Behavior of Strip Footing Resting on Sand Reinforced with Waste Tire Strips

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Abstract. This paper presents the results of Pressure- settlement behavior of strip footing resting on poorly graded sand reinforced with tire strips in layers to improve the bearing capacity. The tire strips of length 3B, 4B and 5B (B = width of footing) and 70 mm width were used. The tire strips were placed at 0.4B, 0.6B & 0.8B from the base of the footing. The tests were carried at 14, 14.2 & 14.3kN/m^3 dry unit weight of sand. From this investigation, it was observed that the bearing capacity of reinforced soil increases with the increase in length of reinforcement, depth of reinforcement, and dry unit weight of sand. With increase in the depth of reinforcement layer, length of reinforcement and number of layer significant reduction in the settlement of sand was observed. It was observed that the settlement reduction effect was higher at higher unit weights.

Keywords: Sand, Waste rubber tire strips, Strip footing, Bearing capacity

1 Introduction

The environmental issues raised by the myriad of scrap tires are becoming a subject of disquietness worldwide. Very Less options are available in front of engineering fraternity regarding the disposal of this menace waste in quantum with the least impact on environment [1]. The biggest venue for massive utilization of scrap tires are in highways and backfill material of retaining walls. The rapid urbanization of cities has led to the sudden decrease in the availability of good construction sites, which compel the utilization of marginal sites having low bearing capacity. Among various existing ground improvement method to improve the resistance of underlying deposit of soil, the newly emerging technique is to replace the existing soil upto shallow depth by granular reinforced soil. Higher densities can be achieved in the case of granular soil reinforced with horizontal layers of reinforcement which provides higher frictional resistance and ultimately increases the bearing capacity of soil. The evaluation of ultimate bearing capacity of strip footing resting on stratified underlying soil is a difficult tasks. Many efforts have been made by the past investigators to assess the bear-

ing capacity of layered soil [2 - 4]. The advantage of using the horizontal layer of reinforcement to improve the bearing capacity of soil have already been substantiated by several researchers [5, 6].
In last three decades reinforced soil foundations has earned significant attention. Binquet and Lee [7] assessed the impact of metal strips reinforcement on the bearing capacity of sand. Since then, enormous research were performed on the bearing capacity of footing resting on reinforced sands [8]. The key findings of past investigations as follows:

1. The depth from where the first layer of reinforcement to be provided from the bottom of footing should lies between 0.2B-0.5B (B, width of footing).
2. The vertical spacing between the horizontal layer should lies 0.2B-0.5B
3. The maximum depth of reinforcement should lies between 1.0B to 2.0B.
4. The effective length of reinforcement should lies between 2.0B to 8.0B.

Several investigators had estimated the ultimate bearing capacity of strip footing rested on stratified layer sand reinforced with geotextile, geogrids, etc [8]. The performance of geogrid reinforced soil was found better than geotextile reinforced soil [8]. The information on pressure-settlement behavior of strip footing rested on stratified soil is limited.

This paper aims to assess the load-settlement behavior of strip footing resting on poorly graded sand horizontally reinforced with waste rubber strips. The effect of unit weight of sand, length and depth of reinforcement and number of layers of reinforcement on the bearing capacity and settlement of strip footing was evaluated through a series of plate load tests. This paper limit upto assessment of effect of reinforcement on bearing capacity of strip footing.

2 Testing Programme and Descriptions

The pressure-settlement behavior of strip footing resting on sand bed reinforced with horizontal waste rubber strip was examined through small scale laboratory model tests. The sand having C_u = 2.33 and C_c = 0.826 was used for foundation soil. As per the unified soil classification system, the sand was classified as poorly graded sand. The other physical properties of sand were G= 2.69, γ_{min} = 13.90 kN/m^3 and γ_{max} = 16.87 kN/m^3, respectively. Waste rubber strip of length 300mm, 400mm, and 500mm having width 70mm and thickness 4mm was used in this investigation. The tensile strength of rubber strips were between 37-70 kN/m. The details of performed tests are given in Table 1. The line diagram of reinforced sand along with details is shown in Fig. 1.

Table 1 Details of model tests performed.

Name of the parameter	**Variation**
Unit weight of sand, γ_d	14, 14.2, 14.3 kN/m^3
Length of reinforcement, L_R	3B, 4B, 5B
Depth of reinforcement, D_R	0.4B, 0.6B, 0.8B
Number of layer of reinforcement, N_R	1, 2, 3

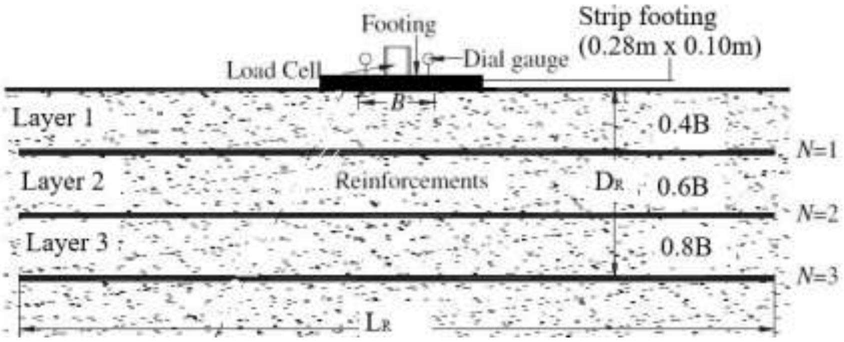


Fig. 1 Line diagram of strip resting on waste rubber strip reinforced sand

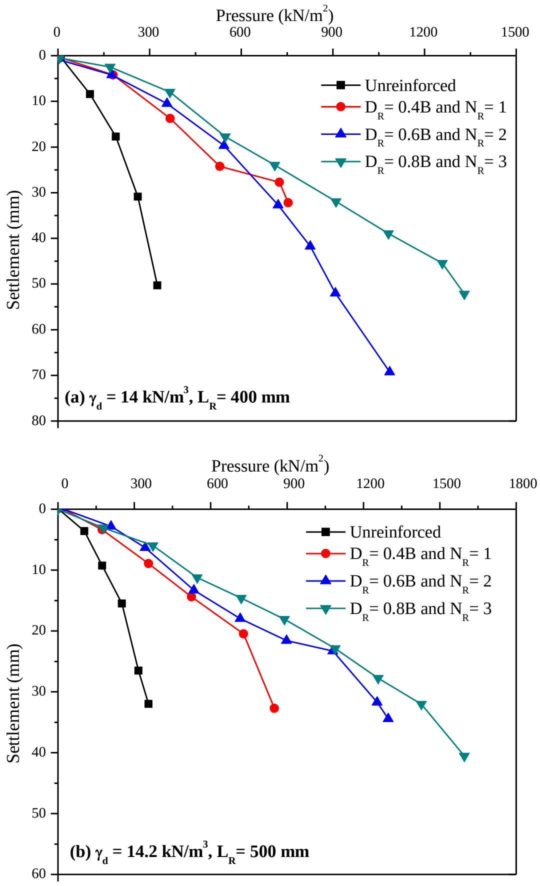
The strip footing of size 0.10m x 0.28m was used in this investigation. To simulate the actual field conditions, the sandpaper was glued at the bottom of strip footing to increase its roughness. The mild steel tank of 0.70m long, 0.30m wide, and 1.0m deep having 5mm thickness was used in this investigation. A hydraulic jack of capacity 250 kN was used to apply the vertical load on the strip footing. Two sensitive dial gauges of least count 0.005 mm with magnetic based mounted on rigid beam used to measure the vertical settlement of the footing.

The sand in tank was filled by rainfall technique to achieve the desired unit weight. The sieve of 0.68m x 0.25m was used to fill the tank. To obtain the unit weight of 14.0 kN/m^3, 14.2 kN/m^3 and 14.3 kN/m^3, the height of fall was kept 400, 500, and 600 mm, respectively. The first layer of reinforcement was placed at a depth of 0.4B below the base of footing. Similarly, second and third layer was placed at depth of 0.6B and 0.8B below the base of the footing. In the reinforced layers, three horizontally strips were provided at spacing of 25mm. After the preparation of tank, the footing was place at the center and load was applied by the mean hydraulic jack. For each increment of load the footing deformation was recorded.

3 Test Results and analysis

In this study total 30 tests were performed on both unreinforced and reinforced sand. Pressure-settlement behavior of some plate load tests are shown in Fig. 2. By using the double tangent method, the ultimate bearing capacity of each plate load test was calculated. One tangent line was drawn along the initial straight portion and other was drawn in latter portion of load – settlement curves. The point where these two lines intersects, the load corresponding to that point was taken as ultimate bearing capacity of the footing.

The obtained data was further assessed in term of bearing capacity ratio (BCR). It is defined as a ratio of ultimate bearing capacity of layered soil to ultimate bearing capacity of homogenous soil. It is help full for better interpretation of results and comparison of unreinforced and reinforced sand. Effect of four parameters such as unit weight of sand (γ_d), length of reinforcement (L_R), depth of reinforcement (D_R), and number of reinforcement layers (N_R) on the BCR were studied.



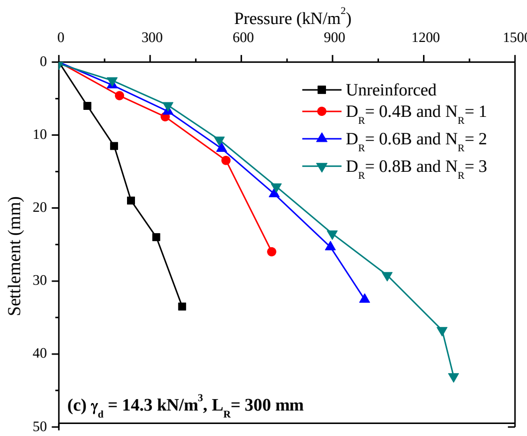


Fig. 2 Pressure-settlement behavior strip footing rested on unreinforced and reinforced sand

3.1 Length of reinforcement

Table 2 show the variation of BCR with length of reinforcement at different unit weights. The results show that BCR values increase with increase in the length of reinforcement. At a given length of reinforcement 3B, 4B and 5B, as the depth of reinforcement increases from 0.4B to 0.8B, increase in BCR is 104.7%, 92.3% and 75.8% respectively at for γ_d = 14 kN/m^3. Similarly, for γ_d = 14.2 kN/m^3, increase in BCR is 95.2%, 85.1% and 85.7% respectively and γ_d = 14.3 kN/m^3, increase in BCR is 136.8%, 88 % and 96.2% respectively. The increase in L_R led to increase in friction resistance due to increase of normal forces may be the possible reason for increase in BCR with increase in L_R.

Table 2 Variation of BCR values with length of reinforcement

γ_d (kN/m^3)	L_R/B	BCR values at D_R of		
		0.4B	**0.6B**	**0.8B**
14 (kN/m^3)	3	2.1	2.8	4.3
	4	2.6	3.1	5
	5	2.9	4	5.1
14.2 (kN/m^3)	3	2.1	3.6	4.1
	4	2.7	4	5
	5	2.8	4.1	5.2
14.3 (kN/m^3)	3	1.9	3.3	4.5
	4	2.5	3.7	4.7
	5	2.7	3.8	5.3

3.2 Depth of reinforcement

Table 3 show the variation of BCR with the depth of reinforcement. BCR increases with the increase in depth of reinforcement. At a given depth of reinforcement 0.4B, 0.6B and 0.8B, as the length of reinforcement increases from 3B to 5B, increase in

BCR is 38%, 42.9% and 15.9% respectively at for γ_d = 14kN/m^3. Similarly, for γ_d = 14.2 kN/m^3, increase in BCR is 33.3%, 13.8% and 26.8% respectively and γ_d = 14.3 kN/m^3, increase in BCR is 37.7%, 15.1% and 17.7% respectively. These reveals that BCR increases with the increase in D_R. It indicates that $D_R \leq 0.8B$ can be sufficient for sand reinforcement to give high resistance.

3.3 Density of soil

As the bearing capacity of unreinforced soil increases with the increase in unit weight, the BCR values, but not the ultimate bearing capacity of reinforced soil, can decrease in some of the cases. The results are listed in Table 4. At a given density of 14.0, 14.2 and 14.3 kN/m^3, as the depth of reinforcement increases from 0.4B to 0.8B, increase in BCR is 109.5%, 95.2% and 129.5% respectively at for L_R = 3B. Similarly, for L_R = 4B, increase in BCR is 92.3%, 85.1% and 88% respectively and L_R = 5B, increase in BCR is 75.8%, 85.7% and 96.2% respectively. With the increase in unit weight of soil ultimate bearing capacity increases both for unreinforced and reinforced soil. This may accredited to increase in frictional force due to increase in the unit weight of soil.

Table 3 Variation of BCR values with different depth of reinforcement

γ_d (kN/m^3)	D_R/B	BCR values at D_R of		
		0.4B	**0.6B**	**0.8B**
14 (kN/m^3)	0.4	2.1	2.6	2.9
	0.6	2.8	3.1	4
	0.8	4.4	5	5.1
14.2 (kN/m^3)	0.4	2.1	2.7	2.8
	0.6	3.6	4	4.1
	0.8	4.1	5	5.2
14.3 (kN/m^3)	0.4	1.96	2.5	2.7
	0.6	3.3	3.7	3.8
	0.8	4.5	4.7	5.3

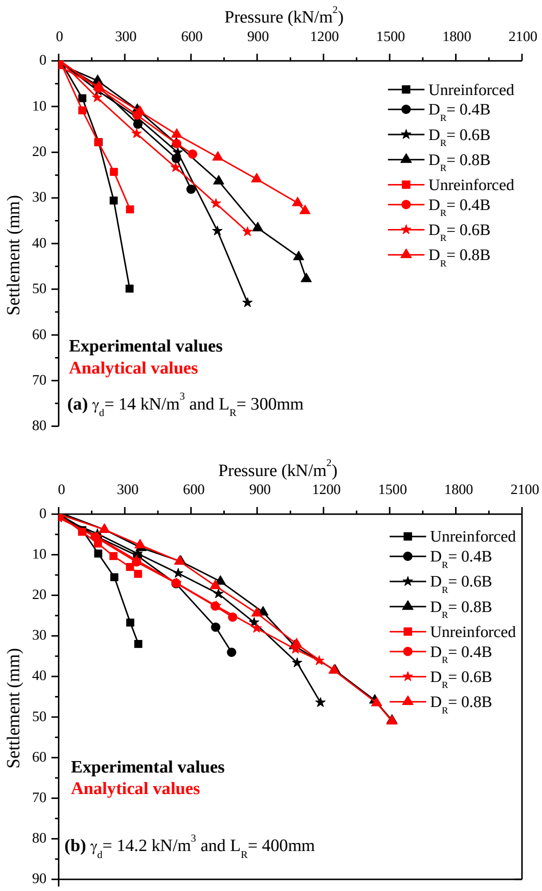
Table 4 Variation of BCR values with different soil densities

L_R/B	γ_d (kN/m^3)	BCR values at D_R of		
		0.4B	**0.6B**	**0.8B**
	14	2.1	2.8	4.4
3	14.2	2.1	3.6	4.1
	14.3	1.96	3.3	4.5
	14	2.6	3.1	5
4	14.2	2.7	4	5
	14.3	2.5	3.7	4.7
	14	2.9	4	5.1
5	14.2	2.1	2.8	4.4
	14.3	2.1	3.6	4.1

3.4 Numerical Modeling

The result obtained from the experiments were validated through analytical approach by using Geostudio Professional 2004 SIGMA/W software. Fig. 3 shows some typical pressure-settlement curves for unreinforced and reinforced sand bed. To carry out the analytical analysis, the modulus of elasticity of each plate load test was determine using the formula $Si = qB\,(1-\mu^2)/E_S$, for $\mu = 0.33$.

The settlement obtained from plate load tests and analytical method for unreinforced and reinforced sand bed were compared at factor of safety = 3 for safe bearing capacity and were shown in Table 5. Table 5 reveals that the analytical settlements of reinforced sand bed was in agreement with the experimental settlements.



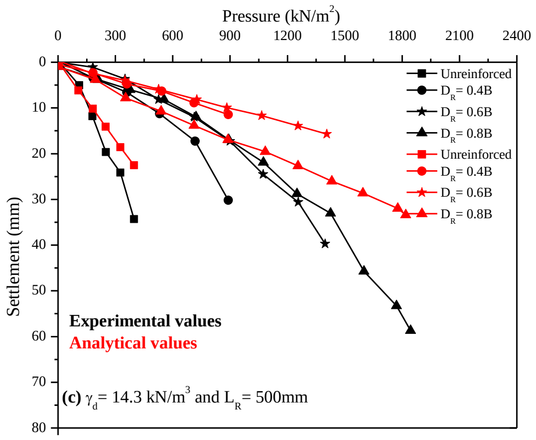


Fig. 3 Comparison between analytical and experimental results

Table 5 Detail of settlement values corresponding to safe bearing capacity (F.O.S=3)

γ_d (kN/m^3)	Description	Unrein-forced Sand(q_{uo})	Reinforced Sand (q_{ur})								
			Single Layer (D_R = 0.4B)			Double Layer (D_R = 0.6B)			Three Layer (D_R = 0.8B)		
	L_R	–	3B	4B	5B	3B	4B	5B	3B	4B	5B
14 kN/m^3	q_s (kN/m^2)	70	150	183	203	197	220	280	307	350	355
	$S_{P(EXP)}$ (mm)	2	3	2	3	6	5	6	8	8	4
	$S_{P(ANA)}$ (mm)	8	5	3	3	8	9	6	8	8	5
14.2 kN/m^3	q_s (kN/m^2)	75	158	207	217	274	300	313	308	375	395
	$S_{P(EXP)}$ (mm)	3	5	8	7	9	7	8	9	9	10
	$S_{P(ANA)}$ (mm)	4	3	6	4	8	11	7	11	9	7
14.3 kN/m^3	q_s (kN/m^2)	83	163	210	225	276	310	317	373	388	447
	$S_{P(EXP)}$ (mm)	4	4	3	5	6	7	7	8	9	6
	$S_{P(ANA)}$ (mm)	4	3	4	3	6	5	3	7	9	8

4 Conclusion

This paper shows the results of experimental and analytical analysis carried out on locally available poorly graded sand reinforced with waste rubber tire strips subjected to plate load tests. The effect of unit weight of sand, length and depth of reinforcement and number of layers of reinforcement on the bearing capacity of strip footing was studied. It had been observed that the increase in L_R, D_R, N_R and γ_d the bearing capacity of sand increases. With increasing the in L_R, D_R, N_R and γ_d, the settlement of strip footing decreases. The values of analytical settlement were closer to the experimental settlement. The experimental results showed good agreement with the analytical results i. e Pressure-settlement behavior was good.

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