Analysis of Railway Embankment under varying Sub Soil Conditions for Different Height of Embankments

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Abstract— The paper discusses the analysis of a railway embankment of different height varying from 4m to 20m for different types of natural soils. Five embankments of different height (4m,8m,12m,16m and 20m) are modeled as per RDSO guidelines and analysis is performed for four diifrent types of soils in natural ground while the property of soil used for the formation of embankment is same in all the cases The effect increase of height of embankment on the stability of slopes is studied. Also the effect of soil type on the stability of slopes is studied.in all the cases water table is assumed to be 10 m below the ground surface. it is found that increase in the height of embankment result in a decrease of factor of stability. Also the factor of safety is very low for soft clay. for cases where f.o.s is less than 1.4 provision of retaining are analysed after provision of retaining wall and also with an increment of their slopes.

Key words: Bishop's Method, Factor of Safety, Slope Stability Analysis, High Level Railway Embankment, Geostudio2004

I. Introduction

Indian Railways is an Indian state-owned enterprise, owned and operated by the Government of India through the Ministry of Railways. It is one of the world's largest railway networks comprising 115,000 km (71,000 mi) of track over a route of 65,436 km (40,660 mi) and 7,172 stations. Such a large rail network passes from different terrain and soil profiles. In hilly terrain or waterlogged area, railway line is normally raised onto an embankment made of earth to avoid a change in level required by the terrain. When a track passes from poor soils, such as the clays or silts of high plasticity and compressibility, a flat slope is needed. In this paper, analysis of a embankments of under following situations is discussed (1) four different types of materials are used as a natural ground material (2) five embankments of different heights are modeled and effect of height is studied (3) Further, if factor of safety in any case falls below 1.4 the probable solution by providing retaining wall and the analysis of stability in this case is presented.

II. Railway Guidelines for Design and Construction of Slope

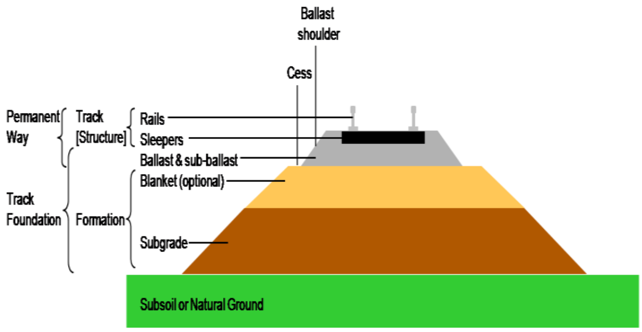

Fig. 1: Typical Cross-section representing Formation Components (http://en.wikipedia.org/wiki/Track_bed).

A few commonly used terms used in railways are mentioned through Fig.1.

RDSO Guidelines for embankment construction, useful in present discussion and analysis, are briefly mentioned below.

1) The soils unsuitable for embankment construction are Organic clays, organic silts, peat, chalks, dispersive soils, poorly graded gravel and sand with uniformity coefficient less than 2,
2) Clays and silts of high plasticity (CH and MH) in top 3m of embankment are not suitable.
3) The poor sub soils are those which have undrained shear strength less than 25 kPa, loose sand strata having N value less than 5, and Ev2 (Elastic Modulus of 2nd plate load test) less than 20MPa.
4) Removal and replacement of weak soil if undrained shear strength is less than 20 kPa or CBR<3. Removal of unsuitable material and replacement with suitable fill, preferably well compacted coarse-grained/ sandy soil, may be carried out.
5) Change the alignment from poor soil site is a most economical option. If it is not possible, then if natural soil of shallow depth is poor, so replacement is better option rather than improvement of soil.
6) A few of the techniques to improve the engineering properties of the soft subsoil are as follow - (a) Preloading, (b) Vertical drain, (c) Stone column,(d) Geosynthetics, (e) Dynamic consolidation
7) Material for construction: Construction of embankment is to be carried out normally with soil available in nearby area, if required soil properties are not available then Mixed Type of Soils may be used. Different types of fill materials, if used; they should be deposited and thoroughly mixed to get approximately homogeneous character of sub-grade. Soils for construction of embankment consist of cobbles, boulders, rock or waste fragments etc., largest size of material should normally not be greater than 2/3rd of the loose layer thickness. However, it should be ensured that after every one to three meter of such construction, a 30 cm layer of properly compacted soil (other than soils in unsuitable category) be provided.

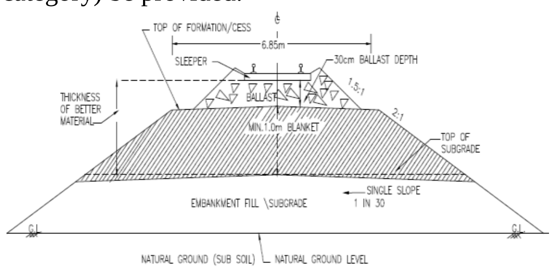

Fig. 2: Typical cross section of Current permanent way

8) Formation Width**:** Currently, the standard width of formation of embankment is 6.85 m for single BG line (Fig.3). However, for new BG track recommended width is 8.5 m for single line and minimum 13.5m for double line tracks.
9) Blanket layer and sand layer: Blanket layer should be coarse, granular, and well graded material with uniformity coefficient Cu > 4 (preferably > 7) and coefficient of curvature Cc should be within 1 and 3 used in top 1m of embankment. Sand layer of 20 to 30cm at every 2 to 3m for soil having permeability coefficient, K value less than or equal to 10-2 cm/Sec are used with slope of 1in 20 in transverse direction of track as shown in Fig. 3 as per GE: G-1, 2003

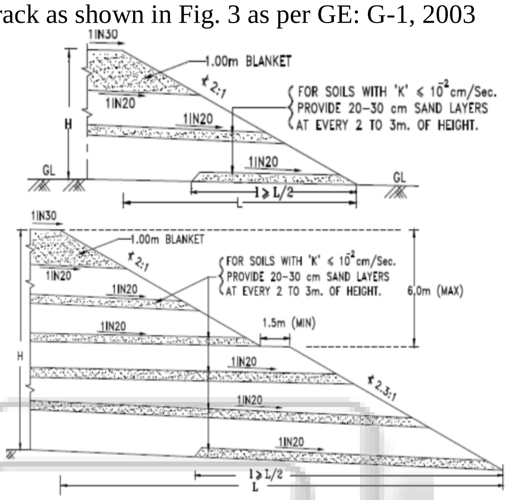

Fig. 3: Typical Embankment profile for sandwich construction with cohesive soil for height up to 6m and 6 to 12m

10) Protection of slope**:** For banks higher than 4.5 meters, suitable slope stability analysis, reinforcement of slopes, plantation of deep root grass and toe wall construction shall be suitably adopted.

In case of high bank on soft sub-soil, flatter slope with berm/sub-bank should be provided after slope stability analysis. Adequate erosion control measures on slopes of bank and cutting should be ensured by vegetation on slopes with deep-rooted Vetiver grass and geo-jute textile, if necessary.

In areas susceptible to flooding, the sides of an embankment should be protected with a layer of rock fill or stones with an intermediate granular layer up to 1 m above HFL.

At locations, where water table is high and fill-soil is fine-grained, it may be desirable to provide a granular layer of about 30 cm thickness at the base, above sub-soil across the full width of formation. Boulder pitching should be done on embankment slope

11) Design of Side Slope of Embankment: As per GE: G-1, 2003, for construction on poor subsoil/with poor soil, slope-stability analysis has to be carried out in detail in following cases.
   - When subsoil is soft, compressible and marshy type for any depth.
   - When subgrade soil (fill material) has very low value of cohesion ' C' ', such that C'/γH (where H is height of embankment and γ is bulk density of soil) is negligible, i.e., in range of 0.01 or so.
   - In situations where mixed type of soil has been used.

Slope stability analysis should be carried out to design stable slopes for the embankment. Usually, slopes of 1V: 2H of embankment up to height of 6.0 m would be safe for most of the soils. However, stability analysis has to be carried out for above 6.0m height in detail.

The analyses should be carried out with Bishop's simplified method, using shear strength parameters. Preferably with Slope 'W' Software (RDSO, GE: G-6).

12) Pressure on Formation and sub-soil**:** The maximum pressure on formation at bottom of sub-soil should not generally exceed 0.1MN/m^2 or 1 kg/cm^2, as per RDSO GE: 0014, 2007 shown in Fig. below

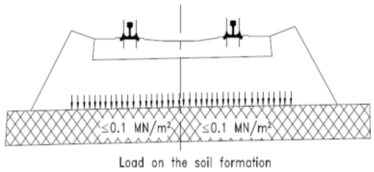

Fig. 4: Pressure on formation

13) Factor of safety: As per GE: G1, 2003 factor of safety of 1.4 should normally be adopted against slope failure. End of construction stage, when pore water pressure dissipates partially, a minimum factor of safety of 1.2 can be allowed to achieve economy but without sacrificing safety for long term – stability. Moving train loads need not be considered in the slope stability analysis for embankments. Overstressing zones in soil mass due to live loads would affect the slope stability adversely because bearing capacity failure mechanism gets mixed up with slope failure mechanism. Hence, minimum FOS of 1.6 should be ensured for slope stability of smaller embankments of height up to 4m.

III. PRESENT STUDY

In the present study, the analysis of soil slope using geostudio2007 have been carried out.FIVE embankments OF HEIGHT 4M, 8M 12m,16m, 20 m has been modeled. the model of the slope is composed of two regions- (1) natural ground soil (2) embankment soil. The side slopes of the embankment has been modeled as per RDSO guidelines and taken as 2H:IV UPTO A HEIGHT OF 4M and a slope of 2.3H:1V for a height a greater than 4m.A berm of 2m is provided after every 6m depth of embankment.A surcharge load of 100kn/m2 has beed applied on the top of embankment.water table is kept at a constant depth of 10m from the top of natural ground level. The natural ground soil has been changed varying from stiff clay, soft clay, dense sand and finally loose sand, each soil having different properties hwere as the properties of embankment soil remains same for all the cases.

Soil properties considered for the present work [Choudhury et al. (2008) & Bowles (1997)]

Properties	Ground Soil				Embankment Soil
	Stiff clay	Soft clay	Dense sand	Loose sand	
Unit weight [γ] (kN/m^3)	17.3	14.2	18.4	14.7	19
Cohesion	75	30	5	5	70

[c] (kPa)					
Friction angle [ϕ]	5°	5°	40°	30°	6°

Table 1: Properties

IV. RESULTS AND DISCUSSIONS

The results of the analysis have been obtained in terms of factor of safety for various type of soils and different height of embankments. four different cases representing different ground soil conditions are tabulated below. Also a graph of each case showing the variation in factor of safety with height is plotted.

A. *Case 1:*

When ground soil is stiff clay-

Case no.	Sub Grade Soil	Embankment soil	Height of Embankment	FOS	Gwl at ground level	Gwl 2m below ngl
1	**Stiff clay** $\gamma = 17.3\ kN/m^3$ $c = 75\ kN/m^2$ $\phi=5^o$	$\gamma=19\ kN/m^3$ $C=70\ kN/m^2$ $\phi=6^o$	4	3.239	3.150	3.200
			8	2.607	2.543	2.579
			12	2.049	1.982	2.010
			16	1.799	1.743	1.765
			20	1.573	1.503	1.522

Table 2: When ground soil is stiff clay

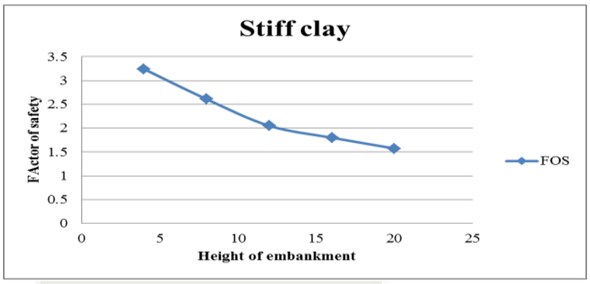

Fig. 1: When ground soil is Stiff Clay

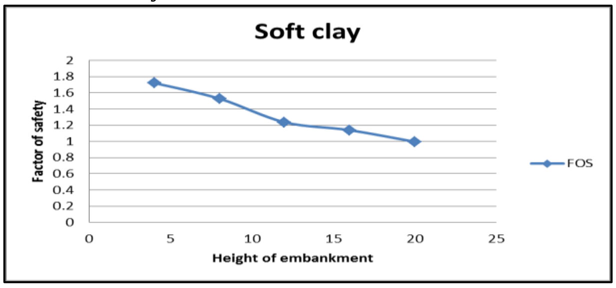

Fig. 2: When Ground Soil is Soft Clay

B. *Case 2:*

When ground soil is soft clay-

Case no.	Sub Grade Soil	Embankment Soil	Height of Embankment	FOS 10 m below ground level	Gwl at ground level	Gwl 2m below ngl
2	**Soft clay** $\gamma=14.2\ kN/m^3$ $C=30\ kN/m^2$ $\phi=5^o$	$\gamma=19\ kN/m^3$ $C=70\ kN/m^2$ $\phi=6^o$	4	1.722	1.633	1.683
			8	1.528	1.463	1.499
			12	1.237	1.167	1.196
			16	1.139	1.081	1.104
			20	0.995	0.923	0.944

Table 3: When Ground Soil is Soft Clay

C. *Case 3:*

When ground soil is dense sand-

Case no.	Sub grade soil	Embankment soil	Height of embankment	FOS	Gwl at ground level	Gwl 2m below ngl
3	**Dense sand** $\gamma=18.4\ kN/m^3$ $C=5\ kN/m^2$ $\phi=40^o$	$\gamma=19\ kN/m^3$ $C=70\ kN/m^2$ $\phi=6^o$	4	2.684	2.265	2.684
			8	2.526	2.088	2.445
			12	2.349	2.028	2.266
			16	2.230	2.048	2.230
			20	2.019	1.975	2.019

Table 4: When Ground Soil is Dense Sand

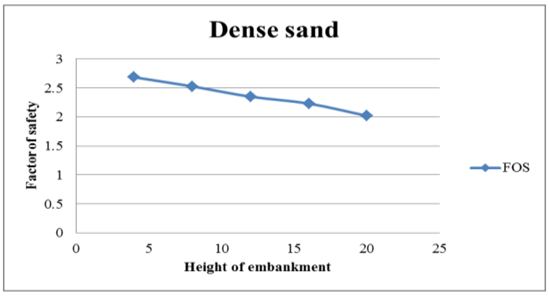

Fig. 3: When Ground Soil is Dense Sand

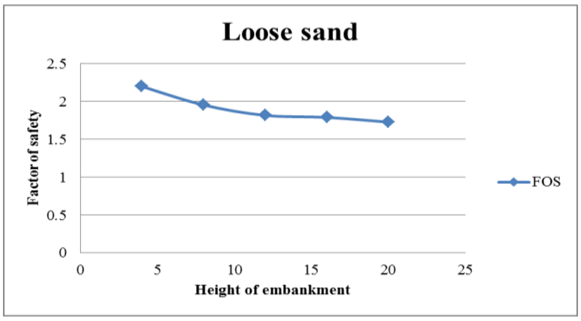

Fig. 4: When Ground Soil is loose sand

D. *Case 4:*

When ground soil is loose sand-

Case no.	Sub grade soil	Embankment soil	Height of embankment	FOS	Gwl at ground level	Gwl 2m below ngl
4	**Loose sand** γ=14.7 kN/m^3 C=5 kN/m^2 ϕ=30°	γ=19 kN/m^3 C=70 kN/m^2 ϕ=6°	4	2.199	1.651	2.006
			8	1.954	1.514	1.762
			12	1.817	1.594	1.758
			16	1.790	1.625	1.751
			20	1.728	1.503	1.626

Table 5: When ground soil is loose sand

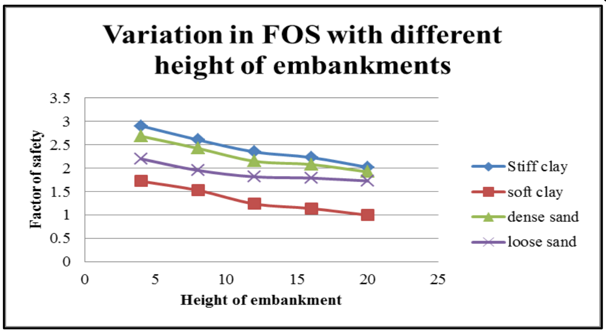

Fig. 5: Variation in FOS

V. SUMMARY AND CONCLUSIONS

This paper illustrates the behavior of railway embankments for various types of soils.It can be observed that stiff clay and dense sand gives higher value of factor of safety for any given height of embankment compared to loose sand and soft clay. Also soft clays gives factor of safety below 1.4 for height of embankment greater than 12 m rendering use of soft clay unfit for these cases. For such cases we can either use a retaining wall or increase the slope of embankment.use of retaning wall is advised in case of land restrictions. reinforcinment of soil using geosynthetics and sheet pile can also be done.

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