INFLUENCE OF BACKFILL TYPE ON THE LOAD CARRYING CAPACITIES OF SQUARE FOOTINGS RESTING ON GEOSYNTHETIC REINFORCED SOIL RETAINING WALLS AS A GREEN BUILDING TECHNIQUE

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Article History: Received: 12.12.2022 **Revised:** 29.01.2023 **Accepted:** 15.03.2023

Abstract

Aim: The aim of the present study is to analyse the effects of different backfill types on the bearing capacity of a square footing located on wrap-around geosynthetic reinforced soil (GRS) retaining wall. **Materials and Methods:** Geosyntheitc reinforced soil retaining wall models are prepared in a transparent container. Square footing is placed on a retaining wall and subjected to compressive load in a loading frame. (**Group 1**: GRS retaining wall with sea sand backfill, N = 17. **Group 2**: GRS retaining wall with M-sand backfill, N = 17). Pre-test power and confidence intervals were chosen as 80% and 95% respectively for sample size calculation. **Result:** Test results show that GRS retaining wall with 4 cm reinforcement spacing performs better than a GRS retaining wall 6 cm spacing. There is a significant difference (2 tailed) between two groups of GRS retaining wall as the value of p is 0.008 ($p<0.05$) for cohesion in statistical analysis. **Conclusion:** Closer reinforcement spacing increases the bearing capacity of square footings.

Keywords: Innovative Geosynthetic, Reinforced soil, Geotextile, Bearing capacity, Retaining walls, Square footing

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1. Introduction

Up to a height of 4 m to 5 m, the gravity type retaining wall is cost-effective (Bari et al. 2021). Retaining walls of the RC cantilever and RC counterfort types can be built to a higher height, but they become prohibitively expensive over 8.0 m (Senthil, Iqbal, and Kumar 2014). If local materials can be used for construction, a reinforced earth wall may be a cost-effective alternative (Galimshina et al. 2022). Internally stabilised wall technologies such as geotextile reinforced walls or anchored earth walls, on the other hand, are more cost-effective (Sakaguchi and Muramatsu 1990). Because practising engineers are unfamiliar with these retaining systems, it is required to demonstrate that internally stabilised retaining walls are superior to traditional retaining walls in terms of cost, time, and convenience of construction (Bourdeau, Fox, and Runser 2001). Relative economy of reinforced soils was demonstrated by (Liu, Wang, and Song 2009). The comparison with conventional and other types of retaining walls was also made. For purposes of illustration, several case studies of cost analyses and numerical examples are also included.

The GRS retaining walls comprised four different types of facings having different degrees of rigidity (Michael Duncan, Wright, and Brandon 2014). The lateral displacement of the facing tends to continuously decrease with the increase of load. More the wall is inclined the more the horizontal stresses behind the wall and values of the tensile stress in the layers of geogrid decrease (Helwany, Reardon, and Wu 1999). The dimensions of modular blocks (types) and the mechanical characteristics of modular blocks (category) have a remarkable effect on the calculation of retaining walls in modular blocks reinforced with layers of geogrid. For a clearer understanding of the behaviour of the wall’s system (Reznik 1998). Numerical modelling is an excellent tool which is input with soil properties, the geosynthetic reinforcement properties to analyse the stability, deformation and the influence of several parameters at any point of the model within a reasonable time. Several researches have been done on the use of geosynthetics as backfill massive reinforcement material that we quoted hereafter some examples of studies based on numerical modelling. The location of maximum reinforcement strains within each layer was found to be consistent with the development of a potential failure surface starting at the toe of the wall and propagating into the soil mass (Letcher 2017). (Dash 2001) studied the creep response of GRS walls under static loads. Isochrone curves were used to interpret the effects of reinforcement stiffness and creep rate on both short-term and long-term performances of GRS walls under operational condition. With an increase in the reinforcement stiffness, the maximum reinforcement load increased (Ramalakshmi and Vidhyalakshmi 2021). The global reinforcement stiffness which is related to the isochrones stiffness of reinforcement as well as reinforcement length was related to the total reinforcement load. An equation was proposed that can be used to predict the maximum reinforcement load in nonuniform reinforced wrapped-face walls of given backfill types and reinforcement configurations similar to those investigated in this study. An equation is proposed by (Koerner 1990) which can be used to predict the maximum reinforcement load in nonuniform reinforced wrapped-face walls of given backfill types and reinforcement configurations similar to those investigated in this study. The amplitude of cumulative facing lateral displacement under base stimulation is reduced with increasing reinforcement length, number of reinforcement layers, and reinforcement stiffness, according to experimental data obtained by (El-Emam and Bathurst 2007).

Our institution is passionate about high quality evidence based research and has excelled in various domains (Vickram et al. 2022; Bharathiraja et al. 2022; Kale et al. 2022; Sumathy et al. 2022; Thanigaivel et al. 2022; Ram et al. 2022; Jothi et al. 2022; Anupong et al. 2022; Yaashikaa, Keerthana Devi, and Senthil Kumar 2022; Palanisamy et al. 2022).Reinforced soil walls are being extensively used in various infrastructure projects. In the view of increasing seismic events, efficient seismic performance of these important public infrastructure facilities must be ensured (Singh, Cheema, and Garg 2021). The reinforcement length, vertical spacing, and stiffness all had a substantial impact on the amount and distribution of reinforcement connection loads (Ramalakshmi and Dodagoudar 2018). The aim of this study is to investigate the influence of backfill type on the foundation stiffness capacity of a square footing located on the GRS retaining wall.

2. Materials and Methods

The tests were carried out in the Saveetha School of Engineering's Soil Mechanics laboratory. Laboratory experiments were used to determine the soil index characteristics. Index properties of soil were determined through laboratory tests. Geotextile was obtained from Geodukan, Coimbatore. Two groups of GRS retaining walls were taken for study: Group-1 (GRS retaining wall with sea sand backfill, N = 17. Group 2: GRS retaining wall with M-sand backfill, N = 17). Performances of the two teams of soil were investigated with relation to the ultimate load values. Size of the samples required was calculated with the help of “clinicalc” software (Khuntia et al. 2015). Values of alpha, pre-test power and confidence intervals are fastened as 0.05, eighty and ninety five percentages respectively. Sample size needed becomes seventeen. Therefore, each teams consisted of seventeen samples amounting to a complete of thirty four samples.

A transparent container with a length of 40 cm and a width of 20 cm is used (Fig. 1 and 2). The container's height is 30 cm. At the bottom of the container, a layer of geotextile is placed. Sand is then filled to a height of 4 cm in the first layer. The backfill in this research is beach sand. Sand is then covered with geotextile. The next layer of geotextile is then applied, followed by the following layer of soil. A GRS retaining wall with a total height of 20 cm is constructed. The innovative geosynthetic reinforced soil wall is then covered with a square footing measuring 6 cm x 6 cm. The square footing is loaded by placing the container in a loading frame. A proving ring is used to determine the magnitude of the load. For the relevant proving ring readings, footing settlement is also indicated. Similarly, tests are carried out using a 6 cm reinforcement gap.

Statistical analysis

Laboratory results obtained from 34 tests (17 tests on square footing located on a GRS wall with sea sand backfill and 17 tests on square footing located on a GRS wall with M-sand backfill) were analysed in statistical analysis software i.e. SPSS version 23. Backfill type was the independent variable while foundation stiffness was dependent variable. An independent-samples-t-test was conducted on the foundation stiffness values obtained from two groups of test results.

3. Results

Load settlement curves for the two groups of tests on the footings resting on innovative geosynthetic reinforced soil walls are shown in Fig. 3. When M-sand was used as backfill, foundation stiffness on the footing decreased (Table 1). Mean values of foundation stiffness for innovative Geosynthetic Reinforced Soil retaining walls with sea sand backfill and M-sand backfill are 6.51 and 5.24 kg respectively (Table 2). Significant difference (two-tailed) between the two groups is 0.0001 (Table 3) indicating a significant difference of behaviour of the two groups of materials considered in the study. Bar graphs showing mean ±1 SD plots of two different backfill materials are shown in Fig. 4. Statistical parameters (Table 3) also indicate that the difference between two groups appears to be significant. It was observed that standard deviation values of cohesion were very less for the 17 samples considered.

4. Discussion

Lesser foundation stiffness was observed for M-sand backfills. This may be due to the relatively uniform gradation characteristics of the M-sand considered in the present study. Soils with good gradation characteristics exhibit better bearing capacity values. Sea sand being naturally available material may consist of different sized particles. Similar observations were made by (Pranavan and Srinivasan 2021) (Li et al. 2013). innovative Geosynthetic Reinforced Soil - IBS performance was evaluated by (Ardah, Abu-Farsakh, and Voyiadjis 2021) in terms of lateral facing displacement, strain distribution along reinforcement, and likely failure zone location. All model configurations had significant down-drag pressures at the back of the stiff face. Changes in reinforcing parameters, on the other hand, had no effect on the observed vertical load at the footing. Depending on the reinforcing design, the horizontal constrained (hinged) toe at the bottom of the rigid face was demonstrated to draw 30–60 percent of the entire horizontal earth force. The results revealed that the backfill material's internal friction angle has a substantial influence on GRS-IBS performance. The performance of GRS-IBS is unaffected by secondary reinforcement, setback distance, or bearing width. The GRS-IBS abutment's possible failure envelope was discovered to be a combination of a punching shear failure envelope (top) that begins under the inner border of the strip footing and extends vertically downward to intersect with a Rankine active failure envelope (bottom).

Seismic analysis of reinforced soil walls is an active research area for the geotechnical community which aids in effective design to ascertain efficient seismic performance (Ortlepp 2017).The horizontal restrained (hinged) toe at the bottom of the rigid facing was shown to attract 30–60% of the total horizontal earth force depending on the reinforcement configuration (Roy 2021). The magnitude and distribution of reinforcement connection loads was significantly affected by the reinforcement length (Latha, Madhavi Latha, and Somwanshi 2009). vertical spacing and stiffness. Measured footing loads, reinforcement connection loads and amplification factors are compared to values calculated using current practice in North America for innovative geosynthetic reinforced soil walls and discrepancies between experimental results and design methods are identifiedThe results are presented and compared (Ugai 1985). It is shown that under static loading conditions involving wall construction, simplistic and

sophisticated analyses produced close results (Tabsh and Geblawi 2006).the construction of retaining walls, embankment slopes, and natural or cut slopes. A variety of available systems for reinforced soil including in-situ soil nailing are described from information assembled from published literature and manufacturers' catalogues (Rowshanzamir and Karimian 2016).
The results of the present study are subjected to variation in the following parameters: 1) reinforcement type 2) height of GRS wall 3) dimensions of reinforcement. The study is limited to only two types of backfills (i.e., sea sand and M-sand). The study can further be continued with other backfills such as those partially replaced with e-waste, quarry dust, marble dust etc.

5. Conclusion

Usage of well graded backfill would result in increased bearing capacity and reduced settlement of footings. The choice of backfill material definitely influences the pressure that can be transmitted to the footings placed over them. If the gradation characteristics are not upto the required standards, partial replacement by mixing different backfill materials can be attempted. Sea sand backfill with widely distributed grain sizes performed better than M-sands with relatively uniform gradation characteristics.

Declarations

Conflict of Interests

No conflict of interest in this manuscript.

Author Contribution

Author SM is involved in data collection, experimental study and manuscript writing. Author RM involved in conceptualization, guidance and critical review of manuscript.

Acknowledgements

The authors would like to express their gratitude towards Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences (Formerly known as Saveetha University) for providing the necessary infrastructure to carry out this work successfully.

Funding

We thank the following organisations for providing financial support that enabled us to complete the study.
1. Geodukan, Coimbatore
2. Saveetha University
3. Saveetha Institute of Medical and Technical Sciences
4. Saveetha School of Engineering

6. References

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Tables & Figures

Table 1. Initial tangent stiffness of square footings resting on wrap around GRS retaining walls constructed with sea sand and M-sand backfills

Sample number	Sea Sand	M - Sand
1	6.3	5.6
2	6.9	4.4
3	7.3	5.4
4	7.9	4.6
5	6.1	5.4
6	7.0	5.2
7	6.8	5.2
8	6.7	5.7
9	6.1	5.3
10	6.2	5.4
11	5.1	4.4
12	5.3	5.0
13	5.6	5.9
14	7.0	5.9
15	7.1	5.2
16	6.8	4.8
17	6.4	5.7

Table 2. Comparison of foundation stiffness of square footing supported on GRS retaining walls having sea sand and M-sand backfills. Sea sand backfill exhibited 25% more stiffness than the m-sand backfill.

	Sample	N	Mean (kg/cm^2)	Std. Deviation (kg/cm^2)	Std. Error Mean (kg/cm^2)

Foundation Stiffness	Seasand	17	6.506	0.7293	0.1769
Foundation Stiffness	m-sand	17	5.241	0.4731	0.1147

Table 3. Mean, standard deviation and significance difference of tangent stiffness of square footing supported on GRS retaining walls with sea sand and M-sand backfills. There is a significant difference (two-tailed) between the two groups as the value of p is 0.0001 for the cohesion values based on Independent-samples-t-test.

		Levene's Test for equality of variance		t-test for equality of means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. Error Difference	95% Confidence Interval Of the Difference	
									Lower	Upper
Cohesion	Equal Variance assumed	3.088	0.088	5.999	32	.000	1.2108	.2108	.8353.	1.6942
	Equal variance not assumed			5.999	27.441	.000	1.2647	.2108	.8324	1.6970

Fig. 1. Front elevation of the experimental test setup

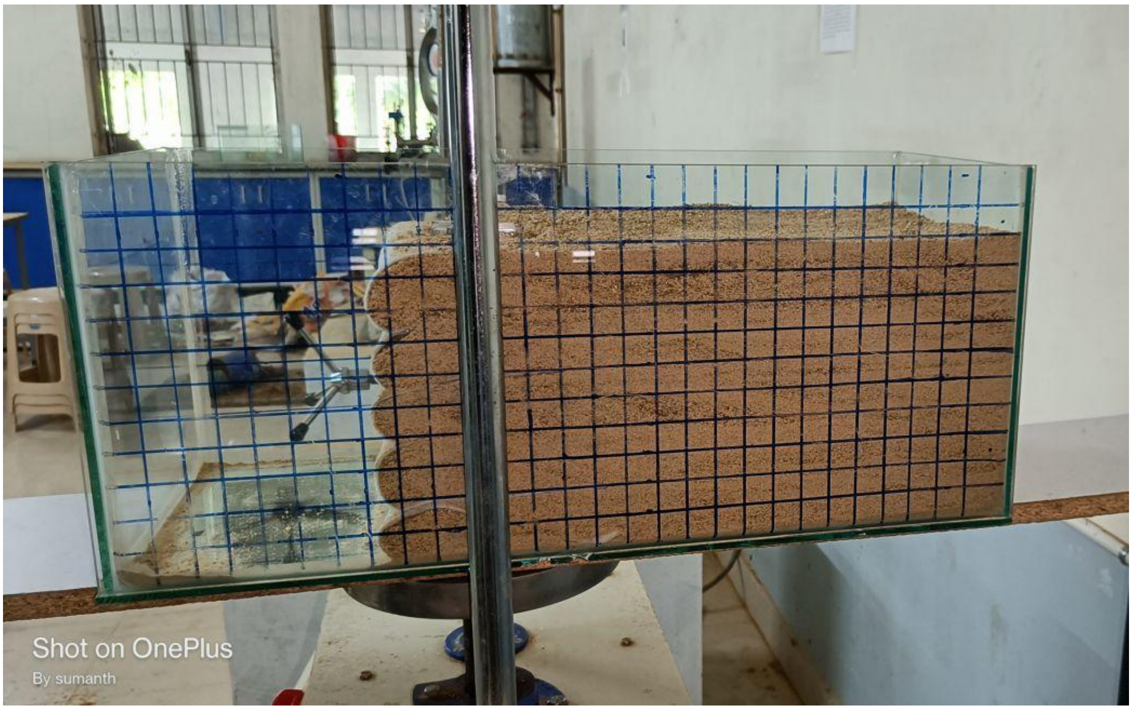

Fig. 2. Side elevation of the experimental set up of GRS retaining wall model

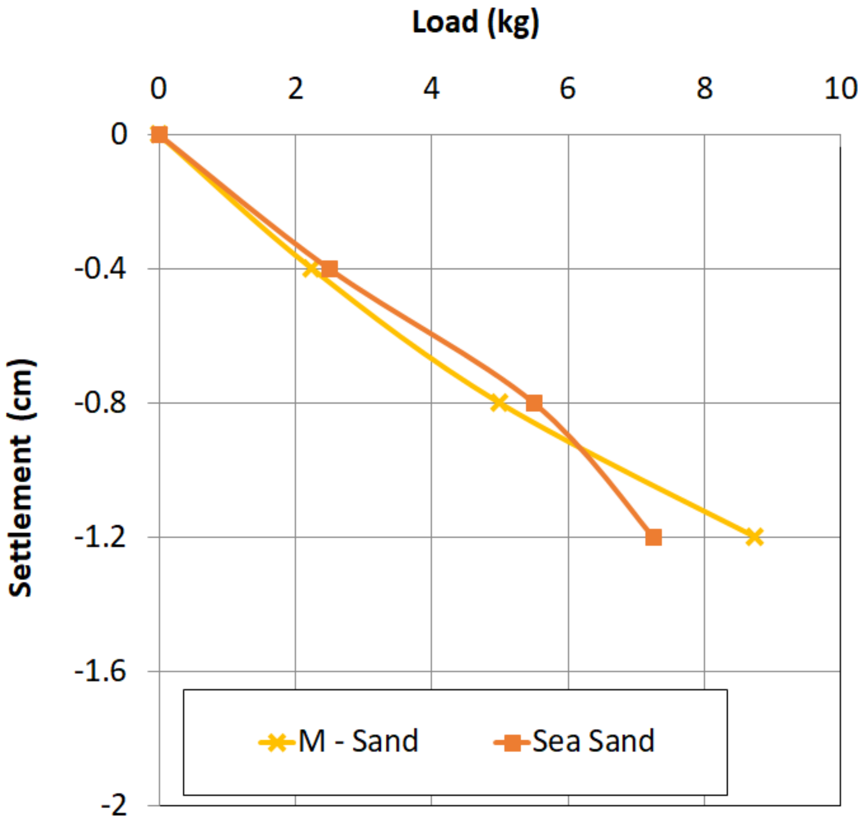

Fig. 3. Load settlement curves of GRS wrap around retaining walls with M-sand and sea sand backfills

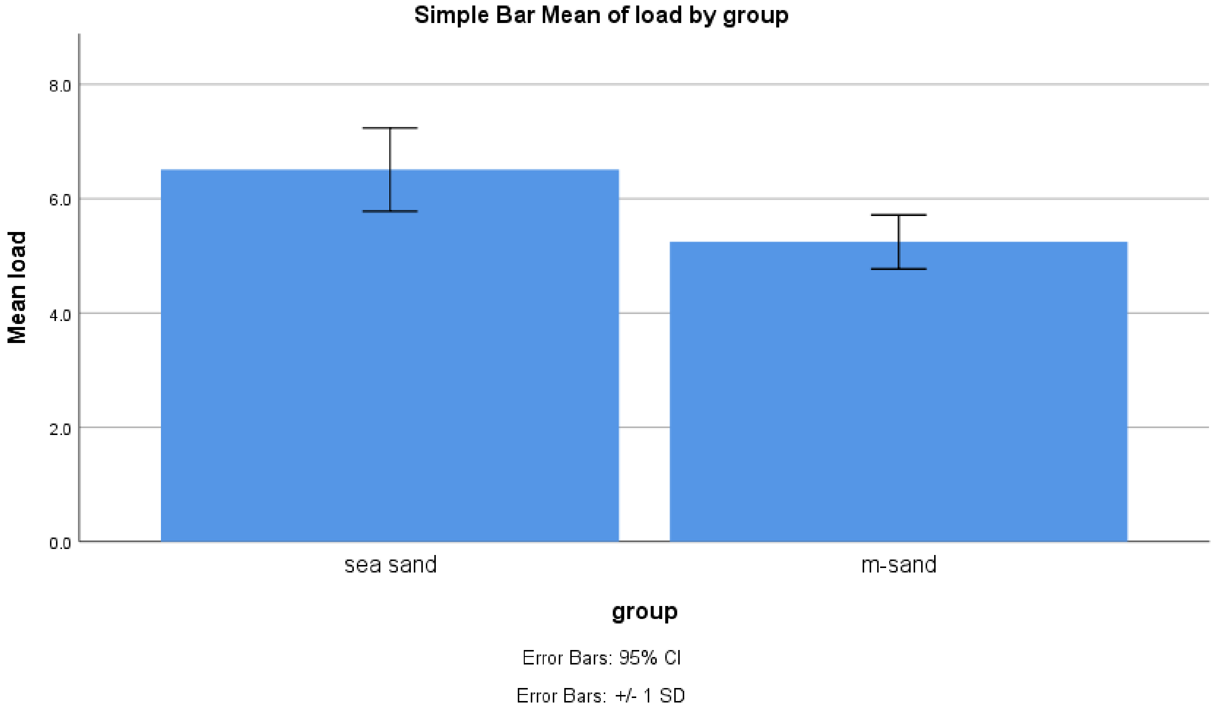

Fig. 4. Bar chart comparison of mean ultimate load capacities of square footing supported on GRS retaining walls with sea sand backfill (6.506 kg) and M-sand backfill (5.241 kg). X Axis: Sea sand backfill vs M-sand backfill, Y axis: Mean value of ultimate load ± standard deviation