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IMPROVEMENT IN UNCONFINED COMPRESSION STRENGTH OF FLY ASH STABILIZED BC SOIL WITH PET FIBRES

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Abstract: Due to the increasing in population and the reduction of available land, more & more civil engineering project have to be carried out on BC soil. Such soil having poor strength and high swelling & shrinking potential, leads to adopt ground improvement techniques. Admixtures, such as fly ash & synthetic fibres are frequently used in practice to stabilize BC soil. This paper present the effect of PET fibres (Polythylene teraphthalate) on the unconfined compressive strength of BC soil-fly ash composite. The main motive of this study was to investigate the innovative reuse of waste PET fibre. The samples of fly ash stabilized BC soil were tested with PET fibres ranging from 1 to 5% by dry weight and cured for 3,7,14,21 & 28 days, after they were tested for unconfined compression test. The results indicated that the unconfined compressive strength of BC soil-fly ash mixes can be greatly improved by the inclusion of randomly oriented PET fibres.

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INTRODUCTION

It is well known that considerable improvement may be made in the geotechnical properties of soil by the incorporation of inclusion in the soil, and that soil reinforcement is not a mid 20th century inventions, most of the natural, animal and early manmade soil reinforcement is achieved through plant roots and animals use combinations of soil and sticks in building their habitat.

Over the last few years, environmental and economic issues have stimulated interest in the development of alternative materials that can fulfill design requirements. The well-established technique of BC soil-fly ash stabilization by the inclusion reinforcement in the form of discrete fibres shows significant modification and improvement in geotechnical properties of BC soil-fly ash mixes.

Black cotton soil covers 30% of the land area in India, a large deposits of black cotton soil exists in a state like Rajasthan, Madhya Pradesh, Gujrat, Telangana, Andhra Pradesh and Maharashtra. These soils show high swelling, shrinking, and compressibility poor strength in contact with moisture creating cracks in the upper surface of temporary roads. The name 'Black cotton soil' has an agricultural origin most of these soils are black colour and suitable for growing cotton. The swelling property is due to presence of montmorillonite mineral.

Fly ash is an essential industrial by product that comes from the burning of coal, utilized for the production of electricity in the country like India, only a small percentage of this is used for the construction activity, while most of the portion is dumped, which causes a serious threats to environment. It has been found that stabilization with fly ash, modifies the engineering and mechanical properties of a soil, so it is a viable option to use fly ash as a admixture. Also, fly ash can provide an array of divalent and trivalent (ca^{2+}, $Al_3^+Fe_3^+$) under ionized condition that can promote flocculation of dispersed clay particles.

For sustainable development, use of locally available waste material should be encouraged in order to save natural resources for future generation, hence in recent years, the use of fibres in various fields have gained much importance. The plastic waste materials are produced plentifully such polyethylene terephthalate (PET) plastic bottles, polypropylene (PP) of plastic sack polypropylene (PP) of carpet.

But such materials have been used little for engineering purpose, and the large amount have been placed in storage or disposal sites. The inclusion of randomly oriented, discrete tensile reinforcement in BC soil-fly ash composite offers good solution to problem of instability.

Randomly distributed fibres offer strength isotropy and limit potential plane of weakness that can develop parallel to oriented reinforcement. This technique has become a centre of interest in recent years. Randomly distributed fibre reinforced soil-fly ash composite may be used in a variety of application such as embankment, sub grade/ sub-base of pavement & shallow foundation.

The main objective of this study is to evaluate the strength behavior of randomly distributed PET fibre (1 cm in length and 0.5 cm wide) reinforced BC soil-fly ash mixture. A series of unconfined compression test were carried out on sample of BC soil, stabilized with fly ash with different percentage of PET fibre.

2. LITERATURE SURVEY

Hoare D.J. (1979), the study was undertaken as a preliminary investigation aimed at determine the feasibility of using randomly oriented discrete fibres as a inclusion to improve the properties of a soil, a granular soil reinforced with polypropylene fibres (in the form of twisted and stapled) was tested to evaluate strength parameters, concluded that both strength and ductility increases considerably by the inclusion of randomly oriented discrete fibres.

Nilo Cesar Consoli et.al., (2002), conducted unconfined compression test, split tensile test on a sand reinforced with randomly distributed waste PET fibre derived from recycling waste plastic bottles. The results show that the polyethylene terephthalate fibre reinforcement improved the peak and ultimate strength of sand.

Muntohar A.S. (2009), studied the strength of stabilized clay-soil reinforced with randomly distributed plastic waste fibres by carrying out unconfined compressive strength and tensile split strength test. The effect of the fibre length & content on the compressive & split tensile strength was investigate included that inclusion of the plastic waste fibre increased significantly both the unconfined compressive strength and tensile split strength of stabilized clay soil, it is also concluded that fibre length plays s significant contribution in increasing the soil strength.

Arvind kumar et.al., (2007), An experimental program was undertaken to evaluate the effect of polyster fibre addition & lime stabilization on the strength properties of fly ash-soil mixture, conducted unconfined compression test and split tensile test on fly ash expansive soil mixture with different % of lime and randomly oriented fibres after 7,14 & 28 days curing of sample. The content of fibre was varied from 0-2% by dry weight, concluded that the expansive soil can be successfully stabilized by the inclusion of fibre.

Pradip D. Jadhao et.al, (2008), conducted a series of unconfined compression strength test on the soil fly ash. The soil-fly ash sample was tested with polypropylene fibre at different % of fibre ranging from 0 to 1.5%. The effect of fibre length was also noted, concluded that the inclusion of randomly distributed fibers significantly increased UCS.

Arvind kumar, Baljit sing Walia et. al., (2006) used polyster fibres as reinforcement in soft clay, to investigate the relative strength gain in terms of unconfined compression. The samples were tested in UCS test with varying % of fibres ranging from 0-2.0% the fibres was plain & crimped, concluded that unconfined compressive strength of clay increases with the addition of fibers & sand.

Yl Cai et.al, (2006) studied soil sample at six different fibre (%) –Lime (%) i.e. 00-0%, 0-2%, 00-8%, 01-8%, 01-6% and 02-6% by weight of raw soil, conducted a series of unconfined compression test & other index tests, concluded that inclusion of polypropylene fibre and lime in soil can greatly improve compression and shear strength, reduce the capacity of swelling and shrinkage and transfer the failure characteristic of soil from brittle to ductile.

Sujeet kumar, Rakesh kumar Dutta (2014) studied the effect of sisal fibres on the unconfined compressive strength of bentonite clay. The bentonite clay was stabilized with lime phosphogypsum & reinforced with sisal fibres. The fibre content was varied from 0.5 to 2%, the result indicated that the unconfined compressive strength of bentonite clay can be increased by the addition of lime, phosphogypsum and sisal fibres. The highest strength was observed at 8% lime, 8% phosphogypsum and 1% sisal fibres.

Kalpana Maheshwari et.al, (2009) studied the effect of polypropylene fibres on the unconfined compressive strength of soft clay. The fibre was varied from 0% to 2.0%. A significant improvement was reported in the ucs of soft clay.

Nilo Cesar Consoli et. Al., (2010) the study aimed to verify the difference in the strength of an artificially cemented sandy soil with and without fibre reinforcement a series of unconfined compression test and suction measures were carried out, reported that fiber insertion in the cemented soil, for the whole range of cement, increase in the unconfined compression strength.

K. Suresh et.al., (2009) an investigated the effect of stone dust and polypropylene fibers on engineering & strength properties of the black cotton soils, reported the addition of optimum dose of stone dust (3%) and optimum dose of fibres (0.6%) improves the strength characteristics of sub grade soil.

Eng chew et.al., (2003), conducted laboratory unconfined compression test on specimen of compacted silty clay to evaluate the effect of the size of specimen used for strength testing of fibre reinforced soil, on the measured strength & stress-strain properties, indicated that there is a significant effect of sample size both in terms of the magnitudes of measured strength as well as in terms of the variability of the measured strength, also reported that the effect of specimen size is found to most important for specimens compacted dry of the optimum moisture.

K.R. Narayana Swamy Shetty et.al., (1987) studied the effect of synthetic fibre on the strength characteristics of locally available lateritic soil, used fibre in the form of randomly oriented with an aspect of about 25, triaxial shear, CBR and tensile strength test are selected as basic engineering test to investigate the effect of inclusion of fibre reinforcement on the strength behavior of the lateritic soil.

Chaosheng Tang et. al., (2007) investigated the effect of discrete short polypropylene fibre on the strength and mechanical behavior of uncemented & cemented clayey soil. The content of fibre was ranged from 0.05% to 0.25% by weight of soil, carried out unconfined compression & direct shear after 7,14 & 28 days curing period, indicated that the inclusion of fibre reinforcement within stabilized soil cause an increase in the unconfined compressive strength, analyzed interaction between fibre face and soil matrix by using scanning electron microscopy.

Khaled Sobhan et.al., (2003) evaluated the mechanical behavior of a soil-cement fly ash composite reinforced with recycled plastic strips (high-density polyethylene), obtained from milk and water container, conducted a series of UCS and split tensile test on cement-fly ash stabilized reinforced with plastic strip soil sample, concluded that soil-cement-fly ash composite, reinforced with plastic strip offers a lot of promise as an alternative material for civil engineering construction.

Sayyed Mahdi et.al., (2012) reviewed the history, benefits, application, and possible executive problems of using different types of natural & or synthetic fibers in soil reinforcement through reference to published scientific data, discussed predictive models for short fibre soil composite, also investigated feasibility of all types fibres have been used in soil reinforcement projects.

Mrs. Gosavi et.al., (2003) investigated the strength behavior of locally available black cotton soil reinforced with randomly oriented geotextile woven fabric & fiberglass fibre reported an increase in the value of cohesion & slight decrease in the value of angle of internal friction with addition of 2% of these fibres in black cotton soil.

C. Rajkumar et.al. (2014), studied industrial and agricultural wastes such coal ash, groundnut shell and bagasse as a stabilizing agent for a highly expansive soil. A series of unconfined compressive strength and CBR was carried out at various combinations of coal ash and natural fibres.

Acharyya R. et.al. (2013), conducted a series of unconfined compression & triaxial compression on a locally collected clayey soil reinforced with randomly mixed PET bottle strip. The % of PET fibre was varied from 0.5% to 2% by weight with different aspect ratio, indicated that the soil shows a significant increase in cohesion & slight decrease in angle of internal friction (μ overall increase in shear strength).

Gopal Ranjan et.al., (1994) reviewed different models for predicting the increase in strength of reinforcement developed by different researchers, concluded that the force-equilibrium method, with proper estimation of the width of shear zone may be recommended for analysis of reinforced soil. The model proposed by Maher and Gray (1990) has predicted reasonable well increase in the strength of randomly distributed fibre reinforced soil, the overage expected orientation of fibres was assumed to the perpendicular to the plane of shear failure. The failure plane was assumed to be the same as given by Mohr-coulomb failure criterion.

Prof. S. Ayyappan et. al., (2010), conducted a series of unconfined compression on soil-fly ash specimens, a polypropylene with different fibre length (6mm, 12mm and 24mm) and content (0-1.5% of dry weight were used in the study, reported a significant improvement by the inclusion of randomly distributed fibres in the unconfined compressive strength of soil-fly ash mixes.

3. EXPERIMENTAL PROGRAM

3.1 Materials

3.1.1 Black Cotton Soil

Natural black cotton soil samples were collected from Green park area, Pusad, this soil was predominantly expansive and its engineering properties were found as given in table no. 3.1.

Table 3.1: The engineering properties of the BC soil

Sr. No.	Properties	Values

1	Liquid Limit	72.66%
2	Plastic Limit	32.55%
3	Shrinkage Limit	***
4	Plasticity Index	39.91%
5	Free swell Index	61.11%
6	Compaction parameters maximum Dry Density (γ_d) Optimum moisture content	61.11% 1.5 gm/cm³ 29%
7	Unconfined Compressive Strength	52.39 KN/m³
8	IS Classification of soil	CH

3.1.2 Fly Ash

Fly ash is silt – size non cohesive material having a relatively smaller specific gravity than the normal soils. The chemical, physical and engineering properties of ash depends on the type and source of coal used, method and degree of coal preparation, cleaning and pulverization, type and operation of power generation unit, ash collection, handling and storage methods etc. So the properties of fly ash vary from plant to plant and even within the same plant.

The fly ash used in this work was procured from "Koradi Thermal Power Plant, Nagpur'' Its chemical properties are given in table 3.2.

Table 3.2: Chemical composition of fly ash

Sr. No.	Chemical constituents	Average%
1	Silica	40.18
2	Iron oxide	6.48
3	Calcium oxide	1.23
4	Titanium oxide	0.04

5	Potassium oxide	0.18
6	Magnesium oxide	0.14
7	Phosphorous pentaoxide	0.19
8	Sulphur trioxide	0.04
9	Disodium oxide	0.05
10	Aluminium	1.42
11	Manganese	0.02
12	Chloride	194mg/kg

3.1.3 Fibres

Fibres used in the present investigation were cut in to pieces from locally available waste PET mineral water bottle. A photograph of the short PET fibre is given in fig 3.1. The polyethylene terephthalate (PET) fibres used was (2 cm x 0.5 cm) with varying percentage, 1 % to 5 % by dry weight of soil.

The physical properties of PET fibres are given in Table 3.3.

Table 3.3: Physical Properties of Fiber

Properties	**Values**
Fibre Length	1 cm
Fibre Width	0.5 cm
Fibre Thickness	0.1 mm
Specific Gravity	1.33
Tensile Load	3.5 Kn

Melting Point	245 ^{0}C to 260 ^{0}C

Fig. 3.1 : Polyethylene Terephthalate (PET) Fibers

3.2: Laboratory Test

The conventional unconfined compression tests were performed on a 50 kN. universal testing machine. The loading rate was maintained as 1.25 mm/min. The tests were conducted in accordance with IS: 2720 part-10, 1991.

3.3: Sample Preparation

The fiber-reinforced specimens were prepared by manual mixing dry BC soil, fly ash, water and chopped PET fibres. During the mixing operation, water was previously been added to the fibres to prevent them from floating. Specimens were statically compacted. The known amount of BC soil-fly ash-PET fibre mix was placed in to cylindrical mould of size 50 mm dia x 100 mm high (fig. 3.2). During filling, the mix was tamped gently and uniformly so that the upper plug can be inserted about 15 mm. The assembled mould was then placed on compression machine and a force was applied until the upper plug was in contact with the barrel of the mould.

Fig. 3.2 : Cylindrical mould (50 mm x 100 mm)

3.4: Sample Proportion

The general expression for the total dry weight W of a soil fly ash fiber mixture is

$$W = W_s + W_f + W_p \quad (1)$$

Where, Ws, Wf and Wp are weights of soil, fly ash and plastic fiber respectively. The proportions of soil, fly ash and plastic fiber in soil fly ash mixture are defined as the ratio of their respective dry weight to the combined dry weight of soil fly ash. Thus, above equation can be written as

$$W = (P_s+P_f+P_p)(W_s+W_f) \quad (2)$$

Where Ps= proportion of soil= Ws/ (Ws+Wf); Pf= proportion of fly ash =Wf/ (Ws+Wf) and Pp=Plastic fiber content =Wp/ (Ws+Wf).

The sum of Ps and Pf is unity. The different values will be adopted in this study for Ps, Pf and Pp.

4. RESULT & DISCUSSION

The effect of fibre inclusion on the Unconfined Compressive Strength was determined as a function of fibre content. Primarily, the tests were performed on Un-reinforced Soil-Fly ash to establish base about Unconfined Compressive Strength so that a relative gain in Unconfined Compressive Strength due to addition of Waste PET Fibres could be estimated.

4.1 Effect of Fly ash on Strength Behavior of Black Cotton Soil

Fig. 4.1 shows the variation of Unconfined Compressive Strength of Black Cotton Soil with varying percentage of Fly ash at different curing days without Waste PET Fibres. It is observed that, an increase in the values of UCS is gradual and relatively small for smaller curing periods of 7 days and 14 days. The improvement in the UCS is comparatively better for a longer curing period of 28 days; as can be seen from the graph pertaining to 28 days curing. The relative increase in the UCS is thus observed maximum when a curing of 28 days is allowed.

It is seen that the strength increases on addition of small percentage of 20% to 30% of fly ash. Further increase in fly ash percentage shows no considerable increase in the strength. This is due to the probable disturbance of soil skeleton and consequent reduction in cohesion. The strength of soil is observed to improve considerably with curing time which is due to the pozzolanic reactivity of the free lime content of the fly ash. The UCS of fly ash stabilized soil at 28 days curing is nearly about three to four times the UCS of virgin soil.

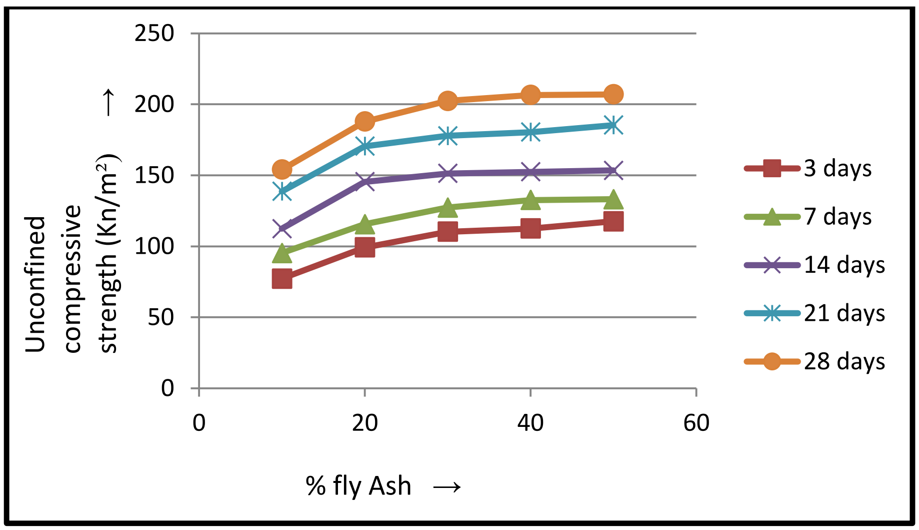

Fig. 4.1 : Variation of Unconfined Compressive Strength with Percentage of fly ash and curing periods

4.2 Effect of Waste PET Fibres on Strength Behavior of Fly ash stabilized Black Cotton Soil

Fig. 4.2 shows the Unconfined Compressive Strength of fly ash stabilized BC Soil with 25 % of fly ash and varying percentage of Waste PET Plastic Fibres (1% to 5%) at different curing days. Fibre inclusion affected the UCS of fly ash stabilized BC Soil showing increase in the peak compressive strength.

It is observed that UCS increases considerably with increasing percentage of waste PET plastic fibres but upto 3 % and beyond that it decreases. The increase in the values of UCS is gradual and relatively small for smaller curing periods of 3 days to 14 days. The improvement in the UCS is comparatively better for a longer curing period of 21 to 28 days; as can be seen from the graph. The relative increase in the UCS is thus observed optimum with 28 days of curing. It is observed that the strength increases on addition of small percentage of 2% to 3% of fibres. Further increase in fibre percentage shows decrease in the strength of Black Cotton Soil. The UCS is found optimum with 3% of waste plastic fibres and 28 days of curing. The UCS of fly ash stabilized soil with 3% fibres at 28 days curing is nearly about 30% to 40% more the UCS of fly ash stabilized soil.

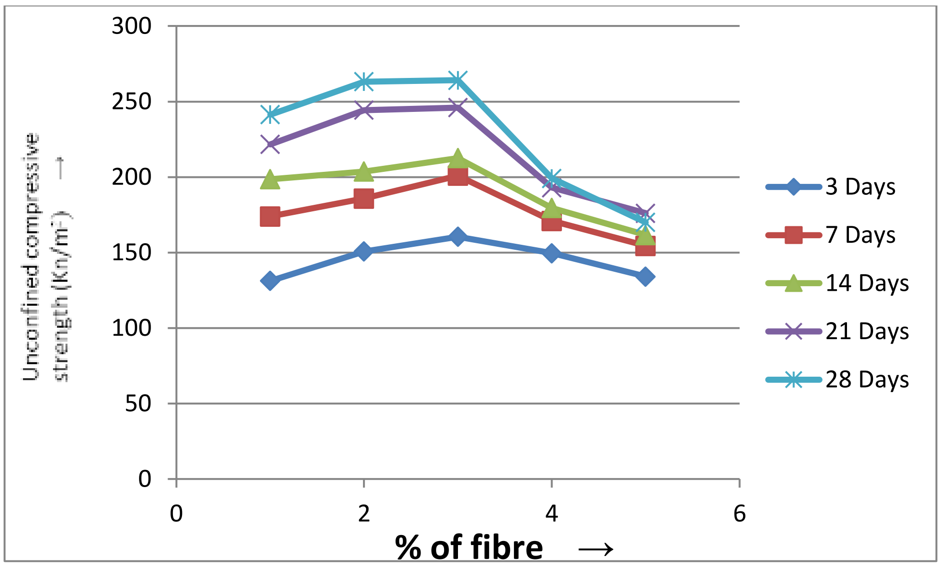

Fig. 4.2 : Variation of Unconfined Compressive Strength of fly ash stabilized BC Soil with % of PET Fibre and curing periods

By comparing Unconfined Compressive Strength, it is observed that inclusion of waste plastic fibres improves the Unconfined Compressive Strength of fly ash stabilized soil significantly than that of fly ash alone. The Unconfined Compressive Strength of fly ash stabilized soil with 3% fibres at 28 days curing is nearly about 4 to 5 times the Unconfined Compressive Strength of virgin soil.

The increase in Unconfined Compressive Strength due to addition of polyethylene terephthalate (PET) fibres is measured in the terms of relative gain (Gpf), which is defined as-

$\% \, q_{ug} = (q_{uFP} - q_{uF}) / q_{uF}$

Where q_{uF} **–** UCS of un-reinforced soil – fly ash specimens,

and q_{uFP} **–** UCS of reinforced soil – fly ash specimens.

It was observed from the results that q_{ug} increases as q_{uF} decreases.

The result shows that, Unconfined Compressive Strength (UCS) of fly ash stabilized soil increases with fibre content. The increase was significant up to fibre content of 3.00 % by weight.

5. CONCLUSION

On the basis of the present study, the following conclusion are made

- Fly ash is beneficial in improving properties of BC soil. With the increase in the percentage of fly ash and curing days, unconfined compressive strength tends to increase and reaches a certain maximum value and thereafter it starts decreasing. By the addition of fly ash, the unconfined compression strength is increase by 275% as compared to virgin soil at 28 days curing. An optimum dose of fly ash is lying in between 20-30%.
- The unconfined compressive strength of reinforced BC soil-fly ash with PET fibre was affected mostly by the amount of fibre and curing period there is significant increase in unconfined compressive strength with the inclusion of PET fibres. The unconfined compressive strength of fly ash stabilized BC soil with 3% fibre at 28 days curing nearly about 30-40% more than UCS of fly stabilized soil.
- In a fly ash mixes, the increase in strength is due to flocculation of dispersed clay particle promoted by cations in fly ash.
- In a BC soil fly ash mixes the increment in strength is due to the change in the physical properties by the addition of PET fibres. The interfacial friction and bond strength seem to be the dominant mechanism controlling the reinforcement benefit.

REFERENCES

1. Jadhao, P. D. and Nagarnaik P. B. (2008), “Influence of Polypropylene Fibres on Engineering Behavior of Soil−Fly Ash Mixtures for Road Construction”, *EJGE*, Vol. 13, bund. 3.

2. Kumar, P. and Singh S. P. (2008), "Fibre-Reinforced Fly Ash Sub bases in Rural Roads", *Journal of transportation engineering*, Vol.134, No. 4, pp 171-180.

3. Chaosheng Tang., Bin Shi., Wei Gao,. Fengjun Cai Chen,. Yi. (2007), "Strength and mechanical behavior of short polypropylene fibre reinforced and cement stabilized clayey soil", Geotextiles and Geomembranes, ELSEVIER, vol.25, (3), pp 194–202.

4. K.Suresh, V. Padmavati and Apsar Sultan, "Experimental study on stabilization of black cotton soil with stone dust and fibres", IGC 2009, Guntur, INDIA.

5. Prof. S. Ayyappan, Ms. K. Hemalatha and Prof. M. Sundaram, (2010), "Investigation of Engineering Behavior of Soil, Polypropylene Fibres and Fly Ash -Mixtures for Road Construction", International Journal of Environmental Science and Development, Vol. 1, No. 2.

6. IS: 2720, Part 10, (1991), "Determination of unconfined compressive strength. Indian standard methods of test for soils", Bureau of Indian Standards, New Delhi, pp 1-4.

7. Nilo Cesar Consoli, Julio Portella, P.D.M. Prietto and Pasa, Giovana Savitri., (2002), "Engineering behavior of sand reinforced with plastic waste". Journal of Geotechnical and Geoenvironmental Engg., ASCE vol. 128 (6), pp. 462-472.

8. Jadhao, D. P. and Nagarnaik, P.B., (2008) "Performance Evaluation of Fibre Reinforced Soil-Fly Ash Mixtures", the 12th International Conference of International Association for Computer Methods and Advances in Geomechanics *(IACMAG)* Goa, India.

9. Muntohar, A.S., (2009), "Influence of Plastic Waste Fibres on the strength of Lime-Rice husk ash stabilized clay soil", Civil Engineering Dimension, Vol.11, No.1, pp 32-40.

10. Arvind Kumar, Baljit Singh Walia, Jatindar Mohan, (2005), "Compressive strength of fibre reinforced highly compressible clay", Construction and building materials ELSEVIER vol. 20, pp 1063-1068.

11. Arvind Kumar., Baljit Singh Walia, Asheet Bajaj. (2007), "Influence of fly ash, lime and polyster fibre on compaction and strength properties of expansive soil". Journal of materials in civil engineering ASCE, vol. 19, (3), pp 242-248.

12. Eng. Chew Ang., J. Erik Loehr. (2003). "Specimen size effect for fibre- reinforced silty clay in unconfined compression". Geotechnical testing journal, vol. 26 (2), pp 1-10.

13. Yi Cai., Bin Shi., Chaosheng Tang., Baojun Wang. (2006). "Pilot study on the mechanical behavior of soil with inclusion of polypropylene fibre and lime" The geological society of London, IAEG paper no. 637, pp 1-6.

14. Prof. S. Ayyappan, Ms. K. Hemalata, Prof. M. Sundaram. (2010). "Investigation of Engineering Behavior of Soil, Polypropylene Fibers and Fly Ash-Mixtures for Road Construction" . International journal of Environmental Science & Development, vol. 1 (2), pp 171-175.

15. Sujit Kumar, Rakesh Kumar Datta. (2014). "Unconfined Compressive Strength of Bentonite-Lime-Phosphogypsum Mixture Reinforced with Sisal Fibres". Jordon Journal of civil engineering, vol. 8 (3), pp 239-250.

16. Kalpana Maheshwari, C.S. Solanki. (2009). "Behavior of Fibre Reinforced Soil" Australian Geomechanics, vol 44 (4), pp 65-74.

17. Gopal Ranjan, R.M. Vasan, H.D. Charan, (1994). "Mechanism of fibre-reinforced soil-state of the art" Indiana Geotechnical Journal, vol. 24 (3), pp 242-261.

18. Khled Sobhan., Mehedy Mashnad., (2003). "Mechanical Stabilization of Cemented Soil-Fly Ash Mixtures with Recycled Plastic Strips". Journal of Environmental Engineering, vol. 129 (10), pp 943-948.

19. Sayyed Mahdi Hejazi, Mohammad Sheikh zadeh, Sayyed Mahdi Abtahi, Ali Zadhoush. "A simple review of soil reinforcement by using natural and synthetic fibers" construction and building materials ELSEVIER vol. 30, pp 100-116.

20. Haore D.J., (1979). Laboratory study of granular soils reinforced with randomly oriented discrete fibres. University of Birminghan U.K, pp 47-50.

21. Mrs. M. Gosavi, Dr. K.A. Patil, Dr.S. Mittal & R.S. Saran(2004),"Improvement of properties of black cotton soil subgrade through reinforcement", Journal of the Institution of Engineers(India) ,vol.84,p.p.257-262

22. K.R. Narayana Swamy Setty, S.V. Gopal Krishna Rao (1987) "Characterization of Fibre Reinforced Lateritic Soil" Indian Geotechnical Conference, Banglore, vol. 1, pp 329-331.

23. Nilo Cesar Consoli, Marcel Antonia Arcari Bassani, Lucas Festugato (2010). "Effect of fiber reinforcement on the strength of cemented soils", Construction and building materials ELSEVIER vol. 28, pp 344-351.

24. K. Suresh, V. Padmavathi, Apsar Sultana. (2009). "Experimental study on stabilization of black cotton soil with stone dust and fibres". Indian Geotechnical Conference, Guntur, vol. 1, pp 502-505.