International Journal of Engineering and Technical Research (IJETR)
ISSN: 2321-0869, Volume-3, Issue-5, May 2015

Effect of Polypropylene Fibre on the Strength Characteristics of the Soils along the Yamuna River Bank in Delhi City

Abhinav Nangia, Sudhir Nigam, Dharmendra Kumar, Shailendra Tiwari

Abstract— **Soil samples from five different locations in Delhi city along Yamuna river bank has been taken to assimilate the spatially varying properties of soil. The direct and shears strength characteristics of soils are evaluated first. Then after the effectiveness of fibre inclusions in the strength characteristics of soils are worked out through a series of shear test and unconfined compression tests. For this purpose, polypropylene fibre of 25 mm in length size is used with the soil samples collected from all five locations. The fibre content was varied as 0, 0.5, 1.0, 1.5, 2.0 and 2.5% of the dry weight of soil samples. The strength behaviour of polypropylene fibre reinforced soil samples were studied using unconfined compressive strength test and direct shear test respectively. The results have been interpreted in terms of stress-strain behaviour, variation of failure strain and stress, effect of fibre content, and other strength parameters. Based on study results it is recommended that use of polypropylene fibre in civil engineering for improving soil properties is advantageous because it causes significant improvement in the compressive and shear strengths of the soil.**

Index Terms— **Shear, Fibre, Random, Polypropylene, Distribution, Strain, Compression**

I. INTRODUCTION

Soil for a geotechnical engineer is the weathered material of earth's crust, with or without organic matter. Because of its universal availability and low cost, it offers great opportunities for skillful use as an engineering material in construction work.The discrete particles that make up the soil are not strongly bonded together. They are free to move relative to each other, which is responsible for their low mechanical properties. Soils are strong in compression but weak in tension. The current practice is to modify the engineering properties of the native problematic soils to meet the design specifications. There are many techniques employed to improve the engineering and mechanical properties of poor soils.

The techniques employed to improve the properties of soil in respect of strength and other relevant characteristics of soil are Soil stabilization. Soil can be stabilized using other material (e.g. chemical additives, rewetting, soil replacement, compaction control, moisture control, surcharge loading, and thermal treatment). All these methods are expensive and do not last for a long time. Fiber reinforcement is the simplest mechanical stabilization processes in which natural or synthetic materials are introduced in the soil mass in the direction of stress to enhance the tensile or shear strength. Reinforcement material generally consists of galvanized or stainless steel, wood, glass, rubber, polymer, plastic etc. in the shape of strips, bars, grids, fibres, sheet, rope, piece, etc. In general mechanical means of soil stabilization are proficient to reduce permeability and compressibility, improves soil strength and bearing capacity and enhances its overall performance at relatively low cost.

Abhinav Nangia, M.tech Scholar CIVIL ENGG. DEPT. LNCT BHOPAL

Sudhir Nigam, Dissertation Supervisor CIVIL ENGG. DEPT. LNCT BHOPAL

Dharmendra Kumar, M.tech Scholar CIVIL ENGG. DEPT. LNCT BHOPAL

Shailendra Tiwari, M.tech Scholar CIVIL ENGG. DEPT. LNCT BHOPAL

Earlier natural (organic) and metallic fibre, wires and sheets; were used as reinforcement which when exposed to aggressive environment like humidity, chemicals, gases and corrosive agents etc. get rusted and decayed rapidly. But with the introduction of manmade fibres like nylon, propylene and other forms of organic stable polymers which can withstand ultra-violet light rays and resistant to acid in industrial applications, the above deficiencies have greatly been overcome.

Now a day's polypropylene (PP) based synthetic fibers and grids are now preferred due to their availability with desired properties and durability. Polypropylene is prone to fire and sun light, water. PP exhibits excellent resistant to abrasion, chemicals and biological (rot) entities investigated the micromechanical interaction behaviour between soil particles and reinforcing PP fibers. They concluded that the interfacial shear resistance of fiber/soil depends primarily on the rearrangement resistance of soil particles, effective interface contact area, fiber surface roughness and soil composition. Soil improvement mainly results in increase in the shear and ultimate strength along with enhancement of other engineering properties e.g. compaction, porosity, capillary absorption, resistance to weathering, filtration capacity, durability etc. In this paper we are presenting study result about the behaviour of soil mass with reference to the strength parameters using polypropylene fibre in five locations of the New Delhi city along Yamuna River.

II. LITERATURE REVIEW:

The capability of synthetic fiber reinforcement for improving the behavior of soil has been demonstrated by using triaxial tests, CBR tests, cyclic triaxial tests, resonant-column and Torsional shear tests (Al-Refeai, 1991; Day et al., 2003; Olaniyan et al., 2011). These studies indicated that fiber inclusions increase the ultimate strength, stiffness, CBR, resistance to liquefaction, and shear modulus and damping of reinforced soil (Hejazi et al., 2012; Ninov et al., 2007). In recent years, many studies have been conducted to improve the engineering characteristics of the soil reinforced with discrete polypropylene (PP) fibers for use in geotechnical applications in civil engineering (McGown et al., 1985; Al-Refeai, 1991; Yetimoglu et al., 2005; Tang et al., 2010 and

Hejazi et al., 2012. Currently PP fibers are used in soil mass to resist tensile failure, cracking, shrinkage, biological decay, acid and alkali attack (Maher and Gray, 1990; Kumar and Singh, 2008). It is observed that an admix of polypropylene fibre into soil have significantly improved its engineering properties (e.g. tensile / compressive / shear strengths, fracture toughness, durability) applied in retrofitting and repairing the covering of structures, carpentries stabilizing, landfill, slope protection, road subgrade etc. (Puppala and Musenda, 2000; Yetimoglu and Salbas, 2003; Yi et al., 2006; Consoli et al., 2009). At the same time soils reinforced with discrete polypropylene fibre have shown considerable decrease in the stiffness of the soil (hence reduced crack) and enhanced the self-seaming ability of soils (Li et al., 1995; Zhang et al., 1998). Moreover, soil reinforced with polypropylene fibre exhibits greater toughness and ductility, increases formability and bending strength and lessen loss of post peak strength, as compared to soil alone (Gray and Ohashi, 1983; Attom and Tamimi, 2010; Freilich et al., 2010; Malekzadeh and Bilsel, 2012).

Through the appraisal of the above literature it is understood that incorporation of PP fibre in soil remarkably improves its load-deformation behavior through surface friction and interlocking between soil particles and fibres. However, studies on application of PP fibre with soil mass are mostly site specific and there is no established formulation to get maximum percentage of synthetic PP fiber to be used in soil to get optimum outcome in terms of soil strength.

The objective of the present study is set to determine the reinforcing effects of randomly distributed, discrete polypropylene fibre on the behavior of the soil. The aim behind is to develop a soil mass with good strength, less porous, less capillarity so that durability will be increased. Five samples of soil mass are taken from the plots along the bank of Yamuna River in the following locations: Srinivaspuri, Sunhari Masjid, Botanical Garden, Kashmiri Gate and Nizamuddin as located in the figure 2. The study focuses on the effect of change of fibre percentage on the engineering properties of compacted soil. Standard proctor compactions tests and direct Shear test (DST) and unconfined compressive strength (UCS) test are to performed to evaluate the mechanical response of fibre reinforced soil in terms of strength and penetration resistance.

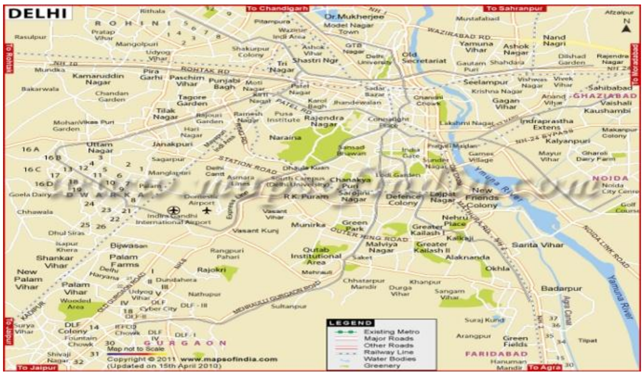


Figure1: Sampling Location across Yamuna River in Delhi

III. METHODOLOGY

For the present study, PP fibres of diameter 0.25 mm are cut into pieces of average length of 25 mm and are randomly mixed with soil in varying percentages (0, 0.5, 1, 1.5, 2, and 2.5) by dry weight of soil.

Properties of Soil Samples: For all soil samples basic properties of soil e.g. pH, Organic Matter contents, determination of amount of N, K, P, Na, K and Mg, and electrical conductivity were tested These properties mainly related to the capability of soil for plant growth but these parameters indirectly affects the engineering properties of soil and a vivid understanding of these parameters are crucial to understand the behaviour of engineering properties of soil. The particle or grain size distribution of soil directly relates to its strength, permeability, density etc. Using results of sieve analysis for the particle size distribution, further particle diameter D10, D30, and D60 which represents a size in mm such that 10%, 30% and 60% of particles respectively are finer than that size and uniformity coefficient (Cu = D60 / D10) and coefficient of curvature ($Cc = D^{2}_{30}/D_{60} \times D_{10}$) can be evaluated for the soil samples. Index properties of soil samples specific gravity, consistency limit (atterberg Limits), optimum moisture content, maximum and minimum dry density and shear parameters, were all determined in the laboratory according to the national criteria for geotechnical tests detailed in relevant IS codes of practice in India.

Strength Characteristics of Soil Samples

An assessment of the behaviour of soil mass using randomly distributed PP fibre is made to enhance the stability and safe functioning of structures through a series unconfined compression strength test, and Shear strength tests. Shearing stresses are induced in the soil through loaded structural members of building and when these stresses reach their limiting value, deformation starts which leads to failure of the soil mass. The shear strength of a soil is its resistance to the deformation caused by the shear stresses acting on the loaded soil. The shear strength of a soil is one of the most important characteristics. The shear resistance offered is made up of three parts: The structural resistance to the soil displacement caused due to the soil particles getting interlocked; the frictional resistance at the contact point of particles, and Cohesion / adhesion between the surfaces of particles. In case of cohesion less soils, the shear strength is entirely dependent upon the frictional resistance, while in others it comes from the internal friction as well as the cohesion. There are several experiments which are used to determine shear strength such as Direct Shear Test (DST) or UCS etc.

Direct Shear Test (DST): This is the most common test used to determine the shear strength of the soil on predetermined failure surfaces.. It can be defined by Mohr-Coulomb theory depicted by the equation goes as follows:

$\tau = c + \sigma * \tan(\varphi)$

Unconfined Compressive Strength (UCS) Test: This test is a specific case of triaxial test where the horizontal forces acting are zero. There is no confining pressure in this test and the soil sample tested is subjected to vertical loading only. The specimen used is cylindrical and is loaded till it fails due to shear. This experiment is used to determine the unconfined compressive strength of the soil sample which in turn is used to calculate the unconsolidated, undrained shear strength of unconfined soil. The unconfined compressive strength (qu) is the compressive stress at which the unconfined cylindrical soil sample fails under simple compressive test.

The study focuses on the effect of change of fibre percentage, with a constant aspect ratio (Ratio of fibre length and diameter) on the engineering properties of soil samples. At first, the different amounts of fibre and soil admixed, and then a volume of water is added corresponding to the optimum dry density and mixed uniformly. The fibres length and diameter are kept constant (25mm and 0.20 mm respectively) for all soil samples. For a particular percentage of fiber content, the 1/3rd of total amount of PP fibres were distributed evenly and mixed thoroughly with wet soil. After mixing the 1/3rd amount, another 1/3rd amount were mixed in the same way. The PP fibres are mixed randomly with soil at (0, 0.5, 1, 1.5, 2, 2.5) percentages of fibre content by dry weight of soil. The soil fibre mixtures were prepared with static compaction method at omc for each percentage of fibre corresponding to maximum dry density.

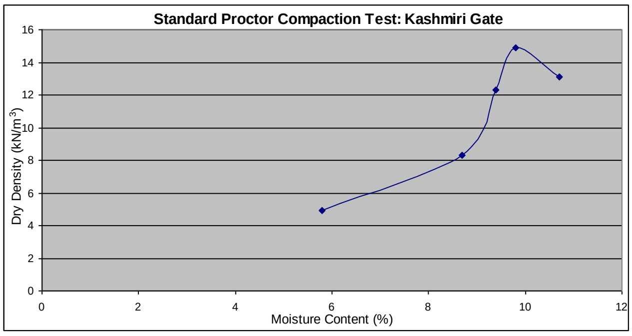
IV. Results

Properties of Soil Samples: All soil samples are examined for their basic soil properties, grain size distribution, atterberg limits and standard proctor test before carrying out specific engineering tests on the soil samples. For determination of grain size distribution, the soil was passed through a set of test sieves having an opening size in mm (according to Indian standard, IS: 2720 part (IV), 1975) as follows:- 20, 10, 6.25, 4.75, 2, 1, 0.425, 0.15, 0.075, and 0.002. Since clay particles are less than 10%, hydrometer analysis was not conducted for finer particles. The results of all these tests are given in table 1 for all five locations of study areas. From the grain size distribution curve it is clear that the soils of all five sampling locations are sandy in nature. The soils from Srinivaspuri, Sunhari Masjid and Botanical gardens belong to well graded group whereas soils from Nizamuddin and Kashmiri Gate locations are poorly graded. Typical values of MDD and OMC for the different soil samples are presented in Figure 3.The increase in OMC is due to increasing amount of fines which require more water because of larger surface area.

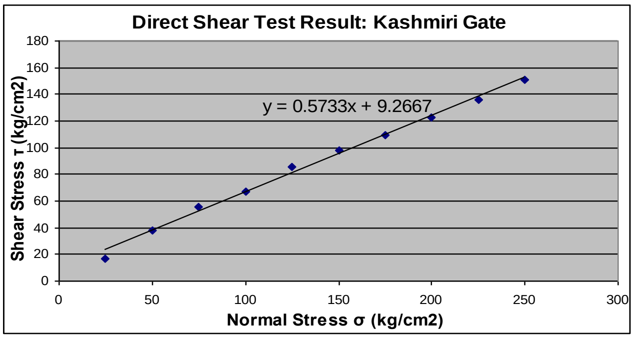
Table 1: Basic properties of Soil Samples

S.N.	Attributes	Srinivaspuri	Sunhari Masjid	Botanical Garden	Nizamuddin	Kashmiri Gate
1	pH	8.4	7.4	8.3	7.91	7.26
2	Electrical Conductivity	897	1152	623	509	352
3	Organic Matters %	0.48	0.68	0.7	2.6	3.5
4	Nitrogen (Kg/Ha)	1609	1096	1572	2903	4562
5	Phosphorus (kg/Ha)	26.8	15.3	<1.0	16.03	48.2
6	Sodium (mg/100gm)	10.56	33.25	10.7	6.12	46.2
7	Calcium (ppm)	2074	3812	2606	1452	5176
8	Potassium(kg/Ha)	63.8	265	111	82.9	485
9	Magnesium (ppm)	78.04	802	279	74.1	396
10	Sand (0.475-0.075 mm), %	67.6	78	80.2	82.6	83.9
11	Silt (0.075-0.002 mm), %	29.46	14	14.8	13.8	12
12	Clay (<0.002 mm), %	2.94	8	5	3.6	4.1
13	Effective size D_{10}, mm	0.006	0.085	0.015	0.023	0.05
14	D_{30} size, mm	0.08	0.18	0.22	0.201	0.15
15	D_{60} size, mm	1.4	0.8	0.8	0.58	0.32
16	Uniformity coefficient, Cu	233	9.4	53.3	25.2	6.4
17	Coefficient of curvature, Cc	0.76	0.476	4.03	3.03	1.4
18	Specific gravity	2.64	2.51	2.66	2.65	2.67
19	Optimum moisture content %	22.2	28	12.8	11	9.8
20	Min. Dry density (kN/m^3)	11.9	12	13.6	14.5	14.9
21	Max. Dry density (kN/m^3)	13.8	15.9	16.9	17.9	18.2

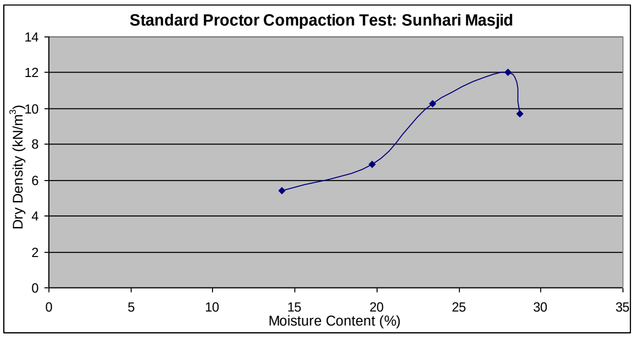
The results show that the stress-strain behaviour is considerably improved by incorporating plastic waste into the soil.



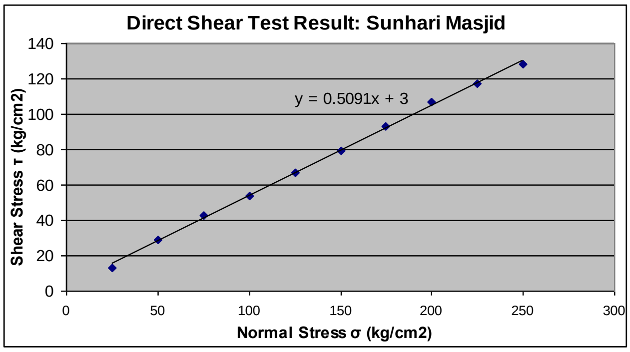
(a)



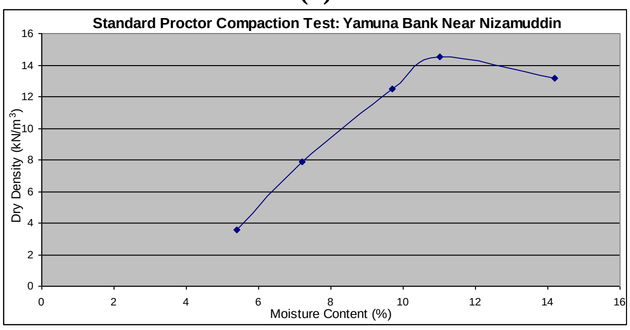
(b)



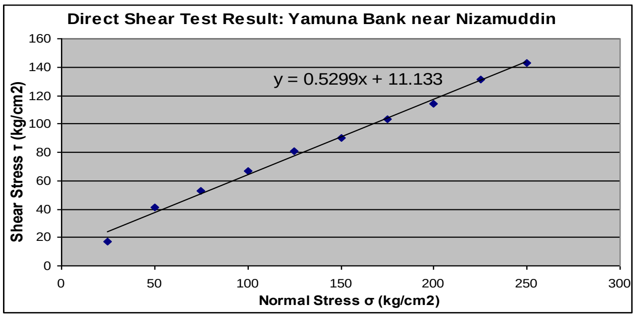
(c)



(d)

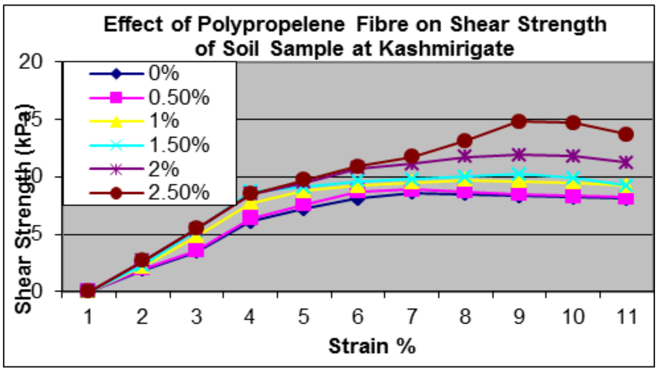


(e)

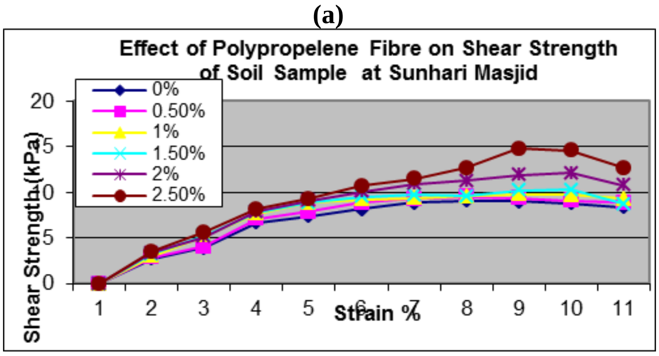


(f)

Figure 2: Optimum Moisture Content vs Dry Density and Normal vs Shear Stress Curves



(a)



(b)

Figure 3: Effect of Polypropylene Fibre on Normal and Shear Load and Strain Variations

V. Conclusion

Optimum Moisture content increases in case of fine soils due to increase in surface areas. Addition of Randomly Distributed fibres gives better shear strength in case of well graded samples as compared to poorly graded samples. Shear strength corresponding to normal stress increases with increase in percentage of fibres. Polypropylene fibre which is commonly known as nylon can be used as reinforcing elements in soils in order to enhance their parameters for effective use in various civil engineering applications.

References

[1] Ahmad F, Bateni F, Azmi M. Performance evaluation of silty sand reinforced with fibers. Geotextiles and Geomembranes 2010; Vol. 28(1):93-99.

[2] Akbulut, S., S. Arasan and E. Kalkan, 2007. Modification of clayey soils using scrap tire rubber and synthetic fibers. Applied Clay Science, 38: 23-32.

[3] Al- Refeai, T.O. (1991). "Behavior of granular soil reinforced with discrete randomly oriented inclusions", Geotextile and Geomembranes, 10, 319-333

[4] Attom, M.F. and Al-Tamimi, A.K., 2010, Effects of Polypropylene Fibers on the Shear Strength of Sandy Soil International Journal of Geosciences, pp 44-50

[5] Bowles, J.E., 1978. Engineering Properties of Soil and Their Measurements. 2nd Edn., McGraw-Hill, United States, New York, ISBN: 007006752X pp: 312.

[6] Carraro, J.A.H., J. Dunham-Friel and M. Smidt, 2008. Beneficial Use of Scrap Tire Rubber in Low Volume Road and Bridge Construction with Expansive Soils. (USDOT-MPC/274 INTERIM REPORT), Department of Civil and Environmental Engineering, Colorado State University.

[7] Chong, S.Y. and K.A. Kassim, 2014. Consolidation characteristics of lime column and Geotextile Encapsulated Lime Column (GELC) stabilized pontian marine clay. Electron. J. Geotech. Eng., 19A: 129-141.

[8] Chore, H.S. Kumthe, A.A., Abnave, S.B., Shinde, S.S. Dhole S.S., and Kamerkar S.G., 2011, Performance evaluation of polypropylene fibers on sand-fly ash mixtures in highways Journal of Civil Engineering (IEB), 39 (1) 91-102

[9] Consoli NC, da Fonseca AV, Cruz RC, Silva SR. 2011., Voids/cement ratio controlling tensile strength of cement-treated soils. Journal of Geotechnical and Geoenvironmental Engineering; Vol. 137(11), pp 126-131.

[10] Consoli, N.C., Vendruscolo, M. A., Fonini, A., and Dalla Rosa., (2009), "Fiber Reinforcement Effects on Sand Considering a Wide Cementation Range", *Geotextiles and Geomembranes*27:196–203

[11] Day, B.; Chand P and singh, J. (2003). "Influence of Fibers on the engineering properties of soil", In: Proceedings of the Conference on Geotechnical Engineering for Infrastructural Development, 397-399

[12] EuroSoilStab. (2002). *Development of Design and Construction Methods to Stabilize Soft Organic Soils: Design Guide for soft soil stabilization.* CT97-0351, European Commission,

[13] Freilich, B.J., Li, C., and Zornberg, J.G. (2010). "Effective shear strength of fiber-reinforced clays". 9th International Conference on Geosynthetics, Brazil, 2010, 1997-2000.

[14] Gray, D.H. and Ohashi, H. (1983). "Mechanics of fiber reinforcement in sand", Journal of Geotechnical Engineering, ASCE, Vol. 109(3), pp 335-353

[15] Guney, Y., Sari, D., Cetin, M., and Tuncan, M. (2007). Impact of cyclic wetting–drying on swelling behavior of lime-stabilized soil. Building and Environment. 42, 681-688.

[16] Hejazi, S.M., M. Sheikhzadeh, S.M. Abtahi and A. Zadhoush, 2012. A simple review of soil reinforcement by using natural and synthetic fibers. Construction and Building Materials, 30: 100-116.

[17] Huat, B. B. K. (2007). Organic and peats soil engineering, University of Putra, Malaysia, 5-11.

[18] IS: 2720(Part 10), 1991 Methods of Test for Soils, Determination of unconfined compressive strength.

[19] IS: 2720(Part 13), 1986 Methods of Test for Soils, Direct shear test.

[20] Kumar, Praveen and Singh, S.P. (2008). "Fiber reinforced fly ash sub-bases in rural roads", Journal of Transportation Engineering, ASCE, 134(4), 171-180

[21] Li C., (2005), "Mechanical Response of Fiber-Reinforced Soil", Ph.D. Dissertation, University of Texas, Austin, USA.

[22] Li, G.X., CHEN, L., ZHENG, J.Q. & JIE, Y.X. 1995. Experimental study on fibre-reinforced cohesive soil. Journal of Hydraulic Engineering, 6, 31-36.

[23] Loehr. , J. E., Axtell, P. J., Bowders, J. J. (2000). "Reduction of soil swell potential with fiber reinforcement". GeoEng2000.

[24] Maher, M.H. and Gray, D.H., 1990. "Static response of sands reinforced with randomly distributed fibres." Journal of Geotechnical Engineering, ASCE, Vol.116(7), pp.1661-1677

[25] Malekzadeh, M., and Bilsel, H., 2012. Effect of Polypropylene Fiber on Mechanical Behaviour of Expansive Soils, Europian Journal of geotechnical Engineering (EJGE), Vol. 17, Bund. A, pp 55-63

[26] McGown, A., Andrawes, K.Z., Hytiris, N and Mercer, F.B., 1985. "Soil strengthing using randomly distributed mesh elements." Proc. 11th International Conf. on Soil Mechanics and Foundation Engg., San Francisco, Vol.3, pp.1735-1738

[27] Ninov, J., I. Donchev, A. Lenchev, I. Grancharov, 2007. Chemical Stabilization of Sandy-siltyIllite Clay. Journal of the University of Chemical Technology and Metallurgy, 42(1): 67-72.

[28] Olaniyan, O.S., R.A. Olaoye, O.M. Okeyinka, D.B. Olaniyan, 2011. Soil Stabilization Techniques Using Sodium Hydroxide Additives. Internal Journal of Civil & Environment Engineering IJCEE-IJENS Vol: 11 No: 06.

[29] Onyelowe Ken C. and Okafor F.O., 2012. A COMPARATIVE REVIEW OF SOIL MODIFICATION METHODS, Asian Research Publishing Network (ARPN) Journal of Earth Sciences ISSN 2305-493X, VOL. 1, NO. 2, pp 36-41

[30] Prabakar, J., N. Dendorkar, R.K. Morchhale, 2004. Influence of fly ash on strength behavior of typical soils. Construction and Building Materials, 18: 263-276.
[31] Puppala, A.J., Musenda, C., (2000) "Effect of fibre reinforcement on strength and volume change in expansive soils", Transportation Research Record, Paper No:00-0716, pp. 134-140.
[32] Ramaji, A. Esmaeil, 2012. A Review on the Soil Stabilization Using Low-Cost Methods Journal of Applied Sciences Research, vol. 8(4): 2193-2196, ISSN 1819-544X
[33] Sharifah Zaliha, S.Z., Kamarudin, H., Mustafa Al Bakri, A.M., Binhussain, M., and SitiSalwa, M.S., 2013, **Review on Soil Stabilization Techniques,** Australian Journal of Basic and Applied Sciences, 7(5): 258-265,
[34] Tang CS, Shi B, Zhao LZ. 2010. Interfacial shear strength of fiber reinforced soil. Geotextiles and Geomembranes, Vol. 28(1), pp 54-62.
[35] Yang, G., H. Liu, P. Lv and B. Zhang, 2012. Geogrid-reinforced lime-treated cohesive soil retaining wall: Case study and implications. Geotext. Geomembranes, 35(0): 112-118.
[36] Yetimoglu T, Salbas O. 2003. A study on shear strength of sands reinforced with randomly distributed discrete fibers. Geotextiles and Geomembranes; vol. 21(2):103-110.
[37] Yetimoglu, T., Inanir, M., and Inanir O.E., 2005. A study on bearing capacity of randomly distributed fiber-reinforced sand fills overlying soft clay. Geotextiles and Geomembranes, 23 (2) pp 174-183. DOI: 10.1016/J.GEOTEXMEM.2004.09.004
[38] Yi, C., Bin S., Chaosheng T., And Baojun, W., 2006, Pilot study on the mechanical behaviour of soil with inclusion of polypropylene fibre and lime, IAEG2006 Paper number 637, pp 1-6
[39] Zhang, X.J., Zhou, K.J. & Zhou, J.X. 1998. Experimental study on dynamic properties of cohesive soil reinforced with fibres. Chinese Journal of Geotechnical Engineering, Vol. 20(3), pp 45-49