Global Stability Analysis of Reinforced Earth Wall Using Basal Reinforcement

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Abstract- *The analysis of global stability of retaining structures has become a crucial aspect to consider before construction. Global stability relies on geometry of soil and is primarily dependent on soil conditions.Geotextiles with high tensile strength can contribute to the load carrying capacity of soil that is poor in tension and good in compression and thus help improve global stability of structures.*

This project is focusses on improving the safety factor of the reinforced earth wall by providing ParaWeb Geogrids between the soil layers as reinforcement and conducting a Global Stability Analysis on Slide 5.0 software. The model is designed on the slope stability software that depicts 8 layers of soil having different soil properties. ParaWeb Geogrid strips are provided between two walls and compacted after each layer. Each strip is having a specific tensile strength and is on a measured height. On the top-most layer of the soil, a Uniformly Distributed Load (UDL) is applied a basal reinforcement is placed at the bottom. The research paper shows how the safety factor can be improved by changing the tensile strengths of reinforcements in an earth wall so as to make it safe for construction and thus, save the structure from unforeseeable hazards.

Keywords- Global Stability analysis, reinforced earth wall, geogrids, geotextile, safe bearing capacity, basal reinforcement, retaining structures.

I. INTRODUCTION

The behavior and design of geosynthetic-reinforced embankments and other retaining structures 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. Use of geosynthetic materials like geogrids, geocells, geomembranes, etc. for reinforcing purposes allows us to replace the massive concrete retaining walls with reinforced earth structures that have numerous advantages in realization of the structure on soft soils having low bearing capacity. Reinforced earth structures also resist the differential settlement very well. Design of such structures include verification of global and internal stability checks.

Basically, there are three types of slope failures in the field of geotechnical engineering. Rotational slips (circular and non-circular), translational slips, and compound slip. The rotational soil failure solely depends on geometrical arrangement of soil and other factors of soil due to its geographic location. Rotational soil failure occurs behind and beneath the fall, therefore, global stability analysis is important before construction.

Geogrids

Early, in 1982, Frank Brian Merce invented geogrids. Later, geogrids were popularized among engineering community by a conference held at the United Kingdom in the year 1984.Geogrids are manufactured under three different processes like extruding, knitting or weaving, and by welding and extrusion. Based on the direction ofstretching, the geogrids are grouped as uni-axial, bi-axial and tri-axial geogrids. Use of geogrids category in structural applications gives promising results in terms of strength and durability. In particular, geogrid reinforcements in structural components is a new technology which increases the overall behavior of structure in terms of improved load carrying capacity and reduced deflection.

Slide 5.0

Slide 5.0 is a comprehensive slope stability analysis software. It has the capability to determine slope failures by using probabilistic approach and analyzing different scenarios. In this project, this software has been used to calculate the global minimum of a slope and determine the factor of safety of a retaining structure. A wide range of parametric analysis can be done.

II. MATERIALS AND THEORY

Model

The model of this project, as shown in the figure, has layers of soil having different properties. There are two walls and between them are ParaWeb geogrids of different lengths and tensile strengths at specific heights. These layers are compacted with RS fill material after laying each geogrid strip.

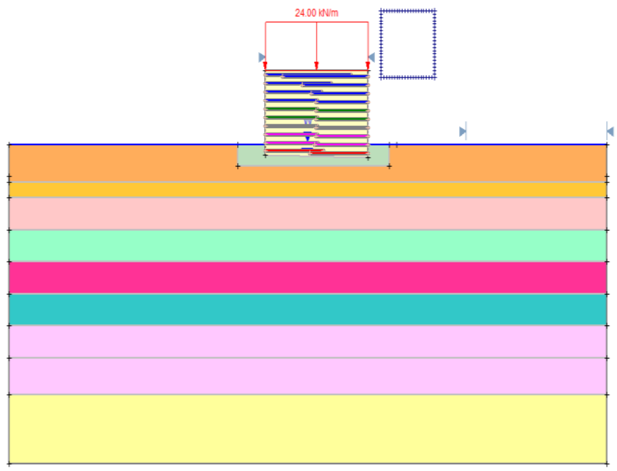

Figure 1 Model

The geogrid strips have hooks on either sides and pinned to the walls from both ends. Height of Reinforced Earth wall is 8 meters.

Soil Properties

As we can see in the model above, there are 8 layer of soils. The following table showsunit weight, cohesion, and friction of all the soil layers.

Table 1 Soil Properties

Soil	Unit Weight(kN/m³)	Cohesion (kPa)	Friction Angle
Soil 1	20.31	52	0
Soil 2	20.31	52	0
Soil 3	20.75	142.38	0
Soil 4	20.38	61.5	0
Soil 5	20	0	24
Soil 6	20	0	26
Soil 7	21.21	158.06	0
Soil 8	20.11	142.04	0

Table 2 Soil Type

Soil No.	Soil Type
1	Reddish Brown Silty Clayey sand with Moorum
2	Reddish Brown Silty Clayey sand with Moorum
3	Reddish Brown Silty Clayey sand with traces of Moorum
4	Reddish Brown Silty Clayey sand with Moorum
5	Mottled brown silty sandy clay with rusty brown silt spots
6	Mottled brown silty sandy clay with rusty brown silt spots
7	Mottled yellow silty sandy clay with rusty brown silt spots
8	Mottled brown silty sandy clay with rusty brown silt spots

Generally, clays are naturally occurring material primarily composed of fine-grained minerals, show plasticity when mixed withappropriate amount of moisture and become hard when dried or fired. Das indicated the characteristics of clay, which included:[2]

a) Small particle size (usually smaller than 0.002 mm)
b) Net negative charge
c) Show plasticity when mixed with moisture

ParaWeb Geogrid Strips

ParaWeb strips that are used are having planar structures and consists of a core made of high tenacity polyester yarn tendons wrapped in a sheet of polythene. The strips are manufactured primarily for reinforcement applications in combination with concrete wall facing panels.

Figure 2 ParaWeb Geogrid

Each geogrid strip attached and compacted in layers have the following tensile strengths.

Table 3 ParaWeb Tensile Strength

ParaWeb Strip Layer	Tensile Strength (kN/m)
P75	837.78
P60	670.22
P50	558.55
P40	446.67
P30	354.82

Table 4 ParaWeb Strip Lengths

P.WEB/Ht. of RE Wall	**8 Meters**		
	P. WEB	**n**	**Length (m)**
	P75	2	6.80
	P60	2	6.20
	P60	2	6.10
	P50	2	6.10
	P50	2	6.10
	P40	2	6.10
	P40	2	6.10
	P30	2	6.10
	P30	2	6.60
	P30	2	7.70
	P30	2	10.00
Required Min. SBC (kN/m^2)	**289.76**		

Basal Reinforcement

The ParaWeb reinforced wall rests on a replacement soil having a better bearing capacity. The depth of replacement soil is 2 meters. At the bottom, basal reinforcement is provided to avoid differential settlement of the earth wall. Safety factor of the structure depends upon the tensile strength of geotextile material provided as basal reinforcement. The two bottom-most layers shown in the figure 3 shows basal reinforcement.

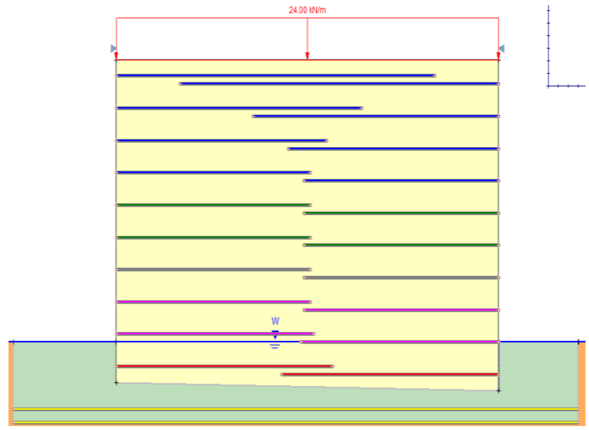

Table 5 Basal Reinforcement

III. CALCULATIONS

Safe Bearing Capacity

All calculations are carried out as per Indian Standards (IS) 6403-1981.

Maximum Design Section = 8 m
Carriage way width = 12 m
Dead Load(DL) + Live Load(LL) = 24 kN/m
Block width, B = 6.8 m
Eccentricity, e = 0.71 m
Effective width, B-2e = 5.38 (As per BS-8006)
Pressure at base of wall= 289.76 $kNmm^2$
Required q_{safe} = 28.976 t/m^2

Following are the shear parameter of the soil of the top layer.

C = 35.0075 kN/m^2(Considering 2/3 C)
F = 0^o(Considering {tan-1(0.67tanΦ)})
g = 20 kN/m^3
D_f = 1 m
For F = 0^o
Nc = 5.14
Nq = 1.0
Ng = 0.0

Depth Factor:

dc =1+ 0.2(Df/B) (N_F)1/2 = 1.0372
dq = dγ=1 for F<100
dq = dγ = 1+0.1(Df/B) (Nø)1/2 for Ø>100
= 1.0000

Shape Factor:

Sc = Sq = Sγ = 1 (For Strip Footing)
Inclination Factor:

$i_c = i_q = i_\gamma = 1$ (For vertical Wall)

$q_{ult} = C\, N_c S_c d_c i_c + q(N_q-1) S_q d_q i_q + 0.5\, g\, B'\, N_\gamma S_\gamma d_\gamma i_\gamma\, W'$

$= 186.63\ kN/m^2$

$q_{safe} = 138.2\ kN/m^2 = 13.82\ t/m^2$

Factor of Safety (FOS) = 1.35

q_{safe} is less than required value. Therefore, it is UNSAFE.

The following figure represents the required factor of safety for reinforced earth walls.

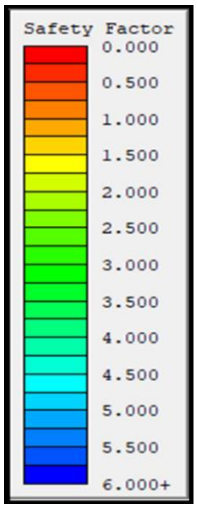

Figure 3 Safety Factor Chart

IV. ANALYSIS

The global stability analysis of the model is done on a slope stability software, Slide 5.0. The software analyses the model of the RE wall as per soil conditions, soil reinforcement tensile strengths, and tensile strength of basal reinforcement. It gives the global minimum, that is, factor of safety by analyzing all the slip circles.

Without basal reinforcement

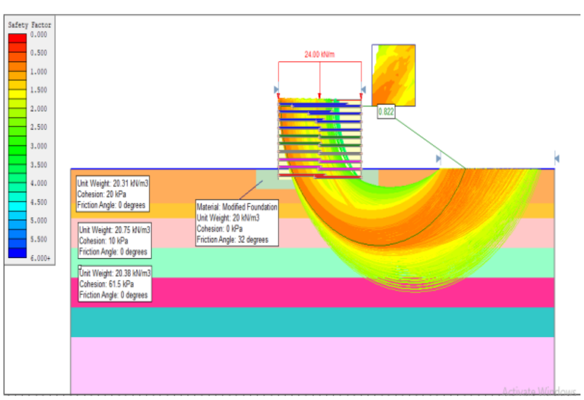

Figure 4 Without Basal Reinforcement

When the basal reinforcement layer in the replacement soil is completely removed, the factor of safety is **0.822**. As we can see in the figure above, the pale yellow color of numerous slip circle shows that the RE wall is not safe.

Factor of safety of 0.822 also defines that the global minimum of all the analysed rotational slip circles.

One Layer of 25 kN/m

Further, if we provide one layer of basal reinforcement having tensile strength of 25 kN/m, the safety factor increases to **0.857**.

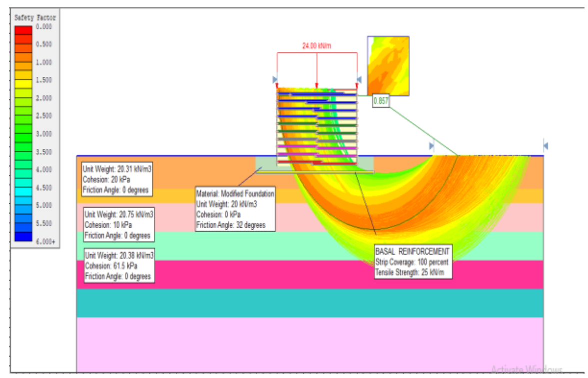

Figure 5 Basal Reinforcement - 1 Layer - 25 kN/m

One Layer of 100 kN/m

The FOS increases further to **0.960** when the tensile strength of basal reinforcement is increases, as shown below.

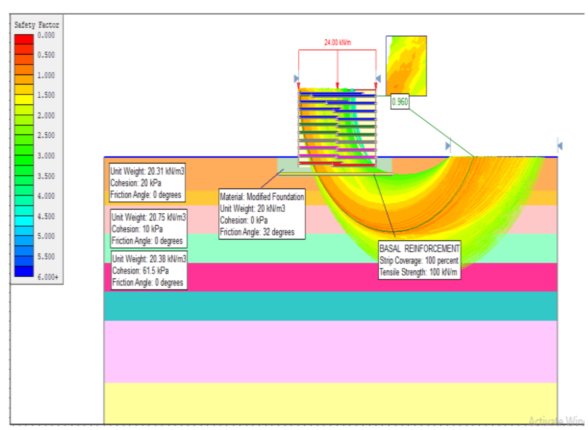

Figure 6Basal Reinforcement - 1 Layer - 100 kN/m

Two Layers of 100 kN/m

The structure is starting to become safe as we increase the tensile strengths and simultaneously the number of layers of basal reinforcements. The FOS has further increased to **1.093** when two layers of basal reinforcements having 100 kN/m tensile strengths each are added.

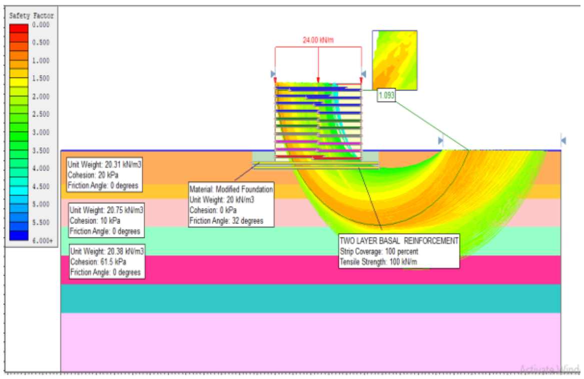

Figure 7 Basal Reinforcement - 2 Layers - 100 kN/m

Two Layers of 200 kN/m

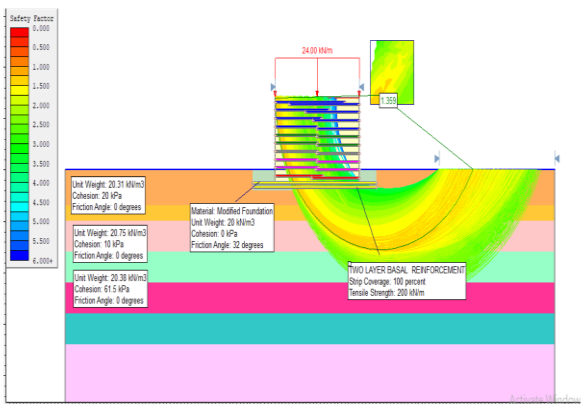

Figure 8Basal Reinforcement - 2 Layers - 200 kN/m

Improved FOS

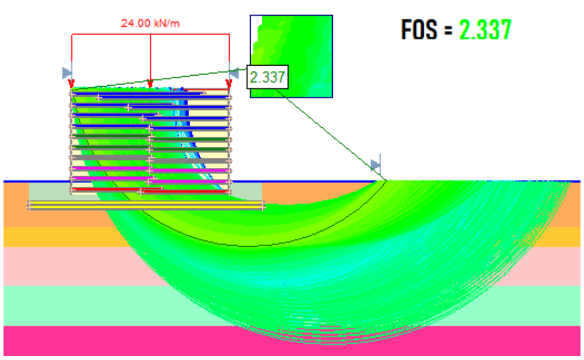

Figure 9 Improved FOS

V. RESULTS& CONCLUSION

The Reinforced Earth wall modeled in Slide 5.0 slope stability analysis software will help in understanding slope failures before construction starts. The contribution of geotextiles and geogrids used as reinforcing agents in soil is very significant. Among lakhs of slip circles, as depicted in interpretation images, the software accurately determines the lowest Safety Factor, that is, Global Minimum.

Tensile strength of basal reinforcement and safety factor are directly proportional to each other. When the basal reinforcement was removed and the wall was resting on replacement soil, the factor of safety was 0.822. As per BS 8006-1:2010, minimum factor of safety should be 1.3, therefore, there was a necessity of basal reinforcement having a high tensile strength so as to make the structure stable. Adding a PET High Strength woven geotextile of 25 kN/m tensile strength increased the bar of safety factor from 0.822 to 2.337.

Alternatively, the experiment also articulated that providing two basal reinforcements of 100 kN/m or 200 kN/m each will let us achieve the required safety factor.

Basal reinforcement not only helps to stabilize the structure by increasing the layer of high tensile strength but also enhances uniform settlement of the soil in foundation.

Providing higher grade reinforcements in construction will significantly solve the problems of global stability of RE walls and embankments.

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