Fifth International Conference on
Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics
and Symposium in Honor of Professor I.M. Idriss
May 24-29, 2010 • San Diego, California

STABILITY ASSESSMENT AND SUGGESTION FOR CONTROL MEASURES OF A POTENTIAL LANDSLIDE SLOPE ON NH 94, UTTARAKHAND HIMALAYA, INDIA

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ABSTRACT

An unstable slope having few houses which were under distress was studied to arrive at suitable control measures. The slope has undergone subsidence at the road level and there are few houses down the road level which have developed major cracks. The study was focused on identification of causes, assessment of slope stability and suggestions for control measures. The study involved geological and geotechnical investigations, slope stability analysis and monitoring of movements. The paper highlights the field observations and results of the study.

INTRODUCTION

Slope failures have caused untold numbers of casualties and huge economic losses in India. Landslide occurrences and their consequences in the form of loss of life and property are quite significant in the state of Uttarakhand in the North Western Himalaya due to the complex geology and tectonic set up supplemented by heavy rainfall. In the recent past there were few major landslide disasters which have taken few lives and caused extensive damage to properties and public utility services such as 1998 Malpa landslide, 2001 Phata landslide, 2003 Uttarkashi landslide (Sarkar et al., 2003) and 2009 Pithoragarh landslide. There is a need to study the potential unstable slopes where habitation and land resources are under risk. One such unstable slope (Figure 1) situated at Agrakhal along Rishikesh – Uttarkashi highway (NH 94) was studied to evaluate the magnitude of instability and to suggest possible control measures. The slope has many houses which have shown distress due to landslide activity. The paper describes the findings of the study and scheme of suggested control measures.

GEOLOGY

Geological formation of the area belongs to the Chandpur Formation of Lesser Himalaya. The main rock types are phyllites, which are thinly bedded and moderate to highly weathered. The rock beds dip 50° towards NW and there are two major joint sets, out of which one joint dipping towards NE is outward dipping favouring slope instability. The soil cover on the slope is about 2-5 m thick. The slope under study is confined between two perennial drains and has a drain in the central portion also. The slope has typical terrace cultivation which is a common practice in hilly regions.

Fig. 1. Study area

A contour map was prepared on 1:1,000 scale with 2 meter contour interval. From the contour map digital elevation model and slope map were generated in GIS (Figure 2). The local relief of the area under study ranges from 1200 m to 1420 m from MSL. The slope map was classified into five classes. It can be seen from the slope map that the study area is mostly having 0-15° and 15-25° classes. The steep slopes more than 45° are the slopes along the drainage channels.

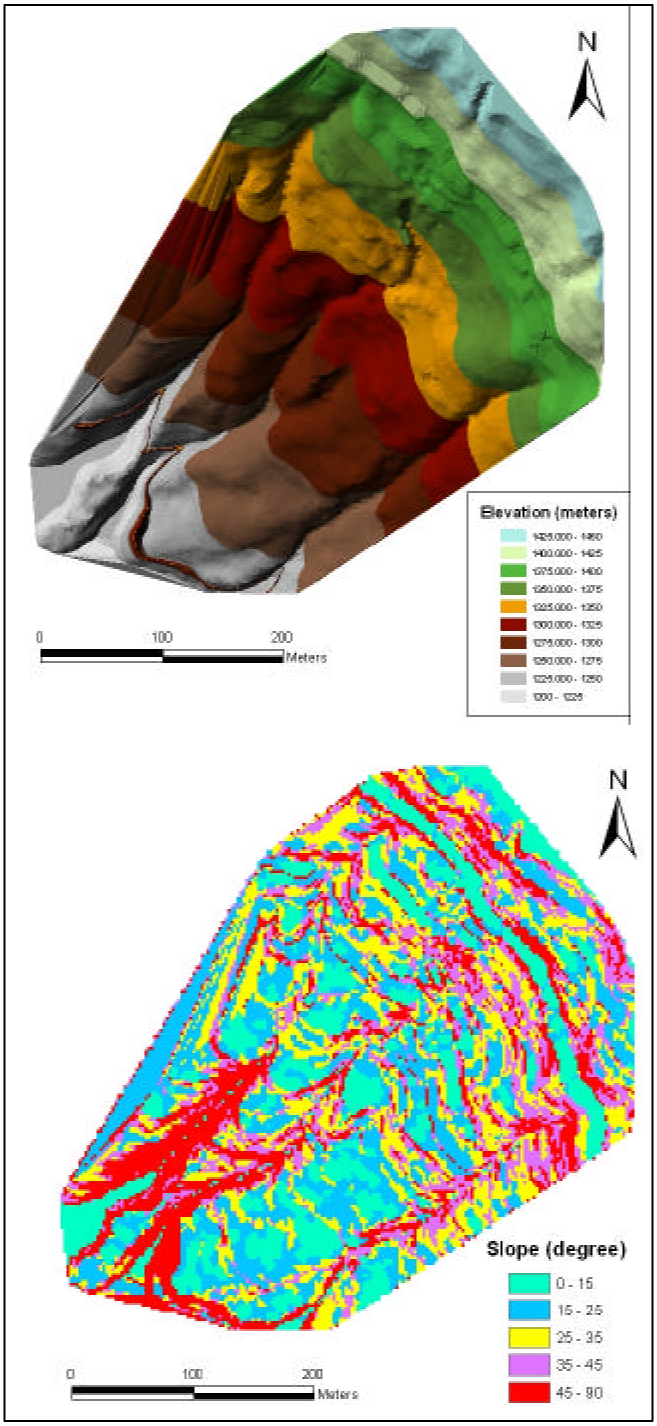

Fig. 2. Digital elevation model and slope map

SLOPE INSTABILITY AND CAUSES

Slope instability in the area is manifested by road subsidence and continuous development of cracks in the houses situated on the slope. A tourist guest house located just below the road has developed major cracks and presently abandoned. The other houses situated on down hill slope have also developed cracks on the walls (Figure 3). Water seepage on the walls was noticed during the rains. There is a local slope failure along the joint plane comprising of rock pieces and loose debris. All these field observation have indicated that the slope is unstable.

Fig. 3. Damaged houses and local slope failure

The morphological expression of the slope and the slope material comprising mainly of gravels and sand indicate that the area is probably a very old slide zone. However, no historical data is available for confirmation. A detailed field investigation has shown that the prime cause of the slope instability is due to underground water seepage. The sub-surface water flow during heavy rains is causing subsidence at various locations resulting into development of cracks in the houses. However, source of underground channel leading to such subsidence is not completely understood.

A regional topography of the catchment area of the slope can be very well seen from the Google image (Figure 4). From this image it may be inferred that a part of the rainfall received by the catchment in the uphill slope bounded by two drains infiltrates into the ground. Further, the central drain above the road disappears for a certain distance below the road and again reappears on downhill slope. Hence it may be inferred that the rain water in the central drain flow underground below road level and probably a source of water seepage in the area.

To confirm this geophysical resistivity survey was conducted at road level. The analysis of the data suggests that the resistivity values are very low at 9 m depth indicating a weathered rock and or wet strata. This partly strengthen the fact that there must be a hidden water channel below the road which allows water to saturate the sub-surface strata and develop pore pressure leading to slope instability. The dissipation of pore pressure during lean period is a likely cause of road subsidence.

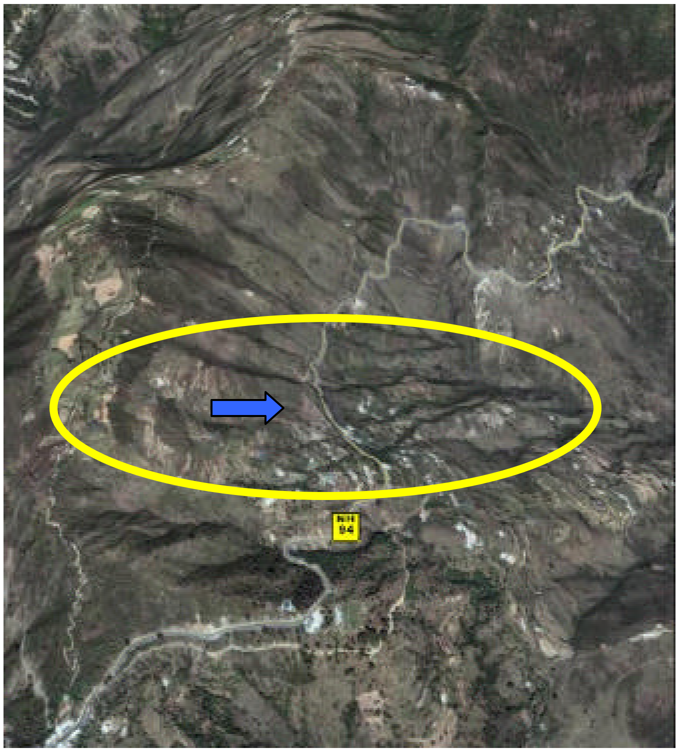

Fig. 4. Regional topography in Google image

SLOPE STABILITY ANALYSIS

Soil samples collected from the field were tested in the laboratory for determining the geotechnical properties. The soil comprises of gravel 34%, sand 35%, silt 29% and clay 2%. The cohesion varies between 0.02 -0.11 Kg/cm^2 and friction angle varies between 40° - 46°. These were obtained from direct shear test. With these soil parameters along with slope geometry stability analysis of the slope was carried out. The factor of safety under static and dry condition was found to be 1.43 which drops down to 1.19 under saturated condition. When considering seismic condition the displacement was only 3-4 cm under dry condition but under saturated condition displacement was quite significant leading to complete disintegration of the slope (Ghosh et al, 2009).

INSTRUMENTATION AND MONITORING

It was felt necessary to monitor the cracks in the houses and also movement of the houses to estimate the degree of sliding activity (Figure 5). For this cracks in the six houses are being monitored using simple devices. So far no significant movement was recorded for the last one year. All these six houses are also being monitored for their horizontal and vertical movement from a stable point using Total Station. An automatic rain gauge has been installed in the area to monitor the daily rainfall. The rainfall data (Figure 6) of August and September 2009 has not shown any major event which substantiates the fact that no significant crack widening was observed in this year. The monitoring study is being continued.

Fig. 5. Houses on the slope which are being monitored

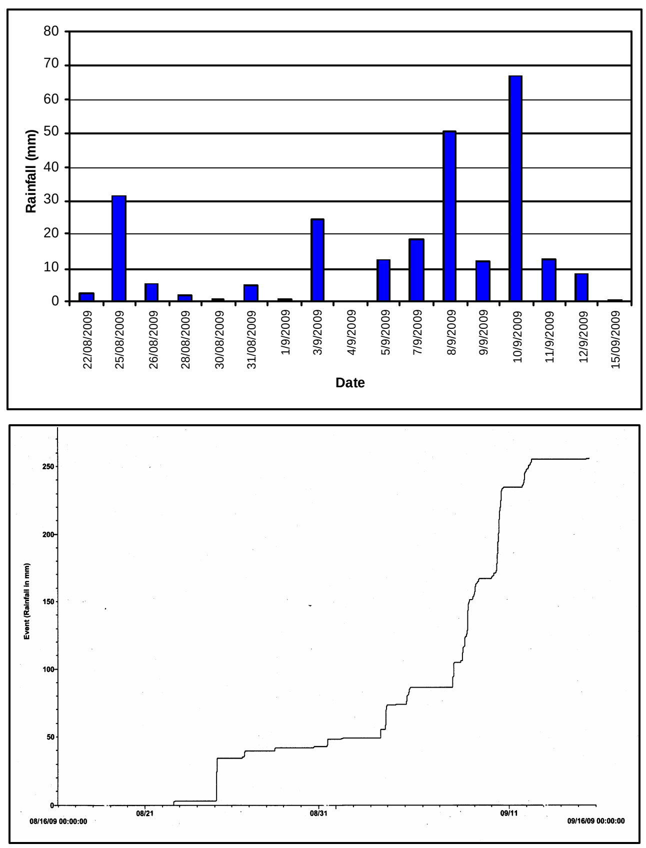

Fig. 6. Daily and cumulative rainfall

CONTROL MEASURES

The different approaches of control measures are mainly to i) avoid the problem, ii) reduce the forces tending to cause movement and iii) increase the forces resisting movement. Among the measures for reduction of driving forces the most commonly used are slope grading, surface drainage, sub-surface drainage and reduction in weight. Since the main driving force as inferred from the field investigation is the underground water seepage, it was decided to install series of sub-surface drains at three suitable locations to drain out the underground water. It may help to arrest subsidence which in tern will reduce development of cracks in the houses. The water collected from the drains will be diverted from the slope to the natural drains. Further to increase the resisting force construction of flexible retaining walls at two locations are proposed. The proposed scheme of the control measures is shown in the Figure 7.

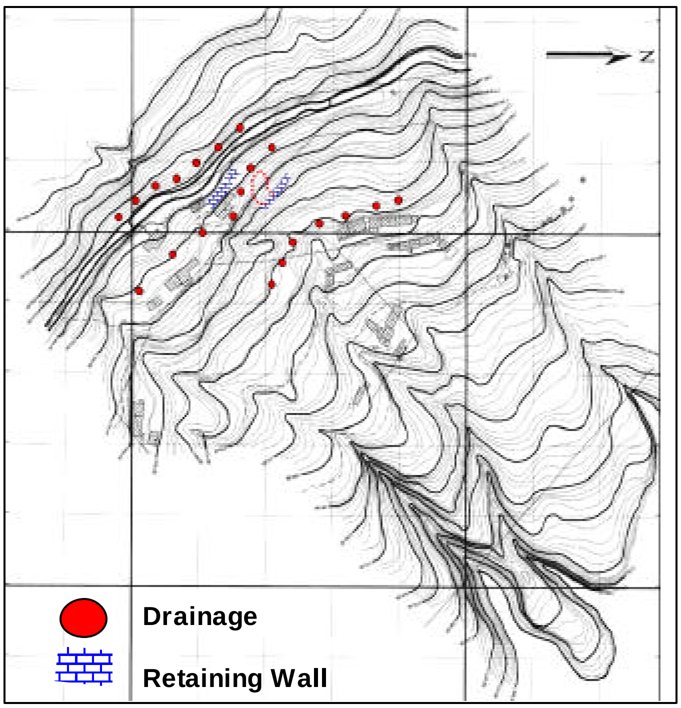

Fig. 7. Scheme of suggestive control measures

CONCLUSIONS

The area under study is a potential landslide where many houses have shown distress due to prominent ground subsidence. Topography and soil cover indicates presence of a old slide zone. The geological investigation has indicated presence of fractured & weathered rocks, underlying loose overburden material allowing easy seepage of underground water. Resistivity survey also indicates a weak zone at 9 m below road level. The structural data shows presence of unfavourable discontinuity. Stability analysis has revealed that the slope in dry condition is stable but under saturated condition the factor of safety considerably gets reduced. Further under seismic and saturated condition the slope undergoes large displacement leading to major failure.

The prime cause of instability is the underground water seepage as the rain water in the catchment area is percolating underground and developing pore pressure causing the ground subsidence. The associated risk in the area is few houses and the highway which are vulnerable to sliding activity. To protect the houses and minimize the risk adequate control measures have been suggested. Though the area at present does not indicate a major landslide scenario in the absence of a major triggering factors but to be more specific about vulnerability assessment, the houses vis-à-vis slope are being monitored through instrumentation. The study is continuing to unfold more facts and design of the suggested control measures.

REFERENCES

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