Landslide Hazard in North East India : A Case Study

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ABSTRACT

With the growing development activities landslide is a recurring problem of Urban & Semi Urban region of hills in North East India. Landslides frequently occur in the region during rainy season. Therefore, most of the landslides are rain induced. Further the hilly topography of the region is characterized by steep slope with weathered, fractured & folded rocks, the hill slope with degraded materials and frequent occurrence of earthquake between 2-6 in Richter scale are responsible for landslide. The present paper aims at the study of Geomorphic and Geotechnical investigations undertaken at two typical landslide hazard prone areas of North East India- Guwahati city area, Assam and Aizwal town area, Mizoram. The hills of Guwahati city area comprises of highly degraded Granito-Gneissic rocks. The landslide of the area occurs primarily due to unplanned and rapid cutting of hill slope. The exposure of rock to weathering due to deforestation and hill cutting increases the pore water pressure on soil after occurrence of rainfall causes landslide. In Aizwal town area, the mechanism of landslide is mainly due to Seismo-tectonic pressure in major shear zones and tropical climate conducive to deep weathering and unplanned hill cutting and resultant reduction of stability of natural slope. The hazard caused by landslide in the North East India is although not alarming may lead to a disastrous situation if present scenario of slope instability continues .The remedial measures for mitigation of landslide problem are designed as - landslide hazard appraisal and application of passive and active measured Viz. proper management of hill slope and forest cover.

Key Words: *Weathering , Hazard, Stability, mitigation,*

INTRODUCTION

The frequent occurrence of landslides both in space and time, undoubtedly makes it most widely occurring environmental hazard. The complex geological set up with contemporary crustel adjustments of Chinese and Indian plate, the mountain and hill ranges of North east India is seismically very unstable and highly prone to landslide.

With the growing development activities in the rugged topography of N.E India characterized by steep slope with highly weathered, fractured & folded rocks, low strength of soil materials, heavy rainfall and frequent occurrence of earthquake ranging between 2-6 in Richter scale are the basic factors of landslide.

Geology and Geomorphologically. North East India comprises of E-W tending tertiary fold mountain ranges of Eastern Himalaya, NNE-SSW longitudinal folded hill ranges of Patkai-Naga and its continuation to N-S hill ranges of Manipur , Mizoram and plateau region of Meghalaya and Karbi Anglong. The faults that divide these domains Viz. Main Boundary Fault, NagaThrust, Haflong -Disang Thrust etc. are extremely active and cause frequent earthquakes. Therefore a large part of Arunachal Pradesh, Assam,

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Nagaland, Manipur, and Mizoram has been ravaged or affected by mass movements. The natural environment of the region is in such a fragile state that slightest tempering on it may change the ecological balance and lead to natural disaster caused by landslide.

CASE STUDY

Landslide is a recurring problem of Urban & Semi Urban region in the hill region of North East India. The present paper aims at the investigation of Geomorphologic and Geotechnical phenomenon of two typical landslide hazard prone urban areas of the region - Guwahati City area, Assam and Aizwal Town area, Mizoram.

Guwahati City area

Guwahati, the capital city of Assam is situated on the south bank of Bramhaputra. The city is located on the outlier of northerly extension of the Meghalaya plateau represented by small hillocks with altitude varying altitude between 100-300m and alluvial plain of the Brahmaputra river. Geologically these hills are primarily composed of Pre-Cambrian Granite, Gneiss, Schiests, Pegmatites etc. Quartz and Quartzo-Feldsphatic veins are common in Granite.

Factors affecting landslide

To understand the problem of hill slope destabilization in Guwahati city area it is necessary to establish a relationship among the various instability factors Viz. Topography, Geology, Soil, Climate and Factors of human interference. A comprehensive analysis of such factors have been outlined as follows:

Topographic factor

The physical configuration of Guwahati exhibits a peculiar characteristic that has no parallel in other parts of the country. The Core of the city is surrounded by hills with varying altitudes between 100-300m. Most of these hills are of denuded type moderately dissected by joints and fractures. The slope angle of the hills varies between 5° to 60°.The average elevation of the low-lying areas of city is 49.0m above mean sea level. About 15% of the total area of the city is occupied by slope above 200, which is more vulnerable to landslide. The average slope of the hills gradually falls towards west.

Geological factor

Geologically and structurally, the hills of Guwahati city comprising of tectonically unstable Precambrian Granite and Gneiss rocks represents different lineaments tending NE-SW, ENE-WSE and W-E. There are three faults concealed under the Brahmaputra alluvium. The trends of these faults are ENE, ENW- WSE and E-W. The joints, foliations and intrusive veins are the plane of weakness in rock formations of the city. These planes of weakness are highly weathered in exposed surface that provides facilities for landslide.

Soil factor

The hill areas of the city are covered by red sandy clayey and laterite soil. The soils of low-lying areas of the city are composed of silt, sand and clay. Soils of the region are the product of mechanical & chemical weathering of rocks. It is the most common process of soil formation. The red clayey soil materials are found to be mixed with grains of Quartz, Feldspar and mica. The presence of such non-cohesive nature of soil will have an important bearing upon the landslide.

Rainfall factor

Guwahati city represents subtropical monsoon climate. The average annual rainfall at Guwahati is 2272mm and about 90% of the total rainfall occurs between May and September. Maximum rainfall occurs during the months of July to August. Study of the intensity of rainfall and rainfall regime is of prime importance because it is closely associated with landslide. The most catastrophic events of landslide are initiated by a spell of rainfall lasting for 2-5 days, usually towards the end of monsoon Season.

Human interference

During the last three decades newly developed settlement are widely scattered on the hill slope of Guwahati city. Rapid growth of settlement on the hill slope plays manifold adverse effect on the slope. Although the actual cause of instability may vary in different parts of the city, basic cause of instability of slope are toe cutting, construction of heavy structures on steep slope, deforestation etc. The study revealed that areas situated above 25° slope are badly affected due to human interference.

Fig 1. Ananda Nagar Slide Area

GEOTECHNICAL INVESTIGATION

Geotechnical study was carried out by laboratory test using disturbed and undisturbed samples of Soil from affected areas of landslide. The depth of collected samples varies between 120-310cm below the surface.Three landslide spots- Ananda Nagar Luit Nagar, and Kamakhya hill were selected for the present study. Ananda Nagar and Luit Nagar are situated on the south eastern part of the Guwahati. The elevation of the hills in the region varies between 80-110M and has been continuously subjected to human interference by construction of houses and other development activities. The region with high slope varying between 30°-50° represents exposed faces without vegetation cover. Ananda Nagar area three and Luit Nagar area experienced one landslide on 15th July1999, 7th August 2000,11th August2000 and 10th July 2000 respectively. Kamakhya is situated at the middle part of the city. During the last few years the region experienced a number of minor slides along the roadside (Das, H.K, 2002). There is possibility of a major slide above the roadway to Kamakhya temple. The hill. Slope varying between 25°-70° represents outcrops of insitu rock covered by red and sandy laterite soil. (Plate- 1,2,3)

Results of Laboratory test

The results of laboratory tests of soil samples collected by open pit excavation and boring at some selected localities are shown in Table-1.

It is observed from table 1 that soil types of landslide areas are either mixture of sand with plastic fines(SC) or inorganic clay of intermediate plasticity(CI). The unconfined compressive strength varies from low to medium. The angle of internal friction varies from 30° to 37°.

Aizwal Town area

In Aizwal town area, landslide occurs mainly due to seismo-tectonic pressure in major shear zones, heavy rainfall conducive to deep weathering and unplanned hill cutting .Landslide is a common phenomenon in and around Aizwal area during rainy season. In the last twenty years several landslide occurred causing loss of life and property. One of the largest landslides occurred on

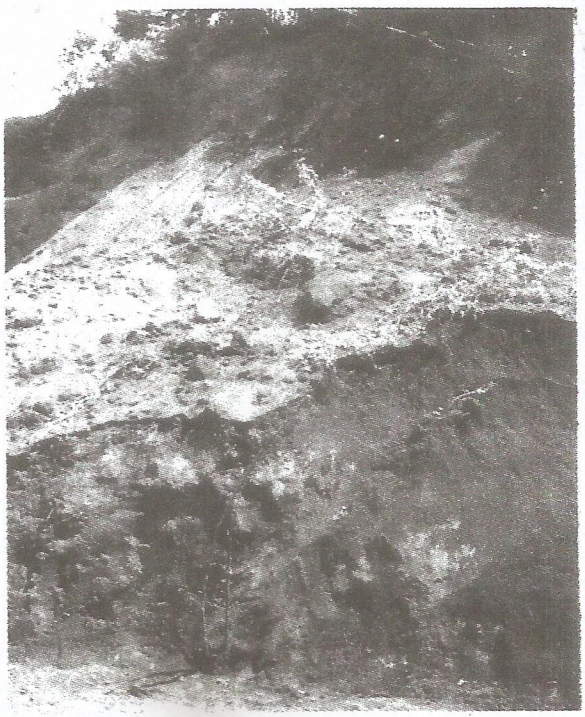

Fig 2. Luit Nagar Slide Area

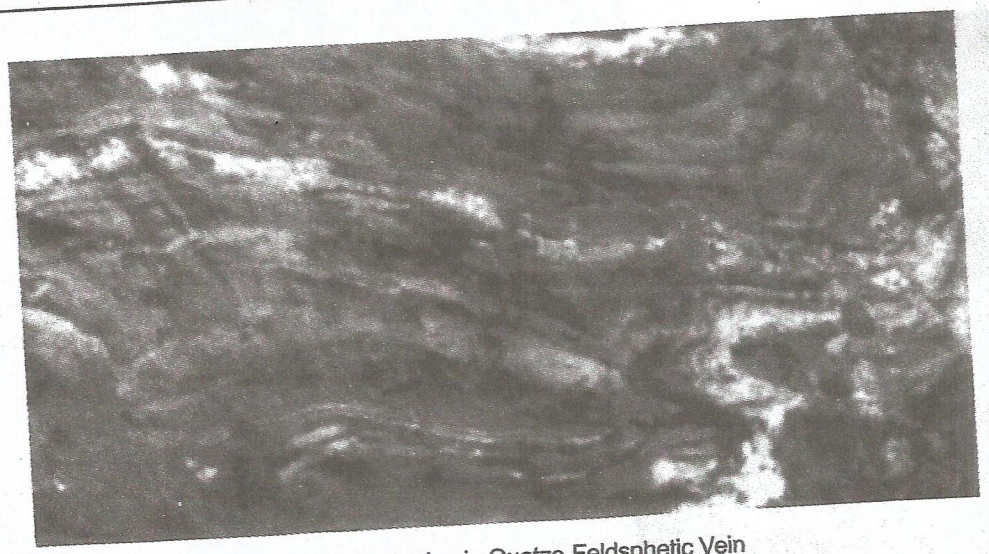

Fig 3. Weathering in Quatzo-Feldsphetic Vein

TABLE -1: *Soil Classification*

Site	Soil Sample No	Depth from Ground level (M)	Grain Size %			Liquid Limit %	Plastic Limit %	Plasticity Index %	Classification
			Gravel %	Sand %	Silt & Clay				
Ananda	1.	130	0	47.0	53.0	44	17	27	CI
Nagar	2.	180	0	59.2	40.8	49	20	29	SC
	3.	210	0	40.0	60.0	45	25	20	CI
	4.	250	1	79.0	20.0	48	26	22	SC
Luit	5.	120	0	40.6	59.4	50	26	24	CI
Nagar	6,	210	0.8	67.2	32.0	49	28	21SC	
Kamakhya	7.	280	0	61.8	38.2	49	26	23	SC
Hill	8.	310	0	56.8	43.2	41	23	18	SC

9th August 1992 in the Hlimen area situated south of Aizwal. It caused 70 casualties and heavy loss of property.

Factors affecting landslide

The factors responsible for hill slope instability in Aizwal town area are both natural as well as man made. The undercutting of hill slope, heavy monsoon rainfall causing deep weathering in young tertiary formations and active erosion of weathered materials, deforestation and ill-planned construction of roads and buildings have been found to be responsible for landslide and other mass materials. A comprehensive analysis the major instability factors in Aizwal Town area Viz. Topography, Geology, Climate Soil, and factors of human interference are outlined as follows:

Topographic Factor

The general topography of Aizwal town area is represented by several N-S tending longitudinal valleys and series of hill ranges. The angle of slope of the hills varies between 30°- 45° , but it is much steeper near the bank of streams or nalas. The Aizwal town is situated at an altitude of 800m.The slope of the hills are dissected by

TABLE-2 : *Index Properties*

Site	Soil Sample	In-situ Bulk Density (gm/cc)	Natural Moisture Content (%)	Specific Gravity	Unconfined Compression Strength (Kg/cm2)	Cohesion C (kg/m2)	Angle of Internal friction in degree
Ananda	1.	1.86	30.5	2.66	0.93		
Nagar	2.	1.79	15	2.64	2.27		
	3.	1.94	28	2.64	0.67	0.3	31°
	4.	1.94	17	2.65	1.01		
Luit	5.	1.89	21.5	2.67	0.49	0.35	30°
Nagar	6.	1.92	24	2.66	1.77		
Kamakhya	7.	2.07	17	2.64	2.94	0.45	37°
	8.	1.96	20.5	2.66	1.6		

number of nalas forming deep gullies. These gullies exerts considerable impact upon hill slope through soil erosion and causes instability of slope.

Geological Factor

Geologically, Aizwal town area is situated on N-S tending anticline composed of sandstone, siltstone and shale of Tertiary Era. These rocks belong to Miocene period. The major structural trend of the region coincides with regional tectonic lineaments. The mining and quarrying undertaken on such rock structure without the knowledge of stress condition of rocks is also responsible for landslide.

Soil Factor

Soil type of Aizwal region town area is sandy clay mixed with broken angular shale of varying sizes. Through there is good percentage of clay in the soil the water holding capacity is very low.

Climatic Factor

The climate of Aizwal region is tropical monsoon. The rainfall of the region is moderately high (170 cm /yr). Therefore hydrological factors play the most important role on the frequency of landslides during monsoon season. Further, there is considerable impact pore pressure generated by rainfall on joints and cracks of rocks. These rock masses under stress condition are not in a position to resist mass movement. The landslide-affected areas traversed by gullies also help in percolation of rainwater into the overburden materials.

Human Interference

The shearing stresses in the slope commonly increases due to overloading, removal of front support and vegetation. The overloading of the slope leading to landslide very often result from human activities viz. building of houses, storage of materials on slope, movement of vehicles etc. Natural overloading of slope may cause due to growing of big trees also.

GEOTECHNICAL INVESTIGATION

Geotechnical study was carried out by laboratory testing through collection of samples (disturbed) from landslide-affected areas. The depth of samples varies from 10 cm to 15 cm. For the present study four landslide sites were selected viz. Bundkawn, College Veng, Langnual and Zuangtui on the basis of vulnerability to landslide. In Bungkawn area landslide occurred on 19th August, 2000 after occurrence of heavy rainfall. The hillside of the area is heavily inhabited. There has been some disturbance caused to the slope in the form of earth cutting and removal of vegetation cover. The slide zone show variable slope 100 to 300 and is disturbed by hill cutting & removal of vegetation cover. The lithology of the region comprises of highly degraded Siltstone and sandstone. The soil is clayey in nature. In College

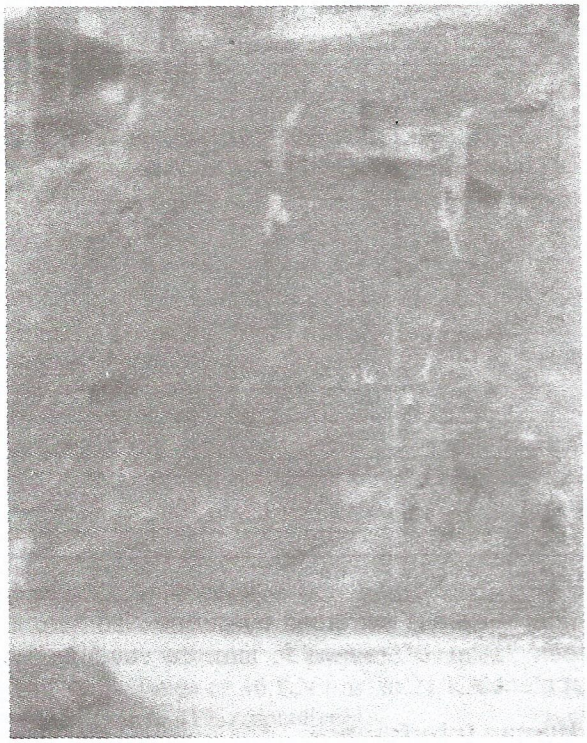

Fig 4. Bungkawn Slide Area

Fig 5. College Veng Slide Area

Veng area landslide occurred on 20th July 2000 suddenly when it was raining. The existing natural slope of the slide area varies from 100 to 120.The slide area is sparsely vegetated with shrubs and grass. Lithology of the area comprises of highly degraded siltstone and sandstone. The soil is mainly clayey mixed with sands and gravel. In Luangmual area landslide occurred in the month of August 2000. The angle of slope of the slide area is about 100. There was thin vegetation cover in the area. The soil type of the slide area is mainly clayey mixed with graded sand and gravel. In Zuangtui area landslide occurred on 27thMay,2000 suddenly when it was raining. Slope of the sliding zone varies between 100 to 120. Lithology of the area is mainly degraded sandstone and siltstone. The soil of the slide area is clayey mixed with sand and gravel. There is not much vegetation cover in the slide area except grass and shrub.(Colney D. Z, 2001).The main cause slide in this area may be due to infiltration of rainwater in soil that increased the pore pressure and weight of the soil and lack of proper drainage system. (Plate-4, 5)

Results of Laboratory test

Results of grain size analysis, liquid limit, plastic limit, specific gravity, unconfined compressive strength(qu) tests are shown in tables 3 and 4.

Remoulded soil samples were prepared for unconfined compression tests. The densities and moisture contents of prepared samples were in the range of 16 KN / m3 to 21 KN / m3 and 23% to 31% respectively.

It is observed that soils from different areas of Aizwal are of diverse nature. Soils have low values of shear strength.

CONCLUSION

1. Although Geological and Geomorphic evolution of the hills of Guwahati city and Aizwal Town areas are different and there are vast differences in rock structure, topography & drainage etc, landslides have been observed to be occurring during and after a spell of continuous rainfall. The exposed rock surface in highly weathered condition and soil

TABLE-3 : *Physical Properties of Soil*

Site	Grain Size iin %			Attenburg limit in %			Soil Classification
	Gravel	Sand	Silt & Clay	Liquid limit	Plastic limit	Plasticity index	
Bungkawn	12	41.7	46. 3	40. 8	22..3	18. 5	Gravel sand with Plastic fines of intermediate compressibility
College Veng	12. 2	57. 8	30	36. 5	24	12. 5	
Luangmual	18	33. 1	48. 9	44. 4	25. 2	21. 4	
Zuangtui	10	35. 7	54. 3	47. 3	29. 4	17. 9	

TABLE 4

Site	Specific gravity	Unconfined Compressive Strength N/cm²	Undrained Shear Strength N/cm²
Bungkawn	2.64	1.92 -4.23	0.96 -2.11
College Veng	2.65	2.50 -4.24	1.25 -2.12
Luangmual	2.61	2.30 -6.14	1.15 - 307
Zuangtui	2.66	4.77 -9.39	2.40 -4.70

surface without any vegetation cover and unplanned hill cutting for construction of roads buildings areas affected severely by rainwater.

2. Geotechnically, soils of both Guwahati city and Aizwal Town area comprise of sandy clay. The percentage of gravel in Aizwal soil is more than that of Guwahati city area.

3. The mechanism of slides in both the area is that due to heavy rainfall there are increase in moisture content and pore pressure and decrease in shear strength of soils & rock. Erosion of soils from the barren and exposed slopes reduces stability considerably.

4. Providing surface drainage and using biodegradable geotaxtiles with vegetation cover on designed slopes and by constructing earth retaining structures, stability of slopes of the study areas can be improved.

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