SOIL STABILIZATION WITH FLY ASH AND COIR FIBER

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Abstract-Construction of any structure on expansive soils is the major issue of concern because these soils have swell or shrink behavior. The workability of structure depends on its foundation and it needs to be strong enough to bear the load of structure. As expansive soils do not stand well in shearing and bearing strength so they need stabilization to make it suitable for construction purpose. It made civil engineers to think about the material which can be effective and suitable to stabilize the soil. There have been many researches carried out to meet this purpose. In India, expansive soils are available in large quantity and it is not possible to ignore it to enhance country's infrastructure development. There is also a problem of disposing waste materials in our environment as they causes hazardous effects. The fly ash is a waste product of thermal power plants and can be used as a stabilizing material for soil. On other hand, coir fiber extracted from coconut shell is also a waste material available in abundant quantity at coastal regions of India. In this study coir and fly ash both used in combination to stabilize the expansive soil. This study reveals around the experimental work done before and after stabilizing soil by coir fiber and fly ash to evaluate the effects of coir fiber and fly ash on bearing strength of soil. For different percentage of fly ash in soil the Proctor Compaction test was carried out. The results indicated that the 15% Fly Ash with coir length 1.5cm shows noticeable changes in value of CBR and it also reduced the cost of construction.

Keywords — expansive soils, CBR value, coir, fly ash, compaction, stabilization

I. INTRODUCTION

Keeping in mind the large geographical area of India (3,287,263 sq. km) and demands of population (1.3 billion approx.) the vast network of structures and roads are required. The land available for construction is very less because of increasing urbanization and modernization. Everywhere land is being utilized for various structures from an ordinary house to sky scrapers, from bridges to airports and from village road to highways or expressway. Soil being the cheapest and readily available construction material, has been popular with the civil Engineers because it plays an important role in the stability of any foundation. The foundation transmits the load of structure to the subsoil present beneath it. It can be concluded that the stability of any structure depends on the physical and chemical properties of soil. Soil can often be classified into four basic types: gravel, sand, clay, and silt. Generally, soil has good compressive strength but low tensile and shear strength and its characteristics may depend strongly on the environmental conditions (e.g. dry versus wet). Construction on expansive soils leads to various ground improvement techniques such as soil stabilization and soil reinforcement. The expansive soils are examples of weak soils or problematic soils in field of foundation engineering. Expansive soil undergoes volume changes when they come in contact with water. They show alternate swelling and shrinkage properties. It expands during monsoon due to swell behaviour and shrinks in summer season due to loss of water content. Expansive soil covers nearly one-fifth of the land mass in India. These soils possess weak properties due to presence of clay minerals. Typical behaviour of these soils results in failure of structure in form of settlements cracks etc. Therefore, it is important to replace the existing weak soil with a non-expansive soil or improve the properties of weak soil by stabilization. Expansive soils exhibit generally undesirable engineering properties. They tend to own low shear strengths and to lose shear strength additional upon wetting or different physical disturbances. They can creep over time underneath constant load, particularly once the shear stress is approaching its shear strength, creating them susceptible to slippery. They develop large lateral pressures. They tend to have low resilient modulus values. It can be concluded that expansive soils are generally poor materials for construction. For all the above reasons, there is a need to improve the soil properties by stabilizing or reinforcing it. It improves the strength of the soil and hence enhances the bearing capability of soil. It's accustomed give additional stability to the soil in slopes or alternative such places. Sometimes soil stabilization is also used to save soil from getting erode and prevent formation of mud or dirt particles, which is incredibly helpful particularly in dry and arid weather. It helps in reducing the soil volume change due to

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change in temperature or moisture content. Soil reinforcement is a procedure where natural or synthesized additives are mixed with soil in different ratios to improve the properties of soils.

The research is carried out to study effects of coir fiber and fly ash on the workability of expansive soils after stabilization as it supposed to improve the behavior of these soils. Soil stabilization is the process of altering some soil properties by different methods, mechanical or chemical in order to produce an improved soil material which has all the desired engineering properties. Soils are generally stabilized to increase their strength and durability or to prevent erosion and dust formation in soils. The main aim of soil stabilization is that the creation of a soil material or system which will hold underneath the planning use conditions and for the designed lifetime of the engineering project. The properties of soil vary an excellent deal at totally different places or in bound cases even at one place; the success of soil stabilization depends on soil testing. Advantages of this method are that there are several different materials that can be used to reinforce the soil, the machinery required is minimal, the fibers can be inexpensive and environmentally friendly, and it can be implemented in all types of soils.

II. LITERATURE REVIEW

Marandi carried out his research by performing unconfined compression strength (UCS), California Bearing Ratio (CBR) and compaction tests on neat and coir fibre reinforced soil samples. He found that at a constant fibre length, with increase in fibre percentage in soil (from 0% to 1%), the maximum and residual strengths were increased, while the difference between the residual and maximum strengths was decreased. A similar result was observed for constant palm fibre percentage in soil and increase in palm fibre length (from 20 mm to 40 mm).

Prabakar and Siridihar conducted a research in which they used 0.25%, 0.5%, 0.75% and 1% of sisal fibres by weight of raw soil with four different lengths of 10, 15, 20 and 25 mm to reinforce a locally available soil. They reported that sisal fibres reduce the dry density of the soil. The increase in the fibre length and fibre content also reduces the dry density of the soil. The results showed that the shear stress increased with increase in length of fibre up to 20 mm and beyond it an increase in length reduced the shear stress. The percentage of fibre content improves the shear strength but beyond 0.75% fibre content, the shear stress reduces with increase in fibre content.

S.Chakraborty carried out an investigation in which he mixed locally available materials like lime and rice husk ash with locally available clayey soil in different proportions at optimum moisture content (OMC). The laboratory test results showed marked improvement of strength of soil on addition of admixtures in terms of California Bearing Ratio (CBR).

C. Gumuser and A. Senol carried out a research to investigate the effect of fly ash and different lengths of polypropylene fibres content on the soft soils. They prepared soil samples at three different percentages of fibre content (i.e. 0.5%, 1% and 1.5% by weight of soil) and two different percentages of fly ash (i.e. 10% and 15% by weight of soil). A series of tests was conducted in laboratory i.e. unconfined compression strength tests, compaction tests and Atterberg's limits test. The experimental results showed that the fibre percentages increased the strength of the soil mass and also changed the fly ash brittle behaviour into ductile behaviour.

B. Pandey, K. Bajaj and A. P. Singh conducted a research to study the effects of pozzolanic materials such as fly ash, jute, lime and water proofing compounds on pavement. The aim of their research was to make an economical pavement. The results concluded that these materials can be used for improving the properties of black cotton soil. It is also concluded that mixing of 1% jute fibre, 20% fly ash and 5% lime together in a soil mass gives satisfactory result in workability of pavement.

III. MATERIALS USED

3.1. EXPANSIVE SOIL

Expansive soils as the name implies are the soils that expands in moisture because they contain clay minerals which help them to absorb water. These soils create problems in bearing load of structure. The disturbed soil sample of expansive soil used in this investigation collected from the pond of Ghodi Bacheda village, GB Nagar district, Uttar Pradesh.

Fig 1 Sample of expansive pond soil

The properties of this soil are shown in Table 1 obtained by specific gravity and Atterberg's limit. The results concluded that the soil is clayey in nature.

Table 1 Geo-Technical Properties of Soil

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3.2. FLY ASH

The Fly Ash collected from the thermal power plant near vivo mobile company, Yamuna Expressway, Noida.

Fig 2 Sample of Fly Ash collected from thermal plant

It is sieved through the 2mm sieve to remove external matters. For this study, the soil samples were prepared with different proportions of fly ash i.e. (5%, 10%, 15% and 20% of soil) respectively.

Table 2 Geo-Technical Properties of Fly Ash

PARAMETERS	RANGE
Specific Gravity	1.90 – 2.55
Plasticity	Non plastic
Maximum dry density (gms/cc)	0.9 – 1.6
Optimum moisture content (%)	18.0–38.0
Cohesion (kN/m^2)	Negligible
Angle of internal friction	$30^0 – 40^0$
Compression index Cc	0.05 – 0.4
Permeability (cm/sec)	$8×10^{-6} – 7×10^{-4}$
Coefficient of uniformity	3.1 – 10.7

3.3. COIR

Previous studies and researches have shown that coir fibers with 1.5 cm length work well in soil stabilization process. So, the fibers were extracted from the waste coconut shell and made finer. Then these fibers were cut into approximate length of 1.5 cm.

Fig 3 Coir fibres extracted from waste coconut shell

Three different samples were prepared by mixing different proportions of coconut fibre into the soil sample containing

PARAMETERS	VALUE
Classification	SC
Specific Gravity (G)	2.46
Liquid Limit (W_L)	29.50%
Plastic Limit (W_P)	17%
Plasticity Index (I_P)	14.92%
Maximum dry density (gms/cc)	1.945
Optimum moisture content (%)	8.85%

15% fly ash by weight. The different proportions of coir fibre content mixed were 1%, 1.5%, 2% fibres of sample respectively.

IV. EXPERIMENTAL PROGRAM

4.1. SAMPLE PREPARATION

First of all, four different samples were prepared with the mixture of soil and fly ash. The different percentages of addition of fly ash in soil by weight are 5%, 10%, 15% and 20% respectively. The LL, PL, OMC and MDD value of these samples was found and graphs were plotted accordingly. From these graphs optimum content of fly ash was obtained. After that the coir fibres in different ratios i.e. 1%, 1.5% and 2% respectively was added to the sample containing optimum content of fly ash. Then OMC, MDD and CBR values evaluated for these samples.

4.2. TEST METHODS

All tests in laboratory were conducted as per IS 2720 specifications.

4.2.1. Pycnometer Test

The pycnometer method was used to find the specific gravity of soil. Specific gravity of air dried soil sample was determined using Pycnometer of about 1 liter capacity. This test was conducted to classify the type of expansive soil. Weighing balance with an accuracy of 1g was used to weight the empty density bottle first then the weight of mass of soil in density bottle and then filled with water and weighted again. After that the bottle is emptied and dried then filled with water only and weighted.

4.2.2. Consistency test (Atterberg's Limits)

Moisture content of soil greatly affects the engineering performance of expansive soils. In the order of rising moisture content, a dry soil changes from solid state to semisolid state, to plastic state, and to liquid state. The moisture contents at the constraints of these states are termed as Atterberg limits.

Liquid limit of soil was accomplished by Casagrande Cup Method**.** The air dried soil sample was mixed with distilled water turning it into a paste. The soil paste is then placed into the cup to its top layer and a groove is then cut at the center of the paste using the grooving tool. Then the brass

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Mix Proportions	Liquid Limit	Plastic Limit
Soil	29 %	14.58%
Soil + 5% Fly Ash	29.50%	14.58%
Soil + 10% Fly Ash	28.50%	13.47%
Soil + 15% Fly Ash	25%	9.80%
Soil + 20% Fly Ash	28%	10.94%

cup controlled by crank repetitively lifted and dropped at the rate of 2 turns per second. The liquid limit obtained was the moisture content required to close the distance of along the bottom of the groove made in the center after 25 blows. This test is repeated to the same soil at varying water contents and five determinations were made. The results are then plotted on a graph with moisture content along the vertical axis and number of blows along the horizontal axis. The moisture content that relates to 25 blows is the liquid limit of the soil.

Plastic limit of soil was evaluated by rolling the moist soil sample into thin threads of approximate 3mm diameter until it starts to crumble. The water content at which the threads break at approximately 3 mm in diameter is the plastic limit of soil. Two determinations were made and the average water content is taken as plastic limit.

4.2.3. Modified Proctor Compaction Test

The modified proctor test was performed as per IS 2720 part VII, 1980. The compaction tests were performed on fly ash-soil mix samples and fly ash-soil-coir mix samples. The air and sun dried sample of soil taken and weighted then the different percentages of fly ash added to this soil to prepare the required samples. The mixture is then wetted by adding water to it. This moist soil mass was compacted into five layers having equal mass using modified proctor rammer of 4.9kg. The MDD and OMC were evaluated from the test.

4.2.4. California Bearing Ratio

The CBR test were performed for different fractions of fly ash and coir fiber in soil as per IS 2720 (part 16) 1987. The samples were casted in a cylindrical mould of 150mm diameter and 175mm height by compaction method. Three different samples of soil were prepared such as soil with optimum content of fly ash and coir fiber proportions 1%, 1.5% and 2% respectively. These samples were tested on CBR test apparatus for each variable percentage of fiber. The soil samples were soaked in water for 96 hours before conducting the test. All samples were perforated under varying loads at penetration rate of 1.25mm/min. until a penetration of 12.5mm was reached. The load penetration curve was plotted for all the samples and CBR value is obtained.

V. Results and Discussions

According to experimental work conducted on expansive soil with various percentages of fly ash and coir fiber. The effect of fly ash and coir fiber fractions on OMC-MDD relationships and CBR values were plotted on graph and compared. The results of tests carried on soil and fly ash mixture are tabulated below:

Table 3 LL and PL for Soil-Fly Ash mixture

Table 3 shows that the liquid limit of soil-fly ash mixture decreases with the increase in varying Fly Ash percentages in soil. It is due to the fact that clay content in soil increases the liquid limit of soil. But addition of Fly Ash decreased the clay content and hence liquid limit decreases.

Table 4 OMC and MDD for Soil-Fly Ash mixture

Mix Proportions	OMC %	MDD gm/cc
Soil	9.90	1.95
Soil + 5% Fly Ash	10.25	1.93
Soil + 10% Fly Ash	10.57	1.90
Soil + 15% Fly Ash	11.80	1.86
Soil + 20% Fly Ash	11.85	1.85

It is determined from the above table that the percent increase in fly ash in soil, instigates the optimum moisture content to increase. This happens because fly ash particles were hollow and when mixed with soil increases the water absorption of soil. They absorbed water and resulted in the increased water content in soil. It is also tabulated that the maximum dry density decreases with increase in fly ash inclusion in soil. When the water content increases, the volume of air voids minimized and results in decreased dry density of soil.

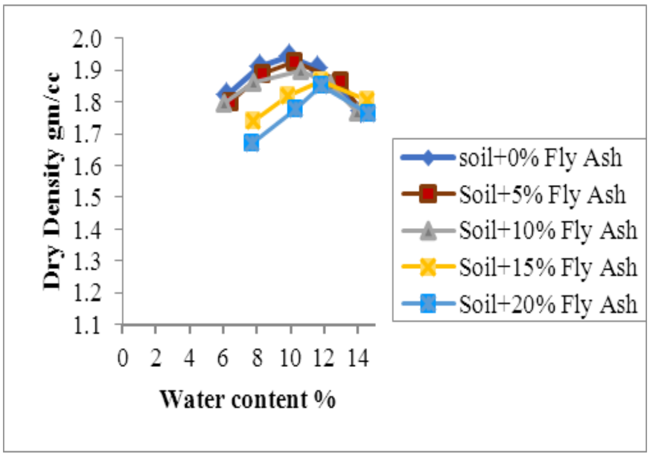

Fig 4 Compaction curves for Soil-Fly Ash mixture

The above graph shows that the OMC from 0% fly ash to 15% fly ash increased rapidly and after this it become gradual. So it can be evaluated from above discussions that the optimum content of fly ash in soil is 15%. Therefore, the soil+15% fly ash sample was further mixed with coir fibre percentages i.e. 1%, 1.5% and 2% of sample respectively to evaluate the results for compaction and CBR tests.

Table 5 LL and PL for Soil-Fly Ash-Coir mixture

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Table 5 shows that the liquid limit of soil-fly ash-coir mixture increases first with the increase in varying coir fiber percentages in soil. The results obtained for Liquid and Plastic Limit of soil-Fly Ash-Coir mixture were similar to that of Soil-Fly Ash mixture in terms of decreasing liquid limits. The liquid limit decreased beyond addition of 1.5% coir.

Table 6 OMC and MDD for Soil-Fly Ash-Coir mixture

Mix Proportions	OMC %	MDD gms/cc	CBR %
Soil+15% Fly Ash+1% coir	10.40	1.86	10.20
Soil+15% Fly Ash+1.5% coir	10.20	1.86	9.20
Soil+15% Fly Ash+2% coir	10.00	1.86	8.30

It can be concluded from the table 6 that OMC decreases with the percent increase in coir fiber. The change in optimum moisture content is very less and MDD change is also negligible. It can be said that the OMC and MDD change is gradual beyond the fiber content of 1%. Beyond the optimum moisture content MDD does not change or increase so the suitable content of fibre is 1%.

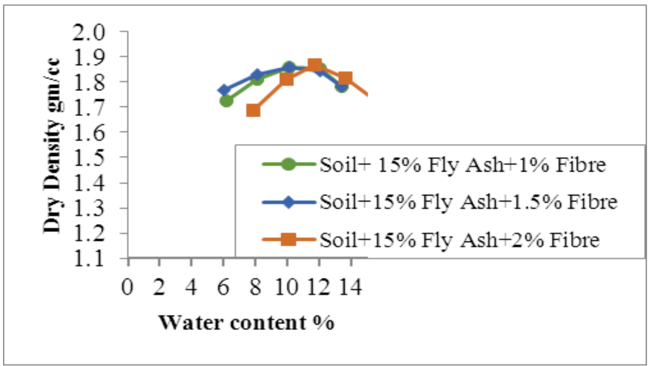

Fig 5 Compaction curves for Soil-Fly Ash mixture

It is also evaluated from the table that CBR test values decreases with percentage increase of coir fibre into soil-fly ash mixture. The maximum CBR value is obtained at the fibre content of 1% with 15% Fly Ash.

VI. Conclusion

OMC increases by increase in percentage of fly ash and percentage of coir fiber because the volume of soil is replaced by fly ash and dry coir fiber due to their absorptive nature. As the percentage of fly ash and coir fiber increases the MDD values of soil decreases along with it. It is because the fly ash and coir fiber both have low density.

The addition of coir fiber is improving the CBR values for soil and fly ash mixture. But the increase in coir fiber percentages decreased the value of CBR beyond 1% coir fiber content. Using randomly distributed fiber in this research helped the soil behavior to improve in terms of tensile strength as coir has good tensile strength.

Mix Proportions	Liquid Limit	Plastic Limit
Soil + 15% Fly Ash + 1% coir	27.20%	11.78%
Soil + 15% Fly Ash +1.5% coir	29.20%	15%
Soil + 15% Fly Ash + 2% coir	27.50%	12%

From the experimental study, it is concluded that 1% coir fiber and 15% Fly Ash in soil is optimum percentage to improve expansive soil properties. It is also very economical to stabilize soil using this method. It is also observed that the maximum CBR value is obtained at the 1% coir fiber in soil-fly ash mixture. It helps to reduce the cost of construction and make this method cost effective.

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BIOGRAPHIES

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