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Failure and Settlement Behaviour of Square Footing on Sand Reinforced with Coir Geotextile Grid

Sushmita Roy[1],
1Post Graduate Student,
Civil Engg Dept. National Institute of Technology,
Agartala, Tripura, India,

Dr. Sujit Kumar Pal[2]
[2]Assoc. Prof.,
Civil Engg. Dept.,
National Institute of Technology,
Agartala, Tripura, India,

Abstract - **Reinforcing soil with the use of natural fibre in civil engineering for improving soil properties is advantageous because they are cheap, locally available, biodegradable and eco-friendly and verified as an alternative to the conventional ground improvement technique under appropriate condition. The natural fibre causes significant improvement in engineering properties of soil like shear strength, bearing capacity and so on. Efforts have been made in this study to investigate the behavior of footings on sand in reinforced and unreinforced condition. Experiments have been carried out by conducting load tests in a model tank. Coir geotextile is chosen for the project as it is reported to be the strongest and most durable material. Coir is a cheap and easily available material. The effect of different parameters like the number of layers of reinforcement, depth of reinforcement, width of footing has been studied. It has been seen from the experimental study that bearing capacity of reinforced sand increases significantly with the inclusion of geotextile for square footing of different sizes. A comparison of the results with those reported in the literature will be carried out.**

Keywords:Bearing pressure, coir, geotextile, model test, reinforcement, sand, settlement

1. INTRODUCTION

To improve the mechanical properties of soils, a variety of materials are used for reinforcement e.g. metallic elements, geotextilesand others. Majority of geotextiles used in civil engineering application are geotextiles are gaining popularity. The inclusion of randomly distributed geotextile increases strength parameters of the soil as in case of reinforced concrete construction and this process is verified as an alternative to the conventional ground improvement technique under appropriate condition.Over the past decades the beneficial use of reinforcement materials to increase the bearing capacity of footing has been clearly established by the various researchers and it has been proven to be cost effective foundation system. The main aim of the project is to study the failure and settlement behavior of square footing resting on geotextile reinforced sand bed. The relation between load and settlement are brought through laboratory model tests.

Several studies have reported the successful use of sand reinforcement as a cost effective method to increase the strength, ultimate bearing capacity and to decrease the settlement values under square and rectangular footings. Adams and Collin (1997) investigated the potential benefits of geosynthetic reinforced soil foundations using large scale of model tests. Kumar and Saran (2003) presented a paper for calculating the pressure of an adjacent rectangular footing resting on sand for a given settlement.Kumar et.al (2004) proposed a method to obtain the pressure settlement characteristics of rectangular footing resting on reinforced sand based on constitutive laws of soil.Rao et al. (2005) illustrated the Strength Characteristics of Sand Reinforced with coir fibres and Coir Geotextiles. Saran et al. (2007) proposed an attempt to obtain the pressure intensity of strip footing on reinforced soil, for a known settlement(S) and pressure intensity (q_0) of the same footing resting on unreinforced sand. Maity et al. (2012) presented a paper on behaviour of different types of sand randomly mixing with various natural fibers. Mondal et al. (2013) proposed a FEM based analysis on effect of u/b ratio on bearing capacity of square footing on reinforced sand.

2. MATERIALS

Various experimental works such as physical properties and engineering properties carried out on sand and geotextile. Laboratory plate load test have been carried out in order to find out bearing capacity of unreinforced and reinforced sand using coir geotextile. A detailed description of test performed is illustrated.

SAND

The investigation carried out on locally available Howrah river sand.

GEOTEXTILE

Coir has been chosen for the project as it offers 100% natural fibre, extracted from coconut husk, adds organic material to soil , high tear-strength resistance and easy to install/ maintain/ patch-up.

FOOTINGS

Square and rectangular footings are chosen as it is easy to construct with square and rectangular framework and the construction work becomes economic.

Square footings which are used in this work are made of mild steel plate of sizes 150 mm × 150 mm,120 mm × 120 mm and 100 mm × 100 mm.

3. EXPERIMENTAL SET UP

Test on model square footing have been conducted by placing the square footing on reinforced sand bed. The test has been carried out in Hydraulics and structural Engineering Laboratory of Civil Engineering Department, NIT Agartala, Tripura, India. The size of steel tank is 300 mm x 300 mm. The test bed prepared in 3 layers at relative density of 70%. The test has been conducted on three layers of sand maintaining equal depth for each of the layers. The test has been done under the computer operated universal testing machine. Vertical load is applied through a screw gear mechanism by a movable cross head jaw. When load is applied the specimen gets compressed and the load and displacement value shows on screen in a tabular form. From the results the load displacement curve has been drawn. The test has been conducted in two phase, i.e., Phase -I: bearing capacity test of unreinforced sand samples, and Phase – II: bearing capacity tests of reinforced sand with varying number of geotextile layers. The geotextile has been laid as a grid pattern. The grid size of the geotextile has been kept square of each geo- grid cell size of 20mm x 20 mm shown in Fig. 3.1 In case of single layered geotextile reinforced sand bed the geotextile has been placed at 1/3 depth from top of the surface of the fill and for double layered geotextile reinforced sand bed the geotextile has been placed at 1/3 depth and 2/3 depth from top of the surface of the fill.

Fig. 1. Geotextile reinforcement as grid pattern of 20 mm × 20 mm

4. RESULTS AND DISCUSSIONS

4.1 Experimental Results

The test results on sand are presented here. The specific gravity, sieve analysis, shear parameters, relative density and laboratory plate load test of square footing on sand bed are tabulated below.

From the test conducted on the laboratory we get the values of load with respect to settlement of 8mm for three different sizes of square plate i.e., (150 mm × 150 mm), (120 mm × 120 mm) and (100 mm × 100 mm). The test has been carried out on sand bed with and without geotextile. The values are tabulated in Table 1 and 2. From the test results graph has been plotted between load and settlement for both reinforced and unreinforced condition. Figs.2 to 4 shows the typical load- settlement curve for unreinforced and reinforced sand bed for three different sizes (150 mm × 150 mm), (120 mm × 120 mm) and (100 mm × 100 mm) of footing. From the test results we can evaluate the values of bearing capacity of the square footing. Bearing capacity of the square footing increases with the addition of geotextile as reinforcement than that of unreinforced condition. During unreinforced condition maximum load for three different sizes of footing has been found out as 2.30 kN, 1.85 kN and 0.80 kN respectively. For single layered reinforced sand bed load increased to 3.50 kN, 2.85 kN and 1.50 kN respectively and for double layered reinforced sand bed it has been increased to 6.05 kN, 4.9 5kN and 2.35 kN respectively. From the results it can be say that with the addition of geotextiles, the load bearing capacityof the sand bed has been increased. The effects of different parameters are highlighted inthe discussions

Table 1 Physical and Engineering properties of sand

PROPERTIES	TEST RESULTS
Specific gravity	2.67
Effective size, D_{10} (mm)	0.10
D_{30} (mm)	0.19
D_{60} (mm)	0.20
Uniformity coefficient	2.00
Coefficient of curvature	1.805
Maximum dry unit weight (kN/m^3)	15.79
Minimum dry unit weight (kN/m^3)	13.15
PROPERTIES	**RESULTS**
Relative density of sand (%)	70
Dry unit weight of sand in experiment (kN/m^3)	14.89
Cohesion (kN/m^2)	0
Angle of internal friction (degree)	40

Table 2 Physical properties of coir geotextiles (Jairajet al. 2013)

PROPERTIES	RESULTS
Colour	Brown
Specific gravity	1.39
Geo grid cell size (mm)	20 × 20
Tensile strength(kN/m)	12.8
Thickness (mm)	0.2 to 0.6

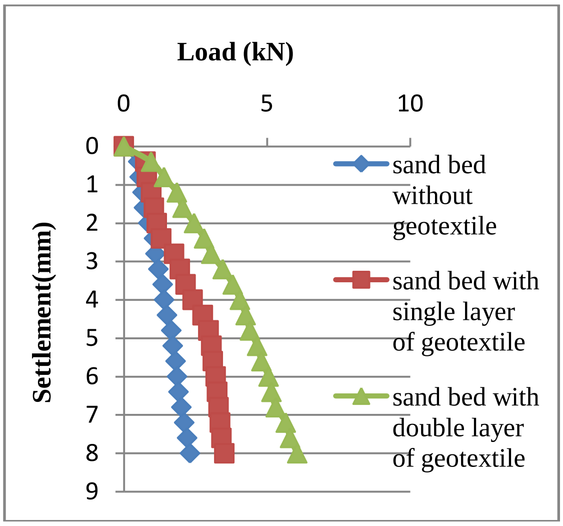

Fig. 2. Load vs. Settlement curves for square footing of 150 mm × 150 mm on unreinforced and reinforced sand bed

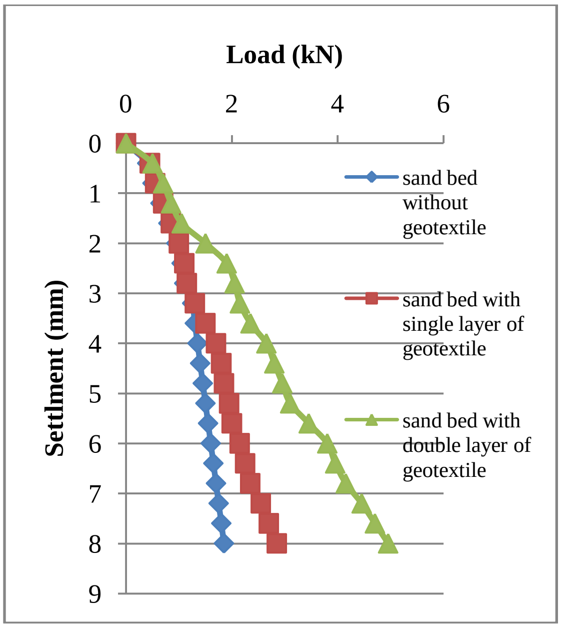

Fig. 3. Load vs. Settlement curves for square footing of 120 mm × 120 mm on unreinforced and reinforced sand bed

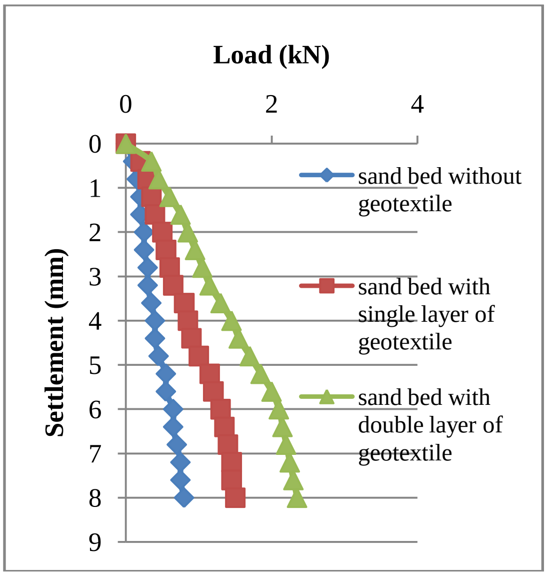

Fig. 4. Load vs. Settlement curves for square footing of 100 mm × 100 mm on unreinforced and reinforced sand bed

4.2 Discussions

Effects of S/B ratio on bearing capacity of square footing on unreinforced and reinforced sand with coir geotextiles, effects of number of layers of reinforcement on bearing capacity at different S/B ratio of square footing on sand bed, and effects of width of footing on bearing capacity ratio (BCR) discussed in detail.

4.2.1 Effects of S/B Ratio on Bearing Capacity of Square Footing placed on Sand in case of Unreinforced and Reinforced with Coir Geotextiles

Figs.5 to 7 shows the effect of settlement to width (S/B) ratio on bearing capacity forthree different sizes of footings. The settlement varies with the addition of reinforcement in sand bed. The settlement to width (S/B) ratio is found out for three different sizes of footing. From the test results on footing of different sizes it has been found that load intensity increases during reinforced condition than that of unreinforced condition. For 150 mm × 150 mm size of square footing, the load intensity increases in case of single layer reinforced sand bed which is about 1.52 times the load intensity found in unreinforced sand bed and for double layered geotextile reinforced sand bed the improvement of load intensity is about 2.63 times the load intensity than the unreinforced sand bed. In case of 120 mm × 120 mm square footing the improvement of bearing capacity for single layer of geotextile is 1.54 times and for double layer reinforced sand bed 2.67 times. Similarly for 100 mm × 100 mm square footing the addition of bearing capacity for single layer of geotextile is 1.87 times and for double layer reinforced sand bed is 2.93 times. The increase in bearing capacity with the addition of geotextile is due to the fact that reinforcing elements interact with the soil particles mechanically through surface tension and by interlocking. The function of the interlock or bond is to transfer the load from soil to the reinforcing element by mobilizing the tensile strength of reinforcing elements which results into the improvement in bearing capacity. Similar trend has been observed by the earlier researchers. Sridhar et al. (2011) reported that reinforced soil medium gives more bearing capacity than the unreinforced soil bed for square footing and concluded that as reinforcement layer increases the bearing capacity of the soil medium also increases.

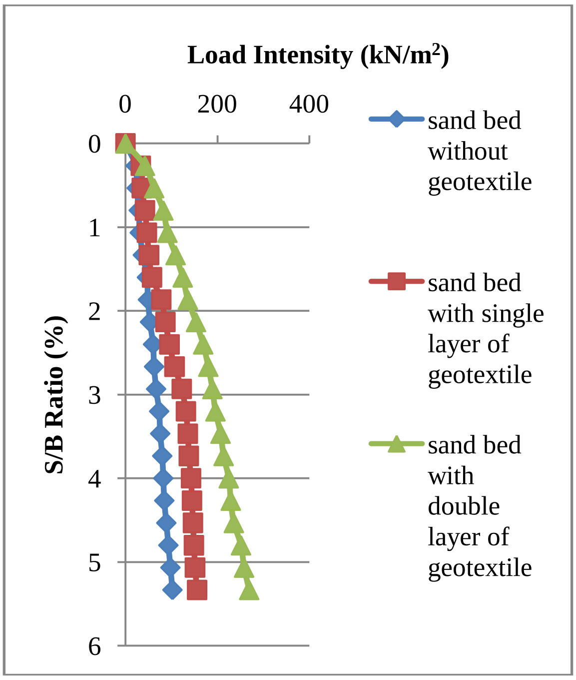

Fig. 5. Load intensity vs. S/B ratio curves for square footing of 150 mm × 150 mm on unreinforced and reinforced sand bed

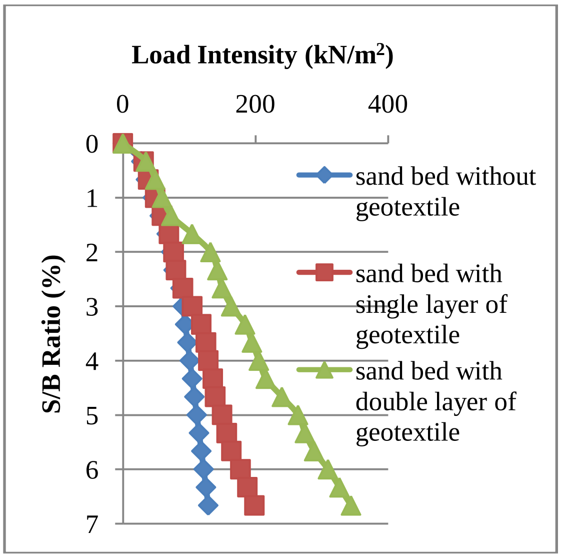

Fig. 6. Load intensity vs. S/B ratio curves for square footing of 120 mm × 120 mm on unreinforced and reinforced sand bed

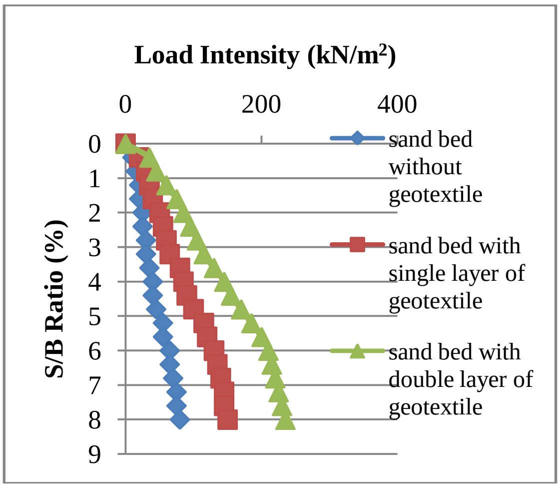

Fig.7. Load intensity vs. S/B ratio curves for square footing of 100 mm × 100 mm on unreinforced and reinforced sand bed

4.2.2 Effects of Number of Layers of Reinforcement on Bearing Capacity at Different S/B Ratio of square Footing on Sand Bed

Number of layers of reinforcement plays a vital role in finding out bearing capacity. Figs.8 to 10 show the typical plot of bearing capacity (q_{rs}) of square footing at different S/B ratio versus number of layer of reinforcement. Form the figures, it reveal that increase in the layer of reinforcement the bearing capacity increases. The load carrying capacity increases as the number of layers increases and this is due to the higher stiffness and confinement for the reinforced region beneath the foundation. For S/B ratio upto 3.2%, bearing capacity remains almost constant but from S/B ratio of 4.0%, the bearing capacity changes rapidly. Adams and Collin (1977) observed similar trend and reported the effect of number of layers of reinforcement for different sizes of square footing. At S/B ratio of 4.8%, the bearing capacity reaches maximum. It has been concluded that for lower settlement, the ratio of increase of bearing capacity with increase in number of layers, remain almost constant.

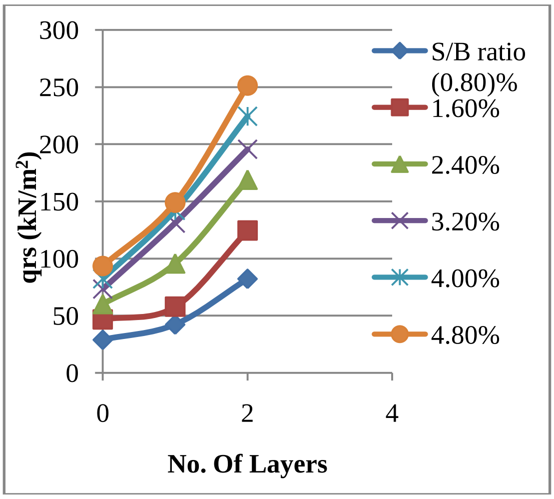

Fig.8. Bearing capacity vs. number of geotextile layer curves at different S/B ratio (in %) for square footing of 150 mm × 150 mm on sand bed reinforced with coir geotextiles

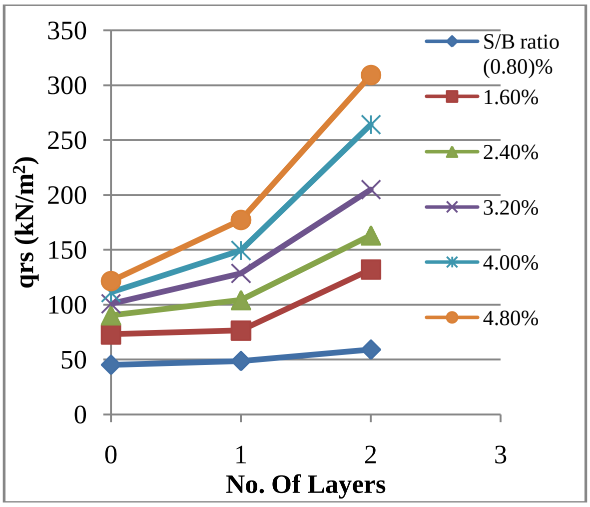

Fig. 9. Bearing capacity vs. number of geotextile layer curves at different S/B ratio (in %) for square footing of 100 mm × 100 mm on sand bed reinforced with coir geotextiles

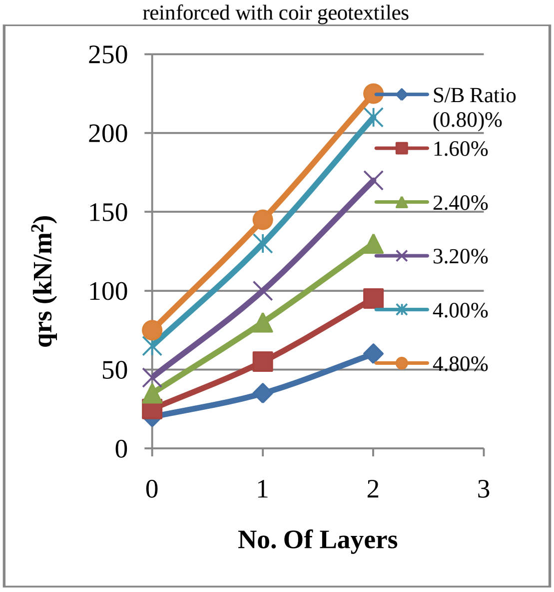

Fig. 10. Bearing capacity vs. number of geotextile layer curves at different S/B ratio (in %) for square footing of 100 mm × 100 mm on sand bed reinforced with coir geotextiles

4.2.3 Effect of width of footing on Bearing Capacity Ratio (BCR)

Bearing capacity ratio (BCR) defined as the ratio of bearing capacity of reinforced sand bed and unreinforced sand bed.

$$BCR = \frac{\text{Bearing Capacity of Reinforced sand bed}}{\text{Bearing Capacity of Unreinforced sand bed}}$$

From the results of the bearing capacity for different sizes of footing i.e., for 100 mm × 100 mm, 120 mm ×120 mm, and 150 mm × 150 mm, it has been revealed that as the width of footing increases the bearing capacity ratio decreases both for single layer and double layer geotextile reinforced sand bed. The plot of BCR versus the size of footing for single layer and double layer sand bed has been shown in Fig.11. For single layer geotextile reinforced sand bed, BCR for square footing of sizes 100 mm × 100 mm, 120 mm × 120 mm and 150 mm × 150 mm are 1.87,1.54 and 0.76 respectively. Similarly for double layer geotextile reinforced sand bed, the corresponding values are 2.94, 2.67 and 2.63 respectively. It has been concluded that the bearing capacity ratio decreases with the increase in width of footing.

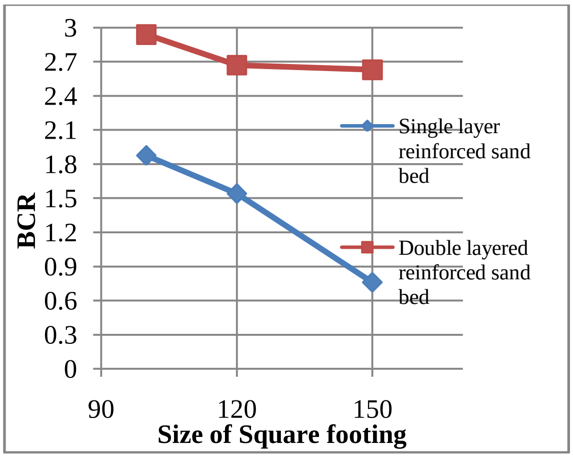

Fig. 11. BCR vs. size of square footing for single layer and double layer geotextile reinforced sand bed

5. SUMMARY AND CONCLUSION

5.1 SUMMARY

In many places the foundation beneath becomes an integral part of construction especially in swampy areas. Hence the role of geotextiles serves as a boon to the present day geotechnical consideration and environmental factors. The availability and low cost of coir fibre makes it an eco-friendly material which suits geotechnical applications. The present work aims to explore the potentiality of coir geotextiles for the construction of footing on sand reinforced with coir fibre over soil stratum by studying its various engineering properties including the variation of bearing capacity from reinforced to unreinforced sand bed. The effects of geotextile layer, number of layers of geotextile, the effect of width of footing on bearing capacity have been highlighted.

5.2 CONCLUSION

Depending upon the test results and detailed discussions, following conclusions have been made in the following:

1. Bearing capacity of square footing increases as settlement to width (S/B) ratio increases, in case of coir geotextiles reinforced sand bed.
2. With the increase in no. of layers of coir geotextile placed in sand bed bearing capacity increases.
3. As the width of footing increases from 100 mm to 150 mm the bearing capacity ratio decreases for both single layer and double layer of coir geotextile grid reinforcement.

REFERENCES

1. Kumar A, Walia BS, Saran S (2005), "Pressure settlement characteristics of rectangular footings on reinforced sand", JL of GeotechGeolEng, Springer Science and Business Media, Vol. 23, pp.469-481.
2. Kumar A, Walia BS (2006), "Bearing capacity of square footings on reinforced layered soil", JL of GeotechGeolEng, Springer Science and Business Media, Vol.24, pp.1001-1008.
3. Kumar A, Saran S (2004), "Closely spaced rectangular footings on reinforced sand", JL of GeotechGeolEng, Springer Science and Business Media, Vol.22,pp.497-524.
4. Maity J, Chattopadhyay BC, Mukherjee SP (2012),"Behaviour of different types of sand randomly mixing with various natural fibers", JL of Inst. Eng. India Ser.A , Vol.93(2),pp.97-104
5. Balamaheswari M, Hamparuthi k (2011), "Performance of footing on reinforced soil bed", proceedings of Indian Geotechnical conference. Paper no D-089.
6. Adili A A, Azzam R, Spagnoli G, Schrader J, (2012), "Strength of soil reinforced with fiber materials (PAPYRUS) ", Soil Mechanics and Foundation Engineering VOL-48 No-6
7. Saran S, Kumar S, Garg K G , Kumar A(2007), "Analysis of square and rectangular footings subjected to eccentric inclined load resting on reinforced sand", Jl of GeotechGeol Eng. VOL-25, PP No-123-137.
8. Kaur A, Kumar A (2014), "Bearing Capacity of eccentrically-obliquely loaded footings resting on fiber reinforced sand", Jl of GeotechGeol Eng. VOL-32, PP No-151-166.

BIOGRAPHIES:

Sushmita Roy presently is a Post Graduate student in Civil Engg. Department, NIT Agartala, Tripura, INDIA. Completed B.Tech (Civil Engg. Department) from NIT Agartala, India in 2013. Her present project work is based on behavior of square and rectangular footings on sand reinforced with coir geotextiles.

Dr. Sujit Kumar Pal is presently working as Associate Professor in Civil Engg., NIT, Agartala, Tripura, INDIA. Completed BE (Civil Engg.) from REC, Surathkal, Karnataka, INDIA (Presently, NIT, Surathkal) in 1986 and M. Tech (Soil Mech. & Foundation Engg.) from IIT, Khragpur, West Bengal, INDIA in January, 1994. He has completed his Ph.D (Engg.) from Bengal Engineering and Science University, Shibpur, West Bengal, INDIA (Presently, Indian Institute of Engineering Science and Technology, Shibpur) in January, 2010. He has a wide range of publications in national and international Journals and conferences like, ASCE, SPRINGER, EJGE, IGC etc. His present research areas are soil characterization, soil dynamics, ground improvement, shallow and deep foundations and soil-structure interaction.