Various parameters and factor of safety equations are described. In this project we study the comparisons were made between strength reduction technique and the effect of search techniques on the results obtained from limit equilibrium method using commercially available programs. A numerical investigation is carried out to compute the present condition of Hyderabad city protection slope under seismic load to protect soil from hazardous waste.

References

1. Abramson, L.W., Lee, T.S., (1996). "Slope Stability and Stabilization Methods," John Wiley and Sons, N.Y.
2. Bishop A W (195). The use of the Slip Circle in the Stability Analysis of Earth Slopes. Géotechniques Vol.5 No.1 pp 7-17.
3. Tanaka Y. and Baker R., (1999).' A convenient alternative representation of Taylor's stability chart'. Proc. Intr. Symp. On Slope Stability Engineering. 253-257.
4. Negre R., Pastor J. Botter A., and Turgeman S., (1980). 'Finite Element Method and Limit Analysis Theory for Soil Mechanics Problems', Computer methods in applied mechanics and engineering, 22 (1980), 131-49.
5. Chakraborty and S.Bhattacharya, G., Jana, D., Ojha, S. (2003). Direct search for minimum reliability index of earth slopes. Computers and Geotechnics, 30(6), 455-462.
6. Chen J., 2004. 'Slope Stability Analysis Using Rigid Element', The Hong Kong poly Technical University, (2004).
7. Lee C.F and Chen Jian, Yin J.H., 2003. 'Upper Bound Limit Analysis of Slope Stability Using Rigid Finite Elements and Nonlinear Programming', Canadian Geotechnical Journal, 40 (2003), 742-52.
8. Chen, R. H. (1981): "Three-dimensional slope stability analysis," Joint Highway Research Project, Eng. Experiment station, Purdue University, Report JHRP-81-17.
9. Chen W.F., Limit Analysis and Soil Plasticity (USA: Elsevier, 1975). Chen W.F. and Giger M.W., 1971. 'Limit Analysis of Stability of Slopes', in (Journal of the soil mechanics and foundations division, Proceedings of ASCE 1971).
10. Morgenstern N.R and Chen Z., and 1983. 'Extension to Generalized Method of Slices for Stability Analysis', Canadian Geotechnical Journal, 20 (1983)104-09.
11. Lau.C.K, and Cheng Y.M. 2008. Slope Stability Analysis and Stabilization (Abingdon, UK: Taylor and Francis, Routledge, 2008).
12. Strack O.D.L. and Cundall P.A, 'A Discrete Numerical Model for Granular Assemblies', Geotechnique, 29 (1978), 47-65.

13. Dr. K. R. Arora “Soil mechanics and foundation engineering”, (1987) Standard publishers distributors, (2015) ISBN: 81-8014-112-8
14. Roth W.H. and Drescher A., Dawson E.M., (1999). 'Slope Stability Analysis by Strength Reduction', Geotechnique, 49 (1999]835-40).