A Study on Engineering Behaviour of Gravel Blended with Palm Oil Fuel Ashand Jute Fibre

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Abstract*-Many gravel roads suffer from reduced bearing capacity mainly during soil frost thawing periods. The bearing capacity is to a large extent influenced by temperature and precipitation. To avoid the reduced bearing capacity, the gravel roads may be stabilized. Use of natural fiber in civil engineering for improving soil properties is advantageous because they are cheap, locally available, biodegradable and eco-friendly. The natural fiber reinforcement causes significant improvement in tensile strength, shear strength, and other engineering properties of the soil. Over the last decade the use of randomly distributed natural and synthetic fiber has recorded a tremendous increase. Keeping this in view an experimental study was conducted on locally available soil reinforced with Jute fiber. In this study the soil samples were prepared at its maximum dry density corresponding to its optimum moisture content in the CBR mould with and without reinforcement. The percentage of Jute fiber by dry weight of soil was taken as 0.5%, 1%, and 1.5%. In the present investigation the lengths of fiber was taken as 30 mm, 60 mm and 90 mm were considered for each fiber length. The laboratory CBR values of soil and soil reinforced with Jute fiber were determined. The effects of lengths of fiber on CBR value of soil were also investigated. Tests result indicates that CBR value of soil increases with the increase in fiber content. It was also observed that increasing the length of fiber further increases the CBR value of reinforced soil and this increase is substantial at fiber content of 1 % for 90 mm fiber length having diameter 2 mm.. Thus there is significant increase in CBR value of soil reinforced with Jute fiber and this increase in CBR value will substantially reduce the thickness of pavement subgrade. Palm oil fuel ash (POFA) in both cost-effective and environmentally friendly ways has potential applications in soft soil stabilization. percentage of palm oil ash i.e. 3%,6% and 9%.*

Key words: *Gravel, POFA, Jute Fiber, Dry density, OMC, CBR Soaked & Unsoaked, and Direct shear.*

I. INTRODUCTION

An extensive and good quality road network is one of the major parameters for the development of a country's social and economic conditions. The basic necessity for a quality road structure is good and strong sub grade over which the road is constructed. But in many parts of the country the
subsoil is of poor quality due to low strength and high compressibility. Also there is scarcity of good quality conventional construction material for sub base and base of the road structureGravels is one of the problematic soils that has high potential for Shrinking or swelling due to change of moisture content. These soils have the tendency to increase in volume when water is available and decrease in volume when waterunavailable and decrease in volume when water is removed. These soils cover about 20% of the total area of India. The problem that causes gravels is that deformations are significantly greater. There deformation cannot be predicted movement of soil is usually in an uneven manner & is of such magnitude which causes extensive damage to structures resting on them. Many stabilization techniques are in practice for improving the characteristics of gravels.

This study is focus on POFA, which was used as stabilization minerals to be mixed with the disturbed sample of gravel. A further reaction can happen between gravel minerals and POFA and depends on the amount of POFA added and reactivity of the gravel. The stabilization was to decrease the permeability of the soil. The laboratory testing was carried in order to study the effect of inclusion of POFA on the engineering behavior of gravel soil in reducing its permeability.

A. Objectives of Study

The main objective of this study is this study is to assess the suitability of palm oil fuel ash and jute fiber
for stabilization of soil by studying the changes in the engineering properties of soil with addition of randomly

oriented palm oil fuel ash. The study is limited to laboratory investigations on sample soil.

II. METHODS

A. Mechanical Method ofStabilization

In this procedure, soils of different gradations are mixed together to obtain the desired property in the soil. This may be done at the site or at some other place from where it can be transported easily. The final mixture is then compacted by the usual methods to get the required density.

B. Additive Method of Stabilization

It refers to the addition of manufactured products into the soil, which in proper quantities enhances the quality of the soil. Materials such as cement, lime, bitumen, palm oil fuel ash etc. are used as chemical additives. Sometimes palm oil fuel ashes are also used as reinforcements in the soil.

1) Oriented Fiber Reinforcement: The fibers are arranged in some order and all the fibers are placed in the same orientation. The fibers are laid layer by layer in this type of orientation. Continuous fibers in the form of sheets, strips or bars etc. are used systematically in this type of arrangement.

2) Random Fiber Reinforcement: This arrangement has discrete fibers distributed randomly in the soil mass. The mixing is done until the soil and the reinforcement form a more or less homogeneous mixture. Materials used in this type of reinforcements are generally derived from paper, nylon, metals or other materials having varied physical properties. Randomly distributed fibers have some advantages over the systemically distributed fibers. Somehow this way of reinforcement is similar to addition of admixtures such as cement, lime etc. Besides being easy to add and mix, this method also offers strength isotropy, decreases chance of potential.

C. Proven Methods of Soil Stabilization

As you can see, GRT and their polymer based methods of soil stabilization offer a number of advantages over the other approaches. They are more cost effective, less susceptible to damage, lasts longer, easier to maintain, and better for the environment. In almost every single metric of import, Global Road Technology products and methods represent a step forward in terms of infrastructure construction methods and technology.

The Global Road Technology Innovative range of products also enhances the properties of the host material by a combination of:

- Reduces Shrinkage
- Increases Water Impermeability
- Increases Strength (both compressive and tensile)
- Increases Load Bearing Capacity
- Increases Durability.

D. Modern Development

The Chikoko soft soil is characterized with high moisture content in excess of 80% and like other soft soils can also be easily interrupted by activities on its surface (Taha, 2009). It is also characterized with high compressibility, low bearing capacity, low strength and low permeability (Otoko 2014). As such, the Chikoko soil is referred to as problematic when structures are constructed on it. They are not also suitable as sub grade material and therefore require stabilization with lime, cement, chemical and other additives or replacement with soil of better quality. Soft soils varyin thickness in coastal areas (Abdullah and Chandra 1989).This also applies to the Chikoko soil of the Niger Delta, Nigeria (Otoko and Onuoha 2015). Soil stabilization entails adding something to the soil to improve its engineering properties (Otoko 2014). Palm ash will continue to be abundant as industrial waste product is continuously created. It is a pozzolona with no cementitious properties and a waste product produced by burning palm oil fiber to ash. It has successfully been used as additive in cement concrete (Awal and Hustin 1997) and can be successfully used in soft soil stabilization if combined with lime, as the palm ash is rich in silica and low in lime (Cao) This study has shown that the abundant Chikoko soil in the Niger Delta of Nigeria can be successfully stabilized with 5% lime and 3% palm oil fiber ash, which is also abundant in the area.

E. Fiber Reinforced Soil

Randomly distributed fibers reinforced soil–termed as RDFS is among the latest ground improvement techniques in which fibers of desired type and quantity are added in soil, mixed randomly and laid in the position after compaction. Thus, the method of preparation of RDFS is similar to conventional stabilization techniques. RDFS is different from the othersoil –reinforcing methods in its orientation. In reinforced earth, the reinforcement in the form of strips, sheets, etc. is laid horizontally at specific intervals, where as in RDFS fibers are mixed randomly in soil thus making a homogenous mass and maintain the isotropy in strength. Modern geotechnical engineering has focused on the use of planar reinforcement (e.g. metal strips, sheet of synthetic fabrics). However reinforcement of soil with discrete fibers is still a relatively new technique in geotechnical project.

F. Types of Fiber

Fibers can be classified in two categories: Synthetic fiber andnatural Fiber. Some commonly used fibers are coconut fiber, Sisal fiber, jute, fiber, Cotton fiber, wool fiber, Asbestos fiber, and metallic fiber and Glass fiber.

G. Synthetic Fibers

The various types of synthetic fiber are polypropylene, nylon,plastic, glass asbestos etc. These are preferred than the natural fibers because of their higher strength and resistance. Polypropylene fiber are resistant to acidic, alkaline and chemicals (Setty and Rao, 1987). These fibers are high tensile strength, resistance to sea water and high melting point i.e. 1650C.Polyimide has inherent defect of getting affected by the ultraviolet rays from sun but as the fiber are embedded they are not affected. An experience fiber, no chemical changes has been detected. Synthetic fibers also show a great biological resistance. Polypropylene fibers are prone to fire and sun light which practically cannot reach inside the soil.The important properties of polypropylene are; its versatility,excellent chemical resistance, low density, high melting point and moderate cost. Plastic fibers show loss in strength with temperature. Nylon is comparable with polypropylene as for as strength, chemical innerness and durability is concerned. Steel fibers are prone to rust and acids. Glass fibers although costly but they can bear temperature up to 1500 F. Asbestos, glass, carbon fibers have been found to be resistant to alkaloids and other chemicals attack.But long exposure to adverse environment, asbestos fibers has been found tolead to corrosion damage.

H. Natural Fibers

The various types of natural fiber available in India are: coir, sisal,jute, bhabar, hemp, munja, bamboo and banana. In order to minimize the cost of ply soil, locally available fibers should be considered in design. But at the same time stability and life of structure should be given prime importance. Coir fibers are even resistant to biodegradation over long period of time. It has been shown that breaking strengths of coir fiber after 15 years of storage in a hanger comes down from 176MPa to 160MPa and elongation from 29% to 21%. It shows that coir becomes slightly brittle with time but best among all natural fibers.

I. Direction of Placement

Fibers can be oriented or randomly mixed in soil. In oriented category, theinclusions are placed within the soil at specific positions and direction where as in random category, inclusions, are mixed with soil and placed within the probable shear zone. The concept of randomly reinforced soil is comparatively new in the geotechnical field. French ministry of public works uses Texsol as RDFS. In the field placing the fibers at some orientation is a tedious job. In reinforced soil the added material (the Geo synthetic sheet, etc) is layered at specific direction and position, which may keep the soil weaken in some other direction.

J. Treatment Procedure:

Normally Jute fiber is swelled and degraded within six months in water. So some chemical treatment is necessary to increase its life span upto 5 –20 years.

K. Advantages of Fiber-Reinforced Soil

Randomly distributed fiberreinforced soil (RDFS) offers many advantages as listed below:

- Increased shear strength with maintenance of strength isotropy.
- Beneficial for all type of soils (i.e. sand, silt and clay).
- Reduce post peak strength loss.
- Increased ductility.
- Increased seismic performance.
- No catastrophic failure.
- No appreciable change in permeability.
- Unlike lime, cement and other chemical stabilization methods, theconstruction using fiber reinforcement is not significantly affected by weather conditions.
- It helpful in eliminating the shallow failure on the slope face and thus reducing the cost of maintenance.

L. Application Areas of Jute Fiber, Inroad, Railway and Embankment Construction

- Controls subsidence of a pavement by separating and preventing intermixing of the soft sub-Grade and the harder sub-base
- Arrests migration of soil particles and allows water to permeate across it.Also acts as adrainage layer along its plain. Can be tailor-

made to cater to the requirements of porometry, permittivity and transmitivity.Enhances CBR-value.

III. MATERIALS

A. Soil

The soil used in this study would be collected from the local area. The various index properties and compaction properties (maximum dry density and optimum moisture content) of soil will be determined in the laboratory.From a brief review of earth construction manuals, we realized that our soil had to contain significant percentage of clay. The particle size distribution of the collected soil would be found from Sieve Analysis which would be useful for finding Fineness Modulus of collected soil sample. To sieve the soil, we will use 2 mm, 1mm, 600 μ, 300 μ, 150 μ, 75 μ and Receiver. We would determine the type of soil by conducting Atterberg's limits.

B. Physical and Chemical Properties of POFA and Jute

1) Chemical Properties Of Palm Oil Fuel Ash

- Silicon oxide(SiO_2) :52.35%
- Aluminum oxide (Al_2O_3) :6.27%
- Iron oxide(Fe_2O_3) :13.36 %
- Calcium oxide (CaO) :11.72%
- Potassium oxide(K_2O) :15.52%
- Sulphur trioxide (SO_3) :1.50 %
- Manganese oxide(MnO) :0.11%

2) Physical Properties of Jute

- Density - 1.47gm/cc.
- Average Fineness - 20 denier, i.e. weight in gm. of 900 meters of filament.
- Tenacity - 4.2gm/denier.
- Average Extension at break - 1.2%.
- Average Stiffness - 330 gm/denier.
- Average Toughness Index - 0.02.
- Swelling water (area) - 40%.
- Specific heat - 0.34 cal/g/c^0.
- Specific internal Surface – 10 to 200m^2/g.
- Hygroscopicity (Average regain at 65% relative humidity) - 13%.
- Available diameters are 2 and 4 mm.

C. Chemical Properties of Jute

- Holocellulose : 82-85%
- Alpha Cellulose : 58-63%
- Hemicellulose : 21-24%
- Lignin : 12-14%
- Pactin : 0.2-0.5%
- Fat & Wax : 0.4- 0.8%
- Protein : 0.8-1.5%
- Mineral Materials : 0.6-1.1%

IV. RESULTS AND DISCUSSIONS

TABLE I: ENGINEERING PROPERTIES OF GRAVEL

Maximum dry density(gm/cc)	2.01
Optimum moisture content (%)	15.17
Sieve analysis (75 micron) (%)	
Specific gravity	2.60
California bearing ratio (at 2.5 mm) (%)	2.28
Direct shear	0.005
Soil type	gravel

A. Comparison of Results for POFA Replacement

TABLE II:VARIATION IN RESULTS OF COMPACTION TEST

% of POFA Added	OMC	Max Dry Density
3%	14.47	1.92
6%	17.12	1.94
9%	15.45	1.89

TABLE III: VARIATION IN RESULTS OF CBR TEST

% of POFA Added	CBR Values (%)	
	Unsoaked	Soaked
3%	2.9	1.78
6%	3.8	3.85
9%	5.13	4.70

TABLE IV: VARIATION IN RESULTS OF DIRECT SHEAR TEST

% of POFA Added	Direct Shear Values	
	C	Ø
Gravel	0.005	$27^0 28^I$
3%	0.029	$14^0 8^I$
6%	0.033	$9^0 15^I$
9%	0.034	$13^0 6^I$

B. Comparison of Results for 6% POFA with Jute Fibre

TABLE V: VARIATION IN RESULTS OF COMPACTION TEST

Length of Jute Fiber	% of Fiber by Dry Weight of Soil	OMC in %	Max. Dry Density
30	0.5	14.59	1.88
	1.0	14.83	1.87
	1.5	15.70	1.77
60	0.5	17.76	1.83
	1.0	19.66	2.50
	1.5	18.20	1.73
90	0.5	16.99	1.85
	1.0	17.23	1.87
	1.5	18.68	1.81

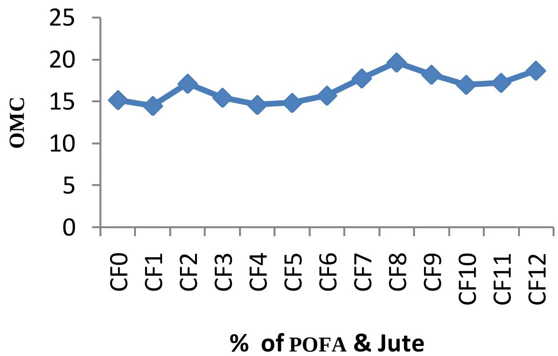

Fig 1: Graph of Variations in OMC values

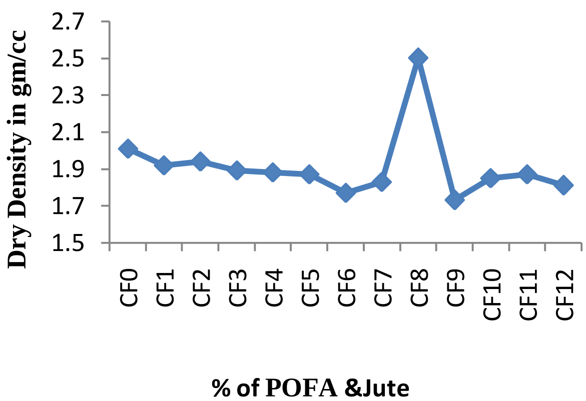

Fig 2. Graph of Variations in Dry Density values

CF0=Gravel
CF1=3% POFA
CF2=6% POFA
CF3= 9% POFA
CF4=6% POFA+3cm @0.5 Jute
CF5=6% POFA+3cm @1 Jute
CF6=6% POFA+3cm @1.5 Jute
CF7=6% POFA+6cm @0.5 Jute
CF8=6% POFA+6cm @1 Jute
CF9=6% POFA+6cm @1.5 Jute
CF10=6% POFA+9cm @0.5 Jute
CF11=6% POFA+9cm @1 Jute
CF12=6% POFA+9cm @1.5 Jute

TABLE VI:VARIATION IN RESULTS OF CBR TEST

Length of Jute Fiber	% of Fiber by Dry Weight of Soil	CBR Values (%)	
		Unsoaked	Soaked
30	0.5	5.40	5.13
	1.0	6.41	5.79
	1.5	7.41	6.41
60	0.5	5.70	5.56
	1.0	8.50	7.69
	1.5	6.27	8.12
90	0.5	5.99	6.41
	1.0	5.56	5.56
	1.5	4.27	5.13

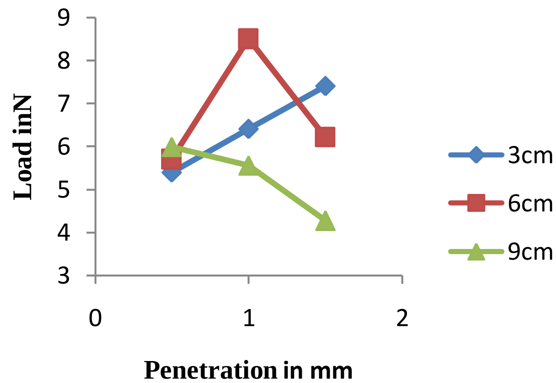

Fig 3. Graph of Variations in CBR

TABLE VII: VARIATION IN RESULTS OF DIRECT SHEAR TEST

Length of Jute Fiber	% of Fiber by Dry Weight of Soil	Direct Shear Values	
		C	Ø
30	0.5	0.042	$11^{0}18^{I}$
	1.0	0.044	$8^{0}31^{I}$
	1.5	0.053	$5^{0}42^{I}$
60	0.5	0.069	$15^{0}25^{I}$
	1.0	0.0724	$4^{0}00^{I}$
	1.5	0.09	$7^{0}48^{I}$
90	0.5	0.11	$7^{0}54^{I}$
	1.0	0.13	$38^{0}29^{I}$
	1.5	0.18	$36^{0}43^{I}$

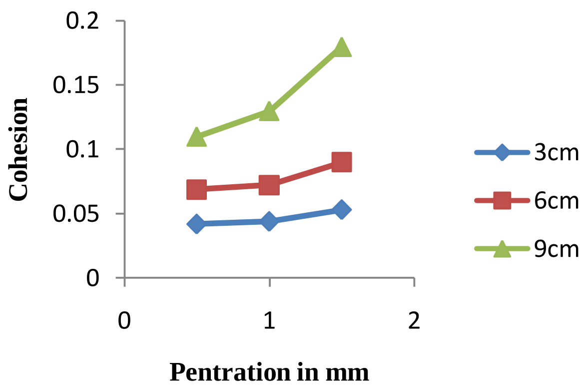

Fig 4. Graph of Variations in Direct shear

V. TYPICAL EXAMPLE FOR FLEXIBLE PAVEMENT

A. Thickness Using Normal And Stabilized Soil For UnsoakedCbr Values

Percentage reduction in pavement thickness =51.17%
From this design we came to know that the gravel sample is replaced with 6% palm oil fuel ash and jute fiber of 60mm length @1% by dry weight of the gravel would be useful in reducing the thickness of flexible pavement up to 51.17%.

B. Thickness Using Normal and Stabilized Soil for Soaked CBR Values

Percentage reduction in pavement thickness =53.67%. From this design we came to know that the gravel sample is replaced with 6% palm oil fuel ash and jute fiber of 60mm length @1.5% by dry weight of the gravel would be useful in reducing the thickness of flexible pavement up to 53.67%.

VI. CONCLUSIONS

The soil was initially tested for the basic properties. Then the addition of palm oil fuel ash and Jute fiber gave considerable variations in values of OMC, Dry Density, CBR and shear stresses. With those results the following conclusions are drawn:

- The Specific Gravity of normal soil sample obtained is 2.60
- From dry sieve Analysis, Fineness Modulus of normal soil sample is found to be 2.19 %.
- From Proctor Compaction Test, Max dry density and OMC for normal soil are found to be 2.01 and 15.17% respectively.
- CBR (unsoaked) value for normal soil at 2.5 mm penetration is found to be 2.28 %.
- CBR (soaked) value for normal soil at 2.5 mm penetration is found to be 1.71 %.
- Direct shear value for normal soil is found to be $0.005N/mm^2$.

Soil sample is replaced with palm oil fuel ash have been tested only for OMC, Dry Density, CBR (unsoaked and soaked) and direct shear stresses. The conclusions drawn from those results are as follows:

- From the results obtained from Proctor Compaction Test, we have observed that there has been increase in the Optimum Moisture content up to 6% palm oil fuel ash and upon there is a decrease in Optimum Moisture content from 17.12% to 15.45%
- From the results obtained from Proctor Compaction Test, we have observed that there has been increase in maximum dry density up to 6% palm oil fuel ash and upon there is a decrease in maximum dry density from 1.94 to 1.89%
- From the results obtained from CBR (unsoaked) test, we have observed that there has been gradual increase in CBR value from 2.9 % to 5.13%.
- From the results obtained from CBR (soaked) test, we have observed that there has been gradual increase in CBR value from 1.78 % to 4.7 %.
- From the results of direct shear test, we have observed that cohesion has been gradual increases with increasing in palm oil fuel ash from 0.029 to 0.034.

Soil sample is replaced with palm oil fuel ash and Jute fiber have been tested only for OMC, Dry Density, CBR (unsoaked and soaked) and direct shear stresses. The conclusions drawn from those results are as follows:

- From the results obtained from Proctor Compaction Test, we have observed that there has been increase in the Optimum Moisture content up to 6% palm oil fuel ash @ 6cm at 1%, and upon there is a decrease in Optimum Moisture content from 19.46% to 18.68%.
- From the results obtained from Proctor Compaction Test, we have observed that there has been increase in maximum dry density up to 6% palm oil fuel ash @6cm at 1%, and upon there is a decrease in maximum dry density from 2.81g/cc to 1.81g/cc.
- From the results obtained from CBR (unsoaked) test, we have observed that there has been gradual increase in CBR value up to 1 % Jute for 60 mm length and upon there is a

gradual decrease in CBR value from 8.5 % to 4.27 %.

- From the results obtained from CBR (soaked) test, we have observed that there has been gradual increase in CBR value up to 1.5 % Jute for 60 mm length and upon there is a gradual decrease in CBR value from 8.12 % to 5.13 %.
- From the results of direct shear test, we have observed that cohesion has been graduallyincreasing in palm oil fuel ash and jute fiber from 0.029 to 0.18.

Based on the present investigation, it is concluded that CBR value of Soil increases with the inclusion of palm oil fuel ash and Jute fiber. When the Jute fiber content increases, the CBR value of soil is gradually increasing and this increase is substantial at fiber content of 1 %.

It was also found that preparation of identical soil samples for CBR test beyond 1.5 % of fiber content is not possible and the optimum fiber content was found to be 1% by dry weight of soil. It is also concluded that there is significant effect of length of Jute fiber on the CBR value of soil. In brief, the CBR value of soil increases with increase in length of the fiber but it is up to a certain extent only.

From the design of Flexible pavement for observed CBR values for normal soil and fiber reinforced soil, we have obtained a reduction in pavement thickness of 53.67%. So, we can conclude that this method of soil stabilization can be effectively used for light weight traffic roads in rural areas where cost of construction of pavement is given the most consideration.

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