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EXPERIMENTAL STUDY OF RECTANGULAR FOOTING RESTING OVER GEO-GRID REINFORCED SAND

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ABSTRACT-*Decreasing availability of good construction sites and increasing construction activities for infrastructural developments throughout the world has forced the civil engineers to utilize unsuitable sites or weak soil. So for sustainable infrastructural development, there is a need to utilize these type of unsuitable land by the use of ground improvement techniques. There are different ground improvement techniques to stabilize the poor ground in which soil reinforcement is an effective and reliable technique. The objective of the present study was to determine the effects of the geo-grid reinforcement on the bearing capacity of sand. The model tests have been conducted using rectangularfooting at u/B=0.25 & 0.55. The average relative density kept up throughout all the tests is 65%. The sand is reinforced by multiple layers (1, 2, 3 & 4) of geo-grid. The ultimate bearing capacity of sand with rectangular footing was computed by load-settlement curve. By these load-settlement curve, an appreciable increase in bearing capacity of sand was observed as the depth to the first layer of reinforcement increased. The optimum depth of placement of the first layer was 0.5B.*

Key word: *Bearing capacity, geo-grid, and Load-settlement curve.*

1. GENERAL

Foundation is an integral part of a structure, whether it is building, bridge, retaining wall and dam, etc. Depending on the depth of embedment, foundations can be classified as shallow or deep. Shallow foundations such as rectangular, square, circular footings are widely used in transmitting loads from the superstructure to the supporting soils.By the civil engineer, soil is considered as a complex material produced by weathering of the solid rock. For the civil engineers, the behavior of soil plays very important role in the stability of any structure. The design of foundation consists of two different parts: one is the ultimate bearing capacity of soil below foundation and second is the acceptable settlement that a footing can undergo without any adverse effect on the superstructure.But recent decades have experienced a massive rise in demand for land owing to rapid industrialization and urbanization and hence the subsequent rise in infrastructure building.

Decreasing availability of good construction sites and increasing construction activities for infrastructural developments throughout the world has forced the civil engineers to utilize unsuitable sites or weak soil. The footing resting on such unsuitable sites or weak soil, have low bearing capacity exhibits large settlement under small loads. For such unsuitable sites or weak soils with large loading condition, raft foundation is preferred which increase the load bearing capacity of such soils. But there are some problems will occur with raft foundation as the excavation of large area is not economical and also if the construction is adjacent to old structures and the foundation depth is large then the excavation area has to be braced during foundation construction. The improvement in strength properties of such soil has become one of the important tasks of civil engineers due to the scarcity of good sites, dramatic rise in land prices and increase in infrastructure growth. For this purpose, many researchers investigated ground improvement techniques for soil to increases the bearing capacity (Patil and Rakaraddi, 2015).

Several types of ground improvement techniques involving stabilizing or reinforcing the soil are used to increase the bearing capacity and make these type of soils suitable for construction. There are different ground improvement techniques to stabilize the poor ground in which soil reinforcement is an effective and reliable technique. The concept of soil reinforcement was first developed by Vidal (1969). He demonstrated that the introduction of reinforcement elements in a soil mass increases the shear resistance of the soil matrix. The primary purpose of reinforcing soil mass is to improve its stability, increase its bearing capacity and reduce settlements and lateral.

Soil reinforcing is defined as, a construction material composed of cohesion less free drainage materials, which is strong in compression but weak in tension, and the reinforcing elements, with high tensile strength materials, placed in the soil fill, supplying the soil mass with the necessary tensions. Reinforcing material like metal strip, geo-fome, geotextile and geo-grids are to enhance the ultimate bearing capacity of the foundation. Now a day’s use of geo-grid has increased due to its high tensile strength at low strain, open grid structure which causes bonding between geo-grid and foundation soil, long service life, light weight.

2. LITERATURE REVIEW

Many investigations have been done to look at the advantage of different types of soil reinforcement techniques on a different type of footings, and their effects to enhancing the property of soil. Some of the previous studies have been summarized below:

Shin *et al.*, (2002) conducted a number of laboratory model tests on granular soil with multiple geo-grid layers to determine the load carrying capacity of a strip foundation working on the influence of embedment. The critical reinforcement-depth ratio below the bottom of the foundation $(d/B)cr$ for deriving the maximum benefit from reinforcement is about 2. The relationship between the bearing capacity ratio at ultimate load and at limited levels of settlement (less than or equal to 5% of foundation width) was also presented. The bearing capacity ratio at limited levels of settlement is smaller than the value at ultimate load.

Boushehrian and Hataf (2003) study was performed on circular and ring footing. Here, the effects of vertical spacing, the number of reinforcement layers on bearing capacity of footing and the depth of the first layer of reinforcement were considered for investigation. Both the experimental and numerical studies showed that, with the use of a single layer of reinforcement, there is an optimum reinforcement embedment depth for which the bearing capacity is greatest. They also found out that, for multi-layer reinforced sand, it requires an optimum vertical spacing of reinforcing layer. It was also found that, with the increase in a number of reinforcement layers, the bearing capacity also increased, provided the reinforcements were placed within a range of effective depths. Further, the analysis indicated that bearing capacity does not increase beyond a threshold value of reinforcement stiffness.

Sitharam and Sireesh (2004) this paper contains the model test conducted to determine the bearing capacity of an embedded circular footing supported by multi-layer geo-grid sand beds. Besides load settlement data, strain in the geogrid layer, pressure distribution on soil subgrade and deformations on fill surface were measured. The results obtained from test shows that the ultimate bearing capacity increases with embedment depth ratio of the foundation. A considerable improvement

Kumar *et al.*, (2005) proposed a method to obtain the pressure-settlement characteristics of rectangular footings resting on reinforced sand based on the constitutive law of soil. The effect of the weight of soil mass has been considered in the determination of stress. The base of footing has been assumed smooth, as the effect of roughness on pressure-settlement characteristics has been found to be negligible Saran (1977). Stresses in soil mass have been computed using the theory of elasticity. Strains have been computed from the hyperbolic soil model defined by Kondner (1963). The analysis has been validated with the model test result conducted by Kumar (1997). Predicted and model test result matches well up to two-third of ultimate bearing pressure.

Kumar *et al.*, (2007) investigated the ultimate bearing capacity of strip footing supported by reinforced and reinforced subsoil consisting of a strong sand layer overlying a low bearing capacity sand deposit. Based on the model test result, the effect of stratified subsoil on foundation bearing capacity, the effect of reinforcing the top layer with horizontal layers of geo-grid reinforcement on the bearing capacity and effect of reinforcing stratified subsoil on the settlement of the foundation has been analyzed. The result showed that there is up to 3 to 4 times increase in ultimate bearing capacity of strip footing resting on the sand after replacing the top 1B thick layer of existing weak soil with well-graded sand layer and reinforcing it with 2–4 layers of geo-grid reinforcement.

Latha and Somwanshi (2009) presented the laboratory model test and numerical simulation result for bearing capacity of square footing resting on geo-synthetic reinforced sand. The effect of various reinforcement parameters like the type and tensile strength of the geo-synthetic material, a number of reinforcement layout, and configuration of the geo-synthetic layer below the footing is studied. The model test result shows that effective depth of the zone of reinforcement below square footing is twice the width of footing, the optimum spacing of reinforcement layer is about 0.4 times the width of footing and the optimum width of reinforcement is 4 times the width of footing.

Lovisa *et al.*, (2010) studied for circular footing to find out the behavior of pre-stressed geotextile-reinforced over the sand bed. A significant improvement to the load bearing capacity and settlement can be achieved by the addition of pre-stress reinforcement. The load-carrying capacity at 5 mm settlement in the pre-stressed case (with pre-stress equal to 2% of the allowable tensile strength of the geotextile) is approximately double that of the geotextile-reinforced sand without pre-stress for surface footing.

Dewaikar *et al.*, (2011) observed on the model circular footing with reinforced soil to study the load-settlement behavior. The study showed that the use of mine waste and reinforcing materials towards the improved performance of a soft clay sub-grade in respect to bearing capacity and settlements, further, in the case of BCR and SRF rubber grid performed better than the Geo-grid. The better performance of rubber grid could be a cheaper and viable alternative for effective ground improvement.

Kolay *et al.*, (2013) investigated the ultimate bearing capacity of rectangular footing supported by geo-grid reinforced silty clay soil with a thin layer of sand on the top. Initially, one geo-grid is placed at the interface of soil with u/B equals to 0.667 and it is found that bearing capacity increases with an average of 16.67% and when one geo-grid is placed at the middle of the sand layer with u/B equals 0.33, bearing capacity increases with an average of 33.33%.

Dhatrak (2014) found out the behavior of Square footings on Pre-stressed Geo-synthetic Reinforced Sand. Laboratory physical model tests and numerical analyses were conducted to study the behavior of pre-stressed geotextile-reinforced sand bed supporting a loaded square footing. In each case, reinforcement depth, pre-stressing force, pre-stress directions are varied of the geo-grid for the purposes of knowing improvement in load bearing capacity of footing. For the model tests, cohesion less, dry, clean and wash sand was used as the foundation material. The model footings of three different sizes were fabricated by using cast iron material. The model footing used was square plates of dimensions 5 x 5, 7.5x7.5 and 10 x 10 cm and 1 cm thick. The Biaxial geo-grid (SG3030) of tensile strength 30KN/m, was used to reinforce the sand bed. For the experimental investigations, the model plate load tests were conducted in accordance with (IS: 1888-1982) laboratory plate load test on soil and to evaluate the bearing capacity and settlement. It was observed that the maximum improvement in settlement behavior occurs when the magnitude of pre-stress is equal to 2% and 3% of the tensile strength of reinforcement, on double layer biaxial pre-stress as to compare to uniaxial pre-stress reinforced sand at depth u=B/2 and u=B/4 respectively.

Azzam and Nasr (2015) found out the ultimate load capacities of shell foundations on unreinforced and reinforced sand by laboratory model tests. A series of loading tests were carried out on model shell footing with and without a single layer of reinforcement. The tests were done for shell foundation at different shell embedment depth and subgrade density. The experimental studies indicated that the ultimate load capacity of shell footing on reinforced subgrade is higher than those on unreinforced cases. The shell foundation over reinforced subgrade can be considered a good method to increase the effective depth of the foundation and decrease the resulting settlement.

Harikumar *et al.*, (2016) performed Laboratory plate load tests on a model footing resting on sand bed reinforced with plastic multi-directional reinforcements. The bearing capacity and settlement were evaluated and the effect of depth to the first layer, the spacing between reinforcements in a layer, number of layers and spacing between layers were investigated. An appreciable increase in bearing capacity was observed as the depth to the first layer of reinforcement increased beyond 0.1B. The optimum depth of placement of the first layer was 0.5B. Placing reinforcements beyond 0.5B depth, in a single layer, resulted in a reduction in the increase of bearing capacity. The bearing capacity increased by 1.3 times and the settlements reduced by almost 72%.

3. MATERIAL AND METHODOLOGY

3.1 MATERIAL

3.1.1 SAND

The sand which we use in our experiment is collected from the Kharka River situated to near Udaipur. It underwent through cleaning to remove the debris from it, like, the leaves, organic particles, twigs, etc. Then it was oven dried and was to pass through a 600µ sieve and retained through 300µ sieve size. And the retained sample was used in our experimental work. As dry sand does not include the effect of moisture, it can be used as soil medium for the test.

The experiments are conducted in the medium dense sand, achieving relative density as 65%. The coefficient of the angle of friction is found out to be 40˚ for the desired density of the sample by the direct shear test. The geotechnical properties of sand are enlisted in the table below.

Table 3.1 Geotechnical Properties of Sand (As per laboratory tests)

S. No	Property	Code referred	Value
1.	Specific Gravity	IS 2720 (Part 3/Sec 1) - 1980	2.62
2	Maximum Dry Density	IS 2720 (Part 7) - 1980	15.08 kN/m^3
3	Relative density, I_d	IS 2720 (Part 14)- 1983	65%
4	Working density, γ_d	IS 2720 (Part 28)- 1974	14.32 kN/m^3

3.1.2 GEOGRID

Biaxial geo-grid (BXF30) was used for this investigation and it was provided by M/s Strata Geo-systems (India) Private Limited. Strata Geo-systems (India) Private Limited is a joint venture company in India with Strata Systems Inc., USA. Strata India is manufacturing the whole range of Strata soil reinforcement products in India. Physical and mechanical properties of biaxial geo-grid are as follows:-

Table 3.2 Properties of the geo-grid (source Strata Geo-systems (India) Private Limited)

Parameters	Value
Type	BXF30 (Biaxial Flexible)
Polymer	Polypropylene Pp
Aperture size (W)	43*43 mm
Aperture shape	Square
Rib width (w)	1.1 mm
Tensile Strength (ASTM D 6637) (1) MD (machine direction) (2) CMD (cross machine direction)	30 kN/m 30 kN/m

3.1.3 MODEL FOOTING

The footing of Rectangular shape are made of mild steel plates in 2cm thickness to provide the rigid footing conditions were used in this investigation. The dimensions of rectangular footing were used 11.8cm×15cm have the area equal to 177 cm2. The bases of the footing was roughened. On footings surface, little grove of 0.5cm was provided to apply load.

3.2 METHODOLOGY

3.2.1 SAND BED PREPARATION

Dimensions of the tank were measured accurately and volume for the required fill was calculated. Now, by adopting rain falling technique, the test tank was filled with sand and height of fall was maintained to achieve the desired relative density of the sand for the experiments work. After several trials, as the relative density was achieved by maintaining the different height of fall, it is spread in 2.5cm layers through rain falling technique, which takes around 17.5kg sand for each layer, which is found out from the calculation. After each fall, the sand layer is leveled by means of a scale.

3.2.2 GEO-GRID PLACEMENT ON SAND

After preparation of sand bed at desired height, the placement of geo-gridwas proceeded for this experimental work. Geo-grids were placed horizontally in between at desired depth from the bottom of footing after leveling the surface. After going through several kinds of literature, the ratio (u/B) was taken 0.25 and 0.50 and ratio (h/B) was taken 0.3 for this investigation for the placing of a different layer of geo-grids. (u= depth of first layer from base of the footing, B= width of model footing and h=distance between two consecutive geo-gridlayer)

3.2.3 EXPERIMENT PROCEDURE FOR RECTANGULAR FOOTINGS

Experimental procedures, which were performed for Rectangular Footing at different depths of reinforcement with varying number of geo-grid layers were listed below:-

- First, the test tank was filled with maintained working density in unreinforced and reinforced condition. And after that, the footing was placed at desired location over the sand fill to transfer the load vertically.
- Then the grooving metallic ball was placed on the depression of center position, and then the load transferring shaft with attached proving ring was placed over it, through which the load was transferred to the footing.
- Two dial gauges were placed on the surface of the footing on the opposite sides of it. Then the initial readings of two dial gauges were noted, and as the load is increased, the readings were noted down.
- The load was applied gradually in an increasing manner and the footing was allowed to settle under the applied load. The load increment was maintained until the footing settlement gets stabilized which was measured from the two dial gauge readings up to 25mm as per IS: 1888-1982 code guideline.

Fig.3.1 Experimental setup for Rectangular footing at u/B ratio 0.25 & 0.50

- Settlement corresponding to each load increment was noted and the test result will be plotted in term of load-settlement curve. Ultimate bearing capacity for each test will be determined from load-settlement curve using tangent intersection method.

4. RESULT AND DISCUSSION

Load tests have been performed on the modelrectangular (11.8cm×15cm) footing resting over unreinforced as well as reinforced sand bed. For preparing reinforced sand bed, multiple numbers (1, 2, 3, and 4) of geo-grid layers have been introduced with varying u/B ratio 0.25 & 0.50 at h/B ratio 0.3. Settlement (up to 25mm as per IS: 1888-1982) corresponding to each load increment is noted and the test result is plotted in term of the load-settlement curve. Ultimate bearing capacity for each test is determined from load-settlement curve using tangent intersection method.

4.1 MODEL TEST RESULT OF RECTANGULAR FOOTING

Results of load test on rectangular footing are plotted in term of the load-settlement curve in Fig. 4.1 and Fig. 4.2 with multiple numbers (1, 2, 3, and 4) of geo-grid layers at varying u/B ratio of 0.25 & 0.50, and h/B ratio of 0.30.

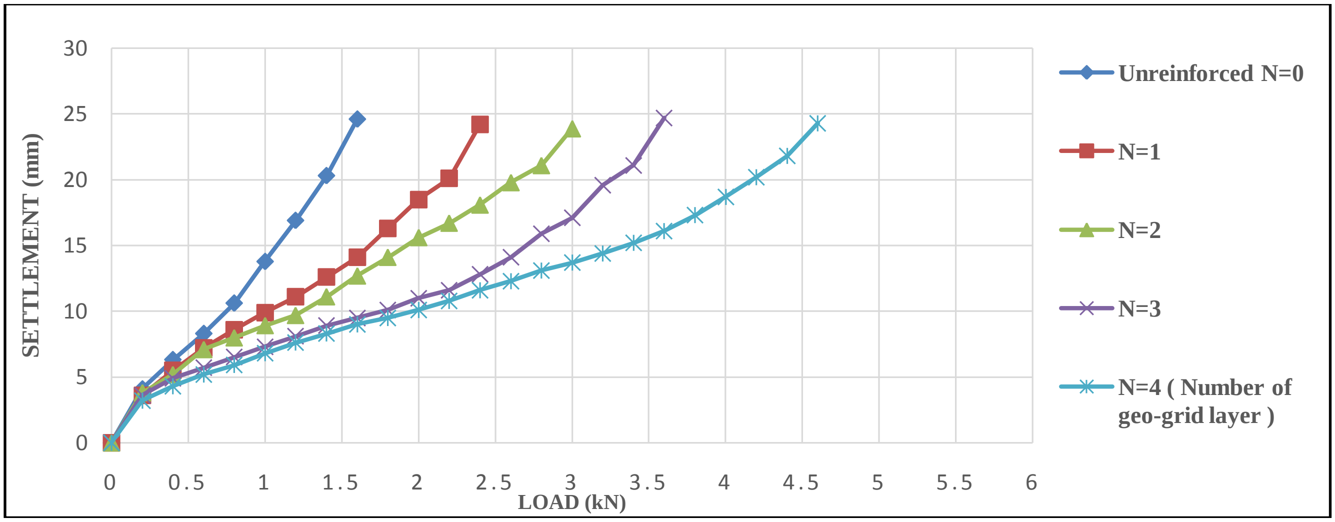

Fig. 4.1 Load-settlement curve of Rectangular footing (u/B = 0.25)

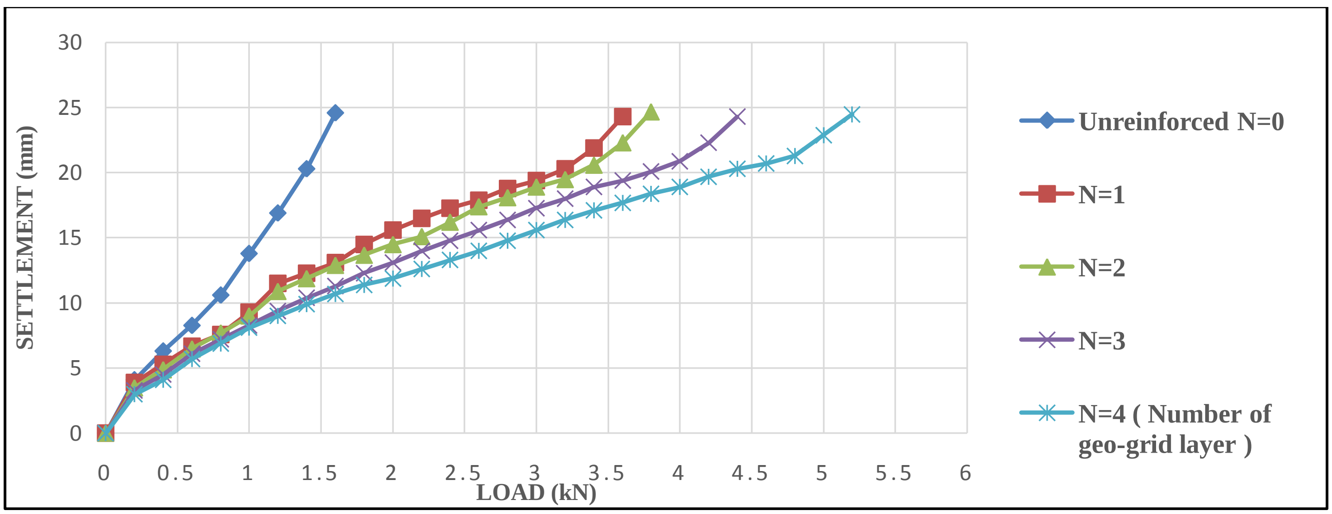

Fig. 4.2 Load-settlement curve of Rectangular footing (u/B = 0.50)

From the load-settlement curve shown in Figure 4.1 and Figure 4.2, the ultimate load carrying capacity of sand at both u/B ratio i.e. 0.25 & 0.50 has been calculated with varying number of geo-grid layers. Fig 4.1 shows that the bearing capacity of unreinforced sand 1.4 kN whereas, the bearing capacity of sand when, rectangular footing resting on 4 geo-grid layers was 4.5 kN at u/B ratio 0.25. From the above test results, it is observed that the bearing capacity of sand was increased after sand reinforced by 4 geo- grid layers about 3.21 times the unreinforced sand's bearing capacity at u/B ratio 0.25.
Fig 4.2 shows, the bearing capacity of unreinforced sand loaded by rectangular footing was 1.4 kN whereas, the bearing capacity sand when, rectangular footing resting on 4 geo-grid layers was 5.1 kN at u/B ratio 0.50. From the above test results, it is observed that the bearing capacity of sand was increased 3.64 times the unreinforced sand's bearing capacity at u/B ratio 0.50, when sand is reinforced by 4 geo- grid layers. From the graph, it is observed that ultimate bearing capacity of sand increases as the number of geo-grid layers increases and also the total settlement at failure load decreases as number of geo-grid layers increases
As shows in fig 4.1 and 4.2, bearing capacity of sand at increasing number of geo-grid layers from 1 to 4 is observed 2.3 kN, 2.7 kN, 3.4 kN and 4.5 kN at u/B ratio 0.25 respectively and 3.4 kN, 3.6 kN, 4.3 kN and 5.1 kN at u/B ratio 0.50 respectively. By comparing the load-settlement curve at u/B ratio of 0.25 & 0.5 (Fig 4.1 and 4.2), it is observed that bearing capacity of sand is increased as an increase in u/B ratio from 0.25 to 0.50.

5. CONCLUSION
6.

In this work, the performance of rectangular footing resting over geo-grid reinforced sand has been studied based on a series of experimental tests. The results of all the experiment test have been discussed in previous chapter. On the basis of discussion of result, following conclusion are made:

1. According to investigation, an appreciable increase in bearing capacity of sand was observed as thedepth to the first layer of reinforcement increased.The optimum depth of placement of the first layer was 0.5B.Thebearing capacity of sand for rectangular footings increased by 1.5 times the unreinforced sand's bearing capacity.

2. Adding one layer of geo-grid improved the load carrying capacity of reinforced sand relatively to that of the unreinforced sand.

3. Increasing the number of reinforcement layers from one to four led to the best responseobserved, in terms of load carrying capacity of reinforced sand. A proper placement of geo-grid reinforcement is required to obtain significant load settlement and bearing capacity improvement.

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