Geotechnical Assessment of Kallar and other Landslides along NH-67 and Mountain Railway Track in the Nilgiri Hills, Tamil Nadu

C.Thanavelu and S.Chandrasekaran

Abstract

Consequent to continuous heavy rains in the Nigeria Hills, twenty eight landslides of medium to large size have occurred at the early hours on 14th November 2006, along NH-67 between Kallar and Pudukkadu villages and along Mountain Railway track between Adderley and Barliyar stations. The landslides have caused loss of one life and injury to three persons. Besides it has washed away a truck, completely damaged a rail and a road bridge and partially damaged many culverts. A detailed study of an important slide that occurred near Kallar village was taken up and inventory of other twenty seven slides were made. The paper deals with the type of slide, triggering mechanism and causative factors and recommends control and corrective measures.

Introduction

Landslide occurrence is a frequent and recurring phenomenon in Nilgiri Hills (Blue Mountain) of Tamil Nadu. The known record of devastating landslide in the Nilgiri dates back to the earlier part of the nineteenth century. A spate of landslides concentrated in a particular area were reported in the years 1881, 1891, 1902, 1905, 1926,1978, 1979,1987 and 1993. In general the slides occurred during or subsequent to continuous heavy rain fall. One such spurt of landslide incidence took place at the early hours on 14th November 2006 subsequent to continuous heavy rain fall. A total of twenty eight landslides of medium to large size have occurred along NH-67 and along Mountain Railway track disrupting traffic in busy road as well as rail traffic between Mettuppalayam and Coonoor. The event has caused loss of one life and injury of three persons, washing away of a truck, complete damage of the rail and road bridges and partial damages of many culverts. Detailed geotechnical investigation was taken up by carrying out of large scale geological mapping of an important slide in terms of size and location at Kallar. Inventory and rapid assessment studies were conducted for the other twenty seven slides.

Geomorphology

Nilgiri Plateau which houses "The Queen of Hills" - Ootacamund, stands out prominently and rise to a height of about 2500 m above mean sea level, is bound by the Mysore plateau in the north, the Coimbatore upland in the east, the Palghat Pass in the south and Wynad Plateau in the west. The longer axis of the plateau is in ENE-WSW direction. The types of landforms observed are plateau and fluvial landforms. The Plateau landforms can further be sub-divided into three categories viz 1. Less dissected undulating plateau, 2. Moderately dissected plateau and 3. Deeply dissected deflection slopes. The central part of the plateau is characterised by gently to moderately sloping undulating hills bordered at northern and southern sides by alternate linear strike ridges and valleys. Alluvial and colluvial fills, river terraces and flood plain deposits are the fluvial landforms present in the Nilgiris. The tributaries, Coonoor and Kallar Rivers, forms part of Bhavani River system draining the area.

Geological Survey of India, Chennai

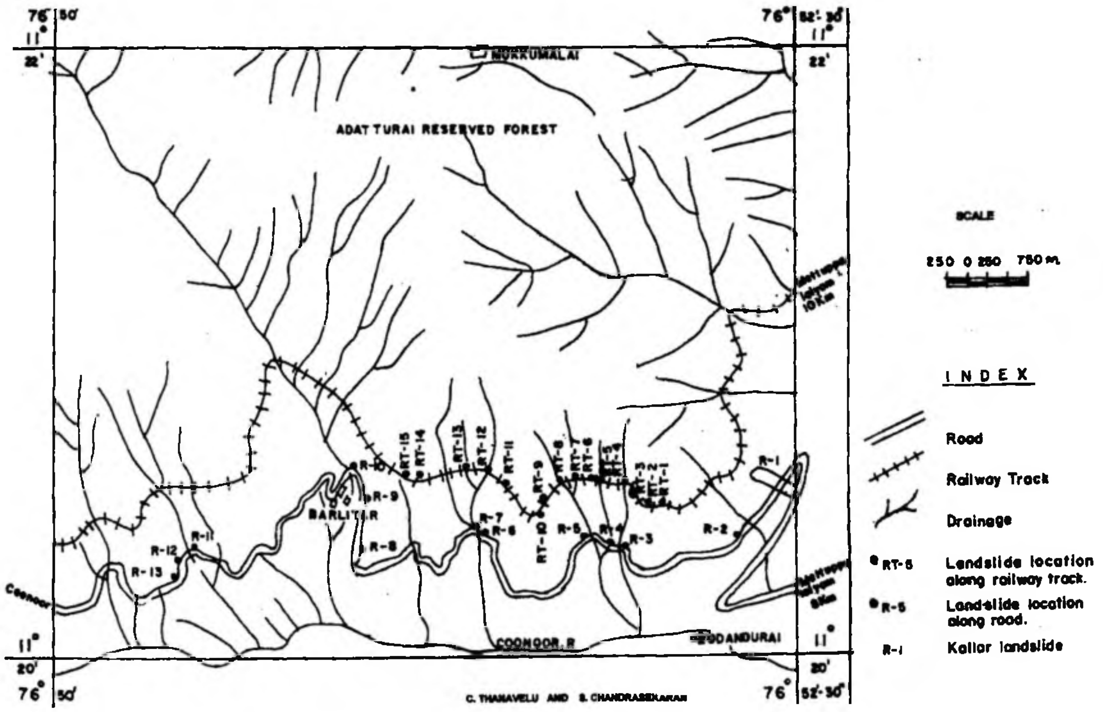
The study area forms a part of the northern flank of the deeply dissected Coonoor River valley. The slope rises from 750m to 1770m in the western part and from 400m to 800m in the eastern part of the area. Cliffs and scarps are common in the western part and the eastern part is characterized by uniform slope. Two arcuate shaped convergent slope facets are present in the middle part of the area. From the geometry of these slope facets and presence of paleo-slide debris at the lower levels of the slope, it is inferred that these facets could have been formed due to slope retreat by continuous processes of weathering, accumulation and sliding/ stripping in conjunction with erosion. The slope angles vary from 35° to 55° below the scarp, whereas it is 25° to 35° at the lower part of the slope. Piedmont zones, colluvial and alluvial fills are observed at lower slopes of Coonoor and Kallar river valleys present south and east of the study area. River terraces are conspicuously noticed along the Kallar River valley.

Geology

The Nilgiri massif consists of high grade metamorphic rocks of Archaean age. Charnockites, with or without garnet and banded garnetiferous biotite gneiss are the country rocks exposed in the area. Small enclaves of metabasites and quartz magnetite schist occur concordantly within the charnockite and biotite gneiss. Pegmatite and quartz veins and basic dykes occur as intrusive into the country rocks.

Blanford (1860) and other earlier workers considered that the Nilgiri plateau to be an uplifted block from Mysore plateau along three major fracture systems, namely E-W trending Moyar fracture in the north, ENE-WSW trending Bhavani fracture in the south and NW-SE fracture in the western part of Nilgiri hills. The structural fabrics noticed in the Nilgiri hills are folds, faults, shear zones, fractures and joints. Imprints of two flexures (Fold) and fracture episodes / deformations have been recorded in the rocks of Nilgiri. The first folding event F_1 resulted in a series of tight antiforms and synforms in ENE-WSW direction led to the development of numerous fractures parallel to their axial trace. The second phase folding (F2) are broad open folds in NW-SE direction. Some of the basic dykes also show flexures parallel to the axial trace of F2 fold besides development of fractures. Two sets of conjugate joints and vertical joint sets are observed parallel to the axial trace of both F1 and F2 folds. In addition, joint system with N – S strike is also observed in the bedrock.

Laterite, rock detritus, alluvial/ colluvial fill and insitu/ transformed soils are the materials overlying the bedrock. Duricrust occurs principally on flat surfaces on the upper parts of the hills, at elevations ranging from 1900 m to 2412m above mean sea level. Detrital laterite is found to occur on slopes at higher levels. Lateritic soil which is light yellow to reddish brown in colour commonly occur in the area and is generally found at the top of in-situ soil profiles, but below the humus layer. In some of the slopes lateritic soil is also seen as transported cover over the humus horizon. Lithomarge clay horizon is found between laterite and weathered bed rock. It is reddish or pinkish in colour. Lithomarge, with or without bauxite, is extensively developed in Nilgiris. Humus soil (peat) is found to occur as top horizon of the soil in areas covered by dense vegetation, in valleys and swampy areas, Saprolite and other rock detritus which are the product of weathering of bedrock are also taken as part of capping/surface material. Weathering processes in the Nilgiri hills are mainly controlled by the altitude and by the composition of rock. Predominantly two types of weathering viz physical and chemical weathering are noticed in the area. Physical weathering is predominant below 1500 m level giving rise to sandy soils. Physical weathering particularly exfoliation type is also seen along escarpment slopes and barren hills above 2500m giving rise to exfoliation domes. Whereas the chemical weathering is predominant above 1500 m level giving rise



to lithomarge clay, bauxite and laterite. The thickness of the overburden varies from 1 m to 5 m in deeply dissected deflection slopes, 5 m to 30 m in moderately dissected plateau slopes and 30 m to more than 40 m in less dissected undulating plateau.

A major part of the land in the Nilgiris (47%) is used for cultivation and tea plantation. Forest and tree plantation occupies about 34% area and about 10% is utilized for residential purposes. The study area is covered with densely wooded forest.

The western and middle part of the Nilgiri Plateau receives average annual rain fall of >2500 mm and 1500 mm to 2500 mm respectively during southwest as well as northeast monsoons. The eastern part receives rain fall mainly during northeast monsoon and the average annual rain fall varies from 1000 mm to 1500mm. The area of investigation is located in the eastern part and the monthly low, mean and heavy rain fall of the area are 40 mm, 101 mm and 280 mm respectively.

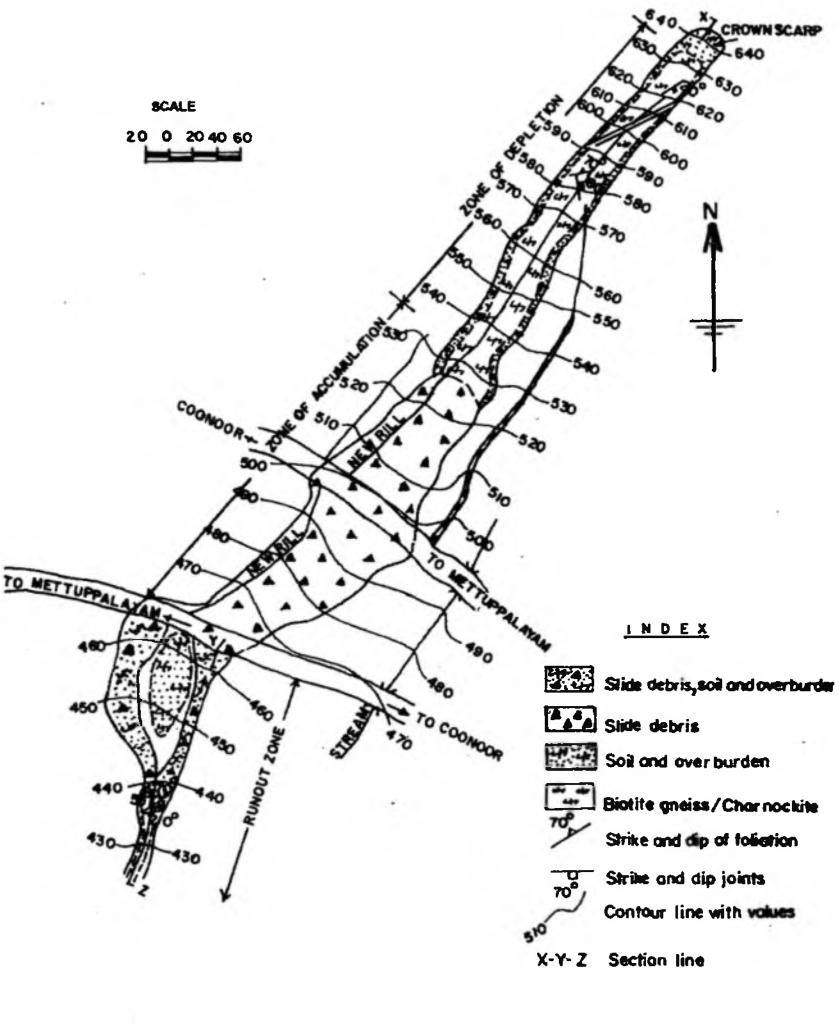
Geotechnical Evaluation

Among the twenty eight slides studied thirteen slides are located along NH-67 road between Kallar and Pudukkadu villages and fifteen are along Mountain Railway track between Adderley and Barliyar stations (Figure -1).

Kallar Landslide

Kallar slide is the largest slide that has taken place between hairpin bends 1 and 2 of Mettuppalayam – Coonoor stretch of NH-67 at Latitude: 11º 20' 21"N, Longitude: 70º51'52"E (figure -1) near Kallar village on the foot hill slope covered with dense forest. The slide has caused partial damage and blocked two arms of the road, uprooted trees and plants and deposited silt and debris over the plantation areas. The Mountain Railway track passes through the slope above the crown. The slope angle prior to failure was 35º, and was covered by the lateritie, lithomarge, saprolite (completely weathered -W6), weathered rock and perched boulders with thin loamy humus soil. The bedrock part of the slope forming material consists of garnetiferous gneiss and charnockite. The depletion part of the slide lies above the upper arm and the accumulation part extends just downside of the lower arm of the road (figure 2). The run out zone was observed to cross the lower arm of hairpin bend -1, west of Kallar village.

The slide flow was towards S 50º E, between elevations +408 m and +637 m. The length and width of the slide are 430 m and 30 m respectively. The height of the crown scarp is 5m. The depth of the slide at the down side end of the zone of depletion is 2.5 m and the average depth worked out to be 3.5 m. It is estimated that 11550 cu.m debris materials has moved out exposing fresh bedrock. Fresh bedrock is also exposed in the run out areas due to erosion and removal of capping/surface material by the rapid movement of fluid debris. The run out fluid debris has also choked and damaged the culverts on either side of the side. Foliation, four sets of joints and one set of shear zone are the discontinuities present in the bed rock. Weathering is controlled by joint set with strike N 50º E – S 50º W, dips S 40º E. The bedrock profile is mildly cascading with



C. THANAVELU AND S. CHANDRASEKARAN

Fig. 2 : Geological Map of Kallar Landslide

minor fall across some of the joints and shear zone. Temporary springs/seepages are noticed at the contact between bedrock and debris. A new rill has been developed due to flow of debris from the crown area to upslope edge of the lower arm of the road.

The landslide is a climatically triggered and is of ' Debris Flow ' type. The failure is rotational cum translational that started as a slip circle failure and moved along the plane of contact between bedrock and overburden. Steep slope, movement of ground water and eluviation process at the contact between the rock and overburden and increase in soil water content due to antecedent rain fall are considered to be the preparatory causative factors. Sudden increment of pore/cleft water pressure due to heavy rain in a short duration is inferred to be the triggering factor. Heavy flow of water reported to have been observed immediately through springs at the contact of overburden with rock support the above inference. The flow has been reduced considerably after ten days and completely dried out subsequently. Similar phenomena was also observed in the neighbouring slide, where 12 lpm of water flow was recorded on 25th November which has been reduced to 1.5 lpm on 29th of the same month. In addition, nineteen new springs have emerged in the area and disappeared after a fortnight.

Stabilization, control and corrective measures

In order to clear the road for light vehicles as early as possible, National Highway Authority of India has taken up removal of slide debris accumulated over the road arms and temporary restoration work. The following stabilization and long term control and corrective measures are recommended for the Kallar slide area.

1. Loose, large sized boulders with weight ranging from 1 to 20 tonnes are lying in the crown scarp and in the slide debris in the accumulation zone. These boulders are to be broken in situ by manual methods or mild blasting and be removed.
2. Construction of gabion across the slide at the end of depletion zone i.e. at about R.L.535m with a cement pipe of suitable size at the newly formed gully location for channelising the surface water.
3. Construction of retaining wall founded from rock on either side of both the arms of the road connecting the parapet of the culverts present near to both the edges of the slide.
4. Training and partial paving of the newly formed rills/gullies so as to lead the surface water to the adjacent culverts at the respective arms and sides.
5. Dressing and leveling of slopes between the proposed gabbion and retaining wall at the upslope side of upper arm and in between retaining walls at down slope side and upslope side of upper and lower arm of the road respectively and turfing/ partial pitching.
6. Cleaning and rectification of culverts present adjacent to the slide which are choked and partially damaged.

Assessment of Other Slides

Most of the other landslides that have occurred adjacent to the road NH-67, railway track and at the top levels of the slope and are located within the two convergent slope facets that have retreated by palaeo slides. The soil/regolith stripping have taken place on 35º - 55º slope causing partial/complete damage to road/rails, culverts and bridges and depletion in forest cover by uprooting many trees and plants. The thickness of soil/ regolith/debris varies from 1 m to 3.5 m. In general, the slides are shallow sheet debris slides occurred along the bedrock overburden interface. Steep slope, removal of lateral support and changes in water content due to continuous heavy rainfall are identified to be the causative factors for the near road/track and top level slides.

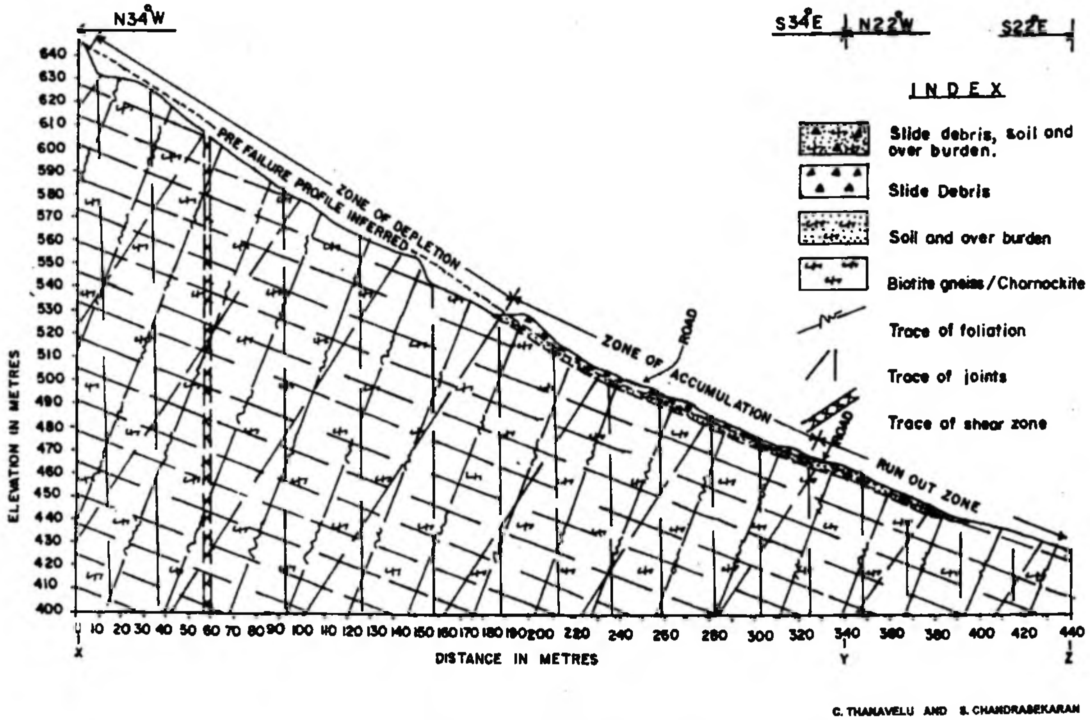


Fig. 3: Longitudinal Geological Section of Kallar Landslide

Effect of Run Out

Slope failures that occurred close to communication corridors have caused only blockade and minor damages to the road/ railway track. Mixing with surface and subsurface water the failed slope mass become saturated and ran out along streams and streamlets. The run - out from the upper level slides caused stream bank failures triggered by instantaneous erosion and removal of toe support along the streams. It was also responsible for choking, partial and complete damages of culverts and bridges. The debris flows culminated in debris flood and flooded the fruit orchid area and left behind strewn boulders and rock fragments.

Cleaning of the culverts/ bridges choked with debris and periodical maintenance will minimize the damages due to such calamities. In order to avoid choking/over toping and damage due to future debris run-out increasing the bay width and height of the culverts may be thought of for existing culverts/ bridges, if not at least where ever new structures are planned.

Conclusions

The landslide occurrence was preceded by heavy rainfall of 152 mm. Major part of the rain was within a short period of about half an hour time. The antecedent rainfall recorded three days (P_3) and 15 days (P_{15}) before was 109 mm and 330 mm respectively. At least three landslide prone stretches are present along the important communication corridors (both road and railway line) connecting the hill station Ootacamund with the plains. Two of the stretches are falling in zone II and III of Landslide macro zonation map by D.N. Seshagiri et al (1982) and the third one falls in zone 'V'. Landslides/soil slips have occurred frequently in these stretches. Hence, it is necessary to carry out a comprehensive meso/micro zonation studies applying the methods in vogue for the entire stretch of the slope from Kallar to Coonoor. Monitoring of the slopes by installing instruments may also be taken up for the critical stretches. As a long term measure, construction of tunnels from right slope of the Kallar stream to Barliyar and from Barliyar to Coonoor may be considered.

Acknowledgement

The authors are thankful to the Director General, Geological Survey of India (GSI), Kolkata for according permission to publish this paper. They are thankful to the Deputy Director Generals, Southern Region and OP:TNPK, GSI, Hyderabad and Chennai for the support rendered. Thanks are due to Shri G. Rajagopalan, the then Director and Shri R. Pitchaimuthu, Director, Engineering Geology Division, Chennai for the guidance during the field work and critically going through the manuscript.

References

1. Thanavelu, C., and Chandra Sekaran, S. (2006) : Report on the Geotechnical Investigation of Landslides of November 2006 Occurred in Mettuppalayam and Coonoor Taluks, Coimbatore and Nilgiri Districts, Tamil Nadu. Unpublished Progress Report for the Field Season 2006-2007.
2. Seshagiri, D.N., and et. al. (1982) : The Nilgiri Landslides, Geological Survey of India, Miscellaneous Publication No.57.
3. Balachandran, V, Thanavelu, C, and Pitchaimuthu, R., (1995) : Marapalam Landslide, the Nilgiri District, Tamil Nadu, India – A Case Study. Poceedings of the International Conference on Disaster Mitigation, Volume – 1, Earthquake and Landslides, Anna University, Chennai India.
4. Narasimha,S., Battacharya, J. and Anantharaman, S. (1981): Geoenvironmental Studies in parts of Nilgiri Hills and Coimbatore District. Unpublished Report, Geological Survey of India.
5. Eckel, E. B. (1967) : Landslides and Engineering Practice. Highway Research Board, Special Report.
6. Crozier, M. J. (1986) : Landslides–Causes, Consequences and Environment, Croom Helm, London.
7. Zaruba, Q and Mencl, V. (1982) : Landslide and their Control, Elsevier Scientific Publishing Company, Amsterdam