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# INFLUENCE OF AGGREGATE FILLED GEOCELL REINFORCEMENT ON THE UPLIFT CAPACITY OF SQUARE ANCHOR PLATES

**Aparnna E M,** Department of civil engineering, IES College of engineering, Thrissur, emaparnna@gmail.com

**Reethi V P,**Department of civil engineering, IES College of engineering, Thrissur,reethi126@gmail.com

ABSTRACT: An anchor is a type of foundation system which is generally used to resist vertical uplift or horizontal pullout forces with the support of surrounding soil in which anchor is embedded. The uplift capacity of plate anchors depends on many factors such as density of soil, embedment depth, the size and shape of anchor etc.If the pulling load to be resisted is large, then we have to increase either the size of the anchor plate or the depth of embedment or both, resulting increase in the size of the excavation area and depth of excavation. This not only leads to increase in size of the foundation area and cost of excavation, but also arises the problem of excavation below the existing water table and compacting fill material below water table at great depths. In such condition we have to find an alternate cost effective method so as to improve the uplift capacity of a shallow anchor.

In the present study, the uplift behavior of horizontal square anchor plate embedded in sand with and without geocell reinforcement has been investigated. Gravel sized material is used to fill in the cells of the geocell so as to improve the grid interlocking. The pullout resistance of plate anchors was investigated using a laboratory small scale modal experiment. Rope and pulley arrangement was used to conduct test on plate anchors. To investigate effect of the width of geocell mattress on the anchor uplift capacity, geocell mattress having width diameter ratios (b/B) of 2,3,4 were considered and the studies were conducted on anchor plates having size 60mm embedded at embedment ratio (L/B) = 4.

The test results indicate that inclusion of geocell increases the uplift capacity of anchor plate in the order of 1.33,1.44 and 1.67 times than that of unreinforced case for each increment in the width ratio of geocell mattresses i.e., (b/B) of 2,3,4 respectively. However, with the addition of aggregates in the cells of the geocell mattresses significantly improves the performance of the plate anchors both in terms of increased uplift capacity and sustained deformations. The increase in the uplift capacity of the plate anchor with the addition of aggregates in the cells of geocell mattresses is in order of 2.56, 3.11 and 3.67 times than that of unreinforced case for each increment in the width ratio of geocell mattresses i.e., (b/B) of 2,3,4 respectively

## Introduction

An anchor is a type of foundation system which is generally used to resist vertical uplift or horizontal pullout forces with the support of surrounding soil in which anchor is embedded. In the design of civil engineering structures which are subjected to vertical and horizontal pullout forces like tall transmission towers, tall chimneys, tunnels, retaining walls bulkhead and railroad/highway bridge abutments etc attractive and economical design solution can be achieved by the use of anchor system.

A large verity of anchor systems have been developed in order to meet the increased demand for the foundation systems which are capable of resisting the pullout forces and overturning moments, plate anchors, helical anchors, under reamed piles soil hook system etc are some of them.The structures subjected to uplift forces also transfer loads from superstructures so the design requirement is there for based on both compressive and tensile criterion in the case of soil anchors tensile criterion is more important compared to compressive criterion. Symmetrical anchor plates are effective in both cases compared to any other type of anchor systems.

The uplift capacity of plate anchors depends on many factors such as density of soil, embedment depth, the size and shape of anchor etc. However when the depth of embedment of such anchor is shallow, then we can reduce the excavation cost of the pit to house the anchor, and also we can easy control the placement density of the filling in the pit. So designing the anchor system as shallow anchor overall economy and quality can be achieved. But if the pulling load to be resisted is large, then we have to increase either the size of the anchor plate or the depth of embedment or both, resulting increase in the size of the excavation area and depth of excavation.

This not only leads to increase in size of the foundation area and cost of excavation, but also arises the problem of excavation below the existing water table and compacting fill material below water table at great depths. In such condition we have to find an alternate cost effective method so as to improve the uplift capacity of a shallow anchor.N.R. Krishnaswamy & S.P. Parashar (1994) reported that only one layer of geosynthetic

Inclusion resting directly on top of the anchor plate gives a maximum increase in the uplift capacity without changing the depth of embedment and size of the anchor plate and the increase in the capacity to resist pulling load of such

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combination will be dependent on the relative size of reinforcement to that of the anchor plate, depth of embedment, characteristics of the geotextile layer and properties of the fill materials However experimental studies on the effect of introduction of Geocell layer over the anchor plate on pullout capacity of such combination are not found in available literature.

Here Geocell is used to reinforce the soil mass. It is a superior form of reinforcement over the conventional ones i.e. planar and random reinforcement. Its three dimensional confining structure that prevents lateral squeezing of soil leading to a coherent mattress. In the present study, the uplift behavior of horizontal plate anchor embedded in sand with and without geocell reinforcement has been investigated. Gravel sized material is used to fill in the cells of the geocell so as to improve the geogrid interlocking. In present study the influence of the width of geocell mattress on the anchor uplift capacity with and without aggregate cell reinforcement has been investigated.

## I. Materials Used

River sand collected from Bharathappuzha was used as soil medium.The coefficient of uniformity (*Cu*) and coefficient of curvature (*Cc*) were found to be 2.80 and 0.92 respectively. The soil can thus be classified as poorly graded sand, SP, as per Unified Soil Classification System (USCS).The physical properties of sand such as specific gravity, maximum dry density and minimum dry density are reported in Table 1.

The geocells used in the present study were prepared from commercially available polyester geogrid made from polypropylene. The properties of the geogrids are listed in Table 2. The geocell is made by cutting and joinig geogrid mattresses in to the requied size and shape. The joints of the geocells were formed by means of 1mm diameter aluminium wires.

Gravel-sized material is used in this study with the specific aim of increasing geogrid interlocking. Aggregates passing through 16mm sieve and retained on 10mm sieve is used fill the cells of the geocell mattress placed in the reinforced region. By using larger granular particles in the immediate neighborhood of the geocell reinforcement and anchor increased interlocking can be achieved between them.

Square anchor plate made up of steel having size 60mm and stem length 400mm is used in this experimental study. Anchor plate is attached to the stem by means of a welded joint. A hook is also provided at the end of the stem to receive the rope of the rope and pully arrangement.

TABLE 1 PROPERTIES OF SAND USED IN THIS STU

| Parameters | Value |
|---|---|
| Specific Gravity, G | 2.67 |
| Effective size, $D_{10}$ (mm) | 0.25 |
| $D_{30}$ (mm) | 0.40 |
| $D_{60}$ (mm) | 0.70 |
| Uniformity Coefficient, $C_u$ | 2.80 |
| Coefficient of Curvature, $C_c$ | 0.92 |
| Gradation of Sand | SP |
| Minimum density, $\gamma_{d\,min}$ (kN/m$^3$) | 15.20 |
| Maximum density, $\gamma_{d\,max}$ (kN/m$^3$) | 18.40 |
| Angle of internal friction for medium dense sand (degree) | 40 |
| Relative density | 50% |
| Dry Density (kN/m$^3$) | 16.70 |

TABLE 2 PROPERTIES OF GEOGRID USED IN THE STUDY

| | | TECHGRID B-30 |
|---|---|---|
| Ultimate tensile strength (KN/m) | MD | 30 |
| | CD | 30 |
| Aperture size (mm) | | 26 X 26 |
| Colour | | Black |
| Polymer | | polyster |
| Roll width (m) | | 5.0 |
| Roll length (m) | | 100 |

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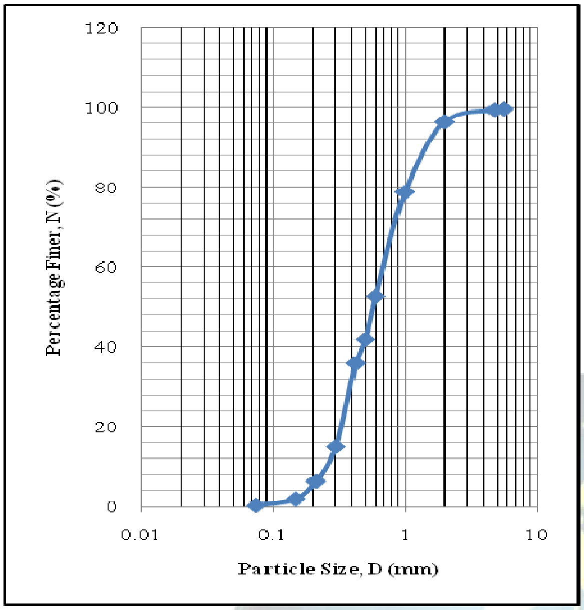


Fig 1. Grain size distribution of sand used in the study

## II EXPERIMENTAL PROGRAMME

The soil beds were prepared in a model tank with inside dimensions of 65mm ×65 mm × 65 mm. The predetermined weight of soil was spread uniformly in the tank, levelled and compacted to achieve the desire density (γd = 16.7 kN/m3). The compaction was done in layers of 100 mm height. A minimum of 150 mm of sand was maintained underneath the plate anchor. The anchor plate rigidly attached to a steel rod was kept in position and geocell mattress placed over it. The hook provided at the end of the steel rod was then connected to the cable, which was passed over a pulley attached rigidly .The soil filled and compacted with the help of tamping rod to achieved desire density. to the loading frame. The loads were used to hang over the plate tied at one end of the rope and the plate anchors were connected to the other end. Gradual incremental load of 1.5 kg was then applied to the one end of the rope pulley system so as to move the plate anchor upward with in the sand into which it was embedded. Corresponding deflection to each increment in load is noticed using dial gauges.

In the phase, were anchor plates reinforced with aggregate cell reinforcement, Aggregates passing through 16mm sieve and retained on 10mm sieve is used fill the cells of the geocell mattress placed in the reinforced region. The different parameters considers in the model tests are the effect of width of geocell mattress (b) on the uplift resistance of aggregate filled geocell reinforcement. All tests were conducted at embedment ratio (*L/B*) of 4 with different width of geocell mattress (i.e. *b/B*=2, *b/B*=3, and *b/B*=4).

L - Embedment depth of anchor plate

B - Width of the anchor plate

b - width of geocell mattresse

Fig 2. Placing anchor plate and geocell at required embedment depth

Fig 3. Filling aggregates in to the cells of the geocell

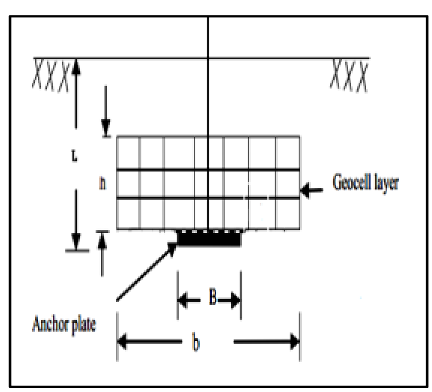

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Fig 4. Schematic diagram of geocell reinforced anchor syste

Fig 5.Test setup

## II. RESULTS AND DISCUSSIONS

Uplift resistance of anchor plate were studied for geocell reinforced and geocell and aggregate combination. From the results obtained it was observed that by using geocell reinforcement, uplift pressure carrying capacity of the plate anchor can be significantly increased than that of unreinforced case.

### A. *Effect of embedment depth on the Uplift Resistance of Anchor Plate.*

Embedment depth has greater influence on the uplift capacity of anchor plate. Increasing the pile embedment depth for the same anchor geometry, the part of the pile length embedded in the stable under laying soils leading to more stability for the pile and greater resistance for the lateral movement of soil particle in front of the anchor plate.

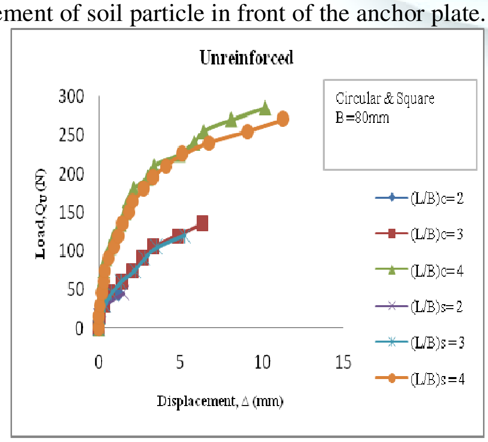


Fig 6. Influence of width of geocell mattress on the load displacement behavior of plate anchor.

### B. *Effect of Geocell Reinforcement on the Uplift Resistance of Anchor Plate.*

Figure 6 compares the load displacement behavior of plate anchors embedded at b/B =4 and in that we found how plate anchors behave at various L/B ratios. The shapes of curves are almost similar and load carrying capacity increase with increase in the L/B ratio.

By considering the graph shown by figure 6 it is observed that inclusion of geocell mattress has greater influence on the uplift capacity of anchor plates. Anchor plate having size 80 mm and placed at b/B ratio 4 and different width ratios shows 1.67 times improvement in the uplift capacity than unreinforced condition.

From Table. 3 it is observed that, Rate of improvement in the uplift capacity corresponding to width ratios 2 and 3are 1.33 and 1.44 respectively. From the results it is clear that the rate of improvement achieved is negligibly small and the improvement found is not satisfactory. So by placing geocell only in the close proximity of anchor plate has very lesser influence on the uplift resistance of anchor plates.

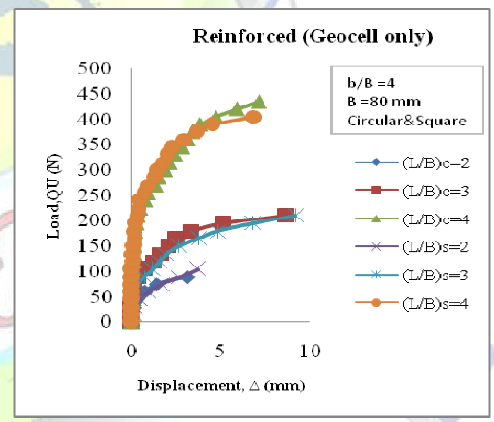


Fig 7. Influence of width of geocell mattress on the load displacement behavior of plate anchor.

### C. *Effect of Aggregate Filled Geocell Reinforcement on the Uplift Resistance of Anchor Plate.*

Figure 7 shows the load displacement behavior of plate anchors embedded at L/B =4 and in that we Can see that how reinforced anchor plates will behave at various b/B ratios. The shapes of curves are almost similar and load carrying capacity increase with increase in the b/B ratio. Drastic improvement in the load carrying capacity can be observed for each increment in the b/B ratio.

Considering the load displacement graph shown in figure 7, it is clear that aggregate filling in the cells of the geocell has greater influence on the uplift resistance. Table 3 shows that 3.67 times improvement in the uplift resistance can be achieved by using aggregate filled geocell mattresses with anchor plates

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From the results it is clear that a marked improvement can be attain in the uplift capacity of anchor plates by reinforcing them with aggregate filled geocell mattresses. The drastic improvement is achieved due to the combined effect of the interfacial friction generated at the interface of geocell sand in which the anchor and gecocell are embedded to and the interlocking of aggregate within the cells of the geocell when the anchor plate just started pulling out.

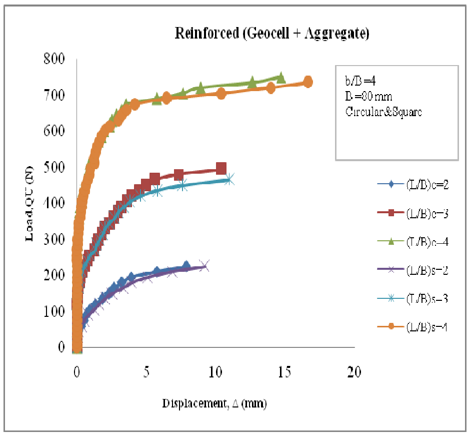


Fig 8. Influence of width of geocell mattress filled with aggregates on the load

TABLE 3 UPLIFT CAPACITY OF ANCHOR PLATES REINFORCED WITH GEOCELL MATTRESSES AT VARIOUS WIDTH RATIOS

| Diameter (mm) | L/B ratio | b/B ratio | Reinforced (Geocell Only) | | Unreinforced | | $Q_{UG}$ / $Q_U$ |
|---|---|---|---|---|---|---|---|
| | | | $Q_{UG}$ (N) | $\Delta_{UG}$ (mm) | $Q_U$ (N) | $\Delta_U$ (mm) | |
| 80 (circular) | 2 | 4 | 90 | 3.12 | 45 | 1.2 | 2.00 |
| | 3 | | 195 | 5.12 | 135 | 6.31 | 1.44 |
| | 4 | | 435 | 7.13 | 270 | 8.13 | 1.61 |

TABLE 3 UPLIFT CAPACITY OF ANCHOR PLATES REINFORCED WITH AGGREGATE FILLED GEOCELL MATTRESSES AT VARIOUS WIDTH RATIOS

| Diameter (mm) | L/B ratio | b/B ratio | Reinforced (Geocell + Aggregate) | | Unreinforced | | $Q_{UA}$ / $Q_U$ |
|---|---|---|---|---|---|---|---|
| | | | $Q_{UA}$ (N) | $\Delta_{UA}$ (mm) | $Q_U$ (N) | $\Delta_U$ (mm) | |
| 80 (circular) | 2 | 4 | 210 | 5.79 | 45 | 1.2 | 4.67 |
| | 3 | | 480 | 6.75 | 13 5 | 6.31 | 3.56 |
| | 4 | | 705 | 7.64 | 27 0 | 8.13 | |

TABLE 4 UPLIFT CAPACITY OF ANCHOR PLATES REINFORCED WITH GEOCELL MATTRESSES AT VARIOUS WIDTH RATIOS

| Diameter (mm) | L/B ratio | b/B ratio | Reinforced (Geocell Only) | | Unreinforced | | $Q_{UG}$ / $Q_U$ |
|---|---|---|---|---|---|---|---|
| | | | $Q_{UG}$ (N) | $\Delta_{UG}$ (mm) | $Q_U$ (N) | $\Delta_U$ (mm) | |
| 80 (square) | 2 | 4 | 105 | 3.73 | 45 | 1.5 | 2.33 |
| | 3 | | 195 | 6.76 | 210 | 5.25 | 1.67 |
| | 4 | | 405 | 6.83 | 255 | 8.15 | 1.59 |

TABLE 5 UPLIFT CAPACITY OF ANCHOR PLATES REINFORCED WITH GEOCELL MATTRESSES AT VARIOUS WIDTH RATIOS

| Diameter (mm) | L/B ratio | b/B ratio | Reinforced (Geocell + Aggregate) | | Unreinforced | | $Q_{UA}$ / $Q_U$ |
|---|---|---|---|---|---|---|---|
| | | | $Q_{UA}$ (N) | $\Delta_{UA}$ (mm) | $Q_U$ (N) | $\Delta_U$ (mm) | |
| 80 (square) | 2 | 4 | 210 | 6.91 | 45 | 1.5 | 4.67 |
| | 3 | | 450 | 7.43 | 210 | 5.25 | 3.75 |
| | 4 | | 690 | 6.46 | 255 | 8.15 | 2.71 |

### *D. Effect of Aggregate Filled Geocell Reinforcement on the Uplift Resistance of Anchor Plate.*

From figure 8 and figure 9 it is clear that, shape of anchor plate has negligible influence on the uplift résistance. Circular anchor plates shows only 3 to 5% increase in the load carrying capacity than square anchor plates having sides equal to the diameter of anchor plates.

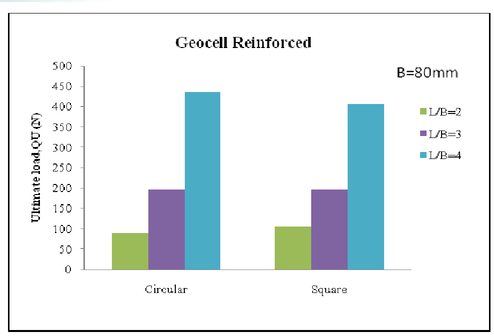


Fig 9 Influence of shape of geocell on the uplift capacity of anchor plate

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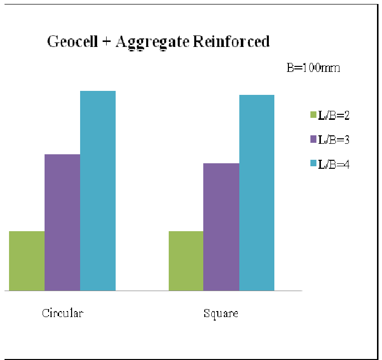


Fig 10. Influence of shape of geocell on the uplift capacity of anchor plate

## III. CONCLUSSIONS

- Putting aggregates in the cells of the geocell mattress has a significant role in improving the uplift resistance of anchor plates.
- An average of 4.67 to 2.60 times improvement than unreinforced condition is observed.
- Displacement corresponding to each increment in loading also reduces by the application of geocell-aggregate mattresses.
- Placing geocell reinforcement only has lesser influence on the uplift resistance. An average of 2.3 to1.5 times improvement is observed.
- The embedment depth plate anchor is a significant parameter on the reinforced soil anchor system.
- Increasing the embedment ratio leads to increasing the anchor capacity and at larger embedment depth displacement corresponding to each incremental load is lesser than that experienced at shallow depths.
- The rate of gain in anchor resistance decreases as the embedment depth become deeper.
- So it can be concluded that for uplift resistance there will not be any appreciable improvement after embedment ratio L/D=4.
- Shape of anchor plate has negligible influence on the uplift résistance. Circular anchor plates shows only 3 to 5% increase in the load carrying capacity than square anchor plates having sides equal to the diameter of anchor plate.

When we put aggregates in to the geocell it increases the interfacial friction between the two mediums, and Geocell can provide lateral confinement to the aggregate so that it can check lateral squeezing of the aggregate. By filling aggregates into the cells of the geocell mattress it can increase the geocell interlocking. Density of filling medium also has a major role in the uplift resistance; aggregate is more denser than sand so uplift resistance also get improved. So by the combined action of the actors discussed above drastic improvement is observed the pull out resistance.

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