Detection of Slip Surface in Landslides using Geo-physical Survey at Bhusmey Landslide, East Sikkim: India

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ABSTRACT

Perennial subsidence zones along road sections in hilly regions is a challenging job for its restorations to site engineers. One of such distress zone along. Rangpo-Rorathang road-section existed from more than a decade has been studied using geo physical technique implementation of Ohm's law (V=IR), where in constant current was supplied through two electrode and resistance of various slopes forming materials was measured at equipotential surface. The low resistivity of the materials is due to the presence of high water activity and such plane is vulnerable to failure. Therefore, detection of slip surface can be of great interest to site engineers for its permanent mitigation measures. Such studies also plays vital role in long term mitigation measures for restoration of roads especially in hilly terrain like Sikkim.

Keywords: Electrical resistivity technique; Soil overburden; Geological mapping; Slip surface detection

INTRODUCTION

The State of Sikkim is located between 270 04' 46" to 280 07' 48" North Latitudes and 880 00' 58" to 880 55' 25" East Longitudes [1]. It is a State located over the mountain system 'The Himalayas' which are recently formed young and folded mountain system as a result of continent to continent collusion of Indians plate with the Eurasian plate [2]. The process of collusion is still an ongoing process where the Indians plate movement north wards is at a rate of 2cm per year and resultantly the rise of Himalayan peaks or mountains is growing at a rate of 2 to 5 mm per year [3]. Such activity makes the effect Sikkim Himalayas fragile geo-environmental mountain system of the world which is vulnerable to various components of hazard and disasters like landslides, earthquakes, flashflood etc. Sikkim has a rugged topography, and geo-morphologically it's has been classified as:-

Lower hills

The hills ranging from 300 m-1 800 m having from the point hilly topography with flat cultivated landinpatches.

Upper hills

The hills are ranging from 1800-3000 m which in the majority is majority is under forest cover.

Snow land

The general slope is from North to South in sloping hills extends South and degree varies from place to place. Glaciers are the important physiographic features of the State and are mostly present in North and West district. The largest glacier is Zemu glacier with 26 km length situated at the base of Mount Khangchendzonga. Tista and Rangit Rivers are the two main drainages subsequently joined by many tributaries, having their confluence near Tista Bazar and finally join the Brahmaputra River flowing towards Bangladesh. The morphometic setting at a glance consists of deep river, terraces, flood plains, steep and gently sloping hills, various Geo-tectonic features such as folds faults etc. The altitude varies from 300 m to 8598 m above mean sea level. The average annual rainfall of Sikkim is in around 2700 mm [4].

Electrical resistivity determination is usually made by injecting a specified amount of electric current electrodes and with the aid of a pair of potential electrodes. The potential difference between any two points at the surface caused by the flow of the electric current in the sub-surface is measured. From the measured current (I) and the voltage (V) values the ensuing resistivity is determined [5].

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Geophysical study provides the subsurface conditions which can be correlated with geo-technical information. Thus, complete information of physical behavior of a sub-surface geology such as movement of ground water, thickness, relief of bed rock, water saturated zone, etc. can be understood using these geo-physical techniques. Electrical Resistivity Tomography (ERT) investigations are widely used because of its cost effective and time efficiency [6].

The ERS technique can be useful for detection of slop surface in landslide/distress zone in hilly terrain, where construction of road formation is difficult and no alternatives exist. Generally in hilly terrains like Sikkim, slopes are greater than 250 of angle onwards, which is more susceptible to failure. The failure occurs at the planes that exist at the contact of soil and bed rock. The fracture, faults, folding, thrust and shear zone of the rock determines the structural geological condition, because the dip of rock foliation parallel to slope direction result into more vulnerable to failure, whereas rock foliation which are perpendicular to the slope direction doesn't contribute towards slope failure and are more suitable for the development of infrastructures [7].

Location and accessibility of the study area

Geographically the area of investigation is located between N 27°11'16 to N27°11'12 Latitudes and E88°33'43" to E88°33'43" Longitudes and at the elevation ranging from 380 m to 484 m amsl. The subsidence area is located at 4th mile, Bhasmey-along Rangpo-Rorathang road section (valley side plot right slope of Rangpo River) and is approximately 6 kms from Rangpo Bazaar, East Sikkim. The location map generated from Google earth image has been shown. The road section is maintained by Border Road Organization (BRO) (Figure 1).

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Electrical resistivity determination is usually made by injecting a specified amount of electric current electrodes and with the aid of a pair of potential electrodes. The potential difference during investigation decade problem spot along road section the is at 15 meters, (having resistivity <1000 ohm-m is measured) the beyond this depth competent strata having resistivity >2500 ohm-m is measured. Therefore, under such geological condition the road formation can be maintained by inserting deep micropiles (depth greater then slip surface 15 m) having diameter slide lessthan 0.50 m or should be diverted away from the slide zone.

Observation from 2D-inversion resistivity in the profile section A-B shows that the top layer consists of loose transported thick soil overburden followed by highly weathered and moderately weathered quartzite phyllite rock in the area. Further, it can also be seen in the tomography that a major groundwater circulation zone exists between 45-70 horizontally with depth between 2.5 m-20 m and highly weathered rock upto 12.5 m (average) followed by moderately weathered rock as seen in the tomography.



LOCATION MAP SHOWING THE STUDY AREA IN RANGPO-RORATHANG ROAD SECTION, EAST SIKKIM, INDIA

Figure 1: The location map of the study area demarcating the landslide zone with 2D profile section made by ERS technique. A-B is the profile section one taken perpendicular to direction of subsidence during ERS survey at field, E-F is the parallel to direction of movement of landslide taken during field data collection. C-D section taken as parallel to road section for field study.

MATERIAL AND METHODS

Geo-physical survey by electrical resistivity method were widely used for estimation of overburden thickness, detection of ground water level, slip surface estimation in landslide by using the basic principle of Ohm's Law (V=IR). If Potential (V) and current (I) were constant, then variation of resistance (R) of the materials can be measured. Resistivity data were collected using Wenner-Schlumberger (Vertical Electrical Sounding) array configuration with electrode separation 2-5 m [8]. Topographic corrections and 2D inversion model were performed using Res2D inv of GEOTOMO Software [9]. This resistivity inversion software based on the least-square method in distances [10]. In all inversion attempts the number of iteration is kept.

The profile sections were taken along A-B, the first electrode is placed at location 0.00 meter of section. (GPS coordinates at N27° 11'15.2" latitude E88° 33'46.4" at an elevation in 442 m ams). The direction of the profile section runs NW-SE from the first electrode. The last electrode was placed at a distance at 90 meters, (GPS coordinates at N27° 11'16.7" latitude to E88° 33'44.9" longitude at an elevation of 445m ams) (profile section 01-01'), to delineate probable sub-surface geology. Further two

more profile sections parallel to road section(C-D) and along the direction of movement of distress zone (E-F) were taken shown. The resistivity value was correlated with subsurface geology inferred from geological literature.

RESULTS

The Electrical Resistivity Survey (ERS) method has been selected to understand the area under investigation in terms of resistance which generated different tomography. The field operational setup for the measurement of sub-surface resistance is shown. Three different 2D-electrical resistivity tomography have been plotted for three different data sets. 2D-electrical resistivity tomography profile section A-B (Table 1).

Observation from 2D-inversion resistivity in the profile section A-B shows that the top layer consists of loose transported thick soil overburden followed by highly weathered and moderately weathered quartzite phyllite rock in the area. Further, it can also be seen in the tomography that a major groundwater circulation zone exists between 45-70 horizontally with depth between 2.5 m-20 m and highly weathered rock up to 12.5 m (average) followed by moderately weathered rock as seen in the tomography. The profile section along E-F shows that the top layer consists of loose transported thick soil overburden followed by highly weathered and moderately weathered quartzite phyllite rock in the area. Further, it can also be seen in the tomography that a major groundwater circulation zone exists between $45 \text{ m-}62 \text{ m} (4 \Omega \text{m-}60 \Omega \text{m})$ horizontally depth between 2 m-5 m and highly weathered rock upto 5 m-15 m (average) intermixed with loose saturated soil as seen in the tomography.

Sl.No	Resistivity in ohm-m	Depth in meters	Sub-surface geological interpretation
1	4-60	3-20	Ground water circulation zone.
2	90-120	2.3-3	Moist saturated clayey soil
3	120-1200	0-10	Loose transported soil overburden
4	2000-2500	15-20	Moderately weathered quartzite phyllite rock and its variants.

Table 1: Resistivity of the materials corresponds with particular depth with sub-surface geological condition at landslide area.

CONCLUSION

The ERS techniques has been used to estimate the depth detection of water bodies, seepage zones as water is high conductor of current and having low resistance. With the help

of water detection, which is acting as lubricating agent for development of slip surface in the landslide area, distress and subsidence zone. The high water circulation zone having resistivity <60 ohm-m and subsidence on road section is clearly visible during the field study and reveled from the topography generated from ERS method. During investigation of this decade problem spot along road section the depth of slip surface is at 15 meters, (having resistivity <1000 ohm-m is measured) beyond this depth competent strata having resistivity >2500 ohm-m is measured. Therefore, under such geological condition the road formation can be maintained by inserting deep micropiles (depth greater then slip surface 15 m) having diameter slide less than 0.50 m or should be diverted away from the slide zone which ever is cost effective. Such study and research is very benificial prior to construction of road in hilly areas and this study is first aproach to transform the research technologies into actual field infrastructural developmental works which will directly guide the site/field engineers engaged in mitigation/ restoration of such troubble spots in the hilly terrain.

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