Stress – Displacement Behaviour of PVC cell Gabion wall with Geogrid Reinforcement

Bhanuchitra, M.[1], Sushmitha, B. [2] and Padmavathi, V.[3]

[1] Research Scholar, Department of Civil Engineering, JNTUH College of Engineering, Jawaharlal Nehru Technological University Hyderabad, 500085
[2] Asst.Professor, Guru Nanak Institutions Campus ,Hyderabad
[3] Professor, Department of Civil Engineering, Jawaharlal Nehru Technological University Hyderabad, 500085
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bhanumaheshwaram@gmail.com,sushmitha149@gmail.com and vpadma70@gmail.com

Abstract. Large volume of scrap tyres was being generated and accumulated causing danger to the environment and health problems to the public. Utilization of local available materials like waste tyres/ drums was cost effective for construction of gabion retaining wall. The aim of present study includes to obtain the deformations of gabion wall after end of the construction and under uniform surcharge loads for various wall face inclinations and reinforcement. Behaviour of the gabion walls build using scrap tyres/ scrap circular MS drums in the field was simulated in the laboratory for constructing retaining walls without and with geogrid using PVC cells. The experimental work was carried out in the laboratory in a steel tank of dimensions 1.44 m × 1.0 m × 1.2 m. Gabion type walls were constructed using PVC pipes of 15 cm diameter and 5.0 cm in height of PVC cells. Poorly graded sand was used as backfill and filling in PVC cells with a relative density of 68% and corresponding unit weight of 18 kN/m^3. Dial gauges were used to measure horizontal displacements at different heights from the bottom of the wall. PVC cell wall was constructed with different wall face inclinations 2.5°, 5.0° and 7.5° to observe the lateral displacements and vertical settlements. A uniform surcharge load was applied on the backfill soil through a solid plate. The wall horizontal displacements were monitored during construction, end of the construction and after application of surcharge for the mentioned wall face inclinations without and with geogrid reinforcement. The maximum normalized wall displacements of reinforced wall with three and five layers of geogrid at the end of construction were 0.0021 for a height of 0.75H and 0.0019 for a height of 0.67H respectively. After the application of uniform surcharge load of 15.48kPa, the normalized displacements were 0.0028 and 0.0023 for three and five layers of reinforced wall for a height of 0.75H, 0.67H respectively.

Keywords: Gabion wall, PVC cell, Scarp tyres, Horizontal displacements, Surcharge load

1 Introduction

Gabion retaining walls have been used widely in the world for geotechnical applications mainly in the case of erosion control projects, soil reclamation work, stream channels etc. Gabions are wire mesh boxes filled by rock and stone in retaining construction which is commonly referred as MSE type gabion retaining walls. Cost effectiveness can be increased by the utilization of locally available materials in the construction of gabion wall. Looking at in this direction, large volume of scrap tyres was being generated and accumulated causing danger to the environment and health problems to the public. This has become a serious problem in many countries. Research into the application of scrap tyres for construction purpose has started some years back in the developed countries like America, Australia and Europe. To reduce the horizontal displacements an innovative method of isolated reinforced earth wall method was developed by Cho et al. (2003), the displacements are reduced from 0.60% to 0.25% with test wall constructed using PVC cells. A low cost alternative technique was proposed by Sayao et al. (1999) for earth retention by constructing gravity type retaining wall using scrap tyres and the lateral displacements were observed with instrumentation which was within reasonable limits. The deformation pattern observed by Lee (2000) which was increased non-linearly from bottom to top with different surcharge loads for geosynthetic reinforced walls those were different for the walls constructed using PVC cells and the normalized horizontal displacements are within limits. The deformations of the galvanized and PVC coated hexagonal wire mesh gabions were observed by Bergado et al. (2000) through pull out test and the deformations were maximum in the top most layers. Ravichandra et al. (2018) proved that horizontal deformations of gabion wall with PVC cells are within limits as per the guidelines by AASHTO.

Benjamim et al. (2007) observed the field test results during and after construction of geotextile – reinforced retaining wall reported that the lateral displacements occurred towards the wall face and higher displacements occurred at the mid height of the wall. Bathurst et al. (2010) summarized the recommended limits and remedies for horizontal displacements of geosynthetic reinforced soil walls. Lin et al. (2010) explained the behavior of reinforced gabion wall through laboratory experiments observed that with the increase of surcharge loads the lateral face deformation of wall were increased. From the literature survey, 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 geogrid gabion wall. The main objective of this paper includes knowing the behaviour of gabion type retaining walls with geogrid using PVC pipes and wall displacements such as vertical and horizontal were studied.

2 Experimental Studies

This includes the soil testing to find the engineering properties of backfilling material; gabion wall construction using PVC cells in a tank and measurement of wall displacements in vertical and horizontal planes and settlements at the end of the construction and under uniform surcharge of 15.48 kPa for three wall face inclinations 2.5°, 5.0° and 7.5° .

Materials used in the study

Sand was procured from the river Godavari near Karimnagar in Telangana which was used as backfill and filling in tyres for gabion retaining wall construction. The properties of sand were presented in Table 1**.**

Table 1. Properties of Sand

S. No	PROPERTIES	VALUE
1	Grain Size distribution	
	Gravel (%)	1.5
	Coarse Sand (%)	21.5
	Medium Sand (%)	69.5
	Fine Sand (%)	6.5
	Clay and Silt (%)	1.0
2	Uniformity coefficient (CU)	3.33
3	Curvature coefficient (CC)	0.85
4	Soil classification	SP
5	Minimum unit weight (kN/m^3)	15.5
6	Maximum unit weight (kN/m^3)	18
7	Maintained Relative Density (%)	68
8	Angle of shearing resistance	42°

The geogrids were used for soil reinforcement which is made of polypropylene (PP) and high density polyethylene (HDPE). Grid SG 200 was used in the present study of the size 18.3 x 16.5 mm and ultimate strength of 52.5kN/m and creep strength of 33.9kN/m. A PVC pipe of 3 m long and 150 mm diameter was made into 5 cm height pieces to have the depth of 50mm and were arranged in two horizontal rows as shown in Fig. 1. PVC cells were placed adjacent to each other and tied with the nylon rope to ensure proper connectivity between PVC cells.

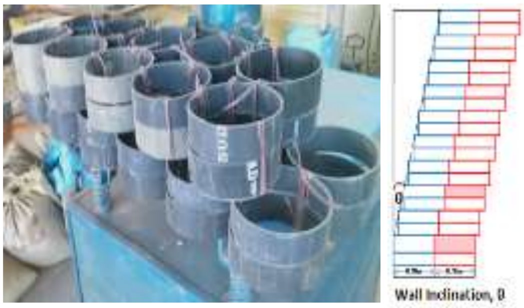

Fig. 1. PVC wall pattern & tying arrangement

3 Methodology

The present investigation involves the study of the PVC cell geogrid gabion wall against lateral and vertical directions due to the application of surcharge load.

Experimental Set up

Experimental set up consists of a model steel tank of size 1.44 m length, 1.0 m width and height of 1.2 m and it had transparent plastic sheet at one face to visualize the wall movement, dial gauges were fixed during the construction phase of the wall to measure the displacements. Four dial gauges were fixed at the centre of the wall at heights of 33 cm, 59 cm, 79 cm and 98 cm from the bottom of the wall. At height of 69 cm two dial gauges were fixed at a distance of 27 cm on the either sides from the centre of the wall (Fig. 2). For monitoring of vertical settlements two dial gauges were firmly fixed to the sides of the MS tank, a rigid MS plate of size 92 cm length 65 cm width and weight 12.5 kg was placed on top, levelled properly and checked with spirit level for loading. Uniform surcharge was applied by placing concrete cubes in layers over the MS plate. The same procedure was implemented for three and five layer reinforced wall.

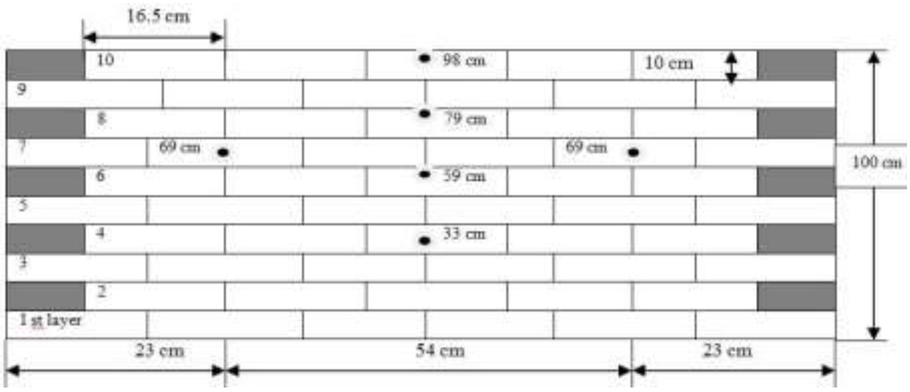

Fig. 2. Set up of Dial Gauges along Height of the Wall

PVC wall construction

The test PVC wall was constructed in three different cases includes gabion wall constructed without reinforcement, with three and five layers of reinforcement for wall face inclinations of 2.5°, 5.0° and 7.5°. The reinforced geogrid layer was placed for every 30 cm height and 20cm height of wall for three and five layer reinforced wall respectively. In case of five layers reinforced wall the first layer was placed at 10cm height.

Test Procedure

Horizontal displacements were measured during the construction phase with the application of various surcharge loads. During construction the first dial gauge was fixed from the bottom of the wall to ensure firm contact with the PVC wall face. Remaining three dial gauges were fixed at 59 cm, 79 cm, and 98 cm from bottom of the wall to monitor and record the values. Concrete cubes were placed on the top for uniform surcharge loading as shown in Fig. 3. Dial gauge readings of both horizontal and vertical displacements were recorded after the readings were constant. For all the three wall inclinations the construction, instrumentation and surcharge loading were same.

Fig. 3. Surcharge Load using Concrete Cubes

4 Results and Discussions

The experimental study involves the measurement of vertical and lateral deformation of the PVC gabion wall for three testing cases namely,

i. Displacement of PVC cell gabion wall
ii. Displacement of wall with three layers of geogrid
iii. Displacement of wall with five layers of geogrid

The displacements were compared for above three cases in vertical plane at inclinations of 2.5°, 5.0° and 7.5°. Figures 4 through 6 show the variation of normalized wall displacement at the centre of wall, δ/H versus height of the wall, h/H for three different inclinations at the end of construction and Figs. 7 through 9 after application of uniform surcharge 15.48 kPa. The normalized displacements were maximum at 0.72H, 0.72H and 0.67H normalized heights from the bottom of the tank in all three cases. Maximum normalized displacements were shown in Table 2. The location of maximum normalized displacement was same for 2.5° and 5° and lesser value for 7.5° wall inclination.

Table 2. Normalized displacements

S.NO	Cases	Maximum Normalized displacements					
		At the end of construction			At uniform surcharge of 15.48 kPa		
		2.5°	5°	7.5°	2.5°	5°	7.5°

1	PVC cell Gabion Wall	0.0028	0.0023	0.0020	0.0061	0.0053	0.0047
2	Gabion wall with three layer Geogrid	0.0021	0.0020	0.0018	0.0027	0.0026	0.0025
3	Gabion wall with five layer Geogrid	0.0019	0.0014	0.0011	0.0023	0.0019	0.0015

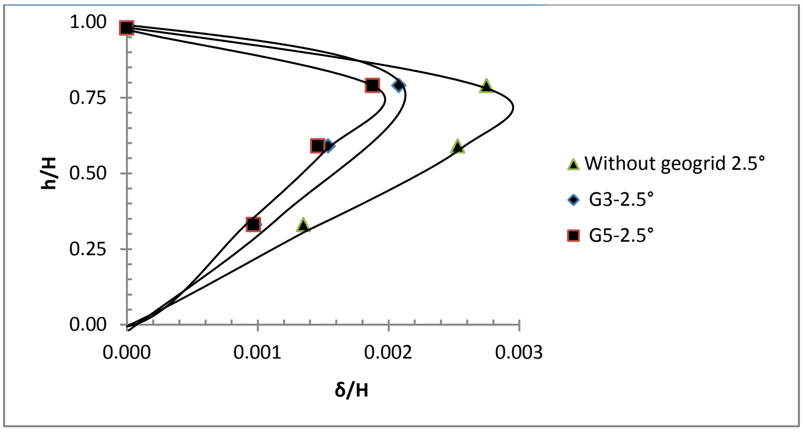

Fig. 4. Normalized Wall Displacement versus Normalized Height of Wall at Center for 2.5° wall Inclination with and without Geogrid at the End of Construction

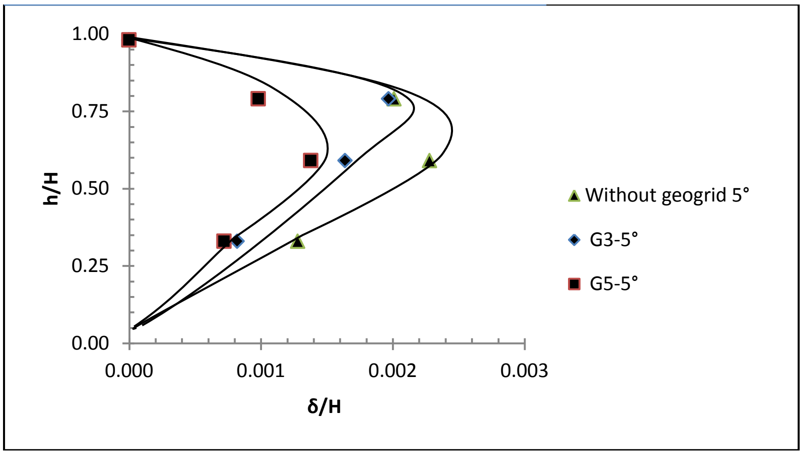

Fig. 5. Normalized Wall Displacement versus Normalized Height of Wall at Center for 5° wall Inclination with and without Geogrid at the End of Construction

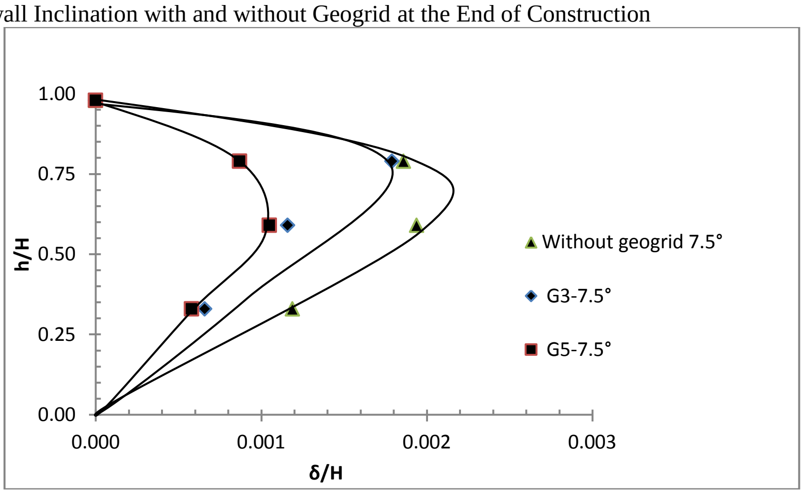

Fig. 6. Normalized Wall Displacement versus Normalized Height of Wall at Center for 7.5° wall Inclination with and without Geogrid at the End of Construction

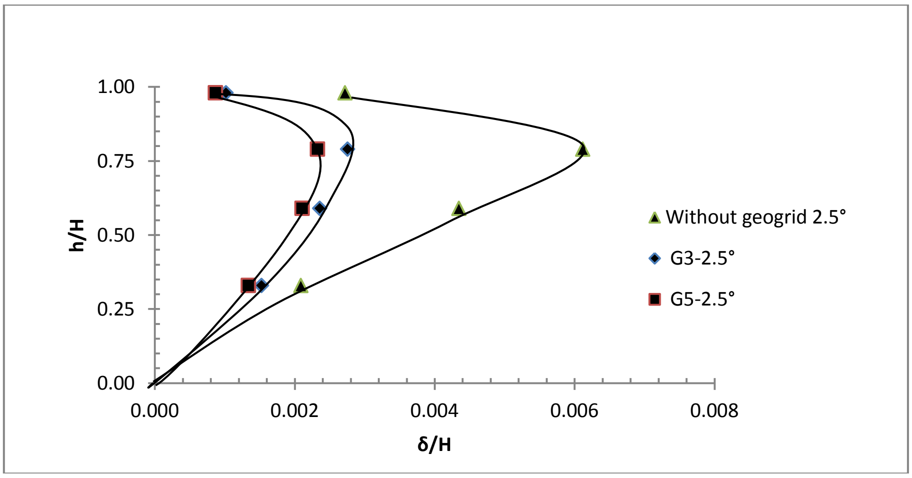

Fig. 7. Normalized Wall Displacement versus Normalized Height of Wall at Center for 2.5° wall Inclination with and without Geogrid at 15.48kPa stress

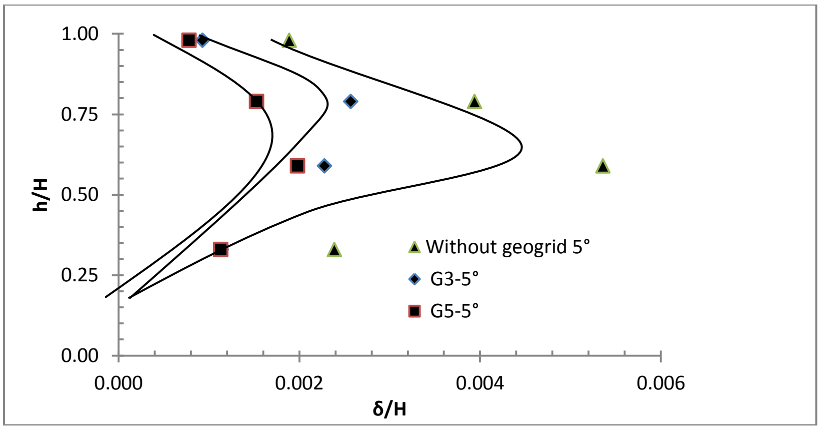

Fig. 8. Normalized Wall Displacement versus Normalized Height of Wall at Center for 5° wall Inclination with and without Geogrid at 15.48kPa stress

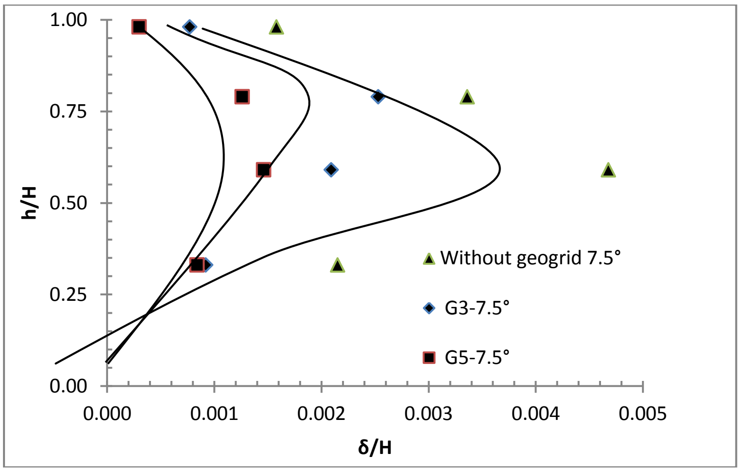

Fig. 9. Normalized Wall Displacement versus Normalized Height of Wall at Center for 7.5° wall Inclination with and without Geogrid at 15.48kPa stress

Comparisons of vertical displacements were made between with and without reinforcement at the wall inclinations of 2.5°, 5° and 7.5°. After the application of surcharge, 15.48 kPa the settlement at point 1 and point 2 were shown in Table 3. The vertical settlements were gradually increased as the inclination increased and the settlements were decreased when reinforcement induces.

Table 3. Vertical displacements

S No	Cases	Vertical Settlements (mm)					
		Point 1			Point 2		
		2.5°	**5°**	**7.5°**	**2.5°**	**5°**	**7.5°**
1	PVC cell Gabion Wall	2.07	2.16	2.25	1.32	1.48	1.74
2	Gabion wall with three layer Geogrid	1.49	1.58	1.65	0.85	0.90	1.18
3	Gabion wall with five layer Geogrid	1.44	1.55	1.58	0.72	0.82	0.99

Conclusions

1. Horizontal displacement of PVC gabion wall at the EOC was increased non-linearly up to a maximum displacement with increase in the height of the wall and then decreased. The maximum normalized displacements decreases up to 9 % from 2.5° to 7.5° wall face inclinations.
2. The maximum normalized displacements increases up to 33 %, 31 % and 28 % from EOC to maximum applied stress 15.48 kPa for 2.5°, 5.0° and 7.5° wall face inclinations respectively.
3. The maximum normalized displacement for reinforced wall with three layers of geogrid at the EOC decreases up to 3 % from 2.5° to 7.5° wall face inclinations.
4. The maximum normalized displacements for reinforced wall with three layers geogrid increases up to 7 %, 6 % and 7 % from EOC to maximum applied stress 15.48 kPa for 2.5°, 5.0° and 7.5° wall face inclinations respectively.
5. The maximum normalized displacement for reinforced wall with five layers geogrid decreases up to 8 % from 2.5° to 7.5° wall face inclinations.
6. The maximum normalized displacements for reinforced wall with five layers geogrid increases up to 4 %, 6 % and 4 % from EOC to maximum applied stress 15.48 kPa for 2.5°, 5.0° and 7.5° wall face inclinations respectively.
7. With increase in surcharge there was no change in the location of maximum normalized displacement because the surcharge location from face of the wall was same for all the cases.

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