GABION RETAINING WALLS WITH ALTERNATE FILL MATERIALS

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**ABSTRACT:** Although gabions have been used from ancient times, it is only in the last few decades that their wide spread use has lead them to become an accepted construction material in Civil Engineering. Gabion retaining walls are mass gravity structure made up of strong mesh containers known as gabion boxes, filled with quarry stone. Considering the cost and scarcity of quarry stones, the replacement of it with some other cheaper material will make the construction more economical. This aspect is studied here. Considering the specific gravity, friction, cost and availability, quarry dust and red soil was selected as the fill material. Model gabion retaining walls were constructed for the purpose in which, different combinations of quarry dust, red soil and coarse aggregate were taken as the filling material. Analyzing the lateral deformations of various cases, it can be concluded that a 50%-50% combination of alternative material and aggregate will perform better than the coarse aggregate alone, considering the cost of construction.

1. **INTRODUCTION**

Retaining walls, one of the major geotechnical applications, are mainly used in the case of highways and railways to support the soil at different levels. In some places they may even be used to support water, coal, dumped wastes etc. Based on the stability, the retaining walls are classified into Gravity wall, Mechanically stabilized earth wall and Semi gravity wall. The gravity retaining wall relies on its own weight for its stability. The mechanically stabilized earth wall uses the principle of introducing reinforcements into a granular backfill through mechanical means such as metal strips and rods, geotextile strips and sheets or wire grids. Semi gravity retaining walls are those in which the size of the section of a gravity retaining wall is reduced by the introduction of small amount of reinforcement in the back fill.

Nowadays, a new type of construction named as gabion retaining wall is gaining momentum as substitute to the conventional retaining walls. This work deals with such a gabion system which resists the lateral pressure by gravity loading as well as by the friction and interlocking between the reinforcement and the back fill which is commonly referred to as MSE type gabion retaining walls.

The cost effectiveness can be further increased if we use locally and cheaply available materials as fill material. An exploration in this direction is also needed. Hence laboratory investigation on model retaining wall using materials like quarry dust and red soil, which are easily available in the locality at lower cost, is proposed.

1.1 **Scope of the Present Study**

Gabion retaining wall system is an emerging technique in the field of retaining walls construction. It is a flexible type of dry stone gravity mass wall made of gabion boxes. They are cost effective, environmental friendly and durable structures. Because of these reasons gabions are widely used now days all over the world. The gabion walls are used for a variety of applications like retaining earth and water, highway protection, rock fall protection etc.

From the economic studies conducted so far [Lee *et al.* (1973), Collin (2001), Koerner *et al.* (2001)], it can be seen that the MSE walls with gabion facing and geotextile reinforcement is very cost effective. Indian railways in 1999 conducted a cost comparison study between gabion and RCC walls. As the height of wall increases the expense of gabion wall is observed to be less when compared to RCC walls. But it is quite obvious that the stone filling used in gabions increase the cost of construction if the quarry stone is not locally available. In such circumstances, there arises the need of an alternate material for the filling of gabions boxes. Alternate material should be such that it is locally available, and, provides the same stabilizing gravity force to the facing as provided by the stone fill. Although, soil filled box gabions are used in practice, they do not offer the same stabilizing force as that of stone filled type. In this work, the possibility of replacement of the stone filling with a mixture of stones and the easily available cheap waste material like quarry dust and red soil are thought of. The use of quarry dust will also help to solve many of its disposal problems.

While using the quarry dust and red soil as a fill material, there is a possibility of the leakage of the material through the voids of the stones and through the mesh of the gabion boxes. Hence the fill material, which is a mixture of stones, quarry dust, and red soil, should be contained inside the gabion boxes with geotextile linings. Thus the facing system used here is the same as that of the soil filled type gabion...
walls and the gabion system proposed here can be considered as a modified form of soil filled gabion walls. For the studies on such a system, a model gabion retaining wall with coarse aggregate, quarry dust and red soil as filling material was constructed in laboratory. Loading tests were conducted in the gabion system with different percentages of coarse aggregate, quarry dust and red soil as filling material. Thus the determination of optimum combination of coarse aggregate and quarry dust, coarse aggregate and red soil filling material, which resists the earth pressure, ensures stability as well as allows sufficient drainage, was the object of the study.

2. EXPERIMENTAL INVESTIGATION

The experimental studies were carried out on a model gabion wall constructed in the Geotechnical Engineering laboratory of School of Engineering, CUSAT. In this project, the physical properties of the material used for the construction, like sand (backfill), coarse aggregate, quarry dust, red soil, and steel mesh were obtained and the behavior of a model gabion retaining wall is studied. A parametric study was also conducted with different material combination to study the advantages of locally available materials.

2.1 Materials Used

The materials used for the construction of model gabion walls were coarse aggregate, sand, quarry dust, red soil, steel mesh and accessories. The details of the physical properties of materials are discussed below.

2.1.1 Coarse Aggregate

The stone filling of size 20 cm–30 cm in an actual field gabion wall was replaced with coarse aggregate having size 20 mm–40 mm in the model studies to conform to the proportion of the size of the mesh opening in the prototype and the model. Coarse aggregate for this purpose was collected from a quarry near Kothamangalam in Ernakulam district of Kerala. The properties of coarse aggregate were found out using different test in the laboratory according to IS specifications and are shown in Table 1.

<table>
<thead>
<tr>
<th>Property</th>
<th>Sand</th>
<th>Quarry dust</th>
<th>Red soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uniformity coefficient Cu</td>
<td>3.3</td>
<td>10.9</td>
<td>6.9</td>
</tr>
<tr>
<td>Coefficient curvature Cc</td>
<td>1.05</td>
<td>1.05</td>
<td>1.51</td>
</tr>
<tr>
<td>Effective size D10 (mm)</td>
<td>0.255</td>
<td>0.034</td>
<td>0.34</td>
</tr>
<tr>
<td>Angle of internal friction φ</td>
<td>38</td>
<td>39</td>
<td>45</td>
</tr>
<tr>
<td>Specific gravity G</td>
<td>2.529</td>
<td>2.639</td>
<td>2.71</td>
</tr>
</tbody>
</table>

2.1.2 Fill Materials

River sand was used as the backfill for model gabion wall. Quarry dust was used as fill material in the model gabion boxes. It is used alone and in combination with coarse aggregate also. This quarry dust was obtained from a quarry near Edayar in Ernakulam district of Kerala. Red soil was also tried as fill material. It is used alone and in combination with coarse aggregate. Tests were conducted according to IS specifications to find out physical properties of sand, quarry dust and red soil are reported in Table 2.

2.1.3 Steel Wire Mesh

In field, actual gabion boxes are made with double twist or triple twist hexagonal wire mesh. For the model gabion box, steel mesh with square opening of was used. The wire diameter of mesh was 1.17 mm and size of square mesh are 12 mm × 12 mm. Tensile strength of mesh was obtained by conducting tension test on steel mesh using universal testing machine and found to be 22.4 kN/m, with a breaking load of 1.75 kN.

2.1.4 Geotextile

Thermally bonded non woven type geotextile was used on the back face of the wall to prevent the entry of back fill sand into the boxes as well as on all faces of each box to prevent the escape of quarry dust and red soil through the mesh opening of the boxes. Terram 1000 obtained from Meccaferri, Pvt. Ltd. was used in this study. The properties of geotextile provided by the suppliers are: Tensile strength = 8 kgf/m, Elongation = 28%, Pore Size = 150 μm, Mass per Unit Area = 1.25 N/m², Permeability = 100mm/s

2.2 Construction of Model Gabion Wall

The model gabion wall was constructed in a test tank of size 1 m × 1 m × 1 m. The height of the wall was 0.6 m. Sixteen number of gabion boxes each of 0.25 m long, 0.15 m wide and 0.15 m high were used to retain the back fill. The boxes were fabricated by stitching steel mesh panels to get the required shape of the gabion box. Four such boxes were stitched one beside the other to form a layer such that they behave as a single unit. The boxes were filled with filling material at an average density of 16 kN/m³. After filling the boxes, top cover was closed and tightly connected to the sides of the gabion boxes using the steel wires. Geotextile was placed behind the boxes in each layer, in order to avoid the entry of granular back fill into the boxes. Then backfilling was done up to the height of the boxes. The backfill sand was compacted in each layer to get an average
density of 16 kN/m³. Each layer of the fill was compacted to get the same density by controlling the weight of soil and thickness of layer. After leveling the backfill, the next layer of gabion boxes was placed above the first layer and they were stitched with steel wires and the procedure was continued up to the required level. Four layers of boxes each of height 0.15 m 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. Markings with small metal strips were made on the front face of the selected boxes at the center for taking deformation measurements with dial gauges.

After the construction of the wall using gabion boxes, loading is done using hydraulic jack and lever arrangement. The loading pattern used is of two-point loading action on a 25 mm thick and 0.2 m wide strip placed over the sand backfill parallel to the gabion wall. Each time the load was applied by pumping oil into the piston with the help of levers. Load is applied in increments of 3 kN. After applying each increment, the load was kept constant till the deformations stabilized. Prior to next increment, lateral deformations were measured using dial gauges. The photograph of the loading setup used in the experiment is shown in Figure 1.

2.3 Parametric Study

The experimental studies were conducted on model wall using five different filling materials inside the gabion boxes. The combinations were varied by percentage volume of the gabion box because in the actual field practice this is the usual filling pattern. The six different cases adopted for the study were

1. Coarse aggregate alone
2. 50% coarse aggregate and 50% quarry dust (as layer)
3. Quarry dust alone
4. 50% coarse aggregate and 50% quarry dust (as core)
5. 50% coarse aggregate and 50% red soil as core
6. Red soil alone

The gabion boxes were filled with the fill material at an average of density 16 kN/m³. For all the cases, the gabion boxes were given a lining of geotextile (Terram 1000) to prevent the escape of the fine materials through the steel mesh openings. For case 2, lower half of each box was filled with quarry dust and upper half with coarse aggregate. For case 4 and 5, a core was made to fill the quarry dust and red soil in it and the coarse aggregate was filled on the two sides of the core. The study was conducted to check the stability of gabion walls with quarry dust and red soil as an alternative to quarry stones inside the gabion boxes so as to reduce the cost of construction of gabion walls using locally available material.

3. RESULTS AND DISCUSSION

Load tests were conducted on the model retaining wall in order to obtain the lateral deformations and bulging characteristics of the model gabion wall for different fill combinations.

3.1 Load Deformation Studies

The model gabion retaining wall was constructed and loading was done using hydraulic jack and lever arrangement. Each time the load was applied by pumping oil into the piston with the help of levers. After applying each increment, the load was kept constant till the deformations stabilized. Lateral deformations were measured at different points using dial gauges.

3.1.1 Lateral Deformation

The variation of the lateral deformation against the load applied shown by dial gauges fixed at the top layers is shown in Figure 2. From the figure it can be seen that as the load applied increases, lateral deformation also increases. The lateral deformation seems to be less for the combination 50% red soil and 50% coarse aggregate. The coarse aggregate alone showed more lateral deformation may be because of the large voids present in the boxes. From the conducted tests, when compared with 100% coarse aggregate, for a lateral deformation of 5 mm, it is seen that the load carrying capacity increases by 31.32% (average) for 50%–50% combinations of red soil and coarse aggregate (as core), 16.55% (average) for 50%–50% combination of quarry dust and coarse aggregate (as core) and 18.5% (average) for 50%–50% combination of quarry dust and coarse aggregate (as layer).

When comparing 50%–50% combination of quarry dust and red soil along with coarse aggregate (as core), the load carrying capacity for 50%–50% combination of red soil and coarse aggregate increases with 13.12% (average) for a lateral deformation of 5 mm. While comparing 50%–50% combination of quarry dust and coarse aggregate (as core and as layer), there is not much variation for the loading capacity for the lateral deformation of 5 mm.
3.1.2 Bulging Patterns

Studying the bulging pattern it was observed that, the first layer from the top experienced the maximum bulging than the lower layers at failure. As the percentage of quarry dust and red soil increases the bulging is observed to increase. The bulging is found minimum for coarse aggregate. Figure 3 shows the bulging patterns of different gabions in a single figure for a particular load 24 kN which corresponds to minimum load at failure. The minimum bulging is observed for the 50%–50% combination of coarse aggregate and red soil (as core). Comparing the lateral deformation at the top of the retaining wall, for 100% of coarse aggregate and 50%–50% combination of red soil and coarse aggregate (as core), the lateral deformation is reduced by 30.11% for 50–50 combination of red soil and coarse aggregate (as core).

When comparing, it has been noted that 50%–50% combination of red soil and quarry dust along with coarse aggregate (as core), the lateral deformation at the top of the retaining wall, is reduced by 11.84% for 50%–50% combination of coarse aggregate and red soil (as core).

Similarly, it is seen that the 50%–50% combination of quarry dust and coarse aggregate (as core and as layer), the lateral deformation at the top of the retaining wall is reduced by 0.92% for 50%–50% combination of quarry dust and coarse aggregate (as core). From the test result, it is observed that, there is not much variation for bulging pattern of 50–50 combination of coarse aggregate and quarry dust (as core and as layer).

4. SUMMARY AND CONCLUSION

Gabion retaining walls with base extensions are very good alternative to expensive RCC walls. They incorporate basic principles of gravity retaining walls and mechanically reinforced earth walls. The economic studies conducted by Indian railways gives a good comparison between gabion and RCC walls, as the height of wall increases the expense of the gabion wall is observed to be less when compared to RCC walls. The percentage cost savings by gabion is of the order ranging from 30% to 60%, since less time is required for the construction. In the construction of RCC walls, as the work involves cost of cement, sand, aggregate, shuttering etc. it becomes more expensive.

In order to reduce the cost of construction further, and to reduce the use of rubbles in gabion boxes, alternative materials are proposed as filling. Here laboratory investigations are conducted on model gabion walls using locally available and cheap materials like quarry dust and red soil. The materials were tried in layers as well as in core. From the result of different test and analysing the lateral deformation, it can be concluded that a 50%–50% combination of alternative material and aggregate will perform even better than the coarse aggregate alone, where as the cost of construction can be drastically reduced.

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REFERENCES


