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Effect of Reinforcement on Bearing Capacity of Sand

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Abstract

The reinforced earth concept, which is now being evaluated with increased significant encompasses formation of a composite of a soil with tension resistance reinforcing elements such as metallic and nonmetallic strips, bars, rods fibers or nets in the soil. The objective of using the reinforcement is to supress the normal tensile strains in the soil mass through frictional interaction. Flexible nature of reinforced earth mass enables it to withstand large differential settlements without distress. Reinforced earth permits construction of engineering structures over poor and difficult subsoil conditions. In situations, where the deformation and displacement of foundation soil are such that only flexible structures can be constructed, reinforced earth is more suitable. The reinforcement of sand is more beneficial in loose sand conditions where the deep foundation is not economical. Thus the reinforced earth has provided geotechnical engineer with a material which when appropriately can offer substantial economies over conventional techniques. The present model study has been carried out using strip footing on a deep, homogenous Ghaggar sand bed reinforced with mild steel wire mesh for obtaining its load settlement behavior. The model is developed by considering and varying parameters such as number of reinforcing layers, depth of first reinforcing layer from base of footing, interspacing between reinforcing layer and density of sand bed. A comparison is made between load and settlement characteristics of un-reinforced sand and reinforced sand.

Keywords: *soil reinforcement, bearing capacity, reinforced earth*

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INTRODUCTION

Reinforced earth is based on a very simple test concept. As originally conceived in the 1960's by its inventor – French architect and engineer Henry Vidal [1], the inter spacing of the soil and reinforcement develops friction at the point of contact between the two, resulting in a permanent and predictable bond and creating a unique composite material. The reinforced earth concept which is now being evaluated with increased significant encompasses formation of a composite of a soil with tension resistance reinforcing elements such as metallic and non-metallic strips, bars, rods, fibers or nets in the soil. Objective of using the reinforcement is to suppress the normal tensile strains in the soil mass through frictional interaction. A well-known fact is that granular soils are strong in compression and shear but weak in tension. Introducing the reinforcing elements in the directions in the tensile strains is going to substantially improve the performance of such soils and the results would be akin to reinforced concrete.

The basic principle of reinforcement of earth Jewell [2] said that when an oriented reinforcement is included, a higher strength is developed in the soil. This is because of increase of normal stresses across the potential rupture plane and simultaneously a decrease of shear stresses act in the soil.
Maximum shear stress is given by:

$$(\tau_{yx})_{max} = \sigma_y \tan\phi_{max} \quad (1)$$

(τ_{yx})max = maximum shear stress, σ_y=Normal shear stress, ϕ_{max} = angle of internal friction,

If a reinforcing layer of strength F_R is introduced at an orientation less than $\phi°$ to the vertical, then maximum shear stress is given by:

$$(\tau_{yx})_{max} = \sigma_y\tan\phi_{max} + F_R/A_S\,(\cos\phi\tan\phi+\sin\phi) \quad (2)$$

F_R is strength of reinforcing layer, A_S is soil area across reinforcing layer, ϕ is angle of reinforcement. The shear strength of the reinforced soil is influenced by factors such as form of the reinforcement (friction between the reinforcement and the soil), orientation of the reinforcement, stiffness of the reinforcement, creep performance of the reinforcement during the lifetime of the corrosion resistance during the lifetime. Reinforcement is increasingly used in temporary structures to improve the shear strength of soil. The fact that large number of structures built on the poor soils have speeded up the development of soil reinforcement techniques. There is growing need in the developing countries for research to be aimed at channeling local technology to the design and construction of low cost highway and housing projects. This is pertinent to the abundance of cheap and locally available raw materials coupled with high cost of improved materials of construction. Thus while in the most documented previous research steel, aluminum. Polypropylene, polythene, PVC, etc. have been used, which are quite costly. In the present case, locally available mild steel wire mesh has been used.

LITRAURE REVIEW

Henry Vidal [1] gave **t**he earliest concept of reinforced earth**.** He built a retaining wall in southern France. It was for a composite material formed from flat reinforcing strips and horizontally in a frictional soil. The interaction between soil and reinforcing member is generated by surface friction. Binquet & Lee [3] conducted tests on reinforced earth slab and investigated the pressure settlement characteristics of a rigid strip footing using different types of foundation beds such as homogeneous deep sand, sand above an extensive layer of very soft material simulating very soft clay or peat and sand above finite pocket of very soft material. They concluded that for every soil condition, there is an optimum arrangement of reinforcement giving maximum increase in bearing capacity ratio (B.C.R.) = q / q_o where q and q_o are average pressure for reinforced and un-reinforced soil at desired density. Talwar [4] investigated the pressure settlement behavior of reinforced earth. The behaviour was investigated for both the failures– friction and rupture modes. Length of reinforcement and its depth from the base of the footing was varied. Increase in length on the reinforcement and decrease in value of first layer of the reinforcement from the base of the footing resulted in increase in bearing capacity. Richard Fragazy and Lawton [5] determined the effect of soil density and length of reinforcing strip on the load settlement behavior of reinforced sand. This study has shown the beneficial results of reinforcing dense sand tested over a wide range of relative densities (D_R =51–90%). When bearing capacity ratio was calculated at a settlement equal to 10% of the footing width, the bearing capacity ratio was found to be independent of soil density. Failure of rectangular footing on dense reinforced sand occur at a larger settlement than an identical footing resting on un-reinforced sand at same density as the strip length increase from three to seven times the footing width, the bearing capacity ratio increases rapidly. Guido, et al. [6] studied the effect of depth of first reinforcing layer, vertical spacing of the layers, width, size of the sheet and tensile strength of the geotextile reinforced foundation. Load foundation curves for reinforced soils have a typical shape of a local shear. In order to obtain the maximum benefit of a geotextile functioning as reinforcement, sufficient deformation was required to mobilize its tensile stress. It was observed that for small settlement, load settlement curve for un-reinforced soil indicated to be stiffer than reinforced soil the tensile strength of the reinforcement is an important factor. As the tensile strength increases, there is a steady increase in bearing capacity ratio. Guido, et al. [7] presented comparison of model test using geotextile and geogrid as reinforcement. The parameters studied were coefficient of friction between the geotextile and the soil, pullout resistance between the geogrid and the soil, depth of first reinforcing layer of reinforcement, vertical spacing of the layers, number of layers, width of square sheet of reinforcement and tensile strength of the reinforcement. For both geotextile and geogrid, after an optimum number of layers, the bearing capacity did not increase. In addition bearing capacity was largest for the geotextile and the geogrid where the first layer was close to the footing and interspacing between the layers was least.

Bearing capacity increased with increasing reinforcement tensile strength for geotextile, however, for the geogrid, aperture size and reinforcement tensile strength must be evaluated simultaneously. K. H. Khing, et al. [8, 9] conducted tests for the bearing capacity of a strip foundation supported by a sand layer reinforced with layer of geogrid. Based on the present model tests results, the bearing capacity ratio with respect to the ultimate bearing capacity and at levels of limited settlement of the foundation, has been determined for practical design purposes, it appears that the bearing capacity ratio at limited levels of settlement is about 67–70% of the bearing capacity ratio calculated on the bases of the ultimate bearing capacity.

EXPERIMENTAL SET UP

Efforts had been done for improvement of sandy soil by using different types of materials like aluminum strips, steel plates and strips, polythene, geogrid, geotextile etc. which results in the improvement in bearing capacity and decrease in settlement. When these materials are used as a reinforcing material they provide requisite strength. One of such commonly material is wire mesh. When it is used in the form of closely woven net, it acts as a flexible structure, which deflects under the superimposed load but regains its original configuration as soon as the load is removed. In case of dead loads like the weight of buildings, this reinforcing material will deflect to a particular configuration and remain in the position provided the distress caused by the loads remains in the tensile stress wires. This concept formed the bases of the series of experiments conducted herein where some parameters were changed and their efforts regarding improvement in bearing capacity of sand studied. Variables, which were changed during the program of experiment, can be listed in Table 1.

Table 1: *Parameters.*

Parameters	Value
u/B	0.267, 0.533, 0.8, 1.0
h/B	0.267, 0.533, 0.8
N	1, 2, 3
Size of mesh	0.5×0.5 cm
R. D	47, 84%

u/B= Depth of first reinforcing layer from the base of footing,. h/B = Interspacing between the r/f layers. N =Number of r/f layers.

Soil Properties

Ghaggar sand from local depot was used for the experimental purposes. Properties of sand used are shown in Table 2.

Table 2: *Soil Properties.*

Characteristics	Values
Soil	Sand
D_{10}	0.1
C_u	1.7
C_c	1.324
G	2.649
e_{min}	0.616
e_{max}	0.92
R.D	47,84%

A tank of dimensions 1.00x0.6x0.6 m was used to carry out the experiments. Fixing angle irons and channels at corners at all corners and top bottom of the tank so that there is no deflection of the tank wall and bottom strengthened the tank. The tank rested on channels and cross beams and was fixed on vertical post made of double channel to support the loading device. A two dimensional failure analysis of sand was carried out using a strip footing. A rectangular mild steel footing of dimensions 59.5x15x1.5 cm was adopted. It was grooved on the lower side to simulate a rough surface that would be similar to actual foundations and also to have a better contact with soil. Centre of footing on the upper side was marked to avoid eccentric loading. Reaction loading was applied to the sand through a hand operative hydraulic jack, which was secured to a horizontal crossbeam through calibrated proving ring of 5000 Kg capacity.

Reinforcement

Square wire mesh of size 0.5×0.5 cm was used as reinforcement. The properties of wire mesh used for experiments are shown in Table 3.

Table 3: *Properties of Reinforcement.*

Property	Value
Material	Mild steel
Diameter of the wire	0.45 mm
Size of mesh	0.5×0.5 cm
Tensile strength	250 MPa
Modulus of elasticity, E	2×10^5 MPa

Testing Procedure

For a model to predict accurate results commensuration with actual field situations, it should be designed as much similar as possible to field conditions. Reliability of such a test program depends largely upon reproducibility of required density. Therefore it was decided herein to deposit sand by 'rainfall' technique for reasons of convenience and nature of experiments. In this method, also referred as to as free fall technique, sand is made to fall from the fixed height under gravity through holes in proper-sized sieves. It was experimentally found out that the diameter, spacing and configuration of holes in the sheet used for depositing sand from a desired height control the density and the uniformity of the deposit. For pouring sand, a thin sheet of steel in rectangular shape and having raised edges all around was fabricated. Size of the sheet was such that it could be lowered into the tank having very little clearance on all sides. Sheet had perforations of 4mm diameter at 3 cm c/c. Sand was deposited in the tank by rainfall method and reinforcement was kept in the deposit. Loads were increased in the small and equal increments. Settlement readings were taken with help of dial gauges placed on the footing at an interval of 1, 5, 10, 20, 40, and 60 minutes and then hourly basis until rate of settlement becomes less than 0.02 mm per hour. After this the next load increment was applied and again a reasonable period was allowed for thew settlement to be constant. Procedure was repeated and continued up to failure of footing. Different curves are drawn for un-reinforced and reinforced sand varying different parameters and then compared.

RESULTS AND DISCUSSION

The results obtained from various experimental tests conducted in the laboratory are as follows:

- Figure 1 shows the comparison between pressure settlement characteristics for dense sand, in which the depth of first reinforcing layer is varied from the base of the footing is varied from u/B=0.267 to u/B=1.0. Curve shows that as the depth is increased, there is decrease in the bearing capacity and increase in the settlement for the same load. The bearing capacity ratio is maximum (2.857) when the u/B is equal to 0.267, u/B=1.0 has no considerable effect on the bearing capacity ratio.
- Figure 2 show the pressure settlement curve for the loose sand in which the depth of first reinforcing layer from the base of the footing is varied from u/B=0.267 to u/B=1.0. Curve shows that as the depth is increased, there is decrease in the bearing capacity and increase in the settlement for the same load. The bearing capacity ratio is maximum (2.458) when the u/B is equal to 0.267, u/B=1.0 has no considerable effect on the bearing capacity ratio.
- Figure 3 shows the curve for bearing capacity ratio versus number of layers. It shows that as the number of layers increases the bearing capacity increases. The increase in bearing capacity is more in dense sand. After three layers the bearing capacity increase is not considerable. Therefore the optimum number of layers for reinforcement is three. Table 4 gives the values of bearing capacity ratios for different number of layers.

Table 4: *BCR.*

RD%	BCR			
	N=0	N=1	N=2	N=3
47	1.00	2.61	3.07	3.57
84	1.00	2.69	3.28	4.3

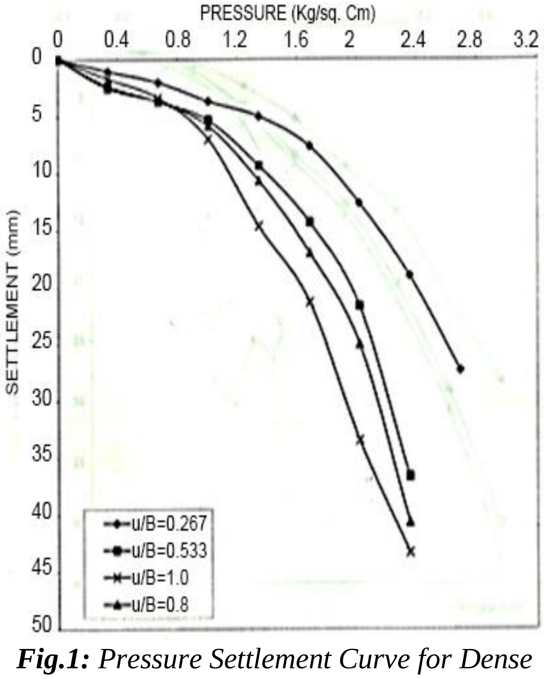

Fig.1: *Pressure Settlement Curve for Dense Sand for Different u/B Values.*

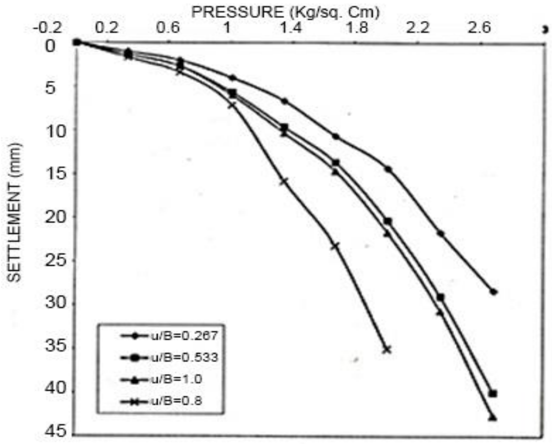

***Fig. 2:** Pressure Settlement Curve for Loose Send for Different Values u/B.*

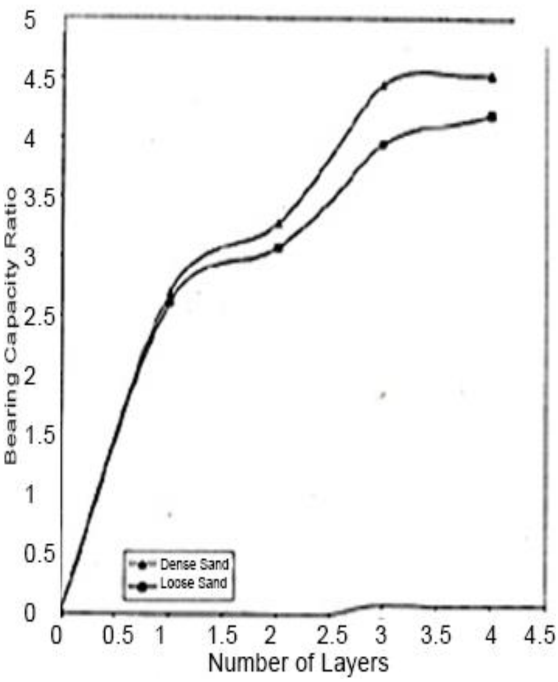

***Fig. 3:** Variation of Bearing Capacity Ratio with Number of Layers.*

CONCLUSIONS

Interpretation of the test data and a study of various test plots lead to the following conclusions: Reinforcement increases the bearing capacity of the sand bed. The bearing capacity ratio is maximum (4.211 for loose sand and 4.747 for dense sand) for the smallest combination of u/B (0.267) and h/B (0.267) ratio and is minimum (1.733 for loose sand and 1.954 for dense sand) for the largest u/B (1.0). To achieve significant increase in bearing capacity, u/B ratios not greater than 0.5 are preferred. The first layer therefore is kept at a depth not greater than one quarter the width of the footing from the base of the footing. The optimum number of reinforcement layers is approximately three. Further increase in the number of layers is not economical. The influence of h/B ratio, in increasing the bearing capacity is very marked for h/B less than 0.5. The best combination for increasing bearing capacity is u/b and h/B = 0.267.

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