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An Experimental Study of M40 Grade Concrete Partial Replacement Cement and Fine Aggregate with Coal Bottom Ash

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ABSTRACT: The natural sources of river sand are getting depleted gradually. The mining of sand also leads to various environmental hazards. The demand for the protection of the natural environment and the ban on mining in some areas is further aggravating the problem of the availability of river sand. Bottom ash is a by-prothe duct of combustion of pulverized coal composed of mainly silica, alumina and iron with small amounts of calcium, magnesium sulphate, etc. The appearance and particle size distribution of coal bottom ash is similar to that of river sand. These properties of bottom ash make it attractive to be used as fine aggregate in the production of concrete. This paper presents the experimental investigation carried out to study the effect of use of coal bottom ash as a partial replacement of fine aggregates in concrete. An experimental program is planned in which controlled concrete of grade M40 is prepared. Fine aggregate is partially replaced with coal bottom ash by 10%, 20%, 30% and 40% and cement is partially replaced with coal bottom ash by 5%, 10%, 15% and 20% the properties of concrete such as workability, compressive strength and flexural strength are evaluated. The test results of this research work indicate that coal bottom ash is a suitable material to be used as fine aggregates and Cement also. Workability decreases with the increase in levels of sand replacement by coal bottom ash in concrete. Both, the compressive strength and flexural strength were not strongly affected up to 20% replacement level of CBA with fine aggregate and 10% with cement. Therefore, 20% of fine aggregates and 10% cement may be replaced with coal bottom ash and a concrete with good strength may be produced with coal bottom ash in concrete.

Keywords: Concrete, fine aggregate, Coal bottom ash, Compressive strength, Splitting tensile strength , Flexural strength.

1. INTRODUCTION

1.1 CONCRETE:

Concrete is a composite material consists of mainly water, coarse aggregate, fine aggregates and cement. The physical properties desired for the finished material can be attained by adding additives and reinforcements to the concrete mixture. A solid mass that can be easily molded into desired shape can be formed by mixing these ingredients in certain proportions. Over the time, a hard matrix formed by cement binds the rest of the ingredients together into a single hard (rigid) durable material with many uses such as buildings, pavements etc., The technology of using concrete was adopted earlier on large-scale by the ancient Romans, and the major part of concrete technology was highly used in the Roman Empire. The colosseum in Rome was built largely of concrete and the dome of the pantheon is the World's largest unreinforced concrete structure. After the collapse of Roman Empire in the mid-18th century, the technology was re-pioneered as the usage of concrete has become rare. Today, the widely used man made material is concrete in terms of tonnage.

1.2 PROPERTIES OF CONCRETE:

Generally, the Concrete is a material having high compressive strength than to tensile strength. As it has lower tensile stress it is generally reinforced with some materials that are strong in tension like steel. The elastic behavior of concrete at low stress levels is relatively constant but at higher stress levels start decreasing as matrix cracking develops. Concrete has a low coefficient of thermal expansion and its maturity leads to shrinkage. Due to the shrinkage and tension, all concrete structures crack to some extent. Concrete prone to creep when it is subjected to long-duration forces. For the applications various tests be performed to ensure the properties of concrete correspond to the specifications. Different strengths of concrete are attained by different mixes of concrete ingredients, which are measured in psi or Mpa. Different strengths of concrete are used for different purposes of constructions. If the concrete must be light weight a very low-strength concrete may be used. The Lightweight concrete is achieved by the addition of lightweight aggregates, air or foam, the side effect is that the strength of concrete will get reduced. The concrete with 3000-psi to 4000-psi is often used for routine works. Although the concrete with 5000-psi is

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more expensive option is commercially available as a more durable one. For larger civil projects the concrete with 5000-psi is often used. The concrete strength above 5000 psi was often used for specific building elements. For example, the high-rise concrete buildings composed of the lower floor columns may use 12,000 psi or more strength concrete, to keep the columns sizes small.

Bridges may use concrete of strength 10,000 psi in long beams to minimize the number of spans required. The other structural needs may occasionally require high strength concrete. The concrete of very high strength may be specified if the structure must be very rigid, even much stronger than required to bear the service loads. For these commercial reasons the concrete of strength as high as 19000-psi has been used.

1.3 USING FIBERS AS CONCRETE ADMIXTURES

Admixtures are the materials other than cement, aggregate and water that are added to concrete either before or during its mixing to alter its properties such as workability, curing temperature range, set time or color. Addition of fiber to concrete 3makes it tough and fatigue resistant such type of admixture is used extensively in important engineering projects. Addition of fiber to concrete is a convenient and practical method of improving several properties of the materials for example toughness, impact resistance and flexural strength. It also assists in changing the flow characteristics of the material. The use of new materials and modern techniques is important in construction activities. Proper use of different kinds of materials and the latest technology becomes imperative to improve quality and cut costs. The life and durability of structure also increases.

1.4 Coal bottom ash:

The coarser material that falls to the bottom of the furnace in the most recent major thermal power plants is known as bottom ash. Coal's bottom ash makes up around 20% of the total ash content in the coal that is fed into the boilers. It is made up of items that cannot be burned and is the component that is left over after the incineration of waste from households and other similar types of businesses. The term "raw bottom ash" refers to a granular material that is made up of a mixture of inert materials such as sand, stone, glass, porcelain, and metals, as well as the ash that is produced when things are burned. When making concrete, it was once thought to be environmentally friendly to limit the amount of cement used. Construction Industry Development Board (CIDB) waste materials have been used to produce concrete from recycled material. CBA is a main waste product from the combustion of coal in a thermal power plant, along with fly ash (FA). This substance's pozzolanic properties can be traced back to the presence of silica oxide and aluminum oxide (Al_2O_3). Additional Calcium Aluminate Hydrate (CAH) and Calcium Silicate Hydrate (CSH) are formed during the cement hydration reaction when calcium hydroxide combines with CBA (CSH). The pozzolanic activity of CBA can be improved with an adequate grinding, which enhanced the strength activity index of bottom ash by up to 27% after 28 days of grinding for CBA for 6 hours. So aggregate and cement are being used in concrete to partially replace it.

2. LITERATUREREVIEW

Kim et al. have published the findings of a study that looked at the effectiveness of cold-bonded bottom ash aggregates (CBBA) in high-strength mortar with regard to the process of internal curing. We took readings on the flow as well as the compressive strength of high-strength mortar that contained CBBA.

Researchers P.Ranapratap et al. (2016) investigated the impact of using bottom ash instead of fine aggregate in concrete of M 40 strength while using OPC-53s cement. Concerns are emerging in India over the lack of river sand, a key ingredient in cement concrete, which is becoming increasingly difficult to obtain. Using bottom ash as a partial sand replacement in the concrete, this study establishes experimental results on concrete strength and economic factors. The use of crusher dust and robo sand as substitutes for natural sand was also investigated, with results showing that bottom ash can partially replace these products. The goal of this project is to develop a high-strength, long-lasting concrete mix from industrial waste. Experiments on M40 grade concrete are carried out using 53 Grade special cement and bottom ash as replacement for fine aggregate. Three control mixtures comprised of sand and robo sand and crusher dust are tested for compressive strength at various stages of development, such as seven days, fourteen days, and twenty-eight days after the ash is replaced by varying percentages. When replacing bottom ash with sand, Robo Sand, or Crusher Dust, the optimal dosage of bottom ash is 10% at 28 days compressive strength of concrete. High early strength concrete can be achieved by using OPC 53 Grade special cement.

In 2016, Abhishek Sachdeva et al. investigated the mechanical characteristics of concrete when cement and fine aggregate were replaced with Alccofine and Bottom ash. Using varied amounts of Alccofine as a

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partial replacement for cement and coal bottom ash as a partial replacement for fine aggregates is the purpose of the research. It is hoped that a controlled concrete of grade M40 (MB1 mix) will be cast, tested for compressive strength after 28 days, and that the results will be published. Bottom ash was used to make three distinct mixes in place of fine aggregates to the extent of 20% (MB2 mix), 30% (MB3 mix), and 40% (MB4 mix). The workability and compressive strength of the MB4 mix had decreased significantly as a result of the tests for these two properties. It was decided to test Alccofine's ability to replace some of the cement in MB4 mix. 5 percent (MB4AL5), 10 percent (MB4AL10), 15 percent (MB4AL15), and 20 percent (MB4AL20) of the cement was replaced with alccofine (MB4AL20 mix). Fine aggregate was substituted with 40% of bottom ash. Based on an analysis of test results, replacing some fine aggregates with coal bottom ash made the concrete less easy to work with and less strong. Workability, compressive strength, and flexural strength all got better in the concrete mix that used bottom ash to replace some of the fine aggregates and Alccofine to replace some of the cement. The workability gets worse as the amount of fine aggregates replaced with bottom ash goes up, but it gets better when part of the cement is replaced with alccofine up to 15% in a mix that already has some fine aggregates replaced with bottom ash. After that, the workability gets worse. By using Alccofine as a partial replacement for cement and bottom ash as a partial replacement for fine aggregates, a high-strength concrete was made

MATERIALS & PROPERTIES

Table-1 Properties of cement

S.NO	Properties	Test results	IS: 169-1989
1.	Normal consistency	0.45	
2.	Initial setting time	29min	Minimum of 30min
3.	Final setting time	598min	Maximum of 600min
4.	Specific gravity	3.18	

Table 2: Properties of Fine Aggregate

S. No	Description Test	Result
1	Sand zone	Zone- II
2	Specific gravity	2.63
3	Free Moisture	0.01
4	Fineness modulus	3.19

Table 3: Properties of Coarse Aggregate

S. No	Description	Test Results
1	Nominal size used	20mm
2	Specific gravity	2.77
3	Fineness modulus	7.22
4	Water absorption	0.15%

3. MIX DESIGN FOR M40 GRADECONCRETE:

[According to investigations done on FA, CA, cement]

DESIGN STIPULATIONS DATA:

Gradedesignation : M40
Typeof cement : OPC 53 grade
Maximum nominal sizeofaggregate : 20 mm
Maximumwater-cementratio :0.45
Degreeof supervision : Good
Typeofaggregate :Crushed angular
Exposurecondition :moderate
Workability :100mm(slump)

TEST DATA FORMATERIALS:

1. Typeof cement : OPC 53 grade conforming to IS:
2. Specific gravityofcement: 3.1

3. Specific gravity of
a) Fineaggregates : 2.71
b) Coarseaggregates : 2.78
4. Water absorption of
a) Fineaggregates : 0.34%
b) Coarseaggregates : 0.6%

TARGET MEANSTRENGTH:

[According to IS 10262-2019, clause 4.2]

$f^{l}ck=fck+1.65(S.D)$ $f^{l}ck=35+1.65(5)$

[here S.D is standard deviation from table 2, clause 4.2.1.3]

$f^{l}ck= 48.25N/mm$

Standard Deviation S=5N/mm

SELECTION OF WATER CEMENTRATIO:

[According to IS 456-2000, table 5] (i)
W/C=0.45
(ii) W/C=0.45(from fig 1, IS 10262-2019)
W/C=0.45

SELECTION OF WATERCONTENT:

[According to IS 10262-2019, table 2]
From table 2 of IS 10262:2009, Maximum water = 197.16lit(for 100mm slump) for 20mm aggregate.
Required water content = 197 liters

CALCULATION OF CEMENT CONTENT:

We have, W/C=0.45

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Cement content=197.6/0.45
=438.13 kg/m^3
From table5 of IS 456-2000, the minimum cement content. For moderate exposure condition =280kg/m^3
450kg/m^3> 320kg/m^3
Hence ok.

ESTIMATION OF COARSE AGGREGATEPROPORTION:
[According to IS 10262-2009, table 3]
Vol. of coarse aggregate corresponding to 20mm size aggregate and fine aggregate (Zone -2) For water cement ratio 0.50=0.62, But our water content is 0.40 Volume of coarse aggregate is required to be increased to decrease the fine aggregate content, as w/c is lower by 0.10, the proportions of volume of coarse aggregate increased by 0.02.
Volume of coarse aggregate for the water cement ratio=0.64
Volume offineaggregate=0.62-0.01
=0.61

MIXCALCULATIONS:
The mix calculations for unit volume of concrete shall be as follows
Total volume = 1m^3
vol of cement = (mass of cement/ specific gravity of cement)×(1/1000)
= (438.13/3.18) × (1/1000)
= 0.137 m^3
vol. of water = (mass of water/ specific gravity of water) ×(1/1000)
= (197.16/1) × (1/1000)
=0.197 m^3
Volume of add mixtures = Nill
vol. of all in aggregates = [(a-b)-(c+d)]
= [(1-0.01)-(0.137+0.197)]
=0.656m
mass of CA = 0.656 × (vol. of CA) × (specific gravity of CA) ×1000
= 0.656 × 0.61 × 2.78 × 1000

=1130.24 kg
mass of FA = 0.656 × (vol of FA) × (specific gravity of FA) ×1000
= 0.656 × 0.39 × 2.71 × 1000
= 693.32 kg
Mix proportions fortrail(1m)
Cement = 438.13kg/m Water=197.16lit
Fine aggregate = 693.32kg Coarse aggregate
=1130.24kg Water cement ratio = 0.45

Mix proportions byweight:Design mix of M30

C	:	FA	:	CA	:	W
438.13	:	693.32	:	1130.24	:	197.16
1	:	1.58	:	2.54	:	0.45

4. EXPERIMENTAL DETAILS

Mix ID	Cement	CBA		Fine aggregate	Coarse aggregate	water
		C	Fine			
C(M40)	437.7	-	-	774.54	983.07	197
C5	415.6	22.1	-	774.54	983.07	197
C10	393.9	43.7	-	774.54	983.07	197
C15	372.05	65.8	-	774.54	983.07	197
C20	350.16	87.4	-	774.54	983.07	197
F 10	437.7	-	77.44	697.10	983.07	197
F20	437.7	-	154.98	619.63	983.07	197
F30	437.7	-	232.36	542.18	983.07	197
F40	437.7	-	309.82	464.72	983.07	197

TESTS TO BE CONDUCTED:
1.Slump test
2.Compressive strength
3.Split tensile strength
4.Flexural strength.

5. RESULTS & DISCUSSION
Slump Conetest:

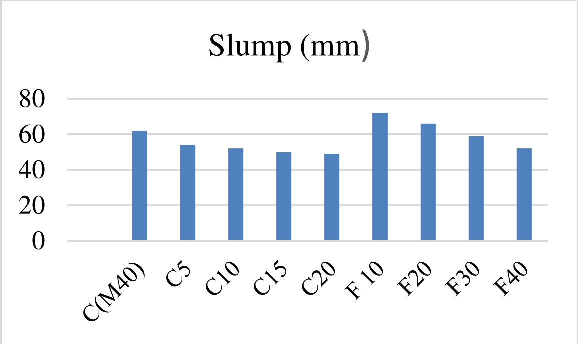

Figure 9: Comparison of workability for different mixes of M40 Grade
From the results it is observed that the workability is decreases with an increase of Glass fiber content over conventional M40 concrete grade.

Compressivestrength:

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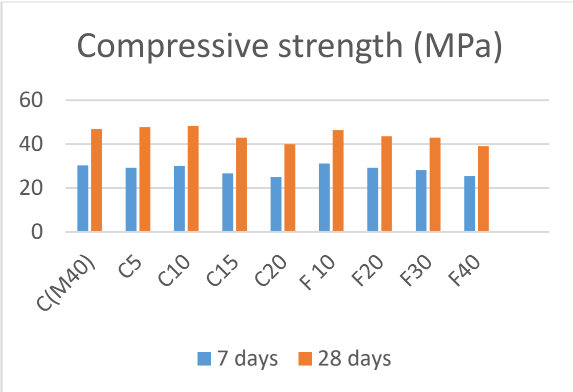

Figure 11: Graph of Compressive Strength comparison at 7days and 28 days for M40 concrete

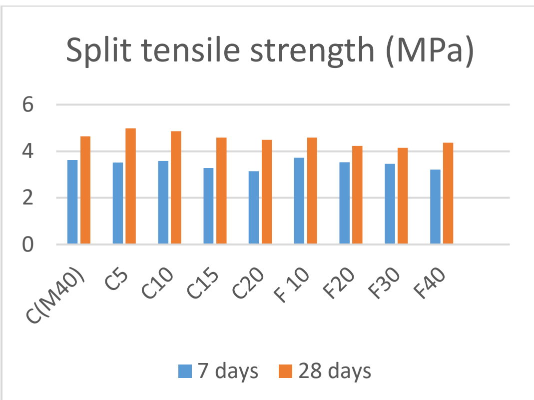

Figure 12: Graph of Split tensile Strength comparison at 7, 14 and 28 days for M40 concrete

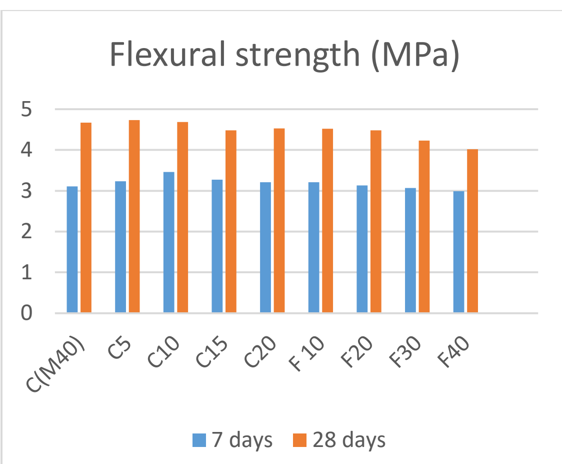

Figure 13: Flexural Strength comparison at 7days and 28 days for M40 concrete

6. CONCLUSION

The study on coal bottom ash as partial replacement of cement and fine aggregate had give interesting results and it gave enhanced ideas on behavior of coal bottom ash. The conclusions are given from the experimental investigation conducted on fresh and hardened properties of M40 grade concrete. The following are the conclusions which were summarized.

- Bottom ash can be used to substitute natural sand and cement in construction projects.
- The workability of Concrete decreases compared to the control mix due to the replacement of cement with coal bottom ash. Contrary, 10% CBA replaced with fine aggregate achieves 16.2% higher than the control mix. Beyond 10% of CBA replaced with fine aggregate slump values are slightly decreased.
- The compressive strength of Concrete increases with the increase of CBA content in both cement and fine aggregate up to certain level. Beyond that level compared to the control mix due to the replacement of cement with coal bottom ash. Contrary, 10% CBA replaced with cement achieves 2.9 % higher than the control mix. Beyond 10% of CBA replaced with cement compressive strength values are decreased.
- The compressive strength of concrete with CBA replaced by fine aggregate strength values are slightly decreased with the increase of CBA.
- The split tensile strength of Concrete increases with the increase of CBA content in both cement and fine aggregate up to a certain level. Beyond that level compared to the control mix due to the replacement of cement with coal bottom ash. Contrary, 10% CBA replaced with cement achieves 4.74 % higher than the control mix. Beyond 10% of CBA replaced with cement split tensile strength values are decreased.
- The split tensile strength of concrete with CBA replaced by fine aggregate strength values is slightly decreased with the h increase of CBA up to 30%. Beyond 30 % replacement of fine aggregate with CBA strength decreases is high.
- The Flexural strength of Concrete increases with the increase of CBA content in both cement and fine aggregate up to a certain level. Beyond that level compared to the control mix due to the replacement of cement with coal bottom ash. Contrary, 10% CBA replaced with cement achieves 0.42 %

higher than the control mix. Beyond 10% of CBA replaced with cement split tensile strength values are decreased.

- The split tensile strength of concrete with CBA replaced by fine aggregate strength values is slightly decreased with the h increase of CBA up to 30%. Beyond 30 % replacement of fine aggregate with CBA strength decreases are high.
- Based on the results, coal bottom ash is replaced by cement with up to 10% mechanical properties like compressive strength, split tensile strength and flexural strength are higher than the control mix. However, the 15% replacement level of CBA mechanical properties is slightly lesser than the control mix.
- Based on the results, coal bottom ash is replaced by fine aggregate up to 20% mechanical properties like compressive strength, split tensile strength and flexural strength are higher than the control mix. However, the 30% replacement level of CBA mechanical properties are slightly lesser than the control mix.

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