Investigation of Geotechnical Properties of the Soil Susceptible to Landslide

Lekshmi J Satheesh[#1], Deepthy B.L[*2]

[#] M Tech student, Department of Civil Engineering, Marian Engineering College, Thiruvananthapuram, Kerala, India

*Assistant Professor, Department of Civil Engineering, Marian Engineering College, Thiruvananthapuram, Kerala, India

Abstract — *Landslides are simply defined as the mass movement of rock, debris or earth down a slope and include a broad range of motions like falling, sliding and flowing under the influence of gravity of dislodged earth material. Due to scarcity of plane area, people do not have other option than to establish their house in hill regions. In this work a site prone to landslide was identified. The area considered is Bonacaud in Vithura village, Thiruvananthapuram. Undisturbed soil samples were collected and were used for determination of shear parameters by conducting unconsolidated undrained tri-axial test under normal loading. Disturbed soil sample were collected for determination of geotechnical properties.*

Keywords — *landslide, geotechnical properties, tri-axial test and undisturbed sample.*

I. INTRODUCTION

Landslides are simply defined as the mass movement of rock, debris or earth down a slope and include a broad range of motions like falling, sliding and flowing under the influence of gravity of dislodged earth material. They cause some of the most spectacular damage that attributes to ground movements. They often take place in conjunction with earthquakes, floods and volcanoes and include mudflows, earth slumps, rock falls and slope failures. The triggering mechanism of the landslides can include rainstorms, landscape irrigation, inadequate drainage, erosion, earth quakes and other natural phenomena and human activities. Due to scarcity of plane area and increase in population, people do not have other option than to establish their house in hill regions. For construction of all facilities in hilly region they are not considering factors like deforestation, erosion, hill face disturbance drainage pattern, weather and seismic activities that are crucial for design of houses, road and other life line facilities. In the hilly terrain of India including the Himalayas, landslides have been a major and widely spread natural disaster that often strike on life and property and occupy a position of major concern.

Buildings, roads and other infrastructural facilities like pipelines that are located within the boundaries or in the path of the landslides are damaged or destroyed completely during the hazard. Even a small slope movement at the early stage of landslide movements can cause substantial damage to structures and other critical facilities like dams, pipelines and roads, resulting in economic damage and loss of life. One of the worst tragedies took place at Malpa, Uttarkhand (UP) on 11th and 17th August 1998 when nearly 380 people were killed when massive landslides washed away the entire village [6]. This included 60 pilgrims going to Lake Mansarovar in Tibet. Consequently various land reform measures have been initiated as mitigation measures.

Based on the surveys conducted on the landslides of India it was observed that a rough estimate of loss in economy to India is of the order of Rs 250- 300 crore/annum. The man – made causes include excavation, loading of slope crest, deforestation, irrigation, mining, water impounds and leakage etc. Although landslides cannot be completely stopped from occurring, several mitigation like drainage correction, proper and use measures, reforestation, creation of awareness among the local population can be adopted to reduce the frequency and the impacts of landslide.

Landslides are classified in a number of ways of which the classification of prime concern is: (a) rain – induced landslides and (b) earthquake – triggered landslides. In rain–induced landslide the mechanism of failure is that the water infiltration causes a reduction in the pore suction in the unsaturated soil and these results in a decrease in the effective stress which is accompanied by a decrease in the soil strength to a point where the equilibrium can no longer hold. In most of the cases of landslides, they take place along with the earthquake shock or after some hours or days after the shock. The large number of landslides that occurred soon after the Uttarkashi earthquake of 1991 is the example of earthquake – triggered landslides in India.

This thesis work involves the investigation of the geotechnical properties of the soil collected from a landslide prone area in Thiruvananthapuram, Kerala. A landslide prone area is identified from the landslide hazard zonation map of Thiruvananthapuram district of Kerala obtained from Center for Earth Science Studies (CESS). The collected soils were taken to the geotechnical laboratory and the properties are analysed by conducting corresponding experiments as per Indian

Standards. Due to the increase of water content the stress increase and the strength decreases leading to landslide causing extensive damages [1]. The susceptibility of slope to failure is dependent on many factors like slope, geotechnical property, cohesion and presence of discontinuity

II. OBJECTIVE

The objectives of the work are summarised below:

- To investigate the properties of the soil collected from the field
- To propose remedial measures that is to be taken to reduce the landslide fatalities

III. METHODOLOGY

This work deals with the investigation of geotechnical properties of soil that are prone to landslide. For this an area identified to be a landslide prone area was identified. In this work the area considered is Bonacaud in Vithura, Thiruvananthapuram which is the base station of the famous peak, Agasthyarkudam, in Agasthya hills. From the hazard zonation map of the area obtained from Centre for Earth Science Studies (CESS) the area of the high hazard, low hazard and medium hazard zones were calculated in square kilometer. About 8 locations for collecting soil samples were selected based on the random systematic sampling carried out in ArcGIS software after proportioning the 8 samples among the three zones. Undisturbed soil samples were collected from the sampling locations and were placed in polythene bags for transporting it to the laboratory. These soil samples were used for determination of shear parameters, cohesion and angle of internal friction, under normal loading by conducting undrained unconsolidated tri-axial test as per IS 2720 (Part 11). Disturbed soil sample were collected for determination of index properties. The Atterberg limits, natural moisture content, maximum dry density, optimum moisture content, percentage composition, permeability, specific gravity and organic content of the soil samples were determined as per IS codes.

IV. RESULT AND DISCUSSION

Table I shows the slope and the hazard zone of the location from where the sample was collected obtained from field. Table II, III, IV and V shows the geotechnical properties of the soil determined in the laboratory.

TABLE I
SLOPE AND HAZARD ZONE OF SAMPLES COLLECTED

Sample	Hazard zone	Ground slope	Natural moisture content (%)
1	High	4.07 H:1V	17.50
2	High	5.14 H: 1V	21.95
3	High	4.51 H: 1V	34.04
4	High	4.22 H: 1V	21.62
5	Medium	2.24 H: 1V	9.43
6	Medium	2.89 H: 1V	10.71
7	Low	3.69 H: 1V	12.59
8	Low	3.42 H: 1V	12.60

TABLE II
PARTICLE SIZE DISTRIBUTION OF SAMPLES

Sample	Particle size distribution			
	% gravel	% sand	% silt	% clay
1	5	58	34	3
2	9	37	31	23
3	10	48	24	18
4	8	46	39	7
5	6	54	24	16
6	6	48	22	24
7	6	43	20	31
8	7	40	25	28

TABLE III
ATTERBERG LIMIT OF SAMPLES

Sample	Liquid limit (%)	Plastic limit (%)	Plasticity index (%)	IS classification
1	30	23.6	6.36	MI
2	41	23.5	18.5	MI
3	43	33.3	9.67	MI
4	43	33.9	19	MI
5	38	25	13	MI
6	48	34.78	13.22	MI
7	44	25	19	CI
8	42	22.3	19.7	CI

TABLE IV
PROPERTIES OF SAMPLE

Sample	OMC (%)	Dry density (g/cc)	Specific gravity	Organic content (%)
1	14.6	1.81	2.47	4.72
2	20.4	1.55	2.36	8.49
3	20.8	1.58	2.36	8.26
4	19.2	1.625	2.50	3.01
5	20.4	1.63	2.41	5.49
6	22.4	1.6	2.47	2.47
7	21.8	1.58	2.44	5.27
8	22.4	1.54	2.39	8.20

TABLE V
SHEAR PARAMETER, PERMEABILITY OF SAMPLE

Sample	Cohesion (kg/cm^2)	Friction angle (□)	Permeability(cm/s)
1	10000	35	22.2×10^{-5}
2	32500	19	1.81×10^{-5}
3	31000	18	1.95×10^{-5}
4	15500	31	1.69×10^{-5}
5	22000	25	1.45×10^{-5}

6	37000	17	1.73×10^{-5}
7	55000	10	7.41×10^{-7}
8	50000	12	6.92×10^{-7}

The particle size distribution of samples is given in the Fig 1 and Fig 2. The compaction curves are shown in Fig 3 and Fig 4.

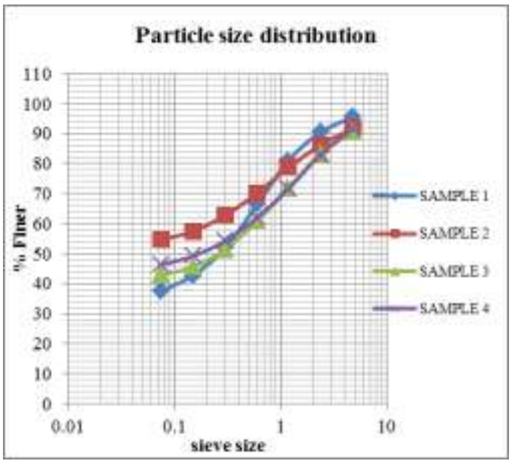

Fig. 1 Particle size distribution of samples 1-4.

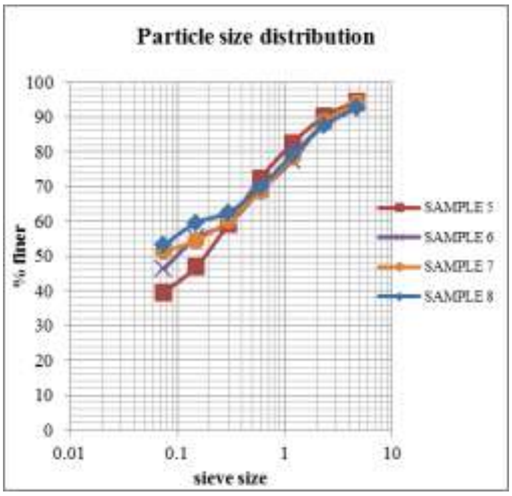

Fig. 2 The particle size distribution of samples 5-8

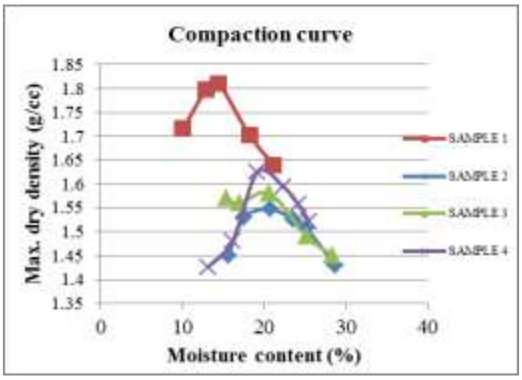

Fig. 3 Compaction curve of samples 1-4

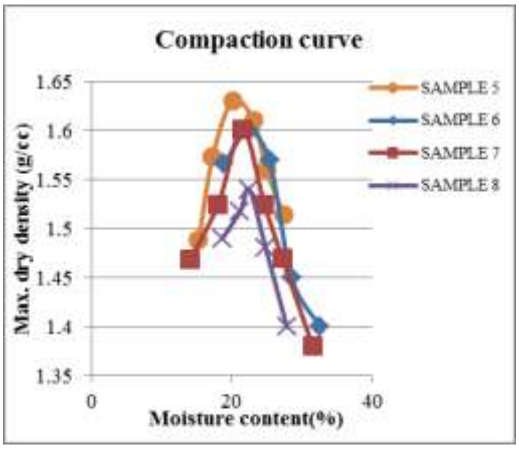

Fig. 4 Compaction curve of sample 5-8

The grain size distribution was determined by conducting sieve analysis and hydrometer analysis. Most of the soil samples collected are of silty sand with a clay content ranging from 3 -31% and silt content varying from 20 – 39% and sand content varying from 37- 58%. The information obtained from the particle size distribution curve can be used for predicting the soil water movement. The soil samples with less clay content are observed to have more permeability to water and therefore have more chances of landslide. The soil samples obtained from low hazard zone were observed to have more clay content and therefore less permeability to water movement.

The Atterberg limits were determined and are widely used for predicting the consistency of cohesive soil. The results obtained provide information about the soil strength behaviour, stability, type and classification of organic or inorganic clay. Most of the samples obtained from high hazard and medium hazard zones were of MI classification and the samples from low hazard zones were of CI classification. Small range between the plastic limit and liquid limit value shows the ability of the samples to change from semi solid to liquid state resulting in significant decrease of cohesion and angle of internal friction and bearing capacity of soil after rain as explained in [1].

Specific gravity of the samples varied from 2.36- 2.5. The low value of specific gravity (< 2.60 which is the specific gravity of soil particles) was due to the presence of organic content in the soil samples. The organic content varied from 2.47-8.49. The shear strength was observed by conducting undrained tri-axial test. The samples obtained from high hazard zones had lower shear strength compared to the low hazard zone samples. As the moisture content increases the shear strength value decreases showing that regular rainfall in less stable areas can easily create landslides.

V. Conclusions

The geotechnical properties of the soil samples were analyzed. The properties of the soil samples collected from high and medium hazard zones showed more susceptibility to landslide or slope failure compared to that of low hazard zone sample. Remedial measure for earth slope stabilization include removal of soil from the head of a slide, reducing the height of the slope loading at the toe of the slope, benching, fattening or reducing the slope angle etc. The mitigation method does not help in avoiding the landslide but helps to reduce the loss of life and damage to the property that can be caused due to the landslides.

- Excavation activities should be avoided in regions that are highly susceptible to landslide or slope instability since that might trigger larger landslide especially in soft clays.
- In regions that are less susceptible to land slide the strengthening of slopes can be carried out with the help of plastic mesh reinforcement, proper drainage networks, check dams, constructing retaining walls, gabion walls etc.
- Providing vegetation on the slopes and other biotechnical slope protection methods like using geonets, planting vetiver etc. also helps in reducing the landslides.
- Reforestation with deep rooted trees and planting trees in rows would help in reducing the landslides by enhancing stability..

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