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Performance Studies on Unconfined Compressive Strength of Fly Ash Mixed Expansive Soil Reinforced With Nylon Fibers

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Abstract— Most State highways in the central part of India (e.g., Maharashtra State) have problems of foundation due to presence of highly compressible clayey soils (mostly black cotton soil). The sub grade soil and its properties are important in the design of pavement structure. It has been the common observation and experience that the pavements of highways and roadways constructed either on in situ soil formations or on compacted black cotton soil embankment show several types of damages to pavement structures, and in many instances the pavements may even become unserviceable because of highly deteriorated conditions of the whole pavement system. The present work is aimed to assess the improvement in the strength and stability characteristics in soft Subgrade soil by using the fly ash for the stabilization and then Nylon fibre as reinforcing material. Randomly distributed fibre reinforced soil (RDFRS) technique is used to prepare the reinforced soil samples. In RDFRS technique the mixing of reinforcement in the soil is very easy and no special skill is required. The reinforcement is added by percentage of the weight of the soil sample and by following certain aspect ratio i.e., length/diameter (L/D) ratio. Attempt is made to determine optimum combination of fly ash and fiber content for maximum gain in strength.

Keywords- UCS, Nylon fibre, Fly ash, Expansive soil.

I. INTRODUCTION

A geotechnical engineer design foundation and other structures supports on the soil after investigation of the type of soil, its characteristics and its extent. If the soil is good at shallow depth below the ground surface, shallow foundation such as spread footings and rafts, are generally most economical. However, if the soil just below the ground surface is good but strong strata exist at a great depth, deep foundation, such as piles, wells and caissons are required. Deep foundations are quite expensive and are cost effective only where the structure to be supported is quite heavy and huge. Sometimes the soil conditions are very poor even at greater depth and it is not practicable to constructs even deep foundation. In such case various methods of soil stabilization and reinforcement techniques are adopted. The objective is to improve the characteristics at site and make soil capable of carrying load and to increase the shear strength and decrease the compressibility of soil.

Large amount of waste are generated from various industries and activities of human being. Wastes can listed as surplus soil, concrete powder, rock powder, coal ash, iron slag, incinerator ash, slurry or sludge, oil and fly ash, scrap tires, plastic material and waste like copper or tailings, iron ore tailings, paper sludge etc., utilizing wastes will reach optimum economic advantages if they exhibit most of the following characteristics:
I. Waste with a low unit cost but high quality which can save the total construction costs,
ii. Waste with available quantity for a project, easy to handle but does not easily deteriorate when stored or under change in environment,
iii. Waste that can be used as an “as is-products” without any treatment or with appropriate cost comprised by additional processing for property modification,
iv. Waste that can be utilized in great quantity without any potentials for degradability of new materials and the environment.

Fly ash and nylon fiber are produced in huge quantity and the utilization of fly ash has become necessary to avoid environmental problems. Fly ash and nylon fiber materials may be used as stabilizing material in the form of fly ash and nylon fiber to enhance the bearing capacity and other parameters of the 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.

II. LITERATURE REVIEW

Nylon is a thermoplastic, silky material, first used commercially in a nylon-bristled toothbrush (1938), followed more famously by women's stockings ("nylons"; 1940) after being introduced as a fabric at the 1939 New York World's Fair. Nylon is made of repeating units linked by amide bonds and is frequently referred to as polyamide (PA).

Concepts involving the reinforcement of soils using fibers have been used since ancient times. For example, early civilizations added straws and plant roots to soil bricks to improve their properties, although the reinforcing mechanism may have not been fully understood. While building the Great Wall of China, the clay soil was mixed with tamarisk branches. The ancient method of addition of straw of wheat locally called "Turi" to the clay mud plaster is still very popular in villages. Improvement of soil by trees roots is similar to the work fibers. Gray (1947, 1978), Waldron (19770 and Wu et al. (1988) reported that plant roots increase the shear strength of the soil and, consequently the stability of natural slopes. Synthetic fibers have been used since the late 1980s, when the initial studies using polymeric fibers were conducted. Specially, triaxial compression tests, unconfined compression tests, direct shear tests and UCS tests had been conducted to study the effect of fiber reinforcement on strength characteristics and other engineering properties of RDFS. During last twenty –five years, much work has been done on strength deformation behavior of RDFS and it has been established beyond doubt that addition of fiber in soil improves the overall engineering performance of soil. Among the notable properties that improve are greater extensibility, small loss of post peak strength, isotropy in strength and absence of planes of weakness. RDFS has been used in many civil engineering projects in various countries in the recent past and the further research is in progress for many hidden aspects of it. RDFS is effective in all types of soil (i.e. .sand, silt and clay).

Scope of present study

Thus, through appraisal of the literature review it is observed that several attempts have already been made by researchers to understand the mechanism of randomly oriented discrete inclusions incorporated into soil improve its bearing capacity. However, in the present study an attempt has been made to improve the Unconfined Compressive Strength (UCS) of soil compacted fly ash and nylon fiber. Hence, the experimental programme undertaken investigates the effect of nylon fiber content & aspect ratio on UCS of reinforced fly ash specimen, effect of fly ash content in soil on the result in increase in shear strength.

III. METHODOLOGY

A. Preparation of Soil Samples

The fly ash were mixed with clayey soil in varying percentage viz. 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, and 50% and the nylon fiber were mixed with optimum percentage of fly ash plus varying percentage viz. 0.5%, 1.0%, 1.5% and 2.0%.

For this purpose the required weight of dry soil sample was taken in container and the required percentage of fly ash and nylon fibers by weight was added to the soil sample. It was than thoroughly mixed manually. The required quantity of water was then added to the soil sample and again mixed thoroughly. The various stages were than conducted on the soil sample, some as in case of untreated soil.

The amount of water added for every test was equal to the optimum moisture content obtained during the standard proctor test. The experiment was categorized into various stages to determine the increase in the UCS after the addition of fly ash at the different proportions.

Then after with the optimum percent of fly ash the various percent of the fiber were involved to determine the further increase in the UCS values. First, the engineering properties and index properties were determined such as the specific gravity, OMC, MDD, swelling index and the Atterberg's limits were determined of unreinforced expansive soil.

Then the Unconfined compressive strengths were determined on various unreinforced soil specimens to determine the UCS value of such soil. Then after the inclusion of fly ash was done so as to determine the increase UCS and after that the nylon fibers were added.

UCS of soil with varying percentage of fly ash as shown in table 1

Table 1: UCS of soil with varying percentage of fly ash

Percentage of soil	Percentage of fly ash
95%	5%
90%	10%
85%	15%
80%	20%
75%	25%
70%	30%
65%	35%
60%	40%
55%	45%
50%	50%

UCS of soil with optimum percentage of fly ash and varying percentage of nylon fiber as shown in Table 2.

Table 2: UCS of soil with varying percentage of fly ash

Optimum percentage of fly ash +	0.5% of nylon fiber
	1.0% of nylon fiber
	1.5% of nylon fiber
	2.0% of nylon fiber

The laboratory investigations have been carried out on the untreated clayey soil for knowing the Index and Engineering properties of untreated soil and also for classification of soil as per IS and also the effect of Fly ash and Nylon fiber with varying percentage. Fly ash a by-product of the coal based thermal power plants contains grains of fine sand to silt size.

The use of randomly reinforced fly ash in geo-technical constructions requires a proper understanding of the interaction between the fly ash and reinforced material. The stability of fly ash reinforced structure depends upon the strength characteristics of the composite material. A series of UCS tests have been carried out on compacted fly ash and soil with different proportion of nylon fiber.

B. Properties of Untreated Clayey Soil

The clayey soil sample used for the project work was collected from the "RAHATGAON ROAD, Amravati". The fly ash is collected from thermal power station which is situated in Koradi at Nagpur.

The properties obtained by performing the various tests as shown in table 3

Table 3: Properties of Untreated Clayey Soil

Sr. No.	Property of soil	Value
1	Liquid Limit W_L	47.60%
2	Plastic Limit W_P	31.28%
3	Plasticity Index	16.75%
4	Specific Gravity G	2.58
5	Maximum Dry Density MDD	1.95gm/cc
6	Optimum Moisture Content OMC	18%
7	Unconfined compression strength(q_u)	0.255Mpa
8	Classification of soil as per is 1898-1974	CI (Inorganic Clay)

C. Classification of soil as per is 1898-1974

According to the colour of soil sample and visual observation, sample was classified as Black Cotton Soil. From the water content of the soil sample, the soil was classified as partially saturated soil, as the water content was less than 100% (i.e 23.45%). As more than 50% of the soil particles are finer and passes through 75µ IS sieve, the soil used is categorized under Fine Grained Soil. Again Fine grained soil is also classified as clayey soil as soil sample passes through 75 µ IS sieve (more than 50%) and also possesses plastic property (plasticity index = 5.43%) . Again this clayey soil is classified on the basis of liquid limit (W_L), As the liquid limit (W_L) of the soil sample is in between 35% to 50% (i.e 47.60%), the soil sample is classified as medium compressible silty soil.
Also from the plasticity chart, (Liquid limit = 30.05% and plasticity index = 5.43%), the soil is classified as organic silt and organic silty clayey soil with medium compressibility (CI).

IV. RESULT AND DISCUSSION

A. Fly Ash

The laboratory investigation have been carried out on the clayey soil treated with fly ash with varying percentages to study the effect of these inclusions on unconfined compression test of the soil. The discussion of these Investigation have been discussed as follows
The UCS values of the soil mixed with fly ash in varying percentage i.e. 5%, 10%, 15%, 20%, 25%, and 30% as determined in the laboratory investigations is presented in table 4.

Table 4: The UCS values of the soil mixed with fly ash

Sr. No.	Particulars	UCS values in Mpa
1	Untreated soil	0.25
2	Soil + 5% fly ash	0.28
3	Soil + 10% fly ash	0.305
4	Soil + **15% fly ash**	**0.317**
5	Soil + 20% fly ash	0.278
6	Soil + 25% fly ash	0.214
7	Soil + 30% fly ash	0.124

From Table 4 and Fig. 1 it is observed that the UCS value for untreated soil is 0.25 MPa whereas the value of UCS differs for various percentage of fly ash. The maximum value of UCS is obtained when soil is mixed with 15% of fly ash. The maximum value is greater than that of untreated soil which is equal to 0.25 MPa. The same results have been presented in the form of graph as shown below. The UCS values increases with increase in the percentage of fly ash up to an extent and then the value further decreases with the increase in percentage of fly ash i.e. the UCS value increases up to a 25% addition of fly ash and then decreases. The increase in UCS value due to inclusion of fly ash is proved to be beneficial in construction of pavement.

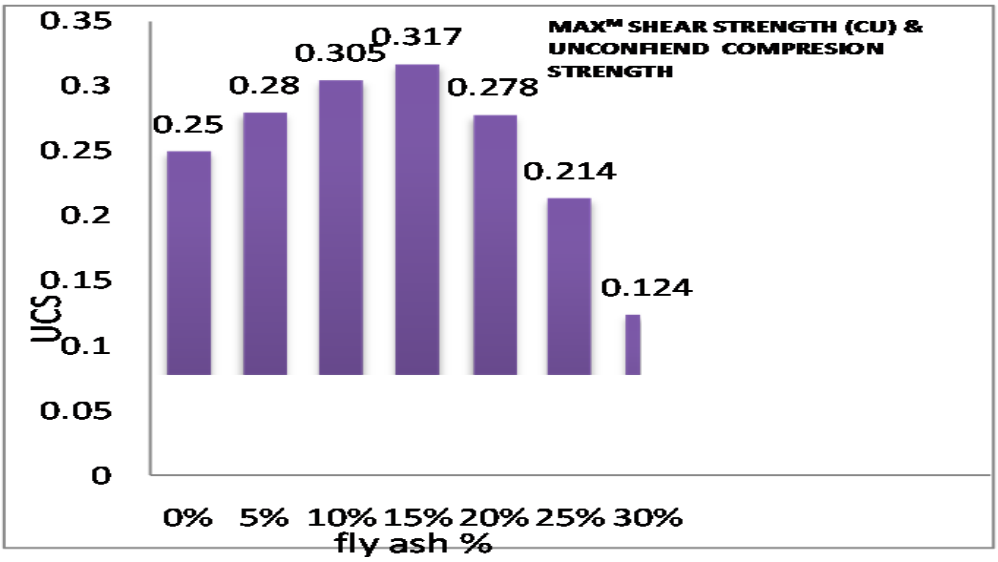

Fig. 1 The UCS values of the soil mixed with fly ash

B. Fly Ash and Nylon Fiber

The laboratory investigation have been carried out on the clayey soil treated with optimum percentage of fly ash and varying percentages of nylon fiber to study the effect of these inclusions on Unconfined Compression Strength of the soil. The discussion of these Investigations has been carried out as follows.

The UCS values of the soil mixed with optimum percentage of fly ash and varying percentage of nylon fiber i.e. 0.5%, 1.0%, 1.5% and 2.0% as determined in the laboratory investigations is presented in table 5.

Table 5: The UCS values of the soil mixed with fly ash & nylon fiber

Sr. No.	Particulars	UCS values in Mpa
1	Soil + optimum percentage of fly ash	0.31
2	**Soil + optimum percentage of fly ash +0.5% nylon fiber**	**0.32**
3	Soil + optimum percentage of fly ash +1.0% nylon fiber	0.26
4	Soil + optimum percentage of fly ash +1.5% nylon fiber	0.2
5	Soil + optimum percentage of fly ash +2.0% nylon fiber	0.14

From Table 5 and Fig. 2 it is observed that the UCS value for soil plus optimum percentage of fly ash is 0.32 whereas the value of UCS differs for various percentage of fly ash i.e. optimum percentage of fly ash plus nylon fibers. The maximum value of UCS is obtained when soil is mixed with optimum percentage of fly ash plus 0.5% of nylon fibers. The maximum value is greater than that of untreated soil plus 15% of fly ash which is equal to 0.32. The same results have been presented in the form of graph as shown below. The UCS values increases with increase in the optimum percentage of fly ash and nylon fiber up to an extent and then the value further decreases with the increase in optimum percentage of fly ash and nylon fiber i.e. the UCS value increases up to a 0.5% addition of nylon fiber in untreated soil with optimum percentage of fly ash and then decreases. The increase in UCS value due to inclusion of optimum percentage of fly ash and nylon fiber is proved to be beneficial in construction of pavement.

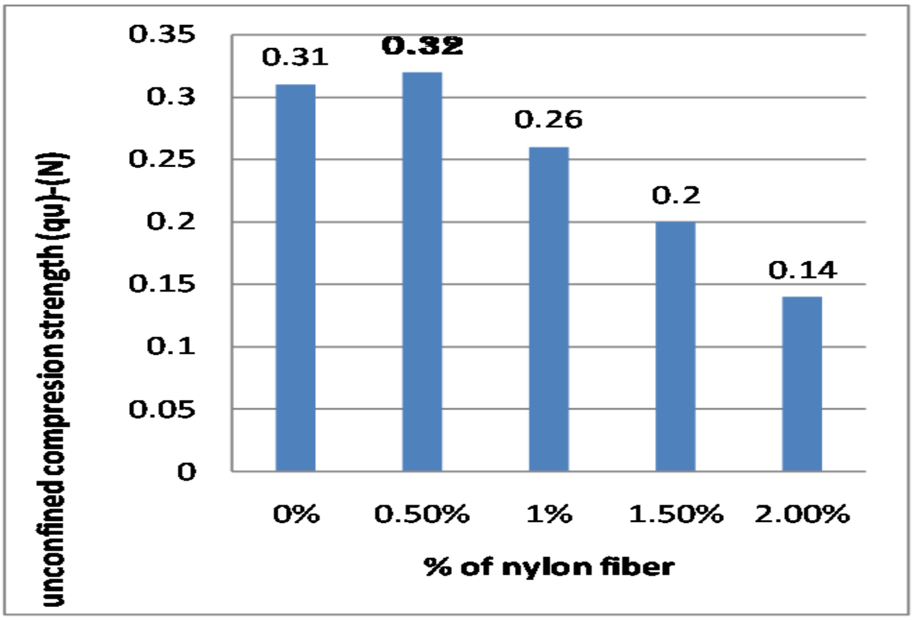

Fig. 2 The UCS values of the soil mixed with fly ash & nylon fiber

V. CONCLUSION

The laboratory investigation has been carried out in order to evaluate the effect of inclusion of fly ash and nylon fiber with expansive soil on the compaction and strength characteristics of soil based upon the laboratory investigation carried out by treating the expansive soil with fly ash and nylon fiber the following conclusions are arrived

- The UCS value of the expansive soil is enhancing by the inclusion of fly ash in soil. The UCS value of mixtures initially increases with increase in the percentage of fly ash up to an extent but decreases with further increase in percentages of fly ash. The maximum UCS value was found to be for 85% soil and 15% fly ash proportion.
- Based upon the study it was concluded that proportion of 85% soil and 15% fly ash is the best proportion having maximum dry density and maximum UCS value.
- The inclusion of fibers had a significant influence on the engineering behavior of soil-fly ash mixture. Different percentage fiber content was added in the proportion of 85% soil and 15% fly ash mixture and it was found that the value of UCS first increases then it decreases with increase in fiber content. The maximum value of UCS was found to be 5.91 % for 0.5 % fiber content.
- Based upon the study it was concluded that proportion of 85% soil + 15% fly ash + 0.5% nylon fiber is the best combination of soil, fly ash and nylon fiber content having maximum UCS value. Hence this proportion may be used in road embankments.
- Based on the findings, fly ash and nylon fiber could be used as alternative reinforcement materials in place of conventionally used reinforcing materials.
- The disposal of Fly ash is a big problem in thermal industries; Fly ash stabilization is one of the best methods for the effective and economical disposal of Fly ash.
- The aim of UCS test of soil mixed with fly ash to bring down the cost of construction of the roads and thus achieved goal of research

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