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BEHAVIOUR OF REINFORCED AND UNREINFORCED SOIL SLOPE UNDER VERTICAL LOADING

Raghvendra Katarpawar[1], Pranjali Vaidya[2], V.S. Ghutke[3]

[1]*Student, Dept. of Civil Engineering, Priyadarshini College of Engineering, Nagpur, Maharashtra, India*
[2]*Student, Dept. of Civil Engineering, Priyadarshini College of Engineering, Nagpur, Maharashtra, India*
[3]*Asst. Professor, Dept. of Civil Engineering, Priyadarshini College of Engineering, Nagpur, Maharashtra, India*

Abstract - *In the current experimental work, the behavior of unreinforced and reinforced soil slopes under diverse vertical loading is carried out experimentally. Sand size soil is used to prepare the slopes with 45° and 60° as two different soil slope angles with the horizontal. To observe the load vs. settlement behavior, a continuous increasing surcharge load is applied on the MS circular bearing plate placed on the crest of the soil slope. These soil slopes are then reinforced by placing the reinforcements like Geonet, Geogrid, Geofoam, and Jute Geotextile at two different inclinations i.e. 45° and 60°. A constant spacing of 50mm is maintained between two successive reinforcement layers. It is observed that maximum load is carried by the slope with 45° slope angle than the 60° slope angle. Also, Geogrid placed at 45° was found to provide maximum stability and was more efficient.*

Key Words*: *Slope Stability, Geosynthetics, Soil Reinforcement, Bearing Capacity, Load Vs Settlement Curve.

1. INTRODUCTION

Landslide is a geological phenomenon that occurs worldwide specially in those areas where the soil or slope does not have much stability. Landslide includes ground movement like deep failure of slope, rock falls. It can rise in onshore, offshore and coastal environments. Landslides can be controlled by adopting appropriate slope & soil stabilization methods. Soil stabilization is a process in which the natural soil is improved to meet the engineering purpose employing physical, chemical, biological, and combined method of all three. Load-bearing capacity and the performance of the in-situ soil and sand can be increased by the soil stabilization methods**.** Owing to rapid urbanization and the dearth of land, structures such as foundations for bridge abutment, electrical transmission tower, building, railways, and highways on hills are being built on a slope, often close to its edge. In contrast to plane ground, foundations on the slope exhibit less bearing capacity, and stability of the slope is also vulnerable. For that reason, the stability of such slopes needs to be improved significantly. Over the years, several slope stabilization methods such as modification of slope geometry, grouting of soil mass with cement, lime, etc., installation of retaining walls, piles, and reinforcing the soil through polymeric geo-synthetics (geotextiles, geogrids, geocells, geo fabrics, geomembranes, etc.) are taken into account by numerous researchers.

Various types of geosynthetics are used for slope stability such as geo-nets, geo-foam, geo-membranes, geocells. Geo-synthetics are the products of synthetic widely used to stabilize the terrain. Nonwoven synthetic fibers like polyester, polyethylene, polypropylene, polymer etc. can be used to strengthen the terrain. The strength of soil can be enhanced using geotextiles, geonets, geogrids which improves the load bearing capacity, shear strength, stiffness, and permeability characteristics, reduce the differential settlement of soil by the frictional contact amongst the soil and geosynthetic material. Reinforced earth structures are utilized to design earth retaining buildings and foundations. Reinforced Earth is created by combining soil with geosynthetics such as geogrid, geonet, and geotextile type materials. Reinforced earth structures are preferred because of the high tensile strength, fast construction, high resistance to earthquakes, economic feasibility, and aesthetic appearance also.

Geosynthetic is a planar product formed from polymeric material used with rock, earth, soil, and supplementary geotechnical engineering material as a vital part of a man-made structure, project, or system. Geotextile is a permeable geosynthetic that is made of woven textiles with different dimensions and filament properties. If the soil is good in compression, geotextile is good in tension. Thus, geotextiles are used to remove the risk of local tearing for clayey soils and in the case of less-strength fine-grained silt. Geotextile has instant, eco-friendly, and economical utilization in various geotechnical areas with more steel reinforcement and vegetation. Also, Geogrid is a mesh-like material manufactured from polymeric materials with rib properties and variable space according to standards. All these reinforcements are utilized to increase soil bearing capacity and to decrease both vertical and horizontal distortions in case of failures like sliding, displacement, overturning, pullout failure, and other general failures. Geotextile is being used effectively on numerous times to stabilize steep slopes in residual soil and weathered rock. Geotextile is used as tensile reinforcement and a sieve to stabilized slopes. The geotextiles are generally placed in horizontal layers within the slope. It is positioned along with the slope cutting across

probable sliding surfaces in the soil. The geotextile diminishes the pore water pressure within the slope during monsoon, therefore increasing the shear strength. It acts as a filter that prevents migration of soil or sometimes called the internal erosion within the slope. Not least of all, the geotextile reinforces the soil along possible sliding zones or planes. All these will upsurge the stability of the slope.

1.1 Scope of the Study

Aim: To determine the behavior of reinforced and un-reinforced soil slope under vertical loading.

Objectives of the study:

- To investigate Geonet, Geogrid, Geofoam & Jute Geotextile as reinforcements for the stability of the slope.
- To study the effect of slope inclinations (45° & 60° angle) for the stability of soil slope.

2. LITERATURE REVIEW

The authors M. Inanc Onur, Mustafa tuncan, Burak Evirgen, Bertan Ozdemir, and Ahmet Tuncan [1] studied the behavior of supported slopes with geogrids and geotextiles. The slope was constructed at 90° with the horizontal plane. The slope was reinforced by placing Geogrid and Geotextile as reinforcements. Geotextile reinforcements were placed at 20mm intervals whereas Geogrid was placed at 16mm intervals vertically. Vertical loading through UTM was applied and load vs. settlement was observed and graphs were plotted accordingly. As a result, Geogrid gave less displacement and more strength than Geotextile members.

The authors Tapan Kumar Nayak, Koushik Halder, Debarghya Chakraborty [2] examined the effect of geogrid as reinforcement on the bearing capacity and displacement of strip footing positioned on the soil slope. The slopes of 30° and 35° were prepared in a box of specific size. Geogrid were placed after a specific interval and sand was continued up to the desired height. A jack was used to apply load on the footing. A total 28 number of tests were performed trying with various positions of geogrid and changing the slope angles. Variation of bearing capacity ratio and the setback distance of footing were observed. It was observed that, more the number of the geogrid reinforcement layers in the soil slope more is the effectives of geogrid as reinforcement. The authors Hymavathi Jampani and Navya Bhupathi [3] determined that the soil slope with various soil types i.e. clayey, silty, gravel and different soil stabilization techniques such as soil nailing, berming, combination of soil nailing & berming and also the effect of the water table and seismic load on the slope's stability was examined. A slope of 50° was constructed and berming and soil nailing was carried out separately followed by the combination of both. Variation of factor of safety for all the three types of soil was examined. It was determined that in clayey soil the combination of berming and soil nailing has proved to be a good for slope stabilization rather than using the two techniques alone.

The authors Alida Mathew and Aswathy Sasikumar [4] examined the evaluation amongst the performance of geonet reinforced soil with bamboo grid reinforced soil. The soft soil bed was prepared in a tank of the specific dimension. The bamboo grid and Geonet were placed in three layers at 50 mm intervals. Load and the corresponding settlement were observed for each & every test. As a result, it was concluded from the observations that soil reinforced with bamboo grid gave better performance than that of geonet reinforced soil. Also, it was observed that as the bearing capacity of reinforced soil increased the settlement for reinforced soil decreased.

The authors Yun Hu, Ga Zhang, Jian-Min Zhang, C.F. Lee [5] investigated the behavior of the geotextile-reinforced cohesive slopes and compared the behavior to unreinforced slopes. The centrifuge model tests were conducted by using the geotechnical centrifuge of 50g-ton capacity. An unreinforced and reinforced slope with geotextile was used to discuss how slope inclination affects the reinforcement behavior by comparing the results with the corresponding results of another slope angle. The deformation history of the slopes was determined with an image analysis system.

The authors Choudhary, P.K., Sanyal, Tapobrata [6] studied that placement of Jute Geotextile as reinforcement within the slope can suitably be useful in soil erosion control and help in the growth of vegetation as a bio-engineering measure. Open weave Jute Geotextile fabric was used to cover up the slope surface primarily to increase the slope stability and to give significant amount of protection against erosion of soil. It was studied that Jute geotextile provides partial cover to the ground and absorbs the effect of the kinetic energy of the falling raindrops.

3. METHODOLOGY

Collected soil sample is used to prepare slope and angle of inclination is taken as 45° & 60°.The layers are formed by placing soil in mild steel box of size (60cm X 35cm X 40cm) and lightly compacting it after placement of each layer. A crest width of 20cm is maintained for constant slope angle and a circular bearing plate is placed on the crest to ensure uniform distribution of load. High density Polyethylene (HDPE) type of geonet, Polypropylene geogrid, geofoam, jute geotextile is used for reinforcement. The arranged soil model is placed on the Universal Testing Machine. A gradually increasing surcharge load is applied to the bearing plate placed on the crest of the slope by the UTM. The settlement of the soil slope is measured in the UTM and load settlement curve is made. After all this work a comparative study of

result of test for the sample will be done to come to a certain conclusion regarding reinforcement as stabilizer for the stability of slope.

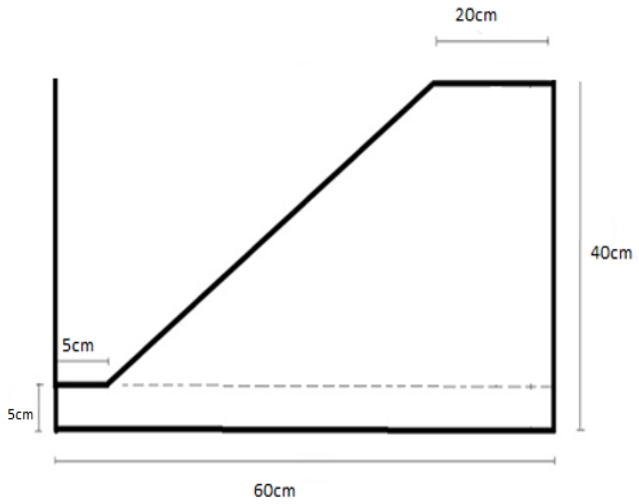

Fig.- 1: Schematic view of test setup

4. TESTING PROCEDURE

The soil slope is prepared at two different inclinations of 45^0 and 60^0 along the length of the model box. Geonet, Geogrid, Geofoam & Jute Geotextile are used as reinforcements and placed horizontally within the slope with equal vertical spacing throughout. The whole built soil model is placed on the Universal Testing Machine. A circular bearing plate made up of mild steel is placed on the crest of the slope for uniform distribution of load. Progressively increasing surcharge load is applied by the Universal Testing machine. Load and the corresponding settlement shown by the Universal Testing Machine are noted down. The settlement of the soil slope per Kilo Newton of the load is observed until the failure of the soil slope. The load and the settlement value of each reinforcement i.e. Geonet, Geogrid, Geofoam & Jute Geotextile in addition to the unreinforced slope are observed. According to observations of load and settlement, a proper Load Vs Settlement curve is drafted showing the slope failure for both 45^0 and 60^0.

Fig.-2: Experimental Setup

5. RESULTS AND DISCUSSION

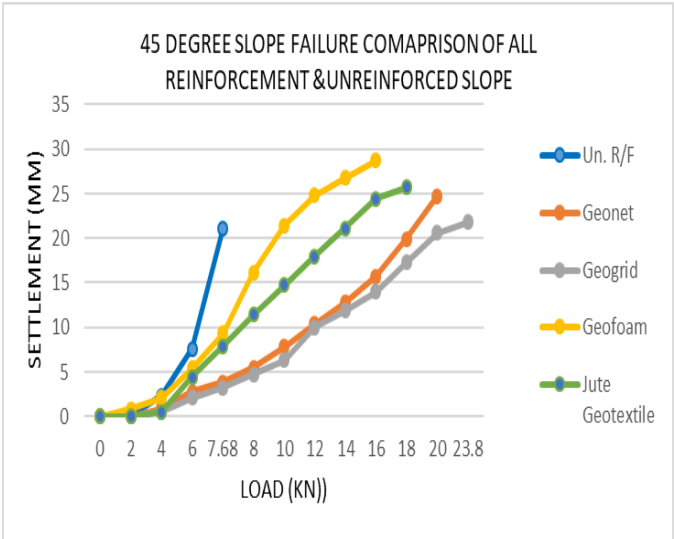

Chart- 1: 45^0 slope failure comparison of all reinforcements and unreinforced slope

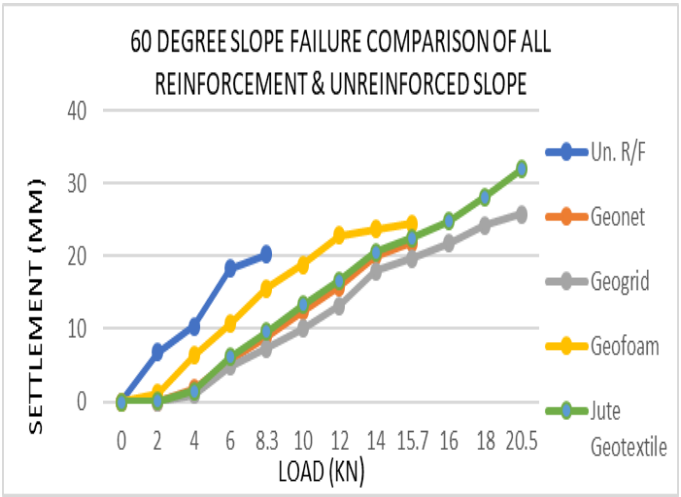

Chart- 2: 60^0 slope failure comparison of all reinforcements and unreinforced slope

Table 1: Observation for failure load and final settlement for different reinforcements with different inclinations of slope

SLOPE ANGLE	REINFOR-CEMENT	FAILURE LOAD(KN)	FINAL SETTLEME-NT(MM)
45^0	Unreinforced	7.68	21.1
	Geonet	20	24.7
	Geogrid	23.8	21.8
	Jute Geotextile	20.6	27.2
	Geofoam	16.8	28.7
60^0	Unreinforced	8.3	20.2
	Geonet	16	24.2
	Geogrid	20.5	25.8
	Jute Geotextile	20.38	32
	Geofoam	15.7	24.5

5.1 DISCUSSION:

- It is observed that by placing different reinforcements, there is a significant amount of increase in the load bearing capacity of the soil slope. In addition to that is was also observed that, due to the use of various reinforcements there is a significant amount of decrease in the final settlement of the soil slope.
- As a result, Geogrid sustained more load followed by Geonet, Jute geotextile, and Geofoam.
- For various reinforcements, it is observed that the 60° slope angle bears less load than the 45° angle of soil slope.

6. CONCLUSIONS

In this study, the behavior of reinforced soil slope with Geogrid, Geonet, Jute Geotextile, and Geofoam was analyzed by performing experiments on slope model in the laboratory on UTM. It is observed that there is a settlement of the crest at first which ultimately leads to the failure of the slope for the unreinforced soil slope. It is also observed that more load is carried out by the 45° slope angle than 60° slope angle. It can be concluded that reinforced soil slope leads to a certain increase in bearing capacity and stability of soil slope as compared to the unreinforced slope. The preparation of soil reinforcement within the soil slope also affects the overall soil slope stability with the significant amount of decrease in the final settlement of the crest. The above study clearly shows that the type of soil reinforcement also affected the stability of soil slope. It can be summarized that the 45° slope angle is the best in this project as compared to 60°.From the above study, it can also be concluded that Geogrid is the best soil reinforcement for both the slope angle 45 and 60 followed by Geonet, Jute Geotextile, Geofoam. The bearing capacity of the soil slope is found to be decreased with an increase in slope angle for both Unreinforced and Reinforced soil slope.

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BIOGRAPHIES

Raghvendra Katarpawar pursued B.E. in Civil Engineering from Priyadarshini College of Engineering, Nagpur-440019 Maharashtra, India

Pranjali Vaidya pursued B.E. in Civil Engineering from Priyadarshini College of Engineering, Nagpur-440019 Maharashtra, India

Asst. Professor V.S. Ghutke Department of Civil Engineering, Priyadarshini College of Engineering, Nagpur-440019 Maharashtra, India. Pursued MTech from IIT-Delhi & currently pursuing PhD in Geotechnical Engineering from VNIT, Nagpur