Application of Non-Woven Polyester Geotextile for Soil Improvement in Pavements

Shalinee Shukla[1], Ayush Mittal[2] [0000-0002-5479-4841], R.P. Tiwari[3] and Kshma Gupta[4]

[1,3,4]MNNIT Allahabad, Prayagraj-211004, U.P., India
[2]REC Ambedkar Nagar, Ambedkar Nagar-224122, U.P., India
ayushmittalce0012@gmail.com

Abstract. The performance of flexible pavements are greatly affected by the type of subgrade, sub-base and base course materials, the most important of these are the properties of soil subgrade, as it serves as the foundation for pavement. In India, around 8 lakh square kilometer area is covered with poor subgrade soil covering central, some parts of southern region and along the coastline. The pavement constructed over such soils will lead to greater thickness requirement and it will also fail prematurely under heavy wheel load. In order to overcome such untoward situation some ground improvement technique has to be adopted. This paper presents the effect of including non-woven polyester geotextile on the strength behaviour of weak subgrade soil. The geotextile sheets are placed in single and multiple layers at various depths of soil subgrade and thereby determination of optimum combination and optimum position of reinforcement based on the California bearing ratio results are done. Greater improvement in CBR is observed for soil samples reinforced with geotextile in upper layers of subgrade as compared to lower ones with a maximum increase of 70% corresponding to double layer geotextile at 0.2H and 0.4H depth from top of mold. It can be concluded that geotextile sheets can be considered as a good earth reinforcement material.

Keywords: California bearing ratio, Compaction, Polyester geotextile, Reinforcement, Subgrade

1 Introduction

Roads are vital to link our communities and sustain the economy and quality of life in society. The overall development of any country cannot be thought off without effective road network, connecting hills to planes and cities to villages. India has a total road network of about 60 lakh kilometers of which 80% consists of rural roads. Around 20% land area is covered with soils having low strength and high expansion potential. It is nearly impossible to provide stable construction platform over soft or weak soils. The intermixing of aggregate and fine soil will take place under heavy traffic load, leading to complete disintegration of pavement. Therefore, reinforced earth technique has to be adopted which includes mechanical or granular, chemical and physical methods. Reinforcing the cohesive soil with geosynthetics is the physical method of stabilization. One of the most common geosynthetic materials is geotextile. The World Bank has made it mandatory to use geotextile in construction projects funded by it. The improved performance of pavement reinforced with geotextile is attributed to three mechanisms namely increased bearing capacity, tensioned membrane effect and confinement or lateral restraint. Many studies have been conducted on use of synthetic fibers [1-25], natural fibers and geotextiles [26-44] on strength behaviour of both cohesive and cohesionless soils. Several investigations have also been conducted on use of synthetic geotextiles [45-52] on granular soils, while limited studies have been found on fine grained soils.

In the present study, effect of non-woven polyester geotextile on the strength behaviour of weak subgrade soil is studied. The geotextile sheets are placed in single and multiple layers at various depths of soil subgrade and heavy compaction and soaked CBR tests are conducted.

2 Materials

The following section presents the details of materials used in conducting laboratory investigations and their various properties.

2.1 Soil

The soil used in the present experimental tests is obtained from Meja (25.13°N, 81.98°E), Allahabad, Uttar Pradesh, India. The soil sample is collected by digging trial pits at 1m below ground surface. The soil is air dried, broken into pieces with a wooden mallet and sieved through 4.75mm sieve in the laboratory. Table 1 shows the various physical and mechanical properties of soil. The soil specimen is classified as clay of intermediate compressibility (CI) as per IS: 1498 (1970). Fig. 1 shows the grain size distribution curve of soil.

Table 1. Physical and Mechanical Properties of Soil

Soil Properties	Value
Specific Gravity	2.71
Grain Size Distribution	
(a) Gravel (%)	0.33
(b) Sand (%)	9.10
(c) Silt (%)	67.47
(d) Clay (%)	23.10
Atterberg's Limits	
(a) Liquid Limit (%)	36
(b) Plastic Limit (%)	19
(c) Plasticity Index (%)	17
Soil Classification (ISCS)	Clay of Intermediate Compressibility (CI)
Water Content (%)	16.82
Free Swell Index (%)	32.54
pH Value	7.55

Optimum Moisture Content (%)	13.60
Maximum Dry Density (KN/m^3)	18.80
Soaked CBR (%)	3.85

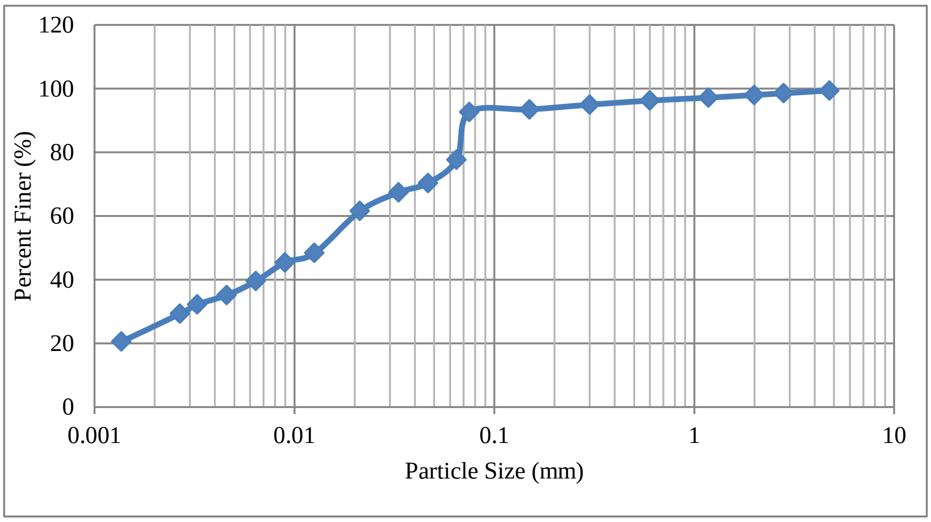

Fig. 1. Grain Size Distribution Curve

2.2 Geotextile

A non-woven synthetic polyester geotextile having mass per unit area of 350gsm is used in the present study. The geotextile supplied by Ocean Non-Woven Pvt. Ltd, New Delhi is shown in Fig. 2. The various index and strength properties of geotextile as provided by manufacturer are presented in Table 2.

Fig. 2. Non-Woven Polyester Geotextile

Table 2. Index Properties of Geotextile

Properties	Unit	Test Standard	Value
Type	-	-	Non-Woven
Material	-	-	Polyester Fibers
Mass Per Unit Area	g/m^2	ASTM D 5261	350
Thickness	mm	ASTM D 5199	2.9
Breaking Strength	KN/m	ASTM D 4595	11
Trapezoidal Tear Strength	N	ASTM D 4533	280
CBR Puncture Strength	N	ASTM D 6241	1800

3 Testing Program

The experimental program is carried out in two parts. First, the physical properties of soil (specific gravity, Atterberg's limits, ISCS classification etc.) were determined and then a series of heavy compaction and soaked CBR tests are conducted in the laboratory based on the standard methods suggested by relevant parts of Indian Standards (IS): 2720 for 'Method of test for soils'. Various positions of geotextile reinforcement in soil subgrade are presented in Fig. 3. The term H signifies the total depth of soil in testing mold which is 12.73cm in both CBR and compaction test.

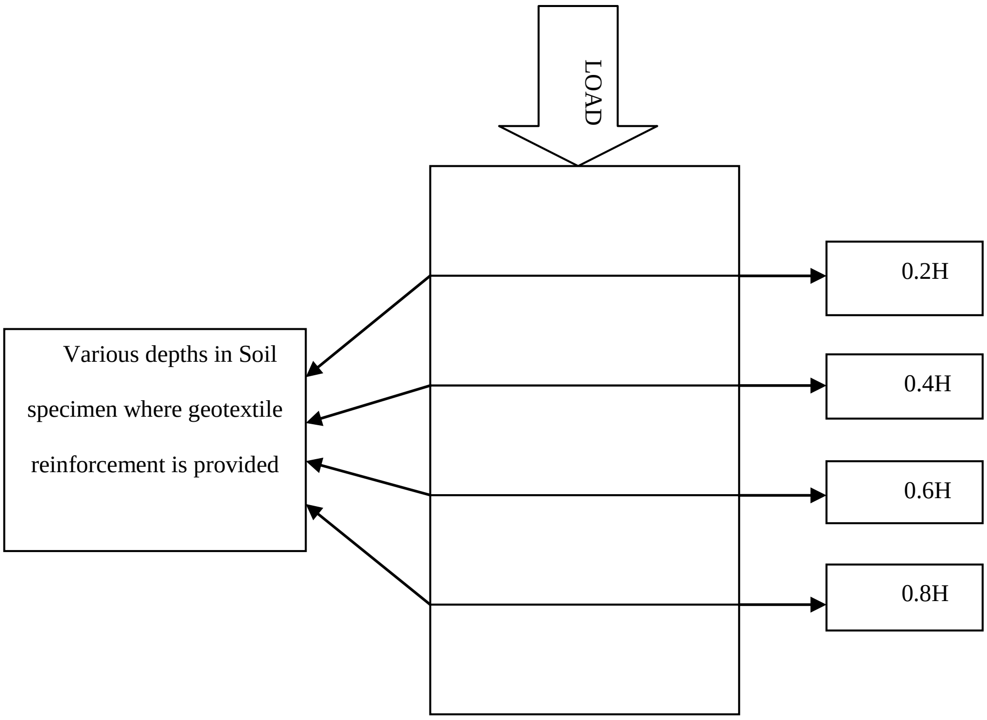

Fig. 3. Position of Geotextile Layer in Soil

4 Results and Discussions

4.1 Heavy Compaction

The results of optimum moisture content and maximum dry density of soil sample reinforced with and without geotextile are shown in Table 3. Increase in MDD corresponding to single and double layer reinforcement as compared to virgin soil specimen is observed. The MDD for unreinforced soil is 18.60KN/m^3 which increases to 19.40KN/m^3, 18.61KN/m^3, 19.44KN/m^3 and 19.37KN/m^3, respectively, for single layer of geotextile at 0.2H, 0.4H, 0.6H and 0.8H depth from top of mold. These value further changes to 18.72KN/m^3, 19.09KN/m^3, 18.69KN/m^3 and 18.66KN/m^3 for double layer of geotextile at 0.2H & 0.4H, 0.2H & 0.6H, 0.4H & 0.6H and 0.6H & 0.8H depths respectively. Reduction in MDD is observed for triple and four layer reinforcement which is even below the virgin soil with a minimum value of 18.38KN/m^3 and 18.31KN/m^3 respectively. The OMC results shows irregular trend, however for most of the cases with increase in MDD reduction in OMC is observed and vice-versa. This increase in MDD for single and double layer reinforcement condition is due to greater compactness achieved with geotextile layers resulting in reduction of voids. However, with further increase in number of geotextile layers this effect is overcome by lower specific gravity of polyester geotextiles as compared to soil as a result of which reduction in MDD is observed.

Table 3. OMC-MDD Values of Soil Reinforced with Non-Woven Geotextile

Depth of Geotextile from Top of Mold	Experimental Value	
	OMC (%)	MDD (KN/m^3)
Unreinforced Soil	13.60	18.60
0.2H	13.20	19.40
0.4H	13.30	18.61
0.6H	13.30	19.44
0.8H	12.90	19.37
0.2H and 0.4H	12.80	18.72
0.2H and 0.6H	14.15	19.09
0.4H and 0.6H	13.02	18.69
0.6H and 0.8H	13.20	18.66
0.2H, 0.4H and 0.6H	13.90	18.50
0.2H, 0.4H and 0.8H	13.80	19.20
0.2H, 0.6H and 0.8H	14.10	18.38
0.4H, 0.6H and 0.8H	13.10	18.52
0.2H, 0.4H, 0.6H and 0.8H	13.80	18.31

4.2 Soaked CBR

The California bearing ratio test results of soil reinforced with and without geotextile in various layers are presented in Table 4. The CBR for unreinforced soil is 3.85% which increases to 6.32%, 4.18%. 4.28% and 6.09%, respectively, for single layer of geotextile at 0.2H, 0.4H, 0.6H and 0.8H depth from top of mold. These value further increase to 6.55%, 5.28%, 5.93% and 5.85% for double of geotextile at 0.2H & 0.4H, 0.2H & 0.6H, 0.4H & 0.6H and 0.6H & 0.8H depths respectively. Reduction in strength improvement is observed for triple and four layer reinforced cases as compared to single and double layers. The CBR is 4.25%, 4.85%, 3.56% and 4.57%, respectively, for triple layer of geotextile at 0.2H, 0.4H & 0.6H; 0.2H, 0.4H & 0.8H; 0.2H, 0.6H & 0.8H and 0.4H, 0.6H & 0.8H depths from top of soil sample. The CBR further decreases to 4.32% for four layer reinforcement. Greater improvement in CBR is observed when geotextile sheets are placed in upper layers of soil subgrade as compared to lower ones. This is because for tensile strength of fabric to come into action certain amount of deformation is required in soil and this will always be more in upper layers of subgrade due to greater traffic load intensity as compared to lower layers.

Table 4. CBR Values of Soil Reinforced with Non-Woven Geotextile

Depth of Geotextile from Top of Mold	CBR (%)
Unreinforced Soil	3.85
0.2H	6.32
0.4H	4.18
0.6H	4.28
0.8H	6.09
0.2H and 0.4H	6.55
0.2H and 0.6H	5.28
0.4H and 0.6H	5.93
0.6H and 0.8H	5.85
0.2H, 0.4H and 0.6H	4.25
0.2H, 0.4H and 0.8H	4.85
0.2H, 0.6H and 0.8H	3.56
0.4H, 0.6H and 0.8H	4.57
0.2H, 0.4H, 0.6H and 0.8H	4.32

5 Conclusions

Based on the experiments performed in laboratory to study the effect of non-woven polyester geotextile on the strength behaviour of poor subgrade soil, the following conclusions are made. As the number of geotextile reinforcing layer increases, reduction in dry density is observed due to lower unit weight of polyester geotextile. The MDD for reinforced soil ranges from 19.44KN/m^3 to 18.31KN/m^3. No fixed pattern is reported in OMC values but for majority of cases OMC decreases with increase in MDD and vice-versa. The range of OMC for reinforced soil is 12.90% to 14.15%. Maximum CBR of 6.32% and 6.55% is reported for single and double layer reinforcement when geotextile is placed at shallow depth of subgrade as against 3.85% for unreinforced soil. This is due to greater resistance to penetration of plunger in upper layers offered by geotextiles. With further increase in number of geotextile layers, reduction in CBR is observed. This is due to loss of integrity in soil system due to separation of soil layers completely from each other resulting in formation of more void spaces causing strength reduction. Double layer geotextile at 0.2H & 0.4H depth from top of specimen is found to be the most optimum position of reinforcement when analyzed on the basis of reduction in thickness and cost of pavement and improvement in CBR. Thus it can be concluded that use of non-woven geotextile in pavement subgrade results in economical pavement design with reduced structural section, saving costly base and sub-base aggregate materials and reducing frequent maintenance requirements.

These conclusions can be used effectively in locations where locally available soil has very low strength and Civil Engineering structures such as pavement and embankment has to be constructed over it. The need for removal and replacement of soil will get eliminated and huge benefits in terms of aggregate saving and environmental protection caused by reduction in aggregate transportation, diesel consumption, noise and air pollution will occur.

References

1. Kalantari, B., Huat B.B.K. and Prasad, A.: Effect of polypropylene fibers on the California bearing ratio of air cured stabilized tropical peat soil. American J. of Engineering and Applied Sciences, 3, 1-6 (2010).
2. Chore, H.S., Kumthe, A.A., Abnave, S.B., Shinde, S.S., Dhole, S.S. and Kamerkar, S.G.: Performance evaluation of polypropylene fibers on sand-flyash mixtures in highways. Journal of Civil Engineering (IEB), 39, 91-102 (2011).
3. Jadhao, P.D. and Nagarnaik, P.B.: Influence of polypropylene fibers on engineering behaviour of soil-flyash mixtures for road construction. EJGE, 13, 1-11 (2008).
4. Mali, S. and Singh, B.: Strength behaviour of cohesive soils reinforced with fibers. International Journal of Civil Engineering Research, 5, 353-360 (2014).
5. Tang, C., Shi, B., Gao, W., Chen, F. and Cai, Y.: Strength and mechanical behavior of short polypropylene fiber reinforced and cement stabilized clayey soil. Geotextiles and Geomembranes, ELSEVIER, 25, 194-202 (2007).
6. Consoli, N.C., Bassani, M.A.A. and Festugato, L.: Effect of fiber-reinforcement on the strength of cemented soils. Geotextiles and Geomembranes, ELSEVIER, 28, 344-351 (2010).
7. Yetimoglu, T., Inanir, M. and Inanir, O.E.: A study on bearing capacity of randomly distributed fiber-reinforced sand fills overlying soft clay. Geotextiles and Geomembranes, ELSEVIER, 23, 174-183 (2005).
8. Akbulut, S., Arasan, S. and Kalkan, E.: Modification of clayey soils using scrap tire rubber and synthetic fibers. Applied Clay Science, ELSEVIER, 38, 23-32 (2007).
9. Botero, E., Ossa, A., Sherwell, G. and Shelley, E.O.: Stress-strain behavior of a silty soil reinforced with polypropylene terephthalate (PET). Geotextiles and Geomembranes, ELSEVIER, 43, 363-369 (2015).
10. Park, S.S.: Effect of fiber reinforcement and distribution on unconfined compressive strength of fiber-reinforced cemented sand. Geotextiles and Geomembranes, ELSEVIER, 27, 162-166 (2009).
11. Consoli, N.C., Vendruscolo, M.A., Fonini, A. and Rosa, F.D.: Fiber reinforcement effects on sand considering a wide cementation range. Geotextiles and Geomembranes, ELSEVIER, 27, 196-203 (2009).
12. Yetimoglu, T. and Salbas, O.: A study on shear strength of sands reinforced with randomly distributed discrete fibers. Geotextiles and Geomembranes, ELSEVIER, 21, 103-

110 (2003).
13. Pradhan, P.K., Kar, R.K. and Naik, A.: Effect of random inclusion of polypropylene fibers on strength characteristics of cohesive soil. Geotechnical and Geological Engineering, SPRINGER, 30, 15-25 (2012).
14. Shao, W., Cetin, B., Li, Y., Li, J. and Li, L.: Experimental investigation of mechanical properties of sands reinforced with discrete randomly distributed fiber. Geotechnical and Geological Engineering, SPRINGER, 32, 901-910 (2014).
15. Fatahi, B., Le, T.M., Fatahi, B. and Khabbaz, H.: Shrinkage properties of soft clay treated with cement and geofibers. Geotechnical and Geological Engineering, SPRINGER, 31, 1421-1435 (2013).
16. Zaimoglu, A.S.: Optimization of unconfined compressive strength of fine-grained soils modified with polypropylene fibers and additive materials. KSCE Journal of Civil Engineering, 19, 578-582 (2015).
17. Chore, H.S. and Vaidya, M.K.: Strength characteristics of fiber reinforced cement-flyash mixes. International Journal of Geosynthetics and Ground Engineering, SPRINGER, 1, 1-8 (2015).
18. Cai, Y., Shi, B., Ng, C.W.W. and Tang, C.S.: Effect of polypropylene fiber and lime admixture on engineering properties of clayey soil. Engineering Geology, ELSEVIER, 87, 230-240 (2006).
19. Correia, A.A.S., Oliveira, P.J.V. and Custodio, D.G.: Effect of polypropylene fibers on the compressive and tensile strength of a soft soil, artificially stabilised with binders. Geotextiles and Geomembranes, ELSEVIER, 43, 97-106 (2015).
20. Kumar, A., Walia, B.S. and Mohan, J.: Compressive strength of fiber reinforced highly compressible clay. Construction and Building Materials, ELSEVIER, 20, 1063-1068 (2006).
21. Viswanadham, B.V.S., Phanikumar, B.R. and Mukherjee, R.V.: Swelling behaviour of a geofiber-reinforced expansive soil. Geotextiles and Geomembranes, ELSEVIER, 27, 73-76 (2009).
22. Li, J., Tang, C., Wang, D., Pei, X. and Shi, B.: Effect of discrete fiber reinforcement on soil tensile strength. Journal of Rock Mechanics and Geotechnical Engineering, CSRME, 6, 133-137 (2014).
23. Tang, C.S., Shi, B. and Zhao, L.Z.: Interfacial shear strength of fiber reinforced soil. Geotextiles and Geomembranes, ELSEVIER, 28, 54-62 (2010).
24. Yi, X.W., Ma, G.W. and Fourie, A.: Compressive behaviour of fiber-reinforced cemented paste backfill. Geotextiles and Geomembranes, ELSEVIER, 42, 207-215 (2015).
25. Sarkar, R., Abbas, S.M. and Shahu, J.T.: Geotechnical behaviour of randomly oriented fiber reinforced pond ashes available in Delhi region. International Journal of Earth Sciences and Engineering, 5, 44-50 (2012).
26. Prabakar, J. and Sridhar, R.S.: Effect of random inclusion of sisal fiber on strength behaviour of soil. Construction and Building Materials, ELSEVIER, 16, 123-131 (2002).
27. Lekha, B.M., Goutham, S. and Shankar, A.U.R.: Evaluation of lateritic soil stabilized with Areca nut coir for low volume pavements. Transportation Geotechnics, ELSEVIER, 2, 20-29 (2015).

28. Bera, A.K., Chandra, S.N., Ghosh, A. and Ghosh, A.: Unconfined compressive strength of fly ash reinforced with jute geotextiles. Geotextiles and Geomembranes, ELSEVIER, 27, 391-398 (2009).
29. Lekha, K.R. and Kavitha, V.: Coir geotextile reinforced clay dikes for drainage of low-lying areas. Geotextiles and Geomembranes, ELSEVIER, 24, 38-51 (2006).
30. Qu, J., Li, C., Liu, B., Chen, X., Li, M. and Yao, Z.: Effect of random inclusion of wheat straw fibers on shear strength characteristics of Shanghai cohesive soil. Geotechnical and Geological Engineering, SPRINGER, 31, 511-518 (2013).
31. Rao, S.V.K. and Nasr, A.M.A.: Laboratory study on the relative performance of silty-sand soils reinforced with linen fiber. Geotechnical and Geological Engineering, SPRINGER, 30, 63-74 (2012).
32. Ghavami, K., Filho, R.D.T. and Barbosa, N.P.: Behaviour of composite soil reinforced with natural fibers. Cement and Concrete Composites, ELSEVIER, 21, 39-48 (1999).
33. Rawas, A.A.A., Hago, A.W. and Sarmi, H.A.: Effect of lime, cement, and sarooj (artificial pozzolan) on the swelling potential of an expansive soil from Oman. Building and Environment, ELSEVIER, 40, 681-687 (2005).
34. Li, M., Chai, S.X., Zhang, H.Y., Du, H.P. and Wei, L.: Feasibility of saline soil reinforced with treated wheat straw and lime. Soils and Foundations, Japanese Geotechnical Society, 52, 228-238 (2012).
35. Anggraini, V., Asadi, A., Haut, B.B.K. and Nahazanan, H.: Effects of coir fibers on tensile and compressive strength of lime treated soft soil. Measurement, ELSEVIER, 59, 371-381 (2015).
36. Ahmad, F., Bateni, F. and Azmi, M.: Performance evaluation of silty sand reinforced with fibers. Geotextiles and Geomembranes, ELSEVIER, 28, 93-99 (2010).
37. Chattopahyay, B.C. and Chakravarty, S.: Application of jute geotextiles as facilitator in drainage. Geotextiles and Geomembranes, ELSEVIER, 27, 156-161 (2009).
38. Methacanon, P., Weerawatsophon, U., Sumransin, N., Prahsarn, C. and Bergado, D.T.: Properties and potential application of the selected natural fibers as limited life geotextiles. Carbohydrate Polymers, ELSEVIER, 82, 1090-1096 (2010).
39. Marin, C.G., Gomez, C.R. and Petric, J.: Clay-based composite stabilized with natural polymer and fiber. Construction and Building Materials, ELSEVIER, 24, 1462-1468 (2010).
40. Kumar, M.T.P. and Sridhar, R., Effect of coir mat and coir fiber reinforcement on shear strength of dry sand. in Proc. IGC-Roorkee, pp. 1-5, December 22-24 (2013).
41. Bouhicha, M., Aouissi, F. and Kenai, S.: Performance of composite soil reinforced with barley straw. Cement and Concrete Composites, ELSEVIER, 27, 617-621 (2005).
42. Dutta, R.K., Khatri, V.N. and Venkataraman, G.: Effect of addition of treated coir fibers on the compression behaviour of clay. Journal of Civil Engineering (IEB), 40, 203-214 (2012).
43. Estabragh, A.R., Bordbar, A.T. and Javadi, A.A.: A study on the mechanical behavior of a fiber-clay composite with natural fiber. Geotechnical and Geological Engineering, SPRINGER, 31, 501-510 (2013).
44. Chegenizadeh, A. and Nikraz, P.H.: Study on strength of fiber reinforced clayey sand. in Proc. International Conference on Science and Engineering (ICSE 2011), pp. 356-359 (2011).

45. Murtaza, G., Shah, S.S. and Ahmad, M.: Geofabrics improve load bearing characteristics of flyash. Construction and Building Materials, ELSEVIER, 3, 78-80, (1989).
46. Viswanadham, B.V.S. and Satkalmi, V.: Field trials with polypropylene woven geotextiles. in Proc. First pan American Geosynthetics Conference and Exhibition, Mexico, pp. 1112-1118, March 2-5 (2008).
47. Tuna, S.C. and Altun, S.: Mechanical behaviour of sand-geotextile interface. Scientia Iranica, Sharif University of Technology, 19, 1044-1051 (2012).
48. Raisinghani, D.V. and Viswanadham, B.V.S.: Evaluation of permeability characteristics of a geosynthetic-reinforced soil through laboratory tests. Geotextiles and Geomembranes, ELSEVIER, 28, 579-588 (2010).
49. Ghazavi, M. and Roustaei, M.: Freeze-thaw performance of clayey soil reinforced with geotextile layer. Cold Regions Science and Technology, ELSEVIER, 89, 22-29 (2013).
50. Scholz, M. and Grabowiecki, P.: Review of permeable pavement systems. Building and Environment, ELSEVIER, 42, 3830-3836 (2007).
51. Haeri, S.M., Noorzad, R. and Oskoorouchi, A.M.: Effect of geotextile reinforcement on the mechanical behaviour of sand. Geotextiles and Geomembranes, ELSEVIER, 18, 385-402 (2000).
52. Ghosh, A. and Dey, U.: Bearing ratio of reinforced fly ash overlaying soft soil and deformation modulus of flyash. Geotextiles and Geomembranes, ELSEVIER, 27, 313-320 (2009).