Geo-Technical and Geological Study, Management Plan of Landslide

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Abstract - Landslide is a natural disaster that occurs when rock, earth, or debris flows to downward slope due to gravity after being detached from slope underneath. It is essential to know the geotechnical properties to analyse the causes of landslide. For the present study geotechnical investigation has been carried out on the slopes of Lonavala and Tamini Hill, Maharashtra . Results obtain from laboratory test and field investigation revealed that the underlying causes of the landslide could be (a) the geological formation of those hills (b) permeability through the different layers of soil (c) shear strength of the soil (d) cutting of hills slope for reconstruction and widening of the road. Landslide triggered due to heavy precipitation during the monsoon season. In north eastern area of India is mainly hilly that's why recent development is going on here. Due to this reasons road construction is going on here. As the whole range is composed of siltstone and mudstone mainly loosely deposited soil they are cutting the hills vertically which unstable the slope. After the thorough investigation we have seen that mainly shallow landslide happen on those two hills.

Keywords - Landslide, debris flow, geotechnical property, shear strength

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1. INTRODUCTION

In India about 10% of total population was affected by natural disaster in 2019. Among this, landslides also play an important role on affecting the people of India. Geological Survey of India says that 15% of the land in our country is hazardous to landslide. North-east portion of the country is vulnerable to the landslide hazard. It is a very common phenomenon in the hilly region of Maharashtra especially in North and Dhalai districts. Almost every monsoon due to heavy rainfall total hilly region is mostly affected by the landslide. Due to its geological instability, non-tectonic activity (Sen et al. 2015) and extreme rainfall infiltration during monsoon season (Wei et al. 2019). As the North-east portion is the developing region there is new road and railways construction along the unstable slope of the hilly region. This road construction and various infrastructural works repeatedly increase the number of landslides on those areas (Ghosh et al. 2012). In the time of rigorous field survey most of the landslide occurred alongside of the NH-44 which connecting Maharashtra state . Due to landslide mainly in monsoon time when rainfall is moderate to heavy (where moderate is defined as 2.6-7.6 mm per hour ≥ 7.6 mm for heavy) blocking and damaging of NH-44 is a common ocurrence. As landslide is a complex phenomenon worldwide it is very difficult to say the exact causes of it. Most of the publications are based on landslide hazard zonation mapping deals with landslide susceptibility mapping (Mandal et al. 2018). But field investigations also helpful to know the type and analysis of landslide as we have seen that there is very heterogeneity in geotechnical properties of soil in a very small area. It also helps us to find the further remedial of landslide. Based on field investigation and laboratory similar case studies have been carried out (Dutta et al.1966, Paul et al.1973, Basu et al. 2000, De et al. 2008). Our present study is the outcome of field investigation and the laboratory testing of soil collected from the landslide areas which help us to analyses the causes of landslide..

2. MATERIALS AND METHODS

The experimental studies and the analysis method is discussed. Also in this chapter how the investigation is done on various site of Lonawala Hill is discussed. Experimental work such as physical and engineering properties are carried out in soil. Physical and engineering properties of soil such as specific gravity, consistency limits, compaction characteristics, and permeability and shear strength characteristics are determined in laboratory. A detailed description of the entire test performed is illustrated.

Steel Tube:

Steel tube is made for collecting undisturbed sample below 1m depth from the ground surface. Those tubes are 30 cm in length and 15cm in diameter.

SOIL SAMPLE

The soil samples are collected from five different sides of Lonawala hills and Tamini hills. Using cylindrical sampler undisturbed soil is taken and also collected some disturbed sample using plastic bag.

Specific Gravity

The specific gravity test is conducted as per IS: 2720 (Part 3/Sec-1) 1980. The specific gravity of soils shall be calculated from the following formula:-

G = [{W2-W1}/ {(W2-W1)-(W3-W4)}]

W1=Weight of the density bottle (g)

W2=Weight of the density bottle + soil (g)

W3= Weight of density bottle + soil + water (g)

W4= Weight of the density bottle full with water (g)

Grain Size Analysis

Grain size analysis has been done to find out the classifications and the group of the soil on the basis of ASTM D6913.The particle size distribution can be explained as a plot of percentage finer to the particle size plot. This is determined to know the exact type of the soil. This is followed the following three steps. i. Dry sieve analysis; ii. Wet sieve analysis; iii. Hydrometer analysis. However for sandy soil dry sieve analysis is enough to have the properties. For dry sieve analysis the dry soil has been taken and sieving is carried out by the standard IS sieves. And the plot is generated. Then the wet sieving is done with the soil solution. And the retained part from 0.075 mm sieve is taken for the hydrometer analysis. In case of hydrometer analysis the soil particles are allowed to settle with time and using stokes law the particle size distribution is generated to have the full profile of grain size distribution of soil.

Atterberg Limits

The Atterberg limits are a basic measure of the critical water contents of a fine grained soil, such as its liquid limit, plastic limit and shrinkage limit. Depending on the water content of the soil, it may appear in four states: solid, semi-solid, plastic and liquid.

Liquid limit (LL): The boundary between the liquid and plastic states;

Plastic limit (PL): The boundary between the plastic and semi-solid states;

Shrinkage limit (SL): The boundary between the semi-solid and solid states;

The amount of water which must be added to change a soil from its plastic limit to its liquid limit is an indication of plasticity of the soil. It is measured by the “plasticity index” which is equal to the liquid limit minus the plastic limit, (PI = LL - PL).

Direct Shear Test

This test is also conducted to find out the ‘c’ and ‘ϕ’ of the soil having more angle of skin friction (i.e. silt, sand etc.). In this test the sample of soil is first subjected to some amount of normal stress. Then the shearing stress is given until the soil sample fails or deforms too much. This one set of experiments will give a point in the plot of normal stress (i.e. ‘σ’) to the failure shearing stress (i.e. ‘τ’).

$\tau = \sigma \tan\phi + c$

Compaction Test

The standard proctor test was invented by R R Proctor (1933) for the construction of earth fill dams in the state of California. Compaction test was done as per ASTM D698-07. The test consists in compacting soil at a range of water contents in the mould, in three equal layers, each layer being given 25 blows of the 2.6 kg rammer dropped from a height of 310 mm. The dry density obtain in each test was determined by knowing the mass of the compacted soil and its water content. About 2.1 kg of oven dried soil passing through 4.75 mm sieve originally depends upon the probable optimum water content for the soil. The empty mould attached with the base plate is weighted without collar. The collar is then to the mould. The soil was placed in the mould and compacted by giving 25 blows of the rammer homogeneously distributed over the surface, such that the compacted height of the soil was about 1/3 the height of the mould. The second and the third layers were similarly compacted, each layer being given 25 blows. The last layer should not project extra than 6 mm into the collar. The collar was separated and the top layer was trimmed off to make it level with the top of mould. The maximum dry density and OMC for the compacted soils were calculated from the following relations:

p=M/V g/cc

pd=p/(1+W) g/cc

Where, p= Bulk density of soil (g/cc)

pd=Dry density of soil (g/cc)

M=mass of wet soil compacted in the mould (g)

W=water content (%)

V= volume of the mould (1000 ml)

The test is repeated with increasing water contents, and the corresponding dry density obtained is therefore determined. A compaction curve is plotted between the water content as abscissa and the corresponding dry densities as ordinates. The dry density goes on increasing till the maximum density is reached. This density is called maximum dry density (MDD) and the corresponding moisture content is called optimum moisture content (OMC).

The constant head permeability test involves flow of water through a column of cylindrical soil sample under the constant pressure difference. The test is carried out in the permeability cell, or permeameter, which can vary in size depending on the grain size of the tested materials. The soil sample has a cylindrical form with its diameter being large enough in order to be representative of the tested soil. As a rule of thumb, the ratio of the cell diameter to the largest grain size diameter should be higher than 12 (Head 1982). The testing apparatus is equipped with an adjustable constant head reservoir and an outlet reservoir which allows maintaining a constant head during the test. Water used for testing is de-aired water at constant temperature. The permeability cell is also equipped with a loading piston that can be used to apply constant axial stress to the sample during the test. Before starting the flow measurements, however, the soil sample is saturated. During the test, the amount of water flowing through the soil column is measured for given time intervals. Knowing the height of the soil sample L, the sample cross section A, and the constant pressure difference ΔT, one can calculate the permeability of the sample as

$$K = QL / (A. \Delta h.\Delta t)$$

Falling-Head Test,

$$k = 2.303 \frac{aL}{At} \log_{10} \frac{h_1}{h_2}$$

h_1, h_2= Height of the water at time interval t.

t = time

A= c/s area of specimen.

L = length of specimen.

a= c/s area of stand pipe.

3. Results

Soil samples collected from various spot in Lonavala and Tamini hills are tested in NITA laboratory.

EXPERIMENTAL TEST RESULTS

We have tested the soil sample collected from various spots. Experimental results are mainly the testing of geotechnical properties of soil samples.

Physical properties of soil collected from Lonawala hills

Table 1: Physical properties of soil collected from Lonawala hills

Engineering Property	Location 1	Location 2	Location 3	Location 4
DIRECT SHEAR TEST Cohesion(c) Angle of internal friction (ø)	c-23.58 kN/m^2 ø - 30.52^0	c-20.62 kN/m^2 ø - 28.23^0	c-11.52 kN/m^2 ø - 25.69^0	c-10.58 kN/m^2 ø - 31.53^0
LIGHT COMPACTION TEST Maximum dry density (gm/cc)	1.54 gm/cc	1.68 gm/cc	1.59 gm/cc	1.62 gm/cc
Optimum moisture content (%)	18%	20.61%	19.23%	23.25%

4. DISCUSSION

Key parts of Northern India, namely Jammu and Kashmir, Himachal Pradesh, Uttarakhand and North East India, Sikkim, Arunachal Pradesh, Mizoram , Nagaland, Manipur, Meghalaya, Assam and Maharashtra, because of the fragile geology, tectonic activity , high relief, critical pastes, heavy precipitation and anthropogenic activity at various sites of these nations, are vulnerable to landslides. Maharashtra state exhibits a broad range of sedimentary rock characteristics of marine mixed fluvial type origin ranging from uppermost Oligocene age (38 million years from now) to recent time. According to GSI, a broad range of environmental conditions controlled by local tectonic movement were laid down in the Surma basin during tertiary period (which lasted for 65 million years). The formation mainly leads to poorly sorted layers of silt or clay resulting in unconsolidated sandy material. We had seen coarse grained sand and mud balls at the time of site inspection. We get weathered shale and fragile mudstone in some parts of the slope which is very prone to landslide. The entire landslide area is composed mainly of huge laminated siltstone, coarse sandstone, and mudstone thicknesses.

The Lonawala hills hill is composed of Surma group which is characterized by alteration of the structure of sand and clay rock and the deposition of fine sand which belongs to the Tipum group of the eastern and western limbs of the Lonawala hills hills. The Lonawala hills hill's latitude is 23^0 53N - $23^0$53N and the longitude is $92^0$42'E-92^0 48'E formed after . Typically, the bockabil is made of clay-gray laminated shale's with minor sandstone.The fluctuation of the micro tidal Aesopian costal climate plays a dominant role in sand to sandy clay formation. In the Bhuban and bokabil the presence of major fault can be created. This is found that where sandstone is available there landslide type of debris flow occurs and where sand and clay type of soil is present earth flow type of landslide. This is also found that other factors for the landslide are unscientific road cutting and unregulated movement of heavily loaded vehicle. Although the effect of landslide in the study is not so damaging, it should be properly monitored. Geologically, Maharashtra is a member of the geological province of Assam Burma. The deposits in the Tertiary touch a great thickness, here potentially thicker than any other region of India. In Maharashtra, the Bar ails and the Dissents are not visible. In the State of Maharashtra and its adjacent areas, the Surma Series has a wide range. It is made of sandstones, sandy shells, mudstones and thin conglomerates that are usually carbonate-free. Petroleum deposit indications are found in many places in the Surma Series. The Surma Sequence is marine but outstandingly unfussy. ENE — WS: W serves as the reservoir on the north and south flowing fluvial rivers in between. All the longitudinal hills and hill-rallies generally differ in their pattern of NNW to NNE. Their mean is north-south, and they form a convex arcade range to the west. Alluvium deposits are circumscribed by the Haora, Manu, the Buri Group, the Khowai and the Dholai Channels. Although the formation of alluvium is being circumscribed by BokaBill in the case of the Deo river in the between Sakhan and Jampui Hills the series of rock is completely reintroduced by sedimentary rocks. Miocene to the Latest usually included sandstone, shale, day and age.those property can trigger the causes of landslide on those areas.

GEO-TECHNICAL AND GEOLOGICAL CHARACTEISTICS AFFECTING LANDSLIDE ON THIS AREA

Effect of soil characteristics

This area's rock is of tertiary Bhuban type. The laboratory test was carried out on the soil and from this it is observed that the area consists mainly of unconsolidated sandy materials with intercalation of moderate to poorly sorted silt or clay layers at times. The entire slope consists of fragile shale and mudstone, which are highly weathered. Coarse grained sand with balls of mud has also been found in some areas of the hill. From the experiment it is found that the entire landslide scar consists mainly of enormous thickness of laminated siltstone, shale with narrow sandstone bands; sometimes lenticular structure of medium to coarse mudstone sandstone. Basically the whole area consists of predominantly silty sandy soil which is why the area is prone to landslide.

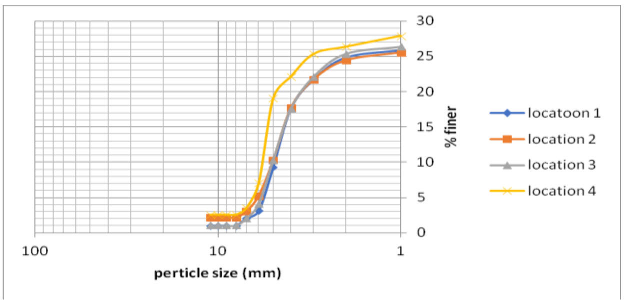

Figure 1: particle size distribution curve of sample collceted from Lonawala hills

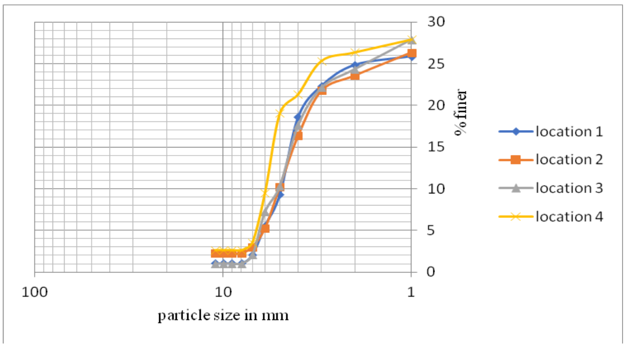

Figure 2: particle size distribution curve of sample collceted from Tamini hills.

Effect of Permeability

It is discovered from the experiment that permeability also plays a significant role in shaping landslide happenings. Permeability test of falling head has been performed for different layers of soil. The permeability of the upper layer soil is found to be less than that of the lower layer soil. In Lonawala hills it is observed that at the first day the permeability ranges from 1-1.510-4m / day and at the end of one week it reduces to 0.4-0.610-4m / day. Sample obtained in the first day from various points of Tamini hills. hill permeability ranging from 1.1-1.410-4m / day to 0.5-0.7510-4m / day. That means that day by day permeability is diminishing. Because of this soil shear strength decreases as the density of the pore water increases. For this the water is logged in the upper layer soil after rainfall naturally developed in this region pore water pressure. Due to the increase in the pore water pressure in this region, the upper layer of the soil get sheared off. Because of this there will be a risk of shear failure beginning after a few more days of rainfall.

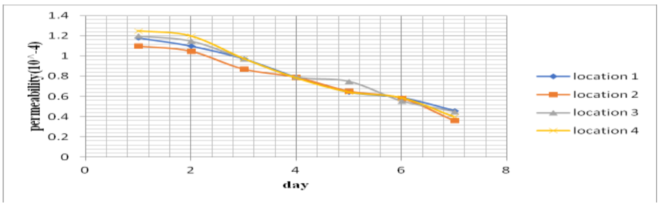

Figure 3: permeability vs day curve of sample collceted from Lonawala hills

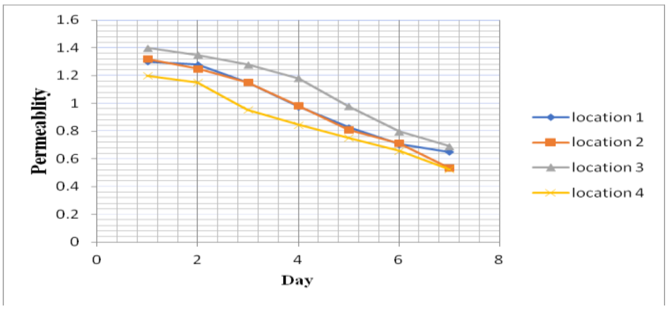

Figure 4: permeability vs day curve of sample collceted from Tamini hills.

Effect of Liquid Limit and Plastic Limit

It is found that in Lonawala hills hill it ranges between 25.25-19.12 percent and 21-22 percent respectively after the liquid limit and plastic limit test. For Tamini hills. hill LL ranges from 25-30 % to 21-25 % plastic limit. Since the soil is primarily silty type and the portion of clay is very small. Because of this limit of liquid and plastic reached within very less water content. And in the monsoon season soil quickly exceeded its liquid limit and sheared quickly from the slope.

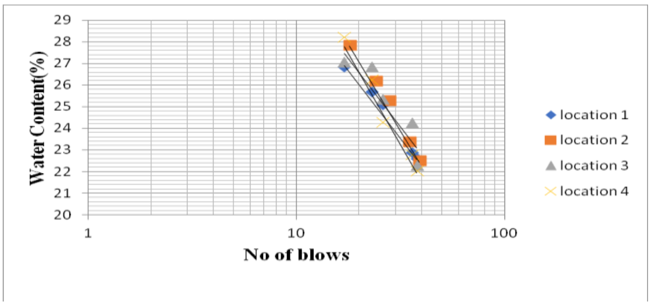

Figure 5: LL curve of sample collceted from Lonawala hills

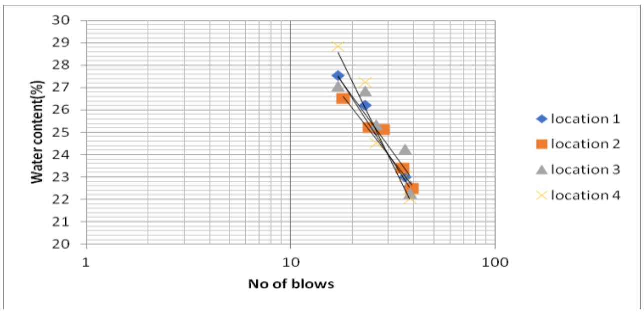

Figure 6: LL curve of sample collceted from Tamini hills.

Effect of Optimum Moisture Content and Dry density

On this road you can see heavy traffic as the NH44 passes by adjacent to this to hilly region. Dry density and optimum moisture content of samples collected from Lonawala hills hill ranges between 1.5-1.7 gm / cc and 18-24%, respectively. For Tamini hills. hill, DD and OMC range between 1.3-1.5 gm / cc and 14-16 % respectively is observed. When heavy rainfall occurs water content often increases in the soil layer and this heavy traffic plays the role of vibrating agent due to the maximum moisture content that the soil quickly reaches. Because of this suddenly increased soil density which helps the soil to shear off from the slope easily.

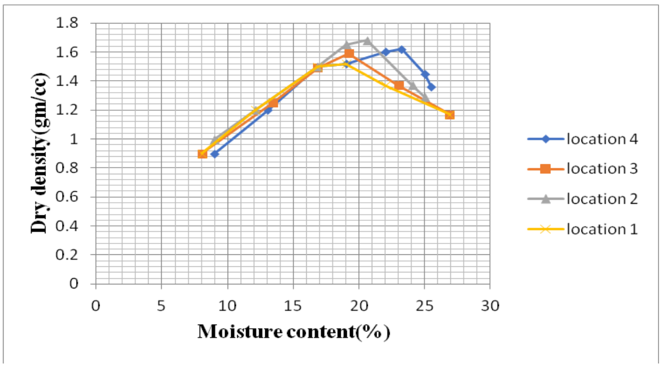

Figure 7: Dry density vs moisture content curve at Lonawala hills

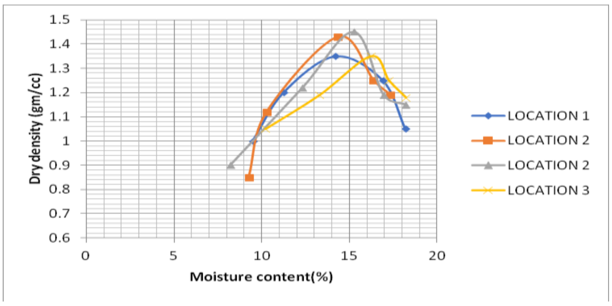

Figure 8: Dry density vs moisture content curve at Tamini hills.

Effect of Cohesion and Shear strength on Landslide

Results obtained from the direct shear strength test on the Lonawala hills hill sample show that the cohesion value is 19-24 kN / m^2 and 250-310 ranges. There's very little value of cohesion in that region. The samples collected in the form of Tamini hills. hill cohesion ranges from 12-30 kN / m^2 to a range of 250-350As the cohesion and angle of internal friction is the main influencing factor for soil resistance to remain in its own position, then this lower angle of friction and cohesion triggers the landslide in this area.

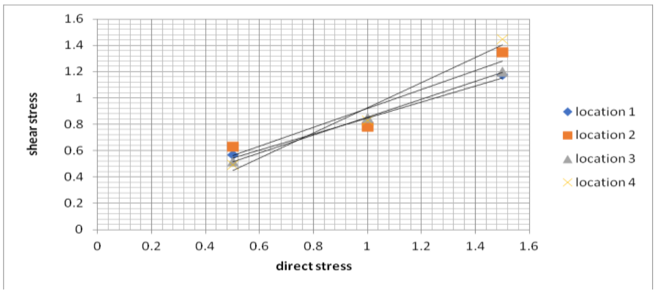

Figure 9: shear stress vs direct stress curve at Lonawala hills

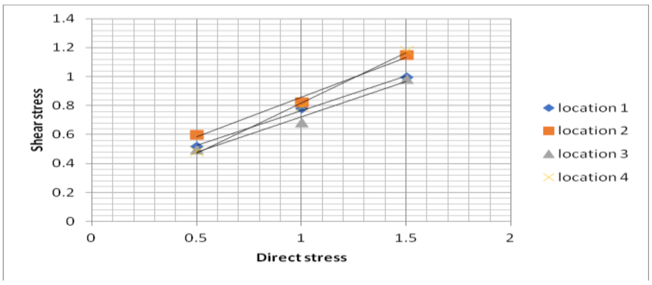

Figure 10: Shear stress vs direct stress curve at Tamini hills.

SLOPE STABILITY ANALSYS

The Taylors stability analysis was used to analyse the slope stability of different locations. The angles to the slope are gathered from the field investigation. After evaluating those it is observed that the factor of protection of the slopes at position 3 & 4 is less than 1 which means that the slope is unstable and this is why the two slopes are vulnerable to landslide.

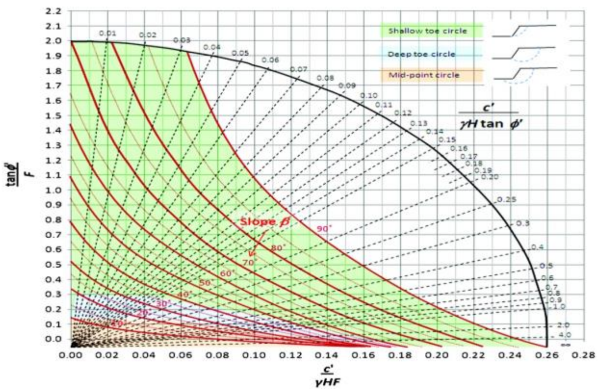

Figure 11: Taylor's stability chart

MANAGEMENT PLAN HELPFUL FOR LANDSLIDE MITIGATION IN LONAWALA HILLS AND TAMINI HILLS. HILLS

By intensively examination of some management strategies, such as Sub-surface drainage building, building of and wall retention extension, cutting / filling Pitch focused on quantitative assessments Suggested. Though some control of the slope plans were put forward to avoid further landslide accidents, hillside cutting slopes will stop. Before constructing new highways, or extending existing roads, Local geological conditions such as dip numbers, dip speed, lithological composition, and soil characteristics should be properly studied and engineering techniques should be applied. The results obtained through this study can be used as basic data to assist in the planning of slope management, road construction and land use. For the prevention, mitigation and better management of this hazard, partnership management work on landslide hazard reduction between regions, governments, universities, research centers, non-governmental organizations and local people in landslide-prone areas is needed.

CONCLUSIONS

Landslide is a complex phenomenon very deep knowledge is required to analyse the causes of landslide. Landslide mainly happened when there is a loosely deposited unconsolidated loosely material. Rainfall is also a triggering factor for occurrence of this hazard. As it is a complex phenomenon a deep knowledge is required to take mitigation steps. It is very difficult to predict the causes of landslide only by checking the geotechnical properties. Type of soil and shear strength has a great impact on the occurrence of landslide. The result obtained from the present study is very helpful for slope management thus its helps to do the further infrastructural works on those landslide prone areas. This whole work can be conclude with the points given below

1. Geological and geotechnical property is found to have a great impact on the study of slope stability which is the main factor of landslide. If we know the type of soil and rock we can predict landslide chances on the area in question.

2. Based on the analysis of slope stability and other factors, we can arrange the appropriate management plan which can significantly reduce the landslide in this area.

3. After considering all the management plan, it is observed that underground drainage, wall retention and slope cutting are three main management plans that we can arrange, because the area consists mainly of unconsolidated silty material

4. It is unable to analyse the effect of rainfall due to the lack of time, but it also has an important effect on the pressure of pore water as well as the stability of the slop

This section is not mandatory but may be added if there are patents resulting from the work reported in this manuscript.

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