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MECHANICAL AND DURABILITY PROPERTIES OF FIBRE REINFORCED CONCRETE MADE WITH OPC, GGBS AND METAKAOLIN

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ABSTRACT:

In the last few decades, Concrete consumption has become multifold and usage has enhanced in massive scale due to the rapid growth of infra sector. Generally, Concrete consists of cement, aggregate, and water; these ingredients become more expensive day by day and additionally hard to please and is increasing widely. During the process of making Ordinary Portland Cement (OPC) produces a large amount of greenhouse gases and the environment being polluted. To minimize the cement utilization and environmental issues is essential to switch the cement by another alternate materials such as pozzolanas. The various number of pozzolanic materials comes from industrial wastes are Groundz Granulatedz Blastz furnacez Slagz (GGBS), xFlyqAsh (FA), zSilicazFume (SF), Metakaolin (MK) etc are utilized in concrete. The excessive usage of natural sand in construction industry day by day, which leads natural sand is getting depleted. Therefore, it is necessary to replace natural sand in concrete by an alternate material either partially or completely without compromising the quality of concrete. Manufactured Sand (M-sand) is adopted to replace river sand.

Concrete is strong in compression and weak in tension. Concrete is brittle and will crack with the application of increasing tensile force. To increase the tensile and flexural strength, fibres are added in concrete. The addition of fibres to concrete will result in a composite material that has properties different from those of un-reinforced concrete. The fibres in the concrete which are randomly oriented, arrests the cracks formation. It offers increasing toughness and ductility, tighter crack control and improved load-carrying capacity. Different types of fibres are available in the market for reinforcing concrete and they are steel, glass, acrylic, aramid, carbon, nylon, polyester, polyethylene, polypropylene, etc. To maintain the workability of concrete Water reducing admixture (super

plasticizer) is used and to maintain less water binder ratio. The percentage of super plasticizer added in the concrete By trial and error method.

An attempt is made in the present investigation to study on properties of fiber reinforced concrete of M40 grade made with OPC, GGBS, MK with different proportions and Natural sand is completely replaced with manufactured sand. qsteelu fibers are adding 1% of binder in every mix. The various mix proportions are M0, M1, M2 and M3 which contains 100% OPC, 80% OPC + 10% GGBS + 10% Metakaolin, 70% OPC + 15% GGBS + 15% Metakaolin and 60% OPC + 20% GGBS + 20% Metakaolin respectively. By casting requisite number of cubes, cylinders and cured in water with 7 days and 28 days. Mechanical properties are determined such as fCompressive strength, sSplit tensile strength tests and in addition to that durability properties are determined by conducting Water absorption and Sorptivity tests. Test results are of M40 grade is shows that the mix M2 contains 70% OPC + 15% GGBS + 15% Metakaolin is optimum for strength and durability criteria.

I. INTRODUCTION

Concrete is one of the most extensively utilized construction material in the world and about 6 billion tons of concrete is consumed by the construction industry every year. At present preparing of concrete is to increase both strength and durability properties to meet the demands of modern construction. concrete is manufactured by mixing the cement, aggregates and water in required proportions. D1. curing cement manufacturing process it emits large amount of CO₂ and environment is polluted. To overcome this problem Ordinary Portland Cement (OPC) is replaced by pozzolanic materials conforming to Ground

Granulated Blast furnace Slag (GGBS), FlyAsh (FA), Metakaolin (MK) etc are used to some extent. These mineral admixtures acts as reactive binder components like cement. Natural sand is mainly obtained by excavation from riverbeds. The availability of Natural sand is getting drained furthermore it turns out troublesome. Because of that Natural sand is completely alter by Manufactured sand (M-sand) in concrete. It not only enhancing the performance of concrete but also of their economic and environmental advantage. Generally Concrete is weak in tension and brittle in nature. Fibers are added to control cracking and also to increase the tensile strength, flexural strength. Based on the availability we use different type of fibers like Steel fibers, Glass fibers, Nylon fibers etc., with different aspect ratio. In the present study hooked end steel fibers are used.

COMPOSITION OF CONCRETE

- Ordinary Portland Cement (OPC)
- Aggregates
- Manufactured Sand
- Water
- Admixtures

NEED FOR PRESENT WORK

Concrete is that the most ordinarily used construction material within the world OPC is conventionally used as primary binder material to provide concrete. each one ton of cement production ends up in the generation of 1 ton of carbon dioxide. the assembly of cement is olympian two.6 billion tons each year worldwide production of cement may be a major contributor for the emission of inexperienced house gas that is concerned to warming and different environmental issues.

For more practical choice to cut back the emission of carbon dioxide once created throughout the cement producing replacement of cement either partly or totally by supplementary building material materials like ash, GGBS, silicon oxide fume etc. ash is associate degree industrial waste that is created from the combustion of small-grained coal in thermal power stations. In order to extend the use of pozzolanic materials instead of merchandising on the world that doesn't pollutes the bottom, it's necessary to use pozzolanic materials in concrete by partial replacement of cement.

The overall objective of this study is to determine the mechanical and durability properties of fibre reinforced concrete made with OPC, GGBS and Metakaolin. The objectives of present study are listed below.

OBJECTIVES

- To study the mechanical and sturdiness properties of fibre concrete of M forty grade, replacement of cement with GGBS and Metakaolin with totally different proportions.
- To check the mechanical properties of concrete which incorporates compressive and split lastingness at seven days and twenty eight days of solidification.
- To test the sturdiness properties of concrete which incorporates water absorption and sorptivity tests ar conducted when twenty eight days of solidification.

II. LITERATURE REVIEW

Some of the first analysis works were created mistreatment totally different mineral admixtures and pozzolanic materials as replacement of cement, mistreatment super plasticizers and fibres for development of strength. Some of the studies were represented below.

kasu naveena et al.,(2017) had investigated in Partial Replacement Of Cement With GGBS And Metakaolin The design parameters are considered as M30 grade of concrete, water-cement ratio 0.45. In this cement is replaced by GGBS with 10%,20%,30% and metakaolin with 10%, 20%,30% respectively. They cast cubes and cured in the water of 3,7,28 days. The test results are compare with the strengths of OPC and replacement of cement with GGBS and metakaolin with different proportions. The test results were indicated that high Compressive strength of 39.55 Mpa, At 28 days curing, in a mixture of 30% replacement of both GGBS and Metakaolin with cement compared to the strength of OPC.

A.H.L.swaroop et al.,(2013) investigated in Durability studies on Concrete with Flyash and GGBS. They mainly focus on the evaluation of compressive strength and weight reduction of M30 grade concrete. They casted cubes containing FA of 20%,40% and GGBS of 20%, 40% replacement with cement. curing is done by normal water, 1% of H₂SO₄ solution and seawater at 7 days,28 days,60days. The test results are indicate that high compressive strength In FA 20% replacement more than the GGBS 20% replacement with normal water and sea water curing 60 days, where as in 1% of H₂SO₄ solution GGBS 20% replacement gives better result. In case weight reduction GGBS gives more resistance than FA.

III. EXPERIMENTAL INVESTIGATION

MATERIALS

The materials used for the present study are cement, fine aggregate(Manufacturing sand), coarse aggregate, mineral admixtures(GGBS, Metakaolin), Steel fibers, super plasticizer and water. The materials were testing and casting according to the IS code specifications. The materials used for casting were discussed below in detail.

1. OPC (ordinary Portland cement)-53 grade
2. Coarse aggregate of size 20mm
3. Manufacturing sand
4. GGBS (Ground granulated blast furnace slag)
5. Metakaolin
6. Water
7. Steel Fibers
8. Chemical admixtures- Super plasticizer (Water reducing agent) - Master Rheobuild920SH

1. OPC (ordinary Portland cement)

Ordinary Portland cement of fifty three grade orthodox to IS: 12269-1987, Specifications for fifty three Grade OPC (PENNA CEMENT). it absolutely was procured from one supply and keep. Care has taken to confirm that the cement of same company and same grade is employed throughout the investigation. The cement so procured was in accordance with the IS: 12269 -1987. Table one shows the

physical characteristics of cement used, tested in accordance with IS:4031-1988.

Methods of physical tests for hydraulic cement.

Table: Physical properties of ordinary Portland cement

| S. no | Property | Test Methods | Test Results | IS Standards |
|-------|--|---|---------------------------|--|
| 1 | Normal consistency | Vicat apparatus (IS:4031 Part-4) | 32% | |
| 2 | Specific gravity | Specific gravity bottle (IS:4031 Part-4) | 3.15 | |
| 3 | Fineness | Sieve test on sieve no.9 (IS:4031 Part-4) | 1.3% | 10% |
| 4 | Soundness | Le-Chatlier method (IS:4031 Part-3) | 1.5 mm | Not more than 10mm |
| 5 | Initial setting time Final setting time | Vicat Apparatus (IS:4031 Part-5) | 45 minutes 182 minutes | Not less than 30 minutes Not less than 10 hours |

2. Coarse aggregate

Table: Physical properties of coarse aggregates

| S. No | PROPERTY | METHOD | TEST RESULTS |
|-------|------------------------|--------------------------------------|------------------------|
| 1 | Specific gravity | Pycnometer (IS:2386 Part 3-1986) | 2.64 |
| 2 | Bulk Density Loose | IS:2386 Part 3-1986 | 1544 kg m ³ |
| 3 | Bulk Density Compacted | (IS:2386 Part 3-1986) | 1605 kg m ³ |
| 4 | Water Absorption | (IS:2386 Part 3-1963) | NIL |
| 5 | Flakiness Index | (IS:2386 Part 1-1963) | 4.28% |
| 6 | Elongation Index | (IS:2386 Part 1-1963) | 5.65% |
| 7 | Fineness Modulus | Sieve Analysis (IS:2386 Part 1-1963) | 7.62 |

3. Manufacturing sand

M-sand was used in place of Natural sand conforming to zone II conforming to IS 383:1970. It was collected from RANK Ready Mix Concrete Private Limited, Hyderabad, India. The Specific gravity, water absorption and Fineness modulus was observed to be 2.6, 2.5% and 3.10 respectively As per manufacturer.

4. GGBS (Ground granulated blast furnace slag)

Ground coarse furnace scum may be a Cementous material used for the replacement of cement that may be a byproduct of iron factory-made blast furnaces. GGBS is obtained by heating of ore, stone and coke in an exceedingly furnace for regarding 1500 C. Formation of GGBS isn't direct one it's the byproduct of producing of iron liquified scum and liquified iron that consists of corundom, oxide and a few different oxides the most constituents of furnace scum ar CaO, SiO₂, Al₂O₃ and MgO. These minerals ar principally found in most of the building material substances.

Table: Physical properties of GGBS (As per manufactures certificate):

| S. No | TEST CONDUCTED | RESULT |
|-------|------------------|------------------------|
| 1 | color | Off white |
| 2 | Specific gravity | 2.8 |
| 3 | Bulk density | 1280 kg m ³ |
| 4 | Fineness | 340m ² kg |

5. Metakaolin

Metakaolin is an anhydrous calcined form of mineral kaolinite. Metakaolin is obtained by calcination of the pure or refined kaolinitic clay at temperatures between 650°C and 850°C followed by grinding to achieve the fineness of 700 to 900 m² kg which has high pozzolonicity.

Table: Physical properties of metakaolin(As per manufactures certificate):

| S. No | Description of physical properties | Results |
|-------|------------------------------------|-------------------------|
| 1 | Colour | OFF white |
| 2 | Bulk density | 365(gm liter) |
| 3 | moisture | 0.27% |
| 4 | PH(10%solids) | 5.5 |
| 5 | RESIDUE on sieve 90µm, 45µm | 1.0% 12.80% |
| 6 | Bline surface area | 11000cm ² gm |
| 7 | Specific gravity | 2.7 |

6. Water

potable water is used which is easily available in lab premises for blending offConcrete ingredients and curing of concrete specimens .The pH≥7 .

7. Steel fibers

In this investigation hooked end steel fibers are used with aspect ratio of 40 as shown in fig 3. Steel fibers added @ 1% by weight of binder in all concrete mixes. Fibers are used to reduce the cracks and increase the strength. Fiber are conforming to IS: 280-2006.

8. Super Plasticizer

To increase workability of concrete super plasticizer is added. **Master Rheobuild 920SH** is naphthalene formaldehyde based polymer. As per IS 9103-1999, it is recommended that super plasticizer can be added up to 1 to 2% of binder. In this study, the super plasticizer adopted is 1.2% of binder.

MIX PROPORTION

Mix Design For M40 Grade Of Concrete

Procedure For Mix Design For M40 Grade Concrete

The design procedure for Concrete mix of M40 grade as per IS 10262-2009

Table: Design stipulations

| | |
|-----------------------------------|---|
| Design of grade | M40 |
| Type of cement | OPC 53 grade IS12269 (PENNA CEMENT) |
| Minimum cement content | 320 kg m ³ |
| Maximum cement content | 450 kg m ³ |
| Type of coarse aggregate | Crushed angular aggregate |
| Maximum nominal size of aggregate | 20mm |
| Type of fine aggregate | Manufacture sand |
| Maximum water cement ratio | 0.40 |
| Workability | 75- 100 mm slump |
| Exposure condition | Severe |
| Degree of supervision | Good |
| Chemical admixture | Superplasticizer (MasterRheobuild920SH) |

TEST DATA FOR MATERIALS

Tests conducted for materials used in Concrete i.e., specific gravity, water absorption and surface moisture content were conducted and the outcomes are tabulated below.

Table 6: Test data for the materials

| | |
|--------------------------------------|------|
| Specific gravity of cement | 3.15 |
| Specific gravity of coarse aggregate | 2.64 |
| Specific gravity of fine aggregate | 2.6 |
| Water absorption of coarse aggregate | NIL |
| Water absorption of fine aggregate | NIL |
| Surface moisture of Coarse aggregate | NIL |
| Surface moisture of fine aggregate | NIL |

Mix proportions

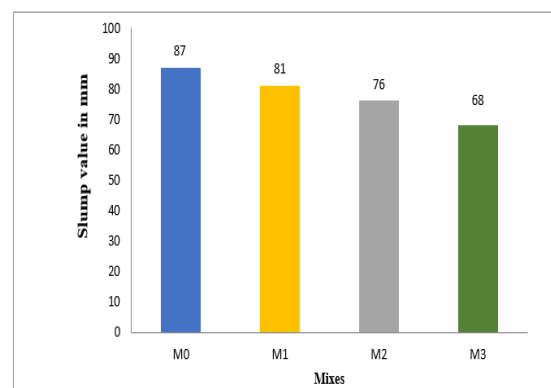
| Water | Cement | Fine aggregate | Coarse aggregate |
|---------|---------|----------------|------------------|
| 156ltrs | 390 kgs | 773.88 kgs | 1089.46 kgs |
| 0.40 | 1 | 1.98 | 2.79 |

IV. EXPERIMENTAL RESULTS AND DISCUSSION

EXPERIMENTAL RESULTS

Workability of controlled Concrete and fibre reinforced concrete using fibres with addition of mineral admixtures (GGBS, METAKAOLIN)

Slump test was carried out for each mix separately to know the workability of controlled concrete and high volume fly ash concrete. The water reducing admixture added 1% of binder is constant for all mixes. The slump test results for all mixes were as shown in histogram wide in fig 15 and tabled below.



From the above results we observe that while increasing the GGBS and Metakaolin percentage up to 10-20 there is a slight decrease in the slump values. Therefore, we observe that there is a decrease in slump value when the percentage of GGBS and Metakaolin added is increased.

Table: Slump values of Concrete mixes M0,M1,M2,M3

| MIX | Slump Value (mm) |
|-----|------------------|
| M0 | 87 |
| M1 | 81 |
| M2 | 76 |
| M3 | 68 |

Mechanical properties of controlled Concrete and fibre reinforced concrete using fibres with addition of mineral admixtures (GGBS , METAKAOLIN)

Compressive strength

7 days compressive strength

Table: Compressive strength of concrete of mixes M0, M1, M2 , M3 for 7 days.

| MIX | Compressive Strength in N mm ² |
|-----|---|
| M0 | 34.6 |
| M1 | 37.56 |
| M2 | 39.72 |
| M3 | 32.5 |

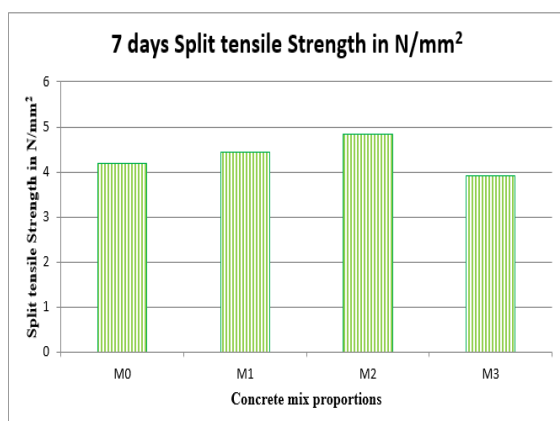
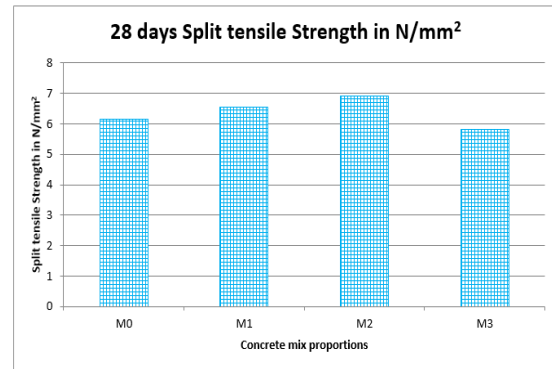
28 days compressive strength

The compressive strength values for all mixes are shown in the table. It is observed that the 28 days compressive strength of mix M2 containing 15% GGBS and 15% Metakaolin is obtain maximum value for comparing to all other mixes. The result obtained are represented as shown in the figure.

| MIX | Compressive Strength in N mm ² |
|-----|---|
| M0 | 51.37 |
| M1 | 54.61 |
| M2 | 57.26 |
| M3 | 46.9 |

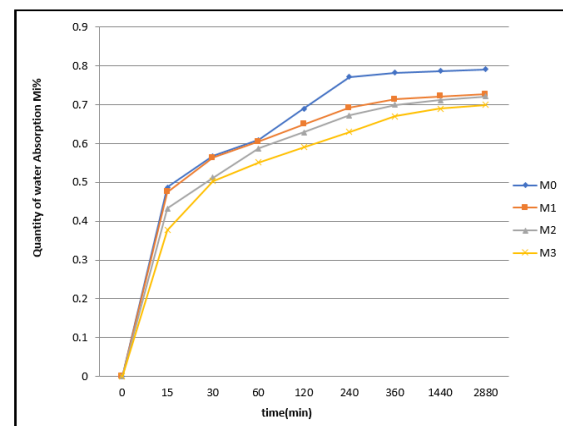
Split Tensile Strength

7 days Split Tensile Strength

**Fig: 7 days Split tensile strength of concrete of mixes M0, M1, M2 , M3 for 7 days.****Fig: 28 days. Split tensile strength of concrete of mixes M0, M1, M2 , M3**

Water absorption

Water absorption test values for all mixes are represented in graphically in fig 21 . It was indicated that is Water absorption decreased with increasing percentages GGBS and MK .

Table: Water absorption of concrete for mixes M0,M1, M2 , M3**Fig: Water absorption of various mixes M0, M1, M2 , M3**

4.5 DISCUSSION OF TEST RESULTS

The Concrete mix of M40 grade is designed as per IS 10262-2009. The partial replacements of OPC with Mineral Admixtures are done based on the basis of weight. Steel Fibers are added 1% of weight of binder. OPC is replaced with mineral admixtures up to 40% in different percentages of GGBS and Metakaolin. Addition of mineral admixtures decreased the workability Super plasticizer is added to increase the workability for same water cement ratio.

V. CONCLUSIONS

Effect of strength appraisal of Fibre Reinforced Concrete made with OPC, GGBS and Metakaolin.

Based on the study, the following conclusions can be made:The workability of concrete is observed to be decreased with addition of mineral admixtures However, required workability can be achieved by adding super plasticizer.

- In order to overcome segregation Steel fibers mixed not more than 2minutes. Steel fibers are added after addition of water to the dry mix of concrete.

- The presence of fibres in concrete acts as crack resistors. The failure of fibre concrete is not so much and hence the ductility property has improved.
- At the age of 28 days FRC with mineral admixtures compressive strength is more than the FRC without mineral admixtures compressive strength. It was observed that in long term process pozzolans are obtaining higher strengths.
- At the age of 28 days ,The percentage increase in compressive strength of FRC with mineral admixtures i.e. OPC 85%+M-Sand+ Coarse aggregate + Fibers (1% of weight of binder) + 10%GGBS +10%Metakaolin of mix M1 compared to compressive strength of FRC without mineral admixtures of mix M0 is observed as 6.30% .
- At the age of 28 days ,The percentage increase in compressive strength of FRC with mineral admixtures i.e. OPC 85%+M-Sand+ Coarse aggregate + Fibers (1% of weight of binder) + 15%GGBS + 15%Metakaolin of mix M2 compared to compressive strength of FRC without mineral admixtures of mix M0 is observed as 11.46%.
- At the age of 28 days ,The percentage decrease in compressive strength of FRC with mineral admixtures i.e. OPC 85%+M-Sand+ Coarse aggregate + Fibers (1% of weight of binder) + 20%GGBS +20%Metakaolin of mix M3 compared to compressive strength of FRC without mineral admixtures of mix M0 is observed as 8.70%.
- It was observed that for 20% and 30% replacements the compressive strengths are more than the target mean strengths and for 40% replacement compressive strength is nearer to target mean strength.
- At the age of 28 days ,The percentage increase in split tensile strength of FRC with mineral admixtures i.e. OPC 85%+M-Sand+ Coarse aggregate + Fibers (1% of weight of binder) + 10%GGBS + 10%Metakaolin of mix M1 compared to split tensile strength of FRC without mineral admixtures of mix M0 is observed as 6.67%
- At the age of 28 days ,The percentage increase in split tensile strength of FRC with mineral admixtures i.e. OPC 85%+M-Sand+ Coarse aggregate + Fibers (1% of weight of binder) +15%GGBS+1 5%Metakaolin of mix M2 compared to split tensile strength of FRC without mineral admixtures of mix M0 is observed as 12.52%.
- At the age of 28 days ,The percentage decrease in split tensile strength of FRC with mineral admixtures i.e. OPC 85%+ M-Sand + Coarse aggregate + Fibers (1% of weight of binder) +20%GGBS+20%Metakaolin of mix M3 compared to split tensile strength of FRC without mineral admixtures of mix M0 is observed as 5.36%.
- It was observed that Water absorption values of FRC without mineral admixtures of mix M0 are more compared to FRC with mineral admixtures of mixes M1,M2,M3.As the addition of mineral admixture increased the amount of Water absorption decreased.
- Sorptivity values of FRC without mineral admixtures (M0) are more compared to FRC with mineral admixtures of mixes M1,M2,M3 .As the addition of mineral admixture increased the Sorptivity values decreased.

SCOPE FOR THE FUTURE WORK

An attempt has been made to study effect of mineral admixtures on engineering properties of fibre reinforced concrete using locally available OPC, aggregates,super plasticizer,water and steel fibers are procured from online market. The Following conclusions are drawn.

- The study made by replacing cement by up to 40% of is not appropriate. This research work can give a scope to work with more percentage replacement of GGBS , Metakaolin .
- Reaserch work on pozzolanic material in fibre reinforced concrete is still limited.It promises great scope in future. For future studies b y changing mineral admixtures like rice husk ash , silica fume etc are used in place of GGBS , Metakaolin.
- This research work can give a scope to work with using different types of fibres like glass, nylon , Polypropylene, Asbestos, Carbon fibers etc.
- Strength , heat resistance power are added to concrete when fibres are incorporated which benefits concrete.
- Mechanical properties and Durability properties are improved on addition of mineral admixtures and steel fibres.

Mineral admixtures are used due to economic and environmental benefits without any compromise with its performance. Studied that all mineral admixtures reduce bleeding in concrete with correct proportion of all ingredients

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