Effects of Byproducts of Thermal Power Plant with Reinforcements of Concrete

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Abstract - *The use of industrial by products in concrete such as fly ash and bottom ash are attaining priority as additives, particularly since they can increase strength and extends durability of concrete. The use of coconut fiber and jute fiber as reinforcement improves the engineering properties of concrete specially toughness and tensile strength. The present investigation is carried out on Fiber Reinforced Concrete to study the effect of strength and shrinkage with inclusion of fly ash and bottom ash with and without natural fibers. Whereas, the following aspects such as shrinkage of concrete, compressive strength, split tensile strength, water absorption and modulus of elasticity are studied. In this study concrete of M30 grade is tried using fly ash as partial replacement for cement at 0% to 40% and bottom ash as partial replacement for sand at 0%, 10% to 40% with addition of jute and coir fibers at 0.5% and 2 % respectively to the weight of cement and they are compared to the conventional concrete. The compressive strength is increased by about 3% and 2.7% in CFRC and JFRC respectively compared to conventional concrete by inclusion of additives, whereas split tensile strength is increased by 14.5% in CFRC and 6.21% in JFRC compared to conventional concrete. By addition of fibers the drying shrinkage is reduced compared to conventional concrete and it further reduces with inclusion of additives.*

Key Words: Concrete, coconut fiber, jute fiber, tensile strength, modulus of elasticity.

1. INTRODUCTION

The major component of concrete is cement. The manufacture and use of cement produce a broad range of environmental and social consequences depending on the considerations, which are both harmful and welcome. Cement industries produce huge amount of CO2, a major greenhouse gas creating up to 5% of global man-made emissions of this gas, of which half of is from the chemical process and remaining resulting from fuel consumption. Attempts have been done for reducing greenhouse gas emissions related to concrete from both industrial and academic sectors by substitution of conventional clinker with industrial by-products like fly ash and bottom ash [1-3]. The use of industrial wastes is gaining importance as additives, because they increase strength, decrease density and also reduces environmental impacts. During the coal combustion process, huge amount of combustion residues are produced and require proper disposal [4-5]. Fly ash and bottom ash are the major ingredients in Coal Combustion Residues (CCR). Fly ash is reprocessed more frequently than bottom ash, as it is used in concrete to escalate its strength [6-9]. Other beneficial uses of CCR covers road-base materials, foundations, masonry and concrete blocks, structural fills, embankments and many others [10-13]. The characteristics of fly ash and bottom ash differ completely even if their source is same. Fly ash, a small particulate grey in color with diameter less than 300 microns, is captured and removed from flue gas by electrostatic precipitators. Bottom ash collects at the bottom of the furnace and consists of larger particles. Coal ashes, in general, are mainly composed of oxides of silica, aluminum, iron, calcium, magnesium and sulphur [14-15].

1.1 Categorization of Fly ash

There are two categories of fly ash according to ASTM C618.

1.1.1 Class-F Fly ash

It is derived by burning anthracite or bituminous coal. It is pozzolanic in nature and the percentage of lime (CaO) is less than 20. Apart from being pozzolanic it demands a binding agent such as quicklime or Portland cement in presence of moisture to react and produce cementations compounds.

1.1.2 Class-C Fly ash

It is derived by burning younger lignite or sub-bituminous coal. It possesses both pozzolanic and self-cementing properties and hence it doesn't need any activator to attain cementations compounds in presence of moisture. The percentage of lime (CaO) is more than 20. Class C fly ash mixes develops more heat of hydration as a result it achieves strength at early age than Class F fly ash (Fig .1) mixes.

Fig -1: Fly ash

1.2 Bottom ash

It is physically coarse, porous, dark grayish and non-combustible material that is accumulated from underneath the furnaces that burn coal. During combustion of coal, 80% of residue will be fly ash and remaining commodity is bottom ash. The usage of bottom ash (Fig .2) as an alternative material for sand in the production of concrete is still in the beginning stage. At present it is mainly used as foundation material for the construction of roads.

Fig -2: Bottom ash

1.3 Coconut fiber

Coconut fiber (Fig .3) is a natural fiber extricated from the outer shell of a coconut which is light in weight. In India Kerala is the major producer of coconut fibers. The common name and scientific name of coconut fiber is Coir and Cocos nucifera. The coir fibers are of two types, brown fiber extricated from ripened coconuts which are thick and strong with high abrasion resistance and white fibers extricated from immature coconuts which are thin and weaker. The advantages of coconut fibers are availability, moth-proof, lightweight, ecofriendly, provide excellent insulation against heat and sound, non-combustible, resistant to wet conditions, tough, durable and resilient. Figure 3 shows coconut fibers and longitudinal and cross section of an individual fiber cell.

Fig -3: Coconut Fibers

1.4 Jute Fiber

Jute (Fig .4) is a long, soft, natural, biodegradable fiber obtained from the bark of the jute plant (Corchorus Capsularis). In India West Bengal is the major producer of jute. Normally jute material is composed of cellulose, hemicellulose and lignin with minor amounts of protein, extractives and in organics. It is the most sought vegetable fiber in terms of usage and production next to cotton. During the harvesting time single hectare of jute plants consume about 15 tons of CO2 and releases 11 tons of oxygen and thus it contributes to the reduction of greenhouse gas. Depletion of resources has influenced the researches to focus on natural fibers in developing Natural Fiber Reinforced Concrete.

Fig -4: Jute fiber

2. MATERIALS AND METHODS

2.1 Ordinary Portland cement

In the present study, Birla Super 53-Grade OPC is used confirming to IS: 12269-1987. Cement is a adhering material in the fine powdered form, which when combined with water sets and hardens due to these properties it has been used as an basic ingredient in making mortar or concrete. The basic materials required for preparation of cement are lime, silica, alumina and iron oxide. Following tables (Table .1) shows the composition limits of oxides in OPC and physical properties of OPC.

Table -1: Physical properties of cement

Properties	Test results
Specific gravity	3.14
Fineness	3.6%
Standard consistency	30%
Initial setting time	43 min
Final setting time	195 min

2.2 Coarse Aggregate

These are the aggregates retained on 4.75 mm IS sieve which are obtained from locally available quarries. They are hard, strong, durable and free from other impurities and the aggregates used was as per IS 383:1970. The properties of the aggregates are given below (Table .2).

Table -2: Properties of Coarse Aggregates

Properties	Values
Shape	Angular
Bulk density of compacted aggregate	1599 kg/m^3
Bulk density of loose aggregate	1.421kg.m^3
Specific gravity	2.68
Water absorption	0.36%
Fineness modulus	2.7

2.3 Fine Aggregate

Aggregates which pass through IS 4.75 mm sieve are termed as fine aggregates. The grading of fine aggregates is determined and it confirms zone II. The properties of fine aggregates are given in the table below (Table .3).

Table -3: Properties of Fine Aggregates

Properties	Values
Bulk density of compacted aggregate	1624 kg/m^3
Bulk density of loose aggregate	1428 kg.m^3
Specific gravity	2.65
Fineness modulus	3.78

2.4 Fly Ash

Fly ash has been obtained from Raichur Thermal Power Station (RTPS) for the present work and the properties of it are thoroughly studied by conducting experiments. The properties and the chemical composition of fly ash are given below (Table .4).

Table -4: Properties of Fly ash

Properties	Values
Specific gravity	2.2
Fineness	2.5%
Normal consistency	31%

2.5 Bottom Ash

Bottom ash obtained from Raichur thermal power plant was used as replacement material for fine aggregate. The following tables (Table .5) explain the properties of bottom ash.

Table -5: Properties of Bottom ash

Properties	Values
Bulk density of compacted aggregate	1250 kg/m^3
Bulk density of loose aggregate	1420 kg.m^3
Specific gravity	2.34

2.6 Coir fiber

Addition of coir fibers has improved the properties of concrete which includes tensile strength, toughness, torsion and also ductility to some extent. The properties of these natural fibers are given below (Table .6).

Table -6: Properties of Coir fiber

Properties	Values
Fiber length	40-80 mm
Fiber diameter	0.1-0.406 mm
Specific gravity	1.12-1.15
Elongation	10-25%
Modulus of elasticity	2750-3770(N/mm^2)
Average tensile strength	150 (N/mm^2)

2.7 Jute fiber

In this present work the Jute twine which is commercially available in the market was chopped into measurable length (20 mm) and used as fiber for reinforcing the concrete (Table .7).

Table -7: Properties of Coir fiber

Properties	Values
Fiber length	20 mm
Fiber diameter	0.10-0.20 mm
Specific gravity	1.02-1.04
Water absorption	25-40%
Modulus of elasticity	26-32 kN/mm^2)

2.8 Mix design of m30 grade concrete

It is a process of choosing desirable ingredients of concrete and finding out the relative proportions with an aim of making a concrete of the expected strength, durability and workability as economic as possible. In the present study M30 grade of concrete is designed as per IS: 10262:2009 (Table .8).

Table -8: Details of Mix Properties

FA and BA Variation in %	Cement	FA	Sand	BA	CA	W/C	Superplasticizer (%)	JF (%)	CF (%)
0	361	0	698	0	1253	0.44	0.91	0.5	2
10	324.9	36.1	628.2	69.8	1253	0.44	0.91	0.5	2
20	288.8	72.2	558.4	139.6	1253	0.44	0.91	0.5	2
30	252.7	108.3	488.6	209.4	1253	0.44	0.91	0.5	2
40	216.6	144.4	418.8	279.2	1253	0.44	0.91	0.5	2

3. RESULTS AND DISCUSSION

3.1. Workability Test

The slump test was conducted before casting specimens for all the variations and the results are given below (Fig .5).

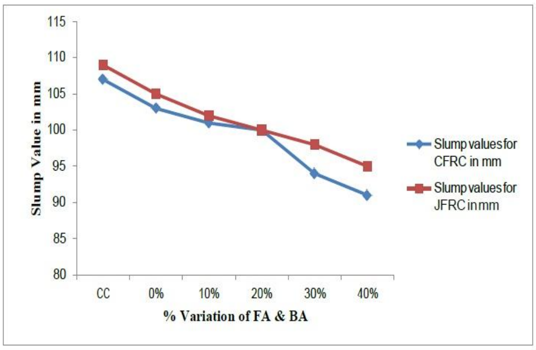

Fig -5: Slump Values of NFRC

Slump test was done for normal concrete by replacing fly ash and bottom ash at 0%, 10%, 20%, 30% and 40% percentages with natural fibers. The slump was in decreasing order with addition of natural fibers which greatly affects the workability of concrete. The decrease in slump may be due to length of fiber which creates balling effect, so to maintain persistent workability the super plasticizers were used.

3.2. Compressive Strength test

The compressive strength of normal concrete and NFRC (Natural Fiber Reinforced Concrete) were determined at 28 and 56 days of curing by considering the average of three specimens. The cubes were casted of standard size 150mm x 150mm x 150mm and then tested in Compression Testing Machine. The test results are shown in below tables and figures (Fig .6).

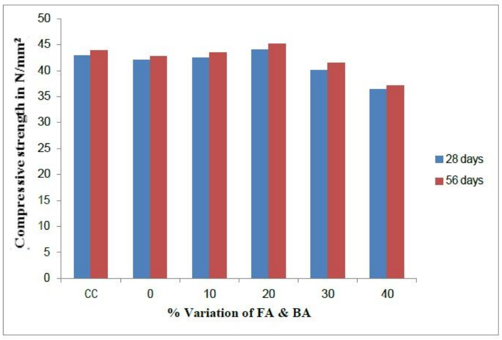

Fig -6: Slump Values of NFRC

The compressive strength of CFRC and JFRC with fly ash and bottom ash replacement was determined and compared with conventional concrete. They were tested at 28 and 56 days and the results are given in the tables illustrated with figures. By addition of fibers the compressive strength has been slightly decreased at 0% FA and BA, this may be due to difficulties in compaction which results in increase in the voids. At 20% replacement of FA and BA the CFRC achieved good strength and is found to be increased by 3% compared to conventional concrete and 5.5% compared to CFRC (0% FA & BA). In case of JFRC the replacement can continue upto 30% and it is found to be optimum percentage. The compressive strength is increased by 2.7% compared to CC and 5.55% compared to JFRC (0% FA & BA).

3.3. Split Tensile Strength

The split tensile strength of normal concrete and NFRCs (Natural Fiber Reinforced Concrete) were determined at 28 and 56 days of curing by considering the average of three specimens. The cylinders were casted of standard size 300mm x 150mm and then tested in Compression Testing Machine (Fig .7).

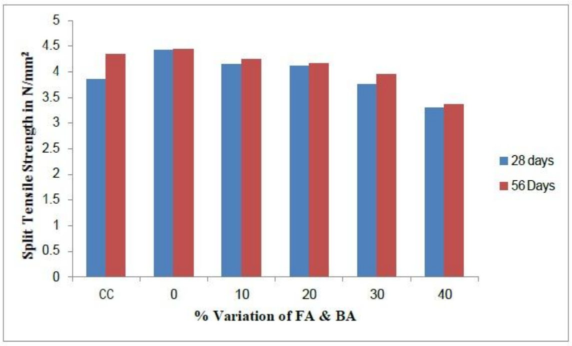

Fig -7: Slump Values of NFRC

Addition of natural fibers has improved the split tensile strength of concrete. For conventional concrete at 28 and 56 days the split tensile strength is about 3.86 and 4.35 N/mm2. By addition of coir and jute fibers with 0% FA and BA the split tensile strength is increased upto 4.42, 4.45 N/mm2 and 4.10, 4.42 N/mm2 for 28 and 56 days respectively. In case of CFRC the FA and BA can be replaced upto 20% and in JFRC it can be replaced upto 10%. By addition of coir and jute fibers the split tensile strength is increased upto 14.5% and 6.21% respectively compared to conventional concrete.

3.4. Modulus of Elasticity (NDT)

The modulus of elasticity is determined at 28 and 56 days by Non-Destructive method using ultrasonic pulse equipment. Cylinders of standard size 300 x 150 mm are tested according to the procedure and the results obtained are given below (Fig .8).

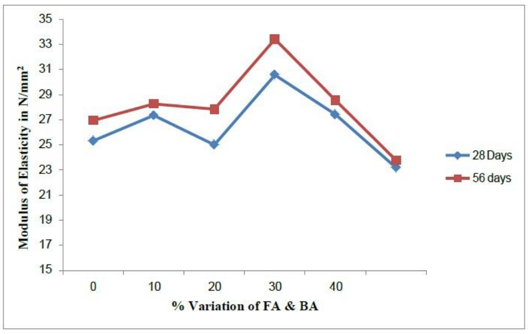

Fig -8: Slump Values of NFRC

The modulus of elasticity was determined at 28 and 56 days by non-destructive method. In CFRC the modulus of elasticity is found to be higher at 20% replacement level and in JFRC the modulus value is higher at 30% replacement level.

3.5. Drying Shrinkage

Drying shrinkage is determined for both the NFRCs for 28 and 56 days period of curing with and without additives. The results obtained are given below (Fig .9).

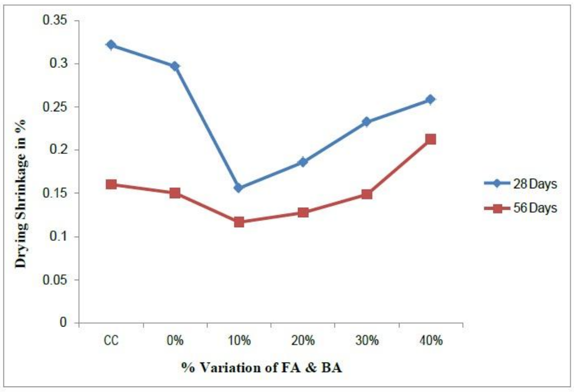

Fig -9: Slump Values of NFRC

The drying shrinkage is found to be higher in conventional concrete and it reduced with addition of fibers as they act as crack arrestors. Further with the replacement of fly ash and bottom ash the shrinkage reduces. With 10% replacement the drying shrinkage is found to be least and it again increases as replacement percentage increases. In both the NFRC the optimum percentage is found to be 10%. Addit ion of fly ash reduces the water demand for a given mix which in turn reduces the drying shrinkage effect on concrete. Also the drying shrinkage depends on several factors such as size of aggregates, curing conditions and type of chemical admixtures being used.

4. CONCLUSIONS

Addition of natural fibers to concrete causes slight reduction in density and compressive strength of concrete. However, with replacement of fly ash and bottom ash the results are good compared to controlled concrete up to some replacement level.

- Modulus of elasticity (Destructive method) is increased in both the NFRC with addition of fly ash and bottom ash.
- In case of CFRC the compressive strength is increased by 3% compared to CC and the optimum % of replacement is found to be 20%.
- In JFRC the optimum % of replacement is found to be 30% and it is increased by about 2.7% compared to CC.
- By addition of coir fibers to concrete the split tensile strength has increased by 14.5% at 28 days compared to conventional concrete.
- By addition of jute fibers to concrete the split tensile strength is improved by 6.21% compared to conventional concrete and at 0% FA & BA the JFRC achieved higher split tensile strength.
- The density of both NFRC decreased with % replacement of fly ash and bottom ash this is mainly due to low specific gravity of additives.

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BIOGRAPHIES

Shaik Mahaboob Subhani is an assistant professor in the department of civil engineering of A.M.Reddy memorial college of engineering and technology. He published several international journals and attended different national and international conferences.