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Influences of fly ash and coir fiber on strength properties of soft soil

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Abstract

Civil Engineers are in search of new competitive material, which can be suitable and effectively used to face many challenges that have cropped up with time in the world. The fly ash is one of the waste materials of thermal power stations, a Coir Fiber (CF) is an abundantly available waste material in coastal India. This paper presents the influence of the inclusion of fly ash and coir fiber on strength properties of soft soil. The review is performed on clayey sand(SC), admixed with class C fly ash and reinforced with coir fibers of aspect ratio(l/d=40) and it is exhibited that discrete as well as randomly distributed coir fibers are instrumental in enhancing the bearing capacity of soil. The soil considered here contains varying percentage of fly ash (range from 5- 20% by weight of soil) and the Coir fibers are added at 3% and 5% for investigation of the relative strength gain in terms of unconfined compression and CBR. Using standard Proctor's maximum density of fly ash and coir fiber, soil was compacted. The present investigation is to evaluate the maximum dry density (MDD), unconfined compressive strength (UCS) and California Bearing Ratio (CBR) of soil utilizing varying percentage of fly ash and coir fiber mixtures. The test outcomes explain that the inclusion of fly ash and coir fibers in soil increases UCS, CBR value and furthermore increase the MDD of soil. The result showed that the optimum percentage of fly ash and coir fiber for achieving maximum strength is 10% fly ash inclusion with 5% coir fiber of the weight of oven-dried soil.

Keywords: Fly ash(FA), Coir fiber(CF), Aspect ratio, OMC, MDD, UCS, CBR.

Introduction

Civil engineering constructions over soft soil must be turned to several cases due to shortage of good bearing soil. Soft soils are perceived by differential settlement, low shear strength and high compressibility. Improving the load bearing capacity of soil is absolutely necessary in the case of high rise buildings constructed over soft soils. To tackle the problems due to soft soil, various techniques have been adopted like soil stabilization, soil reinforcement etc. The heightening expense of materials and absence of accessible assets have inspired Geotechnical engineers to explore advanced substitute.

Fly ash produced from the thermal power plants as by-product. From an environmental perspective, fly ash disposal is major issue in many countries. It is the residual remains after the combustion of coal which is comprised of very fine particles of Silicon Dioxide (SiO_2) (amorphous and crystalline), Aluminum Oxide (Al_2O_3), Iron Oxide (Fe_2O_3) and Calcium Oxide (CaO). According to survey, fly ash is lightweight material and self depleting substance in comparison to raw soil. Additionally fly ash comprises of non-plastic silt size particles of moderately low permeability than sand. Fly ash has been effectively utilized as Concrete Production, in Cement Clinkers, Substitute Material in Brick Manufacturing and Mineral Filler in Bituminous Concrete etc. It is also mixed with clayey soil to construct different civil engineering works like sub grade, foundation base and embankments. The utilization of fly ash as additive in soil stabilization is advantageous because it is moderately economy, compare with cement and lime. Utilization of fly ash advances feasible construction through lessening of vitality utilizes and decreases of greenhouse gases.

Coir is the husk of coconut, a common waste material. Coir fiber is strong and degrades gradually compared to other natural fibers because of high lignin content. The advantages of coir geotextiles are the initial strength, stiffness and hydraulic characteristics of coir reinforcement are practically compared with that of similar items produced using polymer materials. They are of very low raw material price. By chemical treatment and polymer covering, the life of coir items can be made strides. It can be laid on any surface owing to its flexibility and hence it is useful for geotechnical purpose. Coir fibers are environmental friendly, biodegradable and aesthetically pleasing and easy to install and follows the contour the soil surface.

Puppala et al.[1] applied to increase the strength of two expansive soils by using fly ash and fiber reinforcement. It was revealed from the test result that increase of fly ash percentage, decrease plasticity, linear shrinkage strains and free swell of soil. Similarly, reinforcement with fiber not only reduced the vertical shrinkage strains but also raised the free swell values. On addition of both the materials such as fly ash and fiber, the unconfined compressive strength was increased. Mir and Pandian[2] evaluated a series of tests in respect of effectiveness of fly ash on the hydraulic characters of the mixture of soil and fly ash. The result was that swelling pressure of black cotton soil reduced and increased the swelling potential due to inclusion of fly ash. Fly ash provided low permeability values and this minimized the seepage. Manjesh et al.[3] found that, CBR value of the red earth increases with inclusion of Neyveli fly ash. Inclusion of 20% fly ash increased the CBR value marginally but the CBR value reached at the maximum with an addition of 80%. Kaushik et al[4] observed that the addition of fly ash with the fly ash mixed with lime have effect on the index as well as engineering properties of expansive soils. The mixture of fly ash with soil increased the shrinkage limit and CBR value and decreased swelling pressure. The mixture of lime-fly ash in different proportion with the expansive soil resulted in the improvement of index properties as well as the CBR value.

Prabakar et al.[5] examined the nature of soils to raise the load bearing capacity of the soil blended with fly ash. The result show that the dry density and unit weight of soil will be reduced due to inclusion of fly ash with soil. Besides, the shear strength, cohesion, angle of internal friction and CBR value of the mixture were also increased. Mir and Pandian[6] conducted a study on the effectiveness of fly ash on the UCS value of black cotton soil. The result showed that fly ash enhanced the bearing capacity of soil and reduced in cohesive strength of clayey soil. They found that the curing period of Soil-fly ash mixture had great effect on UCS value on black cotton soil. In 7 days curing period of UCS increased significantly with addition of 10% fly ash but in case of 7-28 days, only there was marginal increase. Kolias et al.[7] examined the effectiveness of use of both the high calcium fly ash and cement in stabilization of fine-grained soil. On investigation, it was found that the mechanical properties like modulus of elasticity, flexural strength and CBR value were substantially enhanced.

Shao Li et al.[8] made a group of tests on the effect of fly ash in addition with ordinary Portland cement for the stabilization of highly organic soil. They observed that the effect of stabilization on the mixture of soil-cement enhanced when the optimum value of fly ash was 12%. Olugbenga et al.[9] investigated the geotechnical characteristics of lateritic soils transmuted with husk ash and coconut shell for getting a cheaper and effective road stabilizer. The test was taken up with different percentage of CSHA. They derived that CSHA contents have good potentiality in raising the geotechnical characteristics of lateritic soils. Karthika et al.[10] experimented on stabilization of the soil with coir geotextile. They found that the CBR of soil was stabilized with materials having 5% fly ash content and cement having 2.5% contents and geotextile reinforcement was excellent and its percentage came to 28%.

Lin et al.[11] conducted experiment on two expansive soils during stabilization of Class C fly ash to have a better understanding in respect of the mineralogical, cation exchange capacity and microstructure changes on soil. It was observed that stabilization of CFA, reduced the PI, clay size fraction, swelling percentage, swelling pressure, volumetric moisture contents of the soil, water characteristic curves and enhanced the UCS. The counterrevolution between soil and fly ash has been duly verified by XRD and EDX analysis. Chapale and Dhatrak[12] focused on effect of coir on bearing capacity and settlement of footing, which found various types of bearing capacity improvement techniques. Singh[13] studied the use of coir fibers effect the shear strength parameters and stiffness modulus of fly ash. 1% fiber content provides significant enhancement in the strength parameters of fly ash.

Tiwari and Mahiyar[14] have tested individual behaviour of fly ash, crushed glass and coconut coir fiber with soil, which shows that for adding 10%, 15%, 20%, 25% and 30% FA with soil produces highest CBR of value 4 at max 25%, after that curve height decreases gradually. Singh and Mittal[15] conducted an experimental study on clayey soil blended with different percentage of coir fiber. The result indicated that with the mixture of soil and 1% coir fiber, the soaked CBR value increased by 4.47% and the unsoaked CBR value increased by 4.83%. On addition of coir fiber 1%, the UCS of the soil increased by 3.58 kg/cm². Prasad and Sharma[16] experimented over the usefulness of clayey soil stabilization with fly ash and sand. The result stated that there was a considerable improvement in compaction and CBR value with reduction on the swelling characteristics of clay. Pal and Ghosh[17] presented a theory on consolidation and swelling properties mixed with fly ash and montmorillonite clay. After conducting various tests, they derived that fly ash could reduce the embankment settlement.

Here, in this paper, soil stabilization has been done with the help of fly-ash and coir fibers of various percentages obtained from waste materials. The improvement in the strength parameters has been stressed upon and comparative studies have been carried out using different methods.

Materials and methods

Materials: Soil: The soil, applied for testing was collected from Sambalpur, Odisha, India. The collected soil was sieved through a 4.75mm sieve for separation of remote and vegetative matters. Table-1 and Table-2 presents various Geotechnical properties of soil and Engineering characteristics of soil respectively.

Table-1: Geotechnical Characteristics of Soil.

Properties	Values
Classification	SC
Specific Gravity	2.33
Liquid limit	31.20
Plastic limit	13.63
Plasticity Index	17.47

Table-2: Engineering characteristics of Soil.

Properties		Values
Compaction Test	OMC (%)	13.90
	MDD (g/cc)	1.81
Unconfined Compressive Strength (kN/m²)		34.127
CBR (soaked) test		4.292

Stabilizing Material: The Fly Ash and Coir Fiber was used as stabilizing material. The collection of fly ash was from the nearby Hindalco power plant. The collected fly ash was sieved through 2mm sieve to isolate out the outside matters. Table-3 shows the Physical and Chemical properties of the fly ash.

Test Method: Preparation of Sample: The preparation of five different samples was made with the mixture of dry soil and addition of 0%, 5%, 10%, 15% and 20% of fly ash on the basis of weight of the soil respectively. In order to get homogeneous mix, proper care was taken while mixing the samples. The OMC, MDD, UCS and CBR value of different samples containing different percentage of fly ash was found out. From which Optimum fly ash percentage was determined. Coir fibers having aspect ratio (l/d=40) were added of different proportion (3% and 5%) to the sample having optimum fly ash content and variation of OMC, MDD, UCS and CBR was evaluated.

Table-3: Physical and Chemical properties of Fly ash.

Properties	Value
Type	Class C
Specific Gravity	2.08
Liquid limit and Plastic limit	Non plastic
Silica	60.85%
Alumina	29.14%
Iron Oxide	3.01%
Titanium Oxide	0.68%
Lime	1.88%
Magnesia	0.35%
Potash	0.53%
Soda	0.48%
Sulphate	0.07%
Phosphate	0.68%
Loss on ignition	2.05%

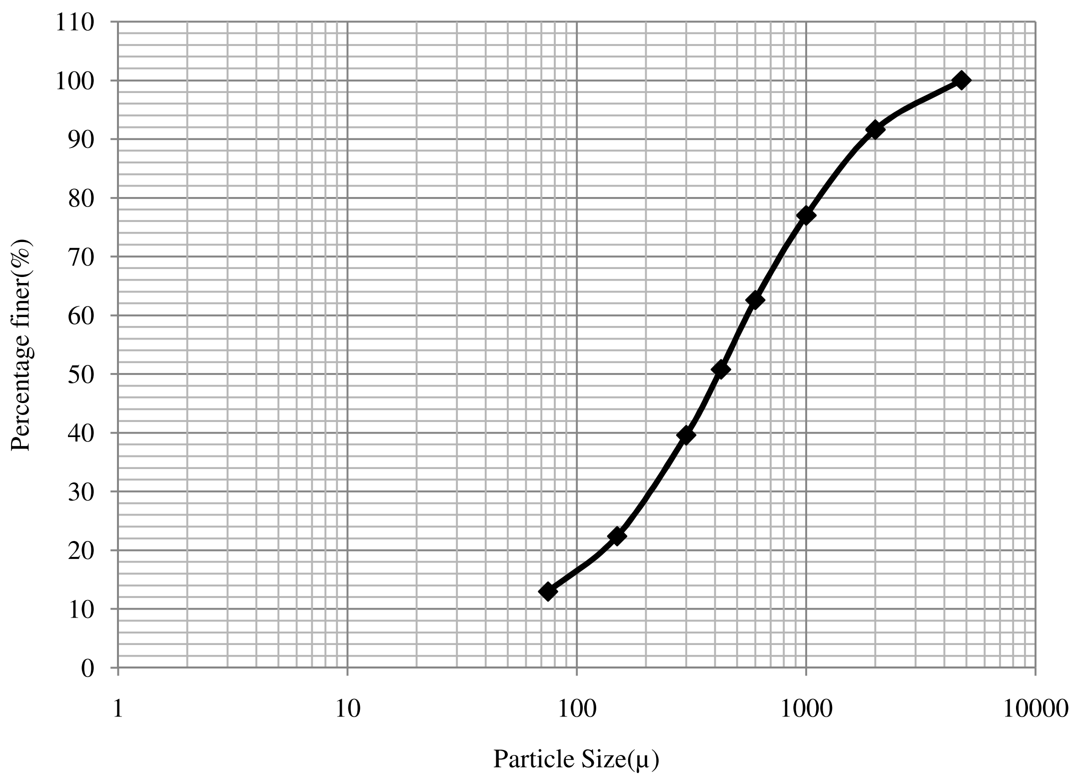

Figure-1: Particle Size Distribution Curve of Soil.

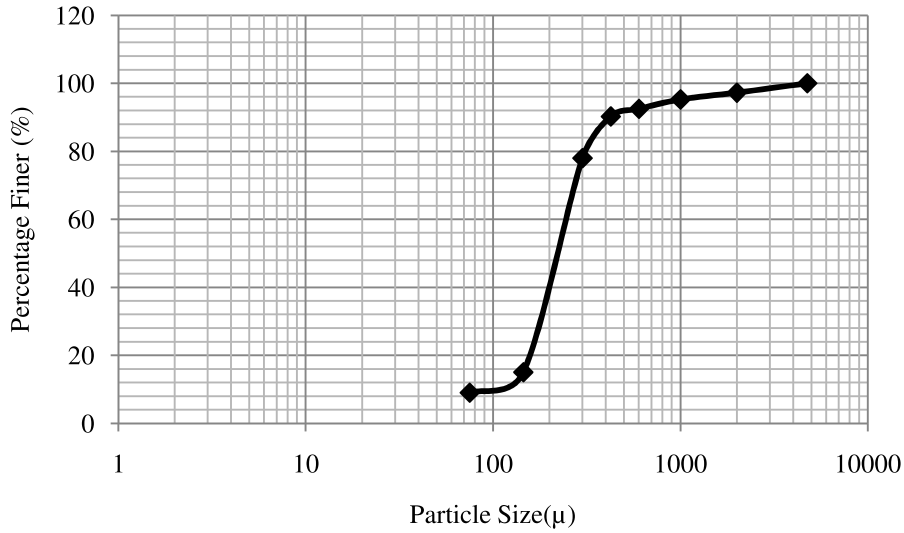

Figure-2: Particle Size Distribution Curve of Fly ash.

Compaction Test: The standard proctor test was performed as per IS 2720 (Part VII) 1980. The compaction tests were done on soil and fly ash blends. The weighted oven dried soil was taken and various percentage of fly ash was added with dry soil. The appropriate quantity of water was added with soil-fly ash mixture and the wet specimen was compacted in mould in three layers utilizing standard proctor rammer of 2.6kg. The MDD and OMC were determined from this test.

Unconfined Compression Test: The mixture of soil-fly ash-coir fiber was compacted in 50mm diameter and 100mm height of cylindrical mould to standard proctor's MDD. Then the sample was extracted from the mould for the further test. The extracted samples were prepared with inclusion of soil with (0%, 5%, 10%, 15% and 20%) fly ash and soil with optimal percentage of fly ash and (3%, 5%) coir fiber. The experiments were regulated at a consistent strain rate of 0.125mm per min according to Indian Standard 2720 (part 10) 1991. Three samples were examined for each variable proportion. The UCS value was calculated from the Stress-Strain curve.

California Bearing Ration Test: The CBR tests were executed for different percentage of fly ash and coir fiber as per IS 2720 (part-16) 1987. The samples were prepared in a cylindrical mould of 150mm dia and 175mm height by compaction of the mixture of soil-fly ash and soil-fly ash-coir fiber to standard proctor's MDD. Samples were made such as Soil with (0%, 5%, 10%, 15% and 20%) fly ash and Soil with Optimal fly ash and (3% and 5%) coir fiber. Three samples were experimented for each variable proportion and the samples were soaked in water for 96 hours before test was conducted. All the experiments were executed at a penetration rate of 1.25mm/min until a penetration of 12.5mm was obtained. CBR values were calculated and the Load-Penetration curve was plotted for all the specimens.

Results and discussion

According to experimental program, numerous tests were executed on soil with various percentages of fly ash and coir fiber. The effect of fly ash and coir fiber inclusion on OMC-MDD relationship, UCS and CBR values were considered. The outcomes are presented in Table-4,5,6 and Figures 1,2,3,4,5.

Compaction Test: It is observed in Table-4 and Figure-3 that the inclusion of fly ash, the OMC and MDD was increased up to certain percentage of fly ash addition and then decreased. On inclusion of 10% fly ash with soil, the optimum value of MDD was obtained. After conducting all the experiment, on addition of optimal percentage of fly ash with two different percentage of coir fiber (3%, 5%) it was observed that the OMC value was increased where as MDD value was decreased.

Table-4: Variation of MDD and OMC for different value of soil-fly ash and soil-fly ash-coir mixtures.

Soil Sample Mix	MDD (g/cc)	OMC (%)
Soil+ 0% Fly ash	1.81	13.90
Soil+ 5.0% Fly ash	1.83	14.80
Soil+ 10.0% Fly ash	1.84	15.37
Soil+ 15.0% Fly ash	1.78	14.70
Soil+ 20.0% Fly ash	1.75	16.10
Soil+10.0% Fly ash+3.0% Coir fiber	1.77	14.85
Soil+10.0% Fly ash+5.0% Coir fiber	1.83	15.17

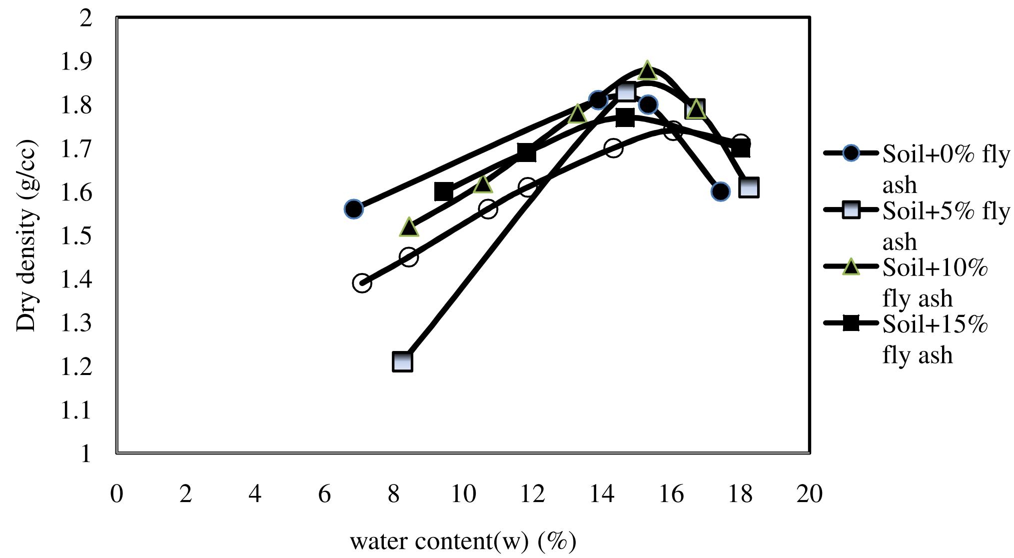

Figure-3(a): Compaction curve for Soil and Fly ash Mixture.

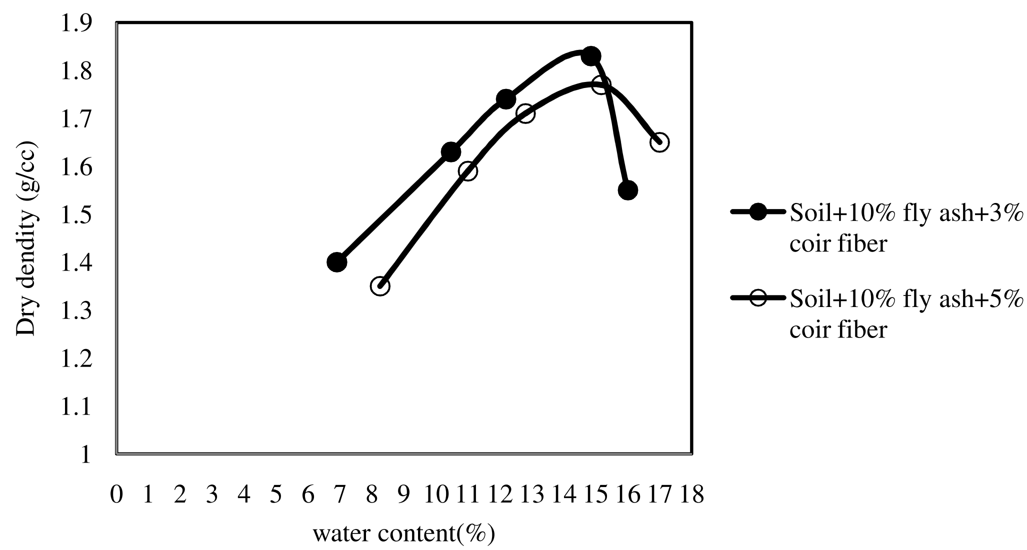

Figure-3(b): Compaction Curve for Soil, Fly ash and Coir fiber mixture.

Unconfined Compression Test: The experimental outcomes of experiments were given in the form of stress-strain curve in Figure-4. In Table-5, the outcomes revealed that the stress value of soil with mixture of 5% fly ash was decreased due to some chemical reactions and with inclusion of 10% fly ash UCS value was increased and then the value decreased with addition of 15% and 20% fly ash.

The stress value was maximum by the admixture of soil and 10% fly ash.

The stress value was further increased with inclusion of 3% and 5% of coir fiber with 10% fly ash. The optimum UCS value was achieved at the blend of Soil addition with 10% fly ash and 5% coir fiber.

Table-5: Variation of UCS value for different percentage of Soil+ Fly ash and Soil+ Fly ash+ Coir fiber.

Soil Sample Mix	UCS value (kN/m²)
Soil+ 0% Fly ash	35.94
Soil+ 5.0% Fly ash	29.91
Soil+ 10.0% Fly ash	59.33
Soil+ 15.0% Fly ash	49.81
Soil+ 20.0% Fly ash	42.65
Soil+10.0% Fly ash+3.0% Coir fiber	60.60
Soil+10.0% Fly ash+5.0% Coir fiber	62.68

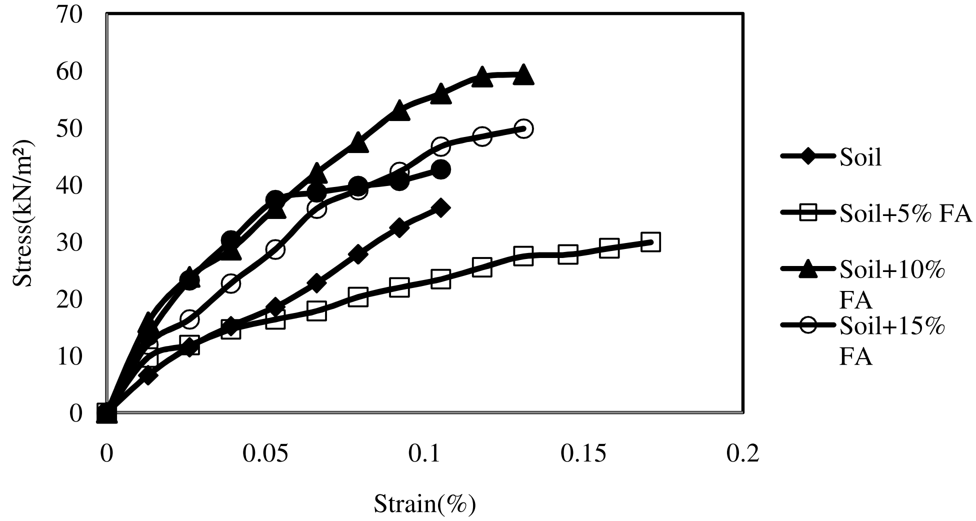

Figure-4(a): Variation of UCS at different Fly Ash contents.

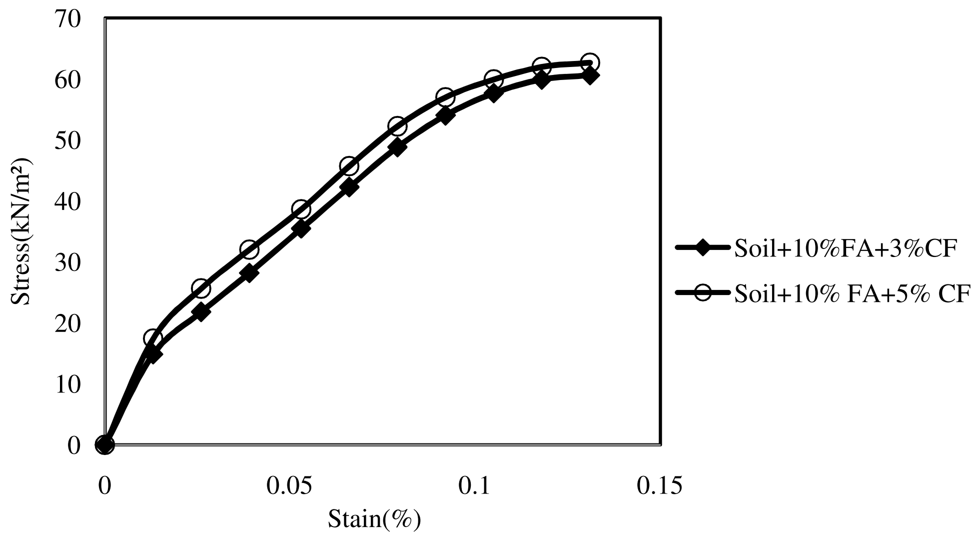

Figure-4(b): Variation of UCS for Soil, Fly ash and Different percentage of Coir Fiber contents.

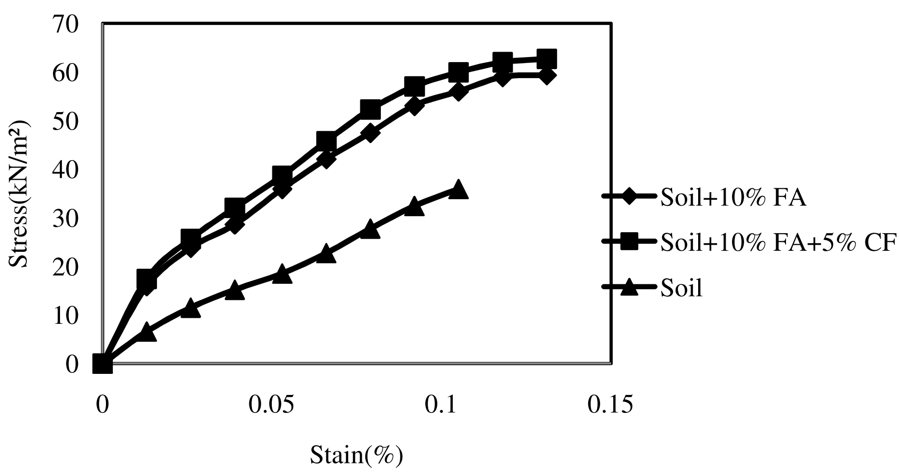

Figure-4(c): Comparison of UCS value**.**

Soaked CBR Test: The outcomes of soaked CBR test from Table-6 and Figure-5 were indicated that the CBR value was decreased by factor 1.945 for 5% inclusion of fly ash with soil due to some chemical reaction, then the value was increased by factor 6.16 for adding of 10% fly ash with soil and finally decreased with inclusion of further higher percentage of fly ash.

Two different percentage of Coir fiber (3%, 5%) was added to the optimum dose of fly ash and soil. The CBR values were increased with addition of 3% and 5% coir fiber with 10% fly ash and soil.

The highest CBR value was obtained from the above experiment was soil with 10% fly ash and 5% coir fiber.

Table-6: Variation of CBR value for different percentage of Soil+ Fly ash and Soil+ Fly as+ Coir fiber.

Soil Sample Mix	CBR Value (%)
Soil+ 0% Fly ash	4.292
Soil+ 5.0% Fly ash	1.945
Soil+ 10.0% Fly ash	6.160
Soil+ 15.0% Fly ash	5.093
Soil+ 20.0% Fly ash	2.205
Soil+ 10.0% Fly ash+ 3.0% Coir fiber	6.552
Soil+ 10.0% Fly ash+ 5.0% Coir fiber	9.730

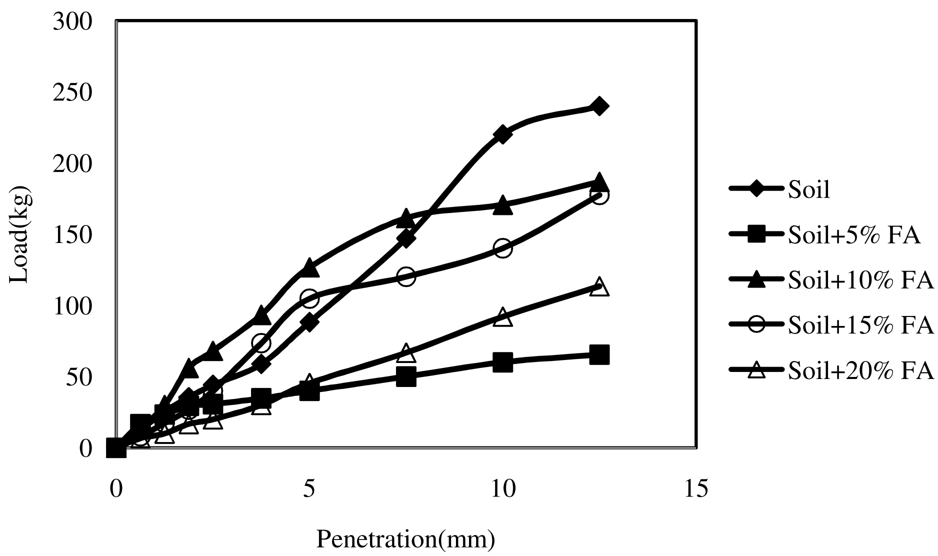

Figure-5(a): Load-Penetration Curve for Soil and various Fly Ash contents.

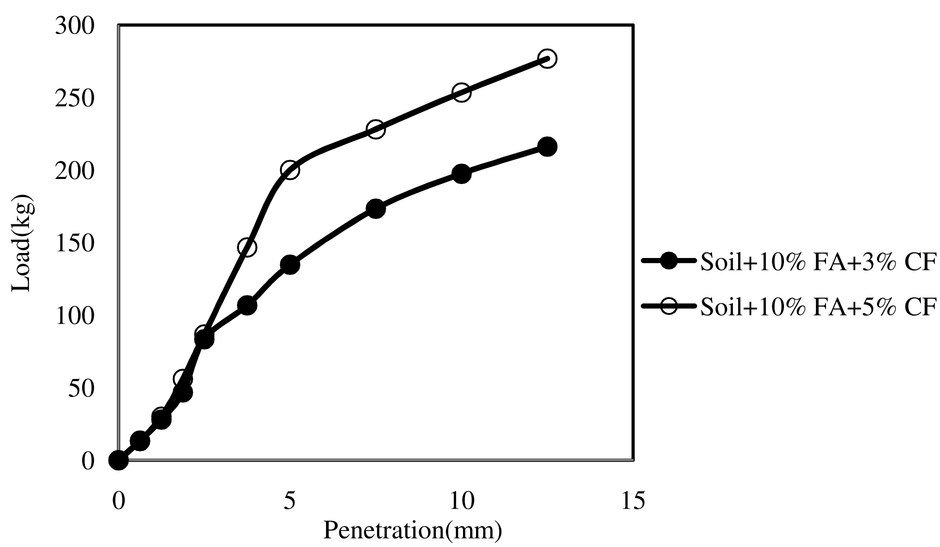

Figure-5(b): Load-Penetration Curve for Soil, Fly ash and various percentage of Coir Fiber.

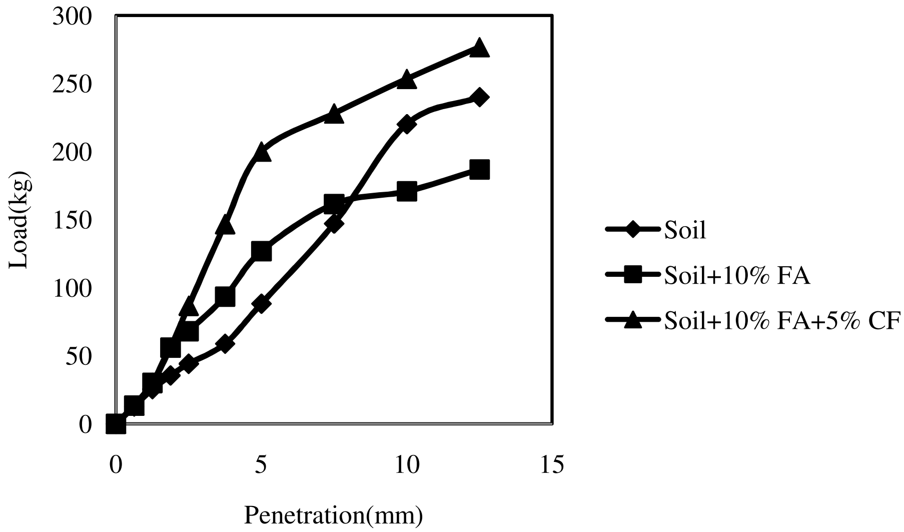

Figure-5(c): Comparison of Load-penetration curve of Soaked CBR.

Conclusion

In the current review, the appropriateness of fly ash and coir fiber blend as a soil stabilizer for soft soil was studied. The accompanying conclusions can be drawn from observations. i. OMC increase with increases of fly ash and percentage of coir fiber. Percentage of fly ash increases with the increase of MDD value. MDD estimation of soil decreases, when the percentage of fiber increments. ii. The inclusion of fly ash is improving UCS and CBR value of all the mixed proportion, but there is an abrupt hike in CBR at 10% fly ash content. iii. Addition of coir fiber increases the CBR value and UCS value in soil+10% fly ash. The present study suggests that 5% of coir fiber with l/d=40, seemed, by all accounts, to be most extreme. iv. From the investigation, it is studied that the mixture of soil, 10% fly ash and 5% coir fiber is optimum percentage and economic.

Based on the result obtained, it is recommended that coir waste can be utilized as reinforced material and the fly ash can be used as additive for soil stabilization. This provided an efficient and economic way to dispose of fly ash and coir waste. It can elevate rustic economy and prompt to helpful impact in engineering construction.

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