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Bearing Capacity Evaluation of Square Footing Resting on Reinforced Sand

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Abstract

An experimental study is carried out to improve the bearing capacity of soils by using geotextile. In the present study geotextile (tire reinforcement) is used as geotextile, whereas sand is used as a soil medium. This research work presents the results of laboratory load tests on model square footings supported on reinforced sand beds. A total of twenty-seven load tests are conducted to evaluate the effects of single layer reinforcement placed below square model footings. The parameters of the testing program of the research work are the depth of reinforcement, the plan area of reinforcement, and the number of reinforcements. From the experimental data, it is indicated that there is an optimum reinforcement depth at which the bearing capacity is the highest. Also, the optimum size of reinforcement is found to be 1.5 B×1.5 B irrespective of the type of reinforcing materials used. The bearing capacity of reinforced sand is also found to increase with the number of reinforcement layer and reinforcement size when the reinforcement is placed within a certain effective zone with high relative density. The optimum placement position of geotextile is found to be 0.5B to 0.75B from the base of the footing .The tests are done at two different relative densities, i.e., 40% and 60%. The bulk unit weight of sandy soil is 14.81 KN/m³. Maximum gain in load carrying capacity is obtained when depth of reinforcement/width of footing (Dr/B) is 0.5 at relative density of 40% and 0.75 at a relative density of 60%.In addition, the data indicate that increasing reinforcement beyond a certain value would not bring about further increase in the bearing capacity of the soil.

1. Introduction

The term "soil" refers to a substance made up of rock pieces that have undergone weathering and deterioration from a number of environmental conditions, as well as organic matter, voids, and the potential to store water.

Usually, structural damage results from building foundation placement on loose soil layers. These loose soil layers are unable to support the structural load of the buildings. Settlement and cracks form on the structures as a result, and the structure will eventually collapse. People decide to build their structures in these loose soil strata using deep foundations. However, using deep foundations can sometimes increase the cost of building a structure. Therefore, the ground improvements are implemented to prevent the aforementioned issues. The most popular technique for improving the ground is the use of geo synthetics. As a result of the soil strata being reinforced with these geosynthetics, their density and strength (bearing capacity) have improved.

Plant roots help to stabilize soil by protecting it against erosion and deep slope collapse in nature. At the moment, strengthening and stabilizing soils using reinforcement is a dependable and successful method. Applications for the approach utilized today ranged from retaining walls and embankments to surge stabilization and surface drainage systems. Consequently, they are viewed as being more troublesome than rocks. The occurrence of issues like liquefaction, slide, collapse, subsidence, bearing capacity, and erosion may depend on the characteristics of the soil and the surrounding environment. Since most soil

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issues are site-specific in these circumstances, the soil qualities should also be addressed using suitable methods.

The phrase "reinforced soil" refers to soil that has been fortified by the incorporation of reinforcing material, such as bars, strips, sheets, or grid (meshes), which is reinforced with soil. These materials withstand the tensile strains that form inside the reinforced soil mass whenever a load is applied to it. Low tensile strength can cause a material to break or give, rendering it useless. The soil may experience significant movement or settlement if the tensile strength is insufficient but the extension under stress is considerable due to the insufficient stiffness of the soil-reinforcement system.

Most of the studies are on strip or circular footings in spite of the fact that the rectangular and square footings are far more common in practice. The resting of square footings on the reinforced soils are studied by very few researchers like [22-28].

Depending on the kind of soil, the intended improvement, the time required for treatment, the availability of materials, and the economic feasibility, there are several approaches for improving the ground. Ground renovation techniques are primarily used to lessen settlement and increase bearing capacity. When choosing the kind and depth of a foundation, the bearing capacity of the foundation is a crucial consideration. The researchers' attention is being drawn to soil enhancement by the incorporation of fresh material into the soil in a variety of ways due to concerns with bearing capacity. Reinforcement is one of the more recent additions to the bearing capacity problem.

In order to stabilize and strengthen the soil, the first textiles used in civil engineering projects were typically buried in it during building and landscaping operations. Manufacturing procedures for geotextiles have evolved over time to the point where they are now considered to be a separate topic of study. Due to technical advance production of geotextiles has increasingly set itself apart from typical textile processes. It is now a highly specialized and technologically advanced sector of the economy. Since the early 1970s, this evolution has made it possible to create cutting-edge technologies and new raw materials that are especially suited for producing technical textiles for use in civil engineering projects.

When utilized as a building material, geo-textile reinforcements efficiently enhance the bearing capacity and decrease settlement of foundations sitting on soft or unsound soils. It may be applied to a variety of geotechnical projects including foundations, retaining walls, embankments, and other heavy and important structures. Geotextiles are breathable fabrics that, when combined with earth, can separate, filter, strengthen, protect, or drain. The development of goods like geo-grids and meshes as well as the introduction of geotextile composites are all results of the growth in the usage of geo-textile fabrics. These goods are collectively known as geotextiles and associated products. To improve the bearing capacity [13], [14] and settlement there are several experiments which are carried out. Geogrid is also used in railroads [6], [2], [7], [8], [10] and strengthening the sub grade in road work jute geotextile is also used. Rubber tire is also used as chipped reinforced sand and pressure settlement behavior is determined. The resting of square footing on the reinforced soil is discussed by [11].Few researcher had used bamboo mat reinforced sand beds to identify behavior of model footing [1], [12].Many researchers [3], [4], [9], [5] had used several wastes to stabilize soil and to improve the properties of soil.

Cracks and cavities belong to two basic forms of damage to the concrete structure, which may reduce the load-bearing capacity [17]. Fly ash [21] and nano silica [18] is used to strength and modify the properties of concretes. Comparative measurements of the fracture toughness together with visual analysis of cracks propagation of concretes made of quaternary binders [19]. Extensive investigations of the fracture mechanics parameters of concretes made of quaternary binder [20].

Several research papers have been published regarding the improvement of soil. The main objective of this paper is to evaluate the improvement in bearing capacity of rubber reinforced soil. Sand is used as the soil media in this research work, while rubber tires are used as the geotextile. The findings of laboratory load experiments performed on model square footings supported on reinforced sand beds are presented in this study. In this work, tests are done on sandy soil with reinforcement and without reinforcement and results are obtained. The result shows us significant change or increase in the ultimate bearing capacity. This paper also includes the effect of relative density on the settlement behavior of sandy soil.

A good quality of sand is very helpful in providing good shear strength and possess high ultimate bearing capacity but often good quality of sand is not found everywhere. Sometimes it is possible to replace the poor quality of soil with good quality of soil, but it is not possible to replace the soil every time. Thus to improve the shearing strength and bearing strength of soil we can use reinforcement within the soil. Few researches [16] had used fiber-glass as a geo-grid in determining the effect of reinforcement on sand settlement and bearing capacity. In this research paper rubber tire is used to improve the shearing and bearing strength of the soil.

The purpose of the current research work is to examine the behavior of reinforced sand that has been reinforced with rubber wastes. The current study's focuses are as follows:

- To evaluate the load settlement behavior of footing with rubber reinforcement and without rubber reinforcement.
- To determine the dimensional parameter of rubber reinforcement like depth, size of reinforcement and number of reinforcements.
- To evaluate the improvement in bearing capacity of rubber reinforced soil.

2. Materials Used

The materials used to evaluate the load settlement behavior are sand and rubber wastes. The sand is obtained from Beas Riverbed near Hamirpur, and wastes rubber tire is collected from local market of Hamirpur, Himachal Pradesh.

2.1. Sand

Sand from the Beas Riverbed at Hamirpur is used to analyze the load settlement behavior. Little mineral shards make up the granular material known as sand. Sand's composition varies, but what sets it apart is the size of the grains. Sand has smaller granules than gravel and is coarser than silt. Sand is a soil type or textural class that is composed primarily of particles with a diameter less than sand. Although silica (silicon dioxide, or SiO2), often in the form of quartz, is the most common component in inland continental settings and non-tropical coastal settings, the composition of sand varies depending on the local rock sources and conditions. To liberate the gathered sand and free from any organic component and impurities, it is cleaned and rinsed. Then the sand is oven dried and passed through IS sieve to obtain the required grade. The dried sand is passed through 2 mm sieve and retained on 75 µ IS sieve. The coefficient of uniformity and coefficient of curvature were found to be 1.44 and 0.98, respectively. By referring to the grainsize distribution curve and as per Bureau of Indian Standard IS 1498, the sand is classified as poorly graded sand (SP). The tests were conducted in accordance with IS: 2720 (1983) to determine the sand's minimum and maximum dry densities. By dumping the sand in its loosest form, the dry unit weight was measured to be as low as 13.08 KN/m^3 and as high as 15.95 KN/m^3 by vibration testing. The angle of internal friction was found to be 32.7° at relative density of 40% and at a relative density of 60%, the angle of internal friction was found to be 35.7°.

On the basis of objectives of the present studies, a tank has been constructed of dimensions 750 mm x 450 mm x 300 mm. Before the experiment several tests have been done and properties of sand are determined. The tests that are conducted on sand are as follows:

- Particle size distribution by sieve analysis.
- Direct shear test.
- Specific gravity test by pycnometer method.
- Relative density.

The values obtained from the above tests are given above in Table 1.

Table 1. Geotechnical properties of sand

Geotechnical properties of sand	Values
Effective grain size D_{10} (mm)	0.16
D_{60}(mm)	0.23
D_{30}(mm)	0.19
Coefficient of curvature (C_c)	0.98
Coefficient of uniformity (C_u)	1.44
Bulk unit weight (KN/m^3)	14.81
Max. dry unit weight (KN/m^3)	15.95
Min. dry unit weight (KN/m^3)	13.08
Maximum void ratio e_{max}	0.73
Minimum void ratio e_{min}	0.54
Relative density (R_d)	60%
Free Swelling Index	0
Shear strength parameters	
Cohesion© (KPa)	0
Friction angle ϕ (degree)	32.7°
Specific gravity (G_s)	2.66

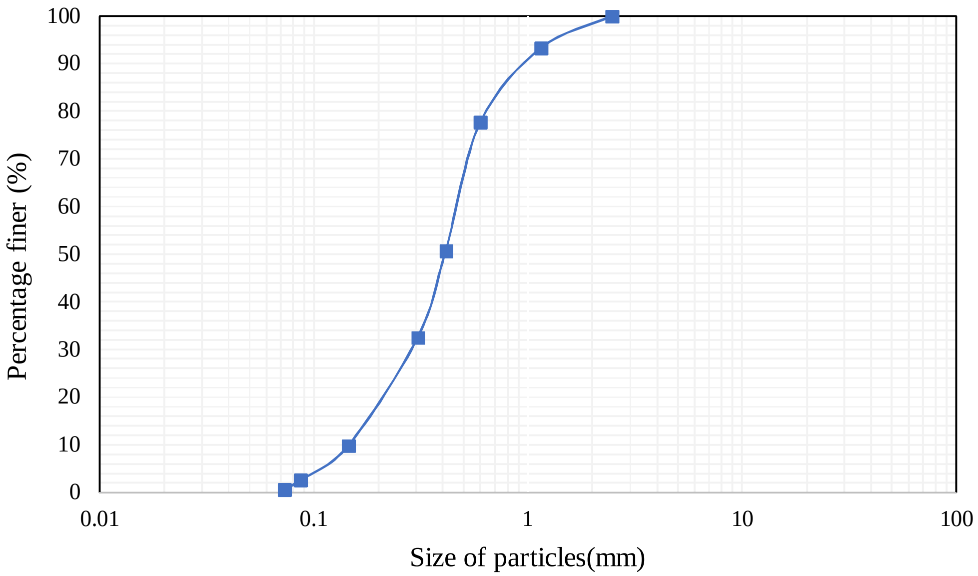

Figure 1. Graph showing particle size distribution.

2.2. Rubber

Rubber tires are now often used as geotextiles in civil engineering since they are both affordable and environmentally friendly. We give an outline of the benefits and characteristics of employing rubber tires as a geotextile in this study. Several research studies had been done on the use of rubber tires as a geotextile in a variety of civil engineering applications, including soil strengthening, erosion control, drainage, and filtration. Rubber tires may be utilized successfully as a geotextile in civil engineering, although the outcomes can be enhanced by combining rubber tires with traditional geotextile materials.

Waste tires have become a global environmental problem because of its storage and separation processes. These tires are flammable, and fire tends to release toxic gases. This situation affects the health of organism and at the same time causes aesthetics discomfort. Rubber tire use as a geotextile has a number of benefits, one of which is the reduction of waste tire buildup and any associated environmental harm. In comparison to synthetic polymer fibers using rubber tire as a geotextile is also less costly. Rubber tires are a good alternative to traditional geotextiles in situations requiring great strength and durability. The physical, mechanical, and hydraulic properties of rubber tires and common geotextile materials have been compared in several other studies and those research findings suggest that when compared to synthetic polymer fibers, rubber tires have a higher tensile strength and a lower elongation at break. Rubber tires were shown to have a lower hydraulic conductivity than typical geotextiles, indicating that they are less permeable to water. The tires waste that is used in this project is totally free from any sort of metal strips. The rubber which is used in this study is used rubber tire of bicycle, which is collected from local market of Hamirpur, Himachal Pradesh. This rubber is made up of butyl polymer (Figure 2), butyl rubber is elastic and airtight synthetic rubber. The rubber is then cut into pieces of desirable dimensions (Figure 3). After cutting, the rubber is jointed with stitched method (Figure 4). Various physical properties of rubber tire are given in Table 2.

Table 1. Physical properties of rubber

Item	Physical properties
Structure	Punched hole
Aperture size(cm)	8 × 8
Number of grids	4
Thickness(mm)	1
Polymer	Butyl rubber
Junction method	Stitched
Width of strip(mm)	13
Ultimate tensile strength(kg/cm^2)	9.2

Figure 2. Rubber tire

Figure 3. Unstitched rubber

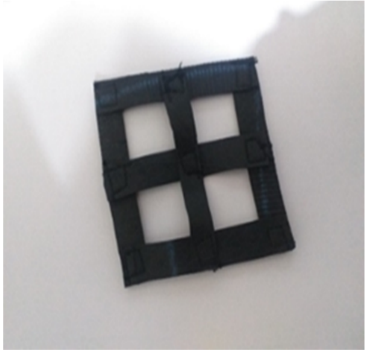

Figure 4. Stitched rubber

3. Test bed preparation for reinforced soil

For the test, a temporary tank (Figure 6) with the dimensions 700 mm x 450 mm x 300 mm is built in the lab. The tank's interior walls were made smooth to lessen side friction. The tank's dimensions were chosen in a way that prevents the failure zones created during testing on model footings from being constrained by the tank's sides and bottom. Then the test bed is set up in the tank with either rubber reinforcement or sand. First, the test tank's volume is determined by precisely measuring the inside measurements of the tank. The footing used is of dimension 80 mm x 80 mm is used in this experimental study. The setup of square footing is shown in Figure 5. The amount of dry sand required is calculated using the tank's capacity and the sand's unit weight of 14.81 KN/m³. Dry sand from above is poured into the tank using a funnel such that the tip of the funnel sits 10 cm above the sand's surface. This is done to ensure that the sand medium inside the tank has a consistent density. The funnel is pushed spirally from the tank's perimeter toward the center while pouring. A straight edge is used to level the top of the sand once the tank has been fully filled. In order to conduct a test with a reinforced soil bed, the tank is filled with sand using the funnel as previously mentioned, while reinforcing material such as rubber tire strips is positioned at the necessary depth. The spirit level is used at the top surface of the sand to examine the horizontality. Before the placement of the rubber (reinforcing material) level is checked by means of straight edge. The tank is completely emptied and filled with sand in a similar manner for future tests. According to the guidelines provided by IS: 1888 (1982), the tank's minimum size must be five times larger than the footing that was utilized for testing in order to avoid the boundary effect. Due to the assumption that the boundary impacts would be minimal, the tank's width and depth were maintained at five times the model footing. Turn on the universal testing machine to apply the load on the reinforced soil specimen. In this experiment different sizes of reinforcement (1B x 1B,2B x 2B,3B x 3B,) are used to reinforce the soil. The tests are done at two different relative densities.

Figure 5. Setup of square footing

Figure 6. Picture of test setup

In the below given diagram, load is applied on the square footing (B is the width of footing).

N; Number of reinforcements

D_r; Depth of reinforcement

S_r; Size of reinforcement

4. Results and Discussion

The load settlement behavior of footing of reinforced sand at various depths of reinforcement i.e., 0.25B to 2.00B is compared with that of unreinforced sand. The results obtained are given in Figure 8 and Figure 9 is obtained at relative density of 40% and relative density of 60%, respectively.

When the reinforcement is placed in varying depth and size in sand bed, the settlement and ultimate bearing capacity has been changed due to effect of depth and size of reinforcement.

The load is dispersed within the influence zone of 2.0B depth when a load is applied to the foundation depth. The load intensity is high at the middle height of the influence zone i.e.,1B. But in the present study, the influence zone is found between 0.5 and 0.75. It is observed that the most effective zone is when D_r/B is within the zone of 0.5 to 0.75.

When the relative density is 40% in case of unreinforced sand, at 5 mm settlement, the bearing pressure is obtained 18 KPa but as we introduce reinforcement, bearing pressure of the sand increases and maximum bearing pressure is 52 KPa when the D_r/B is 0.5. But as we increase the size of reinforcement (D_r), the value of bearing pressure decreases, and when the relative density is 60% in case of unreinforced sand, at 5 mm settlement, the bearing pressure is 17 KPa but as we introduce reinforcement, bearing pressure of the sand increases and maximum bearing pressure is 55 KPa when the D_r/B is 0.75. But as we increase the size of reinforcement (D_r), the value of bearing pressure decreases. Figure 8 represents bearing pressure-settlement behavior of footing on reinforced sand with relative density of 40% and Figure 9 represents bearing pressure-settlement behavior of footing on reinforced sand with relative density of 60%.

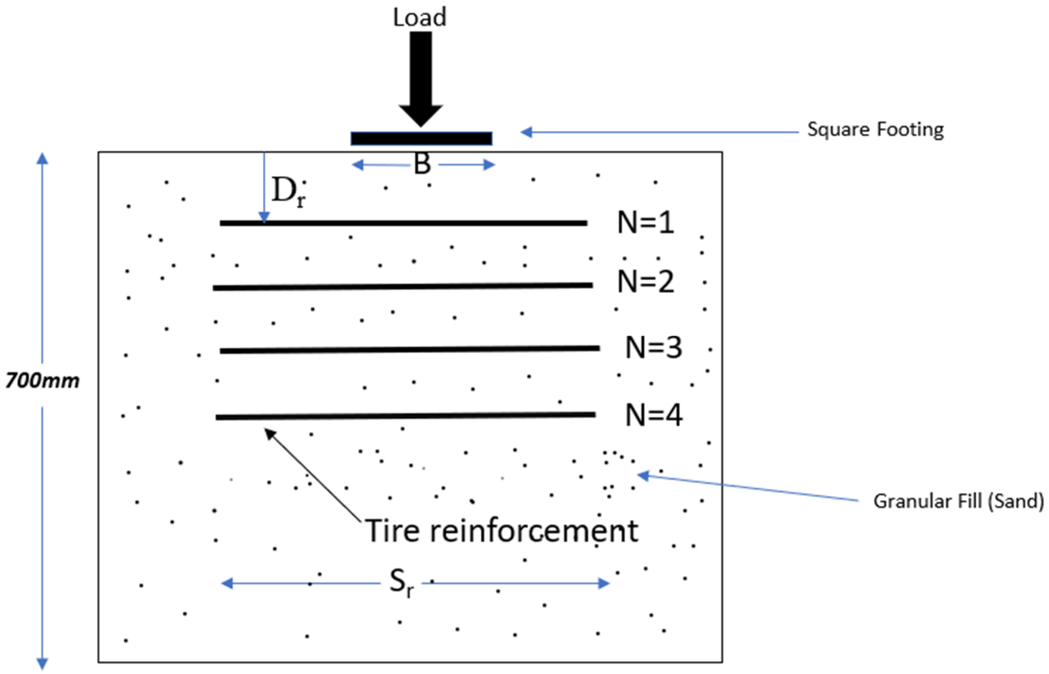

Figure 7. Layout of reinforcement in laboratory tank

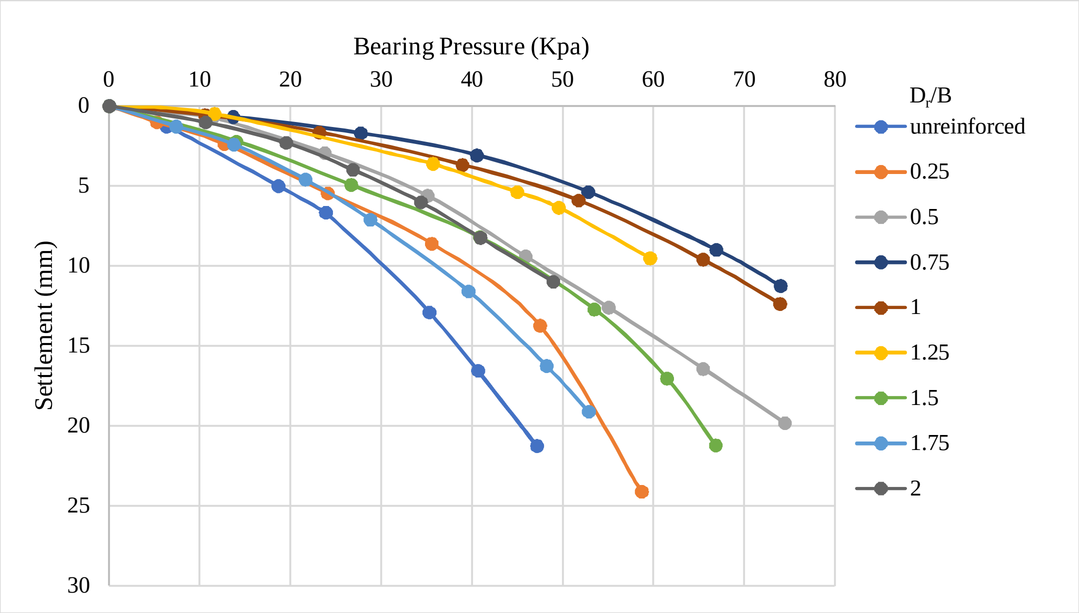

Figure 8. Bearing pressure-settlement behavior of 80 mm square footing on reinforced sand with relative density of 40%.

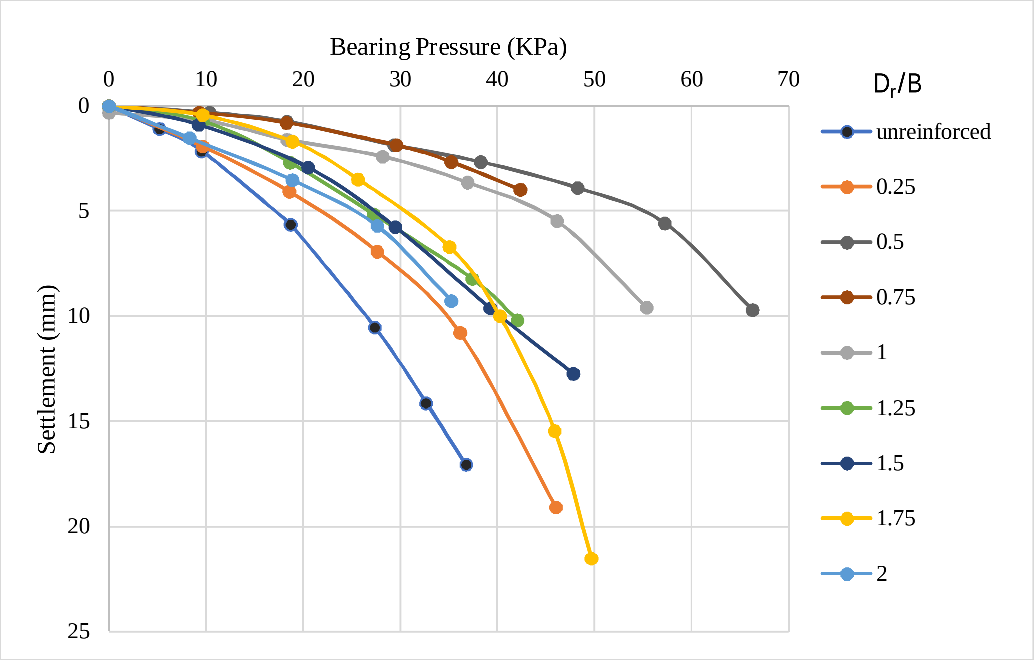

Figure 9. Bearing pressure-settlement behaviour of 80 mm square footing on reinforced sand at relative density of 60%.

4.1 Effect of size of reinforcement

The load tests are also conducted by altering the reinforcement size from 1.0B x 1.0B to 3.0B x 3.0B at the recommended depth (0.5B) of reinforcement at two different relative densities. The result of this test is obtained in Figure 10; this figure is obtained on relative density of 40%, and Figure 11 is obtained on relative density of 60%. It is observed that with increasing the size of reinforcement the bearing capacity of soil increases but up to certain values as shown in below Figures. Also there is an increase in bearing pressure with increases in relative density. As the size is increased the load is distributed throughout the soil sample.

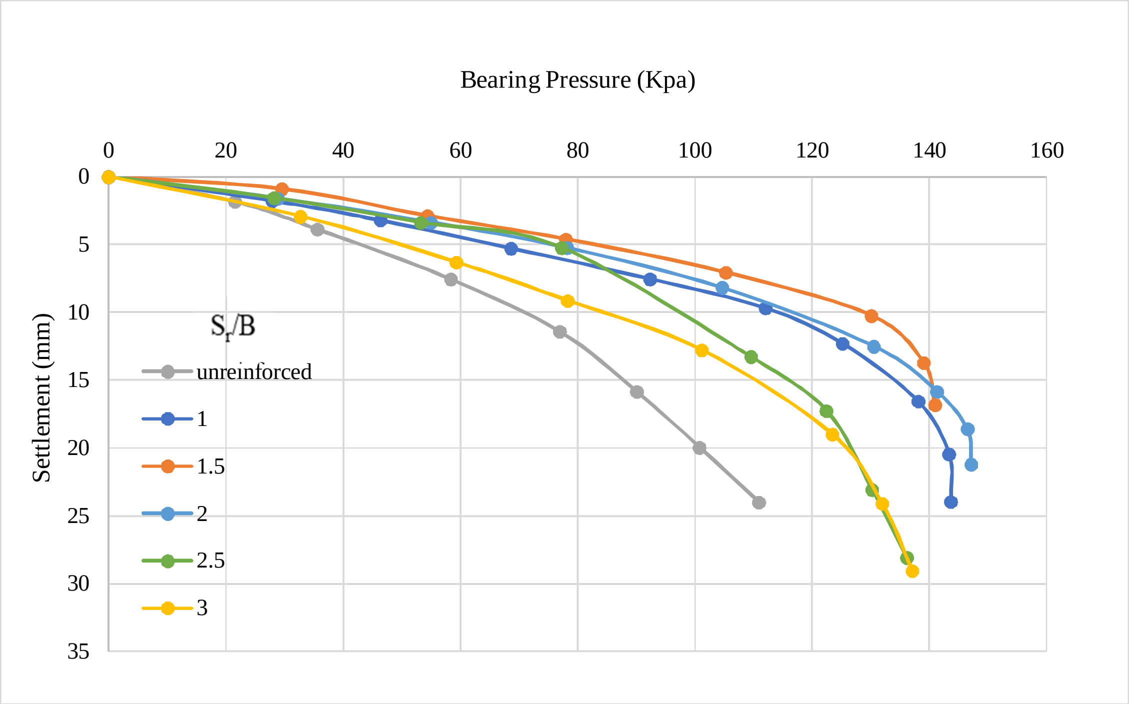

Figure 10. Bearing pressure-settlement behavior of 80 mm square footing on reinforced sand with relative density of 40%.

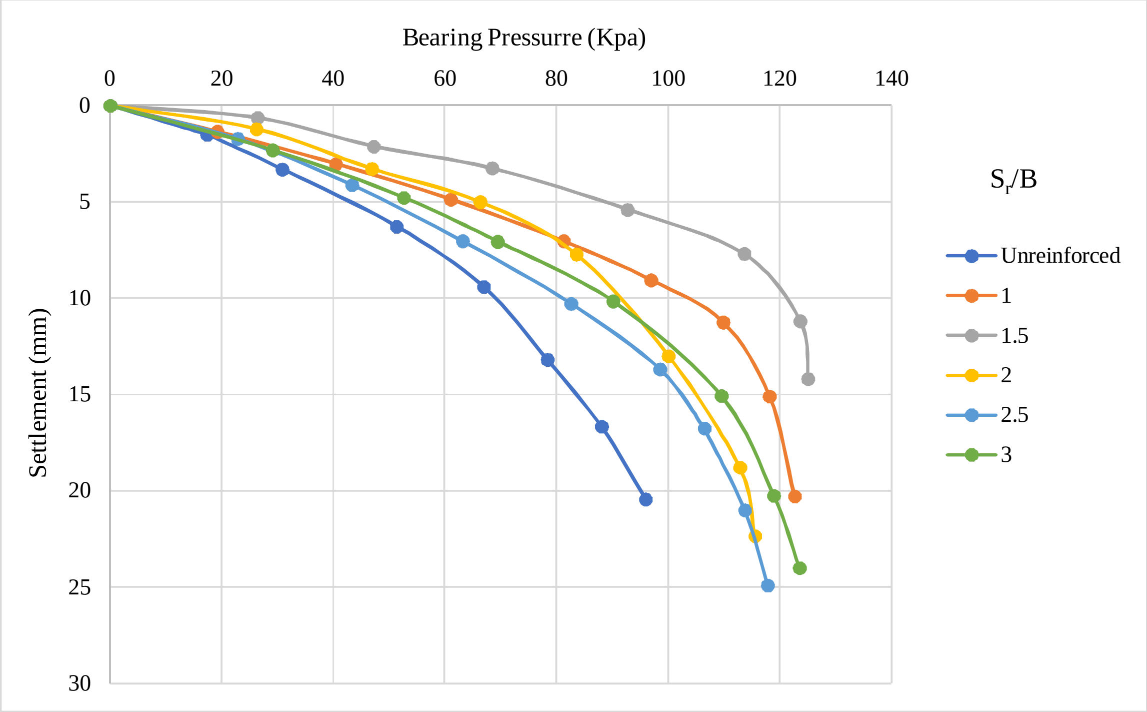

Figure 11. Bearing pressure-settlement behavour of 80 mm square footing on reinforced sand at relative density of 60%.

4.2. Effect of number of reinforcements

For the number of reinforcements, it is found from experiment that placing reinforcement up to depth of 1.5B is significant but beyond that depth, placing of reinforcement is insignificant in case of sandy soil. The result obtained in Figure 12 and Figure 13 is obtained at relative density of 60% and

40%, respectively. In the first case rubber sheet is placed just below the footing at the top of soil specimen and load is applied by using universal testing machine. The results show that up to N = 2 (with corresponding to depth of 1.5B), there is increase in bearing capacity of soil and then decreasing.

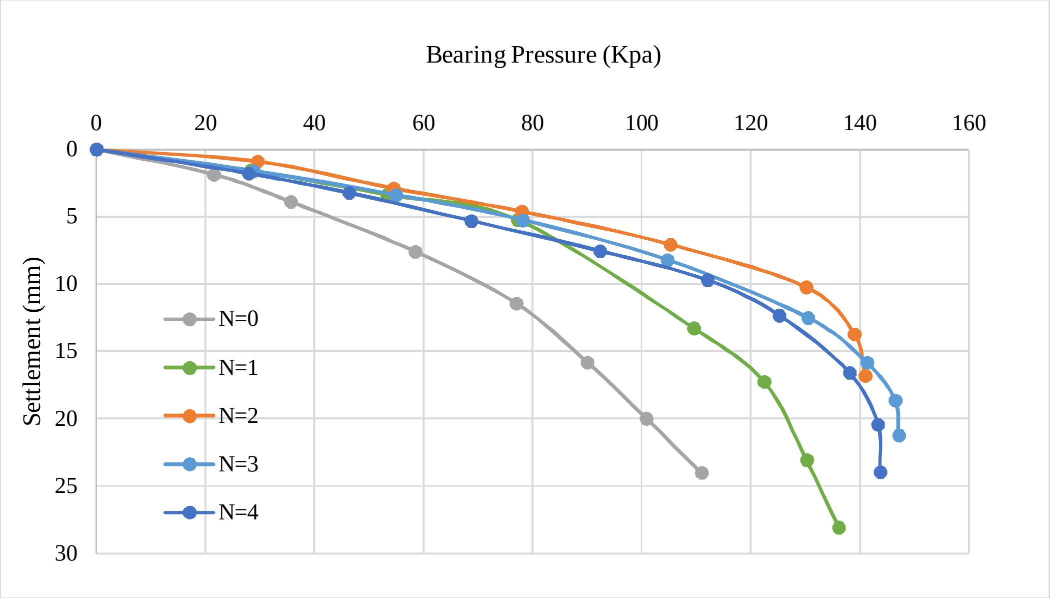

Figure 12. Bearing pressure-settlement behavour of 80 mm square footing on reinforced sand at relative density of 60%.

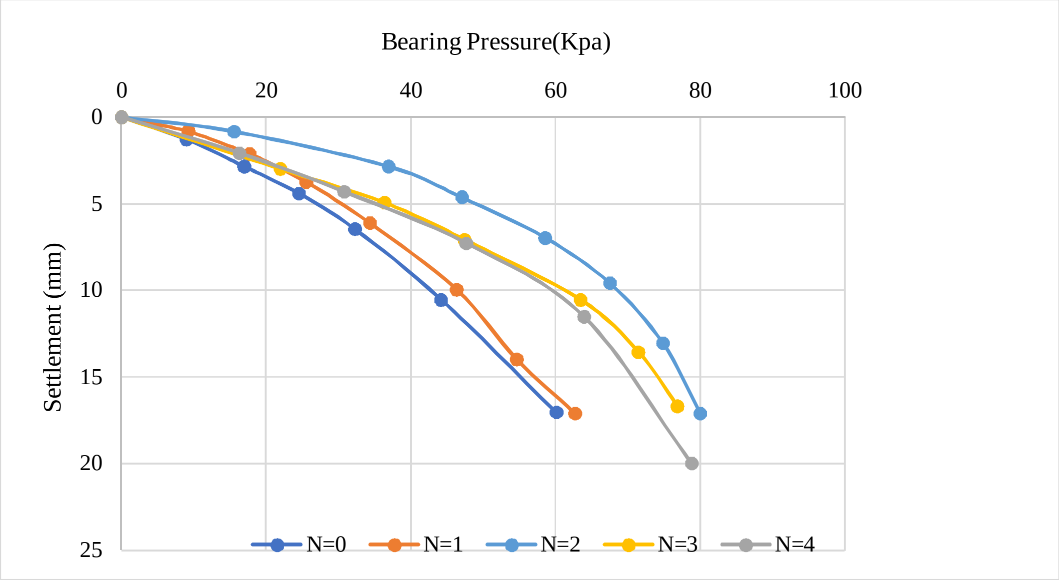

Figure 13. Bearing pressure-settlement behavior of 80 mm square footing on reinforced sand with relative density of 40%.

5. Conclusions

A total of twenty -seven model load tests were conducted to evaluate the bearing pressure-settlement of rubber reinforced sandy soil. A single layer of geotextile (tire reinforcement) was placed beneath the square footings in sandy soil. The ratio of depth of reinforcement to width of footing (Dr/B) varied from 0.25 to 2. Also the area of reinforcement varied from 1B × 1B to 3B × 3B.The number of reinforcements also varied from N = 0 to N = 4 in this research paper.

Based on the experimental studies following conclusions were obtained:

- Maximun gain in load carrying capacity is obtained when depth of reinforcement/width of footing (D_r/B) is 0.5 at relative density of 40% and 0.75 at a relative density of 60%.
- Most effective zone of reinforced lies between depths of 0.5B-0.75B.
- It is also found that with increases in relative density bearing pressure also increases in sandy soil.
- Hence, rubber tire reinforced with sand at the depth of 0.5B-0.75B and at a high relative density can be used to improve bearing capacity of sandy soil.

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ارزیابی ظرفیت باربری پایه مربعی تکیه بر شن و ماسه تقویت شده

عمران خان* و راوی کومار شارما

موسسه ملی فناوری - هامیرپور، هیماچال پرادش، هند

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چکیده:

یک مطالعه تجربی برای بهبود ظرفیت باربری خاک با استفاده از ژئوتکستایل انجام شد. در مطالعه حاضر از ژئوتکستایل (تقویت کننده تایر) به عنوان ژئوتکستایل استفاده می‌شود، در حالی که از ماسه به عنوان بستر خاک استفاده شده است. این کار تحقیقاتی نتایج آزمایش‌های بار آزمایشگاهی را بر روی پایه‌های مربعی مدل پشتیبانی شده بر روی بسترهای ماسه‌ای تقویت‌شده ارائه می‌کند. در مجموع بیست و هفت آزمایش بار برای ارزیابی اثرات تقویت تک لایه قرار گرفته در زیر پایه‌های مدل مربعی انجام شده است. پارامترهای برنامه آزمایشی کار تحقیقاتی عمق آرماتور، منطقه طرح آرماتور و تعداد آرماتورها است. از داده‌های تجربی، نشان داده شده است که عمق تقویت بهینه وجود دارد که در آن ظرفیت باربری بالاترین است. همچنین، اندازه بهینه آرماتور بدون توجه به نوع مواد تقویت کننده مورد استفاده، 1,5 B ×1,5 B است. ظرفیت باربری شن و ماسه تقویت‌شده نیز با افزایش تعداد لایه تقویت‌کننده و اندازه آرماتور زمانی که آرماتور در یک منطقه مؤثر خاص با چگالی نسبی بالا قرار می‌گیرد، افزایش می‌یابد. موقعیت بهینه قرارگیری ژئوتکستایل 1,5 B تا 0,75 B از پایه است. آزمایش‌ها در دو تراکم نسبی مختلف، یعنی 40% و 60% انجام می‌شوند. وزن واحد حجمی خاک شنی 14/81 KN/m³ است. حداکثر بهره در ظرفیت حمل بار زمانی به دست می آید که عمق آرماتور/عرض پایه (Dr/B) 0,5در چگالی نسبی 40% و 0,75 در تراکم نسبی 60% باشد.

کلمات کلیدی: ظرفیت باربری، رفتار نشست بار، ضایعات تایرهای لاستیکی، خاک شنی، پی مربع.
