IOP Conference Series: Materials Science and Engineering

PAPER • **OPEN ACCESS**

Investigating Strength Behaviour of Pond Ash as a Construction fill material

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Abstract: The use of sustainable materials has become a very important issue for the researchers and geotechnical engineers in construction of embankment for highways. Due to the combustion of coal for producing electricity, enormous amount of fly ash is produced, thus causing a serious threat of disposal and creating environmental and health problems. In India, where land to population ratio is too small, it is very difficult to dispose the fly ash on a huge area of land. So, to tackle the above stated problem, it is very important to utilize the fly ash in such a manner that it does not cause any harm to environment. The aim of this study was to conduct different laboratory tests on cement stabilized pond ash, so that it becomes suitable for geotechnical fill material. Cement was added in pond ash at different proportions and the effect of this addition was studied by analyzing the strength properties of pond ash. Synthetic fiber in the form of polypropylene was added to the optimum mix of cement-pond ash in different proportions. After adding the fiber in the optimum mix, flexural behavior was studied and the failure pattern with and without fiber was observed.

Keywords: Pond ash, Sustainability, Stabilization, Fiber, Fill material

Introduction

In order to conserve the natural resources and energy, several waste products have been proposed in recent years for use as sustainable construction materials. One by-product that has shown substantial potential as an alternative construction material is pond ash, if proper and adequate additives are used. Pond ash is a solid residue obtained from the ash pond constructed near the thermal power stations. Thermal power plants have been a major source of power generation in India, where 75% of the total power obtained is from coal-based thermal power plants (Senapati 2011). In India about 120 coal based thermal power stations are producing about 112 million tonne fly ash/ pond ash per year. With the increasing demand of power and coal being the major source of energy the ash generation is expected to increase to about 225 million tonne by 2017 (Kumar *et al.* 2005). Due to enormous production of fly ash/pond ash as a by-product of combustion, it requires huge disposal area and creates environmental problems. In India, where land to population ratio is too small, acquiring huge area of land for the disposal of fly ash is not easy. Hence the proper utilization of fly ash without causing problem to environment is a foremost concern for developing country like India. For many years several researchers contributed their significant research work to convert fly ash into useful construction material (McLaren and DiGioia 1987; Glogowski *et al.* 1992; Kaniraj and Havangi 1999, Sridharan *et al.* 2001; Kaniraj and Gayathri 2003; Das and Yudhbir 2005, Choudhary et al. 2010, Gill et al. 2013). Fly ash can be used in various geotechnical engineering applications such as back fill material in retaining structures, fill material in embankments, sub base material for construction of pavements, foundation base material and as fill material in land reclamation. This problem is to be addressed in such a manner that, the entire ash produced could be converted as a resource material by utilizing it completely. Soil stabilization is the process of treatment of soils to improve or modify their engineering behavior. The objectives of stabilization using admixtures are to control volume stability; improve strength, stress-strain characteristics, permeability, and durability; and to decrease erodibility and compressibility of soils. The mechanism of stabilization of the two commonly used inorganic stabilizers namely Portland cement and lime, are similar with formation of end products calcium silicate hydrates (C-S-H). The reaction mechanism of pond ash and cement resembles with that of the reaction mechanism soil and cement. Pond ash is a lightweight, cohesionless material and composed of silt-sized particles. It is a pozzolanic material and can be stabilized with the addition of various stabilizers like cement and lime. A pozzolan is defined as a siliceous or siliceous and aluminous material which itself possesses little or no cementitious property but which, in finely divided form and in the presence of moisture, will react with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties. The aim of present study is to carry out different laboratory tests on cement stabilized pond ash, so as to see the effect of cement content on the strength properties of the mix. Various %age of cement was added to pond ash based on the result reported by Gyatri and Kaniraj (2012). Effect of curing period on strength was also studied. Flexural tests were also conducted for pond ash-cement-fiber reinforced mix for few specimens to see the effect of fiber.

Experimental Program

Material

Pond ash for the study was acquired from Guru Gobind Singh Super Thermal Power Project (GGSSTP), Ropar, Punjab. OPC 53 grade cement (ACC brand) was procured from local market. Reinforcing fiber for the study was purchased in the form Recron-3s, a product of Reliance Industries. Physical properties of pond ash were determined as per IS standards (Table 1). The properties of fiber were obtained from the supplier and have been reported in Table 2.

Table 1 Physical Properties of Pond ash

S No.	PARAMETER	VALUE
1.	Specific Gravity (G)	2.10
2.	Plasticity	NON PLASTIC
3.	Maximum Dry Density (kN/m^3)	11.01 kN/m^3
4.	Optimum Moisture Content (%)	27.4%
5.	Angle of Internal Friction(ϕ)	33^o
6.	Cohesion (kN/m^2)	1 kN/m^2
7.	Permeability (cm/sec)	1.24 x 10^{-4} cm/sec

IOP Conf. Series: Materials Science and Engineering 1033 (2021) 012085 doi:10.1088/1757-899X/1033/1/012085

8.	Coefficient of Uniformity (C_u)	8.56
9.	Coefficient of Curvature (C_c)	1.41

Table 2 Properties of Recron–3s

Sr. No	Contents	Values
1	Diameter of fiber	0.035 mm
2	Length of fiber	12.0 mm
3	Density of material	9.7 kN/m^3
4	Aspect ratio of fiber (l/d)	343
5	Tensile strength	600 N/mm^2
6	Melting point	Over 250^{0}C
7	Resistance to acid/alkali	Good

Mix Proportions

Mix proportion of pond ash and cement as shown in Table 3 were used.

Table 3 Mix proportions

Sr. No.	Name of proportion	PA : CEMENT
1	PA : CEMENT	97 : 03
2	PA : CEMENT	94 : 06
3	PA : CEMENT	91 : 09
4	PA : CEMENT	88 : 12
5	PA : CEMENT	85 : 15
6	PA : CEMENT	82 : 18

Flexural strength test was conducted on all the above mixes at different curing periods of 7, 14 and 28 days. After studying the optimum relative increase in the flexural strength of different mixes and considering the economic aspect, Polypropylene was only added to the mix number 2 and mix number 3 from Table 3 in different percentages of 0.25, 0.50, 0.75, 1.0, 1.25 and 1.5 % by weight. Flexural strength test was conducted on these two mixes again and the results were compared.

Tests

The tests carried out in the laboratory were Standard Proctor Test, Unconfined Compression Strength Test, Tensile Strength Test and Flexural Strength Test on different mixes of Pond Ash and Cement.

Results and Discussion

Figure 1 and 2 show the results of compaction test. It can be seen from the figure that as the cement content in the mix increases from 3 % to 18 %, the maximum dry density increases and optimum moisture content decreases.

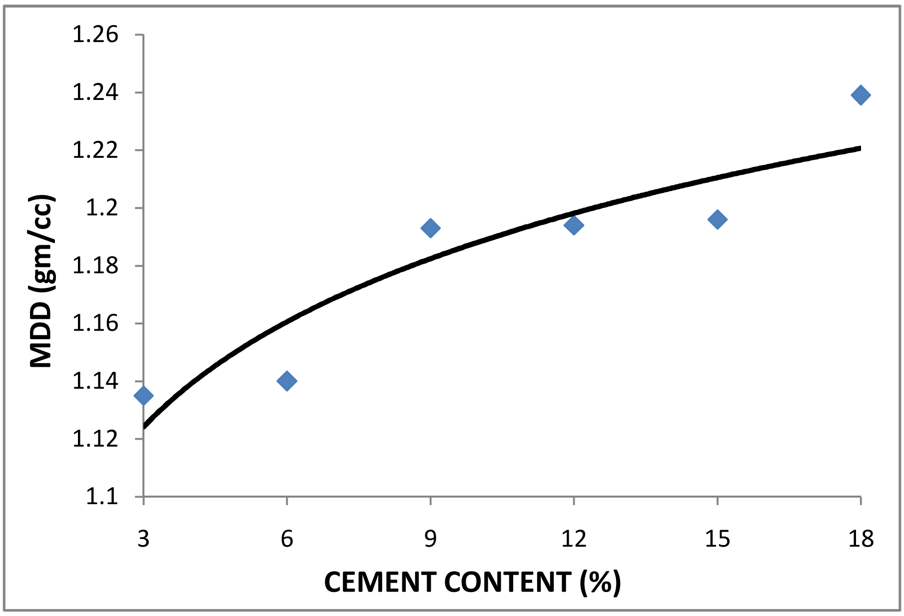

Figure 1 MDD v/s Cement content

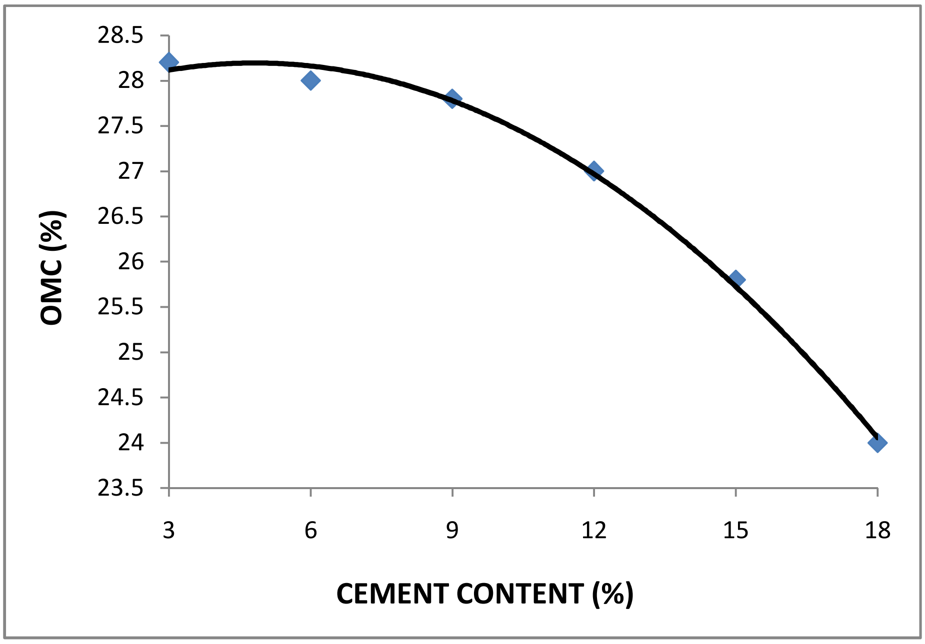

Figure 2 OMC v/s Cement content

Results of unconfined compression test for different pond ash cement mixes are shown in Figure 3. It can be observed from the figure that as the cement content increases unconfined compression strength (UCS) increases for a given curing period. Again for a given cement content, UCS increases with increase in curing period.

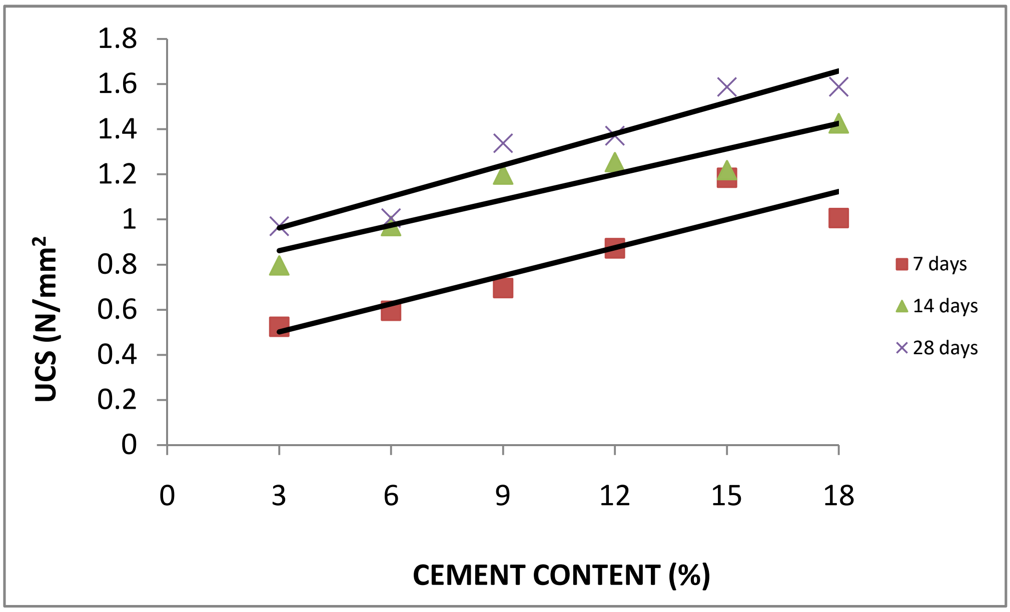

Figure 3 UCS v/s Cement content

Tensile strength (TS) of different Pond ash cement mix was calculated using the formula given below. A typical variation of Tensile strength with cement content after 28 days of curing is shown in Figure 4. Similar results were calculated for 7 and 14 days curing sample also, and has been reported elsewhere.

Tensile strength (T) = 2P/ π*D*L

Where P = Load in Newton and D = Diameter of specimen in mm

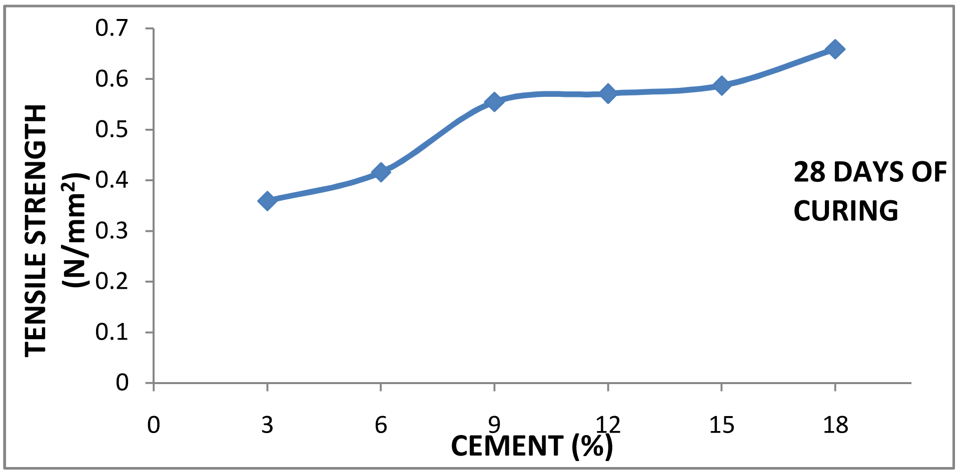

Figure 4 Tensile strength v/s Cement content

Flexural strength (FS) of Pond ash Cement mix after 28 days of curing period was calculated after conducting two point flexural tests shown in Photograph 1. Figure 5 shows typical variation of Flexural strength with cement content after 28 days of curing.

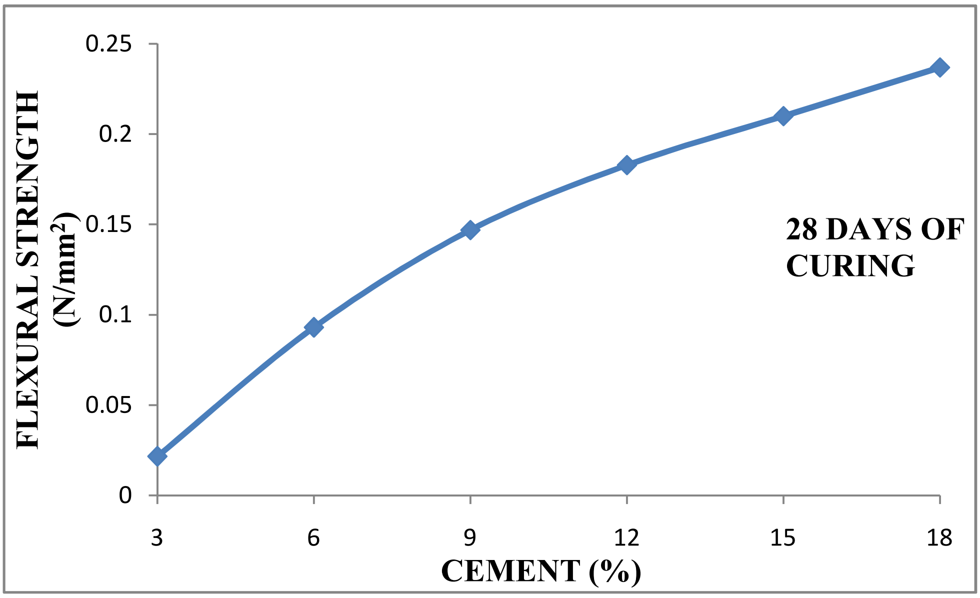

Figure 5 Flexural strength v/s Cement content

Relative increase in Flexural strength (FS) was also determined and has been shown in Figure 6 for 28 days of curing period. Maximum relative increase in flexural strength occurs for 6 % and 9 % cement content.

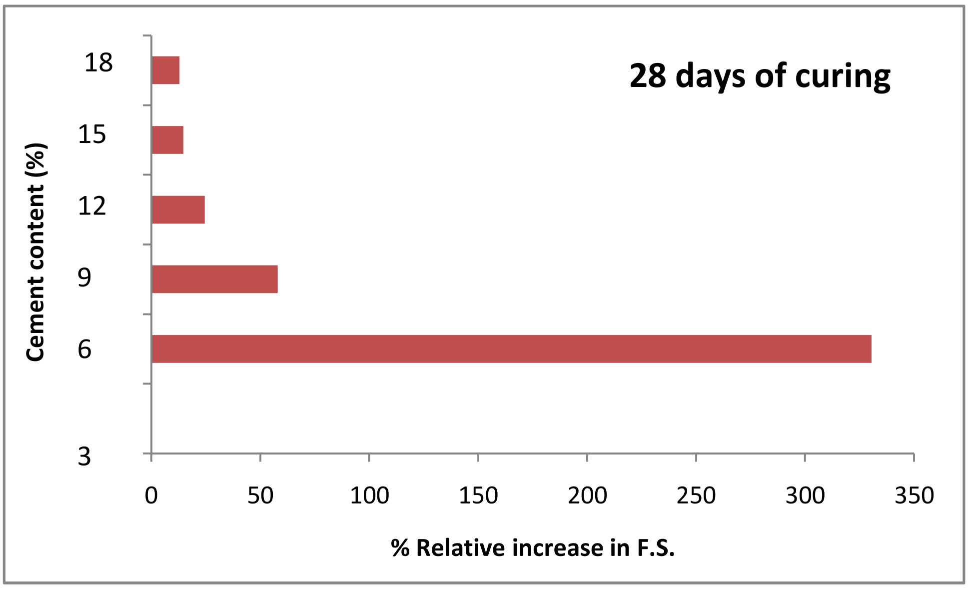

Figure 6 Relative % increases in Flexural strength v/s Cement content

Photograph 1 Typical failure pattern under 2 pt. loading

Synthetic fiber reinforcement was added in PA: CEMENT mixtures of 94:06 and 91:09 in different percentage (0.25 %, 0.50 %, 0.75 %, 1.0 %, 1.25 %, and 1.50 %) by weight. Flexural test was conducted for this mix with 28 days curing period. Figure 7 show the variation of flexural strength with different % age of polypropylene fiber.

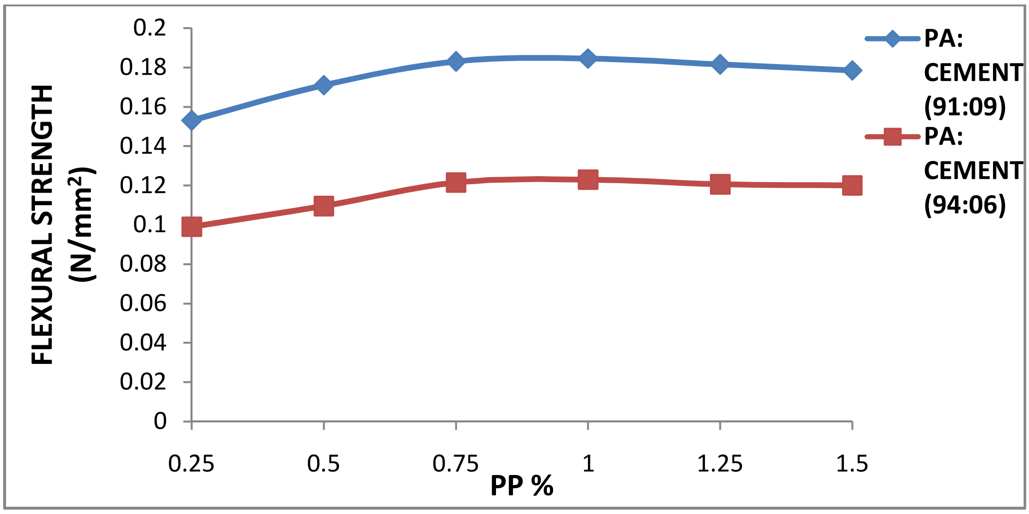

Figure 7 Flexural strength v/s Polypropylene (%)

Conclusions

Based on the study, following conclusions were drawn:

1. Increase in cement content increases the maximum dry density and decreases the optimum moisture content.
2. Unconfined compressive strength increases with increasing cement content and curing period. At a given cement content, unconfined compressive strength increases with increase in curing period.
3. Tensile and Flexural strength also increase with increase in cement content and curing period.
4. Maximum relative improvement in Flexural Strength (FS) was obtained for the specimen, when cement content was 6 % and 9 % after 28 days curing.
5. Flexural strength increases with increase in fiber content up to 0.75 % and after that any increase in fiber content does not improve the flexural strength any further.

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