Back-Analysis And Effect of Benching of slope on Bijbehara-Semithan Road Using GEO-5 Software

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ABSTRACT: Large number of roads are constructed along the hilly slopes all along the world. These roads have a common problem of failure triggered due to many reasons ranging from rainfall to the unstable slope angles. Such roads are quite common in Kashmir Valley which is surrounded by large mountains on all sides. In addition to that Kashmir Valley is also known for its harsh weather conditions in the form of sub-zero conditions during winters. The slope roads thus constructed are in high dangers of failure. Landslides are a common trend in winters on such roads leading to road blockage for days sometimes, causing huge inconvenience to the commuters. In addition to huge expenses on repairs and maintenance, it also causes threat to human lives which are more precious than anything. One such road was selected in this study known as Bjibehara-Semithan road which acts as a link road from Bjibehara town and a place known as Semithan. Analysis using GEO-5 software was already done (Analysis of slope on Bjibehara- Semithan road using GEO-5 software, Umi Salma 2019) to check the safety of the slope. In this study back analysis was done on the same road by using Swedish Circle Method by giving critical conditions in the form of FOS=1 and ϕ=0 and mobilised cohesion c_m was found. The value of c_m came out to be 19.62kPa. Stabilisation of the slope was done in the form of benching by giving critical parameters obtained from back analysis in the GEO-5 software and factor of safety found by Bishop's and Fellenius methods. The FOS was found to be in the range of 1.69 to 1.75. Hence improvement of about 14% was found by benching process.

Key Words: *Factor of safety Back analysis, mobilised cohesion, GEO-5 Software, Benching.*

1. Introduction:

Hilly roads are common in Kashmir. These provide connectivity to different areas of the Valley. However such roads are more prone to landslides leading to blockade of the roads. The Bjibehara-Semithan road is one such connectivity link between Bjibehara town, located in South Kashmir's Anantnag district, and Semithan, a village in the same district. The area consists of karewa soils mainly inorganic silts. The problems associated with the karewa soils is soil erosion and depleting soil fertility. Major slope failures occur during winters when the soil remains under snow cover for prolonged periods causing landslides and thus road blockage and sometimes loss of life and property. The aim of the research to to analyse the slope failures in saturated conditions and critical FOS conditions and to find the cohesion that will be mobilised in case of failure and provide remedial measures in the form of benching etc and again check the safety status on these critical parameters. The goal can be achieved by understanding the geology of the area, finding various soil parameters like density, moisture content, shear strength; after finding these parameters, the slope can be analysed for safety by feeding the acquired data into a software known as GEO-5, which gives the stability status of the slope in terms of FOS. The factor of safely for slope stability analysis is usually defined as the ratio of the ultimate shear strength divided by the maximum mobilized shear stress at incipient failure. There are several ways in formulating the factor of safety. The most common formulation for FOS assumes the FOS to be constant along the slip surface, and it is defined with respect to the force or moment equilibrium (Cheng & Lau, 2008).

1.1: Objective of the current study:

The aim of the research is to analyze the slope failures and to check the effect of stabilisation technique on the slope. The goal is achieved by addressing the fallowing objectives

- To have complete literature review on the topic to understand the problems associated.
- To do back analysis on critical conditions of the slope
- Based on parameters obtained as the result of back analysis, check the safety status of the slope using GEO-5 software.
- Propose remedial measures in the form of benching and check its effect on safety of the slope.

2.Experimental Program:

In this study we do the back analysis of a slope section using Swedish method of analysis (ordinary method of slices) on Bjibehara Semithan road. Analysis using GEO-5 software has already been done by the author (Analysis of slope on Bjibehara- Semithan road using GEO-5 software, Umi Salma 2019) using different analysis methods. In back analysis FOS was taken equal to 1(most critical

value) and ϕ put equal to 0. We got mobilised cohesion c_m value as a result of back analysis. Stabilisation was done in the form of benching with slope section at top equal to 1 in 1.2 and at bottom equal to 1 in 1.5. The slope sections before and after benching are shown in figs. 1 and 2.

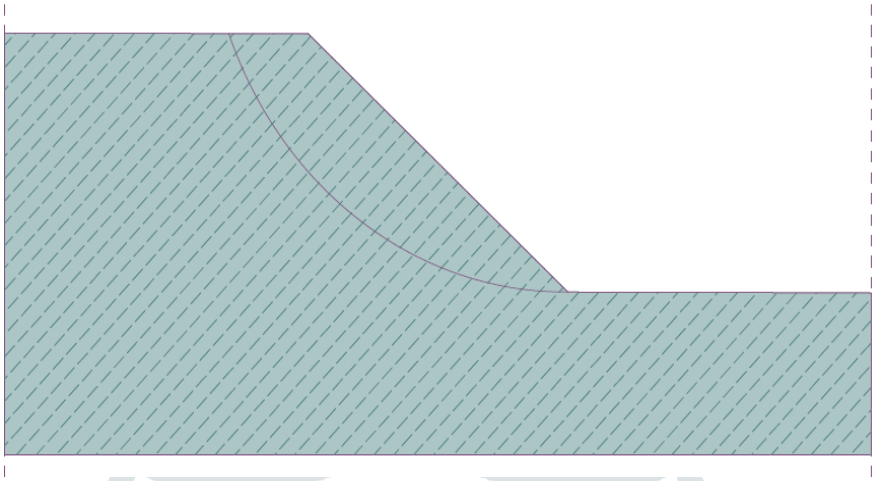


Figure 1-Cross section and critical slip surface of the slope before stabilisation

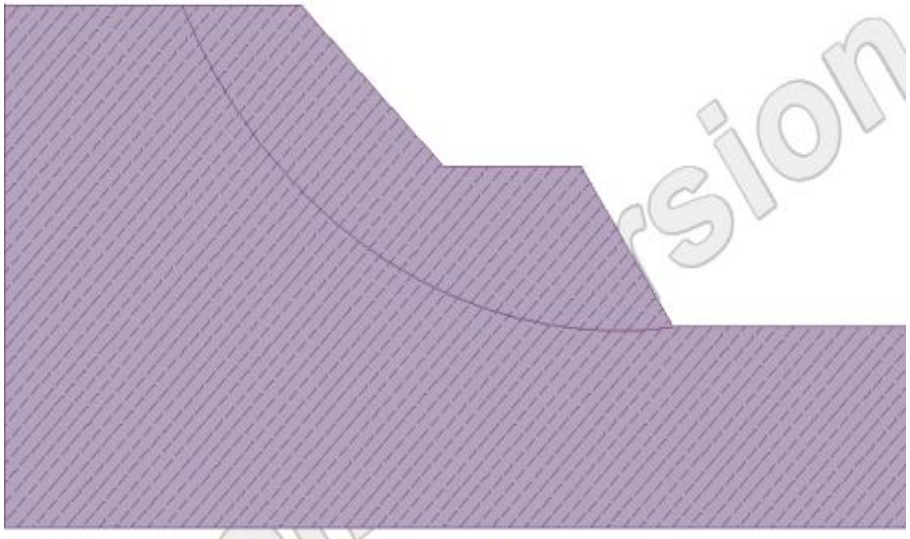


Figure 2-Cross section and critical slip surface of the slope after benching

3. Results and Discussion:

3.1 : Back Analysis:

Back analysis was done using Swedish circle method. The slope section was divided into number of slices as shown in fig. 3 and weight and base angle of each slice found. The analysis was done for ϕ=0 condition and FOS=1. We got cohesion value that will be mobilised at the time of failure.

$$FOS = \frac{c_m\, l}{W sin\alpha}$$

FOS = factor of safety = 1
C_m= mobilised cohesion
L = length of slip surface
W = weigth of sliding mass
α = base angle which sliding soil mass makes with horizontal

The value of c_m was found equal to 19.62kPa.

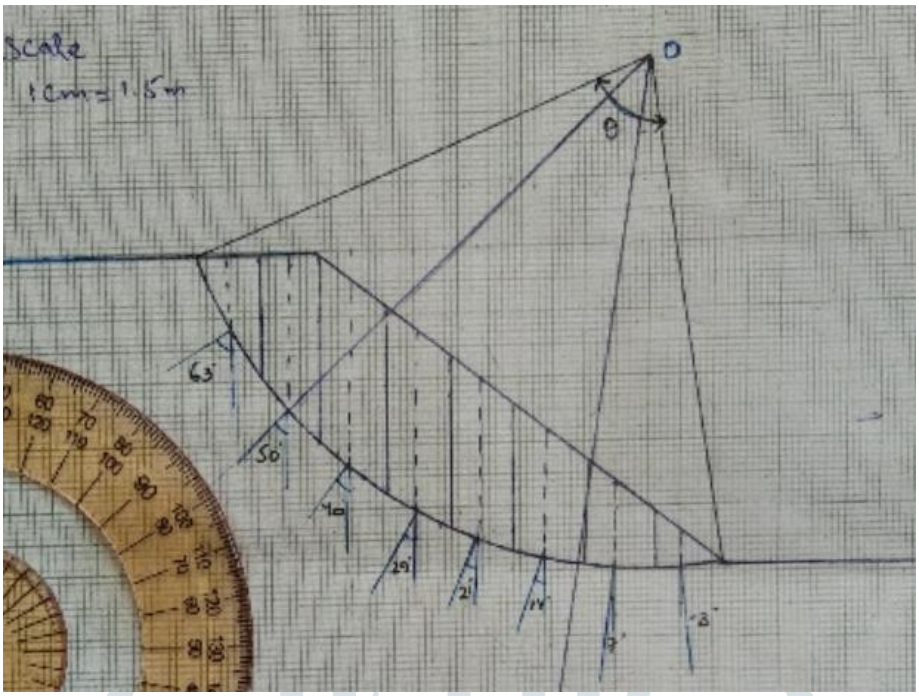


Figure 3- Slope section divided into number of slices (ordinary method of slices)

3.2 : Benching of slope:

The critical cohesion parameter obtained as a result of back analysis was used as input value in GEO-5 software and angle of internal friction obtained in saturated analysis was used and analysis was done in GEO-5 software by Fellenius and Bishop's methods (fig. 4 and fig. 5). The FOS values obtained are shown in table 1.

Table1- FOS values due to stabilization

Method	**FOS**
Fellenius	1.69
Bishop	1.75

3.3: Enhancementof FOS by stabilization:

The FOS values obtained before stabilization (Analysis of slope on Bjibehara- Semithan road using GEO-5 software, Umi Salma 2019) and after stabilization in saturated conditions are summed up in table 2.

Table 2-FOS values before and after stabilization

Method	**FOS (before benching)**	**FOS (after benching)**
Fellenius	1.48	1.69
Bishop	1.53	1.75

Slope stability analysis

Input data

Project

Task : Slope Analysis-Semithan (Benching)
Part : Back Analysis
Description : Fellenius/Petterson Method
Date : 11/28/2019

Settings

India - Standard

Stability analysis

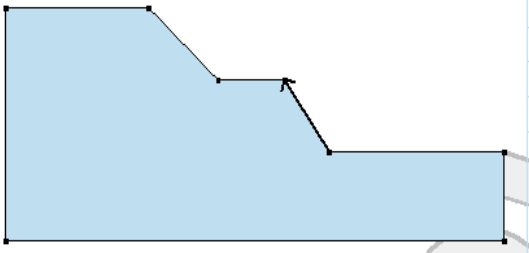
Earthquake analysis : Standard
Verification methodology : Safety factors (ASD)

Soil parameters

Semithan-saturated (MI)

Unit weight : $\gamma = 21.00$ kN/m³
Stress-state : effective
Angle of internal friction : $\varphi_{ef} = 21.00$ °
Cohesion of soil : $c_{ef} = 19.62$ kPa
Saturated unit weight : $\gamma_{sat} = 21.00$ kN/m³

Assigning and surfaces

No.	Surface position	Coordinates of surface points [m] x	z	x	z	Assigned soil
1		19.50	2.00	16.80	6.00	Semithan-saturated (MI)
		12.80	6.00	8.65	10.00	
		0.00	10.00	0.00	-3.00	
		30.00	-3.00	30.00	2.00	

Results (Stage of construction 1)

Analysis 1

Slope stability verification (Fellenius / Petterson)

Sum of active forces : $F_a = 393.36$ kN/m
Sum of passive forces : $F_p = 666.18$ kN/m

Sliding moment : $M_a = 5526.74$ kNm/m
Resisting moment : $M_p = 9359.77$ kNm/m
Factor of safety = 1.69 > 1.50
Slope stability ACCEPTABLE

Figure 4-Fellenius Analysis for benched slope

Slope stability analysis

Input data

Project

Task : Slope Analysis-Semithan (Benching)
Part : Back Analysis
Description : Bishop Method
Date : 11/28/2019

Settings

India - Standard

Stability analysis

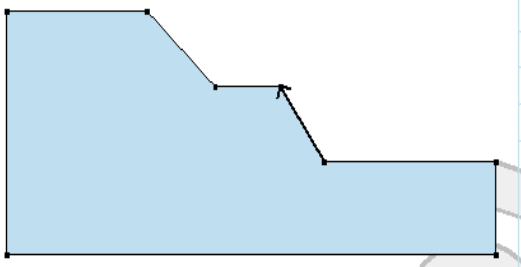
Earthquake analysis : Standard
Verification methodology : Safety factors (ASD)

Soil parameters

Semithan-saturated (MI)

Unit weight : $\gamma = 21.00$ kN/m^3
Stress-state : effective
Angle of internal friction : $\varphi_{ef} = 21.00$ °
Cohesion of soil : $c_{ef} = 19.62$ kPa
Saturated unit weight : $\gamma_{sat} = 21.00$ kN/m^3

Assigning and surfaces

No.	Surface position	Coordinates of surface points [m] x	z	x	z	Assigned soil
1		19.50	2.00	16.80	6.00	Semithan-saturated (MI)
		12.80	6.00	8.65	10.00	
		0.00	10.00	0.00	-3.00	
		30.00	-3.00	30.00	2.00	

Results (Stage of construction 1)

Analysis 1

Slope stability verification (Bishop)

Sum of active forces : $F_a = 377.72$ kN/m
Sum of passive forces : $F_p = 662.12$ kN/m

Sliding moment : $M_a = 6066.14$ kNm/m
Resisting moment : $M_p = 10633.65$ kNm/m
Factor of safety = 1.75 > 1.50
Slope stability ACCEPTABLE

Figure 5- Bishop's analysis for benched slope

4. Conclusion:

1. Back analysis was done by Swedish circle method on the slope section on Bjibehara Semithan road to find the mobilised cohesion value at the time of failure.
2. Benching of the slope was done by giving slope section equal to 1 in 1.2 at top and 1 in 1.5 at bottom section.
3. FOS found after benching of the slope in GEO-5 software was equal to 1.75 by Bishop's method and 1.69 by Fellenius analysis (using critical shear parameters, c from back analysis and ϕ from saturated conditions).
4. FOS obtained from back analysis were compared with FOS obtained from saturated analysis and improvement was found in the values of FOS.

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