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GEO-5 Based Landslide Susceptibility Assessment of National Highway 66 From Mahad to Mangaon, Maharashtra, India

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Abstract—A landslide can be defined as the movement of the mass of rock, debris, or earth down the slope. Environmental impacts including heavy rainfall in study area affects several sectors of the Mahad-Mangaon region, triggering many major and minor landslides and causing severe loss. Slope stability is the process of calculation and assessment of the required stress a particular slope managed before the failure criteria. GEO5 software determines the factor of safety of the desired slopes. The aim of this project is to determine the slope stability of the region belonging to the Ghat sections of Sahyadri mountain region of Maharashtra mainly from NH-66Mahad to Mangaon (27km) using Geo5software. Factors including the soil cohesion, angle of internal friction, and unit weight of soil is determined using the lab experiments. Total station surveying is done to obtain the coordinators of the study area which is used as input for the Geo5 software.

Keywords— landslide, slope stability, GEO5, Raigad, laterite.

I. INTRODUCTION

A landslide can be defined as the movement of the mass of debris, rock or earth down to the slope. Landslides denote down-slope movement of rock and soil under the direct influence of the gravity. Slope stability is the process of calculation and assessment of the required stress a particular slope managed before the failure criteria. Slope failure can be seen in roads, dams, excavated slopes, and soft rock trails in reservoirs. Importance of slope stability to the desired work along with its benefits for the civil engineers to understand proper measures to properly evaluate slope stability with various techniques adopted for the slope stabilization. Heavy rainfall and geology of the region are the major significant reasons for slope instability in our study area. Rainfall saturates and erodes the surrounding. Henceforth it weakens the underlying soil layer and ultimately leads to slope failure. Slope failure can also be the result of the below mentioned also the vibrations due to the earthquakes.

AIMS AND OBJECTIVES

The study area comes under a hot and humid region. The rate of precipitation is high in this region i.e. 1248.4 mm in Mangaon and 1277.4mm in Mahad as per July 2019. Due to heavy rainfall this region is vulnerable to landslide. Landslide is a common problem in this region. Many trees, stone, debris, etc. fall on the road during heavy rainfall and causes long traffic up to several kilometers. Hence, Slope stability analysis is vital for the management and prevention of landslides/slips.

Geologically Konkan lowland could be a platform of marine denuation raised to make a narrow plain. The steep scarps facing the coast and a few what gentle slopes towards the east believed to flow from to extensive faulting of the ghat region. The geology of the whole district consists of dark colored volcanic lava and laterites which itdate back to Mesozoic period. These are displayed within the variety of horizontal sheets and beds and have innumerable spurs, hills, plateau, peaks and ridges within the plains and valleys, the lava flows occurred below a skinny blanket ofsoil which varies in thickness from place to position.

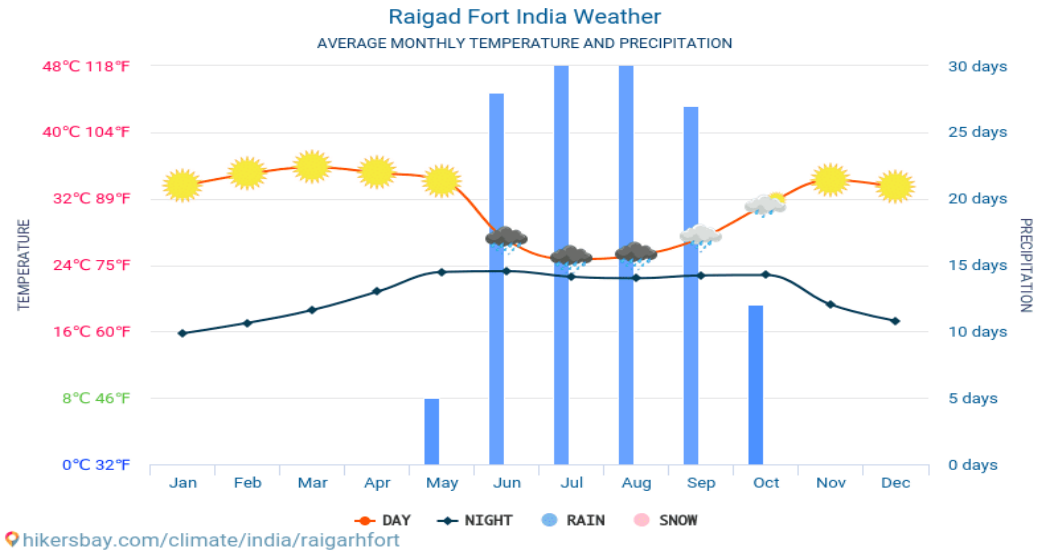


Figure: 1Rainfall report of raigad in 2019

Objectives are as follows:

- To determine properties of soil(unit weight, specific gravity).
- To analyze the stability of slope of hills on NH66 between Mahad to Mangaon using geo5 software.
- Predict the future possibility of landslide.
- Prediction of area affected by landslide.

STUDY AREA

The study area of the project is a stretch of the NH66 state highway i.e. located from Mangaon to Mahad which is situated in the Raigad district of the Maharashtra. Mahad is located in India (Maharashtra) at the longitude of $73^{0}42'00"$ and the latitude of $18^{0}08'00"$.Whereas Mangaon is located at the longitude of $73^{0}28'00"$ and the latitude of $18^{0}24'00"$. Total distance from Mangaon to Mahad is 27 km and 516 meters. Time required for travelling is 27 minutes via car or bus.

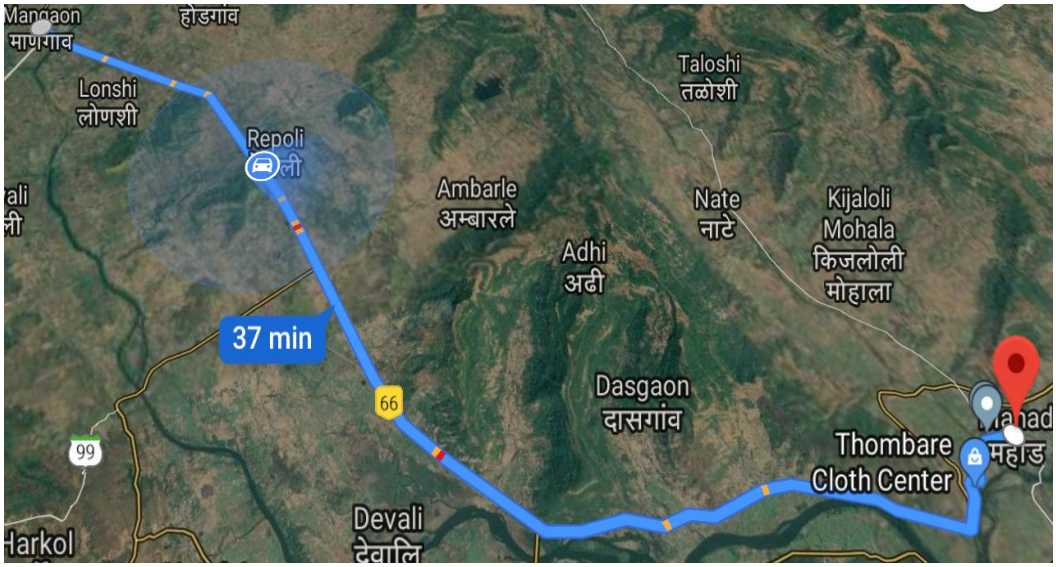


Figure: 2 Location of study area

PHYSIOGRAPHY

The highway spot located in the Raigad district has three physiographic regions as given below:

1) Coastal zone is first
2) Central zone consisting of fertile land is second
3) And lastly the hilly areas in eastern part covered with forest.

This hilly range is characterised by the roughness in the topography along with the line of the peaks. The Sahyadri hills are present in the eastern region and several transverse numbers of subsidiary hills are located towards the westwards direction. The western part of the district consists of the basalt and laterite. Deposits are found comprising of the beach sand and the alluvium along coast and mouth of the river.

The district can be divided as

1) Sahyadri Hills
2) Konkan Forested Hills
3) Kal- Savitri Valley
4) Ulhas Basin
5) Plateau of the Sudhagad
6) Raigad Coasts

CLIMATE OF AREA

Area around study spot has generally moist and humid in nature. As the study area is in the coastal region so the temperature variation cannot be seen to the larger extend. The rainfall is seen mainly from the month of the June to September and in this period mostly the road and rail transportation is seen more prone to landslides due to the loosening of the soil. Winter is from the month of the November to January and temperature rises from the month of February till May due to the summer season.

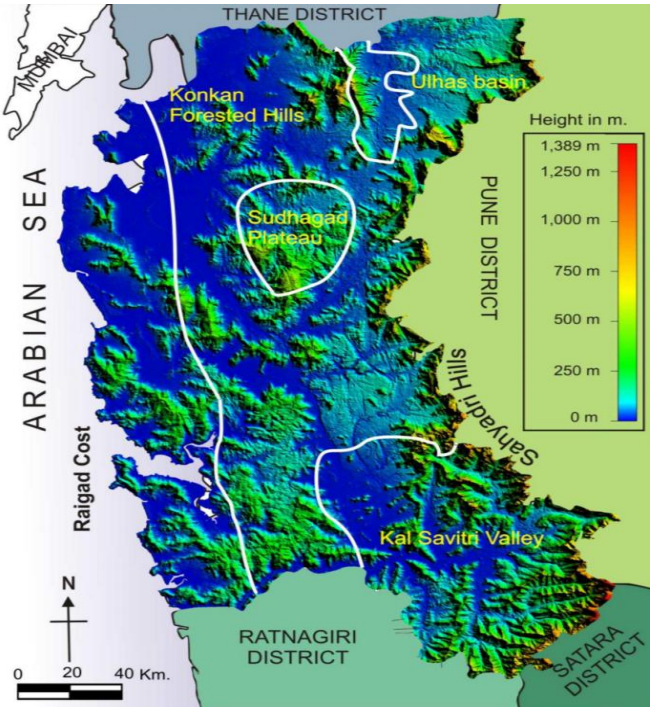


Figure: 3 Physiographic Map of Raigad District

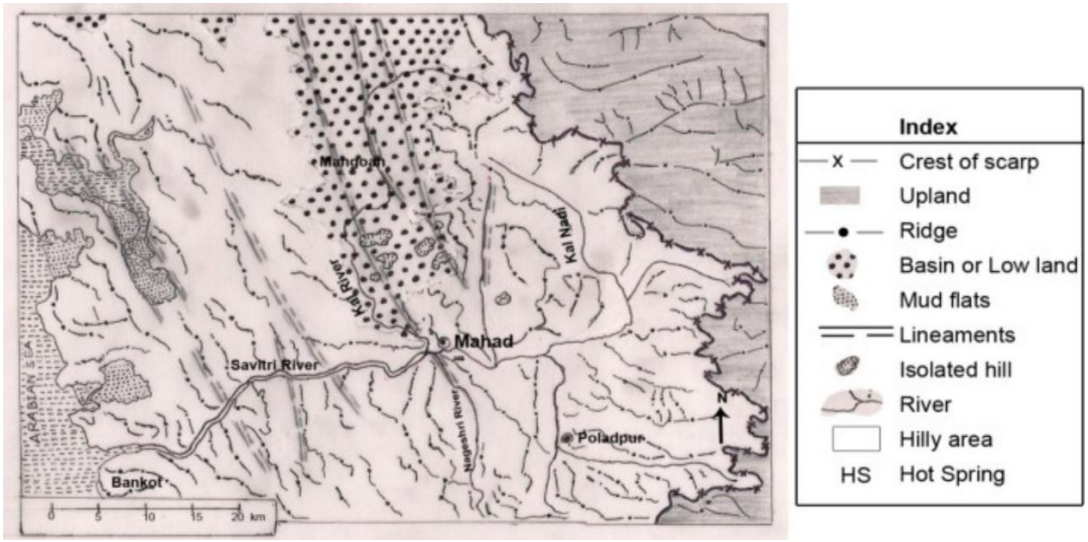


Figure: 4 Geomorphic Map of area near Mahad

RAINFALL

The phenomenon of landslides can be seen mainly in monsoon season. The mean rainfall in Raigad is nearly equal to 3028.9 mm. The rainfall increases towards the Sahyadri hills on the eastern side of the Raigad district. The rainfall is very heavy in district and varies from year to year. The following table shows the significant cumulative rainfall of different regions.

TABLE I

CUMULATIVE RAINFALL IN MANGOAN IN MM

Years	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Raifall	3453.7	3762.1	3787.5	3660.2	3763.0	3183.0	3987.0	3666.0	3358.0	2194.0

II. METHODOLOGY

Basically, in the process of the analysis of the Slope is done in two steps:

Step 1. Survey of the Study Area

Step 2. Collection of sample and software input

Step 3. Analysis using the Geo5 Software

A. *SURVEY OF THE STUDY AREA*

In case of the survey of the slope provide us the input to run the software. The basic Requirement for the software is the coordinates of the Slope to design of diagram of the Slope, and the basic information about the type of soil, stress state, Cohesion of the soil, and other properties of the soil. The cohesion of the soil is calculated by using the Direct Shear Test simply by testing the soil sample in the direct shear apparatus.

C=W/A

Where,

C: soil cohesion

W: measured weight

A: surface area

1) Total Station

A total station consists of theodolite with a built –in distance meter, and so it can measure angles and distance meter at the same time. Today's electronic total station all have not only the opto-electronic distance meter (EDM) but also the electronic angle scanning. The angles and distance are displayed digitally is coded by scales of the horizontal and vertical circles and scanned electronically. all measurements and coordinates along with additional information can be recorded and calculated automatically. Total Station are used wherever the position and height of points, merely their positions, need to be determined. Total Station used for survey is M3 series of Trimble navigation limited. It is well designed in such a way that it is easy to use and learn. Total Station instument provide by Civil engineering department of our institute Dr. Babasaheb Ambedkar Technological university lonere.

Figure:5 Total Station survey

2) Geo5 Software

Slope stability of Geo5 belong to the one of the leading developer of structural engineering software Czech Republic and worldwide. It includes integrated modules such as stability of Slope, nailed Slope, gabions, spread footing, plates, piles, cantilever wall, abutment, gravity wall, rock stability, beams, earth pressure, reinforced slopes, sheeting design, sheeting check settlement, etc. It can be modelled which can be used to study the real behaviour of the material in the structure. There are many software packages available in market. Some that uses the Swedish method of slices and others that use more complicated methods We are using the 19th version of slope stability geo5, fine software.

Data required for analysis includes the grid of centres and increments of radii, other required data

1. Geometry: Slope, inclination & height.

2. Zoning: identification of zones of different soils within the slope and beneath it including depth to hard strata

3. Properties: soil parameters for soil in each zone.

4. Pore water pressure: location and pattern of phreatic line in each zone

5. Water Levels: levels of water body near slope

B..ANALYSIS USING THE GEO5 SOFTWARE

Individual program with a unified and user-friendly interface is easy to use . The modules such as stability of Slope, spread footing, plates, beams, piles, cantilever wall, abutment,, gabions, earth pressure, rock stability reinforced Slope, sheeting design, sheeting check, settlement, gravity wall, etc.

There are various methods for analysis of Slope provided in software such as

1. Bishops
2. Petterson
3. Spencer
4. Janbu
5. Morgenstern-Price

We are using Bishop Method from above all method. The more conservative result of factor of safety might be considered best, and then it makes complete sense. The various methods for determination of slope stability, but we would prefer best, simplified, easy method for analysis. The Bishop method or ordinary method of Spices is simplified and allows for unconstrained slip plans. It can also determine the factor of safety along slip surface. Most of slope stability analysis based computer program on limit equilibrium concept for two dimensions and three dimensions.

1. Bishop's Simplified Method

Verification of the stability of slope, the slip surface is the same as in the first calculation using the Petterson method. Bishop's method simplified the hectic long process work of calculation. The lines replace the hand-made calculation the circular slip surfaces of the individual blocks. The angle between the slip surface and the horizontal plane is determine the inclination of the slip surface The calculation of the pore pressure must be determined the height of the ground water table. The axis of the block is considered as height of the ground water table. The resultant effect of the horizontal forces of the pore pressure is not only significant but also had been neglected.

2. Calculation of the sliding moment:

1) Resultant resisting moment:

$$M_p=\sum_{i=1}^{20} Mpi$$

2) Resultant sliding moment:

$$M_a=\sum_{i=1}^{20} Mai$$

3) Calculation of the safety factor:

$$F.O.S = Mp/Ma$$

3. Design procedure

- To find the Slope stability we use Geo5 software by following these steps:

Initially we setup the ranges of the coordinates with min and max X range. We also define the depth of model below the deepest interface point.

- Add the interface by graphical method or by substituting the x and z values in meter.
- Next step is to add the details of the soil which includes,
  a) name of soil
  b) unit weight
  c) Stress-state
  d) Cohesion of soil
- Assign the definite pattern colour and background of the soil.
- If there exist rigid body on the slope then its effect can also illustrate by assigning its desired values.
- Final step is analysis of Slope stability by Bishop Method circle method.
- Analysis can be done in three ways Standard, Optimization, Grid Search.

- Now, we select the two points to define the chord of slip circle surface. Then we obtain the result by clicking on the analysis button which provides us with the details: Summation of Active and passive forces, sliding and resisting moment and factor of safety.

Note: -If resisting moment is greater than sliding moment then the slope is stable Vice-versa Slope is unstable Measures for stable Slope includes

- Anchors
- Nails
- Reinforcement
- Anti-slide piles
- Surcharge
- Unit weight of soil

$$\gamma_D = W_S/V_{to}$$

4. *Direct shear test*

Geotechnical engineers use direct shear test to measure the shear strength of soil and different properties of soil. This test is usually performed on undisturbed soil samples. This sample is placed in a shear box. Shear box has two stacked to hold the sample. A stress is applying vertically on a sample and the upper ring is pulled laterally when sample fails, then stress strain curve is plotted. Some specimens are tested at different confining stresses to calculate the shear strength parameters. The cohesion of soil (c) and angle of internal friction is called as friction angle. The results obtained are plotted on the graph with peak stress on Y-axis and confining stress on X-axis. Cohesion of the soil is fit by the test results represent on Y intercept on the curve and friction angle give information about the slope of the curve. The Direct shear Apparatus of model AIM 105-3 are used which belong toAimil Ltd .civil engineering.

Figure: 7 Direct shear Apparatus

Apparatus

1. Direct shear box apparatus
2. Loading frame (motor attached).
3. Dial gauge.
4. Proving ring.
5. Tamper.
6. Straight edge.
7. Balance to weigh up to 200 mg.
8. Aluminium container.
9. Spatula.

C. Materials

In study and analysis of the slope stability by using the software such as Geo5.

Requirement of material for analysis

1. Total Station
2. Prism
3. Tripod stand
4. Geo5 software

III. RESULTS

A) ANALYSIS OF STABILITY OF SLOPE FOR SITE A

The site A is 18 km from Mangaon and 11km from Mahad on national highway 66, near to the tolphata bus stop, comes under Dasgaontq. Mangaon 402103 Maharashtra. 18°06’0.71” N70°20'18.8"E.

TABLE II
SLOPE CROSS SECTION READING AT SITE A

Serial No.	**Distance m**	**Height m**	**Slope angle**	**Slope distance**
1	20.125	0	0°	22.125
2	23.323	3.703	7°32’	25.515
3	34.049	10.35	18°80’	30.231
4	49.213	22.215	34°19’	32.120

1) Soil Parameters:

- The unit weight of the lateritic soil is taken as 20.10kN/m^2
- stress strain: - effective
- Angle of internal friction: - 13°
- Cohesion of the soil (C): - 46.1kpa

Analysis of cross section of slope stability of the site A

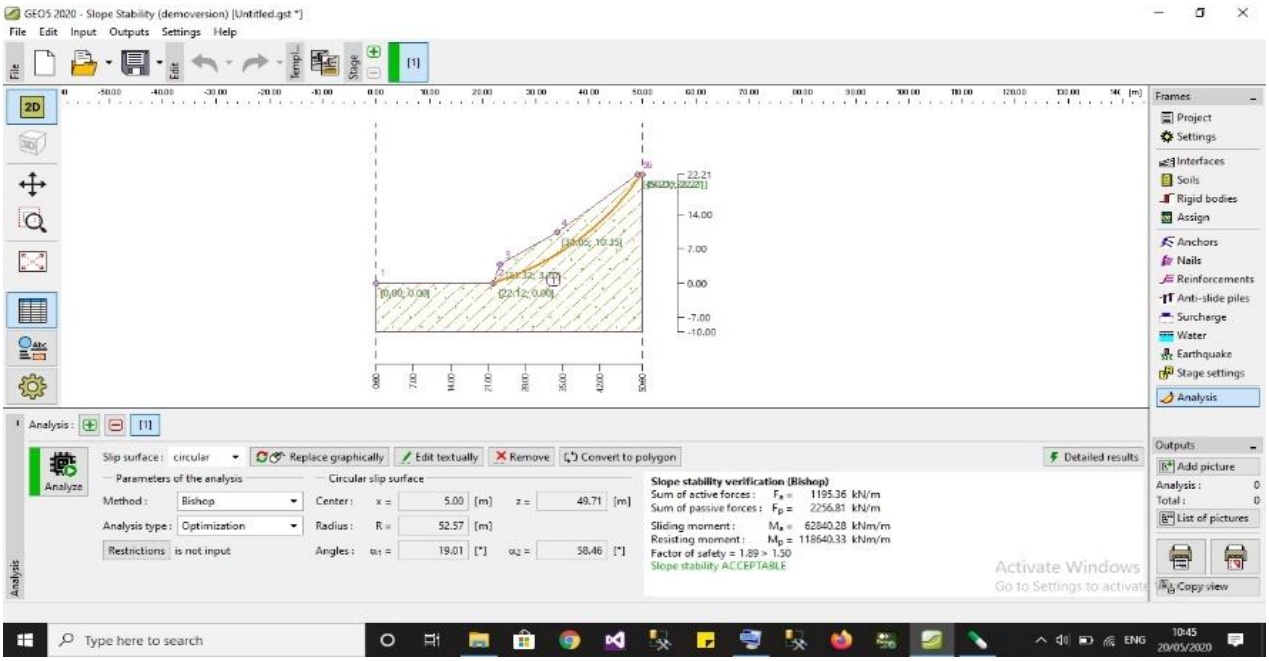


Figure:8 Software Analysis of SiteA

2) Result:

The resisting moment of the cross section of the slope is greater than the sliding moment hence slope stability is Acceptable for site A.

Slope stability verification (Bishop)

Sum of active forces: Fa =1910.37kN/m

Sum of Passive forces: Fp =4762.11kN/m

Sliding moment: Ma=47009.5KN/m

Resisting moment: Mp=117183.90KN/m

Slope stability Acceptable (Mp>Ma)

B) ANALYSIS OF STABILITY OF SLOPE FOR SITE B

The site B and C and 23 km from Mangaon and 4.6 km from Mahad on national highway 66, opposite side of hotel Neelkamal on bank of Savitri river comes under Kemburlital. Mahad 402301 Maharashtra.

For site B 18°05’08.1”N 73°23’21.9”E

For site C 18°5.46’05”N 73°21’14.8”E

Table III

SLOPE CROSS SECTION READING AT SITE B

Serial No.	Distance m	Height m	Slope angle	Slope distance m
1	12.158	0	0°	12.158
2	13.97	2.587	10°34’41”	12.211
3	17.096	7.951	18°39’44”	16.855
4	22.588	20.646	32°9’8”	28.602
5	26.92	38.272	38°31’41”	44.792

1) Soil parameters:

- The unit weight of the lateritic soil is taken as 20.10kN/m^2
- stress strain effective
- Angle of internal friction= 13°
- Cohesion of the soil C =46.1kpa

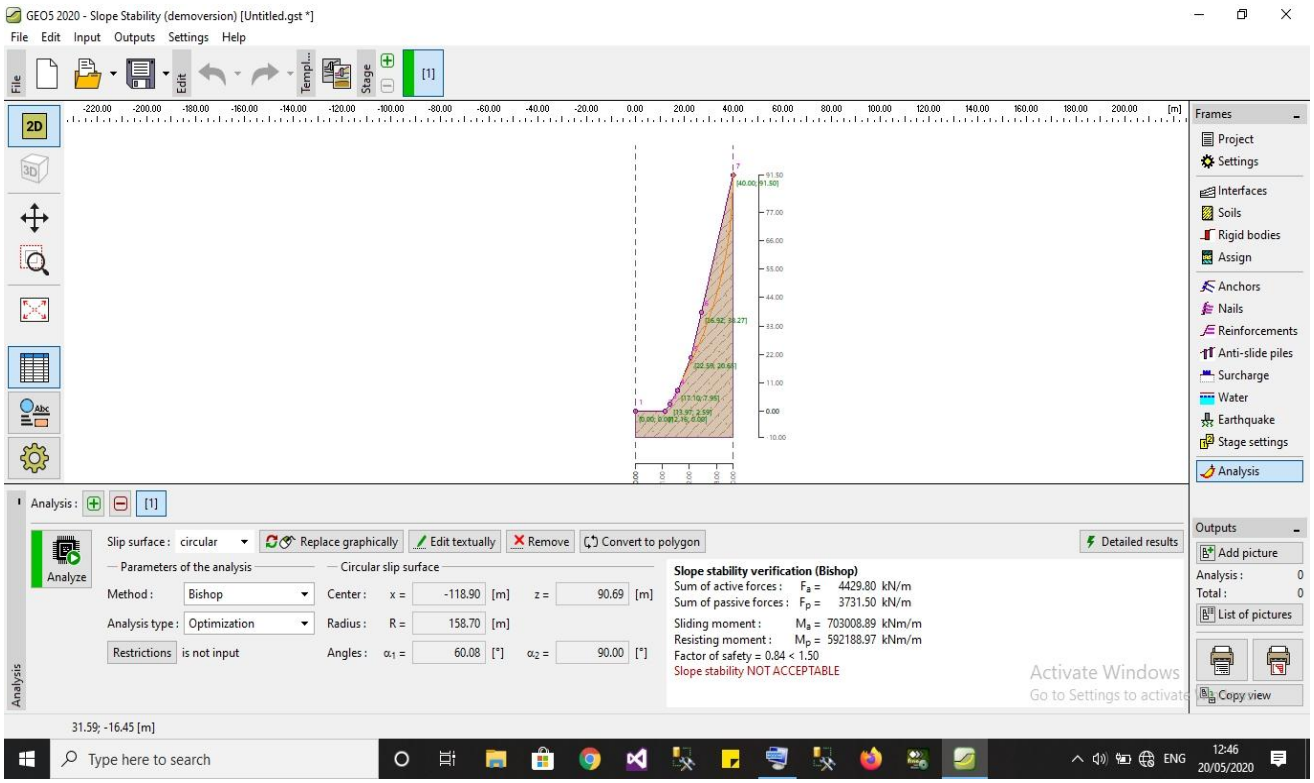


Figure: 9 Software Analysis of Site B

2) Result:

The sliding moment of the cross section of the slope is greater than resisting moment hence slope stability is not acceptable for site B.

Slope stability verification (Bishop)

Sum of active forces: Fa =4429.80kN/m

Sum of Passive forces: Fp =3731.50kN/m

Sliding moment: Ma=703008.89KN/m

Resisting moment: Mp=592188.97KN/m

Factor of safety =0.84<1.50

Slope stability Not Acceptable (Mp<Ma)

C) ANALYSIS OF STABILITY OF SLOPE FOR SITE C

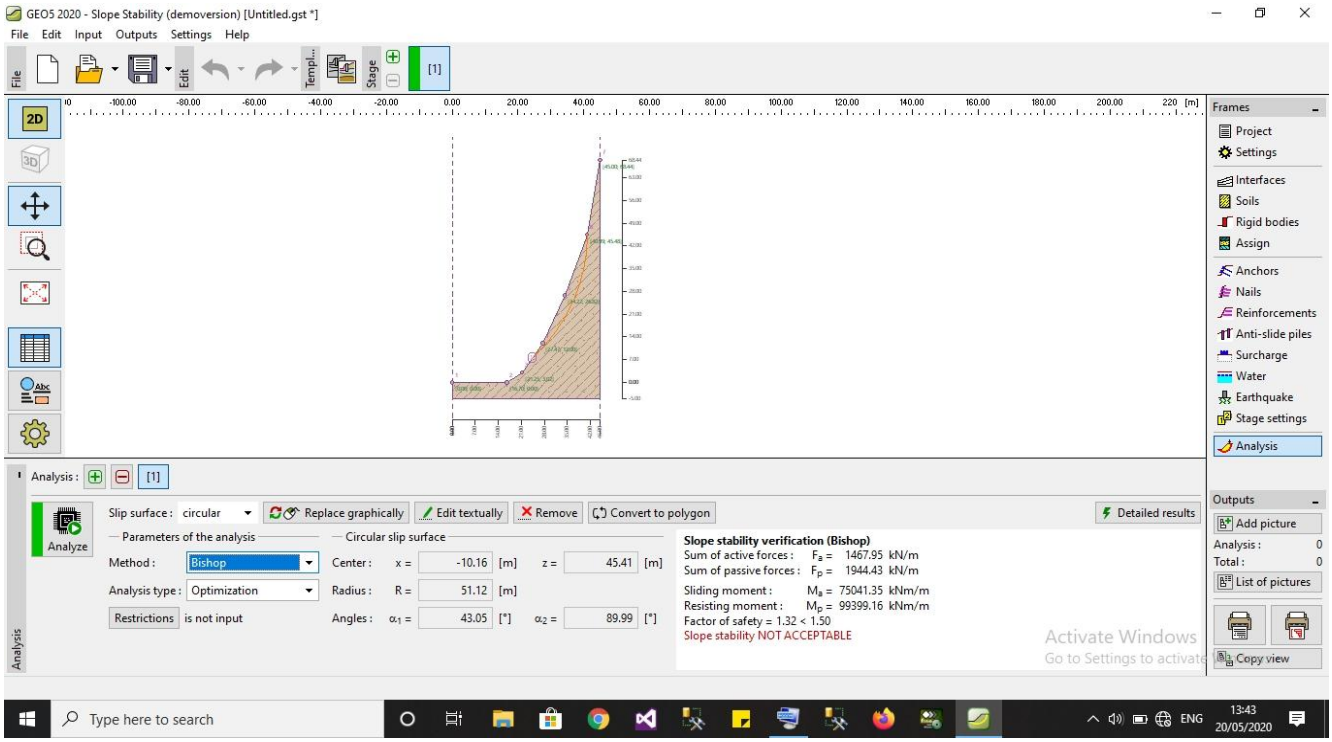
TABLE IV

SLOPE CROSS SECTION READING AT SITE C

Serial No.	Distance m	Height m	Slope angle	Slope distance m
1	16.70	0	0	16.780
2	21.245	3.02	8°4’3”	21.539
3	27.472	11.998	20°46’28”	30.058
4	34.218	26.823	39°17’23”	43.558
5	40.992	45.478	32°41’8”	61.301
6	45.445	68.438	37°37’47"	61.3

1) Soil parameters:

- The unit weight of the lateritic soil is taken as 20.10 kN/m^2
- stress strain: - effective
- Angle of internal friction = 13°
- Cohesion of the soil C =46.1kpa



Analysis of cross section of slope stability of the site C near kemburli Maharashtra, 402301 on NH66

Figure: 10 Software Analysis of Site C

2) Result:

The sliding moment of the cross section of the slope is greater than resisting moment hence slope stability is not acceptable for site C

Slope stability verification (Bishop)

Sum of active forces: Fa =1467.95kN/m

Sum of Passive forces: Fp =1944.43kN/m

Sliding moment: Ma=75041.35KN/m

Resisting moment: Mp=69939.16KN/m

Factor of safety =1.32<1.50

Slope stability Acceptable (Mp<Ma)

IV. CONCLUSIONS

Instability of slopes is a great obstacle in our study area. It's being analysed that landslides are more frequent to occur during rainy season and extreme climatic conditions which may ultimately result in humongous loss of life and property. With the help of Geo 5 software it has vastly facilitated in identifying the landslide prone area. Although landslide is a natural disaster but it may happen in our study area due to several human factors in conjunction with rainfall. Further newly construction of NH66 in our study area has increased the probability of the occurrence of the landslides due to excavations and soil erosion. Below are the three main results which we obtain from our investigation:

1. The factor of safety value obtained from the analysis of site A> 1.5, which designate the low vulnerability of the slope failure along with the resisting moment is greater than sliding moment which clearly state site A is safe and no chances of landslide.
2. The factor of safety value obtained from the analysis of site B < 1.5, which designate the high vulnerability of the slope failure and calculations also indicate the sliding moment is greater than the resisting moment, which clearly indicate the hazard of land slide at site B.
3. The factor of safety value obtained from the analysis of site C < 1.5, which designate the high vulnerability of the slope failure. The site C undergoes the sharp excavation for NH66 which makes the site C Hazardous place.

Factor of safety values if less than 1.5 reveals the perceptivity of slope failure and landslide. If the site ignored then in near future during surplus rainfall it will create a huge crunch. Preventive measures to reduce effect of landslides:

1. Landslides can be prevented by maintaining vegetation on the slopes so as to retain the soil.
2. Water excess should be avoided from rainwater or storm water runoff.
3. Do not set up irrigation system on any hillside.
4. Public awareness should be done related to wavering agricultural methods.
5. Soil erosion should be strictly prevented .All measures to control soil erosion should be encouraged to a larger extend.
6. Convenient engineering technology should be adapted to improve drainage facilities and construction of the retaining walls.
7. Prevention of landslides includes modifying the slope geometry, using desirable chemical agents to reinforce the provided slope material, installing structures which include construction of the piles, further the grouting of the rock joints and fissures can also be the effective measure, diverting the debris pathways, and rerouting the surfaces.

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