Analysis of slope on Bijbehara-Semithan Road using GEO-5 Software

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ABSTRACT: Kashmir is surrounded by mountains on all sides, hence there are many roads constructed along the slopes. These slopes are prone to failures triggered by certain factors like rainfall, steep slope, etc. The slope failures cause road blockades, sometimes pose danger to road users also. In order to prevent such failures, we will evaluate a certain slope situated on Bjibehara-Semithan road, which is a link road connecting Bjibehara town with Semithan Village. Since this is a small road used as a link road, therefore no analysis has been done till now on the said road. We chose a certain slope at a distance of 2.5km from Bjibehara town at RD 700m. The purpose of this study was to evaluate its safety so that it poses no threat to the road users. Slope failure investigations reported in literature are mostly concerned with shear strength parameters (the most critical factor in slope stability analysis) and material properties to be used in analysis of slope failures. Hence direct shear tests were performed on the soil samples to obtain the shear strength parameters. Based on observations, the soils were classified based on Atterbergs limits and particle size distribution as silts of medium plasticity (LL= 40, P.I = 8). The DST results showed that the cohesion values range from 18 kPa to 20.16 kPa , angle of shearing resistance = 210 to 24°. The above data was used as input in GEO-5 software in present research and factor of safety was found using Janbu, Fellenius and Bishop's methods of analysis. We got the required Factor's of safety (FOS) as output, which gave the safety status of the given slope. FOS was found to be ranging from 1.62 to 1.68 in unsaturated conditions and 1.48 to 1.54 in saturated conditions. The FOS was also calculated manually to compare the results with software. The conclusion derived from the analysis suggested that the slope is safe in unsaturated condition from all three methods and nearer to critical safety factor in saturated conditions.

Key Words: *Shear strength parameters, Factor of safety, GEO-5 Software.*

1. Introduction:

The Bjibehara Semithan road is located in South Kashmir in Anantnag district. The area receives an annual rainfall of 1103mm and has an average temperature of 8-33°C. The geology of the area reveals that soils are karewa soils consisting mostly silt and certain percentage of sand and clay. As major of the roads are constructed along these hilly karewa lands to provide connectivity to far flung areas, to provide transport facilities to orchards to boost economy etc. Therefore analysis of risk assessment of these slopes is necessary to assess remedial measures and design the stability / remedial measures accordingly and that remedy will be feasible, economical and stable for a reasonable life span. The slope failures are usually either due to sudden or gradual loss of strength by the soil or to a change in geometric conditions, for example steepening of an existing slope (Terzaghi and Peck) .For cut slopes, the common factors influencing slope stability or failure are as follows: a) Presence of perched ground water, b) Excessive infiltration from upslope increases the unit weight of soil c) Presence of unsuitable geological discontinuity/settings (Neoh (2001)). Since Kashmir is known for subzero temperatures in winter season, hence it leads to frozen soil conditions which results in slope failures. In addition to it, failure also occurs during rainfall seasons in major slope roads. In this study we analyse the safety of the given slope road to have the knowledge of risk prior to finalizing the design of the slope and its various improvements. Software known as GEO-5 was used for slope stability analysis. We feed certain soil parameters into the software and in result it gives us the safety status in the form of Factor of Safety, from which it becomes clear whether the given slope is safe in present conditions or not. We found the slope to be absolutely safe in dry conditions and almost safe in wet conditions.

2. Methodology:

A slope is selected at RD 700m on the given road. The slope height was found to be 10m and the slope angle was equal to 37.3°. The undisturbed samples were collected from the given site and its various parameters were calculated. Firstly the grain size analysis was done to get the required quantity of different soils, since clay percent was also found hence Hydrometer analysis was also done. Then various Atterberg's limits like liquid limit, plastic limit, liquidity index, etc were found. The bulk unit weight and specific gravity of soil was also found. After that Direct Shear Test (DST) was done on the soil sample in both saturated and unsaturated conditions, from which the parameters like cohesion intercept c and angle of shearing resistance ϕ, were found. The above calculated parameters were fed into the GEO-5 Software and a certain slip surface was predetermined (fig 1) for analysis and then the analysis was done in unsaturated as well as saturated conditions by following three methods:

1. Janbu's Simplified Analysis,
2. Fellinius Method of Analysis, and
3. Bishop's Method of Analysis.

We got the Factor of Safety in each case from which we got the safety status of the slope.

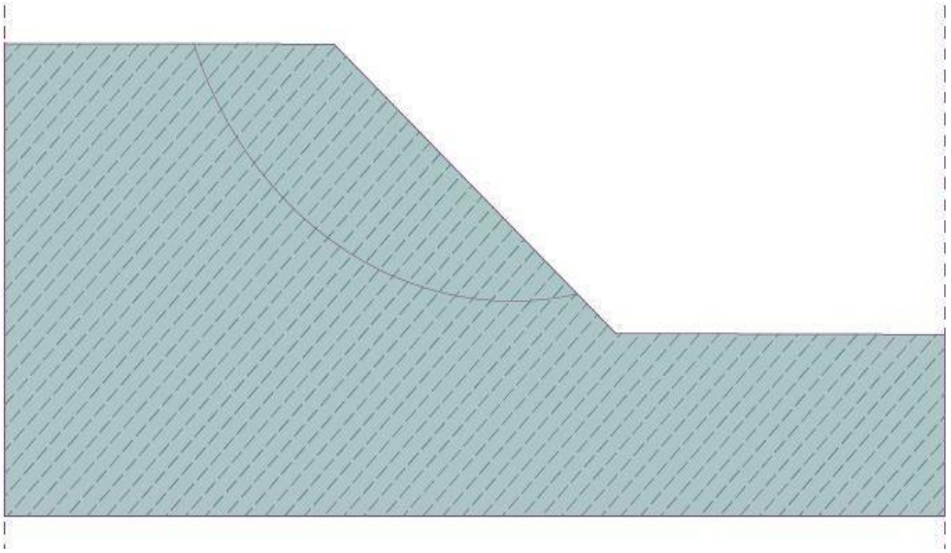

Figure1-Specified slip surface

3. Results and Discussion:

Field density, Moisture content and Specific gravity:

The field density was found to be 17.62kN/m3. Moisture content was found to be 35.21% and specific gravity equal to 2.65.

Soil Gradation:

The soil was found to contain 95% silts, 5% clay and 5% sands.

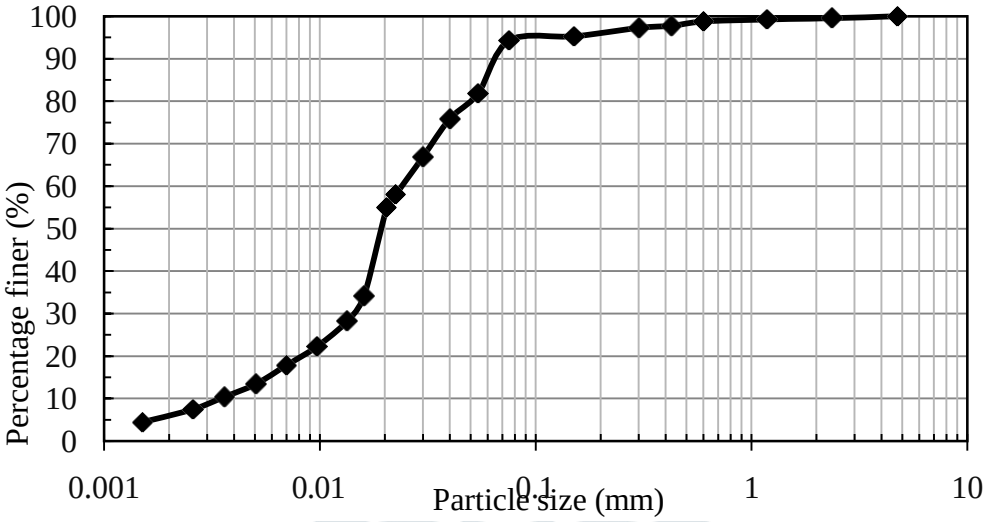

Figure 2-Gradation curve of the soil sample

Atterberg's limits:

Based on values of liquid limit, plastic limit and plasticity index, soils were classified as inorganic silts of medium plasticity. The results are shown in table 1.

Table 1 showing results of Atterberg's limits

Property	Value
Liquid limit (%)	40
Plastic limit (%)	32
Plasticity index (%)	8
Soil Classification	MI

Compaction Characteristics:

The OMC was found to be equal to 18.2% and corresponding MDD was20.1kN/m^3.

Shear Strength parameters:

Unconfined Compression Test:

The unconfined compression strength(q_u) was found to be 84kPa and the shear strength(c_u) was found 38kPa.

Direct Shear Test:

The c and ϕ parameters in both saturated and unsaturated conditions are given in table 2 and figures corresponding to unsaturated and saturated failure envelopes as a result of direct shear tests are shown in figures 3 and 4.

Table 2 DST Parameters

Condition	Cohesion c' (kpa)	Angle of friction ϕ'
Unsaturated	18	24°
Saturated	20.16	21.4°

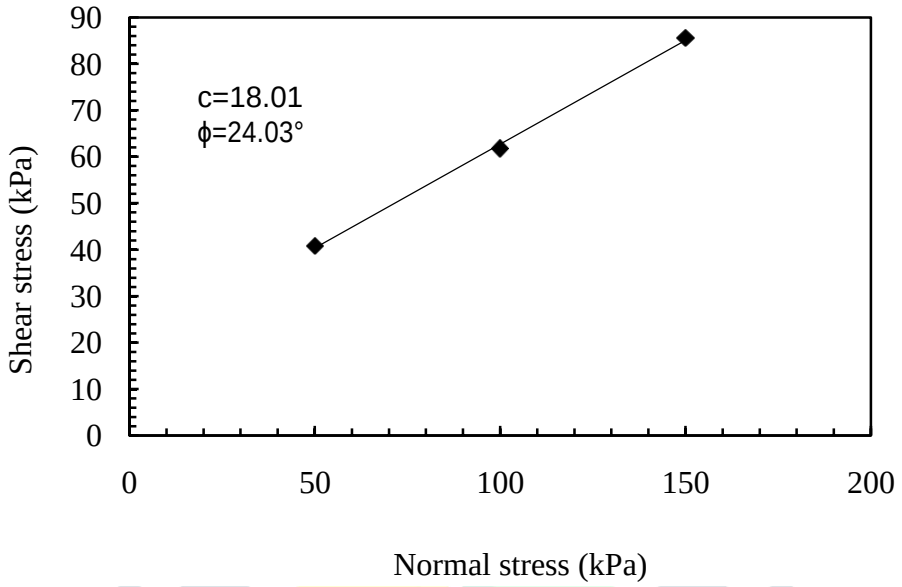

Figure 3- Failure envelope of unsaturated DST

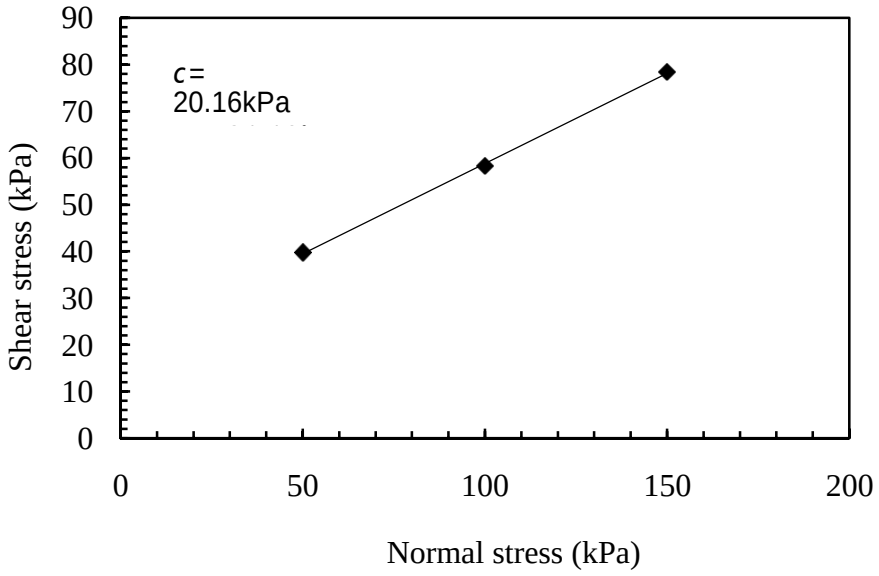

Figure 4- Failure envelope of saturated DST

Factor Of Safety: 3.6.1 GEO-5: The different FOS values obtained from different analysis methods are summed up in table 3.

Table 3- Stability analysis using different methods

Method Of Analysis	FOS (unsaturated)	FOS (saturated)
Janbu Analysis	1.68	1.54
Fellinius Analysis	1.62	1.48
Bishop's Analysis	1.68	1.53

After running the analysis we got optimized slip surfaces (which are the most critical surfaces of the slope). The critical surfaces obtained as a result of these methods are shown in figures 5 and 6 and 7.

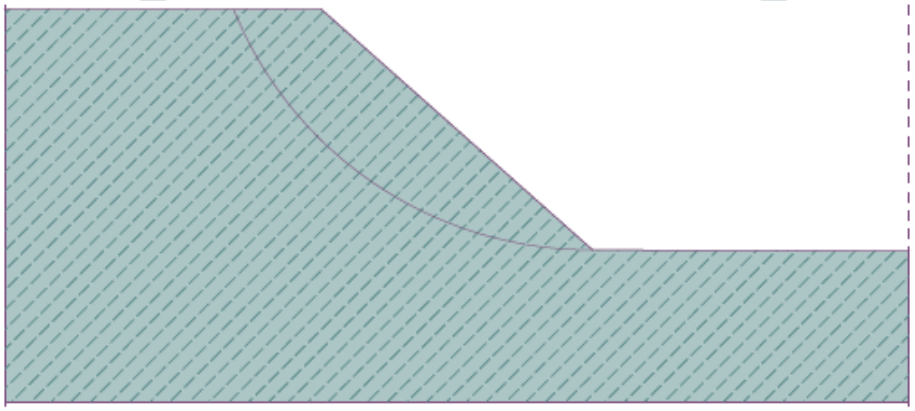

Figure 5-Optimized slip surface from Janbu's analysis (unsaturated)

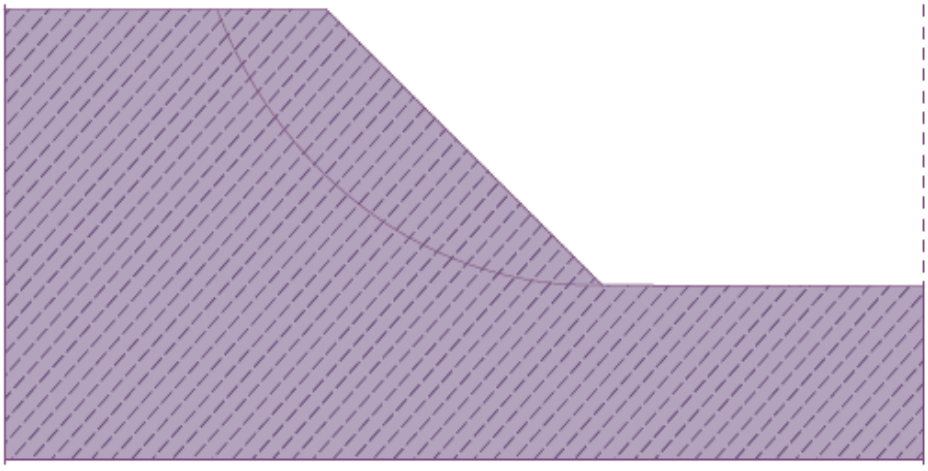

Figure 6-Optimized critical slip surface from Fellinius analysis (saturated)

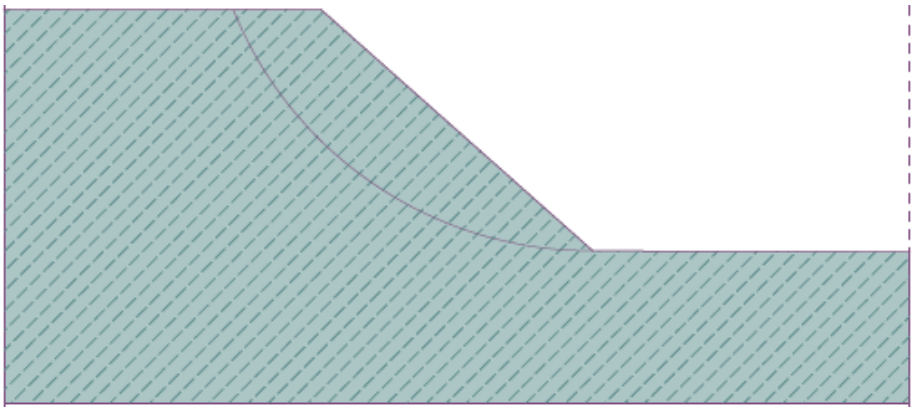

Figure 7-Optimized critical slip surface from Bishop's analysis (unsaturated)

3.6.2 Swedish Circle Method: Factor of safety was found by dividing the soil wedge into number of slices. The shear strength parameters obtained as a result of unconfined compression test were used to calculate the FOS. The FOS was found to be equal to 1.93. The cross section of the slip surface is shown in fig. 8.

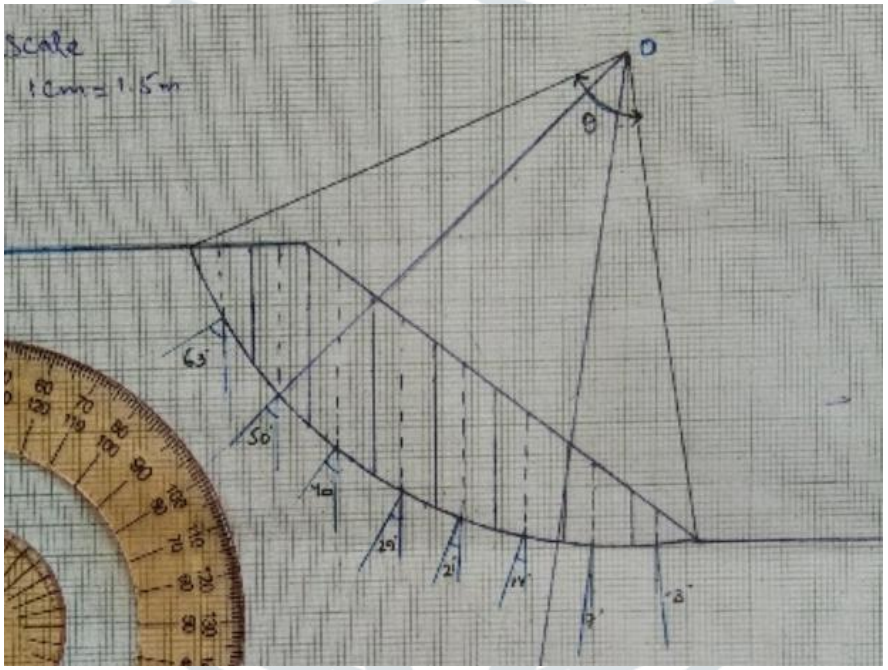

Figure 8-Cross section of slip surface

4. Conclusion:

1. The factor of safety of the slope was found to be in the range of 1.62 to 1.68 in unsaturated conditions by GEO-5 software.
2. The given road is safe for movement of vehicles and pedestrians in dry conditions.
3. The analysis results obtained from the software match the ground conditions.
4. In saturated conditions, FOS was found in the range of 1.48 to 1.54, which is closer to critical factor of safety, hence slope needs improvement for wet conditions.
5. The FOS was again calculated by Swedish Circle method and found equal to 1.93.
6. The analysis results obtained from the GEO-5 software and from analytical method matched in unsaturated conditions while showed variation in saturated conditions.
7. The slope stability can be improved by some stabilization techniques like benching, flattening etc.

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