EFFECT OF POLYPROPYLENE FIBRES ON THE INDEX AND COMPRESSIVE STRENGTH OF COHESIVE SOILS.

[1]MBAMALU C.F , [2]OYELAKIN, M.A, [3]OKEKE E.C, [4]UMAR L.

[1,2,4]Department of Civil Engineering, Federal Polytechnic Offa, Kwara state, Nigeria [3]Department of Civil Engineering, Akanu Ibiam Federal Polytechnic, Unwana, Ebonyi state, Nigeria

ABSTRACT

The effects of polypropylene (PP) fibres on the index and compressive strength properties of cohesive soils have been studied. The PP fibres were sourced from open dump sites in Offa, Kwara State, Nigeria. They were cleaned and diced to an average size of 50mm by 50mm. Two cohesive soil samples were collected, dried and deflocculated. The index properties of the soils and that of the soil mixed within PP fibres in the percentages of 0.5%, 1%, 1.5% and 2% was determined. Subsequently the test samples were moulded into cubes of 100mm x 150mm x 45mm (WBH) and subjected to compression test with an initial load of 1.0 N and a penetration speed of 2.5mm/min. From the results obtained, both samples were classified as sandy clay (SC) according to the Unified soil classification system (USCS) and A-6 according to the AASHTO classification system. The PP fibres had a negative effect on the plastic and liquid limits of the soil samples as their values continued to decline on the addition of PP fibres and at 2% addition of PP fibres, the sample could no longer be moulded. The PP fibres improved the compressive strength of the soil samples to a peak value of 1.3N/mm2 from 0.3N/mm2 and 1.12N/mm2 from 0.29N/mm2 for samples one and two respectively. These peak values were attained on the addition of the PP fibres at 0.5%. The young modulus (stiffness) and the applied load during penetration followed similar trends on the addition of the PP fibres. The force required to make the samples yield upon loading rose from 5056.1N to 19,322N for sample 1 and rose from 4877.5 N to 18562.1N for sample 2 on the addition of the PP fibres at 0.5%. This value started decreasing as the volume of the PP *sample was increased. The findings gotten from this research suggests that PP fibre is a good stabilizer for soils classified as SC or A-6 and 0.5% should be used to achieve optimal strength. However, it can be added up to 2% in cases where the intent is to re-use or safely dispose the PP.*

Keywords: *Polypropylene (PP), AASHTO classification, compression test.*

INTRODUCTION

The relative abundance of polymer products in the environment has continued to be on the increase despite the global efforts put in place to reduce environmental pollution caused by polymer waste. PP polymers are harmful because they are non-biodegradable and they have caused huge water pollution in our oceans and some of the aquatic lives consume them thereby making humans susceptible to various degrees of illnesses when they eat these contaminated animals.

The use of PP fibre inclusion for the improvement of the mechanical properties of weak soils is a method that has gained wide spread attention in the field of geotechnical engineering. The behaviour of fibre reinforced soils have been a common subject of research for the past 20 years. More specifically, many researchers have focused their research on the mechanical behaviour of fibre reinforced sandy soils (Gray and Ohashi 1983, Shew bridge and Sitar 1990, Maher and Gray 1990, Murray *et al.* 2000, Consoli *et al.* 2002).

The experimental results obtained from these studies indicates that the use of discrete fibres for reinforcing soils consisting of very small particles, like cohesive soils, can substantially improve their strength, hence providing suitable solutions for many issues of geotechnical construction or soil stabilization. Previous studies on reinforced cohesive soils have shown a significant improvement of shear strength (Consoli *et al.* 2003, Casagrande *et al.* 2006, 2007, Falorca *et al.* 2006).

In addition, there is a growing attention to soil reinforcement with different types of fibers. According to Heineck et al. (2005) experimental results gathered, showed the potential of different types of fibers in reinforcing problematic soils. In order to wholly understand the strength behavior of fibered and non- fibered soils, Prabakar and Sridhar (2002) carried out a sequence of experimental works on a non-expansive soil and assessed the suitability of sisal fiber, which is a natural fiber of Agavaceae family traditionally used in making twine and ropes, as a reinforcement material in cohesive soils. Freilich and Zornberg (2010) observed an increase in the shearing strength of the soils with the presence of randomly distributed PP fibers. In 2000, Loehr reported that PP fibers, which is a kind of thermoplastic polymer, appears to be a great potential for reducing the detrimental effects on buildings, earth retaining structures, and roadways induced by expansive soils. However, there are no studies carried out on the effect of PP fibres on the index and compressive strength of cohesive soils. In this experimental investigation, the aim is to study the effect of PP fibres on the index and compressive strength of soils and the objectives will be to collect and prepare two disturbed soil samples from the field, classify the soils, determine its index properties and that of the PP-soil mixtures, determine their compressive strengths, stiffness (young modulus), stress at peak and that of the PP soil mixtures. Also to determine the optimum PP content of the soil mixtures.

MATERIALS AND METHODS

The PP fibres used are traditionally used as twines in packaging market produce like cartons of frozen fishes, cartons of floor tiles and cartons of most house hold appliances they are mostly found in long rectangular strips and were gotten from an open dump site in offa, kwara state, Nigeria. The fibres were washed with clean water and air dried for 3 days. The cleaning process was done to eliminate any possible contamination it must have picked up from the dump site. Furthermore, the fibres were diced manually to an average size of 50mm by 50mm as shown in the figure 1. Two disturbed soil samples were collected from various locations as shown in table 1 for various testing techniques.

Figure 1: PP fibers cleaned and diced to size

Table 1:

Sample Name	Location	Longitude	Latitude
Sample 1	Stadium Fedpoffa	8° 7' 56" N	4° 42' 36" E
Sample 2	Behind Adesoye Hall, Fedpoffa	8° 7' 58" N	4° 42' 55" E

The tests conducted include, Natural moisture content, particle size distribution, specific gravity Atterberg's limit and compressive strength tests using UTM machine. These tests were performed on the natural soil and subsequently on the polypropylene-soil mixture on each sample collected. The samples were mixed at 0%, 0.5%, 1%, 1.5% and 2% by weight of the soil sample (this mix proportion was selected as a trial mix)**.** Soil samples were dried, deflocculated and sieved prior to analysis

The test samples were moulded into cubes of 100mm x 150mm x 45mm (WBH) and subjected to compression with an initial load of 1.0N. the penetration speed is at 2.500mm/min. The values obtained during compression tests until the sample yields are given in table 4.

RESULTS AND DISCUSSIONS

Preliminary tests conducted to determine the natural properties of the soil revealed that the soil samples have relatively low natural moisture content of 15.92% and 11.32% for sample 1 and sample 2 respectively. This is because samples were collected during dry season within a depth of 450mm from the surface. The index properties are summarized in Table 2.

Table 2- Index properties of the natural soils.

Properties	Sample No 1	Sample No 2
Natural moisture Content (%)	15.92	11.32
Liquid limit (%)	34.05	33.28
Plastic limit (%)	29.8	24.72
Plasticity index (%)	4.25	8.56
Specific gravity	1.284	1.018
Percentage passing through No 200 sieve	38.11	37.06
AASHTO Classification	A-6	A-6
USCS classification system	SC	SC

Both samples are classified as sandy clay (SC) according to USCS classification system because of their very low percentage of fines passing through the sieve no. 200 and they were classified as A-6 according to the American association of state highway and transport official (AASHTO). Sample 1 had coarser aggregates with a cumulative retention of 44.25% in the 1.0mm aperture sieve. The second soil sample is less coarse than the first sample as it can be seen on the particle size distribution in fig. 1. It has a cumulative retention of 59.94% in sieve 0.425 and 28.26 grams retained in the pan.

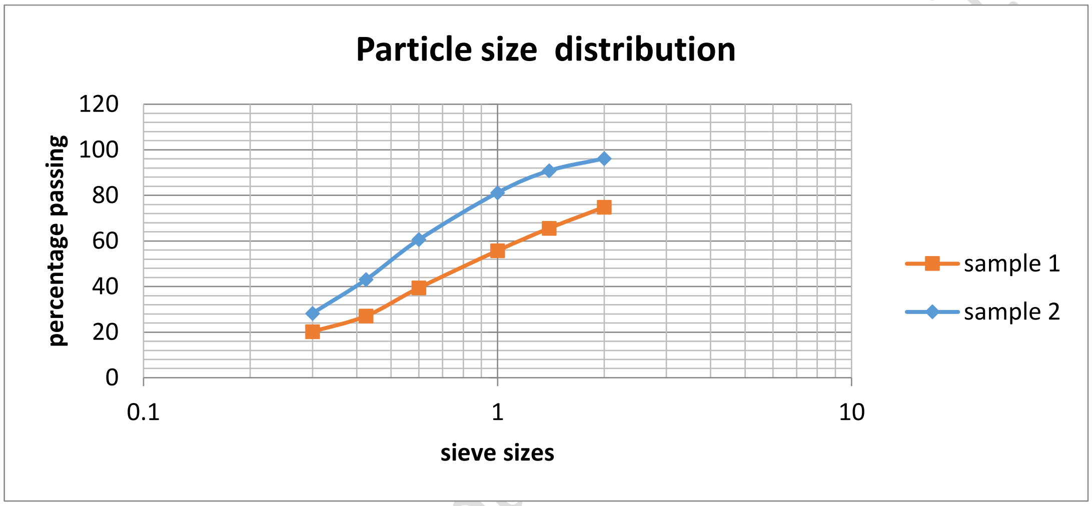

Figure 2. The particle size distribution of the soil samples.

According to the Federal Ministry of Works and Housing (1997) specification (Bello and Adegoke, 2010), only the samples that have percentage passing on No 200 BS sieve less than 35% is suitable for sub base and base materials. Therefore, it can be affirmed that both sample with percentage passing on No 200 BS sieve as 22.17% and 26.60% respectively satisfy these criteria and therefore are sufficient to be used as sub base and base materials.

Table 3; Index property results of the soil-PP mixtures

SAMPLE No	Atterberg limit	0% PP strip	0.5% PP strip	1.0% PP Strip	1.5% PP strip	2.0% PP strip
Sample 1	Liquid limit	34.05	26.15	18.066	16.066	-
	Plastic limit	29.8	24.77	15.073	13.045	-

	Plasticity Index	4.25	1.38	2.993	3.021	
Sample 2	Liquid limit	33.28	19.67	16.944	12.057	-
	Plastic limit	24.72	17.75	14.016	12.074	-
	Plasticity Index	8.56	1.92	2.928	0	

Table 3 shows the various soil mixtures with their liquid limits, plastic limits and plasticity index.

The PP fibres were mixed using various percentages of; 0%, 0.5%, 1% ,1.5% and 2%. the results showed a continuous decrease in the liquid and plastic limits of the natural soil. At 2% mix, the samples could no longer be moulded into a 3.2mm thread for the plasticity test, it kept crumbling on every attempt to perform the test and this was attributed to the coarse nature of the polypropylene strip which comes into full effect when added in excess.

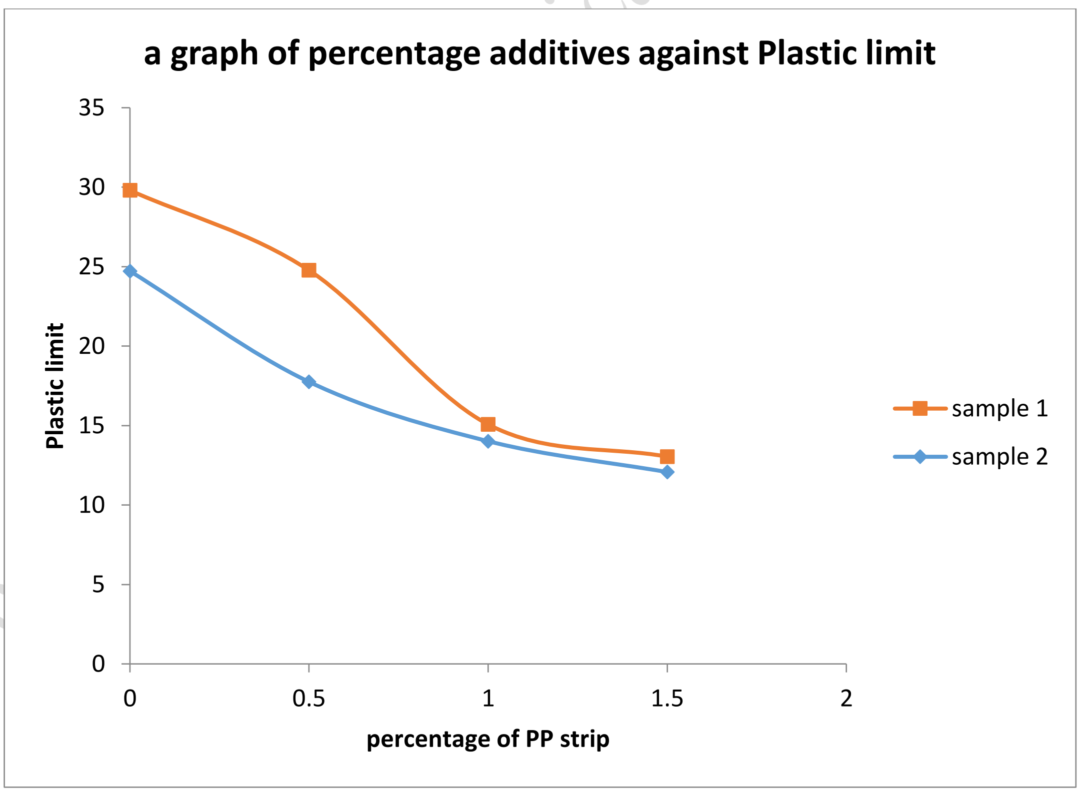

Figure 3: A graph of plastic limit plotted against percentage PP additives

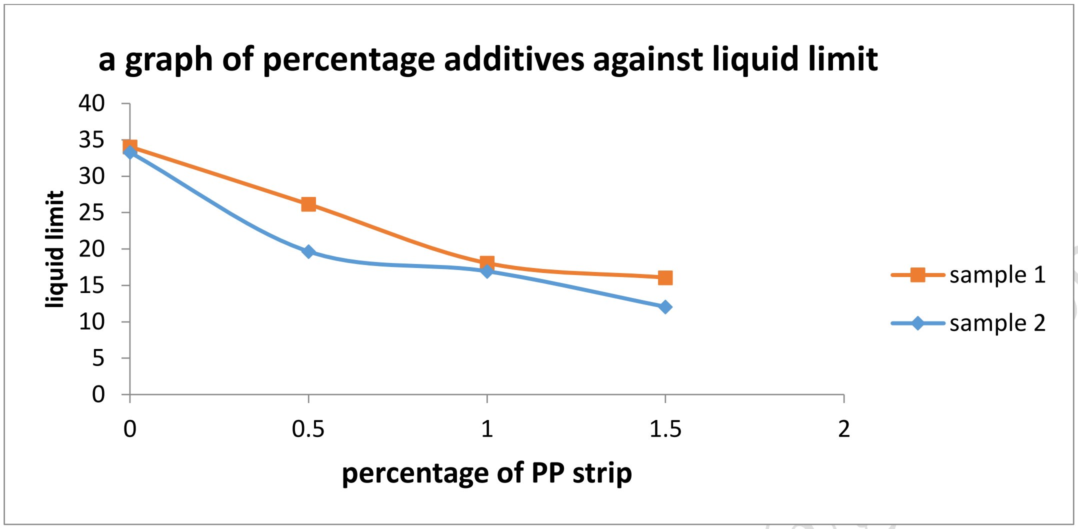

Figure 4: A graph of liquid limit plotted against percentage PP additives

Figures 2 and 3 shows the trend in which the atterberg limits of the soil samples under study followed upon the addition of additives. Overall, sample 1 had a relatively higher liquid limit than sample 2, this accounts for the reason why its points on the graph lie above those of sample 2. The soil samples were also found to crumble upon the addition of the strips in excess of 1.5%.
The plastic and liquid limits continued to dip progressively upon the addition of the additives and this suggests that the PP strips have a negative impact on the soil and this negative impact is as a result of the coarse and non-absorbent nature of the propylene strip which comes into full effect when the moisture content is held constant and the strip is added in excess.

Table 4: Showing Mechanical properties of the soil samples mixed with PP fibers.

SAMPLE A					SAMPLE B				
Percentage additives	**Compressive strength / Stress at peak. (N/mm2)**	**Stress @yield**	**Force at Yield (N)**	**Young modulus**	Percentage additives	**Compressive strength / Stress at peak. (N/mm2)**	**Stress @yield**	**Force @ Yield (N)**	**Young modulus**
0%	0.337	0.337	5056.1	3.336	0%	0.299	0.299	4877.5	2.933
0.50%	1.288	1.288	19322	6.283	0.50%	1.125	1.125	18562.1	5.856
1%	1.046	1.046	15687.6	4.352	1%	1.001	1.001	14587.6	3.886
1.50%	0.786	0.786	11792.3	3.178	1.50%	0.545	0.545	10452.3	2.952
2%	0.414	0.411	6160.7	1.674	2%	0.390	0.390	5950.7	1.238

The test conducted showed that sample A gained maximum strength on the addition of the polypropylene fibres at 0.5% mix. In the control mix, 5056.1N was applied before the sample yielded but this value increased significantly to 19,322N upon the addition of the PP fibres at 0.5% and this value started decreasing as the PP mix was increased. It was also observed that at 2% additives, the strength of the soil had almost returned to its original strength because just 6,160.7N was required to make the soil yield which is almost equivalent to the force of 5056.1N required for same purposes in the control setup (0% mix). Similar trend was observed in sample B upon loading, the control setup required a force of 4,877.5N to yield but this value increased to 18,562N upon the addition of 0.5% Polypropylene. This force further dropped to 14,587.6N and 10,452.3N as the polypropylene mix increased to 1% and 1.5% respectively. At 2% mix, the force/load required to make the soil sample yield was observed to be 5,950.7N which is almost same strength gotten at 0% mix. Therefore, this suggest that polypropylene fibres in excess of 2% will negatively impact the compressive strength of the soil.

From the analysis done, it is recommended that the strip should not be added in excess of 2% in occasions where desired goal is to safely dispose or re-use the PP fibres as this will have a negative effect on the original strength of the soil. Also, for stabilization purposes, 0.5% of the strip is recommended as the best mix proportion for the soil to achieve maximum compressive strength.

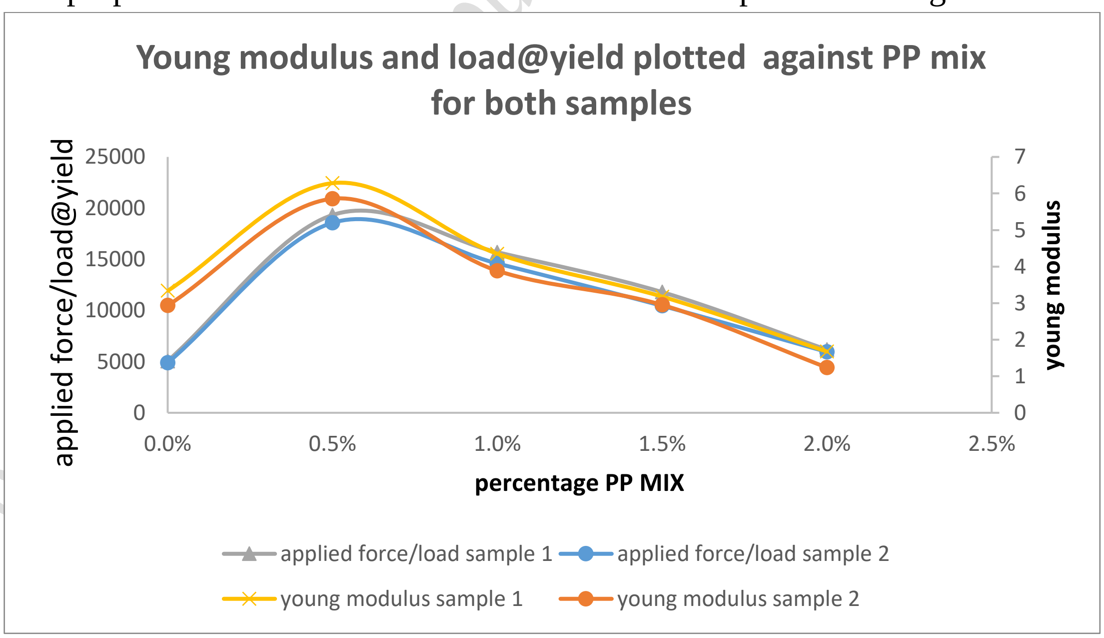

Figure 5: Young modulus and load @ yield plotted against PP mix for both samples

Young's modulus measures the resistance of a material to elastic (recoverable) deformation under load. From fig 5, the young modulus of both samples which is the measure of stiffness of both samples maintained the same trend with the applied force. 0.5% of the PP strip was able to withstand the maximum load before deformation. The young modulus of the samples continued to deplete as the PP fibres was increased.

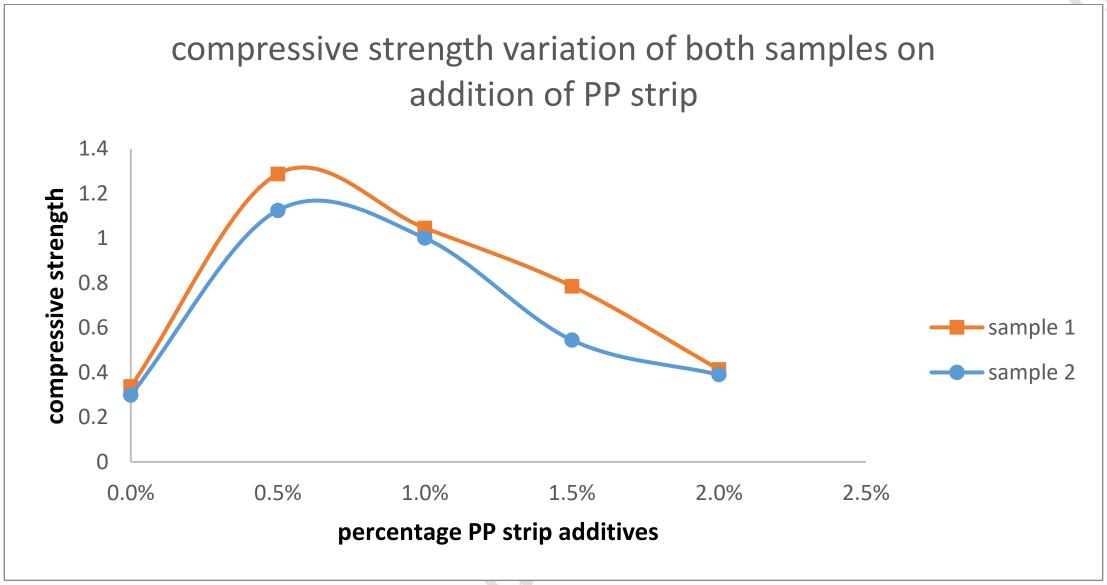

Figure 6: compressive strength variation of both samples on addition of PP strip

The compressive strength also known as the stress at peak is a highly localized stress that exists at a discontinuity in the load path. From the test conducted, it was observed that the compressive strength followed similar pattern as the young modulus upon the addition of polypropylene strips. The compressive strength reached its peak value of 1.3 N/mm^2 at 0.6% mix of the PP strip and subsequent addition of the strips showed a continuous decline of the compressive strength in both samples as shown in figure 6.

Conclusion

The effect of PP strips on the index and compressive strength properties of cohesive soils was studied in this research work. Two soil samples both classified as sandy clay (SC) using the USCS classification system and A-6 according to AASHTO soil classification system and the findings indicated that the Atterberg's limit of the samples decreased progressively as the PP fibre content was increased, it was also observed that when the PP fibres were added in excess of 1.5%, the sample became very coarse in nature and could not be molded in to a 3mm diameter thread for the plasticity to be determined. The compressive strength, young modulus and the load at yield were greater than those of the parent soil. The compressive strength, young modulus and the load at yield of PP reinforced soil experienced an initial increase followed by a decrease with increasing PP fibre content and hence the optimal PP fibre content was found to be 0.5% by weight of the parent soil in the investigation. Therefore, the results obtained showed that the presence of polypropylene fibres could effectively contribute to the improvement in the strength and stability of the parent soil.

REFERENCES

BS 1377:1990 Methods of test for Soil for Civil Engineering purposes – Part 1: General requirements and sample preparation. British Standards Institute, London.

BS 1377:1990 Methods of test for Soils for Civil Engineering purposes – Part 2: Classification tests. British Standards Institute, London.

BS 1377:1990 Methods of test for Soils for Civil Engineering purposes – Part 4: Compaction-related tests. British Standards Institute, London.

Casagrande, M.D.T., (2006). Behaviour of a fiber reinforced bentonite at large shear displacement (discussion closure paper). Journal of Geotechnical and Geoenvironmental Engineering, 133(12): 1635 – 1636.

Consoli N.C., (2003): Plate load test on fiber reinforced soil. Journal Geotechnical and Geoenvironmental Engineering Vol. 129, No, 10 PP. 951 – 955.

Consoli, N.C., (2002): The mechanics of fiber reinforced sand – Geotechnique 60(10). Doi: 10, 1680/geot. 8. PP. 159.

Falorca, I.M.C.F.G., (2006): Evaluation of the shear strength behaviour of polypropylene and carbon – fiber Reinforced Cohesive Soil. Journal of Applied Science Engineering and Technology 7(20): 4327 – 4342.

Federal ministry of works and Housing (1997). General specification for Roads and Bridges volume 2, Federal Highway Department, FMWH: Lagos 317

Freilich B.J.L., and Zornberg J.G., (2010): Effective shear strength of fiber reinforced clays. 9th International Conference on Geosynthetics.

Gray, D.H. and Ohashi .H., (1983): Mechanics of fiber reinforcement in sand. Journal Geotech Eng. Div. 109(3): 335 – 353.

Heineck K.S., Crop M.R., (2005): Effect of microreinforcment of soils from very small to large shear strain. Journal of periodontoogy 149 – 156.

Loehr, J.E, Axtell, P.J., Bowders, J.J., (2000): REducation of soil swell potential with fiber reinforcement. Geo. Eng. 2000.

Maher, M.H., Gray D.H., (1990): Static response of sands reinforced with randomly distributed fibers .J. Geotech Eng. Div 116(11), 1661 – 1677.

Michalowski R.L., and Germark .J., m(2003). Triaxial compression of sand reinforced with fibers. J. Geotech. And Geoenvirm. Eng. 129(2): 125 – 136.

Michalowski, R.L., (1997). Limit stress for granular composites reinforced with continuous filaments. J. Eng. Mech. 123(8): 852 – 859.

Murray J.J., (2000): Behavior of sandy silt reinforced with discontinuous recycled fiber inclusion .J. Transp. Rea Board, N0 1714, PP. 00 – 1303, PP. 9 – 17.

Prabakar .J., and Sridhar R.S., (2002): Effect of random inclusion of sisal fiber on strength behavior of Soil Construction and Building Materials. 16, 123 – 131..

Zornberg, J.G., (2002): Discrete framework for limit equilibrium analysis of fiber reinforced soil. Geotechnique 52(8): 593 – 604.