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Remedy Measure for the Kotropi Landslide (Mandi, H.P.) India: A Case Study

Pankaj Sharma, Saurabh Rawat and Ashok Kumar Gupta

Jaypee University of Information Technology, Waknaghat, Himachal Pradesh, India
E-mail: iisc0700ps@gmail.com, saurabh.rawat@juit.ac.in, ashok.gupta@juit.ac.in

Abstract—*Landslide is geologic process in which gravity force causes rock, soil, artificial fill combination of the three to move down a slope. Landslide also occurred due to slow weathering of rocks as well as soil erosion due to heavy rainfall, which cause loss of life and property too. To understand the behavior of slope, it must require a critical analysis. In current research paper author study the shear strength parameter of kotropi landslide and critical analyze the problem. There are various methods exist for the analysis of slope, in current study using SLOPE/W (Limit equilibrium based) method for the analysis. It is found that the factor of safety obtained from the analysis is very low i.e. 0.93. So, author suggest utilizing helical soil nail walls for stabilization of active landslides.*

Keywords: *SLOPE/W, triaxial test, FS*

1. INTRODUCTION

Natural slopes are unstable by a detachment and sliding of a soil along a failure surface, this collapse may be developed due to excavation activities and infiltrating. In this research paper, author study a massive landslide occurred near the village of Kotropi in Mandi District of Himachal Pradesh, on 13th of August, 2017. The landslide occurred on National Highway 154, the road between Mandi and Pathankot (figure 1). Media reports suggest that a section of the slope collapsed totally and two buses of Himachal State Transport along with few other vehicles were buried under the debris. As of now, news reports suggest that there have been 47 fatalities from the incident. Around 300 m of the highway has been completely buried under debris, thus washing of communication on a very important road (Govt. report).Geologically the area is in a thrusted contact between the Siwaliks and the Shali Group of rocks consisting mainly of dolomites, brick red shale, micaceous sandstones, purple clay and mudstones (source: Geological Survey of India). To check the reason of slope failure, author apply the check for factor of safety for the given slope using SLOPE /W(Limit equilibrium based), based upon the LEM analysis suggest the remedy measure for the given slope.

Fig. 1: Section of Kotropi (Mandi, Himachal Pradesh) landslide

National Remote Sensing Centre/ISRO, Hyderabad shows the image of pre-landslide and post landslide (figure 2). This indicates that the slope was unstable and was prone to a failure. Post-event satellite data over the landslide affected area were acquired by ISRO on 15 August 2017 through emergency payload programming of Resourcesat-2 satellite. Analysis of Resourcesat-2 LISS-IV FMx shows the occurrence of a large landslide in the area where old landslide was observed in the pre-event satellite data. National remote sensing report suggest that this is debris flow' type landslide, with long run outs, evident that excessive rainfall is the main cause of its occurrence. The width of the landslide is 190 m and the run out length is 1155 m (down the road).

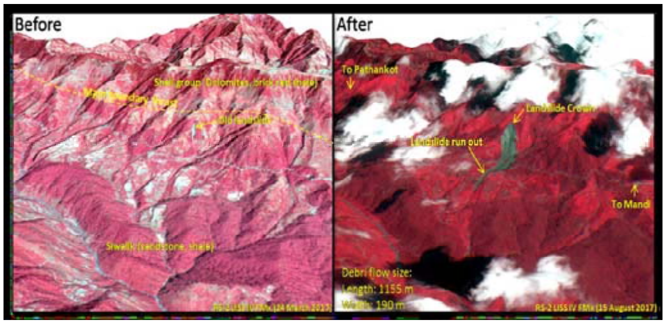

Figure 2: 3D perspective view of the Kotropi landslide.(National Remote Sensing Centre/ISRO, Hyderabad (2017))

2. EXPERIMENTAL METHODOLOGY

A series of laboratory test were carried out on the soil sample of study area, whole landslide area is divided into two sections. Total number of sample is six in number collected from 0.5m, 1m, and 1.5m depth. Test were conducted on two sample i.e. at 1m depth in both upper and lower section.

2.1 Triaxial shear test: Triaxial shear test conducted on sample according to IS: 2720, part-11.

2.2 Numerical analysis of slope using SLOPE/W (Limit Equilibrium method)

3. RESULT AND DISCUSSION

To understand the shear strength parameter of kotropi landslide soil triaxial shear tests are presented in the following section.

3.1. Triaxial Shear Test (IS: 2720, Part- 11)

Triaxial shear test (UU) was conducted on soil sample in order to determine the shear strength parameters of soil. The triaxial shear test was conducted on unconsolidated undrained condition with 50kPa, 100kPa and 200kPa confining pressures. Table.1 represents the cell pressure, deviator stress and axial stress in two samples. Test has been performed as IS: 2720, Part -11.

Table 1: UU test on all three sample

Section	σ3(kN/ m²)	σd (kN/ m²)	σ1 (kN/ m²)
Upper	50	196	245
	100	363	461
	200	562	762
Lower	50	198	247
	100	362	460
	200	550	750

From table 1, by drawing MOHR – STRESS circles for UU test; it is observed that the value of c and Φ for upper section is 26 kN/m² and 32.5° and for lower section and 28kN/m² and 32.5° respectively.

3.2 Numerical Analysis using SLOPE/W

The actual site condition is simulated in geometry as shown in fig.3. The area which taken under consideration is 30m above the road and 30 m below the road, the angle of elevation are taken for upper and lower section using theodolite i.e. 65° and 68° respectively. The slope is modelled according to site drawing, assign the material property for upper and lower both section. The limit equilibrium method, carried out by Morgenstern – Price Method which use relation between interslice shear forces and interslice normal force. The interstice function selected in the analysis is a half sine function with a constant factor of safety distribution calculation (Rawat S and Gupta AK)(2016).The parabolic shape in fig.3 showing slips surface area, which is analysed by SLOPE/W method. The detailed analysis is given as follow:

3.3. Analysis Settings

Unit System: International System of Units (SI)

SLOPE/W Analysis

Kind: SLOPE/W

Method: Morgenstern-Price

Settings

Side Function

Interslice force function option: Half-Sine

PWP Conditions from: (none)

Unit Weight of Water: 9.807 kN/m³

Slip Surface

Direction of movement: Left to Right

Use Passive Mode: No

Slip Surface Option: Entry and Exit

Critical slip surfaces saved: 1

Optimize Critical Slip Surface Location: No

Tension Crack Option: (none)

Distribution

F of S Calculation Option: Constant

Advanced

Geometry Settings

Minimum Slip Surface Depth: 0.1 m

Number of Slices: 30

Factor of Safety Convergence Settings

Maximum Number of Iterations: 100

Tolerable difference in F of S: 0.001

Solution Settings

Search Method: Root Finder

Tolerable difference between starting and converged F of S: 3

Maximum iterations to calculate converged lambda: 20

Max Absolute Lambda: 2

Materials

Upper

Model: Mohr-Coulomb

Unit Weight: 16 kN/m³

Cohesion': 26 kPa

Phi': 32.5 °

Phi-B: 0 °

Lower

Model: Mohr-Coulomb

Unit Weight: 16 kN/m³

Cohesion': 28 kPa

Phi': 32.5 °

Phi-B: 0 °

Slip Surface Entry and Exit

Left Type: Point

Left Coordinate: (0.58176, 28.97336) m

Left-Zone Increment: 4

Right Type: Point

Right Coordinate: (40, -30) m

Right-Zone Increment: 4

Radius Increments: 4

Slip Surface Limits

Left Coordinate: (0, 30) m

Right Coordinate: (40, -30) m

Points

	X	Y
Point 1	0 m	30 m
Point 2	0 m	-30 m
Point 3	40 m	-30 m
Point 4	24 m	0 m
Point 5	17 m	0 m
Point 6	0 m	0 m

Regions

	Material	Points	Area
Region 1	upper	1,6,5	255 m²
Region 2	lower	2,3,4,5,6	960 m²

Current Slip Surface

Slip Surface: 5

Factor of Safety: 0.932

Volume: 507.11618 m³

Weight: 8,113.8589 kN

Resisting Moment: 366,992.65 kN·m

Activating Moment: 393,971.08 kN·m

Resisting Force: 3,519.6033 kN

Activating Force: 3,778.2896 kN

Slip Rank: 1 of 5 slip surfaces

Exit: (40, -30) m

Entry: (0.58176202, 28.973361) m

Radius: 66.630844 m

Center: (67.186673, 30.832181) m

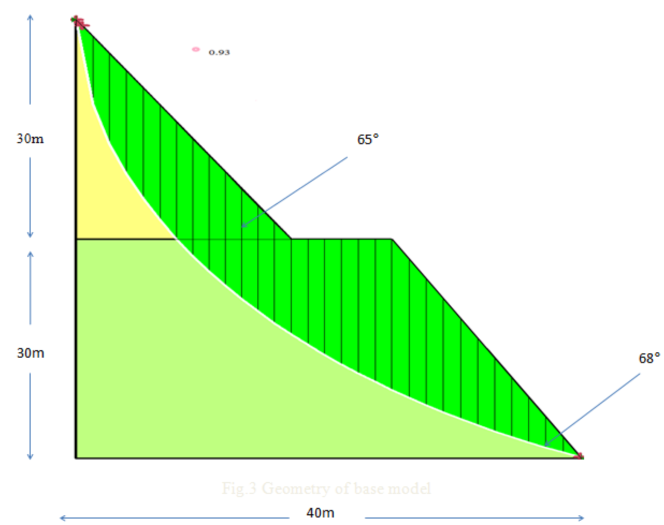

Fig. 3: Geometry of base model

3.4 Factor of safety from SLOPE/W

It is observed that the factor of safety calculated for current slope using Limit equilibrium method is found to be 0.93, which is much smaller than the Global safety factor i.e. 1.5(According to FHWA). From literature review author suggest helical soil nails to stabilize the given slope, the helical soil nails produces a greater interface friction between soil- nail interfaces than conventional nails. This due to the rough surface enhances the soil nail interaction (Rawat S and Gupta AK (2017)). The helical soil are grout free soil nail and easy to install so that it will help in increases factor of safety of slope.

4. CONCLUSIONS

The case history illustrates factor of safety for kotropi landslide to the long term stability of slope. The shear strength parameter of kotropi soil suggests that soil is like dense sand. The average value of c and Φ is 27kN/m³ and 32.5° respectively. From the test result is found that factor of safety for the current slope is found to be 0.93. The factor of safety for current slope may be increases by using helical soil nail as suggest by (Rawat S and Gupta AK)(2016).

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