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Stability analysis of reinforced earth wall for the approach road of a R.O.B along National Highway: A case study

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Abstract: *Soft ground usually possesses low shear strengths and high compressibility. Reinforced earth (RE) wall is constructed on this soft ground have a tendency to fail. In literature stability of this reinforced earth wall is improved by providing geo-grid reinforcement. In the present paper stability analysis of a highway embankment is presented. The proposed highway embankment is provided along the approach on either side of bridge. The maximum height of embankment is 7m and its stability is a concern. In the preset study modeling and stability analysis of the embankment at typical sections is computed using slope/W using Morgenstern price method. Results of lab tests on subgrade and stability results are presented. It is observed that, the stability is improved using geosynthetics provided near slope face and at base. Parametric study is carried out by varying tensile capacity of geo-grid, number of layers and their influence on stability is quantified and presented.*
Keywords: *soft subgrade, reinforced earth wall, geo-grid reinforcement, factor of safety.*

I. Introduction

Reinforced Soil concept described the mechanisms by which reinforcement could improve the performance of embankments on soft soil. (Jewell 1987) The behaviour and design of geosynthetic-reinforced embankments over soft soil have attracted considerable attention in both practice and the literature. Among geosynthetics, grid type geosynthetics reinforcements were found to be more effective than the sheet type reinforcement. For unreinforced embankment (Low 1989) presented the solutions for critical slip circle, minimum factor of safety for a given limiting tangent. By modifying (low 1989) equations Kaniraj and Abdullah (1993) presented the simple solutions for effect of berm and full height dry tension crack on stability of embankment is done by analytical approach. Kaniraj and Abdullah (1992b, 1994) presented the solutions for critical slip circle, minimum factor of safety and maximum reinforcement capacity required for a given limiting tangent. Several techniques have been developed for the safe and cost-effective construction of embankments over soft soil deposits. Geosynthetic basal reinforcement is simple technique for easy construction and suitable type with less cost of construction. Reinforcement may be placed at foundation level (basal layer) to prevent shear failure both in the embankment fill and in the foundation soil. Reinforcement in the form of geogrid, geocell, geotextiles etc, can be placed in the embankments at designed spacing to improve the strength of the embankments.

II. Details Of Study Area And Problem Statement

The study area of proposed rail over bridge (ROB) is located at Bendigate near Palasa, Srikakulam district; A.P is shown in "Fig.1". In the present study the subgrade soil is weak to bear the load coming in to the subgrade for construction RE wall as approach of ROB. to sustain the load coming on to the subgrade So improvement is suggested and stability analysis is carried out in slope/w for critical sections on either side i.e., H=6.8m towards Visakhapatnam side is shown in "Fig.2" and H=5m towards Palasa side is shown in "Fig.3".

2.1 Data collection and details of experimental study

a) Soil sample collection

Soil sample is collected from the site of construction proposed rail over at Bendigate near Palasa, Srikakulam district; A.P is shown in "Fig.4", is the subgrade soil and the RE wall fill soil also collected.

b) Tests conducted on soil sample

Tests for index and engineering properties namely gradation, consistency limits, compaction charecterstics and shear strength parameters and CBR are performed on subgrade soil and embankment fill. Results are presented in the subsequent headings.

Fig. 1 Project site marking image

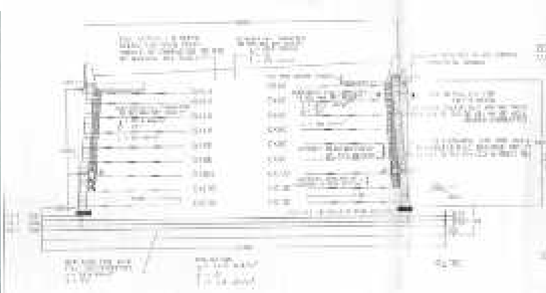


Fig. 2.Cross section towards Palasa

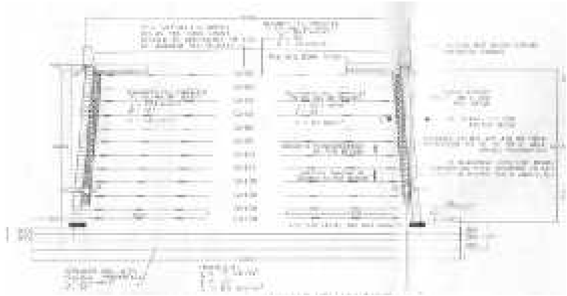


Fig.3.Cross section towards Visakhapatnam

Fig.4.The author is collecting soil sample

2.2 Stability Analysis for RE wall

Stability analysis is carriedout using slope/W software. The method is based on Morgenstern price theory. The crtical slip circle is identified from global stability and factor of safety is computed. The slip circles are generated for various input parameters namely., geodrid tensile capacity and number of layers.Analysis is done for critical slip circle with minimum factor of safety by adjusting slip surface grid is shown in “Fig.12-16” and “Table 7-8”.

III. Results And Discussions

3.1 Presentation of results on subgrade and embankment fill soil

The results are presented from “Table 1- 2” and “Fig. 5-11”

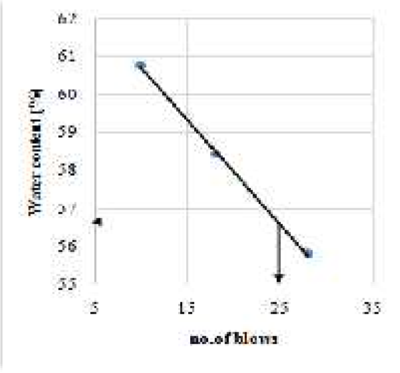


Fig. 5 Flow curve for subgrade sample

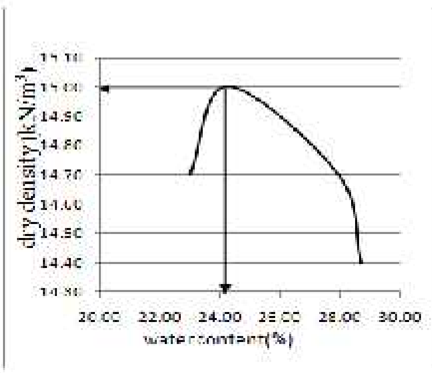


Fig. 6 Compaction test graph for subgrade

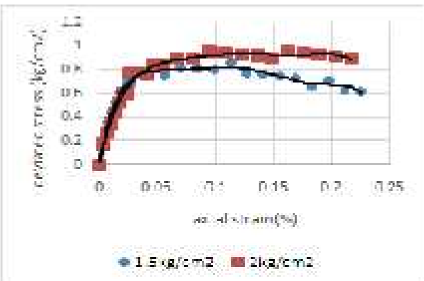


Fig. 7 Triaxial test performed on subgrade soil for two cell pressures

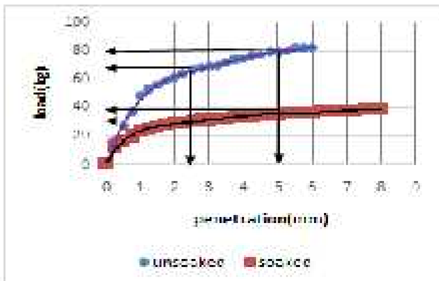


Fig. 8 CBR test performed

Table 1 Test results of subgrade soil

Parameters	Results
Liquid limit	56.5%
Plastic limit	28.63%
Plasticity index	27.87%
USCS Soil classification	CH
Optimum moisture content	24.25%
Maximum dry density	14.95 KN/m^3
Cohesion (c)	19.6kPa
Angle of internal friction (ϕ)	6.6 degrees
CBR unsoaked	4.83%
CBR soaked	2.18%

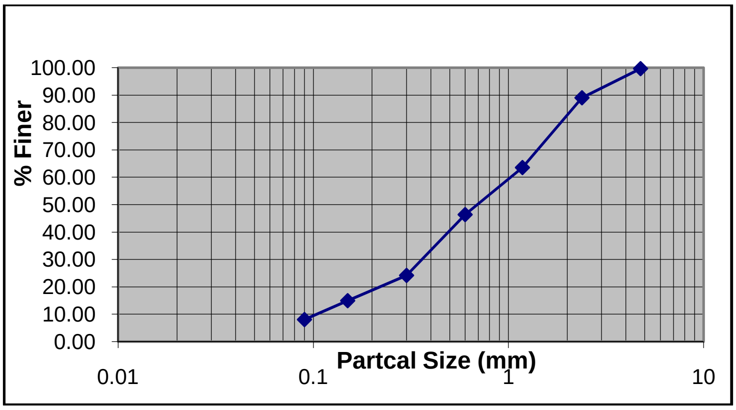


Fig. 9 Grain size distribution curve for embankment fill soil

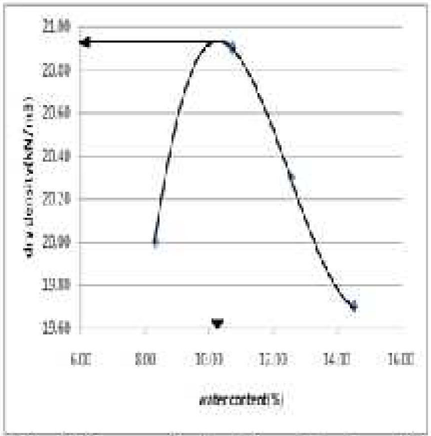


Fig. 10 Compaction test for embankment fill soil

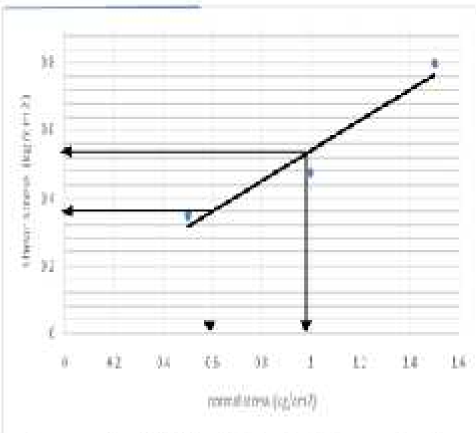


Fig. 11 Direct shear test for embankment fill soil

Table 2 Test results of embankment filling soil

Parameters	**Results**
Soil classification	SW
Optimum moisture content	10.73%
Maximum dry density	20.9 KN/m^3
Cohesion(c)	9.1 kPa
Angle of internal friction (Ø)	24.20^0

3.2 Modelling and stability analysis

Table 3 Geometry and Properties for RE wall @5m cross-section

Properties		H_g(m)	γ (kN/m^3)	C kPa	Ø (^{0})
Ground	Layer-1	1.2	14.95	19.6	6.6
	Layer-2	10	20.9	9.1	24.20
Fill		5.0	20.9	9.1	24.20

Table 4 Reinforcement properties for RE wall @5m

Parameters	Results
Type	Geogrid
No. of layers	3
Location	In the filled layer below embankment at depth 0.3, 0.6, 0.9m respectively
Length L_r	16.4m
Tensile capacity T_{ult}	300kN/m
Interface friction Ø	2/3Ø

Table 5 Geometry and Properties for RE wall @7m cross-section

Properties		H_g(m)	γ (kN/m^3)	C (kN/m^2)	Ø (^{0})
Ground	Layer-1	1.6	14.95	19.6	6.6
	Layer-2	10	20.9	9.1	24.20
Fill		6.8	20.9	9.1	24.20

Table 6 Reinforcement properties for RE wall @7m

Parameters	Range
Type	Geogrid
No. of layers	2 to 4
Location	In the filled layer below embankment at depth 0.4, 1.2m respectively
Location	In the filled layer below embankment at depth 0.3, 0.8, 1.3m respectively
Location	In the filled layer below embankment at depth 0.35, 0.65, 0.95, 1.25m respectively
Length L_r	16m
Tensile capacity T_{ult}	300 - 500kN/m
Interface friction Ø	2/3Ø

Presentation of results of slope stability

The modeled RE wall, global stability analysis and slip circles are presented in "Fig.12-15". The results are presented in "Table.7". The slip circles indicated a factor of safety 1.672, 1.315, 1.329 which is satisfying the norms. Also the contribution of geosynthetic at base is significant. From the results is observed optimum number of layers are three.

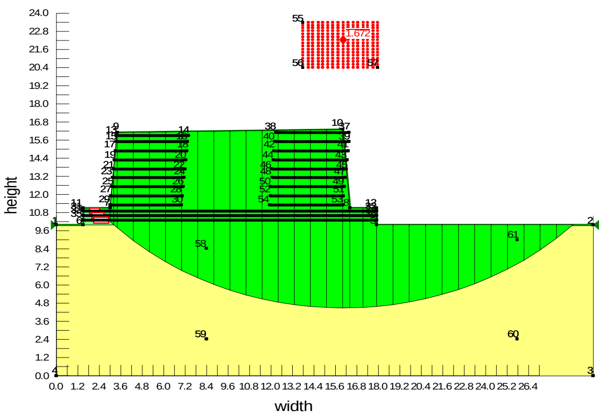


Fig .12 Modelling of reinforced earth wall Palasa and slip circle

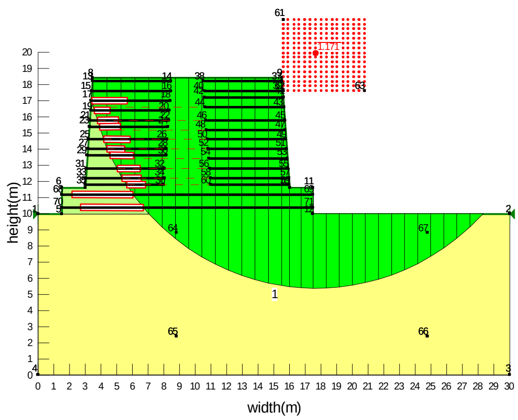


Fig .13 Modelling of reinforced earth wall towards towards Visakhapatnam and slip circle

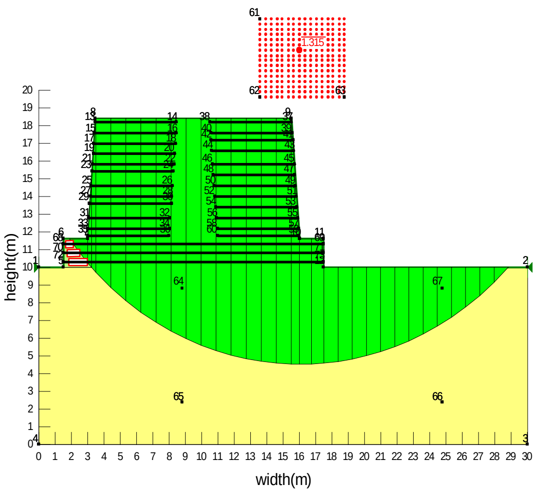


Fig .14 Modelling of reinforced earth wall towards Visakhapatnam and slip circle

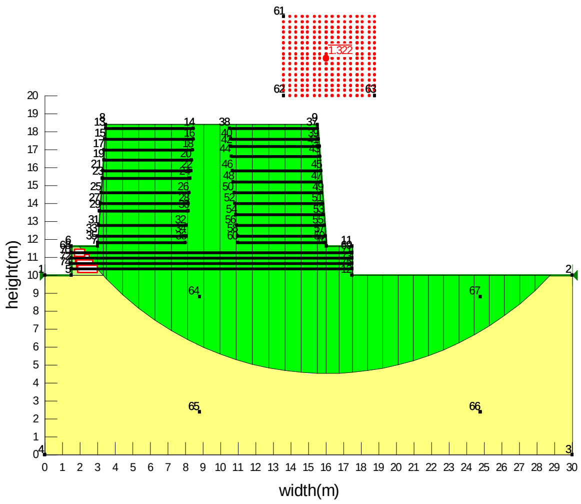
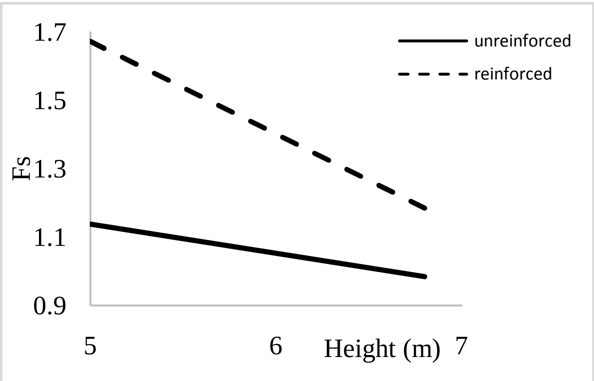


Fig .15 Modelling of reinforced earth wall towards Visakhapatnam and slip circle

Table 7 Presentation of Fs of slope stability for reinforced earth wall

He	No. of layers	Factor of safety		
		T=300 kN/m	T=400kN/m	T=500kN/m
5m	3	1.672	-	-
7m	2	0.846	1.008	1.174
7m	3	1.098	1.315	1.315
7m	4	1.329	1.329	1.329



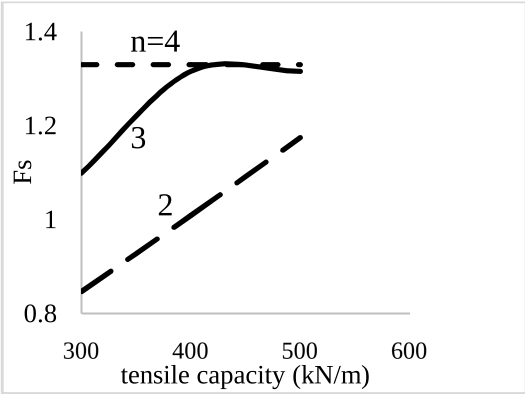


Fig.16 Variation of Fs with H: effect of reinforcement **Fig.17 Variation of Fs with Tult: effect of reinforcement no. of layers of for (H=7m)**

Variation of Fs with H is shown in Fig-16, as the height of RE wall increases factor of safety decreases from 1.672 to 1.184 in reinforced case and in unreinforced case it is dropped from 1.138 to 0.984. The results indicated the need for provision of reinforcement. From the slip circle rupture failure is noticed for the bottom layers.

Variation of Fs with reinforcement is shown in “Fig.17”, as the reinforcement capacity increases Fs increases. marginally but in case of no. of layers 4 the increase of reinforcement also there is no change in Fs. In case of 3 layers the increase of Fs is more compared to other layers.

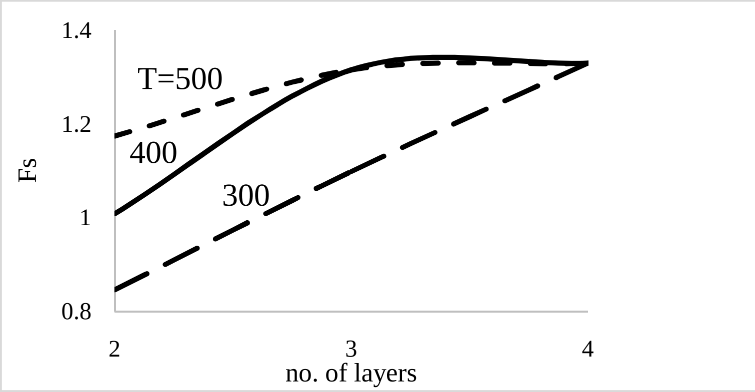


Fig.18 Variation of Fs with no. of layers: effect of reinforcement for (H=7m)

Variation of Fs with no. of layers is shown in "Fig.18", as the no. of layers increase Fs increases.

IV. Conclusions

The modeled RE wall and analysis will help in understanding failures before construction is taken up. The contribution of reinforcement in improving stability is significant. There is an improvement of 1.2 to 1.5 in Fs with reinforcement. Higher tensile capacities are recommended for Higher Fs requirement.

Since loading from RE wall self weight is dominant for 7m high, as expected Fs is low when compared with 5m high RE wall. Providing higher grade reinforcement may solve stability problems for high RE walls. By observing the results of Fs with no. of layers 4 layers 300kN/m is very small increase in Fs compared to 3 layers 400kN/m so the optimum no. of layers provided is three.

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