

Case Study: Slope Stability Analysis of Panikhaiti Area of Kamrup Metro District, Assam

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ABSTRACT: Slope failure, commonly known as landslide may occur due to various reasons like gravitational force, pour water pressure, change in overburden pressure etc. Earthquake or seismic force is also a major cause for slope failure. A slope otherwise stable may fail during an earthquake causing serious damage to life and property. In this study, for slope stability analysis Pseudo-Static method has been used. Both horizontal and vertical seismic co-efficient are considered for finding out factor of safety. Different load combinations are used to find out the minimum factor of safety. Computer programming using MATLAB software is done to find out the factors of safety for different load combinations.

KEYWORDS: Slope stability analysis, Pseudo-Static Method, Horizontal seismic co-efficient, Vertical seismic co-efficient, MATLAB.

I. INTRODUCTION

Panikhaiti area is located in Chandrapur Tehsil in Kamrup Metro District of Assam State, India. It is located 14 KM towards East from District head quarters Guwahati. Area of this village is 304.74 hector and population is about 4000 (as per census 2011). Panikhaiti is rural area located near to Guwahati city, which will be a part of Guwahati metropolitan area by 2017 as declared by Guwahati Metropolitan Development Authority. It is basically a hilly area. State highway no – 3 passes through this area. River Brahmaputra is at north and Amachang Wildlife Sanctuary area surrounds it. Due to rapid growth of the Guwahati city and its adjacent areas like Panikhaiti has seen huge effect on environment due manmade activities.

A study is carried out to find out factor of safety of the slopes of this region. Seismic factor or the seismic co-efficient must be considered for finding out factor of safety in this region as northeast India is in zone V from earthquake hazard point of view i.e. highest risk zone. And also to find out maximum slope angle that can be provided in these slopes without any retaining structures or with minimum protective measures. So that, man triggered landslides can be prevented and losses of life and property due to landslide brought to minimum.

II. FIELD STUDY

Boreholes are done at TEN different slopes to find out SPT values and collecting both disturbed and undisturbed samples to find out the soil properties. Classification of the soil profile is done up-to termination level of the boreholes and ground water table is also recorded. Slopes in which boreholes are done are name as Slope A, Slope B to Slope J and respective boreholes are marked as Borehole A, Borehole B to Borehole J. Physical measurements of the slopes such as height of the slope, slope angle and shape of the slope are also recorded during the field study. After applying all these 4 steps, we get a filtered image that contains only text regions.

Table: 1 Field data of the slopes

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Serial no.	Slope Identification	Height of the slope (m)	Slope angle	Cross-sectional area (sq.m)	Wedge failure line, L (m)
1	Slope A	9.23	29.93	24.496	21.840
2	Slope B	9.51	31.5	24.699	22.500
3	Slope C	9.37	22.66	40.914	22.170
4	Slope D	15.09	36.97	147.315	35.690
5	Slope E	6.77	11.36	2.711	4.990
6	Slope F	9.95	26.89	8.546	23.540
7	Slope G	13.22	30.56	39.398	31.280
8	Slope H	17.41	24.36	222.999	41.200
9	Slope I	13.18	29.93	106.406	31.220
10	Slope J	10.00	19.56	41.226	23.660

III. LABORATORY EXPERIMENTS

Different laboratory experiments are done on both disturbed and undisturbed soil samples to find out the various properties of the soil of each slope. The test are done to find out following properties – Moisture content, Specific gravity, Bulk density, Dry density, Submerged density, Saturated density, Void ratio, Porosity, Cohesion, Angle of Internal Friction, Liquid Limit, Plastic Limit and Plasticity Index. Grain size analysis is also done to find out percentage of Clay, Silt, Fine Sand, Medium Sand, Coarse Sand and Fine Gravel.

Table: 2 Properties of soil in each borehole.

Slope	Cohesion (kN/sq.m)			Angle of Internal Friction			Density (kN/cubic m)			Weight for 25 degree slope (kN)		
	C max	C avg	C min	ϕ max	ϕ avg	ϕ min	γ max	γ avg	γ min	W max	W avg	W min
Slope A	17.7	15.7	13.7	28.0	25.6	23.0	20.1	19.6	19.1	492.4	480.6	468.6
Slope B	42.2	26.5	11.8	29.0	19.8	8.0	20.1	19.7	19.2	496.5	487.0	474.9
Slope C	40.2	34.3	25.5	18.0	13.3	10.0	20.3	20.1	19.8	830.8	822.5	810.8
Slope D	39.2	17.7	0.0	32.0	20.8	9.0	20.5	20.1	19.6	3020.4	2961.3	2890.3
Slope E	36.3	28.4	7.8	26.0	16.5	11.0	20.2	20.1	19.8	54.8	54.5	53.7
Slope F	22.6	20.6	15.7	24.0	15.5	10.0	20.2	19.1	1.9	172.7	163.5	16.2
Slope G	19.6	19.6	19.6	27.0	27.0	27.0	21.4	21.4	21.4	842.6	842.6	842.6
Slope H	35.3	25.5	15.7	27.0	17.6	9.0	20.7	19.8	19.3	4615.9	4418.9	4309.7
Slope I	37.3	23.5	0.0	32.0	18.8	9.0	20.5	19.6	19.1	2181.6	2087.7	2035.5
Slope J	33.4	15.7	4.9	28.0	21.3	10.0	20.6	19.8	19.2	849.3	816.9	792.7

IV. METHOD OF ANALYSIS

A slope otherwise stable may fail during an earthquake and the study area of this paper is located in the highly seismic zone (zone - V). So, it is absolutely necessary to consider a method which can accommodate seismic load for

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analysis of the factor of safety. Again, many methods are available in which seismic forces can be considered. For this study, pseudo-static method (Seismic slope stability analysis by simple wedge failure theory for C- ϕ soil) is used for analysis. This is a simple method, where dynamic force of seismic activity is considered to be a static force. The shape of the sliding mass is considered to be wedge type and all the forces are considered to act through the centre of gravity of the sliding mass. Forces considered are Total stress (Weight of the sliding mass), Horizontal (both outward and inward) seismic acceleration and Vertical (both upward and downward) seismic acceleration. From these three considered loads when combinations were made, we get six load combinations. Load combinations used for analysis are denoted as I, II, III, IV, V and VI. For the different load combinations, factors of the safety are determined. So for each set of data, we will get six factor of safety value. The factors of safety are denoted as F1, F2, F3, F4, F5 and F6. From these six factors of safety value, the minimum value has to be considered as the final factor of safety for that slope. Load combinations used are – Load combination **I** = total stress & horizontal seismic acceleration (outward). Load combination **II** = total stress & horizontal seismic acceleration (inward). Load combination **III** = total stress, horizontal (outward) & vertical seismic acceleration (upward). Load combination **IV** = total stress, horizontal (outward) & vertical seismic acceleration (downward). Load combination **V** = total stress, horizontal (inward) & vertical seismic acceleration (upward). Load combination **VI** = total stress, horizontal (inward) & vertical seismic acceleration (downward).

V. PARAMETER SELECTION

In this analysis, i.e. pseudo-static method (Seismic slope stability analysis by simple wedge failure theory for C- ϕ soil) of analysis following parameters are required – cohesion, angle of internal friction, slope angle, length of sliding surface, weight of the sliding wedge and seismic co-efficient i.e. horizontal earthquake acceleration and vertical earthquake acceleration. The parameters are selected on the basis of the following criteria-

V.I Cohesion- From the test results of borehole data; we have different values of cohesion for different depths of the borehole. Among the values of cohesion available for different depths three values of cohesion are considered for analysis. The depth up-to which values are considered is equal to the height of the slope. If slope height is more than the depth of borehole than data available up-to maximum depth of the borehole is considered for analysis. The values of cohesion used for analysis are maximum value of cohesion (C_{max}), minimum value of cohesion (C_{min}) and average value of cohesion (C_{avg}).

V.II Angle of internal friction- From the test results of borehole data; we have different values of angle of internal friction for different depths of the borehole. Among the values of angle of internal friction available for different depths three values of angle of internal friction are considered for analysis. The depth up-to which values are considered is equal to the height of the slope. If slope height is more than the depth of borehole than data available up-to maximum depth of the borehole is considered for analysis. The values of angle of internal friction used for analysis are maximum value of angle of internal friction (Φ_{max}), minimum value of angle of internal friction (Φ_{min}) and average value of angle of internal friction (Φ_{avg}).

V.III Safe slope angle- Field slope angles are found out during the field experiments. In this study, slopes with slope angle 25 degree with horizontal surface are considered as safe slopes as no actual slope failures occurred during the study.

V.IV Density of soil- From the test results of borehole data; we have different values of density of soil for different depths of the borehole. Again we have Bulk density, Dry density, submerged density and saturated density. Saturated density is considered as it's the maximum among the densities and slopes are more vulnerable when soil is wet. Among the values of saturated density of soil available for different depths three values of saturated density of soil are considered for analysis. The values of saturated density of soil used for analysis are maximum value of saturated density of soil (γ_{max}), minimum value of saturated density of soil (γ_{min}) and average value of saturated density of soil (γ_{avg}).

V.V Length of the sliding surface & cross-sectional area- Length of the failure surface is the wedge line which is considered or found out at site investigation. In this study, length of wedge line considering 25 degree with horizontal surface are considered as line of failure surface as no actual slope failures occurred during the study. As, these lines cannot be measured at site. Slopes with its actual dimensions are drawn using Auto-CAD software and these lines are

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measured. Same procedure is followed to find out the cross-sectional area of the slope. The cross-sectional areas are found out with the help of Auto-CAD drawings.

V.VI Seismic co-efficient- Selection of the pseudo-static coefficient is thus the most important aspect of pseudo-static analysis, but it is also the most difficult. Significant differences in approaches and resulting values clearly exist among the studies cited. Normally, only the horizontal component of earthquake shaking is modeled because the effects of vertical forces tend to average out to near zero. But in this study, the effect of both horizontal component and vertical component of earthquake is considered. So, both horizontal co-efficient and vertical co-efficient are used for the analysis. The horizontal co-efficient is considered to be 0.15 [Seed (1979)] and vertical co-efficient is considered to be 0.075 for this study. This co-efficient are valid up-to magnitude 8.25 earthquakes and minimum factor of safety to be considered is 1.15.

V.VII Weight of the sliding wedge- weight of the sliding wedge is calculated considering the cross-sectional area of the slope and density of soil. Though cross-sectional area of each slope is constant but three different densities considered. So, weight of the failure wedge will be different. Three weights of the failure wedge are calculated. The weights are maximum weight (W_{max}), average weight (W_{avg}) and minimum weight (W_{min}).

Based on the above parameters, four combinations of the parameters are considered and they are termed as Set1, Set2, Set3 and Set4. In **Set1** parameters considered are maximum weight, maximum cohesion and minimum angle of internal friction. In **Set2** parameters considered are average weight, average cohesion and average angle of internal friction. In **Set3** parameters considered are minimum weight, minimum cohesion and maximum angle of internal friction. In **Set4** parameters considered are maximum weight, minimum cohesion and minimum angle of internal friction. MATLAB software is used to develop a programme to find the out factor of safety for the given set of parameters. For each set of data it gives the six factor of safety for six different load combinations. For each slope, from four combinations of parameters we got twenty four numbers of factors of safety. Based on these factors of safety minimum one is considered.

VI. RESULTS

Based on various field experiments and laboratory experiments following results are obtained and they are analysed. Variables for each borehole and each set are mentioned in tabular form with six factor of safety. The data which are constant for a borehole and are already mentioned are not included in these tables. Minimum factor of safety for each set of data is marked in yellow and lowest factor of safety for a borehole is written in red over yellow.

Table 3: Results showing the factors of safety for borehole A.

Borehole A: SET1		Borehole A: SET2	
FOS for load combination I, F1	1.78	FOS for load combination I, F1	1.74
FOS for load combination II, F2	3.21	FOS for load combination II, F2	3.16
FOS for load combination III, F3	1.85	FOS for load combination III, F3	1.79
FOS for load combination IV, F4	1.72	FOS for load combination IV, F4	1.69
FOS for load combination V, F5	3.48	FOS for load combination V, F5	3.42
FOS for load combination VI, F6	2.98	FOS for load combination VI, F6	2.94
Borehole A: SET3		Borehole A: SET4	
FOS for load combination I, F1	1.69	FOS for load combination I, F1	1.50
FOS for load combination II, F2	3.09	FOS for load combination II, F2	2.73
FOS for load combination III, F3	1.74	FOS for load combination III, F3	1.55
FOS for load combination IV, F4	1.64	FOS for load combination IV, F4	1.46
FOS for load combination V, F5	3.34	FOS for load combination V, F5	2.96
FOS for load combination VI, F6	2.89	FOS for load combination VI, F6	2.55

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The above table presents the factors of safety for four sets of parameters for borehole A. For each set of parameters minimum factor of safety is marked (marked with yellow). Again among the minimum factors of safety for each set least one is marked (bold red). For this study minimum factor of safety is considered among the twenty four available factor of safety. Depending upon the importance of the structure or the design different factor of safety can be considered.

Table 4: Results showing the factors of safety for borehole B.

Borehole B: SET1		Borehole B: SET2	
FOS for load combination I, F1	3.11	FOS for load combination I, F1	2.31
FOS for load combination II, F2	5.18	FOS for load combination II, F2	3.95
FOS for load combination III, F3	3.29	FOS for load combination III, F3	2.42
FOS for load combination IV, F4	2.94	FOS for load combination IV, F4	2.21
FOS for load combination V, F5	5.72	FOS for load combination V, F5	4.32
FOS for load combination VI, F6	4.73	FOS for load combination VI, F6	3.65
Borehole B: SET3		Borehole B: SET4	
FOS for load combination I, F1	1.52	FOS for load combination I, F1	0.86
FOS for load combination II, F2	2.72	FOS for load combination II, F2	1.47
FOS for load combination III, F3	1.56	FOS for load combination III, F3	0.90
FOS for load combination IV, F4	1.48	FOS for load combination IV, F4	0.82
FOS for load combination V, F5	2.92	FOS for load combination V, F5	1.61
FOS for load combination VI, F6	2.56	FOS for load combination VI, F6	1.36

The above table presents the factors of safety for four sets of parameters for borehole B. For each set of parameters minimum factor of safety is marked (marked with yellow). Again among the minimum factors of safety for each set least one is marked (bold red). For this study minimum factor of safety is considered among the twenty four available factor of safety. Depending upon the importance of the structure or the design different factor of safety can be considered.

Table 5: Results showing the factors of safety for borehole C.

Borehole C: SET1		Borehole C: SET2	
FOS for load combination I, F1	2.56	FOS for load combination I, F1	2.34
FOS for load combination II, F2	5.57	FOS for load combination II, F2	5.05
FOS for load combination III, F3	2.66	FOS for load combination III, F3	2.45
FOS for load combination IV, F4	2.46	FOS for load combination IV, F4	2.24
FOS for load combination V, F5	6.21	FOS for load combination V, F5	5.66
FOS for load combination VI, F6	5.07	FOS for load combination VI, F6	4.56
Borehole C: SET3		Borehole C: SET4	
FOS for load combination I, F1	2.16	FOS for load combination I, F1	1.39
FOS for load combination II, F2	4.68	FOS for load combination II, F2	3.03

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FOS for load combination III, F3	2.25	FOS for load combination III, F3	1.45
FOS for load combination IV, F4	2.07	FOS for load combination IV, F4	1.34
FOS for load combination V, F5	5.23	FOS for load combination V, F5	3.38
FOS for load combination VI, F6	4.25	FOS for load combination VI, F6	2.76

The above table presents the factors of safety for four sets of parameters for borehole C. For each set of parameter, out of six factors of safety minimum factor of safety is marked (marked with yellow). Again among the minimum factors of safety for each set least one is marked (bold red). For this study minimum factor of safety is considered among the twenty four available factor of safety. Depending upon the importance of the structure or the design different factor of safety can be considered.

Table 6: Results showing the factors of safety for borehole D.

Borehole D: SET1		Borehole D: SET2	
FOS for load combination I, F1	0.80	FOS for load combination I, F1	0.67
FOS for load combination II, F2	1.25	FOS for load combination II, F2	1.14
FOS for load combination III, F3	0.84	FOS for load combination III, F3	0.68
FOS for load combination IV, F4	0.76	FOS for load combination IV, F4	0.66
FOS for load combination V, F5	1.36	FOS for load combination V, F5	1.21
FOS for load combination VI, F6	1.16	FOS for load combination VI, F6	1.09
Borehole D: SET3		Borehole D: SET4	
FOS for load combination I, F1	0.61	FOS for load combination I, F1	0.16
FOS for load combination II, F2	1.15	FOS for load combination II, F2	0.29
FOS for load combination III, F3	0.60	FOS for load combination III, F3	0.15
FOS for load combination IV, F4	0.63	FOS for load combination IV, F4	0.16
FOS for load combination V, F5	1.19	FOS for load combination V, F5	0.30
FOS for load combination VI, F6	1.13	FOS for load combination VI, F6	0.29

The above table presents the factors of safety for four sets of parameters for borehole D. For each set of parameter, out of six factors of safety minimum factor of safety is marked (marked with yellow). Again among the minimum factors of safety for each set least one is marked (bold red). For this study minimum factor of safety is considered among the twenty four available factor of safety. Depending upon the importance of the structure or the design different factor of safety can be considered.

Table 7: Results showing the factors of safety for borehole E.

Borehole E: SET1		Borehole E: SET2	
FOS for load combination I, F1	10.15	FOS for load combination I, F1	8.39
FOS for load combination II, F2	70.13	FOS for load combination II, F2	58.16
FOS for load combination III, F3	10.56	FOS for load combination III, F3	8.70
FOS for load combination IV, F4	9.77	FOS for load combination IV, F4	8.11
FOS for load combination V, F5	99.20	FOS for load combination V, F5	81.97
FOS for load combination VI, F6	54.34	FOS for load combination VI, F6	45.51

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Borehole E: SET3		Borehole E: SET4	
FOS for load combination I, F1	3.47	FOS for load combination I, F1	2.61
FOS for load combination II, F2	24.46	FOS for load combination II, F2	18.25
FOS for load combination III, F3	3.51	FOS for load combination III, F3	2.69
FOS for load combination IV, F4	3.42	FOS for load combination IV, F4	2.55
FOS for load combination V, F5	33.72	FOS for load combination V, F5	25.51
FOS for load combination VI, F6	19.43	FOS for load combination VI, F6	14.30

The above table presents the factors of safety for four sets of parameters for borehole E. For each set of parameter, out of six factors of safety minimum factor of safety is marked (marked with yellow). Again among the minimum factors of safety for each set least one is marked (bold red). For this study minimum factor of safety is considered among the twenty four available factor of safety. Depending upon the importance of the structure or the design different factor of safety can be considered.

Table 8: Results showing the factors of safety for borehole F.

Borehole F: SET1		Borehole F: SET2	
FOS for load combination I, F1	5.63	FOS for load combination I, F1	5.61
FOS for load combination II, F2	11.63	FOS for load combination II, F2	11.62
FOS for load combination III, F3	5.94	FOS for load combination III, F3	5.90
FOS for load combination IV, F4	5.36	FOS for load combination IV, F4	5.34
FOS for load combination V, F5	13.08	FOS for load combination V, F5	13.04
FOS for load combination VI, F6	10.48	FOS for load combination VI, F6	10.49
Borehole F: SET3		Borehole F: SET4	
FOS for load combination I, F1	4.529	FOS for load combination I, F1	4.01
FOS for load combination II, F2	8.523	FOS for load combination II, F2	8.29
FOS for load combination III, F3	4.753	FOS for load combination III, F3	4.22
FOS for load combination IV, F4	4.329	FOS for load combination IV, F4	3.81
FOS for load combination V, F5	9.434	FOS for load combination V, F5	9.31
FOS for load combination VI, F6	7.787	FOS for load combination VI, F6	7.48

The above table presents the factors of safety for four sets of parameters for borehole F. For each set of parameter, out of six factors of safety minimum factor of safety is marked (marked with yellow). Again among the minimum factors of safety for each set least one is marked (bold red). For this study minimum factor of safety is considered among the twenty four available factor of safety. Depending upon the importance of the structure or the design different factor of safety can be considered.

Table 9: Results showing the factors of safety for borehole G.

Borehole G: SET1		Borehole G: SET2	
FOS for load combination I, F1	1.78	FOS for load combination I, F1	1.78
FOS for load combination II, F2	3.21	FOS for load combination II, F2	3.21
FOS for load combination III, F3	1.84	FOS for load combination III, F3	1.84
FOS for load combination IV, F4	1.73	FOS for load combination IV, F4	1.73
FOS for load combination V, F5	3.48	FOS for load combination V, F5	3.48
FOS for load combination VI, F6	3.00	FOS for load combination VI, F6	3.00
Borehole G: SET3		Borehole G: SET4	

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FOS for load combination I, F1	1.78	FOS for load combination I, F1	1.78
FOS for load combination II, F2	3.21	FOS for load combination II, F2	3.21
FOS for load combination III, F3	1.84	FOS for load combination III, F3	1.84
FOS for load combination IV, F4	1.73	FOS for load combination IV, F4	1.73
FOS for load combination V, F5	3.48	FOS for load combination V, F5	3.48
FOS for load combination VI, F6	3.00	FOS for load combination VI, F6	3.00

The above table presents the factors of safety for four sets of parameters for borehole G. For each set of parameter, out of six factors of safety minimum factor of safety is marked (marked with yellow). Again among the minimum factors of safety for each set least one is marked (bold red). For this study minimum factor of safety is considered among the twenty four available factor of safety. Depending upon the importance of the structure or the design different factor of safety can be considered.

Table 10: Results showing the factors of safety for borehole H.

Borehole H: SET1		Borehole H: SET2	
FOS for load combination I, F1	0.82	FOS for load combination I, F1	0.92
FOS for load combination II, F2	1.70	FOS for load combination II, F2	1.98
FOS for load combination III, F3	0.85	FOS for load combination III, F3	0.94
FOS for load combination IV, F4	0.79	FOS for load combination IV, F4	0.91
FOS for load combination V, F5	1.87	FOS for load combination V, F5	2.14
FOS for load combination VI, F6	1.56	FOS for load combination VI, F6	1.85
Borehole H: SET3		Borehole H: SET4	
FOS for load combination I, F1	1.06	FOS for load combination I, F1	0.50
FOS for load combination II, F2	2.34	FOS for load combination II, F2	1.07
FOS for load combination III, F3	1.06	FOS for load combination III, F3	0.51
FOS for load combination IV, F4	1.06	FOS for load combination IV, F4	0.49
FOS for load combination V, F5	2.49	FOS for load combination V, F5	1.16
FOS for load combination VI, F6	2.22	FOS for load combination VI, F6	0.99

The above table presents the factors of safety for four sets of parameters for borehole H. For each set of parameter, out of six factors of safety minimum factor of safety is marked (marked with yellow). Again among the minimum factors of safety for each set least one is marked (bold red). For this study minimum factor of safety is considered among the twenty four available factor of safety. Depending upon the importance of the structure or the design different factor of safety can be considered.

Table 11: Results showing the factors of safety for borehole I.

Borehole I: SET1		Borehole I: SET2	
FOS for load combination I, F1	1.05	FOS for load combination I, F1	0.99
FOS for load combination II, F2	1.85	FOS for load combination II, F2	1.82
FOS for load combination III, F3	1.10	FOS for load combination III, F3	1.01
FOS for load combination IV, F4	1.00	FOS for load combination IV, F4	0.97
FOS for load combination V, F5	2.03	FOS for load combination V, F5	1.96
FOS for load combination VI, F6	1.70	FOS for load combination VI, F6	1.71
Borehole I: SET3		Borehole I: SET4	
FOS for load combination I, F1	0.79	FOS for load combination I, F1	0.20

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FOS for load combination II, F2	1.59	FOS for load combination II, F2	0.40
FOS for load combination III, F3	0.77	FOS for load combination III, F3	0.19
FOS for load combination IV, F4	0.80	FOS for load combination IV, F4	0.20
FOS for load combination V, F5	1.65	FOS for load combination V, F5	0.42
FOS for load combination VI, F6	1.55	FOS for load combination VI, F6	0.39

The above table presents the factors of safety for four sets of parameters for borehole I. For each set of parameter, out of six factors of safety minimum factor of safety is marked (marked with yellow). Again among the minimum factors of safety for each set least one is marked (bold red). For this study minimum factor of safety is considered among the twenty four available factor of safety. Depending upon the importance of the structure or the design different factor of safety can be considered.

Table 12: Results showing the factors of safety for borehole J.

Borehole J: SET1		Borehole J: SET2	
FOS for load combination I, F1	2.28	FOS for load combination I, F1	1.68
FOS for load combination II, F2	5.71	FOS for load combination II, F2	4.34
FOS for load combination III, F3	2.38	FOS for load combination III, F3	1.72
FOS for load combination IV, F4	2.19	FOS for load combination IV, F4	1.65
FOS for load combination V, F5	6.48	FOS for load combination V, F5	4.83
FOS for load combination VI, F6	5.11	FOS for load combination VI, F6	3.97
Borehole J: SET3		Borehole J: SET4	
FOS for load combination I, F1	1.30	FOS for load combination I, F1	0.62
FOS for load combination II, F2	3.48	FOS for load combination II, F2	1.61
FOS for load combination III, F3	1.29	FOS for load combination III, F3	0.62
FOS for load combination IV, F4	1.31	FOS for load combination IV, F4	0.61
FOS for load combination V, F5	3.78	FOS for load combination V, F5	1.78
FOS for load combination VI, F6	3.26	FOS for load combination VI, F6	1.48

The above table presents the factors of safety for four sets of parameters for borehole J. For each set of parameter, out of six factors of safety minimum factor of safety is marked (marked with yellow). Again among the minimum factors of safety for each set least one is marked (bold red). For this study minimum factor of safety is considered among the twenty four available factor of safety. Depending upon the importance of the structure or the design different factor of safety can be considered.

VII. CONCLUSION

Following conclusions can be drawn from the results obtained-

- (a) Slopes having height more than 15 meters are found to be unstable.
- (b) Load combination IV produces the worst factor of safety.
- (c) Set4 i.e. parameters considered are maximum weight, minimum cohesion and minimum angle of internal friction produces the least factor of safety.
- (d) Factor of safety has to be selected wisely among the available factor of safety depending upon the importance of the structure. Otherwise design may not be economic.
- (e) Table 13: Summary of the minimum factor of safety of the all ten slopes.

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Serial no.	Slope Identification	Minimum factor of safety	Remarks
1	Slope A	1.460	Stable slope
2	Slope B	0.825	Unstable slope
3	Slope C	1.339	Stable slope
4	Slope D	0.152	Unstable slope
5	Slope E	2.547	Stable slope
6	Slope F	3.815	Stable slope
7	Slope G	1.729	Stable slope
8	Slope H	0.492	Unstable slope
9	Slope I	0.195	Unstable slope

The above table presents the minimum factors of safety for each borehole. Slopes are marked as stable and unstable depending up-on the minimum factor of safety.

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