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Improvement of bearing capacity of strip footing on sand by using metal strip reinforcement

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Abstract

This study has been carried out to investigate the increase of bearing capacity of strip footing by using metal strip reinforcement resting upon sand deposit. The sand bed consists of horizontally placed metal strip reinforcement in one layer, two layers, and three layers. Model tests were conducted to investigate the bearing capacity and settlement of strip footings in two different speeds of loadings.

Tests were carried out in a tank on beds of sand having average densities varying from 14.67 kN/m^3 to 15.78 kN/m^3. The sand bed thickness was maintained to 3.9 times the least dimension of the footing. The effect of number of reinforced layers; effect of speed on bearing capacity is studied. The result is established, discussed and compared among different layers of reinforcement and two rates of speeds. From the experimental result for the case of reinforced sand bed, it is observed that the bearing capacity of the footing increases significantly compared to an unreinforced bed. In most of the test, it is observe that with the increase in number of the layers of reinforcement, bearing capacity has been improved. Due to change in speed of loading the bearing capacity and settlement have been affected .The results also indicate that for slow speed, bearing capacity was of higher value than that of higher speed of loading. On the other hand, settlement due to slow speed of loading is lower than that of higher speed of loading.

Keyword: Bearing capacity, metal strip, Sand bed, strip footing.

1. Introduction

The bearing capacity of foundation is an important factor for designing the type of foundation and depth of foundation .A footing foundation is the supporting base of a structure, which transmits the loads to the natural ground. Bearing capacity problems are getting wider day by day with the advent of the researchers to improve the foundation

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soil condition by including new material into the soil in various forms. One of the recent inclusions in bearing capacity problem is that of reinforcement. A reinforced earth slab is essentially a soil foundation containing horizontally embedded thin flat ties with relatively high tensile strength developing strong frictional bond with the soil. Because the reinforcing action requires good frictional bond between the ties and the soil, only free draining granular soils are considered (Binquet and Lee, 1975).

The bearing capacity of reinforced soil depends on various factors like length of reinforcement, number of reinforcement layers, placement of layers, angle of internal friction of soil and interface friction between soil and reinforcement. In the developing countries there is a growing need for research to be undertaken aimed at channeling local technology to the design and construction of low cost high way and housing project. It is expected that the locally available metal strips may provide a good reinforcement to the foundation soil in particular to long-term construction involving heavy loads over inferior foundation soil condition.

This study deals with the characteristics of metal strip reinforced sand beds to affect the bearing capacity of strip footing resting on these. The sand bed consists of layers of sand of varying depths with horizontally placed metal strips in one layer, two layers, and three layers and used at the same number of metal strips in every layer. Model test were conducted to investigate the effect of bearing capacity and settlement of rough based strip footing in different rate of applied vertical load on the footing. A series of model tests were carried out in the Geotechnical Engineering Laboratory of Bangladesh University of Engineering and Technology (BUET). The tests apparatus mainly consists of a model tank of dimensions 57cm×85.5cm×60cm, a sand spreader, a leveling apparatus, a strip footing, a loading rig having a various capacity, two settlement transducers, a data logger, a load cell and a computer. The test was performed on a strip footing having a width of 10cm in a model tank. Uniform sand bed was prepared by using a sand spreader. Two deformation transducers were used to measure settlement. A strain controlled loading rig was used to apply load on the footing. A load cell measured the load. All of the measuring devices were connected to a computer through the Data Logger.

2. Experimental set up

The experimental set up was improved to investigate the bearing capacity of footing on a sand bed layer with and without reinforcement. Air-dried sand was used in the present investigation. Horizontal metal strip reinforcements were laid in single, double and triple layers in the sand bed are shown in Fig. 1.

2.1 The tank

The tank designed and constructed by Quadir (1990) was used in the investigation to house the foundation system. A view of the tank is shown in Fig. 2.

The skeleton of the tank is constructed of 35mm×35mm×4.5mm mild steel angles. The members of frame were connected to each other by providing necessary bolting and or welding. The 60cm deep tank has an inside dimension of 57cm×85.5cm.The longer side are bounded by 10mm thick glass sheets whereas wooden plates of 25mm thick are used on the shorter sides. Four steel wheels are fitted to the bottom of the tank, which rests on a rail system designed to facilitate shuttling of the tank in between the sand spreader and loading rig. Details of tank are shown in Fig. 3.

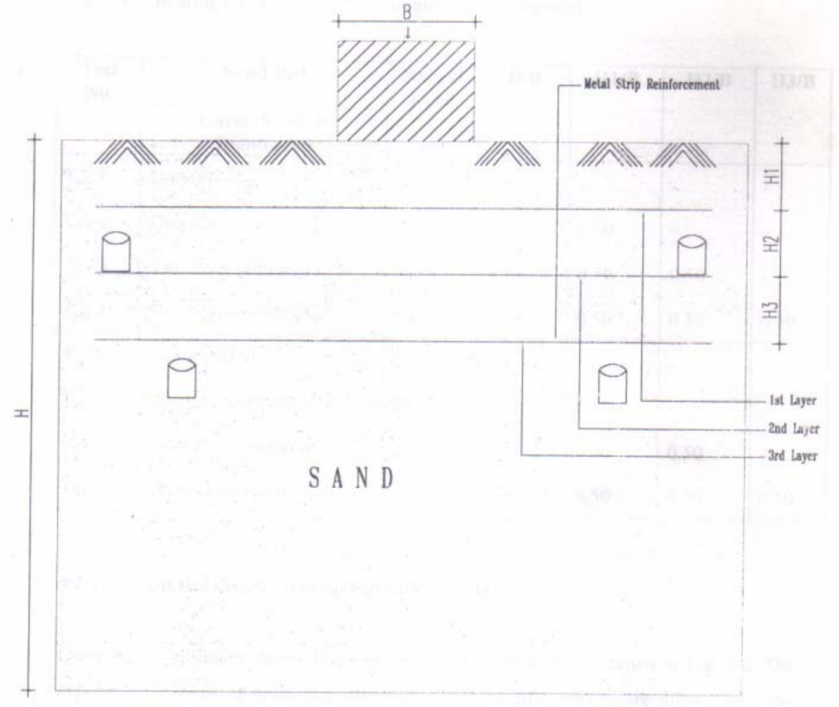

Fig. 1. The sand bed

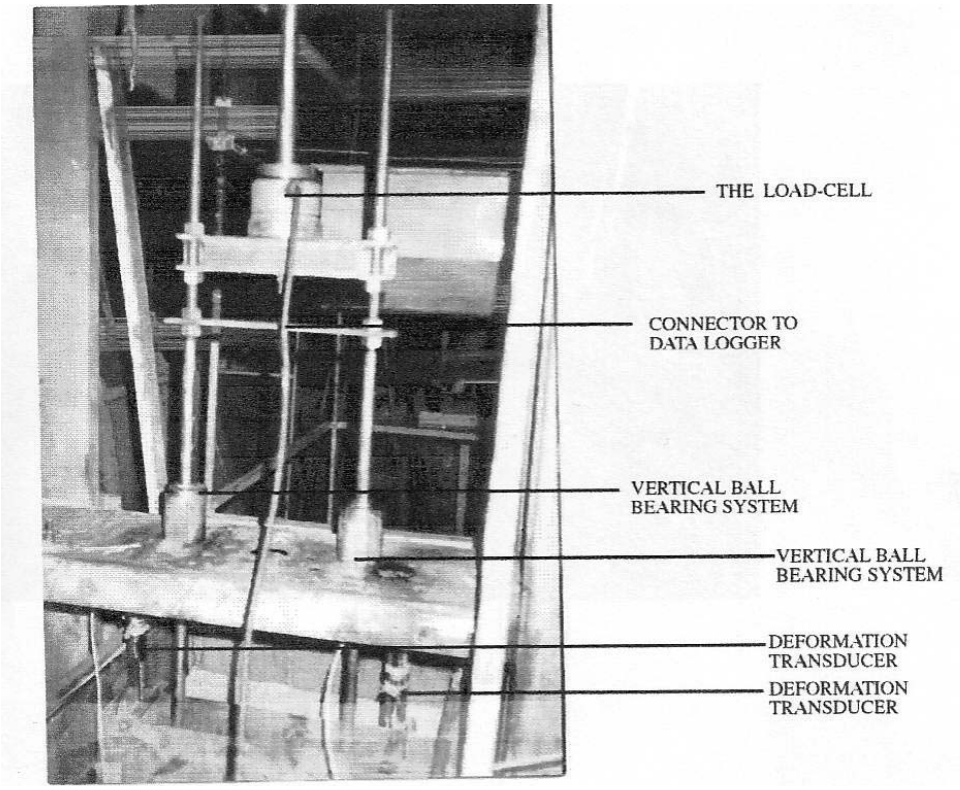

Fig. 2. Detailed of experimental setup

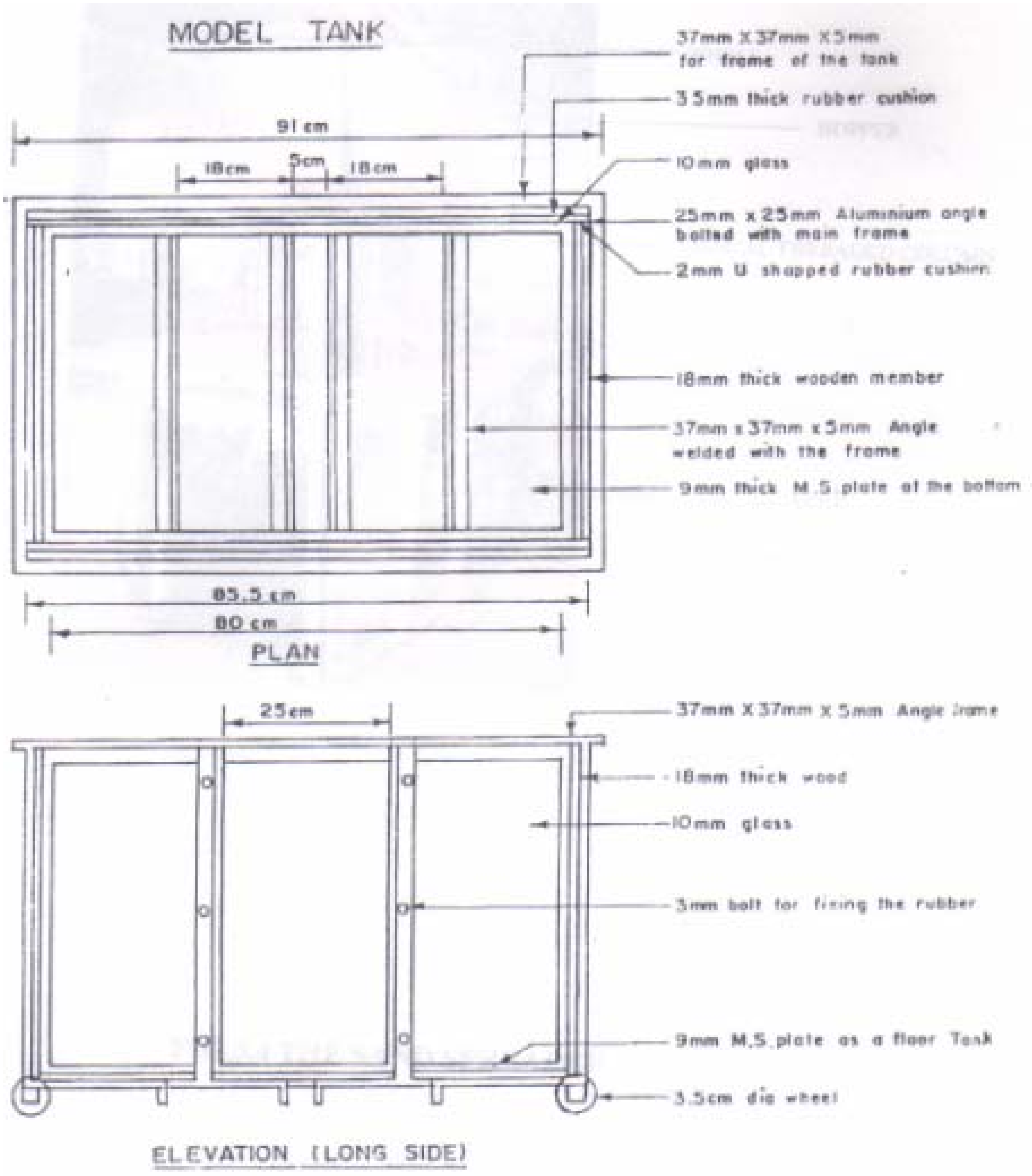

Fig. 3. Detailed skeleton of the tank

2.2 *The sand spreader*

A sand spreader, designed and constructed by Quadir (1990), was used to form a uniform sand bed in the tank shown in Fig. 2. The sand spreader has a movable steel hopper supported on four wheels. The horizontal forward and backward movements of the hopper are controlled by chain gear system. The hopper moves for a distance about 130cm on two horizontal rails which can be raised or lowered, over a distant of 80cm on four vertical threaded columns is used to rotate the steel roller. A 0.7mm sieve is placed on the top of the hopper in order to prevent undesirable particles from entering the hopper. The sand spreader is mobile and runs on wheels over 37mm×37mm× T-Section rails.

2.3 The sand leveling apparatus

After the sand spreading in the tank it was required to level of the sand bed in order to achieve the desired depth of the bed and perfect horizontal surface. The height of the leveler can be adjusted to desired depth.

2.4 The footing

A strip footing of dimension 100mm×508mm was used in the present investigation shown in Fig. 4. The model strip footing is made of a prefabricated mild steel channel. Welding M.S.plates of proper sizes covered the ends of the channel. Two V-shaped grooves are out on base plate to have proper seats for the knife edged loading blades.

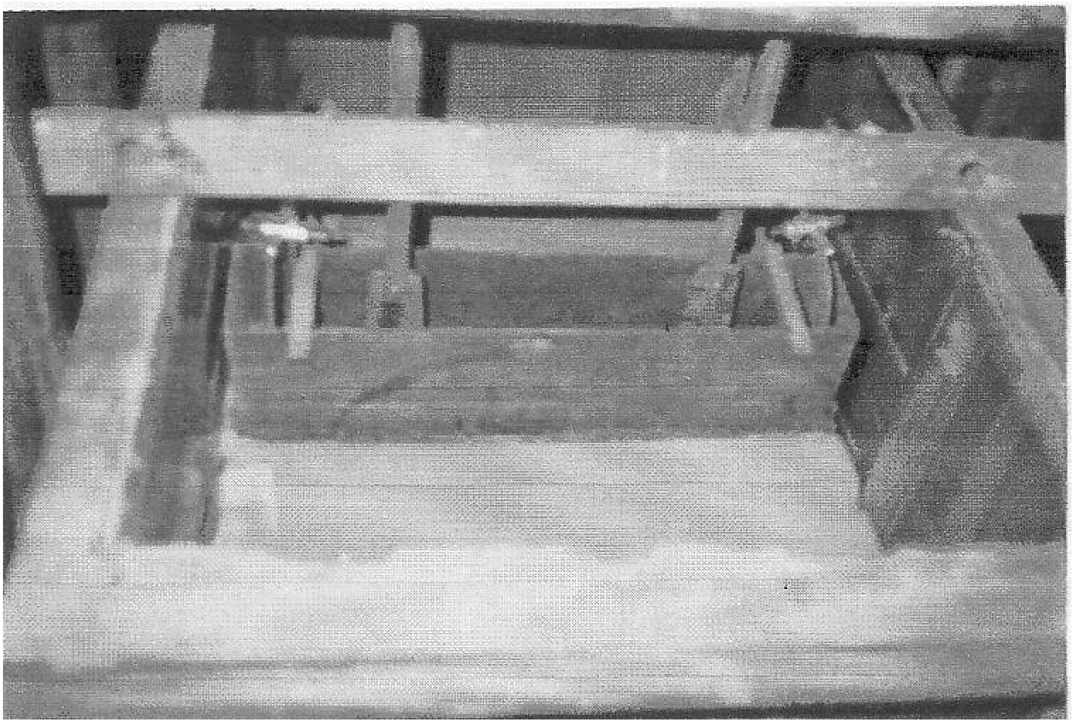

Fig. 4. The strip footing

2.5 The loading rig

A strain controlled loading rig was used in this investigation .The loading mechanism is mainly composed of a loading frame, a variable speed electrical motor, a speed control box, a gear box, a vertical threaded shaft, two loading bars, load cell, connector for data logger, two deformation transducers etc shown in Fig. 5.. The author has been modified the loading rig (2003) to suit the purpose of automated and accurate data recording.

2.6 The tank maneuver system

The loading frame and sand spreader are mounted on a wooden frame. The vertical threaded columns of the sand spreader are fixed with the floor. The two 2.82m long, 37mm×37mm, T-Section were used as a rail and fixed with the floor over which the tank can move smoothly to its desired position.

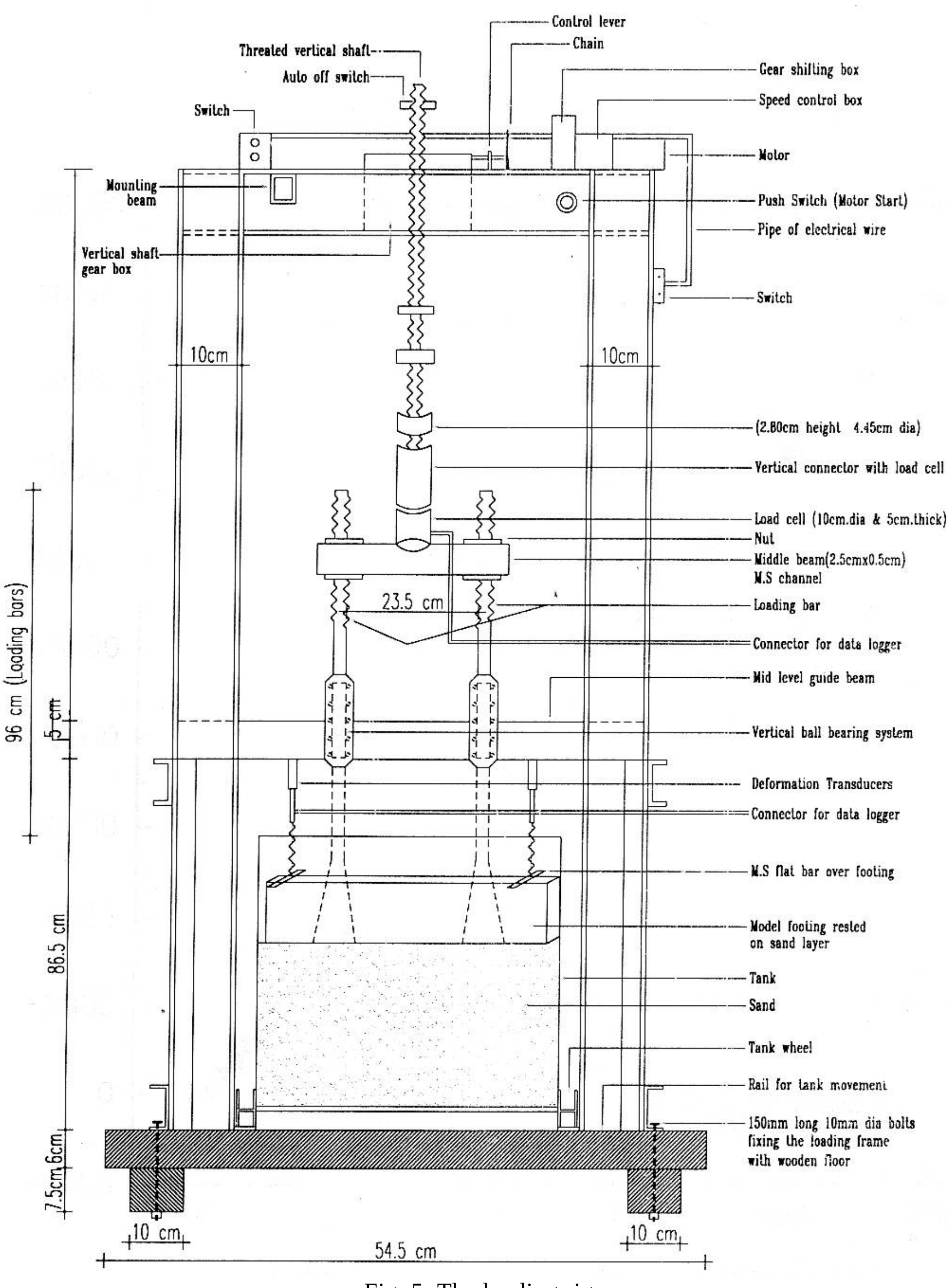

Fig. 5. The loading rig

2.7 *The load cell*

The Load Cell was used to transfer vertical load on the footing. The seating arrangement of the loading cell in the loading rig have been improved by Author (2003) which shown in Fig. 5.The diameter of the loading cell is 10cm and height is 5cm.It was placed at the mid portion of horizontal middle beam which was supported by two loading bar. A connector goes out from the side of load cell, which connects it to the data logger. The load cell connector was composed of four wires such as black, white, red, and blue. They were connected to four point of the Data logger. The red wire is connected to the (*), black to the (R), White to the (-), and blue to the (positive) point of the Data logger respectively. The capacity of load cell is 20 ton & calibrated in SM. Laboratory in (BUET) for several times. The calibration chart given in Fig. 6

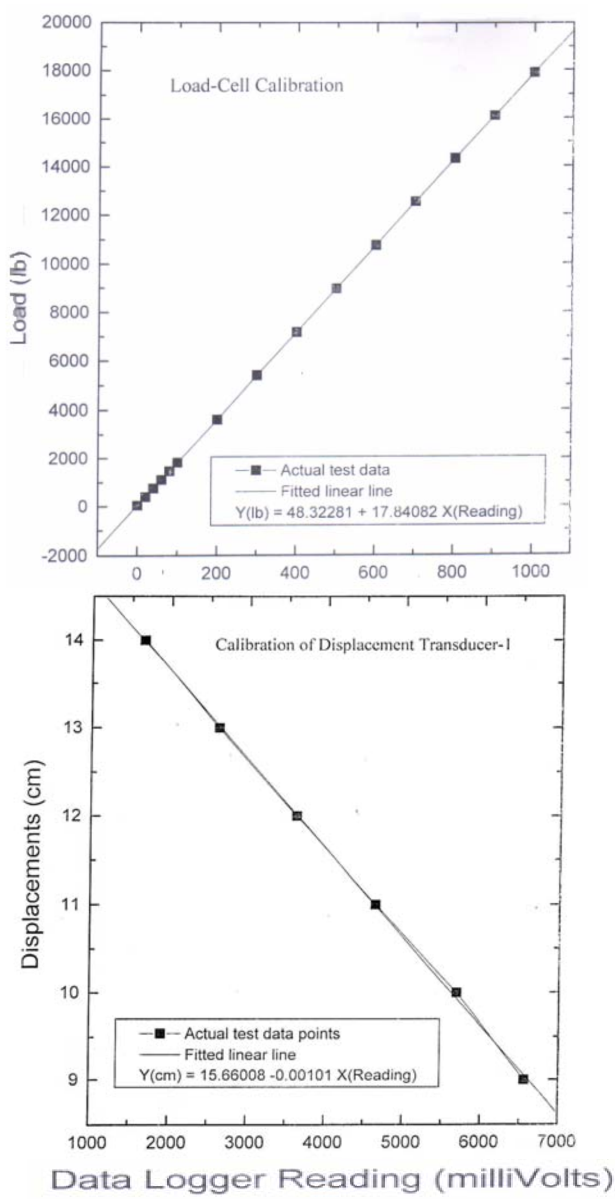

Fig. 6. The Load-Cell and deformation transducer calibration

2.8 The deformation transducer

The Deformation Transducer is a modern gauge which is used to measure the settlement of a strip footing with the help of data logger through recording analog voltage reading. With magnetic stand the two deformation transducers have been set over the two side of the footing. A connector goes out from the side of the transducer, which connects it to the data logger. The transducers connectors were composed of four wires such as red, green, blue and neutral. The red wire is connected to the (positive), green to the (-), blue to the (R) and neutral to the star (*) point of the data logger respectively. The Deformation Transducer is calibrated in S.M. Laboratory (BUET).

2.9 The data logger

The data logger is electronic equipment, which is used to record analog voltage reading from load cell and deformation transducer and pass it to computer digital data. The data logger composed of four connectors. The first and second connectors fill up the connections, which come from the two deformation transducers. The third connectors are connected to the load cell connector and fourth circuit was free from any connection. Beside these, there are another two connections, which were connected to the power and to the computer shown in Fig. 7.

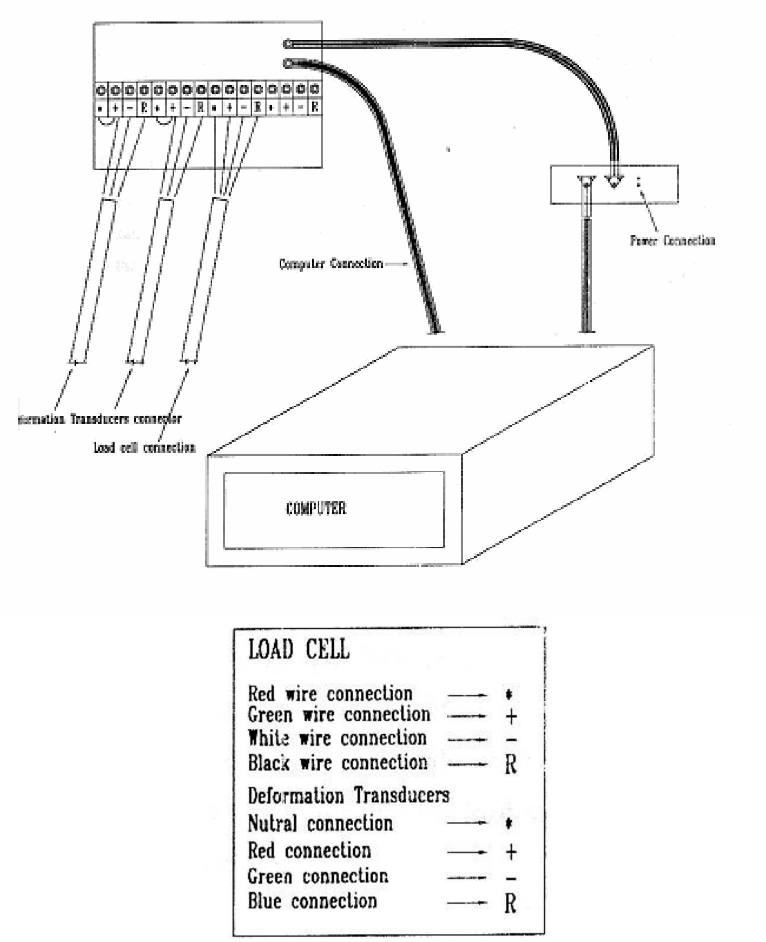

Fig. 7. The data logger

3. Test program

Tests were conducted using rough and rigid based strip footing on sand layers without and with different layers of metal strip reinforcements. Total twelve number bearing capacity tests were performed but due to experimental errors, four tests were discarded. Two of them were on unreinforced sand bed, two of one layer reinforced; two of two layers reinforced and the rest were on the three layers reinforced bed. The total bed depth was 39cm.Initially a base sand bed was formed into the tank using the sand spreader for preparation of reinforced sand bed. The reinforced metal strip has been placed on the single layer, two layers and three layers.

Table 1
Bearing Capacity test programmed (Surface footing)

Test No	Sand bed Unreinforced or Reinforced	Rate of Load	H/B	H1/B	H2/B	H3/B
T_{un}-1	Unreinforced	5.0	3.90	-	-	-
T_{R1}-2	One layer reinforced	5.0	3.90	0.50	-	-
T_{R2}-3	Two layer reinforced	5.0	3.90	0.50	0.50	-
T_{R3}-4	Three layer reinforced	5.0	3.90	0.50	0.50	0.50
T_{un}-5	Unreinforced	25.0	3.90	-	-	-
T_{R1}-6	One layer reinforced	25.0	3.90	0.50	0.50	-
T_{R2}-7	Two layer reinforced	25.0	3.90	0.50	0.50	-
T_{R3}-8	Three layer reinforced	25.0	3.90	0.50	0.50	0.50

Table 2
Height of fall and Density

Test No.	Height of fall (mm)	Dry Density KN/m^3	Average density KN/m^3
T_{un}-1	825	14.57	15.78
	900	14.79	
	940	14.83	
	010	14.97	
T_{R1}-2	830	14.69	15.00
	895	14.82	
	945	15.51	
T_{R2}-3	830	15.05	15.30
	895	15.22	
	969	15.62	
T_{R3}-4	825	14.05	15.16
	890	14.88	
	955	15.52	
	1008	15.69	
T_{un}-5	830	14.27	14.67
	895	14.60	
	960	14.84	
	1012	14.97	
T_{R1}-6	828	14.77	15.06
	895	14.8	
	950	14.27	
	1010	15.42	
T_{R2}-7	840	14.67	14.99
	910	14.72	
	960	15.24	
	1015	15.32	
T_{R3}-8	880	14.60	15.00
	895	14.89	
	930	15.21	
	050	15.30	

Finally a top sand layer has been placed on it. Throughout the entire test programme the thickness of sand layer was kept constant. The first layer of metal strip was 5cm, 2nd layer was 10cm, and 3rd layer was 15cm below the top surface of the sand layer. The lengths of metal strip reinforcement were 5 feet, which placed laterally below the strip footing. Every layers of metal strip reinforcement consist of six numbers of metal strips, which were placed, with center-to-center distance of 10.6cm. The parameters studied are listed in Table 1.

The result of Fineness Modulus is 1.17, grain sizes d_{10}, d_{30}, and d_{60} are 0.15, 0.19, 0.26, uniformity coefficient is 1.73, coefficient of curvature is 0.93 and specific gravity is 2.61.

There are four cylindrical density pots were placed in the tank sand bed at different depths and places. After complete the bearing capacity test of the footing the tank remove to its position for cleaning and carefully collect the pots with sample and find out the density and average density.

3.1 Properties of metal strip reinforcement

The strength properties of metal strip reinforcement were determined in the S.M.Laboratory (BUET). The cross sectional area of the metal strip reinforcement is 16mm^2.and breaking strength is 341.18mm^2.

3.2 Calibration

The machine and apparatus used in this investigation such as Motor speed, load cell and the deformation transducers have been calibrated, the calibration curves are shown in Fig. 6.

3.3 Bearing capacity test procedure

The respective tank was brought under the sand spreader and the sand spreader was placed in position, which covered the whole tank area. For find out the effect of metal strip reinforcement of bearing capacity with a particular sand type, the sand bed was formed up to a desired depth and the metal strip laid in single layer, double layers, triple layers in different stage of height. Then the surface model footing was placed in proper position. The tank was pushed very slowly to move toward the loading rig after the sand bed prepared. Two deformation transducers were placed on the footing for measuring settlement of footing during loading. When load applied on the footing, the load cell data and the deformation transducer data were automatically recorded as analog voltage reading through data logger and pass it to computer as digital data. This was continued until a decrease or a small rate of increase in its reading.

4. Experimental result

The experiment was performed in two different speeds of loadings such as 0.007cm/sec and 0.015cm/sec. The observed settlement against applied load on the footing is presented in Fig.8. Four experiments were carried out in high speed. It has been observed from Table 3.1that bearing capacity from un- reinforced condition with high speed of loading increases than that of the slow speed rate of loading. In other three tests bearing capacity from the slow speed rate of loading were of higher value than higher speed of loadings. Again it has been observed from Table 3.2 that the settlement of the strip footing is higher in high speed of applied load than lower speed of loading condition.

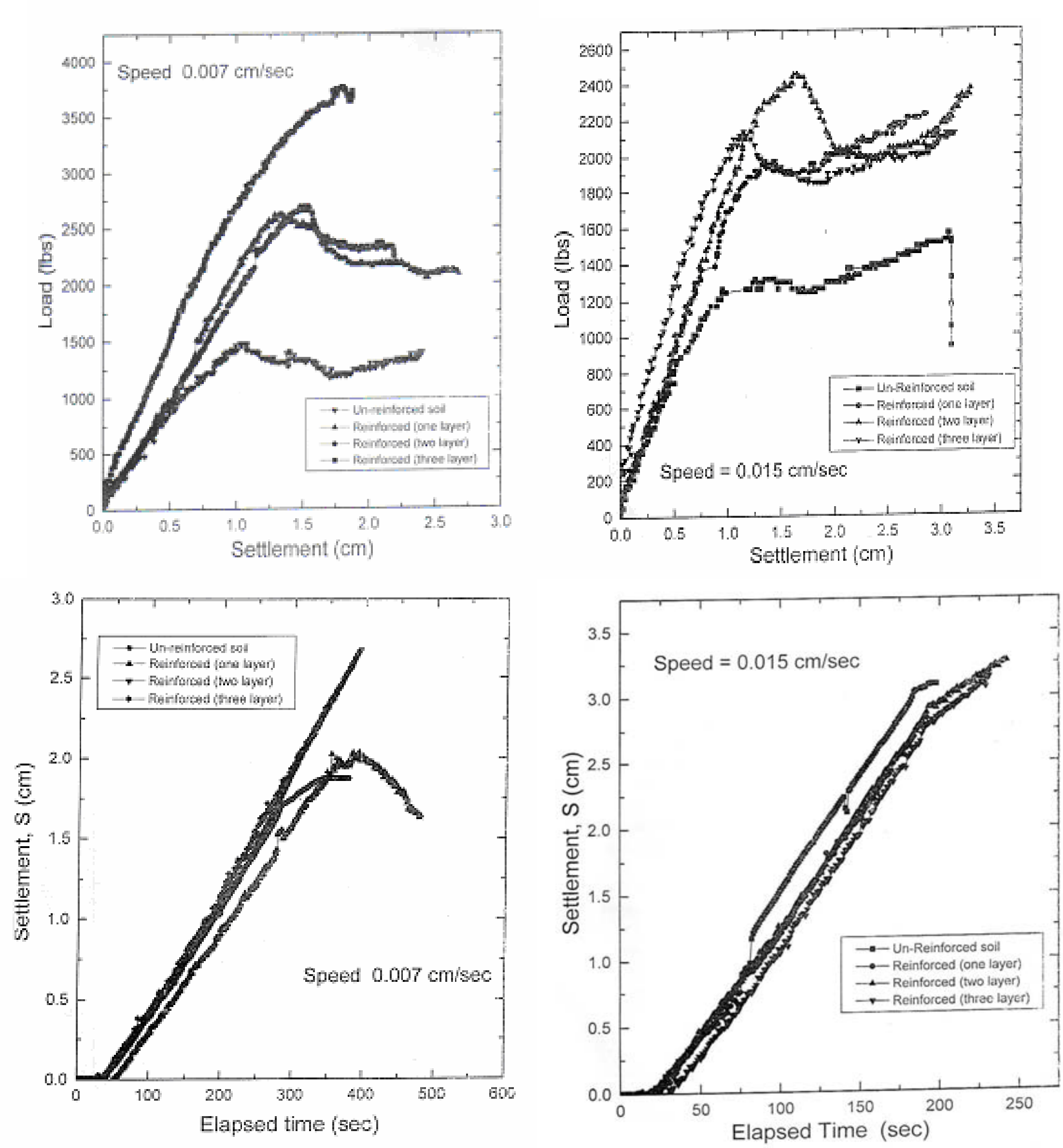

Fig. 8.Experimental results

Table 3.1
Peak load

Reinforced layer	Speed 0.007cm/sec	Speed 0.015cm/sec
Unreinforced	1500Ibs	1550Ibs
Reinforced (one layer)	2650Ibs	22500Ibs
Reinforced two layers)	2700Ibs	2450Ibs
Reinforced (three layers)	3800Ibs	2150Ibs

4.1 Effect of number of reinforced layer

In this investigation, eight experiments have been successfully done. The bearing capacity Ratio (BCR) of the reinforced and un reinforced layer in the present study are shown in Table 3.3 The BCR ratios of the slow speed were 1.77 for one layer, 1.8for two layers but 2.53 for three layers. During the experiment of the three layers configuration, the density pots were kept below the footing. The ratios of the 2nd speed were 1.45 for one layer, 1.58 for two layers and 1.39 for three layers. The last ratio is lower than the 1st two ratios. The minimum BCR ratios of the two speeds was 1.39 and maximum ratio was 2.53.

Table 3.2
Settlement at Peak load

Reinforced layer	Speed 0.007cm/sec	Speed 0.015cm/sec
Unreinforced	2.43cm	3.15cm
Reinforced (one layer)	2.65	2.88cm
Reinforced (two layers)	2.20	3.30cm
Reinforced (three layer)	1.55	3.13cm

Table 3.3
Bearing Capacity Ratio (BCR) of reinforced and unreinforced

Reinforced layer	Speed 0.007cm/sec	Speed 0.015cm/sec
Unreinforced	1.77	1.45
Reinforced (one layer)	1.80	1.58
Reinforced (two layers)	2.53	1.39

5. Conclusions

The present investigation was aimed at the development of an experimental set up and to study the behavior of a centrally loaded strip footing resting on a sand bed reinforced with a one layer, two layers and three layers of metal strip. On the basis of experimental observation the following conclusion can be summarized as follows:

(1) The existing loading arrangement was remodeled. A newly devised electronic load cell and a couple electronic deformation transducers augmented the loading frame.
(2) To automate and record accurate readings to computer as digital data, a data logger logs all data.
(3) In the present research, using new equipment set up, 8 successful laboratory scale bearing capacity model tests were carried out using strip footing resting on a sand bed reinforced with single, double and triple layers of metal strips.
(4) The ultimate bearing capacities of the footing on sand bed reinforced can be improved by a factor of about 1.39 to 2.53 times the bearing capacity of an unreinforced soil for otherwise identical conditions.
(5) From the experiment data it is observed that the bearing capacity of strip footing was affected by the speed of loading. It is found that slow speed of loading gives higher value of bearing capacity than that of higher speed of loading.
(6) In most cases the settlement at ultimate bearing pressure of unreignforced soil were greater than that of reinforced soil and gives high magnitude in higher speed of loading than lower speed of loading.

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