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Stability Analysis of Cut-slope: A case study of Kathmandu–Nijghad Fast track

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Abstract
This paper deals with the analysis of cut slope located in different chainage section of Kathmandu Nijghad Fast track using limit equilibrium method. The paper deals with numerical simulation of cut slope stability problems by using computer based geotechnical software code Slope/W (Geo-studio). The numerical model presented in this paper is based on the results of laboratory tests carried out in many samples in order to determine physical and mechanical properties of soils. The influence of cohesion, internal frictional angle, rise in water table on factor of safety was investigated through series of examples. Factor of safety for the cut slope was determined for different anticipated conditions. The result shows that factor of safety increases with increase in cohesion and internal frictional angle of soil layer while with increase in water table factor of safety decrease

Keywords
Slope stability – SLOPE/W – Factor of saftey(FOS) – cohesion – internal friction angle

1. Introduction

1.1 Background

The slope stability analysis is performed to assess safe and economic design of human made and natural slopes. The term slope stability may be defined as the resistance of inclined surface to failure by sliding or collapsing. The main objectives of slope stability analysis are finding the endangered areas, investigation of potential failure mechanism, determination of slope sensitivity towards different triggering factors, designing of optimal slope with regards to safety reliability and economics, designing possible remedial measures. In assessment of the slopes, engineers primarily use factor of safety values. If factor of safety is greater than 1, resistive shear strength is greater than driving shear stress and the slopes is considered stable. When factor of ratio is close to 1, shear strength is nearly equal to shear stress and the slope is close to failure, if FOS is less than 1 the slope should have already failed.

1.2 Study area

The proposed study area lies in Kathmandu-–Nijghad Fast track at the chainage 47+000 to 52+000 in Makawanpur district near Shreepur area as shown in figure 1.

Figure 1: Alignment of Kathmandu-Nijgad fast track and study area

1.3 Objective of study

The main objective of the study is to study cut slope stability of Kathmandu-Nijghad Fast Track using Geo-studio 2007 at chainage section 47+00 to 52+000 in Makawanpur District. However the specific objectives of this study are as follows:

- Carryout the geological study of the cut slope, soil type and its role in stability of the slope.
- Generate the slope model of the main cut slope using Geo studio 2007 in static conditions.
- Assess the safety of a cut slope in terms of factor of safety.
- To locate critical failure surface and to know its shape of failure.
- To understand and numerically evaluate the sensitivity of cohesion, friction angle and unit weight.

2. Literature Review

For a slope to be stable, the resisting forces in the slope must be sufficiently greater than the forces causing the failure [1]. To perform a slope stability analysis the geometry of the slope, external and internal loading, soil stratigraphy and strength parameters and variation of the ground water table all along the slope must be defined. In the current state of practice, there are many number of slope stability analysis methods available. However, the scope of this report is limited to a discussion on the limit equilibrium methods and finite element methods.

2.1 Limit Equilibrium Method

Limit equilibrium analyses consider force and/or moment equilibrium of a mass of soil above the potential failure surface. The available shear strength is assumed to be mobilized at same rate at all points on the potential failure surface. Therefore, as a result the factor of safety is constant over the entire failure surface. Limit equilibrium analysis provide no information on slope deformations. A variety of limit equilibrium procedures have been developed to analyze the static stability of slopes. Slope that fail by translation on a planar failure surface such as a bedding plane, rock joint, or seam of weak materials can be analyzed quite easily by the Cullman method [2]. Slopes in which failure is likely to occur on two or three planes can be analyzed by wedge methods [3, 4]. Surfaces are very close, homogeneous slopes are usually analyzed by methods such as the ordinary method of slices [5] or Bishop‘s modified method assume circular failure surfaces. When sub-surface conditions are not homogeneous (e.g., when the layers with significantly different strength, high anisotropic strength, or discontinuous exists), failure surfaces are likely to be non-circular In such cases, methods like those of [6, 7, 8] may be used. Nearly all limit equilibrium methods are susceptible to numerical problems under certain conditions. These condition vary for different methods but are most commonly encountered where soil with high compressive strength are present at the top of the slope and/or when failure surfaces emerge steeply at the base of slopes in soils with high frictional strength.

2.2 Finite Element Method

The finite element method considers linear and non-linear stress – strain behavior of the soil in calculating the shear stress for the analysis. In a finite element approach the slope failure occurs through zones which cannot resist the shear stresses applied. Hence, the results obtained from this analysis are considered to be more realistic compared to limit equilibrium method [9]. The types of soil stress-strain relationships that can be used are linear elastic, elastoplastic, hyperbolic, Modified Cam Clay, elastoviscoplastic and multilinear elastic models. The selection of a particular stress-strain relationship depends on the state of the soil structure to be analyzed, its purpose of analysis and its laboratory and field properties available. The determination of soil properties in the field involves a large amount of uncertainty and so the application of finite element analyses imposes complexity on the stability problem [9]. Traditionally, the slope stability analysis with a finite element approach is performed by Strength reduction method (SRM). In this method, the factor safety is defined as the factor by which the original shear strength parameters must be divided to bring the slope to be in failure mode [9]. A systematic estimation is required for the SRF value to find out the value which will just cause the slope to fail. The SRF value, at which the slope fails is known as the factor of safety. The failure condition in this method could be when 1) the non-linear equation solver cannot achieve convergence after a few iterations, 2) sudden rate of change in displacement and 3) a failure mechanism is developed. However, this method has some limitations such as appropriate selection of constitutive model and geologic parameters, boundary conditions and defining a failure condition [10].

3. Research Approach and Methodology

A conceptual frame work on slope stability studies was developed trough a systematic literature review. Before field different work have been done to acquire the detailed information about the area and to be well prepared for field work. Since there are several studies are carried out in the past by many researchers in the field of natural slope and man-made slope therefore as a part of literature review exhaustive review of previous studies was also undertaken. The methodology include the preparation of the contour map of the slope to determine the geometry and assessing the soil characteristics over the entire slope by collecting fairly representative sample and determining the input soil parameter from laboratory. The stability of the existing slope was obtained by calculating the factor of safety of the slope by using Slope/W software and. Three different Slope sections (SS1, SS2 and SS3 at the chainage of 51+050, 48+804 and 47+745 respectively) were selected for this research purpose and parametric study was performed by considering different geotechnical parameters of slope.

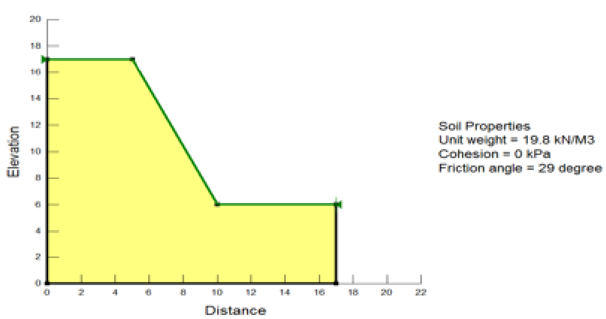

Figure 2: Cut slope model at for SS1 in Slope/W

4. Result and Discussion

Three cut slope model were prepared in suitable scale and geotechnical parameters were assigned according to laboratory test. Slope stability analysis was performed under static dry condition .In this case ground water table level is considered to be much below the influence zone i.e. the ground water level is believed below the possible failure surfaces.

4.1 Stability analysis by using slope/w software

For slope section SS1 For the slope stability analysis unit weight of 19.8 kN/m3, cohesion 0 kPa and friction angle of 29 degree were taken as per laboratory test. The stability analysis result indicates that the FOS of the slope section SS1is 0.259.The result indicates slope is unstable under static dry conditions.

For slope section SS2 For the slope stability analysis unit weight of 20.5 kN/m3, cohesion 17.78 kPa and friction angle of 24 degree were taken as per laboratory test. The stability analysis result indicates that the FOS of the slope section SS1is 0.928.The result indicates slope is unstable under static dry conditions.

For slope section SS3 For the slope stability analysis unit weight of 18.5 kN/m3, cohesion 33 kPa and friction angle of 18 degree were taken as per laboratory test. The stability analysis result indicates that the FOS of the slope section SS1 is 1.205.The result indicates slope is stable under static dry conditions.

4.2 Parametric study

4.3 Influence of Cohesion of cut slope material in stability of slope

The variation of factor of safety with variation of cohesion of the slope materials are shown in figure3.The factor of safety increased with increased in cohesive nature of the slope materials for all methods of analysis. A linear relationship exists between two parameters.

4.4 Influence of Internal Frictional angle of slope material in stability of slope

The variation of factor of safety with variation of internal frictional angle of the slope material are shown in figure 4.The factor of safety increased with increased in internal friction angle of the slope materials for all methods of analysis. Almost a linear relationship exists between two parameters

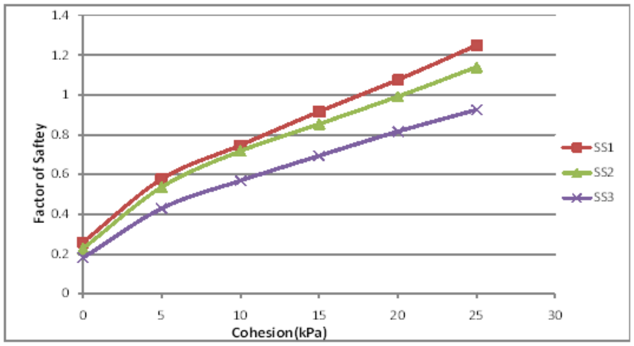

Figure 3: Variation of Factor of safety with variation of cohesion of slope materials for different sections

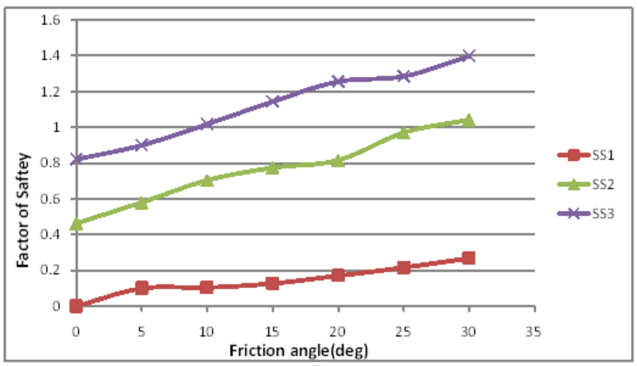

Figure 4: Variation of factor of safety with variation of friction angle of slope materials for different slope sections.

4.5 Influence of depth of water table from top of the slope surface

The variation of factor of safety with variation water table is show in figure 5.The factor of safety increased with increased in depth water table from top of cut slope for all methods of analysis.

5. Conclusion

The Slope section SS1 and SS2 are unstable during dry condition and slope section SS3 is stable in dry condition. Based on the susceptibility classification, the calculated FOS values for slope SS1 and SS2 fall in the class very high landslide susceptibility and slope SS3 falls in high landslide susceptibility .Thus, stabilization measures are needed to mitigate the problem of instability of cut slope. And from the result of numerical calculation, it is found

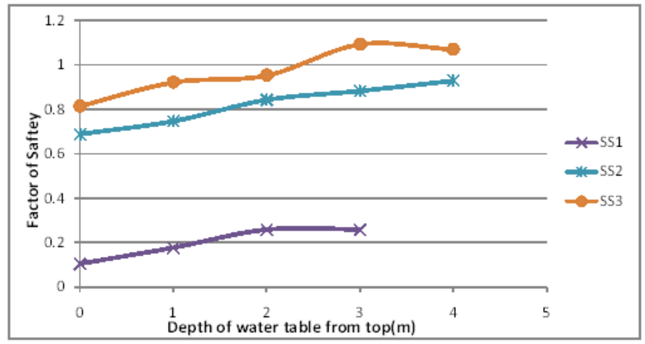

Figure 5: Variation of factor of safety with variation of water table.

that all parameters studied have significant influence on the stability of cut slope.

References

[1] JM Duncan and SG Wright. Soil strength and slope stability, john willey & sons. *Inc., Hoboken, New Jersey*, 2005.

[2] Donaldw Taylor. *Fundamentals of soil mechanics*. Chapman And Hall, Limited.; New York, 1948.

[3] William H Perloff and William Baron. Soil mechanics. principles and applications. 1976.

[4] TW Lambe and RV Whitman. Soil mechanics, 553 pp. *Jhon Wiley & Sons, N. York*, 1969.

[5] GG Meyerhof. The ultimate bearing capacity of foundations on slopes. In *Proc., 4th Int. Conf. on Soil Mechanics and Foundation Engineering*, volume 1, pages 384–386, 1957.

[6] NR Morgenstern and V Eo Price. The analysis of the stability of general slip surfaces. 1965.

[7] E Spencer. A method of analysis of the stability of embankments assuming parallel inter-slice forces. *Geotechnique*, 17(1):11–26, 1967.

[8] N Janbu. Slope stability computations, soil mechanics and foundation engineering report. *Technical University of Norway, Trondheim*, 1968.

[9] DV Griffiths and PA Lane. Slope stability analysis by finite elements. *Geotechnique*, 49(3):387–403, 1999.

[10] J Krahn. Limit equilibrium, strength summation and strength reduction methods for assessing slope stability. In *Rock Mechanics: Meeting Society's Challenges and Demands*, pages 311–318. sn, 2007.