INCLUSION OF COCONUT COIR FIBER IN SOIL MIXED WITH COAL ASH

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Abstract

An experimental study is conducted on local soil i.e. silty sand (SM) mixed with varying percentage of coal ash and coconut coir fiber. Unconfined compressive strength (UCS) and California bearing ratio (CBR) tests are conducted on the soil mixed with coal ash/coir fiber/ both. The percentage of coal ash by dry weight of soil is taken as 20%, 30%, 40% and 50%. A significant increase in UCS and CBR value is observed for addition of 20% of coal ash in the soil.UCS value is maximum (1.81 kg/cm^2) for 20% coal ash mixed with soil. The unsoaked and soaked CBR values as 10.5% and 5.6% increase to 27.7% and 14.6%, respectively. Rate of increase in CBR values decreased after further addition of coal ash beyond 20%. Randomly mixed coconut coir fiber is included in optimum soil-coal ash mix (i.e. 80% soil and 20% coal ash) and varied as 0.25, 0.50, 0.75 and 1.0%. UCS value increases substantially with inclusion of coconut coir fiber in soil - coal ash mix. The optimum percentage of soil-coal ash-coir fiber mix is arrived at 79.75:20:0.25 (by weight). Adding of these waste materials (coal ash + coconut coir fiber) results in the increase strength of soil and less thickness of pavement due to increased CBR of mix and hence saving of the stone aggregates in base and sub-base course for sustainable development in construction of highway.

Keywords: *Coal ash, Coconut coir fiber, Unconfined compressive strength (UCS) and California bearing ratio (CBR).*

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1. INTRODUCTION

Keeping in mind the large geographical area of India (3,287,240 sq. kms) and population of India (125 million approx), a vast network of roads is required. Presently, road network in India is second largest in the world and amounting to 33 Lakhs km (Approx) consisting of Expressways (200 kms), National Highways (79,243 kms), State Highways (1,31,899 kms), Major District Roads (4,67,763 kms), Village Roads and other Roads (26,50,000 kms),[1]. Road development programme in India is in progress with a speedy pace to meet the present day traffic growth (number vehicle increasing at an average pace of 10.16% annum over the last five years) by way of new construction, Strengthening/widening the existing Highways,[1]. The granular materials (stone aggregates) required for construction and maintenance of such a gigantic road network are immense in quantity. The construction of road imposes a heavy pressure on limited resources like suitable earth, stone aggregates binders etc. For sustainable development use of locally available materials, waste material should be encouraged in order to save the natural resources for future generation. There are many types of waste material found in India like coal ash, stone quarry, plastics, recycled aggregate, geonaturals and polythene bags etc. One of the best solutions widely accepted is to improve strength of subgrade soils using lime, fly ash and the pozzalonics waste, fiber *etc*. resulting in reduction of overall thickness of pavement and saving of construction materials. Now a day, coal ash has been extensively used in the construction of embankment and highways. Reinforced coal ash embankment with height varying from about 5-7 m has been successfully made in Vishveshvaraya setu at Okhala, New Delhi. In the construction of embankment for four-lanning of NH-6 from Dankuni to Kolaghat near Kolkata in west Bengal, pond ash were used. The height of embankment varies from 1.5-4.0 m. Similarly, the pond ash from Uchahar thermal power plant has been economically used in the construction of Allahabad bye pass. All these successful cases of ash utilization in the embankments suggests that it can be safely and economically used where the coal ash is available at shorter lead than good borrow earth [2]. IRC SP-58 (2001) [3] gives the guidelines for use of fly ash in road embankments. This paper focuses on studying the feasibility of improving local soil with coal ash and coconut coir fiber as admixtures. Accordingly, an experimental study is planned to improve the characteristics of locally available soil (SM) in terms of unconfined compressive strength (UCS) and California bearing ratio (CBR) by mixing of the waste materials coal ash and coconut coir fiber as admixtures.

2. REVIEW OF LITERATURE

There have been many studies reporting to the utilization of coal ash in conjunction with lime for the stabilization of soil. Some of the prominent investigation reported in the literature includes Ingles and Metcalf [4], Mitchell and Katti [5], Maher et al. [6], Brown [7] and Edil *et al*. [8]. In the nineteen eighties, the researchers *viz*. Chauhan et al,[9] Consoli et al, [10] Sadek et al, [11] Chore et al and Gray and Ohashi [12] *etc*., started using fibers in the utilization of the waste material in conjunction with the different types of soils in order to improve the strength and /or enhance certain properties thereof. Gray and Ohashi [12] indicated that with the inclusion of discrete fiber, shear strength and ductility increases and post peak strength loss reduces. Along similar lines, many researchers worked on the aspect ratio of fiber *viz.* Gray and Al-Refeai, [13]; Gray and Maher [14]; Al-Refeai, [15]; Michaowski and Zhao [16]; Ranjan *et al*., [17]; Michaowski and Cermak [18]. Maher and Ho [19] reported consolidated drained triaxial test results in respect of lime- fly ash – fibres mixture. There are different types of fiber used in previous studies. While the investigation reported by Consoli et al. [10] used plastic waste and polyethylene terephathalate fibers as the reinforcing material, polypropylene fibers were used by chore et al. [20]. Parbhakar and Shridhar [21] worked on soft soil reinforced with bio-organic materials such as sisal fibers. Most of the fibers were randomly distributed and in discrete fashion. The studies concerning the utilization of only fly ash along with the fibers are reported by Dhariwal et al. [22], Kaniraj and Gayatri [23]. Jadhav and Nagarnaik et al. [24] reported the performance evaluation of soil and randomly distributed coir fibers. Some of the significant studies that dealt with the system of soil- fly ash- fibers include those by kaniraj and Havanagi [25]. Most of the studies have been conducted mostly on black cotton soils, lateritic soil and soft soil. Keeping this in mind the present study has been are conducted on improving silty sand mixed with waste material like coal ash and coconut fire.

3. Materials

3.1 Soil

The locally available soil from campus of PEC University of Technology, Chandigarh (India) has been taken for the study. The index properties, compaction characteristics, UCS and CBR are conducted on the soil as per relevant parts of IS 2720 and results are reported in Table 1. The soil is classified as silty sand (SM) as per IS 1498:1970[26].

Table-1: Properties of soil

S.No.	Properties	Value
1	Liquid Limit (%)	-
2	Plastic Limit (%)	-
3	Specific Gravity	2.6
4	Gravel Size (>4.75mm)	0
5	Sand Size (0.075-4.75mm)	61%
6	Silt Size (0.002-0.075mm)	31%
7	Clay Size (<0.002mm)	8%
8	Maximum Dry Density (gm/cc)	18.9
9	O.M.C. (%)	9.17
10	U.C.S Value (kg/cm^2)	1.73
11	C.B.R Value (%) unsoaked	10.56
12	C.B.R Value (%) soaked	5.59

3.2 Coal Ash

Coal ash is the ash produced by burning of pulverized coal in thermal power plants that gets collected at the bottom of furnace as well as in electrostatic precipitators. The coal ash generated from all the existing thermal power plants is over 160 million tons per year. Its quantum is projected to be 450 million tons by year 2020-21 and 900 million tons by the year 2031-32. The percentage utilization of coal ash in various construction activities is still limited to 50-60% of generated ash and the rest amount of coal ash has to be suitably disposed off on land as a waste material by creating an engineered ash pond to take care of environmental concerns, Singh and Datta [27].

The coal ash used in the present study is taken from Guru Gobind Singh Thermal power plant, at Ropar (India) and stored in dry containers. The index properties, compaction characteristics, and Shear strength parameters for compacted coal ash are reported in Table 2. The coal ash can be classified as non-plastic sandy silt (ML) as per IS 1498:1970[26].

Table-2: Properties of coal ash

S.No.	Properties	Value
1	Liquid Limit (%)	-
2	Plastic Limit (%)	-
3	Specific Gravity	2.1
4	Gravel Size (>4.75mm)	0
5	Sand Size (0.075-4.75mm)	26%
6	Silt Size (0.002-0.075mm)	72.5%
7	Clay Size (<0.002mm)	1.5%
8	Maximum Dry Density (gm/cc)	1.18
9	O.M.C. (%)	31
10	Cohesion	0
11	Angle of internal friction compacted At MDD	31

3.3 Coir Fiber

Coconut coir fiber is obtained from the husk of coconut and belongs to the group of hard structural fibers. The fibrous husks are soaked in pits or in nets in a slow moving body of water to swell and soften the fibers. The long bristle fibers are separated from shorter mattress fibers underneath the skin of nut, a process known as wet milling. The coir fiber is elastic enough to twist without breaking and it holds a curl as though permanently waved. It is an important commercial product used in mattress. Shorter mattress fibers are separated from the long bristle fibers which are in turn a waste in the coir fiber industry.

The coir fiber is obtained from industrial area of Chandigarh as a waste material. Diameter of the fiber is 0.5 mm. The coir is cut into pieces of length varying from 3cm to 5cm. The fibers are mixed randomly in the soil-coal ash mixture during experiments in various percentages as 0.25, 0.50, 0.75 and 1.0%.

4. EXPERIMENTAL PROGRAM

The main objective of the experimental programme is to study strength characteristics of soil-coal ash mixure with inclusion of coconut coir fiber. The parameters that are studied include UCS and CBR. Firstly coal ash is mixed in soil in dry condition uniformly in different percentages as 0, 20, 30, 40 50 and 100. UCS (compacted at OMC) and CBR (in unsoaked and soaked condition) of the soil-coal ash mix are determined. The randomly oriented fibers are mixed in the soil-coal ash mixture in various percentages as 0.25, 0.50, 0.75 and 1.0%. UCS and CBR for soil-coal ash-coir fiber mix are determined.

Total ten samples having various proportions of soil coal ash and coir fiber mix are prepared for the present series of tests. The mixes are designated with symbols in which S stands for soil, CA stands for coal ash and C stands for coir. Samples with notation S_{100} has 100% of soil, CA_{100} contained only coal ash. Sample prepared by mixing four parts of soil and one part of coal ash by weight is designated as CA_{20}. In a similar lines samples CA_{30}, CA_{40}, CA_{50} had 30%, 40% and 50% coal ash of the total weight of the mix. In similar lines, samples $C_{0.25}$ $C_{0.50}$, $C_{0.75}$, $C_{1.0}$ had 0.25%, 0.50%, 0.75% and 1.0% coir of the total weight of the mix of soil and coal ash. Different percentage of coir fiber (0.25, 0.50, 0.75 and 1.0%) by weight are mixed in soil and 20% coal ash mix and are designated as $CA_{20} + C_{0.25}$, $CA_{20} + C_{0.50}$, $CA_{20} + C_{0.75}$, $CA_{20} + C_{1.0}$. The symbolic designation of mixes is summarized in Table 3.

Table 3: Symbolic Designation of Mixes

S.N	Mix	Symbolic Designation
1	100% of soil	S_{100}
2	Soil+20% of coal ash	CA_{20}
3	Soil+30% of coal ash	CA_{30}
4	Soil+40% of coal ash	CA_{40}
5	Soil+50% of coal ash	CA_{50}
6	100% of coal ash	CA_{100}
7	Soil+20% of coal ash+0.25% of coir	$CA_{20} + C_{0.25}$
8	Soil+20% of coal ash+0.50% of coir	$CA_{20} + C_{0.50}$
9	Soil+20% of coal ash+0.75% of coir	$CA_{20} + C_{0.75}$
10	Soil+20% of coal ash+1.0% of coir	$CA_{20} + C_{1.0}$

5. RESULTS AND DISCUSSIONS

Experiments are carried out to determine UCS and CBR of different soil-coal ash mixes. MDD and OMC from Standard Proctor test on Different mixes are given in Table 4. Perusal of the test results in Table 4 indicates that the maximum dry density decreases and optimum moisture content increases with increasing percentage of coal ash in the soil. The maximum dry density of soil varies from 1.89 gm/cc for untreated soil to 1.42 gm/cc for soils mixed with 50% coal ash and the dry density of 100% coal ash is 1.18 gm/cc. The decrease in dry density of soil and increase in OMC by addition of coal ash may be due to lower specific gravity of coal ash and more water required for lubrication of coal ash.

Table-4: MDD and OMC from Standard Proctor Test

S. No.	Specimen	% Coal ash	OMC (%)	MDD (gm/cc)
1	S_{100}	0	9.17	1.89
2	CA_{20}	20	11.04	1.65
3	CA_{30}	30	12.50	1.57
4	CA_{40}	40	16.30	1.50
5	CA_{50}	50	17.56	1.42
6	CA_{100}	100	31.00	1.18

Tests for UCS and CBR are carried out at maximum dry density (MDD) corresponding to optimum moisture content (OMC). The graphs for UCS and CBR (unsoaked and soaked) for soil-coal ash mix are depicted through Figs 1 and 3, respectively.

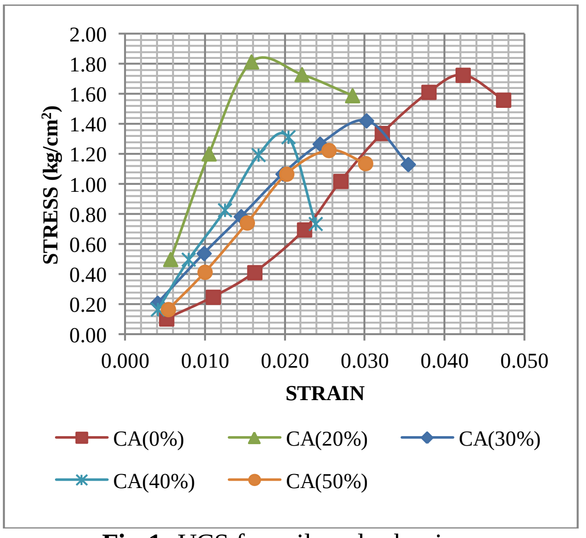

Fig-1: UCS for soil-coal ash mixes

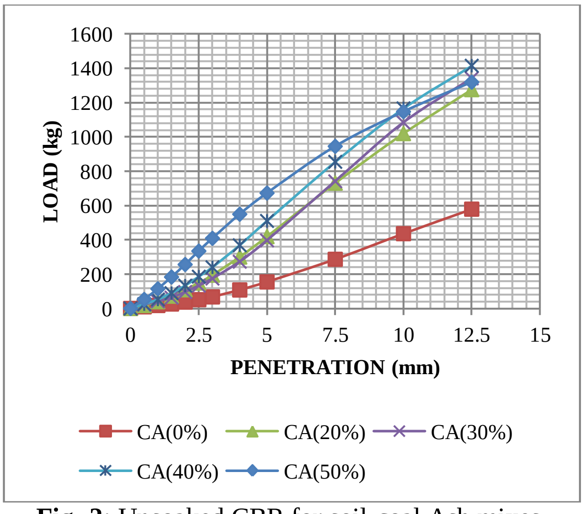

Fig.-2: Unsoaked CBR for soil-coal Ash mixes.

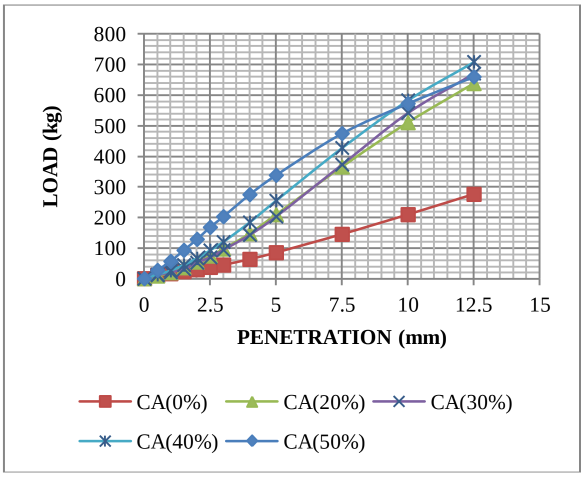

Fig.-3: Unsoaked CBR for soil-coal Ash mixes.

The values for UCS and CBR (unsoaked and soaked) for soil-coal ash mix are tabulated in Table 5.

Table-5: UCS and CBR for soil-coal ash mix

Sample	U.C.S (kg/cm^2)	C.B.R Unsoaked (%)	C.B.R Soaked (%)
S_{100}	1.73	10.56	5.59
CA_{20}	1.81	27.74	14.60
CA_{30}	1.42	32.60	15.56
CA_{40}	1.31	33.09	16.54
CA_{50}	1.23	35.04	17.46

From Table 5 the range of unconfined compressive strength of soil varies from 1.73 kg/cm^2 to 1.81 kg/cm^2 (mixed with 20% coal ash). It is noted that when the percentage of coal ash is increased beyond 20%, UCS starts decreasing. Also, CBR (unsoaked and soaked) values of soil increases substantially (2.6 times) upon addition of 20% coal ash in the soil. A nominal increase in value of CBR is observed for further increase in the percentage of coal ash (*i.e.* beyond 20%) in the soil. Therefore, it is concluded that soil mixed with 20% of coal ash yield the optimum results in terms of UCS and CBR.

Subsequently, coconut coir is mixed in this optimum soil-coal ash mix (in various percentages as 0.25, 0.50, 0.75 and 1.0%) with an intention to argument the strength of mix further. UCS and CBR of Soil-coal ash – coir fiber mix are reported in Table 6.

Table- 6: UCS and CBR for soil-coal ash-coir fiber mix

Sample	U.C.S (kg/cm^2)	C.B.R Unsoaked (%)	C.B.R Soaked (%)
S_{100}	1.73	10.56	5.59
CA_{20}	1.81	27.74	14.60
$CA_{20} + C_{0.25}$	**5.0**	**26.27**	**19.46**
$CA_{20} + C_{0.50}$	5.31	24.61	12.0
$CA_{20} + C_{0.75}$	5.73	23.34	11.46
$CA_{20} + C_{1.0}$	5.78	21.37	8.27

It is observed from Table 6 that there is continuous increase in the value of UCS with an increase in the content of coconut coir fiber. However, sharp increase in UCS has been observed corresponding to 0.25% of coir fiber. The values of U.C.S. are increased from 1.81 kg/cm^2 for CA_{20} mix to 5.78 kg/cm^2 for CA_{20} + $C_{1.0}$ mix. Also, The soaked CBR values is maximum and increases from 14.6% to 19.4% upon addition of 0.25 % of coconut coir fiber in the soil mixed with 20% coal ash. However, unsoaked CBR is not observed to increase upon inclusion of coir fiber. This may be due to increase in elasticity in the coir fiber in wetted condition. The road crust in high rainfall area is designed based upon soaked CBR, therefore the inclusion of fiber is helpful in augmenting the soaked CBR and hence, resulting in less thickness of pavement crust. On this account, not only natural resources of stone aggregates are saved due to reduced thickness of pavement, but at the same time waste product like coal ash and coconut coir fiber are also gainfully used reducing the burden of its disposal. That is why, it is inferred that the optimum soil-coal ash – coir fiber mix in terms of strength characteristics is 80% soil + 20% coal ash mixed with coconut coir fiber @ 0.25% by weight of soil-coal ash mix.

6. CONCLUSIONS

The present study has shown quite encouraging results and following important conclusions can be drawn from the study:

- Coal ash is an industrial waste which could be utilized in a sub base for flexible and rigid pavements.
- The O.M.C. of soil-coal ash mix increase with increasing the percentage of coal ash. The maximum dry density (MDD) is observed to decrease with increase in the percentage of coal ash.
- Relative increase in unconfined compression strength value is maximum when 20% of coal ash is mixed with soil and the value is 1.81 kg/cm^2. Also, there is significant increase in the value of CBR (unsoaked and soaked) at 20% coal ash mixed in the soil (SM). It shows that optimum percentage of coal ash to be mixed in soil for UCS and CBR is 20%.
- Inclusion of coconut coir fiber further augment C.B.R. and U.C.S. values of soil-coal ash mix.
- Maximum improvement in U.C.S. and C.B.R. values are observed when 20% of coal ash and 0.25% of coir fiber is mixed with the soil.
- Presence of coir fiber increases value of soaked CBR. The soaked C.B.R. value is increased from 161% to 248%. Therefore the inclusion of fiber is helpful in augmenting the soaked CBR and hence, resulting in less thickness of pavement crust in high rainfall area.
- It is concluded that inclusion of 0.25% coconut coir fiber in 80% soil and 20% coal ash by weight is optimum percentage of materials in consideration of soaked C.B.R. value and U.C.S. Hence, this proportion may be economically used in road pavement and embankments.

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