A parametric Study on Slope Stability of Earthen Dam

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Abstract--A parametric study on the slope stability of earthen dam has been carried out in this paper. Swedish Slip Circle method has been applied for the purpose. A program has been written for the parametric study on slope stability. The effect of variation of soil parameters, dam geometry, starting point of slip circle etc. on minimum factor of safety (FOS), have been studied. Based on the result obtained in the present study, important conclusions have been drawn at the end.

Keywords-- Slope stability, Swedish slip circle, factor of safety.

I. INTRODUCTION

The stability analysis of earth slopes is one of the important aspects in geotechnical engineering. Slope stability is a matter of tremendous concern in construction of earthen dams where the failure of slopes may incur severe loss of life and damage to property. It is therefore very important to design the dam in such a way that it satisfies both safety and economic consideration. This paper involves in the study of variation of different parameters like the dam height, dam top width, radius of slip surface, chord length of slope, soil strength parameters etc. Seismic force has been considered as per reference IITK-GSDMA guidelines, in which the horizontal seismic force is given as: $F_H = \frac{1}{3} \times Z \times I \times S \times W$, where, Z = Zone Factor, I = Importance Factor, S = Seismic Empirical Coefficient, W = Weight of the sliding mass. There are four failure modes of soil slope as detailed in later section.

II. LITERATURE REVIEW

Pham and Fredlun (2003) presented a paper on the applicability of the dynamic programming method to two-dimensional slope stability analysesusing a computer program named DYNPROG and the results obtained were compared with those obtained using other well-known limit equilibrium methods. Aryal (2006) presented his thesis on slope stability evaluations based on limit equilibrium and finite element method, and carried out parametric study. Lakehal*et al* (2011) presented a paper showing nomograms of various parameters for the calculation of factor of safety of homogeneous earthen dams. Tanpure and Koranne (2012) introduced a simplified graphical technique for the stability analysis of slope by making a few modifications on existing methods. Patel and Sanghvi (2012) presented a paper examining the static and dynamic analysis of Kaswati Dam located in Bhuj. Chatterjee and Choudhury (2012) analysed the stability of a model soil slope comprising of an embankment with two canal bunds at the top, at different stages of construction in different seismic zones. Pandit*et al*. (2013) derived equations and developed methodology using Microsoft Excel program for various methods and the derived results were compared. Siddappa and Shanthakumar (2014) studied slope stability using the software SLOPE/W to analyze the homogeneous slope for various cohesive strengths and compared the FOS with other existing limit equilibrium methods.

III. SCOPE OF THE PRESENT STUDY

The present research is directed towards the parametric study of slope stability of earthen dam carried out using Swedish Slip Circle method. Various dam heights, dam top width and soil strength parameters have been considered. The failure surface of various categories have been treated. The effect of radius of slip circle and different slope lengths have been considered. Seismic force has been considered compatible to Zone V.

IV. RESULTS OF PARAMETRIC STUDY

Slope failure can of four types, namely: local slip failure, superficial failure, general slip failure and deep seated failure. The cases are discussed below

Local slope failure.

The dam section shown in Fig. 1 considers the slip circle encompassing a part of the downstream face of the dam. The left end point of the top width is taken as the starting point of the slip circle while the end point of the slip circle is kept on changing as a percentage of total downstream slope length (or chord length) Fig. 1. Variation of FOS with percentage chord length of d/s face of dam is shown in Fig. 2 and Fig. 3. It is observed that the FOS against slope failure decreases with increase in percentage chord length. Also lowest FOS is obtained when the entire downstream face is taken as the chord length.

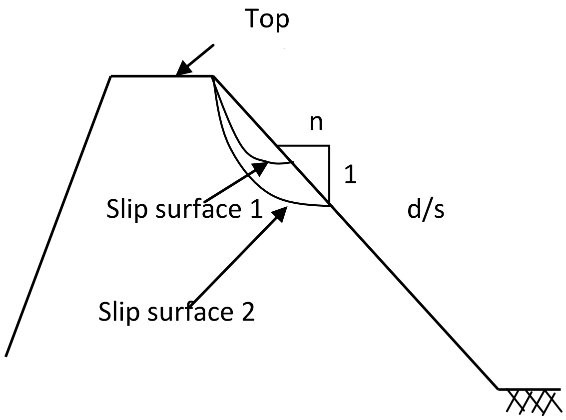

Fig 1: A section of dam showing slip circle comprising of part of chord length.

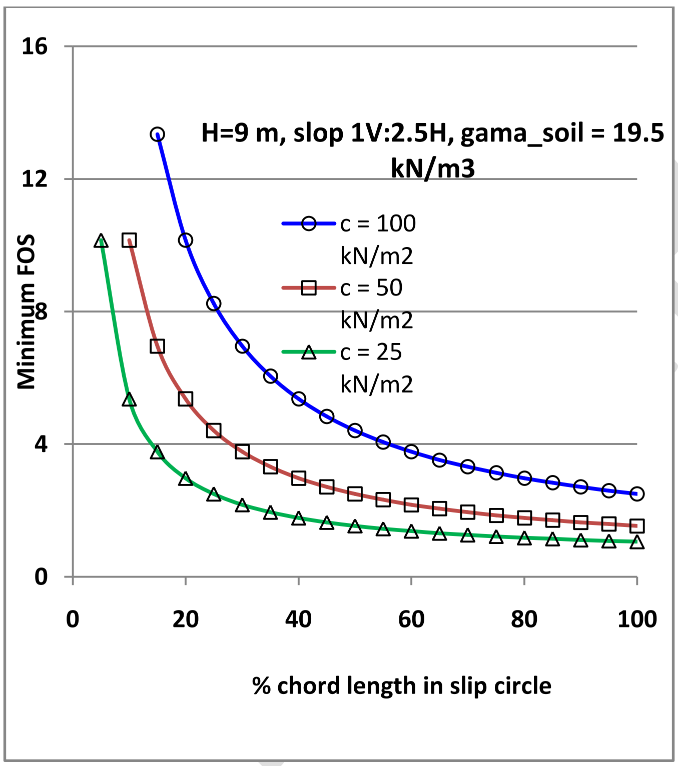

Fig 2: Variation of factor of safety with percentage chord length

From Fig. 2 it can be concluded that as the percentage length of the chord subtended by the slip circle is increased, the FOS goes on decreasing. The same figure also shows that as the soil cohesion is increased, the FOS increases. Fig. 3 shows the effect of variation of angle of repose. The FOS increase with increase with increase of angle of repose.

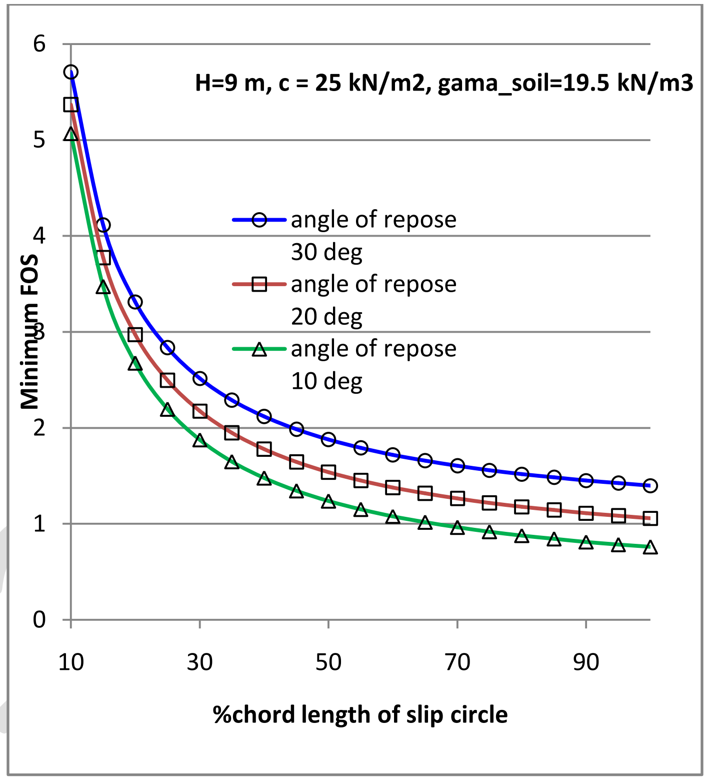

Fig 3: Variation of factor of safety with % chord length and angle of repose

Superficial slope failure.

The dam section is shown in Fig. 4 considers the slip circle encompassing the entire part of the downstream face of the dam. This is superficial slope failure. Variation of FOS with varying radius of slip circle is shown in Fig. 5 and Fig 6. In general the FOS is less when radius of slip circle is less.

In Fig. 5 is shown the variation of FOS when seismic force is ignored and when it is considered. It is obvious that with incorporation of horizontal seismic force, the FOS decreases. In subsequent study here only the cases with seismic force have been reported

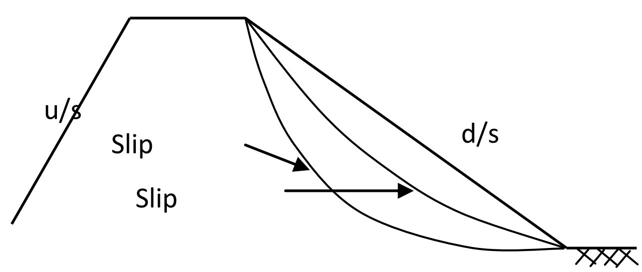

Fig 4: A section of dam showing slip circle with varying radius and arc length

From Fig. 6 we observe that FOS decreases with increase of steepness of d/s slope. The same figure gives an interesting trend of topmost two curves, where the FOS is not lowest at smallest radius of slip circle. Fig. 7 reflects the effect of angle of repose and soil cohesion on FOS. The same figure shows that the FOS increases with increase of angle of repose and soil cohesion

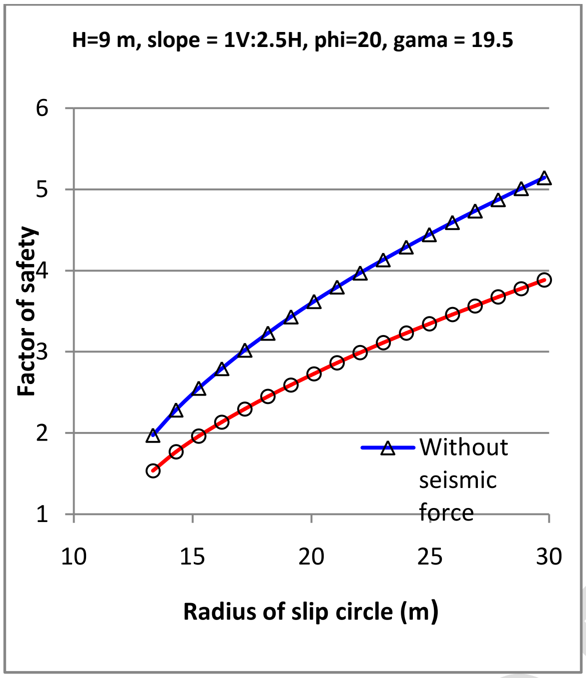

Fig .5 : Variation of F.O.S with variation in slope

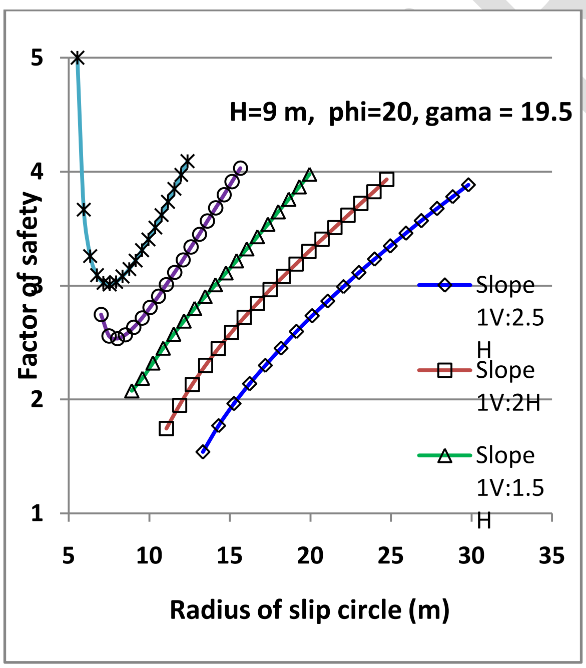

Fig .6 : Variation of factor of safety with and w/o seismic force

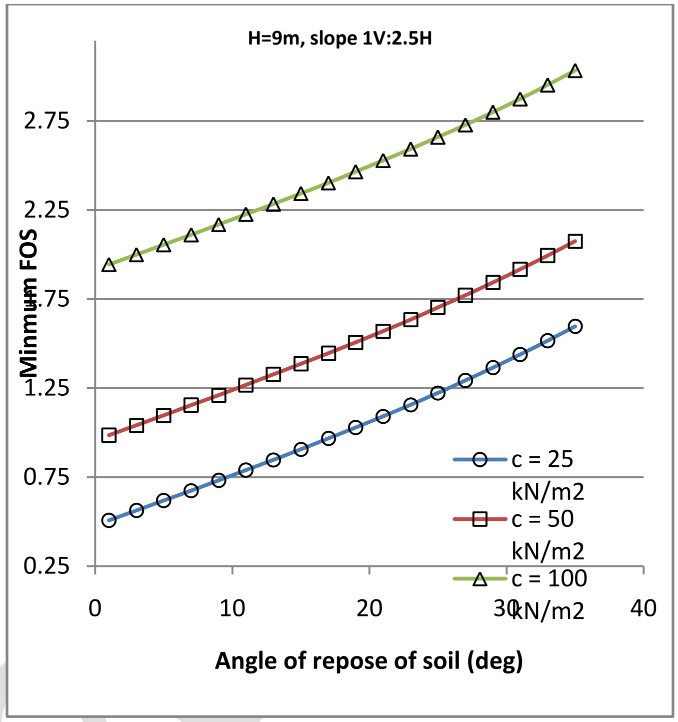

Fig 7 : Variation of factor of safety with cohesion and angle of repose.

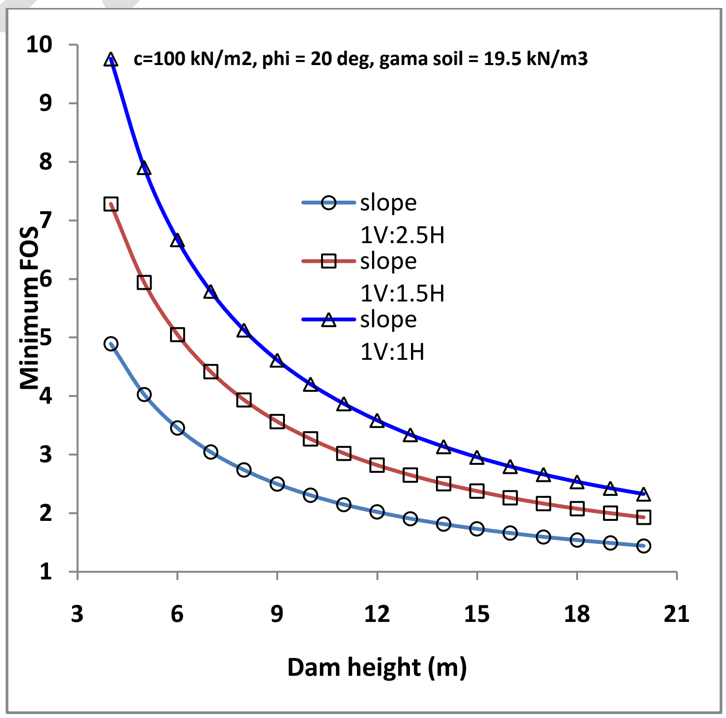

Fig 8 : Variation of factor of safety with dam height and slope.

The effect of variation in dam height and slope is shown in Fig. 8. With increase of dam height, the FOS decreases. Also the FOS is minimum for the dam with the steepest slope angle.

General slip failure

The dam section is shown in Fig. 9 considers the slip circle encompassing entire or part of the top width of dam. This is general slip failure. Variation of FOS with top width of dam is shown in Fig. 10. It is observed that the FOS decreases with increase of dam top width. Fig. 11 shows the effect of starting point of slip circle on top width of dam and radius of slip circle. This figures shows that the FOS is lowest when entire top width is considered. As usual the FOS is lower for lower radius of slip circle.

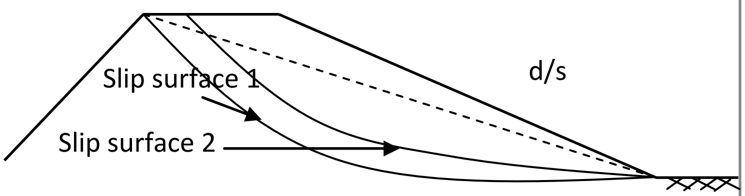

Fig. 9: Section of dam showing slip circle starting at left corner

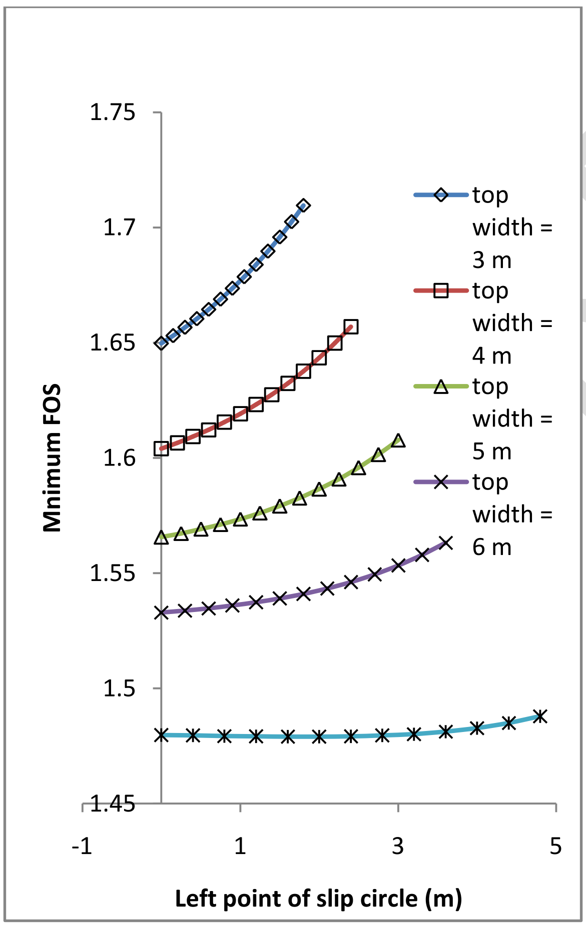

Fig. 10 : Variation of FOS with top width of dam.

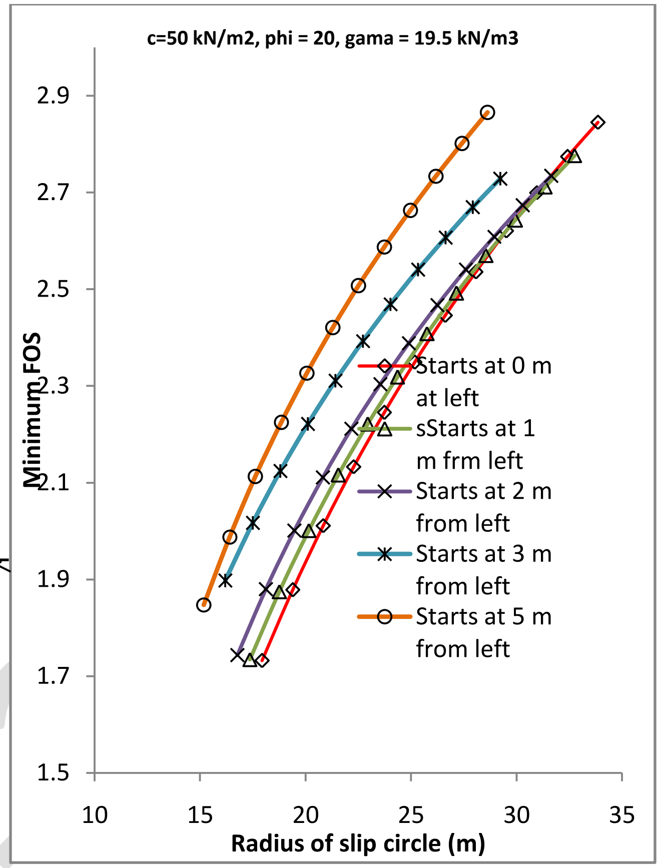

Fig. 11 : Variation of FOS with radius of slip circle

V. CONCLUSIONS

- The steeper the slope the lower is the value of FOS against slope failure. However, for a particular slope, the FOS generally decreases with decrease in radius of slip circle.
- FOS against slope failure reduces with the introduction of seismic force in the analysis.
- FOS against slope failure is decreases with decrease of soil cohesion.
- FOS against slope failure is decreases with decrease of angle of repose of soil.
- FOS against slope failure decrease with increase of height of dam.
- The more the top width of the dam, the lower is the FOS against slope failure
- The minimum FOS against slope failure is obtained when the entire top width of the dam is considered in the analysis.

REFERENCES

[1] Aryal Krishna Prasad (2006), Slope Stability Evaluation by Limit Equilibrium and Finite Element Methods, Doctoral Thesis at Norwegian University of Science and Technology, Trongheim, ISNB 82-471-7881-8, April.

[2] Chatterjee K. and Choudhury D. (2012), Seismic Stability Analysis of Soil Slopes Using Analytical and Numerical Approaches, ISET Golden Jubilee Symposium, Indian Society of Earthquake Technology, Dept. of Earthquake Engineering, IIT Roorkee, Roorkee, Oct 20-21, paper no. C005.

[3] IITK-GSDMA (2007) Guidelines For Seismic Design Of Earth Dams And Embankments

[4] K Patel Samir and Sanghvi C.S. (2012), Seismic Slope Stability Analysis of Kaswati Earth Dam, International Journal of Advanced Engineering Research and Studies, E-ISSN 2249-8974, IJAERS/vol 1/issue 3/ /305-308. April-June.

[5] LakehalRidaand DjemiliLakhdar and HouichiLarbi (2011), Nomograms for Calculating the Safety Factor of Homogeneous Earth Dams in Long-Term Stability, African Journal of Environmental Science and Technology vol.5(9) pp.755-759, ISSN 1996-0786, September.

[6] Pandit V.B., Patel J and Thakare A.K. (2013), Comparative Study of Advanced Two Dimensional Methods of Slope Stability Analysis, International Journal of Advanced Technology in Civil Engineering, ISSN:2231-5721, Vol 2, Issue-1.

[7] Pham Ha T.V and FredlunDelwyn G. (2003), The application of dynamic programming to slope stability analysis, Journal of geotechnical engineering, Canada, Can.Geotech.J.40:830-847.

[8] Siddappa G.and Shanthakumar M.C. (2014), Stability Analysis of Homogeneous Earth Slopes, International Conference on Geological and Civil Engineering, IPCBEE vol.62 IACSIT press, Singapore, DOI:10.7763/IPCBEE.2014.v62.12.

[9] Tanpure N M.andKoranne S.S. (2012)., Use Of Graphical Technique for Stability Analysis of Embankment, Jounal of Mechanical and Civil engineering(IOSR-JMCE). ISSN:2278-1684, volume 3,issue 5, PP 01-10,Sept-Oct.