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Analysis of Stability of Road Embankment Slope for Sandy Soil for Different Height of Embankments

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Abstract— ***The paper discusses the analysis of a road embankment of different heights for sandy soil under different variations of embankment slope. Four embankments of different height (1.5m, 3m, 5m and 6m) under four variations of slope (1H:1V, 1.5H:1V, 2H:1V and 2.5H:1V) were modelled in Geostudio2018 and the analysis is performed for the stability of slope of road embankment for different values of unit weight and friction angle of sandy soils by Bishop's method of slope stability using Geostudio2018 software. The effect of increase of height of embankment on the stability of slopes is studied. Also the variation of soil property on the stability of slopes is studied and it is found that increase in the height of embankment result in a decrease of factor of safety against slope failure. For cases where factor of safety is less than 1.4, they are considered to be the case of slope failure as per the guidelines of IRC75:2015.***

Keywords— ***Bishop's Method, Friction angle, Factor of Safety, Slope Stability, Geostudio2018***

I. INTRODUCTION

Slope stability analysis provides the safe design of earth slopes under the influence of gravity force. It accesses the possibilities of earth slope failures either natural or human made slopes. These slope failures can often be catastrophic and sometimes involve extensive loss to economy, society and environment. The identification of most sliding surface named as critical slip surface is associated with least factor of safety. In case of slope failure, there are driving forces like weight of the moving soil, surface loads, earthquake loads and resisting forces like internal friction force and the cohesion of the soil at the failure surface.

Stability of high embankment depends on various factors like foundation profile, fill material quality, extent of compaction, drainage arrangement both surface and sub-surface, and embankment geometry like height of embankment, slope angle, ground profile etc., external factors like traffic or earthquake load or presence of any water body by the side of the embankment or development of pore water pressure due to infiltration from heavy rain. All these parameters and conditions make significant impact on overall stability of the embankment [1].

II. IMPORTANCE OF STUDY

The basic purpose of slope stability analysis in application of engineering field is lead to the safety of road. The results of this study are of importance in planning detailed investigations of major projects. Engineers must consider all the factors affecting their design and possible natural disasters which can have obliterating social and monetary impacts. Stability of slopes is important throughout all aspects of construction and a small difference in the calculated factor of safety can result in a noteworthy increment in costs both in construction and ongoing maintenance.

III. DATA FOR ANALYSIS

The road embankments were analysed for sandy soil for different values of unit weight and friction angle under the different variations of height and slope to check their stability against slope failure. The values of unit weight and friction were taken from reference [2][3]. The values taken are given in Table I and II.

TABLE I
Typical Values of Soil friction Angle for Sandy Soil [2]

S.NO.	Description of Soil	USCS*	Soil friction angle, ϕ (°)	
			Minimum	Maximum
1	Sand	(SW,SP)	37	38
2	Loose Sand	(SW,SP)	29	30
3	Medium Sand	(SW,SP)	30	36
4	Dense Sand	(SW,SP)	36	41

*USCS means "Unified Soil Classification System"
SW means "Well Graded Sand"
SP means "Poorly graded Sand"

TABLE II
Typical Values of Unit Weight of Sandy Soil [3]

S.NO.	USCS	Description	Dry unit Weight, γ (KN/m3)
1.	SW	Well graded Sand, gravelly Sands, with little or no fines	20.5±2
2.	SP	Poorly graded sands, gravelly sands, with little or no fines	19.5±2

IV. RESULT AND DISCUSSION

The following cases were considered for the analysis of slope stability in Geostudio2018 for analysis is as follows:

A. For Sandy Soil:
A1. γ=18 KN/m^3, ϕ=37°
A2. γ=20 KN/m^3, ϕ=37°
A3. γ=22 KN/m^3, ϕ=37°
A4. γ=18 KN/m^3, ϕ=38°
A5. γ=20 KN/m^3, ϕ=38°
A6. γ=22 KN/m^3, ϕ=38°

B. Loose sand
B1. γ=18 KN/m^3, ϕ=29°
B2. γ=20 KN/m^3, ϕ=29°
B3. γ=22 KN/m^3, ϕ=29°
B4. γ=18 KN/m^3, ϕ=30°
B5. γ=20 KN/m^3, ϕ=30°
B6. γ=22 KN/m^3, ϕ=30°

C. Medium Sand
C1. γ=18 KN/m^3, ϕ=30°
C2. γ=20 KN/m^3, ϕ=30°
C3. γ=22 KN/m^3, ϕ=30°
C4. γ=18 KN/m^3, ϕ=36°
C5. γ=20 KN/m^3, ϕ=36°
C6. γ=22 KN/m^3, ϕ=36°

D. Dense Sand
D1. γ=18 KN/m^3, ϕ=36°
D2. γ=20 KN/m^3, ϕ=36°
D3. γ=22 KN/m^3, ϕ=36°
D4. γ=18 KN/m^3, ϕ=41°
D5. γ=20 KN/m^3, ϕ=41°
D6. γ=22 KN/m^3, ϕ=41°

The value of factor of safety for the above cases were obtained by Bishop's method [4] for the different parameter and different cases are mentioned in Table from III to XX:

TABLE III
Factor of Safety Values for Different Heights of Embankment with Variation of Slope for Case A1. γ=18 KN/m^3, ϕ=37°

Slope	**Factor of Safety values for different heights of Embankments**			
	1.5m	**3m**	**5m**	**6m**
1H:1V	1.103	1.051	0.755	0.748
1.5H:1V	1.203	1.160	1.325	1.133
2H:1V	1.758	1.510	1.510	1.795
2.5H:1V	1.949	1.902	1.902	1.994

TABLE IV
Factor of Safety Values for Different Heights of Embankment with Variation of Slope for Case A2. γ=20 KN/m^3, ϕ=37°

Slope	**Factor of Safety values for different heights of Embankments**			
	1.5m	**3m**	**5m**	**6m**
1H:1V	1.103	1.051	0.755	0.748
1.5H:1V	1.203	1.160	1.325	1.133
2H:1V	1.758	1.510	1.510	1.795
2.5H:1V	1.949	1.902	1.902	1.994

TABLE V
Factor of Safety Values for Different Heights of Embankment with Variation of Slope for Case A3. γ=22 KN/m^3, ϕ=37°

Slope	**Factor of Safety values for different heights of Embankments**			
	1.5m	**3m**	**5m**	**6m**
1H:1V	1.103	1.051	0.755	0.748
1.5H:1V	1.203	1.160	1.325	1.133
2H:1V	1.758	1.510	1.510	1.795
2.5H:1V	1.949	1.902	1.902	1.994

From tables III to V, for a given value of ϕ=37°, it is observed that the embankment of height 1.5m,3m,5m and 6m are stable for slope 2H:1V and flatter slopes whereas for steeper slopes the embankment is found to be unstable. It is also observed that for a particular height of embankment, factor of safety increases with increase in the flatness of the slope. It is also seen from these tables that for a given value of ϕ, there is no effect of increase in the value of dry unit weight of soil on the stability of slopes.

TABLE VI

Factor of Safety Values for Different Heights of Embankment with Variation of Slope for Case A4. γ=18 KN/m^3, ϕ=38°

Slope	**Factor of Safety values for different heights of Embankments**			
	1.5m	**3m**	**5m**	**6m**
1H:1V	1.144	1.090	0.783	0.776
1.5H:1V	1.248	1.203	1.374	1.174
2H:1V	1.823	1.566	1.566	1.861
2.5H:1V	2.020	1.971	1.972	2.068

TABLE VII

Factor of Safety Values for Different Heights of Embankment with Variation of Slope for Case A5. γ=20 KN/m^3, ϕ=38°

Slope	**Factor of Safety values for different heights of Embankments**			
	1.5m	**3m**	**5m**	**6m**
1H:1V	1.144	1.090	0.783	0.776
1.5H:1V	1.248	1.203	1.374	1.174
2H:1V	1.823	1.566	1.566	1.861
2.5H:1V	2.020	1.971	1.972	2.068

TABLE VIII

Factor of Safety Values for Different Heights of Embankment with Variation of Slope for Case A6. γ=22 KN/m^3, ϕ=38°

Slope	**Factor of Safety values for different heights of Embankments**			
	1.5m	**3m**	**5m**	**6m**
1H:1V	1.144	1.090	0.783	0.776
1.5H:1V	1.248	1.203	1.374	1.174
2H:1V	1.823	1.566	1.566	1.861
2.5H:1V	2.020	1.971	1.972	2.068

From tables VI to VIII, for a given value of ϕ=38°, it is observed that the embankment of height 1.5m,3m,5m and 6m are stable for slope 2H:1V and flatter slopes whereas for steeper slopes the embankment is found to be unstable. It is also observed that for a particular height of embankment, factor of safety increases with increase in the flatness of the slope. It is also seen from these tables that for a given value of ϕ, there is no effect of increase in the value of dry unit weight of soil on the stability of slopes.

It is also noticed from tables III to VIII that with increase in the value of ϕ from 37° to 38°, the factor of safety values increase which means more the value of angle of internal friction, more is the stability of slopes.

TABLE IX

Factor of Safety Values for Different Heights of Embankment with Variation of Slope for Case B1. γ=18 KN/m^3, ϕ=29°

Slope	**Factor of Safety values for different heights of Embankments**			
	1.5m	**3m**	**5m**	**6m**
1H:1V	0.812	0.773	0.556	0.551
1.5H:1V	0.885	0.853	0.975	0.833
2H:1V	1.293	1.111	1.111	1.320
2.5H:1V	1.433	1.400	1.400	1.467

TABLE X

Factor of Safety Values for Different Heights of Embankment with Variation of Slope for Case B2. γ=20 KN/m^3, ϕ=29°

Slope	**Factor of Safety values for different heights of Embankments**			
	1.5m	**3m**	**5m**	**6m**
1H:1V	0.812	0.773	0.556	0.551
1.5H:1V	0.885	0.853	0.975	0.833
2H:1V	1.293	1.111	1.111	1.320
2.5H:1V	1.433	1.400	1.400	1.467

TABLE XI

Factor of Safety Values for Different Heights of Embankment with Variation of Slope for Case B3. γ=22 KN/m^3, ϕ=29°

Slope	**Factor of Safety values for different heights of Embankments**			
	1.5m	**3m**	**5m**	**6m**
1H:1V	0.812	0.773	0.556	0.551
1.5H:1V	0.885	0.853	0.975	0.833
2H:1V	1.293	1.111	1.111	1.320
2.5H:1V	1.433	1.400	1.400	1.467

From tables IX to XI, for a given value of ϕ=29°, it is observed that the embankment of height 1.5m,3m,5m and 6m are stable for slope 2.5H:1V and flatter slopes whereas for steeper slopes the embankment is found to be unstable. It is also observed that for a particular height of embankment, factor of safety increases with increase in the flatness of the slope. It is also seen from these tables that for a given value of ϕ, there is no effect of increase in the value of dry unit weight of soil on the stability of slopes.

TABLE XII

Factor of Safety Values for Different Heights of Embankment with Variation of Slope for Cases B4. γ=18 KN/m^3, ϕ=30° and C1. γ=18 KN/m^3, ϕ=30°

SLOPE	**Factor of Safety values for different heights of Embankments**			
	1.5m	**3m**	**5m**	**6m**
1H:1V	0.845	0.806	0.519	0.573
1.5H:1V	0.922	0.889	1.016	0.868
2H:1V	1.397	1.157	1.157	1.375
2.5H:1V	1.493	1.457	1.457	1.528

TABLEXIII

Factor of Safety Values for Different Heights of Embankment with Variation of Slope for Cases B5. γ=20 KN/m^3, ϕ=30° and C2. γ=20 KN/m^3, ϕ=30°

Slope	**Factor of Safety values for different heights of Embankments**			
	1.5m	**3m**	**5m**	**6m**
1H:1V	0.845	0.806	0.519	0.573
1.5H:1V	0.922	0.889	1.016	0.868
2H:1V	1.397	1.157	1.157	1.375
2.5H:1V	1.493	1.457	1.457	1.528

TABLE XIV

Factor of Safety Values for Different Heights of Embankment with Variation of Slope for Case B6. γ=22 KN/m^3, ϕ=30° and C3. γ=22 KN/m^3, ϕ=30°

Slope	**Factor of Safety values for different heights of Embankments**			
	1.5m	**3m**	**5m**	**6m**
1H:1V	0.845	0.806	0.519	0.573
1.5H:1V	0.922	0.889	1.016	0.868
2H:1V	1.397	1.157	1.157	1.375
2.5H:1V	1.493	1.457	1.457	1.528

From tables XII to XIV, for a given value of ϕ=30°, it is observed that the embankment of height 1.5m,3m,5m and 6m are stable for slope 2.5H:1V and flatter slopes whereas for steeper slopes the embankment is found to be unstable. It is also observed that for a particular height of embankment, factor of safety increases with increase in the flatness of the slope. It is also seen from these tables that for a given value of ϕ, there is no effect of increase in the value of dry unit weight of soil on the stability of slopes.

It is also noticed from tables IX to XIV that with increase in the value of ϕ from 29° to 30°, the factor of safety values increase which means more the value of angle of internal friction, more is the stability of slopes.

TABLE XV

Factor of Safety Values for Different Heights of Embankment with Variation of Slope for Cases C4. γ=18 KN/m^3, ϕ=36° and D1. γ=18 KN/m^3, ϕ=36°

Slope	**Factor of Safety values for different heights of Embankments**			
	1.5m	**3m**	**5m**	**6m**
1H:1V	1.064	1.014	0.728	0.722
1.5H:1V	1.160	1.119	1.278	1.092
2H:1V	1.695	1.456	1.456	1.730
2.5H:1V	1.879	1.833	1.834	1.923

TABLE XVI

Factor of Safety Values for Different Heights of Embankment with Variation of Slope for Cases C5. γ=20 KN/m^3, ϕ=36° and D2. γ=20 KN/m^3, ϕ=36°

Slope	**Factor of Safety values for different heights of Embankments**			
	1.5m	**3m**	**5m**	**6m**
1H:1V	1.064	1.014	0.728	0.722
1.5H:1V	1.160	1.119	1.278	1.092
2H:1V	1.695	1.456	1.456	1.730
2.5H:1V	1.879	1.833	1.834	1.923

TABLE XVII
Factor of Safety Values for Different Heights of Embankment with Variation of Slope for Cases C6. γ=22 KN/m^3, ϕ=36° and D3. γ=22 KN/m^3, ϕ=36°

Slope	Factor of Safety values for different heights of Embankments			
	1.5m	3m	5m	6m
1H:1V	1.064	1.014	0.728	0.722
1.5H:1V	1.160	1.119	1.278	1.092
2H:1V	1.695	1.456	1.456	1.730
2.5H:1V	1.879	1.833	1.834	1.923

From tables XV to XVII, for a given value of ϕ=36°, it is observed that the embankment of height 1.5m,3m,5m and 6m are stable for slope 2H:1V and flatter slopes whereas for steeper slopes the embankment is found to be unstable. It is also observed that for a particular height of embankment, factor of safety increases with increase in the flatness of the slope. It is also seen from these tables that for a given value of ϕ, there is no effect of increase in the value of dry unit weight of soil on the stability of slopes.

TABLE XVIII
Factor of Safety Values for Different Heights of Embankment with Variation of Slope for Cases D4. γ=18 KN/m^3, ϕ=41°

SLOPE	Factor of Safety values for different heights of Embankments			
	1.5m	3m	5m	6m
1H:1V	1.273	1.213	0.871	0.863
1.5H:1V	1.388	1.338	1.329	1.306
2H:1V	2.028	1.742	1.742	2.070
2.5H:1V	2.248	2.194	2.194	2.301

TABLE XIX
Factor of Safety Values for Different Heights of Embankment with Variation of Slope for Cases Case D5. γ=20 KN/m^3, ϕ=41°

Slope	Factor of Safety values for different heights of Embankments			
	1.5m	3m	5m	6m
1H:1V	1.273	1.213	0.871	0.863
1.5H:1V	1.388	1.338	1.329	1.306
2H:1V	2.028	1.742	1.742	2.070
2.5H:1V	2.248	2.194	2.194	2.301

TABLE XX
Factor of Safety Values for Different Heights of Embankment with Variation of slope For Case D6. γ=22 KN/m^3, ϕ=41°

Slope	Factor of Safety values for different heights of Embankments			
	1.5m	3m	5m	6m
1H:1V	1.273	1.213	0.871	0.863
1.5H:1V	1.388	1.338	1.329	1.306
2H:1V	2.028	1.742	1.742	2.070
2.5H:1V	2.248	2.194	2.194	2.301

From tables XVIII to XX, for a given value of ϕ=41°, it is observed that the embankment of height 1.5m,3m,5m and 6m are stable for slope 2H:1V and flatter slopes whereas for steeper slopes the embankment is found to be unstable. It is also observed that for a particular height of embankment, factor of safety increases with increase in the flatness of the slope. It is also seen from these tables that for a given value of ϕ, there is no effect of increase in the value of dry unit weight of soil on the stability of slopes.
It is also noticed from tables IX to XIV that with increase in the value of ϕ from 36° to 41°, the factor of safety values increase which means more the value of angle of internal friction, more is the stability of slopes.

V. CONCLUSIONS

The following conclusions are drawn from the above study:

1. For a particular height of embankment, factor of safety against slope stability increases with increase in the flatness of the slope.
2. For a given value of friction angle, there is no effect of increase in the value of dry unit weight of soil on the stability of slopes.
3. With increase in the value of friction angle, the factor of safety values increase which means more the value of angle of friction more is the stability of slopes.

4. In case of sandy soil embankment of heights 1.5m, 3m,5m and 6m, for the variation of friction angle from 37° to 38° and dry unit weight of soil from 18KN/m^3 to 22KN/m^3, it is observed that the embankment slope is stable for 2H:1V and flatter slopes.
5. In case of loose sand embankment of heights 1.5m,3m,5m and 6m, for the variation of friction angle from 29° to 30° and dry unit weight of soil from 18KN/m^3 to 22KN/m^3, it is observed that the embankment slope is stable for 2.5H:1V whereas for steeper slopes the embankment is found to be unstable.
6. In case of medium sand embankment of heights 1.5m,3m,5m and 6m, for the friction angle value of 30° and variation of dry unit weight of soil from 18KN/m^3 to 22KN/m^3, it is observed that the embankment slope is stable for 2.5H:1V whereas for steeper slopes the embankment is found to be unstable.
7. In case of medium sand and dense sand embankment of heights 1.5m,3m,5m and 6m, for the friction angle value of 36° and variation of dry unit weight of soil from 18KN/m^3 to 22KN/m^3, it is observed that the embankment slope is stable for 2H:1V and flatter slopes.
8. In case of dense sand embankment of heights 1.5m,3m,5m and 6m, for friction angle value of 41° and variation of dry unit weight of soil from 18KN/m^3 to 22KN/m^3, it is observed that the embankment slope is stable for 2H:1V and flatter slopes whereas for steeper slopes the embankment is found to be unstable.

REFERENCES

[1] IRC: 75-2015. *Guidelines for The Design of High Embankments*, New Delhi.
[2] Geotechdata.info, *Angle of Friction*, http://geotechdata.info/parameter/angle-of-friction.html (as of September 14, 2013).
[3] Geotechdata.info, *Dry unit weight*, http://geotechdata.info/parameter/soil-dry-unit-weight.html (as of August 29, 2013).
[4] Bishop, A.W. *The Use of Slip Circles in the Stability Analysis of Earth Slopes*. Geotechnique, pp.7-17, 1955, Vol.5.