DEFORMATION AND BEHAVIOR OF GEOGRID UNDER REINFORCED SOIL WALL

USFOOR JAHAN GULAM ABBAS
CIVIL DEPARTMENT ,MITTULALJI SARDA POLYTECHNIC BEED,MAHARASHTRA,INDIA

ABSTRACT

Static response of geogrid reinforced soil walls with wrap around facing resting on firm foundation to the externally imposed surcharge is presented in this paper. A series of small-scale experimental tests is performed on the model geogrid reinforced soil walls with variation in reinforcement spacing and reinforcement length. Parametric variation made is compared with the established codal provisions of BS-8006-2010 and FHWA-NHI-00-043. Experimental analysis will be performed in a prefabricated MS strong box. A thick glass panel was fixed on the front side of the box so as to capture mmovements and behaviour of reinforcement under the action of load.facing technique was used Reinforcement spacing was 0.084H for each model configuration.

Reinforcement length was 0.7H for each model configuration. Surcharge loading was applied on each model in the form of 0.1m wide strip load. Each model test was monitored through front glass of the strong box using digital camera. Series of images is taken at fixed time interval for each test. Digital image analysis is performed on captured images to evaluate the movements in geogrid reinforced soil wall models at pre-failure and failure conditions. The post failure investigation was performed to assess the rupture points in the geogrid layers at failure of the geogrid reinforced soil wall models. The study demonstrates the comparison between design of geogrid reinforced soil wall models using standard guidelines of BS-8006-2010 and FHWA-NHI-00-043 with the actual experimental model tests performed in this study.

Keyword: - *Geogrids, Reinforced soil, Image analysis.*

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1. INTRODUCTION

1.1 Introduction To Soil Reinforcement

Now a day‟s geosynthetic reinforced soil structures are widely used because of the technical and economical advantages. Soil reinforcement is a technique to improve strength and stiffness of a soil; it is widely used to stabilize retaining wall, embankments, etc. Interaction between the soil and reinforcement is a key factor of affecting the performance of reinforced soil structure such as retaining wall. Life span of geogrid material is near about 120 years and material is a polymeric material. Steel bar reinforcement has risk of corrosion in aggressive soil environments but Geogrid have no risk of corrosion in any type of environment. Soil reinforcement, as a technique to improve the strength and stiffness of in-situ soil, is widely used to stabilize retaining walls,artificial slopes,embankment etc.The interaction between the soil and the reinforcement is a important factor affecting the performance of reinforced soil structures.

Conventional reinforcement materials in geotechnical engineering come with certain shortcomings. For instance, steel reinforcements bar have a risk of corrosion in aggressive soil Environments. Geosynthetics normally made of polymeric materials, are also found to deteriorate over time. Fiber reinforced polymer (FRP) materials, with several advantages over convention materials, are able to address these problems. Glass fiber reinforced polymer (GFRP) and carbon fiber-reinforced polymer (CFRP) are two commonly used Fiber Reinforced polymer materials for construction. Compared with steel, FRP materials enjoy a number of benefits, such as better corrosion resistance, lighter weight, easier sites maneuvering, and the ability to maintain similar or even better material strengths.

1.2 Terzaghi's Bearing capacity Theory

Terzaghi (1943) used the same form of equation as proposed by Prandtl (1921) and extended his theory to take into account the soil weight and the effect of soil above the base of the foundation on the bearing capacity of soil.

Terzaghi made the following assumptions for developing an equation for determining bearing capacity for a C- Φ soil.

(1) The soil is semi-infinite, homogeneous and isotropic,

(2) The two-dimensional problem,

(3) The footing base is rough,

(4) The failure is general shear,

(5) The load is vertical and symmetrical,

(6) The ground surface is horizontal,

(7) The principle of superposition is valid, and

(8) Coulomb's law is strictly valid. Mechanism of Failure:

The shapes of the failure surfaces under ultimate loading conditions are given in The zones of plastic equilibrium represented in this figure by the area *gedcfmay*be subdivided into

1. Zone I of elastic equilibrium
2. Zones II of radial shear state
3. Zones III of Rankine passive state

When load *qu*per unit area acting on the base of the footing of width *B* with a rough base is transmitted into the soil, the tendency of the soil located within zone I is to spread but this is counteracted by friction and adhesion between the soil and the base of the footing. Due to the existence of this resistance against lateral spreading, the soil located immediately beneath the base remains permanently in a state of elastic equilibrium, and the soil located within this central Zone I behave as if it were a part of the footing and sinks with the footing under the superimposed load.

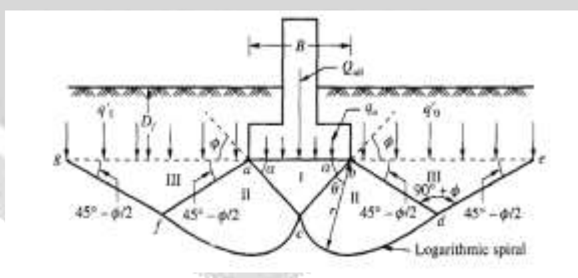

Fig1.1. General Shear failure surface as assumed by Terzaghi for a strip footing

The depth of this wedge shaped body of soil *abc* remains practically unchanged, since the footing sinks. This process is only conceivable if the soil located just below point *c* moves vertically downwards. This type of movement requires that the surface of sliding *cd* through point c should start from a vertical tangent. The boundary *be*of the zone of radial shear *bed* (ZoneII) is also the surface of sliding. point of the zone of plastic equilibrium at an angle (90-Φ).Therefore the boundary *be* must rise at an angle Φ to the horizontal provided the friction and adhesion between the soil and the base of the footing prevent sliding of at base.

1.3 Mechanism

Soil has an inherently low tensile strength but a high compressive strength which is only limited by the ability of the soil to resist applied shear stresses .An objective of incorporating soil reinforcement is to absorb tensile loads, or shear stresses, thereby reducing the loads that might otherwise cause the soil to fail in shear or by excessive deformation. Reinforced soil walls are based on the limit equilibrium approach. The walls are designed such that they can resist internal and external pressure . Design reinforcement length should be such that they prevent all modes of failure at minimum factor of safety.

1.4 Lateral Earth Pressure Theory

Structures that are built to retain vertical or nearly vertical embankment or any other material are called retaining walls. Retaining walls may be constructed of masonry or sheet piles. Retaining walls may retain water also. The earth retained may be natural soil or fill.The principal types of retaining walls . Whatever may be the type of wall, all the walls listed above have to withstand horizontal pressures either from earth or any other material on their faces. The pressures acting on the walls try to move the walls from their position. The walls should be so designed as to keep them stable in their position. Gravity walls resist lateral movement because of their heavy sections. They are built of mass concrete or stone or brick masonry. No reinforcement is required in these walls. Gravity walls are havier than semi-gravity walls. A small amount of reinforcement is used for reducing weight of concrete. The stems of cantilever walls are thinner in section. These walls are made of reinforced cement concrete. Counterfort walls are similar to cantilever wallsonly that difference is the counterforts. On the backfill side counterforts are provided. The difference between buttressed and counterfort wall is only,the brackets or buttressed are provided on the backfill side. In all these cases,the wall moves due to backfill pressure. The movement of the wall is partly resisted by the wall itself and partly by soil in front of the wall. Sheet pile walls are more flexible than the other types. There is another type of wall that is gaining popularity. This is mechanically stabilized reinforced earth retaining walls (MSE) which will be dealt with later on.

There are two classical earth pressure theories. They are;

1.Coulomb's earth pressure theory.

2.Rankine's earth pressure theory.

The first analysis of the problem of lateral earth pressure was published by Coulomb in (1776). Rankine (1857) proposed a different approach to the problem. These theories propose to estimate the magnitudes of two pressures called active and passive earth pressure as explained below. Consider the cohessionless soil is filled on the backfill of the rigid retaining wall. If the wall does not move even after back filling, the pressure exerted on the wall is termed as pressure for the at rest condition of the wall. If suppose the wall gradually rotates about point *A* and moves far from the backfill, the unit pressure on the wall is gradually reduced and after a particular displacement of the wall at the top, the pressure reaches a constant value.This pressure is termed the *active pressure* since the weight of the backfill is responsible for the movement of the wall. If the wall is smooth. the resultant pressure acts perpendicular to the face of the wall. If the wall is rough, it makes an angle <5 with the normal on the wall. The angle *8* is known as the angle of wall friction. As the wall moves far from the backfill, the soil tends to move forward

1.5 Use Of Geogrid

Geogrid are strong, durable and flexible materials.If soil settles it will not seperatede and are superior to concrete or metallic material.Geogrid are very versatile and can perform many functions and some individual materials can simultaneously perform two or more functions. The applications of the geogrid in various fields are considered really important. By using geogrid in reinforced soil wall, bearing capacity and strength increases of soil. Geogrid can be used for temporary or permanenterosion control measures alongside slopes. Temporary erosion control geogrid comprise of natural biodegradable fibers. They are spread on the slope in the form of grids or mats and they prevent errosion until vegetative growth occurs and later degrade.

1.6 Need for investigation

Steelbar reinforcements have a risk of corrosion in aggressive soilenvironments. Geosyntheticsnormallymade of polymeric materials, are also found to deteriorate over time. Fiber reinforced polymer materials, with several advantages over conventionalmaterials, are able to address these problems. Glass fibe reinforcedpolymer and carbon fiber-reinforced polymer are two commonly used FRP materials for construction. Compared with steel, FRP materials enjoy a number of benefits, such as better corrosion resistance, lighter weight, easier site maneuvering, and the ability to maintain similar or even better material strength.

1.7 Deliverables and beneficiaries

The evolution and advancement in transportation facilities have been closely linked with the development of human being throughout the history of world. Road development plan vision 2020 is prepared by IRC at the initiative of the ministry of road transport and highways. In case of flyover we use reinforced soil for increase the stability of structure and preventing soil erosion and increases life span of the flyover.

2.SYSTEM DEVELOPMENT

2.1 Materials

2.2.1 Soil

Soil may be defined as the naturally deposited unconsolidated material which covers the earth's surface, whose physical,chemical and biological properties affect growth of plants.The siol is a naturally decompositiuon of rock due to physical chemical forces on it and also on vegetation and on animal matters ,it required some year or in some cases its required thousand of years. The factors involved in the formation of natural soils are: (1) living matter (plants, animals, micro-organisms); (2) climate (cold, heat, snow, pricipitation, wind) (3) fineness of particle size as well as their chemical and mineralogical composition; (4) relief (slope and landform) and (5) time. Soil is a life of plants. The physical properties of a soil largely determine the ways in which it can be used. The size, shape,etc are known as the physical properties of soil. Other important physical properties center on the size and shape of the spaces between the particle arrangements, called the void space, which has a direct effect on the movement of air and water, the ability of the soil to supply nutrients to plants, and the amount of water available to the plant. The proportions of the four major components of soils – inorganic,organic particles,air and water can vary greatly from place to place and with depth. Chemical properties of soils are important in that, along with their physical and biological. properties, they regulate the nutrient supplies to the plant. Without these nutrients supplied by the soil or applied as fertilizer plant growth not possinble.

Fig.2.1: Sand

2.2.1 Geogrid

There are various type of geosynthetics materials available which can be used for different purposes. Few of the geosynthetics materials are as follows:

Geotextiles: Geotextiles are defined as "any permeable textile used with foundation soil, rock, earth, or any other geotechnical engineering-related material as an integral part of a human-made project, structure, or system". For agriculture purposes geosynthetic are used. These are cloth-like materials that are classified based on the method used to place the threads or yarns in the fabric: either woven or non-woven. Geotextiles come in sizes to approximately 5.6m wide and 50 to 150m long

Geo-Grids: Geo-Grids are open mesh-like materials of integrally connected polymers, as shown in Figure; 2.2. They are polymeric material consisting of regular open network of connected tensile elements with square or rectangular openings. The linkage between the tensile elements can be extrusion, bonding etc. They are used primarily for soil reinforcement. Their strength can be greater than the more common geotextiles. Geogrids have a low strain and stretch only about 2 to 5% under load

Geocells : They are typically formed from polyethylene sheets and expand out like an accordion when use for opened. They are meant to contain soil,or other fill material within their maze of cells or pockets and may be voids to allow water movement. They are used on slopes with soft subgrades and in erosion control in channels. They can be used over top of a geotextile or geogrid. While they come in compact bundles when collapsed, they typically cover an area 2.5m (8 ft) wide by 6 to 12m (20 to 40 ft) long when expanded

In this study we use geogrid material.Geogrid used for test consists of 90% openings and they are square in shape. Geogrid is easily available in the market and it is like mosquito net.

Fig.2.2: Geogrid

2.2.1 Geofoam

Lightweight fill solutions have been used in many civil engineering projects throughout the world. At locations with bad soil conditions, alternative light weight construction fill materials such as expanded polystyrene (EPS) geofoam, and tyre wastes may be used instead of conventional fill materials. These materials are used as an support for the soil. It is known that the type, aspect ratio and content of the admixtures have an important role in the mechanical properties of the mixtures. They may be used as fill over soft clay sites to prevent excessive settlements; as backfill for retaining and basement walls to reduce the horizontal acting forces; as fill material to increase factor of safety for slopes by reducing driving forces; as seismic buffers to prevent seismic forces, and so forth. Various types of lightweight fills, such as expanded polystyrene (EPS)-block geofoam

Fig.2.3: **Geofoam**

2.2 Methodology

2.2.1 UTM

The test are conducted on universal testing machine (UTM).UTM is available in college. Having capacity 1000 KN. On UTM compression, Tensileetctest are can be carried done. Available UTM is manufactured by Hydraulic and engg. Instruments, New Delhi (HEICO).

Fig.2.4: Universal Testing Machine

2.2.2 Box

The test setup consists of a strong mild steel (MS) box having 498 mm in length, 165mm in breadth, and 400mm in height (internally). Four handle are provided on top side for holding purpose.

Fig2.5: Mild steel box

2.2.3 Transparent Glass

The front wall of a model test package is formed with a120 mm thick glass sheet which enabled to view deformation and image analysis purpose.

2.2.4 Marker

Before placing polythene sheet strips, a rectangular grid of permanent markers were placed on the outer side of glass sheet. Plastic markers are in L-shape.

2.2.5 Polythene

The front walls were coated with a thin layer of white petroleum grease and polythene sheet strips of 60 mm width were placed to reduce boundary friction effects.

2.2.6 Camera

In order to view front elevation of the model during testing a digital photo camerais mounted along with the model test package.

2.2.7 Formwork

In order to get desiredslope inclination, a formwork was placed temporarily withinthe strong wooden box. The wooden box is in C-Chanel section, having length 115mm and height 430 mm (externally).

3. PERFORMANCE AND ANALYSES

Following figure shows conceptual diagram of test. In that figure 3.1 shows the conceptual diagram without geofoam and figure 3.2 shows the conceptual diagram with geofoam. In this experiment wrap around facing technique is used.

In this study we vary footing position. In first case footing is on reinforcement that is 0.5Lr from crest of the wall and in second case on centre of reinforcement that is 1.78Lr from crest of the wall.

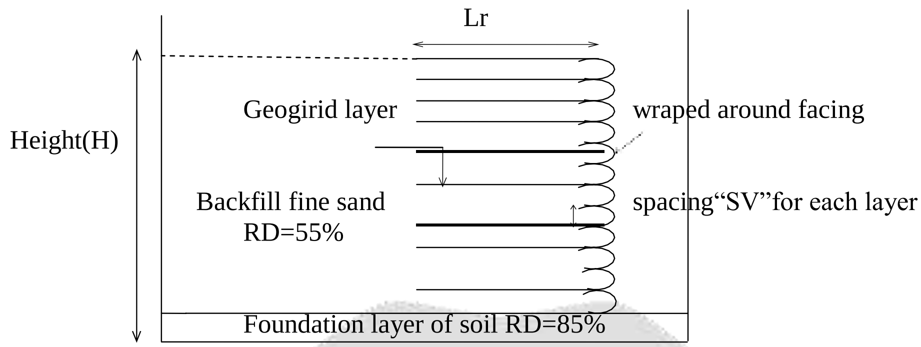

Fig.3.1 Conceptual diagram without geofoam

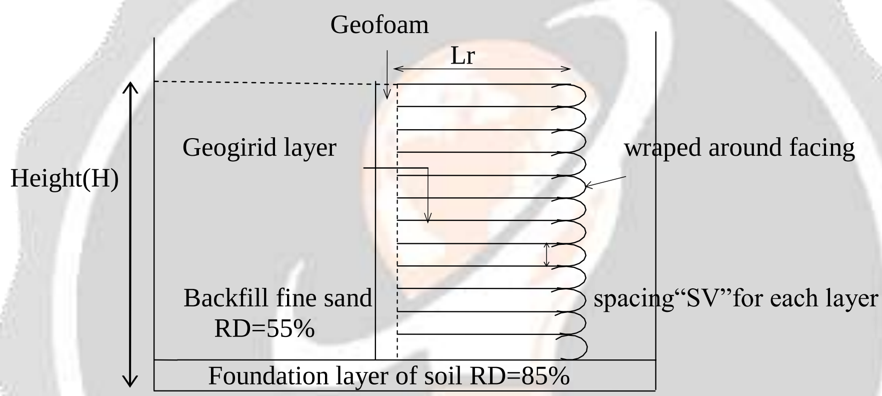

Fig.3.2 Conceptual diagram with geofoam

3.1 Model Making

At the time of making model, after placing polythene sheet strips, a 30mm thick foundation layer was placed at a relative density of 85% to represent a firm foundation. For each model, desired numbers of geogrid layers were placed one by one and dry sand was placed in between two geogrid layer at a relative density of 55%. In order to trace the movement of geogrid layers in the box L-shaped plasticmarkers were glued on to model geogrid layers. One leg of plastic marker was glued to model geogrid layer and other portion was applied white petroleum grease layer to facilitatemovement. Plastic marker was glued on geogrid at spacing 20 mm center to center.

All geogrid layers were numbered from inincreasing order. Geotextile material has been used so that the sand does not fall off from the retaining wall. Strips of graph papers were attached to the model in order to maintain the soil level. And for leveling the soil a paint brush was use.

Fig.3.3 Test set up

3.2 Effect of geofoam

When the geofoam is not used, then there is no resistance to pressure and load is directly transfer to the reinforcement(i.e.Geogrid) and hence there will be chances of failure of wall.

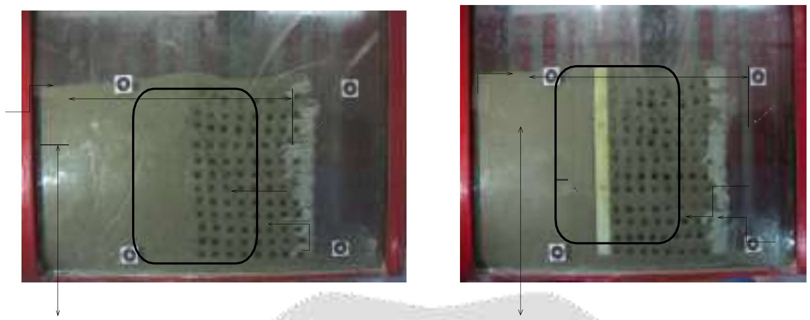

Fig 3.4 Test package with and without geofoam footing position is on centre of reinforcement

Fig.3.5 Failure Mechanism

In figure 3.4 first part shows the footing is on the centre of reinforcement and in this no use of geofoam. Due to the no use of geofoam deformed zone is maximum and heave formation are occur at the top side, and due to this reason there is chances of failure of reinforced soil wall. In second part we used geofoam, due to the geofoam internal pressure is reduced and no heave formed no top side so there is no chance of failure of reinforced soil wall. When footing position is on centre of reinforcement top geogrid layers are get failed. In figure 4.5 failure mechanism is shown. Following fig shows failure of geogrid.

Fig.3.6 Failure Of Geogrid

After placing footing on soil the load is applied on that that was point load. Due to the applied load the position of marker was changed. These changing positions of marker are captured in digital image analysis. By using this image analysis software we can find out the displacement and strain.

4 CONCLUSION

4.1 Conclusion:

Based on the analysis and interpretation of geogrid reinforced soil wall model test results, the following conclusions can be drawn:

1. Terzaghi‟s general shear failure was observed in all the model walls.Failure of geogrid layer is also according to the general shear failure.

2.Ingeogrid reinforced soil wall maximum peak strain was observed on the top layer and strain is decreased from top to bottom. This strain was maximum when there was no use of geofoam .

3.Ingeogrid reinforced soil wall when footing is on centre of reinforcemen at that time wall face moment was maximum. This wall face moment is reduced when used geofoam.

However, further investigations are warranted in order to undrstand the stability and deformation behaviourofgeogrid reinforced soil walls.

4.2 Future Scope:

The evolution and advancement in transportation facilities have been closely linked with the development of human being throughout the history of world. Road development plan vision 2020 is prepared by IRC at the initiative of the ministry of road transport and highways. In case of flyover we use reinforced soil for increase the stability of structure and preventing soil erosion and increases life span of the flyover.

A large variety of detrimental factors affect the service life of roads and pavements including environmental factors, sub grade conditions, traffic loading, utility cuts, road widening, and aging. These factors contribute to an equally wide variety of pavement conditions and problems which must be addressed in the maintenance or rehabilitation of the pavements, if not dealt with during initial construction. Pavement maintenance treatments are often ineffective and short lived due to their inability to both treat the cause of the problems and renew the existing pavement condition. The main cause of distress in pavements is that they are quite permeable with 30 to 50% of precipitation surface water infiltrating through the pavement, softening and weakening the pavement sub grade and base, accelerating pavement degradation. Existing pavement distress such as surface cracks, rocking joints, and sub grade failures cause the rapid reflection of cracking up through the maintenance treatment.

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