LANDSLIDE ZONATION MAPPING USING REMOTE SENSING AND GIS

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Abstract: Landslides are the natural hazards which are caused due to various reasons like shaking of the ground due to earthquake, volcanic eruption, heavy rainfall, steep slope etc. It has been occurred in the hilly area which is affected by heavy rainfall, steep slopes and weak geotechnical properties of the soil. The result of the landslide is the heavy destruction to the properties like building, roadways, railways and human life. The study has been carried out with the aim of preparation of landslide hazard zonation map of study area by using remote sensing. The present study area is Malshej ghat region. In this study various factors are studied like geotechnical properties by performing various tests like direct shear test, sieve analysis, plasticity index, etc. It includes the study of ground surface by using Arc GIS and marking the susceptible points in the verge of landslide. The nature of the soil is sandy and loses its shear strength. There is need to provide suitable measures to avoid future landslides.

Index Terms **–** Landslide, GIS, Malshej ghat, Remote sensing

1. Introduction

Landslide causes the economic and human damage to the community. The downward moment of the rock mass due to shaking of the earth surface is called as landslide. Major causes of the landslide are earthquake, volcanic eruption, testing of atomic explosives, mining work, heavy rainfall, steep slope etc. Malshej ghat is the region of high altitude with steep slopes. It results in the failure of soil due to heavy rainfall. Average height in malshej ghat area is 700 metre from mean sea level. Malshej ghat consists of the roadway which one side is in cutting of the hill and on other side deep valleys are observed. Roadway is constructed in the red soil and clayey soil. Rainfall in the malshej ghat is more as compared to the normal rainfall intensity places. The importance of the study in this area is due to frequent occurrence of landslide. Motive of the study is to identify the points susceptible to the landslide. To suggest suitable measures to avoid or minimise the risk of landslide in malshej ghat region.

1.1 Study area

The study area is located in the western ghat on the NH- 222 Nagar-Kalyan Maharashtra India. Area of survey is near about 7 sq. km. points susceptible for landslide are to be found out and their exact location is marked with the help of GPS. The area falls under SOI toposheet no. 47E/11 and 47E/15. Lowest and highest elevation in ghat region is 250 and 920 M respectively, forming steep to cliff slope along highway. Average annual temperature in the study area is 27 ^{O}C to 35 ^{O}C

Regional Geology

Malshej ghat is mountain situated in Deccan trap basalt. It consists of amygdaloidal basalt which is exposed due to weathering effect like soil erosion due to rain. Alternate bands of red boll are observed which susceptible for landslide. The study area is covered by deccan basalt of various degree of compaction and mineralogical variation. In the study area, lava flow shows various types of structure such as joints, fractures, vesicles, veins, spheroidal weathering and amygdules. The peaks of Malshej Ghat depict the step like geometry. These peaks are made of several lava flows with the thickness of individual flow varying from a few meters to several meters. The compact flows from the top of the terraces and plateaus and have steep slopes. Vesicular flows produce gentler slopes and have infilling of secondary minerals like varieties of silica, calcite and zeolite. (Sharma et. al. 2017)

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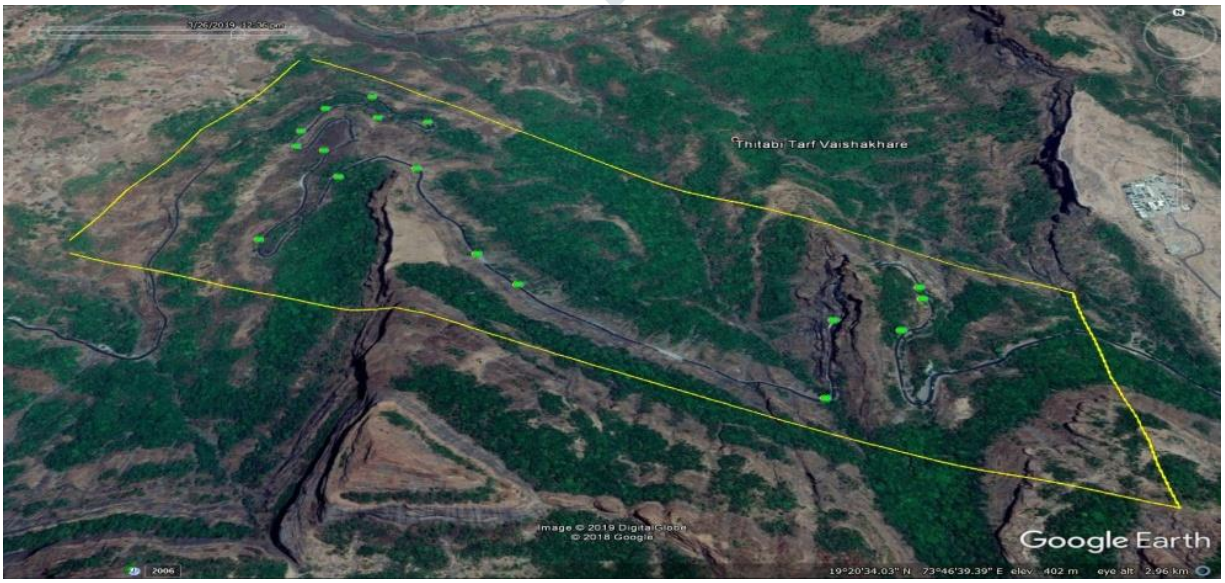

Fig1.Study area with sample points

2. Materials and method

Present study is carried out by using SOI,Toposheet, geological map, ArcGIS and DEM. Representative soil samples soil samples were collected from six vulnerable soil slopes to evaluate the shear strength. Standard Laboratory testing equipments such as Casagrades apparatus, microwave oven, shear test apparatus, mechanical sieve shaker are used for the geotechnical analysis and ASTM (ASTM 2008, 2010, 2011, 2012, 2013) standards are adopted for the soil sample collected from various points. The results give the exact soil characteristic of surrounding. Results obtained give the clear idea of soil behavior under various conditions like rainy season, steep slopes and angle of interaction.

ArcGIS is widely used to make thematic maps preparation to collect various type of information. DEM is downloaded from www.bhuvan.nrsc.gov.in. Contour map and aspect maps are prepared by using ArcGIS for the study area. By superimposing or analyzing these maps, susceptibility of landslide is marked. Zonation map is validated by the various points of occurrences which were found by the field survey noted with their exact coordinates.

2.1 Digital elevation model (DEM)

Digital elevation model (DEM) is nothing but a 3-Dimensional representation of a earth surface. The Digital Elevation Model can be prepared by using GIS software. It can be represented on Raster data as well as vector data. Various colour bands are observed according to ground elevations. Lowest and highest elevation in ghat region is 250 and 920 M respectively, forming steep to cliff slope along highway.

In this DEM higher elevations are represented by using red colour and relatively lower elevations are represented by dark green colour. DEM was used for identification of topography, slope, and elevation from mean sea level, curvature and aspect (Praveen B. Gawali et al 2017).

2.2 Contour map

Contour is the imaginary line joining equal elevations on the ground surface from sea level. The contour map for the malshej ghat region is prepared by using ArcGIS. The overall region is highly steep in slopes hence it is observed that there are large no of contours in contour map. High density of the contour gives the idea about the high steepness of the ground surface in malshej ghat region. Overhanging portions of the hilly area gives the crossing of contour line of different elevation otherwise there crossing of contours of different elevation is not observed.

2.3 Aspect map

Generally it is observed that aspect gives great influence on the vegetation (Pooja Gujarathi 2013). There are various parameters of aspect are exposure to sunlight, drying due to winds, rainfall in that area and discontinuities which may control or predicts landslides in hilly area.

2.4. Slope Map

A Slope map is representation of slope including topography of area along with topographic features. It is simplest tool for determining the average flow of hills. It can be determined in two ways percent gradient or angle of slope. Slope map is often used for describing steepness of ground surface it is measured as increase in elevation in some unit of measure over the run. Slope categories are expressed in degrees by using different colors such as

- Very gentle (0 to 3)
- Moderate (3 to 8)
- Strong (8 to 15)
- Extreme (15 to 33)
- Very steep (> 33)

2.5 Sieve analysis

Sieve analysis is a laboratory test used to determine particle size distribution. A weighed sample of material is separated through a series of sieves (or screens) with progressively smaller openings. Particle size distribution is determined by weighing the material retained on each of the sieves and dividing these weights by the total weight of the sample. A correction is made for the moisture content of the sample so that all calculations are based on dry weight.

2.6 Consistency limit

The Atterberg limits are a basic measure of the critical water contents of a fine-grained soil its liquid limit, plastic limit, and shrinkage limit.

Liquid Limit (LL) is defined as the moisture content at which soil begins to behave as a liquid material and begins to flow. The liquid limit is the moisture content at which the groove, formed by a standard tool into the sample of soil taken in the standard cup, closes for 10 mm on being given 25 blows in a standard manner. This is the limiting moisture content at which the cohesive soil passes from liquid state to plastic state.(IS: 2720 (Part 5) 1985)

Plastic Limit (PL) is defined as the moisture content at which soil begins to behave as a plastic material. The water content corresponding to an arbitrary limit between the plastic and the semisolid state of consistency of a soil; water content at which a soil will just begin to crumble when rolled into a thread approximately 3 mm in diameter. The minimum amount of water in terms of percent of oven-dry weight of soil that will make the soil plastic.(IS: 2720 (Part-5) 1985)

Shrinkage Limit (SL) is defined as the moisture content at which no further volume change occurs with further reduction in moisture content. The shrinkage limit of soil is the water content of the soil when the water is just sufficient to fill all the pores of the soil and the soil is just saturated. The volume of the soil does not decrease when the water content is reduced below the shrinkage limit. (IS-2720-PART-6-1972)

2.7 Direct shear test

A direct shear test is a laboratory test used to measure the shear strength properties of soil. For any soil Cohesion (C) and Angle of Internal Friction (Ø) are two important engineering properties, which indicate the shear strength of soil. These two parameters are required for design of slopes, calculation bearing capacity of any strata, calculation of consolidation parameters and in many other analyses.

3. Results

3.1 Digital elevation model (DEM)

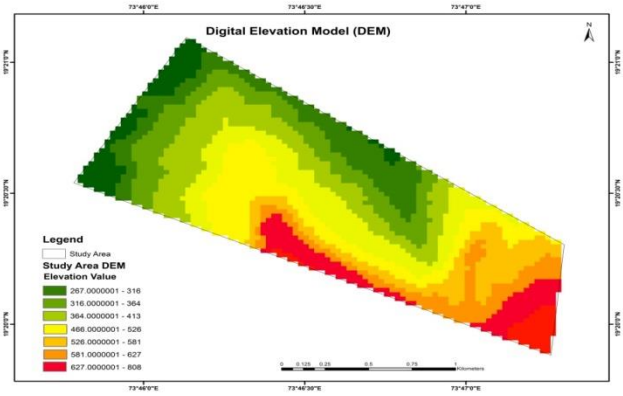

Fig2.Digital elevation model (DEM)

Lowest and highest elevation in ghat region is 250 and 920 M respectively, forming steep to cliff slope along highway.

3.2 Contour map

Contour map of the study area shows Highest and lowest contour value in malshej ghat are 760 and 300 M respectively. Contour interval for the study area is 20 M. The topographical studies are done on the basis of contour map formed by input of the contour interval in ArcGIS.

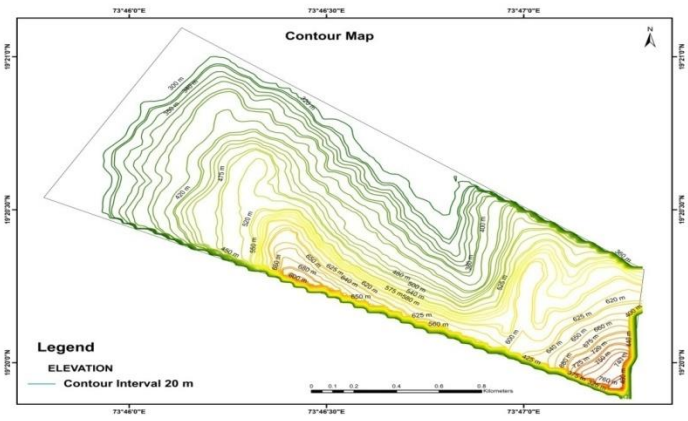

Fig3. Contour map

3.3 Aspect map

Aspect is direction of the compass which faces the slope in hilly area.

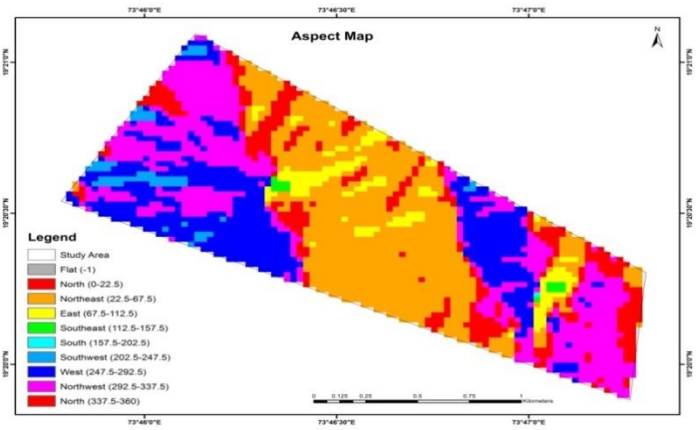

Fig4. Aspect map

It indicates that aspects values are more in NE direction followed by NW direction.

3.4 Slope Map

Aspect is direction of the compass which faces the slope in hilly area.

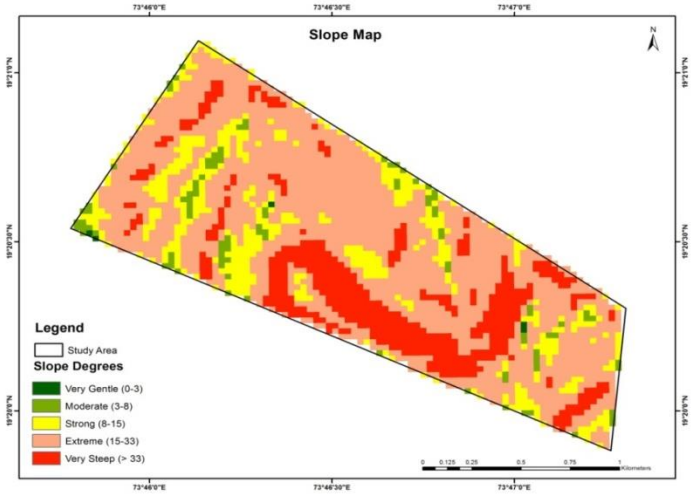

Fig5. Slope map

The fig 5 shows the slope map of the study area. The maximum area falls in the Extreme slope category i.e. 15-33 degree. The central part of the study area consisting NH 222 and surrounding falls under very steep category of the slope. The slope in this portion of the area is more than 33 degrees and is vulnerable to the landslide hazard.

3.5 Sieve analysis

Table1. Sieve analysis

Effective size	P1	P2	P3
D10	0.76	0.850	0.436
D30	2.56	1.245	0.850
D60	4.37	4.34	3.74
Cu	5.75	5.11	8.57
Cc	1.97	0.419	0.44

Obtained values shows that the Coefficient of curvature (Cc) of collected soil P1 lies between 1-3. Hence, P1 is well-graded and P2 and P3 are poorly graded (Cc of soil P2 and P3 is less than 1).Similarly, obtained value of Coefficient of uniformity (Cu) for collected soil is lies between 4-8.5. Hence, soil is gravely and sandy. Value of Cu of P1& P2 is greater than 4 and less than 6 hence, the soil gravely. Value of Cu of P3 is greater than 6 hence, the soil is sandy.

3.6 Consistency limit

Table2. Consistency limit

Soil Properties	Sample P1	Sample P2	Sample P3
Liquid Limit	49	43	50.38
Plastic Limit	34	33.29	41.69
Plasticity Index	15	9.71	8.69
Shrinkage Limit	0.48	0.58	0.58
Clay %	7.83	4.49	19.81
Silt %	31.954	38.47	47.51
Sand %	60.3	57.07	32.68
Type of Soil	Sandy Loam	Sandy Loam	Medium Loam

These tests were performed as per ASTM D4318 (2010) & ASTM D4943 (2008) observations made on the basis of Shrinkage and Plastic limit which clearly indicates that soil of all collected stations are moderately expansive in nature. Plasticity index of collected soil samples which indicates the plastic nature P1 (15) considered as Medium plastic soil, P2(9.71) Medium plastic soil, P3(8.69) Medium plastic clay loam soil. Liquidity index for all three soil samples P1, P2, P3 is 0.398, 0.144, and 1.31 respectively. Hence, it is said to have Low-Medium plasticity. According to Liquidity index and Plasticity index, it's proven that soils plasticity remains in low to medium ranges of Plasticity for all sampling stations.

3.7 Direct Shear Test

Table3. Direct shear Test.

Sr. no	Proving Ring Reading		Normal Stress	Shear strength
	Division	load (Kg)	Vertical Load (Kg/cm2)	
1	10	25.48	0.05	0.707
2	23	60	0.1	1.633
3	43	110	0.2	3.04

Value of shear strength of soil obtained by lab test is less than 20 KPa it shows soil has poor shear strength. Soil result assigned during lab test shows that partially saturated soil is susceptible to landslide.

4. Conclusion

The studies carried out using GIS and Remote sensing for Landslide zonation reveal that the study area is having maximum area under extreme to very steep slope. From the geotechnical studies it can be observed that, Coefficient of curvature (Cc) of collected soil P1 lies between 1-3. Hence, P1 is well-graded and P2 and P3 are poorly graded. Liquid limit is between 41-55% and plastic limit is between 30-40%. So type of soil is sandy soil. Which has more chances of settlement. Value of shear strength of soil obtained by lab test is less than 20 KPa it shows soil has poor shear strength. Soil result assigned during lab test shows that partially saturated soil is susceptible to landslide. The studied soil slopes are subjected to landslide in rainy season due to heavy and prolonged rainfall.

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