EXPERIMENTAL INVESTIGATION ON IMPROVEMENT IN STRENGTH CHARACTERISTICS OF GABION WALL

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ABSTRACT

Gabion faced retaining walls are semi rigid structures that can accommodate large lateral and vertical movements without excessive structural distress. They can be constructed either as gravity type or reinforced soil type; this work mainly deals with the reinforced wall as they are more suitable for larger heights. In the present study, unlike the conventional method, the gabion boxes are made of geogrid instead of steel or rope. Experimental investigations were carried out on small scale model (in Laboratory) to suggest an alternative fill material for gabion faced retaining wall. The studies were conducted using different types of gabion fill materials. The variation was achieved by replacing the coarse aggregate with 25% sand. The deformation of the wall face was measured and the behavior was analyzed. It was observed that when 25% of the fill material in gabions is replaced with sand reduces the deformation behavior to large extents. A comparison was made for the deformation of geogrid gabion wall with conventional gabion wall. The result shows that the lateral deformation for the geogrid gabion wall and geogrid gabion wall (partial replacement with sand) was reduced by 20% and 55% respectively, when compared to conventional gabion wall.

Keywords: Cohesion less back fill, Gabion wall, Geogrid gabion wall, Material Properties, Parametric studies, Reinforced soil.


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1. INTRODUCTION
To meet the demand of the growing population of the world, consumption of the land for various infrastructure developments has become mandatory. This leads to the increased responsibility of the Geotechnical Engineer to improve the strength characteristics of the soil, for the maximum utilization of land. In that context, Mechanically Stabilized Earth (MSE) Technology has gained its momentum in 1980’s. The technology has segued into polymeric reinforcement such as geo-grid, geo-textile, geo-synthetics etc.

Geo-synthetics play a major role in improving the strength characteristics and stability of the retaining walls. Gabion wall is one of the ground improvement technique used for slope retaining structures. Gabion walls designed as gravity wall can be used up to a lower height, along with the reinforcement to a medium height. So, use of geosynthetics, instead of steel baskets in the construction of gabion walls will lead to its usage to greater heights. The advantages of these walls over the gravity type gabion walls are added stability and the reduction in cost of the structure.

The objectives of the present study involve
- To study the strength characteristics of coarse aggregate filled geogrid gabion wall
- To study the strength characteristics of coarse aggregate + sand filled geogrid gabion wall
- To compare the strength characteristics of conventional gabion wall with coarse aggregate filled geogrid gabion wall
- To compare the strength characteristics of conventional gabion wall with coarse aggregate + sand filled geogrid gabion wall
- To compare the strength characteristics of coarse aggregate filled geogrid gabion wall with coarse aggregate + sand filled geogrid gabion wall

2. LITERATURE SURVEY
It has been a long time since boxes made of hexagonal mesh fabric, known as gabions, have become an effective technical solution in the design, construction and maintenance of a variety of protective flexible structures. Gabions, by virtue of their matchless strength, excellent engineering adaptability and reliability, have become the chosen building material for a tremendous variety of construction works. These include road construction, river training, weirs, control and training of natural and flood waters, earth retaining structures, water recharge dams, rock slide protection, soil erosion protection and bridge protection. An extensive literature survey was conducted to identify the research works conducted on gabion faced retaining walls. Literatures on experimental works were collected to understand how the retaining wall can be modelled physically and how the deformations can be measured.

Garg (1997) highlighted two innovative technologies for stabilization of slopes. One was a reinforced gabion wall and the other was an anchored drum diaphragm wall implemented successfully in the Garhwal Himalaya during eighties to improve stability of slopes at comparatively lesser cost and time than conventional retaining walls.

Ferriolo et al. (1997) presented the use of flexible gabion structures for landslide, road protection and river training works. The authors explained the phenomena of landslide and erosion as modification of equilibrium condition of soil at specific surfaces due to a natural configuration or due to a human activity. Gabion mattresses being flexible structures have added advantages in their use in these areas. It is also mentioned that the internal structure details of the gabions such as opening size, double twist mesh, hexagonal shape, and Wire
diameter, extent of galvanization, diaphragms and joint details play an important role in the functioning of the structure as a whole.

Simac et al. (1997 A and B) described the design and construction of the MSE walls on the Tellico plains to Robbinsville highway. The walls were built with hybrid wall system components, consisting of geogrid reinforcement and PVC coated gabion baskets. The selection of these materials was based primarily on the presence of a chemically active environment, availability of an economical fill source, aesthetic appearance and overall cost. The paper summarized the design procedure utilized to ensure wall stability along a mountainous highway alignment. The paper also examined how the general MSE design guidelines presented in the project specifications can be augmented with currently accepted methods of analysis to provide CI safe but economical wall design. The authors concluded that hybrid MSE systems like the one mentioned above can be successfully designed by implementing currently accepted methods of analysis for geo synthetic reinforced soil walls. But appropriate facing connection tests should be done before implementation of this system. The latter paper also describes the specialized laboratory testing that was carried out to ensure that the connection formed between gabion baskets and reinforcement was adequate.

Bergado et al. (2000 B) studied the horizontal deformations of gabion walls on a fully instrumented test embankment reinforced with hexagonal wire, constructed on a soft Bangkok clay foundation in Thailand. The reinforced wall consisted of an inclined gabion facing on one side and a sloping unreinforced sand wall on the opposite side, with a total height of 6 m. Two different types of hexagonal wire mesh were utilized for the study. The wall system extensively instrumented both in the foundation subsoil and the embankment, in order to monitor the behaviour of the wall both during and after the construction phase. A maximum settlement of 0.35 m was observed 200 days after construction. It was found that there is a direct correlation between displacement and stress in hexagonal wire mesh reinforcement. For both types of meshes, the maximum deformation was observed in the top most layers.

Bergado et al. (2001) conducted pull out tests on hexagonal wire mesh of gabions embedded in silty sand locally known as Ayutthaya sand to investigate the soil reinforcement interaction. Two types of hexagonal wire mesh were tested, namely: (a) galvanized (zinc coated) which had smaller aperture (cell) dimension of 60 mm x 80 mm and (b) PVC coated which had larger aperture (cell) dimension of 80 mm x 100 mm. The tests were conducted under normal pressures ranging from 35 to 91 K Pa and the specimens were pulled at a rate of 1 mm/min. The total pull out resistance of hexagonal wire mesh reinforcement consist of two components, namely: friction and bearing resistance. It was seen that the bearing resistance is higher than the friction resistance for both types of reinforcement. Higher friction coefficient as well as greater number of transverse obtained with increasing normal pressures. The friction and bearing resistances mobilized on the galvanized wire mesh were greater than the PVC-coated wire mesh, due to higher friction coefficient as well as greater number of transverse and longitudinal members (elements) per unit width in the former than the latter. The authors proposed an analytical method for predicting the pull-out resistance and displacement relation using the basic soil and reinforcement properties which agreed reasonably well with the test results.

From the literature survey, which is extensively collected it is clearly understood that, the studies comparing to the replacement of material used inside the gabion boxes is more, when compared to the material replacement for the gabion boxes. Hence, the present investigation focuses on the study of behavior of geo grid gabion wall.
3. EXPERIMENTAL INVESTIGATION

3.1. Methodology

The present investigation involves the study of the geogrid gabion wall against lateral deformation due to the application of surcharge load. A comparative study is made between the (1) conventional gabion wall and geogrid gabion wall, (2) gabion wall with coarse aggregate and geogrid gabion with coarse aggregate + 25% of sand. Fig. 3.1 shows the schematic representation of the methodology followed for the study.

![Figure 3.1](image_url)  
**Figure 3.1** shows the schematic representation of the methodology

3.2. Experimental Set up

Experimental set up is a scale model (1:10) consist of wooden box of size 40 cm X 40 cm. Bi axial polyester geo-grid with aperture size (10mm x 10mm), is used to make basket of size 7cm X 5cm X 5cm. The basket has a lid to open and close. An anchorage length of 10 cm is provided at the rear face of the basket to enhance interface between the gabion wall and the back fill. Coarse aggregate passed on 16mm sieve and retained 13.55mm with properties: G = 2.87, D = 13 mm, Cu = 1.313 is used to fill the basket with the density of 2.85g/cc. Forty numbers of gabion boxes each 70 mm long, 50mm wide and 50mm high and with Anchorage development reinforcement of 100mm were used to retain the sand backfill inside the tank. The rows of gabions are filled up subsequently in a sequential manner after ensuring that each gabion is properly fixed to adjacent gabions on all sides. Fig. 3.2 shows the geogrid used for making the gabion wall. The gabion boxes are connected with each other by the steel wires of twisted connections as shown in Fig. 3.3. Fig. 3.4 shows the model gabion wall made for the study. Well graded sand (SW) with properties: G = 2.7, D = 0.2mm, Cu = 2.6, is used as a back-fill material for the proposed study. The back fill is compacted in to the box of study with the density of 1.37g/cc. Each layer of the fill was compacted to get the same density by controlling the weight of soil and thickness of layer. After levelling the backfill, the next layer of gabion boxes was placed above the first layer and they were stitched with nylon wires and the procedure was continued up to the required level. Eight layers of boxes each of height 40 mm were placed one above the other to complete the construction. The layers were also interconnected using steel wires such that the entire wall behaves as a single block. Fig. 3.5 shows the experimental set up mounted on the UTM for testing.
Figure 3.2 shows the geogrid used for making the gabion wall

Figure 3.3 Twisted connections between Gabion boxes

Figure 3.4 shows the model gabion wall made for the study

Figure 3.5 shows the experimental set up mounted on the UTM for testing
3.3. Experimental Study
The present experimental investigation involves in the study of the geo grid gabion wall, with the baskets filled in coarse aggregate alone and coarse aggregate + sand. In gabion walls, gravity force (self-weight) is the predominant stabilizing force, which depends on the unit weight of the material used for construction. In the present study, the conventional gabion baskets are replaced with the geo-grid boxes. The material used for filling the box are coarse aggregate and coarse aggregate + sand. The experimental study aims to investigate the strength and deformation behaviour of the scale model of the geo-grid gabion wall. For the load tests using coarse aggregate alone as the filling material, the above described model gabion boxes were used as such. But for the cases where sand is also used as filling material, the inner sides of the gabion boxes were stitched with geo-textile Terram 1000. Nylon wires were used for stitching. The geotextile prevents the escape of sand through the mesh openings. Markings with small metal strips were made on the front face of the circled boxes at the centre for taking deformation measurements with dial gauges. Photographic view of the test tank is shown in Fig 3.6. Fig.3.7. shows the arrangement of gabion boxes for testing case II (i.e.) Geo-grid gabion wall with filling 75 % coarse aggregate + 25 % Sand.

![Figure 3.6 Scale model set up of gabion wall](image)

![Figure 3.7 shows the arrangement of gabion boxes for testing case II (i.e.) Geo-grid gabion wall with filling 75 % coarse aggregate + 25 % Sand](image)

4. RESULTS AND DISCUSSION
The Experimental study involves the measurement of lateral deformation of the gabion wall for two testing cases namely,

**Case I:** Geo-grid gabion box filled with coarse aggregate alone

i. At the centre

ii. At the right side

iii. At the left side
**Case II**: Geo-grid gabion box filled with coarse aggregate + Sand

i. At the centre  
ii. At the right side  
iii. At the left side

Fig. 4.1 shows the schematic diagram of forces acting on a retaining wall without surcharge load. Fig. 4.2 shows the schematic diagram of forces acting on a retaining wall with surcharge load. Fig. 4.3 represents the schematic diagram of forces acting on reinforced geo-grid gabion wall with surcharge load used for the study.

After the construction of the wall using gabion boxes, loading is done using hydraulic jack and lever arrangement (UTM). The loading pattern used is of one-point loading acting on a 25mm thick and 0.2 m square plate placed over the sand backfill parallel to the gabion wall. Load was applied using a hydraulic jack, in increments of 1 KN till failure. After applying each increment, the load was kept constant till the deformations stabilized and the deformations were measured using dial gauges. Fig. 4.4 shows the experimental set up along with dial gauges used to measure the lateral deformations mounted on the UTM for testing (Case I). Fig. 4.5 shows the experimental set up along with dial gauges used to measure the lateral deformations mounted on the UTM for testing (Case II).

**Figure 4.1** Schematic diagram of forces acting on a retaining wall without surcharge load

**Figure 4.2** Schematic diagram of forces acting on a retaining wall with surcharge load
Figure 4.3 Schematic diagram of forces acting on reinforced geo-grid gabion wall with surcharge load

Figure 4.5 shows the experimental set up along with dial gauges mounted on the UTM for testing (Case I and II (i))

4.1. Load Deformation Characteristics of Geo-grid Gabion Wall (Case I (i))

Case (i) represents the geo-grid gabion wall with the filling of coarse aggregate alone and the deformations are measured at the centre of the wall (along the width) and at three positions along the height of the wall (Top, Middle, Bottom). The experimental setup was mounted in the UTM and three dial gauges were fixed on the gabion wall surface from top to bottom to measure the deformation. The load was applied gradually on the square plate which is placed on the backfill soil. For every 1 kN load increment the dial readings were observed. Table 4.1 shows load deformation characteristics of the geo-grid wall with gabions filled with coarse aggregate alone. Fig. 4.6 shows the deformation of the wall as the load increases.

<table>
<thead>
<tr>
<th>Loading (kN)</th>
<th>Dial 1 (Top)</th>
<th>Dial 2 (Middle)</th>
<th>Dial 3 (Bottom)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.21</td>
<td>1.52</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>9.95</td>
<td>2.54</td>
<td>1.13</td>
</tr>
<tr>
<td>3</td>
<td>16.07</td>
<td>3.61</td>
<td>2.06</td>
</tr>
</tbody>
</table>
4.1.1. Load Vs Deformation Curve for (Case I(i))

Figure 4.6 shows the deformation of the wall as the load increases.

The graph shows the lateral deformation of the wall along the height due to application of load. It is observed from the graph that the deformation increases as the load increases irrespective of the position of the dial gauges. The lateral deformation for the load of 3KN is 80.02% is higher than the lateral deformation for 1 KN for all the position of the dial gauges. The deformation at the top of the wall is more when compared to the bottom of the wall irrespective of the quantity of load applied. For the load of 1 kN, the deformation at the top of the wall is increased by 100%and 52.6% when compared to the bottom and middle of the wall respectively. Similarly, for 3 kN load, the deformation at the top of the wall is increased by 87%and 77% when compared to the bottom and middle of the wall respectively.

4.2. Load Deformation Characteristics of Geo-grid Gabion Wall (Case I (ii)) and (Case I (iii))

Case I(ii) represents the geo-grid gabion wall with the filling of coarse aggregate alone and the deformations are measured at the right side of the wall (along the width) and at three positions along the height of the wall (Top, Middle, Bottom).

Case I (iii) represents the geo-grid gabion wall with the filling of coarse aggregate alone and the deformations are measured at the left side of the wall (along the width) and at three positions along the height of the wall (Top, Middle, Bottom).

Table 4.2 and Table 4.3 shows load deformation characteristics of the geo-grid wall Case I (ii) and (iii) respectively.

<table>
<thead>
<tr>
<th>Loading (kN)</th>
<th>Deformation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dial 1 (Top)</td>
</tr>
<tr>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td>2</td>
<td>3.48</td>
</tr>
<tr>
<td>3</td>
<td>4.32</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Loading (kN)</th>
<th>Deformation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dial 1 (Top)</td>
</tr>
<tr>
<td>1</td>
<td>1.83</td>
</tr>
<tr>
<td>2</td>
<td>3.77</td>
</tr>
<tr>
<td>3</td>
<td>5.8</td>
</tr>
</tbody>
</table>
Fig. 4.7 and 4.8 shows a similar trend as in Fig. 4.6. (i.e.) as the load increases the lateral deformation increases irrespective of the position of the dial gauges vertically and horizontally. The lateral deformation for the load of 3KN is 65.5% and 70% higher than the lateral deformation for 1KN for all the position of the dial gauges for Case I (ii) and Case I (iii) respectively.

4.3. Load Deformation Characteristics of Geo-grid Gabion Wall with box filled with CA+ sand (Case II (ii))

Fig. 4.9 shows the load deformation curve for Case II(i). The lateral deformation for the load of 3KN is 75% is higher than the lateral deformation for 1 KN for all the position of the dial gauges. The deformation at the top of the wall is more when compared to the bottom of the wall irrespective of the quantity of load applied

4.3.1. Load Vs Deformation Curve for (Case I(ii))

Figure 4.7 shows the deformation of the wall as the load increases

4.3.2. Load Vs Deformation Curve for (Case I(iii))

Figure 4.8 shows the deformation of the wall as the load increases
For the load of 1 kN, the deformation at the top of the wall is increased by 100% and 53% when compared to the bottom and middle of the wall respectively. Similarly, for 3 kN load, the deformation at the top of the wall is increased by 87% and 78% when compared to the bottom and middle of the wall respectively. Similar trend and increase in deformation were observed for Case II (ii) and (iii). Fig. 4.10 and Fig. 4.11 shows the load deformation curve for Case II (ii) and (iii) respectively.

4.4. Effect of partial replacement of CA with sand in the Gabion Box (Case I and Case II)

Fig. 4.12 and Fig. 4.13 shows the comparison of load deformation curve of the geo-grid gabion wall with gabion box filled with coarse aggregate alone (Case I(ii)) and gabion box filled with coarse aggregate + sand (Case II (ii)).

4.4.1. Load Vs Deformation Curve for (Case II(i))

![Graph of Load Vs Deformation Curve for (Case II(i))](image)

Figure 4.9 shows the deformation of the wall as the load increases

4.4.2. Load Vs Deformation Curve for (Case II(ii))

![Graph of Load Vs Deformation Curve for (Case II(ii))](image)

Figure 4.10 shows the deformation of the wall as the load increases
4.4.3. Load Vs Deformation curve for (Case II(iii))

Figure 4.11 shows the deformation of the wall as the load increases. It is observed from the graph that when the gabion box is filled with CA + sand, the deformation is reduced when compared with that of the gabion box filled with CA alone. From Fig. 4.12, the deformation in Case II is reduced by 32% when compared with Case I for 1kN. For 2 kN and 3 kN the deformation decreases by 40% and 23% respectively in Case II when compared with Case I. Similar observation was made irrespective of the position of the dial gauge.

4.4.4. Comparison of Deformation Curve for Case I and II at Rightside of the Wall

Figure 4.12 Comparison of Load Deformation Curve for Case I and II
4.4.5. Comparison of Deformation Curve for Case I and II at Leftside of the Wall

![Graph](image)

**Figure 4.13** Comparison of Load Deformation Curve for Case I and II

4.5. Effect of replacement of Steel mesh Gabion Box with Geo-grid gabion box

The main objective of the present study is to find a better alternative for the steel wire mesh gabion box. In the study it is replaced with geo-grid box and the experiments have been performed. The lateral deformation of the geo-grid gabion wall is compared with that of the conventional gabion wall [7]. Table 4.4 shows the comparison of the deformation of steel gabion wall with geo-grid gabion wall.

**Table 4.4** Comparison of Lateral Deformation of Steel Wire Mesh Gabion with Geo-Grid Gabion

<table>
<thead>
<tr>
<th>Wire mesh Gabion with Coarse Aggregate (3kN)</th>
<th>Geo grid Gabion with Coarse Aggregate (3kN)</th>
<th>Geo grid Gabion with Coarse Aggregate +Sand (3kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 mm of deflection</td>
<td>16 mm of deflection</td>
<td>9mm of deflection</td>
</tr>
</tbody>
</table>

The deformation for 3kN load of steel gabion is compared with that of the geo-grid gabion. The deformation is decreased by 20% and 55% for geo-grid gabion wall Case I and Case II, respectively, when compared with that of steel wire mesh gabion.

5. CONCLUSION

Gabion faced retaining walls which are gaining fast momentum in construction recently. A vast literature survey was conducted wherein it was found that the number of research works conducted on these types of walls is very much limited. Thus, there arises an urgent need to study in detail the performance of gabion faced retaining walls which has been taken present investigation. This study is limited to geo-grid gabion faced reinforced earth walls as they are more suited to larger heights. The investigation reveals that the performance of geo-grid gabion wall is better than the conventional gabion wall.
REFERENCES


