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Load – Settlement Characteristics of Reinforced and Unreinforced Foundation Soil

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Abstract: **In this paper, an effort has been made to study the improvement in load carrying capacity, settlement behavior and shear failure mechanism of a square and circular footing on a reinforced granular bed overlying weak soil. The effects of different shapes of isolated footing, the number of reinforcement layers and length of reinforcement are being studied. The foundation soil bed consists of horizontally laid reinforcements in 1, 2, 3, or 4 layers. From these studies it has been observed that 4-layers of geotextile of size 40cms x 40cms under circular footing shows better results when compared with square footing. In general, the inclusion of reinforcement in soil improved its bearing capacity by altering the type of failure. In foundation soil, the failure changed from local to general shear failure.**

Keywords: **Geotextile, square and circular footing, sand, soil, settlement, reinforcement.**

I. INTRODUCTION

The scarcity of suitable land for construction, has forced civil engineers to improve sites containing weak soil to make it fit for the safe and stable construction of buildings. There are different methods which help in improving the granular soil such as vibro-flotation, compaction pile, earth reinforcement, grouting, compaction with explosives etc. The availability of materials required and methods adopted for improving the soils also affect the cost of construction. Nowadays, geosynthetics are being used extensively as reinforcement in soils. In nature, the roots of the trees and plants are the best examples of earth reinforcement which hold the earth . The use of geosynthetics to improve the bearing capacity and settlement performance of shallow foundation has gained a lot of attention in the field of geotechnical engineering.

Several studies have demonstrated the improvement of bearing capacity and the settlement characteristics of foundation soil by the usage of geosynthetics . Binquet et al. (1975) [1] conducted a research on bearing capacity of reinforced earth slabs, Milligan et al. (1986) [2] conducted studies on model and full-Scale tests on granular soil reinforced with Geogrid, Ashmawy et al. (1995) [3] studied the geosynthetic reinforced soils under repeated loading along with comparative design, Perkins et al. (1997) [4] studied the synthesis and evaluation of geosynthetic-reinforced base layers in flexible pavements , Som et al. (1999) [5] conducted a model study in bearing capacity of a geotextile-reinforced unpaved road as a function of deformation, Marei (2007) [6] studied the response of different footing shapes resting on reinforced sandy soil underlain by weak soil, Naeini et al. (2008) [7] studied the effect of geotextile and grading on the bearing ratio of granular soils, Mosallanezhad et al. (2010) [8] conducted a three dimensional bearing capacity analysis of granular soils, reinforced with innovative grid-anchor system, and Kalpana et al. (2011) [9] studied the application and modeling of fiber reinforced soil.

Most of the researchers have demonstrated that improvements in settlement shear deformation characteristic and ultimate bearing capacity can be achieved by using soil reinforcement such as fiber and geosynthetic materials. They also demonstrated that the response of shallow foundation on reinforced soil depends not only on type of reinforcements but also on the shape of footings and length of reinforcements adopted.

In this paper, a comparative study is made through experiments that are being carried out in the laboratory to study the response of foundation on reinforced soil like settlements, load bearing capacity, by using two different shapes of isolated footing (square and circular footing), two types of soil (river sand and silty clay soil), and reinforcement of two different lengths (geotextile of size 80cm x 80cm and 40cmx 40cm).

II. Experimental Programme

A. *Properties of Material used*

In this study, biaxial geotextile which is made up of polyethyelene (polymer material) having a thickness of 0.56mm, is used as soil reinforcement. River sand and silty clay soil which is abundantly available in the Dakshina Kannada (D.K) are used as foundation granular bed. The engineering properties of geotextile, sand and soil are given in Table 1 and Table 2 respectively.

TABLE I. Properties Of Geotextile

Property	Values
Mass per unit area (gm/m^2)	200.00
Breaking strength-(5cm x 20cm)	257
Thickness(mm)	0.56
Style (Quality no.)	P.D. 381
Colour	Yellowish-white
Polymer	Polyethyelene

TABLE II. Properties Of Sand and Soil

Property	Values	
	Sand	Soil
Specific Gravity,(G_s)	*2.73*	*2.40*
Density for Loose Sand,(γ_{dmin}) (kg/m^3)	*13.6*	*N/A*
Max. Density, (γdmax) (kN/m^3)	*17.8*	*16.0*
Coefficient of Uniformity (C_u)	*1.72*	*N/A*
Coefficient of Curvature (C_c)	*0.98*	*N/A*
Angle of Internal Friction for Loose sand (Φ),	*31.0*	*N/A*
Angle of Internal Friction for Dense sand (Φ),	*36.0*	*N/A*
Undrained Cohesion (C), (kN/m^2)	*N/A*	*42.0*
Liquid Limit (LL), (%)	*N/A*	*37.55*
Plastic Limit (PL), (%)	*N/A*	*18.0*
Optimum Moisture Content (OMG), (%)	*N/A*	*21.0*
Classification	*SP*	*CI*

B. *Experimental Setup*

1) Model Tank: The Model tank used in this study is made up of Ferrocement and has internal dimensions of 900mm in both length and width, and 800mm depth. It has been designed in such a way that both the length and width are atleast nine times that of footing dimensions so that there should not be any effect on the boundaries while conducting the plate load tests. The experimental setup is shown in Fig. 1, Fig. 2 and Fig. 3.

2) Model Footing: In this study, the two different shapes of isolated footing are used, namely square and circular footing which are made up of steel. The square footing has a dimension of 100mm x 100mm and is 30mm thick. The circular footing has 100mm diameter and is 30mm thick.

3) Test Details: In this study, the weak silty soil is filled in the tank upto the required level with compaction done in layers by using circular steel hammer having a weight of 148 N, to achieve predetermined density. Then sand is filled upto the bottom level of the reinforcement and compacted. The reinforcement is placed with its center exactly beneath the jack and sand is filled again before load is applied at regular intervals and the corresponding settlement is measured using the two dial gauges and their average value is obtained at regular intervals till failure. Fig. 2 and Fig. 3 shows the test set up.

Fig. 1 Photograph of Test setup for various cases

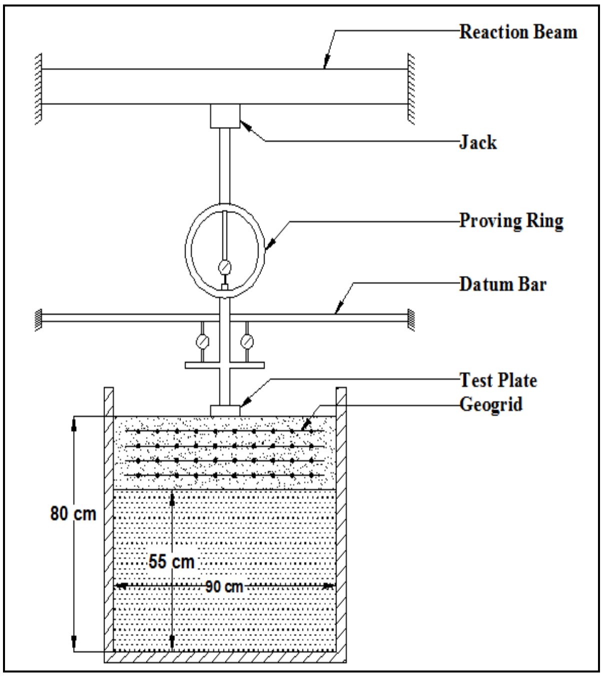

Fig . 2 Test set up for sand as foundation bed.

In this study, the depth of 0.5B for first reinforcement is adopted and for further addition reinforcements 2, 3, 4…..N at different layers, each depth (d) of the reinforcement layer from the base of a footing can calculated by using equation [13] as given below. Arrangements are shown in Fig.2, and Fig3.

$$\mathbf{d = u + (N\text{-}1) \times h} \qquad \text{-----(1)}$$

Where,

d is the depth of reinforcement layer from the base of footing.

u is the depth of the first layer reinforcement from the base of the footing.

N is the number of reinforcements provided.

h is the distance between two reinforcement layers.

To conduct the model test by using silty soil at particular predetermined depth for both unreinforced and reinforced, it is also very important to predetermined and decide the magnitude of parameters like *b/B, h/B, u/B,* and *d/B* ratio. Where *b* is the width of the reinforcement. The following are the adopted parameters for this study:

Number of reinforcement layers (N) = 0, 1, 2, 3, 4
Width or length of each reinforcement (b) = 800mm & 400mm
b/B = 10 & 4
h/B = 0.5
u/B = 0.5
d/D = 0, 0.0625, 0.125, 0.187, & 0.25

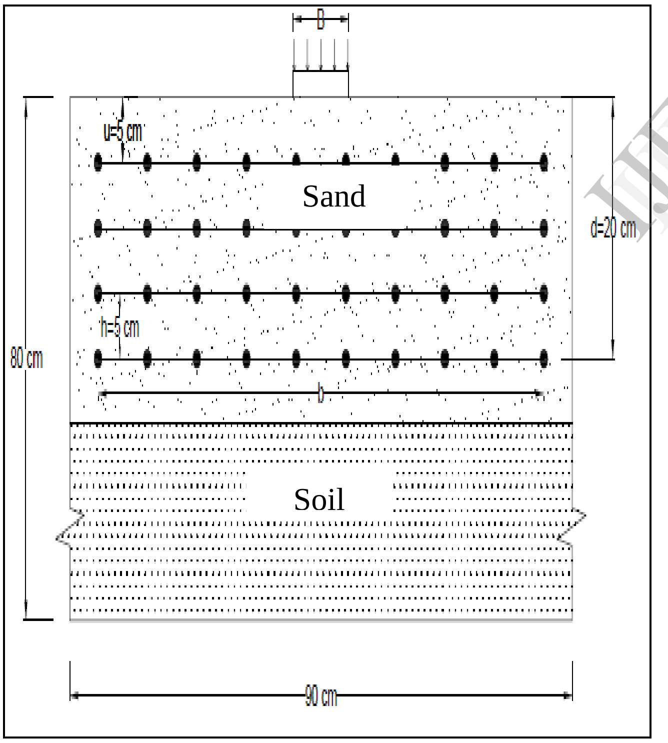

Fig. 3 Test setup for granular bed overlying soil

III. RESULTS AND DISCUSSION

Stress vs Settlement curves are shown in the Fig (4-8). The settlement is plotted along the y-axis and the stress is plotted along x-axis. It is clearly observed that the inclusion of reinforcement improves the load carrying capacity of the soil. The settlement of soil is also significantly reduced.

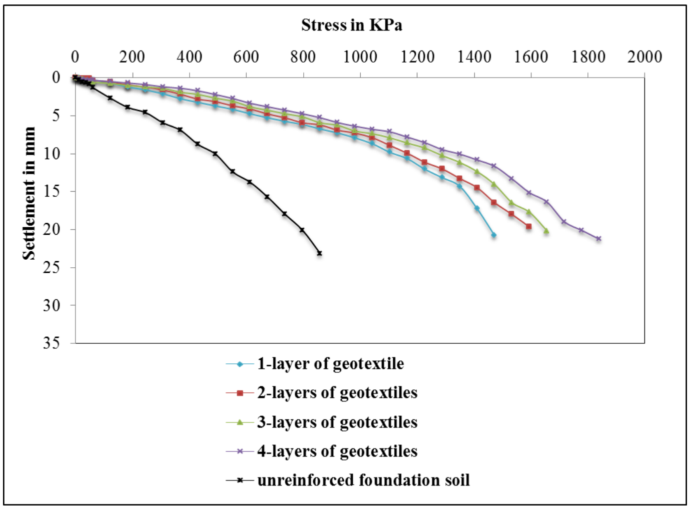

Fig. 4 Stress versus Settlement curves for reinforced soil for different layers of geotextiles of size (40cms x 40cms) under circular footing.

The results obtained from the plate load tests for reinforced granular bed for different layers (1, 2, 3, 4) of geotextiles of size 40cms x 40cms for soil as foundation bed with circular footing are plotted as shown in the Fig. 4. It is observed that the geotextiles with the 4-layers show significantly more load carrying capacity (nearly 2.14 times) when compared with unreinforced foundation bed with circular footing. It is also observed that the nature of failure occurring in unreinforced granular soil bed is local shear failure whereas the reinforced soil (1, 2, 3, or 4 layers of geotextile) shows the general shear failure

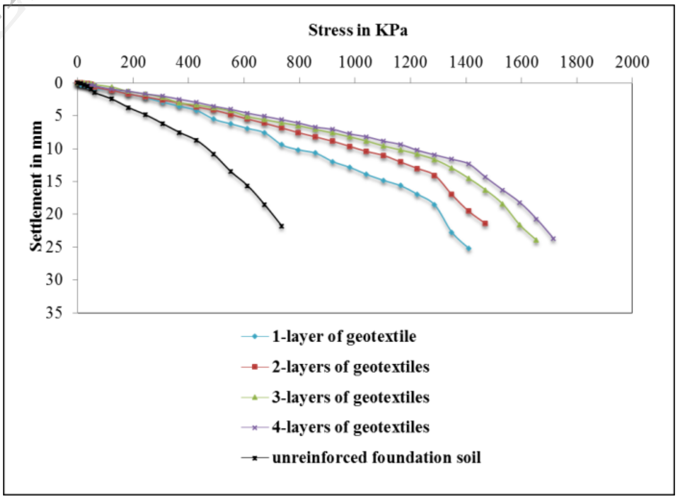

Fig. 5 Stress versus Settlement curves for reinforced soil for different layers of geotextiles of size (40cms x 40cms) under square footing.

The results obtained from the plate load tests for reinforced granular bed for different layers (1, 2, 3, 4) of geotextile of size 40cms x 40cms for soil as foundation bed with square footing are plotted as shown in the Fig. 5. It is observed that the geotextiles with the 4-layers show significantly more load carrying capacity (nearly 2.33 times) when compared with unreinforced foundation bed with square footing. It is also observed that the failure occurring in unreinforced granular soil bed is local shear failure whereas the reinforced soil (1, 2, 3, or 4 layers of geotextile) shows the general shear failure.

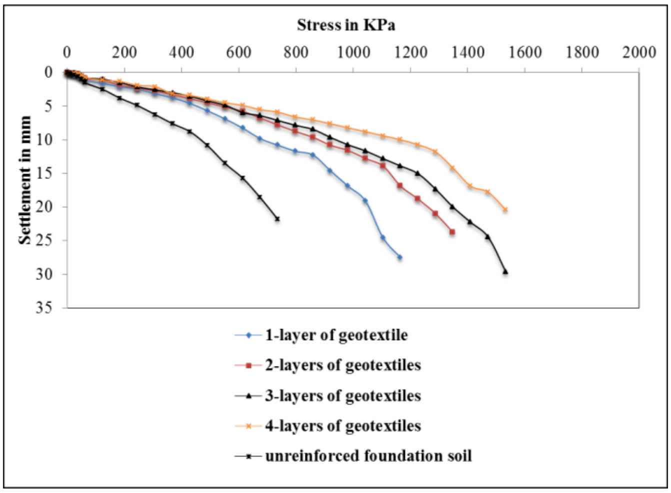

Fig. 6 Stress versus Settlement curves for reinforced soil for different layers of geotextiless of size (80cms x 80cms) under square footing.

The results obtained from the plate load tests for reinforced granular bed for different layers (1, 2, 3, 4) of geotextiles of size 80cms x 80cms for soil as foundation bed with square footing are plotted as shown in the Fig. 6. It is observed that the geotextiles with 4-layers show significantly more load carrying capacity (nearly 2.1 times) when compared with unfeinforced foundation bed with square footing. It is also observed that the nature of failure occurring in unreinforced granular soil bed is local shear failure whereas the reinforced soil (1, 2, 3, or 4 layers of geotextile) shows the general shear failure.

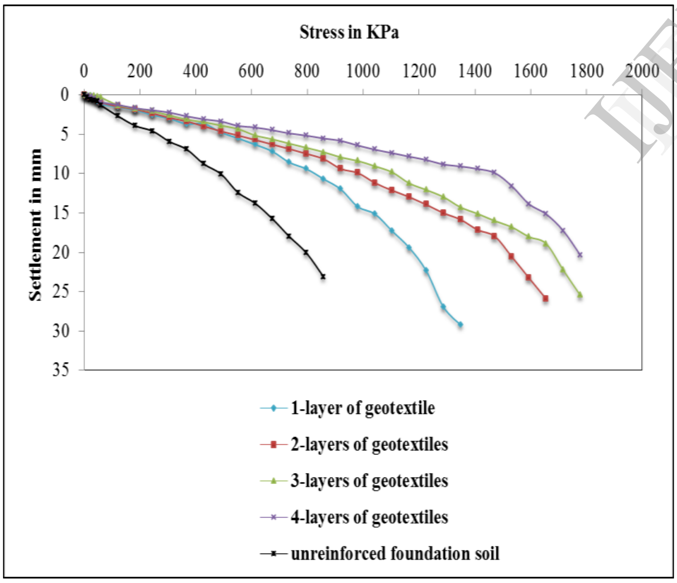

Fig. 7 Stress versus Settlement curves for reinforced soil for different layers of getextiles of size (80cms x 80cms) under circular footing.

The results obtained from the plate load tests for reinforced granular bed for different layers (1, 2, 3, 4) of geotextiles of size 80cms x 80cms for soil as foundation bed with circular footing are plotted as shown in the Fig. 7. It is observed that the geotextiles with 4-layers show significantly more load carrying capacity (nearly 2 times) when compared with 1-layers of geotextile with circular footing.. It is also observed that the nature of failure occurring in unreinforced granular soil bed is local shear failure whereas the reinforced soil (1, 2, 3, or 4 layers of geotextile) shows the general shear failure.

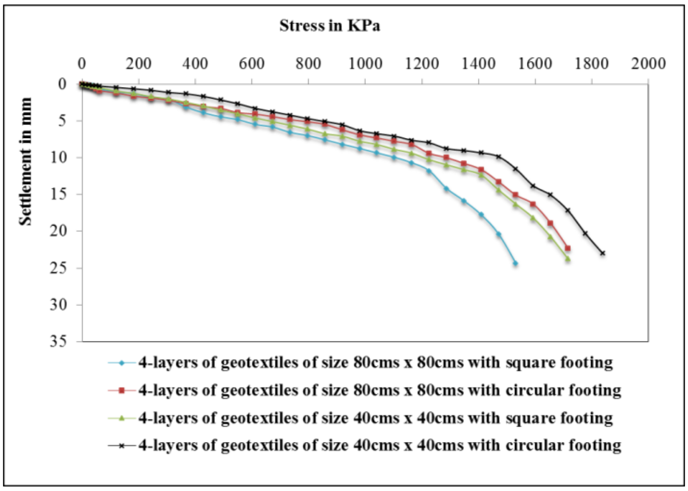

Fig. 8 Stress versus settlement curves for reinforced granular bed with 4-layers of getextiles of different sizes and shapes of isolated footing including 4-layers of geotextiles reinforced in foundation soil.

The results obtained from the plate load tests for reinforced granular bed with 4-layers of geotextile of different sizes and shapes of isolated footing are shown in the Fig.8. It is observed that the maximum improvement was when 4-layers of geotextiles of size 40cms x 40cms are used under circular footing. It is also observed that the performance of geotextiles of sizes 40cms x 40cms for circular footing on foundation bed show significantly more load carrying capacitry (nearly 1.2 times) when compared with the geotextiles of size 80cms x 80cms under square footing. It is also observed that the maximum stress of 1839 KPa with the settlement of 23.1mm is carried by 4-layers geogrids of 40cms x 40cms with circular footing and the minimum stress of 1532.5 KPa with the settlements of 24.4mm is carried by the 4-layers of geotextiles of size 80cms x 80cms under square footing. Hence the reinforced earth with 80cms x 80cms geotextile is found to have more displacement for a given stress when compared with foundation soil with geotextile of size 40cms x 40cms. However the failure in bigger size geotextile is gradual whereas smaller size results in sudden failure (4-layers of geotextiles). Generally the nature of failure occurring in 4-layers of geotextiles for both the sizes are of general shear failure.

IV. CONCLUSIONS

Based on the tests carried out it is observed that

1) There is a considerable improvement in load carrying capacity in reinforced soil over unreinforced soil for geotextiles and for both the lengths.

2) It is also observed that the load carrying capacity of soil below circular footing for 4-layers of geotextiles of size 40cms x 40cms are maximum compared to square footing on foundation bed (soil and sand).

3) From the experimental results it is proved that geotextiles beyond the effective length of (4.0B-6.0B) provides negligible reinforcement benefit.

4) However the failure in bigger size geotextile is gradual whereas smaller sizes result in sudden failure for 4-layers.

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REFERENCES

[1] J. Binquet and K. L. Lee, "Bearing capacity analysis of reinforced earth slabs," *Journal of Geotechnical Engineering Division*, vol. 101, no. 12, pp. 1257–1276, 1975.

[2] G. W. E. Milligan, R. J. Fannin, and D. M. Farrar, "Model and full-scale tests on granular layers reinforced with a geogrid," in *Proceedings of the 3rd International Conference on Geotextiles*, vol. 1, pp. 61–66, Vienna, Austria, 1986.

[3] Ashmawy, A.K., and Bourdeau, P.L., 1995, "Geosynthetic-Reinforced SoilsUnder Repeated Loading:A Review and Comparative Design Study", *Geosynthetics International*, Vol. 2, No. 4, pp. 643-678.

[4] Perkins, S.W. and Ismeik, M., 1997, "A Synthesis and Evaluation of Geosynthetic-Reinforced Base Layers in Flexible Pavements: Part II", *Geosynthetics International*, Vol. 4, No. 6, pp. 605-621.

[5] Som, N. and Sahu, R.B., 1999, "Bearing Capacity of a Geotextile Reinforced Unpaved Road as a Function of Deformation: A Model Study", *Geosynthetics International*, Vol. 6, No. 1, pp. 1-17.

[6] N. E. Marei "Response of different footing shapes resting on reinforced sandy soil underlain by weak soil," in *Proceedings of[th] Twelfth international colloquium on structural and geotechnical engineering*, 10-12 Dec-2007

[7] S. A. Naeini and M. Mirzakhanlari, " Effect of Geotextile and Grading on the bearing Ratio of Granular Soils", EJGE, vol. 13, bound. J, 2008.

[8] M. Mosallanezhad, N. Hataf, and A. Ghahramani (2010) "Three dimensional bearing capacity analysis of granular soils, reinforced with innovative grid-anchor system",Iranian journal of science & technology,Transaction B: Engineering ,vol.. 34 , No. B4, pp419-431

[9] Kalpana maheshwari, a. k. desai, and c. h. Solanki (2011) "Application and Modellingof fiber reinforced soil", Prceeding of indian Geotechnical Coference, Kochi (paper No H-362)

[10] P.K. Aminaton Marto, Mohsen Oghabi, and Amin Eiszadeh (2013). "The Effect of Geogrid Reinforcement on Bearing Capacity Properties of Soil Under Static Load; A Review", EJGE (Vol. 18 [2013], Bund. J)

[11] E. C. Shin, B. M. Das, V. K. Puri, S. C. Yen, and E. E. Cook, "Bearing capacity of strip foundation on geogrid-reinforced clay," *Geotechnical Testing Journal*, vol. 17, no. 4, pp. 535–541, 1993.

[12] B. R. Phanikumar, R. Prasad, and A. Singh, "Compressive load response of geogrid-reinforced fine,mediumand coarse sands," *Geotextiles and Geomembranes*, vol. 27, no. 3, pp. 183–186, 2009.

[13] Kolay, S. Kumar and D. Tiwari (2013). "Improvement of Bearing Capacity of Shallow Foundation on Geogrid Reinforced Silty Clay and Sand", *Hindawi Publishing Corporation Journal of Construction Engineering* (Volume 2013, Article ID 293809, 10 pages)

[14] Y. L.Dong, J.Han, and X.-H. Bai, "Bearing capacities of geogridreinforced sand bases under static loading," in *Proceedings of GeoShanghai International Conference: Ground Improvement and Geosynthetics*, pp. 275–281, June 2010.

[15] V. A. Guido, D. K. Chang, and M. A. Sweeney, "Comparison of geogrid and geotextile reinforced earth slabs," *Canadian Geotechnical Journal*, vol. 23, no. 4, pp. 435–440, 1986.

[16] B. M. Das, K. H. Khing, and E. C. Shin, "Stabilization of weak clay with strong sand and geogrid at sand-clay interface," *Transportation Research Record*, no. 1611, pp. 55–62, 1998.

[17] C. R. Patra, B. M. Das, and C. Atalar, "Bearing capacity of embedded strip foundation on geogrid-reinforced sand," *Geotextiles and Geomembranes*, vol. 23,no. 5, pp.454–462, 2005.

[18] Pardeep Singh, and K.S. Gill (2012) "CBR Improvement of clayey soil with geogrid reinforcement", International journal of Emerging technology and advasnce engineering (ISSN 2250-2459, vol. 2, issue 6)

[19] Bergado, D.T., S. Youwai, C.N. Hai, P. Voottipruex (2001) Interaction of nonwoven needle-punched geotextiles under axisymmetric loading conditions. Geotextiles and Geomembranes, Vol.19 , pp .299-328

[20] Fannin, R.J., O. Sigurdsson (1996) Field observations on stabilization of unpaved roads with geosynthetics. ASCE Journal of Geotechnical Engineering 122 (7), 544–553

[21] Haeri, S.M., R. Nourzad, A.M. Oskrouch (2000) Effect of geotextile reinforcement on the mechanical behavior of sands. Geotextiles and Geomembranes 18 (6), 385–402.

[22] Latha, G.M, V. S. Murthy (2007) Effects of reinforcement form on the behavior of geosynthetic reinforced sand. Geotextiles and Geomembranes 25, 23–32.

[23] Michalowski, R.L. (2004) Limit loads on reinforced foundation soils. Journal of Geotechnical and Geoenvironmental Engineering 130 (4),381–390.

[24] Park, T., S.A. Tan (2005) Enhanced performance of reinforced soil walls by the inclusion of short fiber. Geotextiles and Geomembranes 23 (4),348–361.

[25] Patra, C.R., B.M. Das, C. Atalar (2005) Bearing capacity of embedded strip foundation on geogrid-reinforced sand. Geotextiles and Geomembranes 23 (5), 454–462.

[26] Raymond, G., Ismail, I.,(2003) The effect of geogrid reinforcement on unbound aggregates. Geotextiles and Geomembranes 21, 355–380.

[27] Resl, S., Werner, G., (1986) The influence of nonwoven needle-punched geotextiles on the ultimate bearing capacity of the subgrade, Proceedings of the Third International Conference on Geotextiles, Vienna, Vol. 4, pp. 1009– 1013.