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RESEARCH ARTICLE

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BEHAVIOR OF CONCRETE PRODUCED BY REPLACING CEMENT BY METAKAOLIN AND GROUND GRANULATED BLAST FURNACE SLAG AND NATURAL SAND BY BOTTOM ASH

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ABSTRACT

Concrete is an important and successful material in the construction industry for a long time. It has so many applications and utilization in the construction field. Due to advancement in technology and constantly increasing economy, construction industry develops in everlasting leaps and bound day by day. This boom in construction demands massive amount of concrete to be produce to satisfy the current need. This enormous quantity of concrete requires a deal of quality raw material which produce concrete. Out of many waste materials available, metakaolin, blast furnace slag, bottom ash are few of them. These waste materials in civil engineering applications will not only solve the disposal problem but also will offer a cost-effective substitute for conventional materials. The main objective of this work is to study the behavior of blended concrete, in which the cement is replaced by metakaolin and GGBFS in fixed proportion (20%).The sand is replaced by bottom ash in different proportions such as 0%, 10%, 20%, 30%, 40%, 50%, and 60%. The experiments are conducted on M30 grade concrete with 28 days of curing. The strength properties studied are compression strength, tensile strength, flexural strength, shear strength, & impact strength. The workability characteristics are studied through slump cone test, compaction factor test, flow table test, & Vee-Bee consistometer test. Also an attempt is made to study the water absorption and sorptivity characteristics.

Keywords: Bottom ash, Concrete, GGBFS, Industrial waste, Metakaolin, Compression test, Split tensile, Shear test

INTRODUCTION

Concrete is prepared by mixing various constituents like cement, aggregates, water, etc. which are economically available. Concrete is the second most highly used item in the world after water. Production of cement used in concrete involves emission of large amount of CO2 which is the major contributor for green house effect and global warming. Energy is the main backbone of modern civilization of the world over, and the electric power from thermal power stations is a major source of energy, in the form of electricity. In India, over 70% of electricity generated by combustion of fossil fuels, out of which nearly 61% is produced by coal-fired plants. This results in the production of roughly 110 million tons of ash per year. Replacing cement by pozzolana leads to lower heat of hydration. Commonly used industrial waste materials are fly ash, bottom ash and blast furnace slag. Alternative cementations materials such as metakaolin, silica fume, steel fibers, quarry dust, wood ash, lime stone, calcined clays are of interest in concrete. The use of coal ash in normal strength concrete is a new dimension in concrete mix design and if applied on large scale would revolutionize the construction industry, by economizing the construction cost and decreasing the ash content.

Objectives and Scopes:

1. To effectively utilize the waste material from the industries.
2. To reduce the problem of disposal of industrial waste.
3. To prove that the industrial waste from industries can be a replacement for fine aggregate.
4. To study the physical and chemical properties of industrial waste and are the ingredients in concrete.
5. To study the strength properties by replacing the cement by metakaolin and GGBFS.
6. To replace the fine aggregate by industrial waste bottom ash in different ratio such as 10%, 20%, 30%, 40%, 50% and 60% in M30 mix concrete
7. To determine the compressive strength, Split tensile strength, Flexural strength, Shear strength, Impact strength and compare it with both metakaolin and GGBFS.

TESTING PROGRAMME

In the present study various tests on material such as cement, fine aggregate, coarse aggregate and the waste material from industries were performed as per the Indian Standards.

Materials Used

1. Cement: Portland Pozzolanic Cement of 43 grade was purchased from the local supplier and used throughout this project. The properties of cement used in the investigation are presented in table 1.

Table 1: Properties of Cement

Sl. No	Property	Value
1	Specific Gravity	3.15
2	Fineness	
3	Standard Consistency	32%
4	Initial Setting Time	45 min
5	Final Setting Time	345 min
6	Fineness Modulus	4%

2. Metakaolin: In this experimental work, metakaolin from 20micron company, vadodara, Gujarat india. Confirming to IS 3812 (part 1):2003 was used.

3. Ground granulated blast furnace slag: In this experimental work, Ground granulated blast furnace slag is received from ACC Cement factory, hospet, india, Confirming to IS 3812 (part 1) :2003 was used.

4. Fine Aggregate: Locally available river sand confirming to zone II of IS: 383–1970 was used for the project work. The specific gravity of the fine aggregate was found to be 2.61.

5. Bottom ash: In this experimental work, bottom ash is collected from the dumping yard of electric thermal power plant, Raichur, india. Confirming to IS 3812 (part 1):2003 was used.

6. Coarse Aggregate: Locally available crushed aggregates confirming to IS: 383–1970 is used in this project work of size 20mm below. The specific gravity of coarse aggregate was found to be 2.67.

7. Water: Water used in this project is potable water.

8. Super Plasticizers: Here the super plasticizer "Conplast SP-430" is used. In the experimentation suitable dosage of 0.5% is added to achieve high workability and slump value for flowability.

PREPARATION OF SPECIMENS

Based on the above results the water quantity, cement, fine aggregate and coarse aggregate required for design mix of M30 were calculated based on the procedure given in IS code method in IS :2009. The final mix ratio was 1:1.462:2.695 with water cement ratio of 0.44. The measurement of materials was done by weight using electronic weighing machine. Water was measured in volume. Concrete was placed in moulds in layers. The cast specimens were removed from moulds after 24 hours and the specimens were kept for water curing.

Figure 1: Specimen Moulds

The details of mix designation and specimens used in experimental program are given in table 5.

Table 2: Mix Details (For both Metakaolin and GGBFS 20% is in fixed proportion)

Sl. No.	% replacement of	Cement	Sand	Aggr-egates	Bottom ash
1	0	18.272	33.82	58	0
2	10	18.272	30.438	58	3.382
3	20	18.272	27.056	58	6.764
4	30	18.272	23.674	58	10.146
5	40	18.272	20.292	58	13.528
6	50	18.272	16.91	58	16.91
7	60	18.272	13.528	58	20.292

Figure 2: Demoulded Specimens

TESTING OF SPECIMENS

For each batch of concrete, 3 cubes of 150mm x 150mm x 150mm size were tested to determine compressive strength of concrete, 3 cylinders of 150mm diameter and 300 mm length were tested to determine split tensile strength of concrete, 3 prisms of 100mm x 100mmx 500mm were tested to determine flexural strength of concrete, 3 L-Shape specimens of 150mm x 150mmx 90mm were tested to determine shear strength of concrete and 3 cylinders of 150mm diameter and 60mm height were tested to determine impact strength of concrete.

RESULTS AND DISCUSSIONS

Figure 3 shows the variation of compressive strength test results for fixed percentage variation of cement with 20% of MK and GGBS and the natural sand with BA.

Figure 4 shows the variation of tensile strength test results for fixed percentage variation of cement with 20% of MK and GGBS and the natural sand with BA.

Figure 5 shows the variation of flexural strength test results for fixed percentage variation of cement with 20% of MK and GGBS and the natural sand with BA.

Figure 6 shows the variation of shear strength test results for fixed percentage variation of cement with 20% of MK and GGBS and the natural sand with BA.

Figure 7 shows the variation of impact strength test results for fixed percentage variation of cement with 20% of MK and GGBS and the natural sand with BA.

Table 3: Compressive strength test results at 28 days curing

Sl. No.	% replacement of Bottom ash	Compressive strength N/mm^2	
		20% Metakaolin	20% GGBFS
1	0	30.44	28.96
2	10	32.67	29.78
3	20	36.74	31.11
4	30	40.07	34.74
5	40	36.22	38.74
6	50	32.96	28.67
7	60	24.81	23.19

From the above table it is found that the compressive strength of the control concrete was 30.44 N/mm^2 for Metakaolin and 28.96 N/mm^2 for GGBFS. The compressive strength was found to be maximum at 30% (40.07 N/mm^2) for Metakaolin and 40% (38.74 N/mm^2) for GGBFS. The replacement of cement by industrial wastes Metakaolin and GGBFS, which gives the greater strength than the conventional concrete. The compressive strength reduced beyond 30% replacement for Metakaolin and 40% replacement for GGBFS.

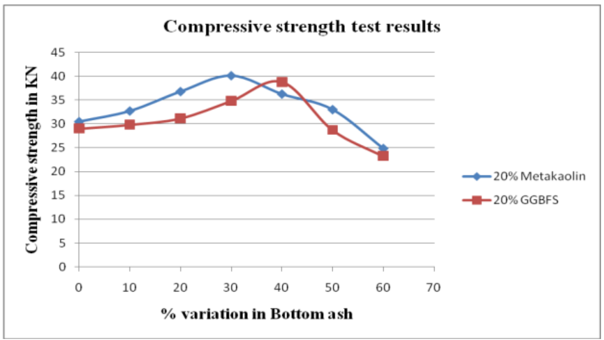

Figure 3: Compressive strength after 28 days of curing

Table 4: Split Tensile Strength Test Results at 28 days curing

Sl. No.	% replacement of Bottom ash	Split Tensile strength N/mm²	
		20% Metakaolin	20% GGBFS
1	0	5.16	4.95
2	10	5.3	5.02
3	20	5.45	5.09
4	30	5.66	5.23
5	40	5.38	5.45
6	50	5.16	5.16
7	60	5.02	4.88

From the above table it is found that the Split tensile strength of the control concrete was 30.44 N/mm^2. The Split tensile strength was found to be maximum at 30% (5.66 N/mm^2) for Metakaolin and 40% (5.45 N/mm^2) for GGBFS. The replacement of cement by industrial wastes Metakaolin and GGBFS, which gives the greater strength than the conventional concrete. The Split tensile strength reduced beyond 30% replacement for Metakaolin and 40% replacement for GGBFS.

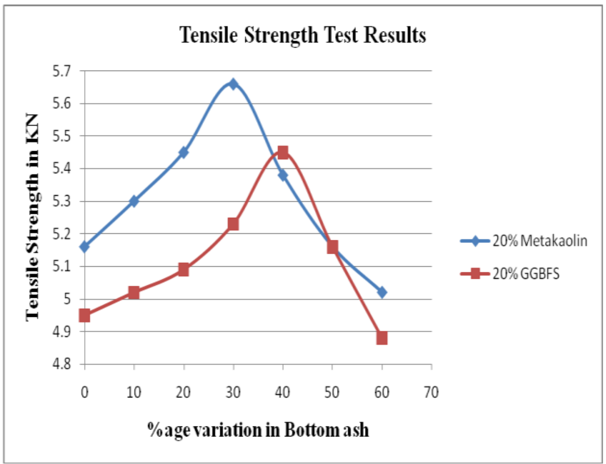

Figure 4: Split tensile strength after 28 days of curing

Table 5: Flexural Strength Test Results at 28 days curing

Sl. No.	% replacement of Bottom ash	Flexural strength N/mm²	
		20% Metakaolin	20% GGBFS
1	0	6.4	5.4
2	10	6.6	5.8
3	20	7.2	6.4
4	30	7.4	6.6
5	40	6.4	7.0
6	50	5.8	5.8
7	60	5.2	4.4

From the above table it is found that the Flexural strength of the control concrete was 30.44 N/mm^2. The Flexural strength was found to be maximum at 30% (7.4 N/mm^2) for Metakaolin and 40% (7.0 N/mm^2) for GGBFS. The replacement of cement by industrial wastes Metakaolin and GGBFS, which gives the greater strength than the conventional concrete. The Flexural strength reduced beyond 30% replacement for Metakaolin and 40% replacement for GGBFS.

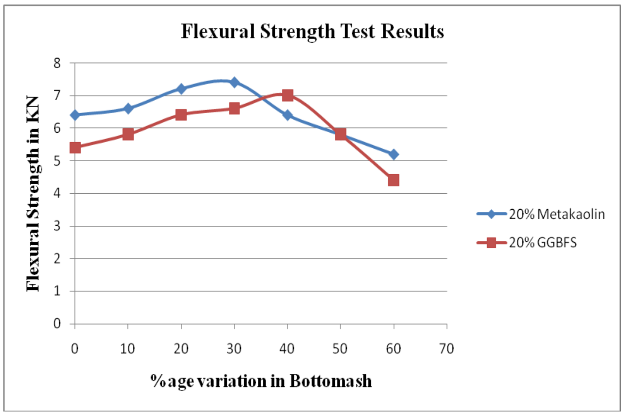

Figure 5: Flexural strength after 28 days of curing

Table 6: Shear Strength Test Results at 28 days curing

Sl. No.	% replacement of Bottom ash	Shear strength N/mm²	
		20% Metakaolin	20% GGBFS
1	0	1.67	1.50
2	10	1.87	1.65
3	20	2.81	2.56
4	30	4.15	3.37
5	40	2.17	3.87
6	50	1.59	1.44
7	60	1.06	1.04

From the above table it is found that the Shear strength of the control concrete was 30.44 N/mm^2. The Shear strength was found to be maximum at 30% (7.4 N/mm^2) for Metakaolin and 40% (7.0 N/mm^2) for GGBFS. The replacement of cement by industrial wastes Metakaolin and GGBFS, which gives the greater strength than the conventional concrete. The

Shear strength reduced beyond 30% replacement for Metakaolin and 40% replacement for GGBFS.

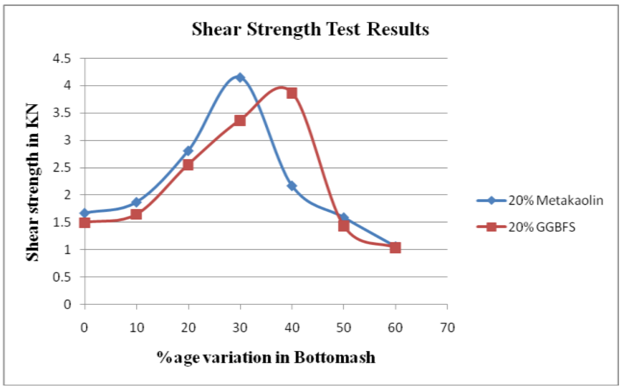

Figure 6: Shear strength after 28 days of curing

Table 7: Impact strength test results at 28 days curing

Sl. No.	% replacement of bottom ash	Impact strength (N-m)		Impact strength (N-m)	
		Initial crack for 20% metakaolin	final crack for 20% metakaolin	Initial crack for 20% GGBFS	Final crack for 20% GGBFS
1	0	433.20	519.84	324.9	368.22
2	10	606.48	779.76	389.88	498.18
3	20	758.10	1126.32	476.52	606.48
4	30	1018.02	1841.10	779.76	801.42
5	40	649.80	736.44	1191.3	1277.94
6	50	389.88	519.84	606.48	736.44
7	60	281.58	346.56	303.24	454.86

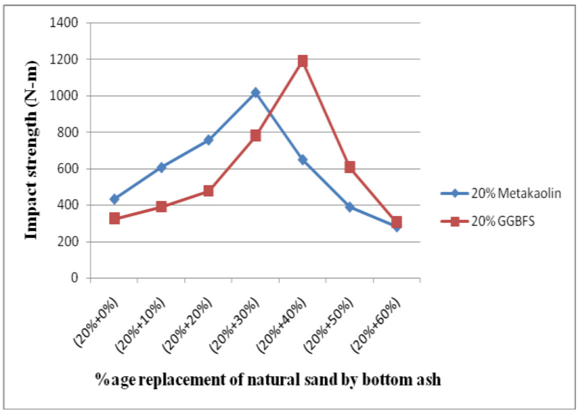

Figure 7: Variation in impact strength for initial crack

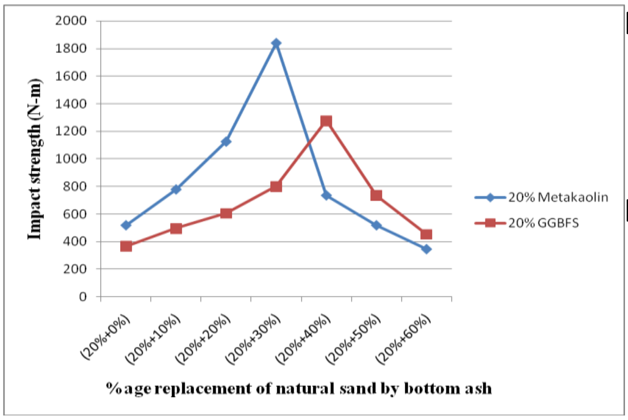

Figure 8: Variation in impact strength for final crack

CONCLUSION

The following conclusions may be drawn based on the experimentation conducted on the behavior of concrete produced by replacing cement by metakaolin and ground granulated blast furnace slag and natural sand by bottom ash. The compressive strength, tensile strength, flexural strength, shear strength and impact strength of concrete reaches higher value when 30% natural sand is replaced by bottom ash with cement replaced by metakaolin. Also it can be concluded that the strength of concrete reaches the higher value when 40% natural sand is replaced by bottom ash with cement replaced by ground granulated blast furnace slag.

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