Instrumentation Based Dynamics Study of Tangni Landslide near Chamoli, Uttrakhand

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Abstract- Tangni landslide located near Pakhi village in between Pipalkoti and Joshimath on NH-58 is an active landslide. The highway connects Badrinath Dham, an important Hindu pilgrimage centre and other hill cities to rest of the country. Any kind of slope failure disrupts traffic along this important hill route leaving behind the locals, pilgrims and tourists stranded for hours. Therefore it becomes essential to assess and predict the landslide hazard in the Himalayan terrain. Geological and Geotechnical investigations followed by instrumentation and monitoring of Tangni landslide was carried out to notice the rate, magnitude and direction of movement on its surface and subsurface. Based on the study the alert can also be generated for the site.

Index Terms- Landslide monitoring, sensors, Instrumentation, Slope monitoring.

1. INTRODUCTION

Disasters caused by landslides are frequent in mountainous regions such as Himalayas which cause massive destruction of human life, natural resources and infrastructure. The landslides triggered by rainfall are caused by the buildup of water pressure into the ground (Campbell, 1975; Wilson, 1989). If such area is located in high seismic zones, such slopes become highly susceptible to landslides. Besides this, the geology, hydrology, geomorphology, anthropogenic factors and development of tension cracks due to prolonged wet and dry cycles of soil also contribute largely towards destabilization of slopes. Understanding the geology, geomorphology and hydrogeology of a landslide site is a significant factor in determining the location of failure surface(s) and the potential mechanism causing failure.

In this paper, based on the detailed geological investigation with relevant geotechnical parameters incorporated, an attempt is being made to determine the impact of rainfall infiltration on magnitude and direction of displacement and pore water pressure generation through installation of sensors. A continuous monitoring of landslide displacement and deformation is important in order to better understand the complex relationship between triggering factor i.e. rainfall and the dynamics of movement. The infiltrated water basically increases the moisture content of soils, alter soil structure and thereby reduce the frictional and cohesive strength. The situation worsens if water seep down further deep into the soil through tension cracks, if present. The movement of landslides may be extremely rapid and catastrophic or extremely slow or dormant. Generally, landslides experience a few millimeters of movement per year. Initiation and rates of movement are dependent upon soil conditions such as soil type, pore water pressure, geometry, erosion etc.

2. STUDY AREA

Tangni landslide falls in the Survey of India (SOI) toposheet No. 53 N/7 and is situated at about 8km from Pipalkoti. The precise geographic location of Tangni landslide is Lat 30° 27’ 54.3” N and Long 79° 27’ 26.3” at an elevation of 1524 m.

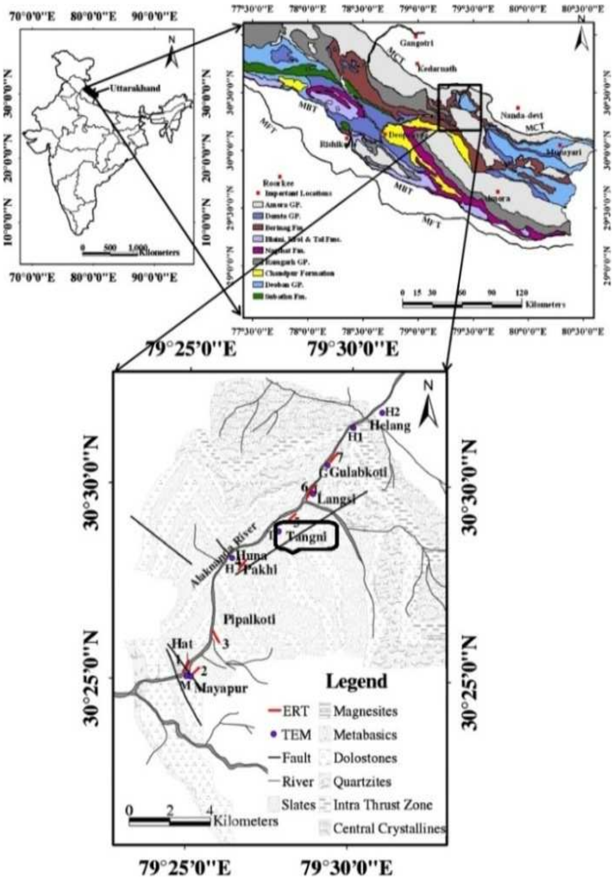


Fig.1 Study Area

Fig.2 Tangni Landslide

3. GEOLOGY

The geology of the area is complex, consisting of Precambrian lithological units of Garhwal region of the NW Lesser Himalaya. The study area lies in the vicinity of Main Central Thrust (MCT). Besides MCT there are other faults also. Because of the tectonic setup, this area is tectonically active and experiences moderate to high magnitude earthquake. Physiographically, the area shows a natural topography, which has undergone rejuvenation resulting in a combination of highly dissected topography with valleys showing vertical walls and scarps in the lower parts and gently sloping concave hill tops in the upper wider parts. The area is drained by the river Alaknanda and its tributaries. Geologically the rocks in the landslide area belong to the Tejam and Damtha Group. The rocks mainly comprises of phyllites/slates and dolomites. The rocks are well jointed having bedding dipping 35° towards North. The slope is continuous and is inclined at about 35˚ above road level and 42˚ below road level in dip direction of N10˚. The right flank of slide consists of jointed and fractured rocks while left flank consists of loose soil and debris material

4. GEODETIC AND GEOTECHNICAL INVESTIGATION

The average slope of whole landslide is about 35 degrees. The slide mass is about 1200 m long and 600m wide. The direction of movement is towards North-west. A secondary direction of movement towards the Nalah is also observed in the upper slide units. The most active area is the lower unit. Tangni landslide is of translational type.Fig.3 gives a contour sketch of landslide and location of monitored points and boreholes.

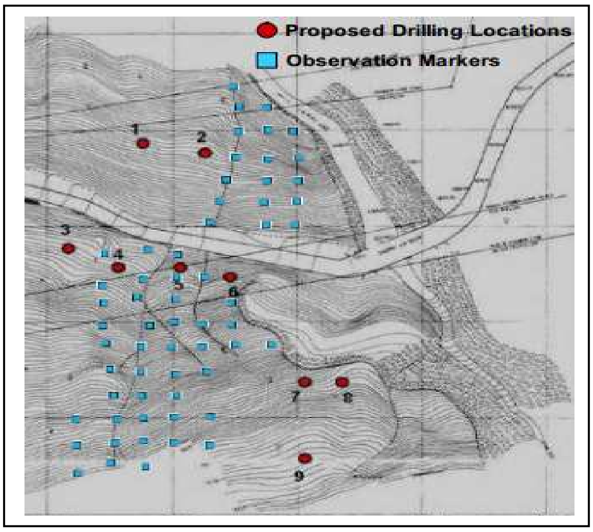


Fig.3 Contour Map showing drilling locations

5. ELECTRICAL RESISTIVITY SURVEY

Electrical resistivity surveys have progressed from the conventional vertical soundings (Schlumberger method), which provide layer depths and resistivities at a single place, to techniques that provide 2D and even 3D high resolution electrical images of the subsurface. Electrical resistivity was done to understand underneath rock strata and identify the probable depth of failure plane that comes out to be between 9-12 m beneath the surface as a sharp dip in resistivity value is obtained between these depths as shown in fig. 4.

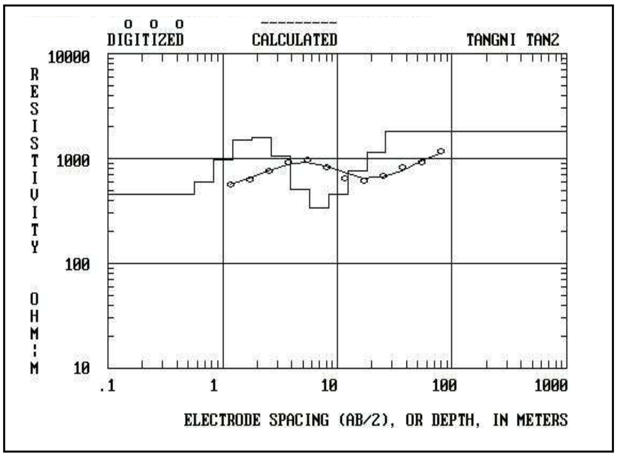


Fig. 4 Electrical resistivity survey of the Tangni Landslide area

6. NEAR REAL TIME MONITORING SYSTEM

The purpose of landslide monitoring in this case is to get the observations (data) that can be interpreted to improve the understanding of landslide kinematics and mechanisms. The near real time data provided from the instrumentation was pore water pressure, rainfall intensity and duration and lateral slope deformation at an hourly interval. The instrumentation system was implemented after a detailed geomorphologic, geodetic and geotechnical survey. The zone of high movement rate and depth of failure plane were estimated earlier with the help of these surveys. After that nine boreholes were digged of depth 15 m each covering the entire body of the landslide i.e. from crown to toe. In even numbered boreholes i.e. 2, 4, 6 and 8, one **Vibrating wire piezometer** was installed to measure pore water pressure. Each VWP was calibrated over a range of pressures. It is a temperature sensitive instrument and a thermistor is included in the sensor to apply the temperature correction. In odd numbered boreholes i.e. 1, 3, 5, 7, 9; **In-Place inclinometers (IPIs)** are installed to determine magnitude, rate, direction, depth and type of landslide movement. These informations are important for understanding cause, behavior and remediation of landslide.IPI probe is inserted inside Acrylo nitrile Butadiene Styrene (ABS) plastic casing which is corrosion resistant, flexible and does not easily deform or break under a range of temperatures. Each probe is calibrated from vertical to a range of ± 10º. A- Axis is aligned to expected direction of movement while B-axis measures the movement 90º to the A-axis. Measurement in B-axis should be minimized if casing is successfully aligned in the expected direction of movement.

Mikkelson (1996) recommends drilling the borehole 6m deeper than the zone of suspected movement to anchor the casing into competent strata. Five IPI sensors were connected and installed in each casing to span the zone of movement Each IPI sensor has a dimension of 192mm X 36mm and weight of 540g with a 6 mm probe and 3m gauge tubing. One rain gauge was also installed to monitor rainfall intensity and duration.

All of these instruments can be attached to a programmed on-site datalogger. The datalogger can collect readings on hourly basis and stored the values of rainfall, lateral displacement, and pore pressure. These data are transmitted automatically using GSM Modems, stored, processed and visualized on a DTRL base-station computer.

The near real time monitoring system is an excellent risk management tool for Tangni landslide. Due to the rate and magnitude of the movement, the instrumentation system may destroy soon. The dataset produced allow for evaluation of the landslide and performance of the IPIs.

7. CALCULATION AND DATA ANALYSIS:

7.1 IPI Data analysis:

The output signal from the IPIs is recorded in terms of voltage. All calibration factors are provided on a unique calibration sheet for each sensor based on serial number. Four conversion factors for each axis are provided to convert the voltage reading directly to engineering units of mm/m.

Deformation

(mm/m) = b0+b1*V+b2*V*V+b3*V*V*V-- (1)

Where b0 to b3 are unitless calibration factors.

Once the value is in the form of mm/m, the total displacement can be determined simply by multiplying the value by the gauge length of the instrument.

These calculated values are valid based on two main assumptions:

i) The top of the casing provides a fixed reference point. And

ii) The entire gauge length of 3m is rigid.

7.2 Vibrating wire Piezometer data analysis

The instrument output is a frequency recorded in Hz or Hz^2. This frequency unit is converted to units of pressure in KPa or Kg/cm^2 using the calibration factor provided on sensor calibration sheet. The pressure value was then converted to a pressure head and added to the elevation of pizometer tips to obtain a total head reading.

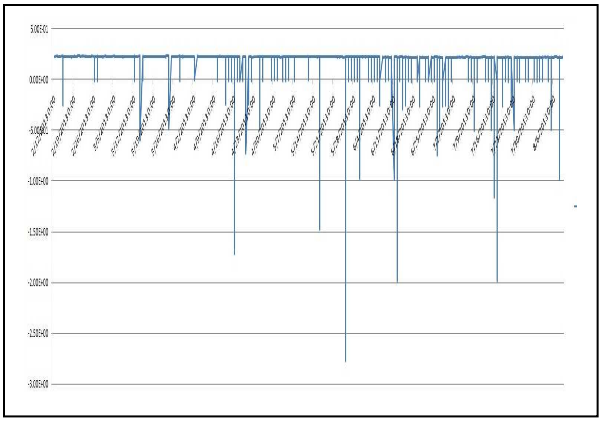


Fig. **5** Plot of VWP response located at Toe

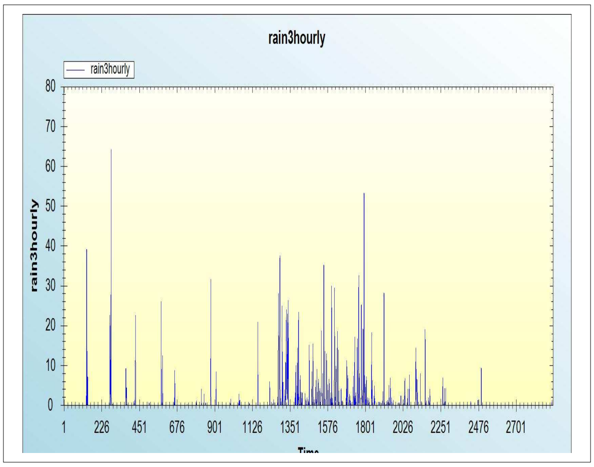
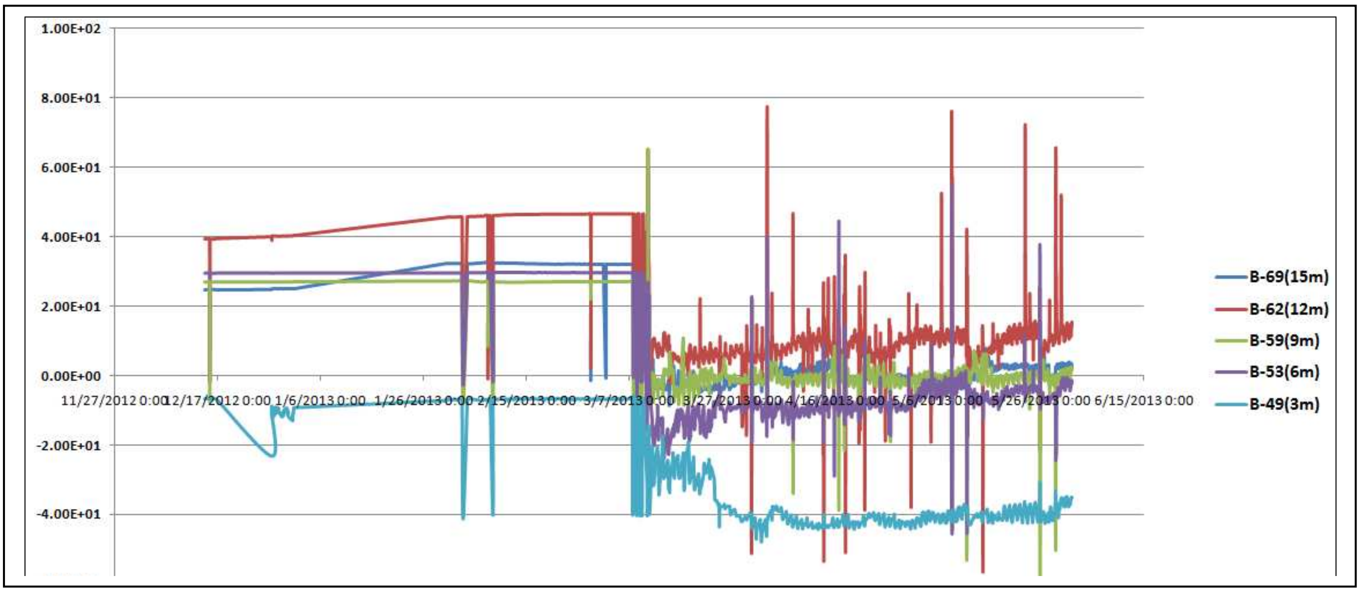
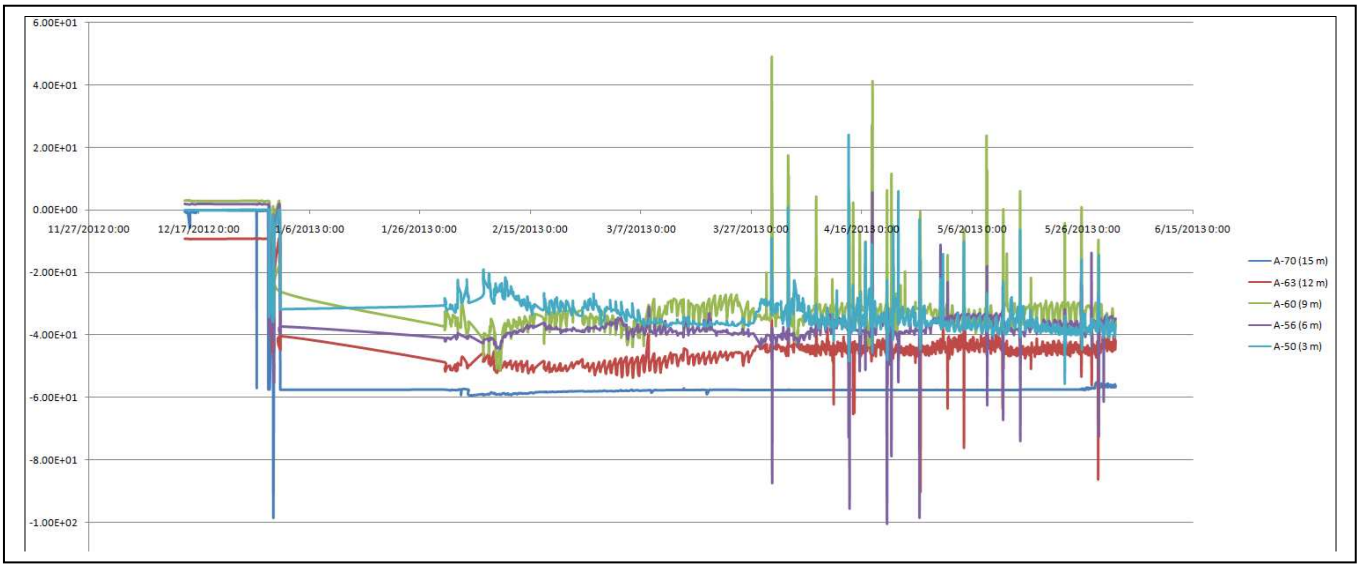


Fig.6 Plot 3hourly Rainfall data





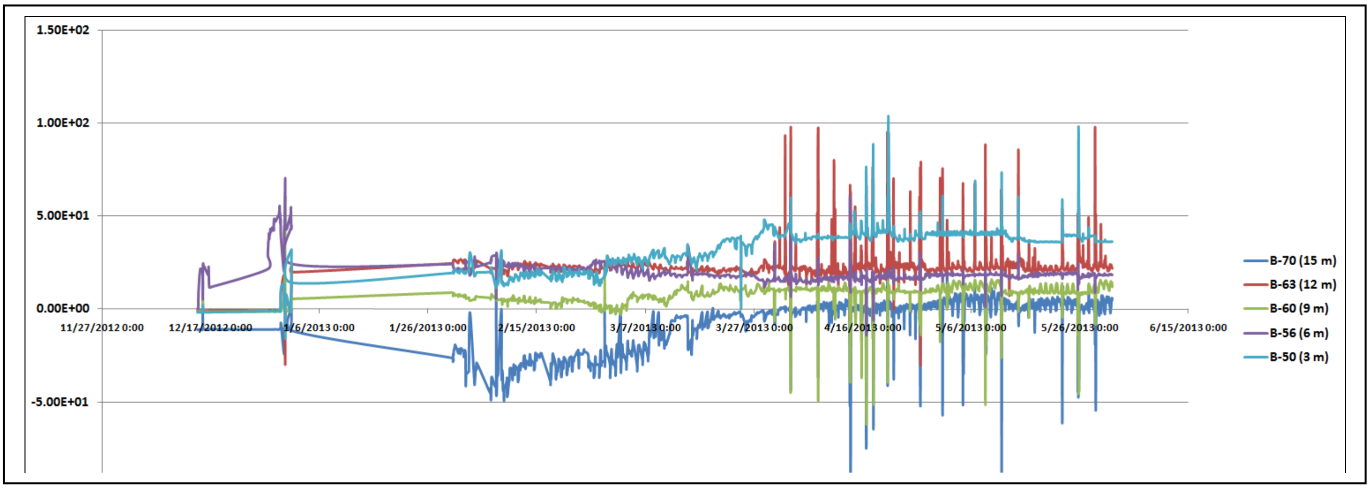


Fig. 7 Plot of IPI sensors at borehole 1, 3 and 5

8. RESULT & DISCUSSION

In general, pore pressure conditions at or above road changed sharply during or after movement occurred. This indicates that rapid changes in pore water pressure were likely shear induced. Since records of long term pore water pressure at the site were not available, ground water conditions prior to movement cannot be determined. Without pre-slide pore water pressure data, it cannot be determined if a long term pore water pressure increase within the slope played a role in destabilizing the slope.

Displacements measured with sensors at borehole locations 1,3 and 5are shown in fig.7. The first three boreholes are located in the lower landslide unit whereas borehole 7 and 9 are located in the middle and upper unit respectively. During the observational period (from Jan-13 to Dec-13), the landslide never stopped. However, rates of movement were different at each morphological unit and experienced significant changes in relation to the rainfall. The lower unit was the most active with an accumulated displacement of the sensors of over 90 mm in borehole 1.The highest landslide activity period took place in the second half of July and during August-13;

during which rates of movement upto 5 mm/day and 18 mm/week were recorded in borehole. The intermediate unit was much less active. At the borehole 7, the total accumulated displacement was less than 21 mm during the observational period. Slope inclinometer monitoring showed that the toe of the slope is moving at greater rates and magnitudes than the crest and middle portion of the landslide body. This observation of movement is consistent in literature regarding other landslides.

9. CONCLUSION

Instrumentation data has been continuously retrieved, analyzed and monitored for the Tangni landslide since December 2012. The existing instrumentation system against rain induced slope failure is based on real time displacement measurement in the subsurface. Although, this method can be applied to the individual slope, this gives short time for evacuations as displacement is measured when slope moves. However, this instrumentation will provide much of the information necessary, not only to monitor the dynamics of slopes, but to obtain some of the necessary parameters to determine factor of safety using conventional and finite element method.

10. ACKNOWLEDGEMENT

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