EXPERIMENTAL INVESTIGATION ON THE MECHANICAL PROPERTIES OF CONCRETE WITH PARTIAL REPLACEMENT OF CEMENT BY METAKAOLIN AND GGBS

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Abstract - *Concrete is very important elements since it is utilised in building. The focus of this project work is on the utilisation of cementitious materials such as, Ground Granulated Blast Furnace slag (GGBS) with various percentages of 10%, 20% & 30% and Metakaolin of 5%, 10% & 15% In concrete, as a partial substitute for cement. Water Cement Ratio of, 0.4%, 0.43% & 0.45% and about 162 Cubes of size, 100 ×100 ×100 mm and 162 cylinders of size 300 mm height and a diameter of 150 mm were cast in M40 concrete and tested for compressive and spilt tensile strength for 7 and 28 days, respectively. To determine their strength qualities. Steel fibres of 0.5%, GGBS of 10%, Metakaolin of 10% And water cement ratio, of 0.4% is used in beam of size 150x250x1500mm is cast for M40 grade of concrete and tested for flexural behaviour of 28 days. The acquired results were regarded to be encouraging, and this study can be expanded by adding other mineral admixtures.*

Key Words: Metakaolin, steel fibres, Compressive Strength, Ground granulated, Blast furnace Slag (GGBS), Flexure test, Split tensile strength.

1.INTRODUCTION

Concrete plays a significant part in the rapidly increasing creative discipline. New techniques and technologies in construction, structural, and civil engineering have resulted in more stringent standards for this material. Cement use will rapidly increase all across the world. The amount of CO2 emitted into the atmosphere must be reduced. Reduce the cement content of the material and utilise pozzolanic materials for concrete is one of the treatments to overcome this example (CO2). Metakaolin, ground granulated blast furnace slag, Micro Silica, Fly Ash, and other materials are some of them.

Since concrete is second only to water in terms of consumption, a lot of research and adjustments are being done to make concrete with the needed qualities. The strength, workability, durability, and other qualities of conventional concrete needed to be modified to make it more suited for diverse conditions as technology progressed and the area of use of concrete and mortars grew. This has resulted in the usage of cementitious materials like as GGBS, fly ash, silica fume, metakaolin and others, which is have contributed to improved performance, energy conservation, and economic efficiency. When GGBS and metakaolin are used to partially replace cement in concrete, the amount of cement used is reduced, carbon dioxide (CO2) emissions are reduced, existing resources are conserved, and concrete strength and durability are improved.

Recent research in many regions of the world have showed that ggbs concrete may better preserve steel reinforcement and hence the structure as a whole, allowing it to withstand corrosion. Ggbs concrete is a form of concrete in which a portion of the cement is replaced by an industrial by product called ground granulated blast furnace slag. As a result, the use of GGBS concrete can significantly reduce corrosion. Furthermore, it can lead to a significantly more robust construction without a significant cost rise. Because ggbs from current thermal power plants does not require processing before being integrated into concrete, it is regarded as an environmentally friendly input material. When used in concrete, ggbs can be utilised as a partial replacement for Portland cement without affecting compressive strength.

Metakaolin enhances the qualities of concrete by raising compressive and flexural strength, giving chemical resistance, decreasing permeability, limiting alkali silica reaction, decreasing efflorescence and shrinkage, and avoiding steel corrosion.

2. OBJECTIVES

- The purpose of this study is to observe the behaviour of GGBS and Metakaolin content in the compressive and split tensile strength of concrete after 7 and 28 days.
- To examine the workability characteristics of various mixes.
- To evaluate the compressive strength and split tensile strength of concrete with the combined effect of GGBS and Metakaolin application.
- To investigate the flexural behaviour of a beam using 10% GGBS and 10% Metakaolin as cement substitutes, as well as the inclusion of 0.5 percent steel fibres.
- To examine the strength properties of concrete by replacing cement in concrete.

3. LITERATURE REVIEW

- **S.Mallikarjuna et.al, (2016),** A study was performed on the strength properties of GGBS used as a cement substitute in concrete. When GGBS was used to replace 10% of the cement in M40 grade concrete, the compressive strength was found to be the highest, compared to 20%, 30% and 40% cement replacement with GGBS. The compressive strength of M20 grade concrete was found to be maximum at 10% cement substitution with GGBS, followed by 20, 30 and 40% cement substitution with GGBS, in that order. The authors concluded from the test findings that the efficiency factor for M40 grade concrete was showed to be greatest at 10percent cement substitution with GGBS at 28 days.
- **Venu Malagavelli et.al (2018)** performed research on the impact of metakaolin on concrete as a partial replacement for cement. The compressive strength of concretes after 7 and 28 days. The compressive strength is varies from 23.9 to 28.5 MPa after seven days and from 47.3 to 55.2 MPa after 28 days. In 28 days, all modified and regulated concretes reached the required strength of 35MPa. With addition of 5% and 10% metakaolin to the cement, the compressive strength of concrete is raised by 7% and 16.75%, respectively. Similarly, a 15% and 20% addition of metakaolin increases compressive strength by 11.42 percent and 6%, respectively. This clearly reveals that the optimal proportion of metakaolin in the concrete is 10%. For 28 days, the % increase in strength characteristics in compressive strength is 16.75, split tensile strength is 7.1, and flexural strength is 7.88, respectively. A maximum of 10% of the cement can be substituted with metakaolin.
- **Deepthi Dennison, et.al (2014)** The influence of metakaolin on the behaviour of normal and steel fibre reinforced concrete beams was investigated. The mechanical qualities of concrete mixes with varying % of cement replaced by MK improve as the proportion of MK increases from 0 to 10%. Beyond 10% replacements, all mechanical characteristics show a deteriorating trend. This is because MKC has a weak diluting effect after this amount of MK. As a result, the gap in mechanical qualities between CC and MKC becomes reduced. As a result, the ideal replacement percentage of MK chosen is 10%. In flexure, the load deflection pattern of metakaolin crimped steel fibre concrete beams demonstrates better load bearing capacity and deflection than control the specimens. In flexure, reinforced concrete beams containing 10% MK and 1.5 percent CSF exhibit greater energy absorption and ductility than HESF with the same volume fraction.
- **Girija Vidnyan Gaikwad et.al (2019)** Experimental Investigation on Metakaolin Modified Fibre Reinforced Concrete was undertaken. Workability is observed to reduce when fibre content and Metakaolin levels rise. When comparing normal concrete to 3 percent fibre and 10% metakaolin concrete, the compressive strength rose by 3.2 percent. The amount of steel fibre and MK in concrete mix enhances the split tensile strength. At 9% fibre content by volume fraction and 25% MK by weight of cement, the maximum strength was achieved. When it is compared to conventional concrete, the split tensile strength rise by 56.29 percent
- **Karikalan A T et.al (2021)** according to the study, the flexural behaviour of GGBS concrete beams with steel and hybrid FRP, and GFRP bars was investigated. And here, partial replacement of cement with GGBS is used. The percentages of replacement are 5, 10, 15, 20, 25, 30, 35%, and 40%. The strength of concrete will be affected by the content of GGBS. Strength tests carried out. It has been shown that the strength of concrete is deteriorating up to 25% due to the presence of GGBS. The 30 percent GGBS content indicates that the strength was good, but after another 30 percent, the results began to decline. The optimal amount of cement substitution by GGBS is 30 percent. GGBS concrete has a compressive strength of 28.23 N/mm2 and a tensile strength of 2.83 N/mm2. The paper concluded that GGBS concrete beams with hybrid FRP bars are stronger than GGBS concrete beams with GFRP bars. The quantity of FRP used enhances the strength.
- **Egwuonwu, William, C et.al (2019),** The Effect of Metakaolin as a Partial Replacement for Cement on the Compressive Strength of High Strength Concrete at different W/C ratios was investigated. In this experiment, the maximum compressive strength (95.33 MPa) was recorded, after the curing period of 28 days, with a 10% substitution of cement with metakaolin at a w-c ratio of 0.2. As a result, for realistic applications, a 10% replacement might be advised. Metakaolin was shown to boost compressive strength by 28.85 percent at 10% replacement level after the 7 days of curing when compared to the control mix. This steady improvement in strength as curing age rises might be attributed to a large reduction in voids, which enhances the degree of hydration.
- **Dr. B. Vidivelli et.al (2016),** performed a work on the flexural behaviour of reinforced concrete beams reinforced with GGBS, steel fibre and GGBS 40% are the cement substituents and Steel Fibre 1% by cement replacement, the high range water reducing additive SP-430 is used to cast the specimens and with cure times of 7 and 28 days. When compared to the normal beam, the modified concrete beams had a 40% improvement in ultimate load bearing capability. When compared to the beam, the modified beams demonstrate a 3% decrease in deflection at the ultimate level.
- **Dr.K.Srinivasu et.al (2014),** performed study on metakaolin admixed in concrete. The use of metakaolin in concrete at a 25 percent replacement rate for cement resulted in improved strength and durability. The addition of metakaolin enhanced water permeability and absorption, resulting in an increase in concrete density. Metakaolin was used to make acid resistance concrete with good results in terms of chloride permeability and sulphate resistance. The addition of steel fibres, fly ash, and silica fume to metakaolin produced better results than standard

concrete. The metakaolin improved the flowability of concrete and cement mortar.

4. MATERIALS AND PROPERTIES

4.1 Cement

Ordinary Portland Cement (OPC) 43 grade, which complies with IS: 8112 - 1989, was utilised in this work. The cement used was Ultratech cement, which was received from local dealers.

Table -1: Cement properties (opc 43)

Material Specifications	Results
Specific gravity	3.125
Normal consistency	32%
Initial setting time	38 min
Final setting time	10 hrs
Compressive strength	48.44 N/mm^2

4.2 Fine aggregates

The project work was done with naturally available river Sand from zone 2, IS 383-1970. Table 2 shows the material properties of the fine aggregates used.

Table -2: Material properties of the fine aggregates

Material Specifications	Results
Specific gravity	2.57
Fineness modulus	3.38 %
Water absorption	1%

4.3 Coarse aggregates

In this experiment used a local available crushed aggregates that conform with IS 383-1970.

Table -3: Material properties of the coarse aggregates

Material Specifications	Results
Specific gravity	2.54
Fineness modulus	8.36 %
Water absorption	0.5%

4.4 Metakaolin

Metakaolin is gained on heating of kaolin at the temp. of 650-900 °C. It is neither an industrial by product nor a natural available material. Metakaolin reduces the consumption of cement and increases the properties of cement, because it is much finer than cement particles.

Table -4: properties of metakaolin

Material Specifications	Values
Specific gravity	2.6
Mean Grain Size (µm)	2.54
Specific Area (cm^2/g)	150000 - 180000
color	Ivory to green

4.5 Steel fibers

Steel fibres are circular, square, crescent shaped and irregular. Steel fibres are obtained from melt excavation process. Circular steel fibres can be produced by cutting wire of diameter 0.10 to 0.30 inches. Crimped steel fibres of 30mm long and a diameter of 0.6mm and an accept ratio of 50 are used in the test. Accept ratio is equal is length divided by diameter of the fibre. Density of steel fibres is 7840 kg/m^3 and specific gravity of 7.9 is used in the experiment.

4.6 Ground granulated blast furnace slag(GGBS)

The blast furnace generates GGBS as a byproduct, which heats iron ore, limestone, and coke to 1500°C to produce iron. When these components melt in the blast furnace, they produce molten iron and molten slag. The molten slag floats on top of the molten iron because it is lighter. The molten slag is mostly made up of iron ore silicates and alumina, with some limestone oxides thrown in for good measure. The granulating process includes cooling the molten slag using high-pressure water jets. This quickly cools the slag, producing granular particles with diameters smaller than 5mm. The rapid cooling prevents the formation of larger crystals, resulting in 95 percent non-crystalline granular calcium alumina silicates. Another good cementitious material is GGBS cement.

5. MIX DESIGN

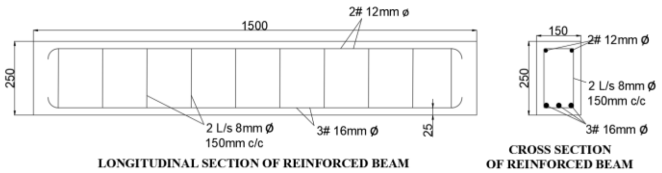
The study uses the design mix M40 grade of concrete using 53 grades OPC in the study. The Mix design was performed as per IS 10262: 2019. The water cement ratio's for the mixes is 0.4,0.43,0.45%. The following mix proportion was obtained from the mix design.

Table - 5: Mix designs properties.

GRADE OF CONCRETE	CEMENT	FINE AGGREGATE	COARSE AGGREGATE	W/C RATIO
M40	1	1.95	2.69	0.4
M40	1	2.13	2.91	0.43
M40	1	2.28	3.03	0.45

6. DESIGN OF BEAM

Design of beam was carried with references of IS 456-2019 for M_{40} grade concrete and Fe_{500} steel.



All dimensions are in meters

7. METHODOLOGY

Cubes of length, width, and thickness of 100mm x 100mm x 100mm is used in the experiment, Cylinders of size 150mm diameter and 300mm height is used, and the beam of length 1500mm, width 150mm and height 250mm is used, and casted with different proportions and cured for 7 and 28 days. After curing the specimens (cubes and cylinders) were tested in CTM in accordance with IS: 516-1959 for cubes, and IS: 5816-1976 for cylinders. Beams tested for flexural strength according to IS: 516-1959.

Table - 6: Methodology.

Water cement ratio	% of GGBS (54 cubes & 54 cylinders)	% of Metakaolin (54 cubes & 54 cylinders)	Combination of GGBS and Metakaolin (54 cubes & 54 cylinders)
0.4 %	10 %	5 %	10%GGBS + 5% MK
	20%	10%	20%GGBS +10% MK
	30%	15%	30%GGBS+15%MK
0.43%	10 %	5 %	10%GGBS + 5% MK
	20%	10%	20%GGBS +10% MK
	30%	15%	30%GGBS+15%MK
0.45%	10 %	5 %	10%GGBS + 5% MK
	20%	10%	20%GGBS +10% MK
	30%	15%	30%GGBS+15%MK

Fig -1: Mixing And Casting

8. EXPERIMENTAL TEST RESULTS

8.1 Slump cone test results

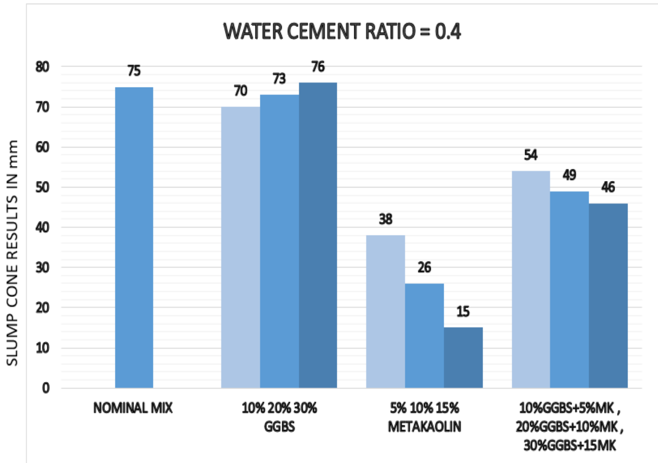
The slump test results of concrete made using Metakaolin (MK) and ground granulated blast furnace slag (GGBS) in replacement of cement are shown in the table below.

Note: Nominal mix slump value = 75mm

8.1.1 WATER CEMENT RATIO = 0.4

Table - 7: slump cone values of 0.4 water cement ratio.

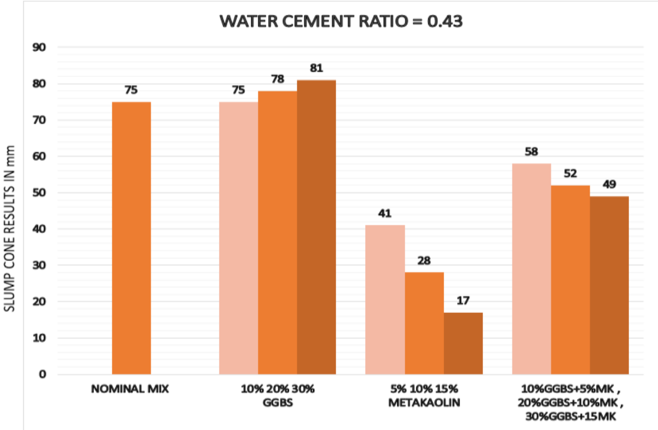
% of GGBS	SLUMP (mm)	%of Meta kaolin	SLUMP (mm)	GGBS and Metakaolin	SLUMP (mm)
10 %	70	5 %	38	10%GGBS + 5% MK	54
20%	73	10%	26	20%GGBS +10% MK	49
30%	76	15%	15	30%GGBS+15%MK	46



8.1.2 WATER CEMENT RATIO = 0.43

Table - 8: slump cone values of 0.43 water cement ratio.

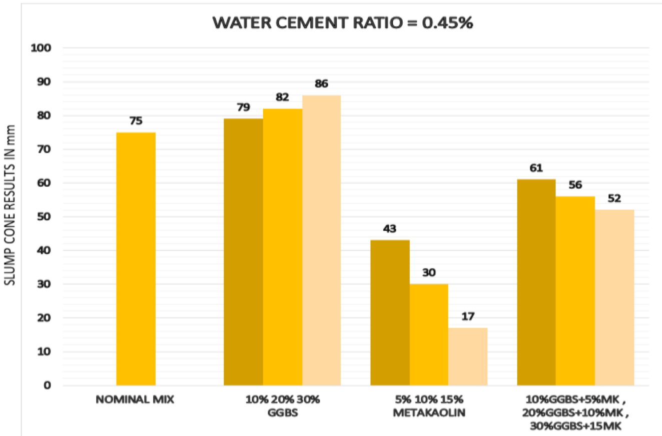
% of GGBS	SLUMP (mm)	% of Meta kaolin	SLUMP (mm)	GGBS and Metakaolin	SLUMP (mm)
10 %	75	5 %	41	10%GGBS + 5% MK	58
20%	78	10%	28	20%GGBS +10% MK	52
30%	81	15%	17	30%GGBS+15%MK	49



8.1.3 WATER CEMENT RATIO = 0.45

Table - 9: slump cone values of 0.45 water cement ratio.

% of GGBS	SLUMP (mm)	% of Meta kaolin	SLUMP (mm)	GGBS and Metakaolin	SLUMP (mm)
10 %	79	5 %	43	10%GGBS + 5% MK	61
20%	82	10%	30	20%GGBS +10% MK	56
30%	86	15%	17	30%GGBS+15%MK	52



8.2 STRENGTH TESTS

The specimens are allowed to dry for 24 hours after being removed from the curing tank. Three strength tests were carried out, and the results are as follows:

- A 100mm x 100mm x 100 mm cube is used to measure the compressive strength.
- A 150mm dia x 300mm height cylinder has been used to perform a tensile strength test.
- A 1500mm x 150mm × 250mm beam has been used to test flexural strength.

8.2.1 COMPRESSIVE STRENGTH TEST

$$compressive\ strength = \frac{P}{A}$$

Where, P = Load (N), A = surface area of cube,
= 100 X 100 mm^2.

The compressive strength test results of concrete made with GGBS and Metakaolin in place of cement are shown in the tables below.

Calculation formula $= \frac{P}{A} \times 1000\ N/mm^2$

where, P = failure load, A = area of cube (B x L),B = breadth (100mm) of the cube, L = length (100mm) of the cube

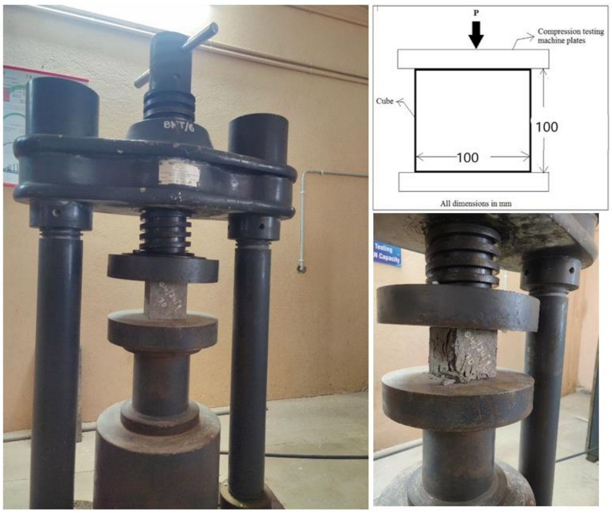


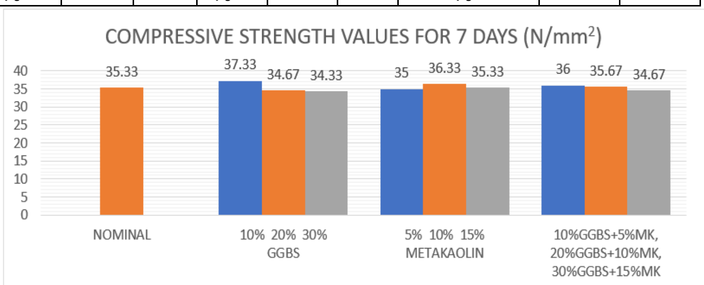
Fig -2: Compression test

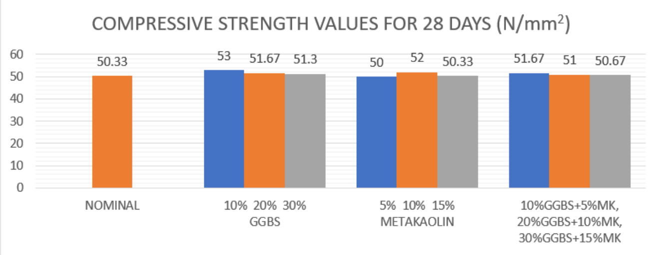
8.2.2 WATER CEMENT RATIO = 0.4

For 7 days, the nominal mix compressive strength value is 35.33 N/mm^2 And For 28 days, the nominal mix compressive strength value is 50.33 N/mm^2.

Table - 10: Compressive strength values of 0.4 w/c ratio.

GGBS In %	7 days	28 days	M K In %	7 days	28 days	GGBS and Metakaolin	7 days.	28 days
10 %	37.33	53	5 %	35	50	10%GGBS + 5% MK	36	51.67
20 %	34.67	51.67	10 %	36.33	52	20%GGBS +10% MK	35.67	51
30 %	34.33	51.3	15 %	35.33	50.33	30%GGBS +15%MK	34.67	50.67



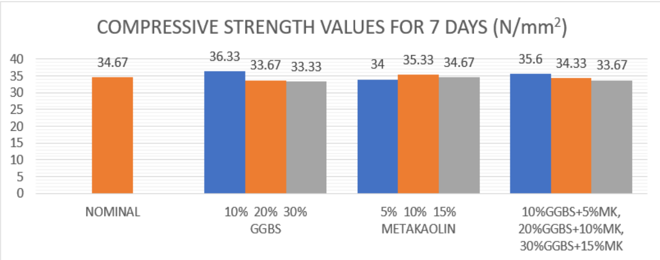


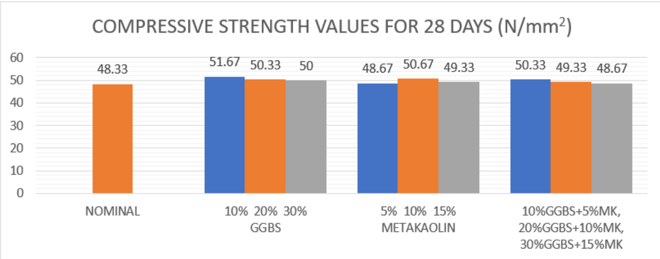
8.2.3 WATER CEMENT RATIO = 0.43

For 7 days, the nominal mix compressive strength value is 34.37 N/mm^2 And For 28 days, the nominal mix compressive strength value is 48.33 N/mm^2.

Table - 11: Compressive strength values of 0.43 w/c ratio.

GGBS In %	7 day s, N/mm^2	28 day s. N/mm^2	M K In %	7 days N/mm^2	28 days N/mm^2	GGBS and Metakaolin	7 days, N/mm	28 days, N/mm^2
10 %	36.33	51.67	5 %	34	48.67	10%GGBS + 5% MK	35.60	50.33
20%	33.67	50.33	10%	35.33	50.67	20%GGBS +10% MK	34.33	49.33
30%	33.33	50	15%	34.67	49.33	30%GGBS+15%MK	33.67	48.67



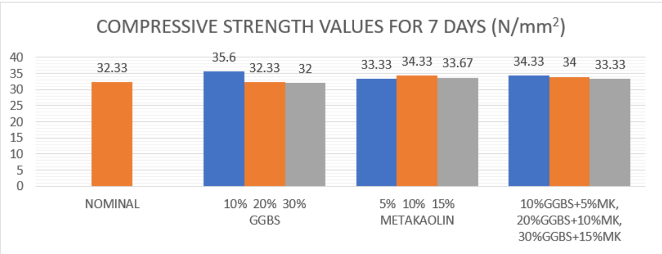


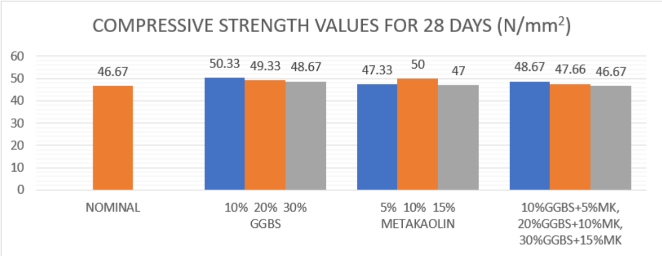
8.2.4 WATER CEMENT RATIO = 0.45

For 7 days, the nominal mix compressive strength value is 32.33 N/mm^2 And For 28 days, the nominal mix compressive strength value is 46.67 N/mm^2.

Table - 12: Compressive strength values of 0.45 w/c ratio.

GGBS In %	7 days, N/mm^2	28 days, N/mm^2	M K In %	7 days, N/mm^2	28 days, N/mm^2	GGBS and Metakaolin	7 days, N/mm^2	28 days, N/mm^2
10 %	35.6	50.33	5 %	33.33	47.33	10%GGBS + 5% MK	34.33	48.67
20%	32.33	49.33	10%	34.33	50	20%GGBS +10% MK	34	47.66
30%	32	48.67	15%	33.67	47	30%GGBS+15% MK	33.33	46.67





8.3.1 TENSILE STRENGTH TEST

The tables below show the test results of concrete made by substituting cement with metakaolin and GGBS at various percentages.
Calculation formula $=2P/\pi LD \times 1000$ N/mm² ,Where P= failure load, L = cylinder length, (300mm),D = cylinder diameter, (150mm)

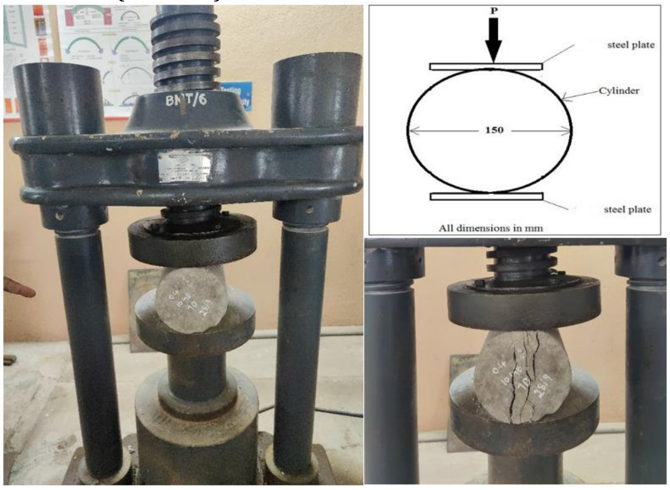


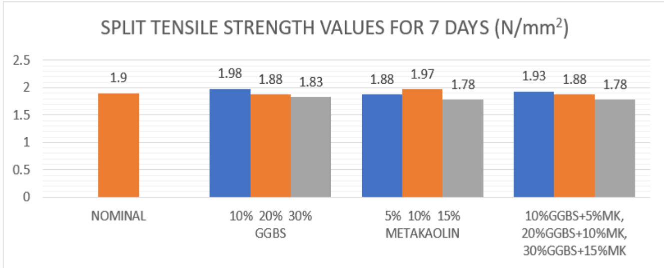
Fig -3: Split tensile test

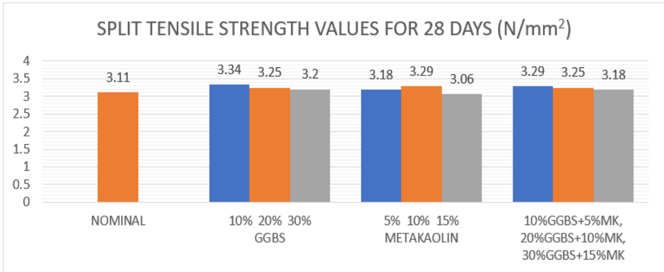
8.3.2 WATER CEMENT RATIO = 0.4

For 7 days, the nominal mix split tensile strength value is 1.9 N/mm² And For 28 days, the nominal mix split tensile strength value is 3.11 N/mm².

Table - 13: split tensile strength values of 0.4 w/c ratio.

GGBS In %	7 days N/mm²	28 days N/mm²	M K In %	7 days N/mm²	28 days N/mm²	GGBS and Metakaolin	7 days N/mm²	28 days N/mm²
10 %	1.98	3.34	5 %	1.88	3.18	10%GGBS + 5% MK	1.93	3.29
20%	1.88	3.25	10%	1.97	3.29	20%GGBS +10% MK	1.88	3.25
30%	1.83	3.20	15%	1.78	3.06	30%GGBS+15% MK	1.78	3.18



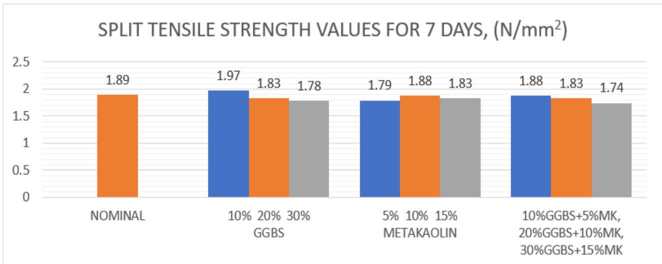


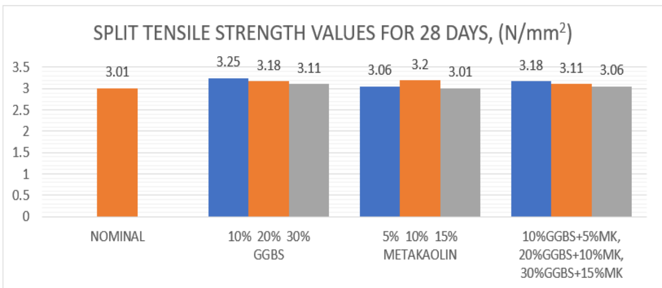
8.3.3 WATER CEMENT RATIO = 0.43

For 7 days, the nominal mix split tensile strength value is 1.89 N/mm² And For 28 days, the nominal mix split tensile strength value is 3.01 N/mm².

Table - 14: split tensile strength values of 0.43 w/c ratio.

GGBS In %	7 days N/mm²	28 days N/mm²	M K In %	7 days N/mm²	28 days N/mm²	GGBS and Metakaolin	7 days N/mm²	28 days N/mm²
10 %	1.97	3.25	5 %	1.79	3.06	10%GGBS + 5% MK	1.88	3.18
20%	1.83	3.18	10%	1.88	3.2	20%GGBS +10% MK	1.83	3.11
30%	1.78	3.11	15%	1.83	3.01	30%GGBS+15% MK	1.74	3.06



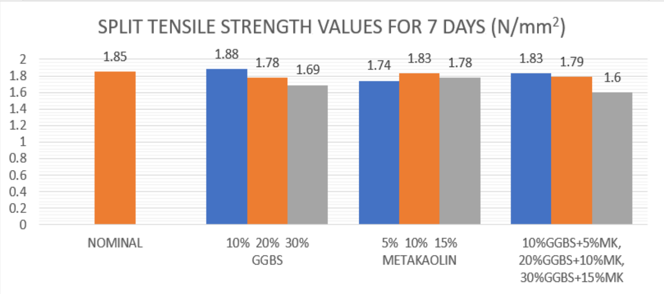


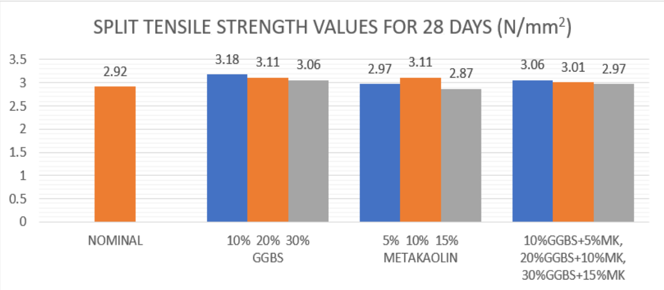
8.3.4 WATER CEMENT RATIO = 0.45

For 7 days, the nominal mix split tensile strength value is 1.85 N/mm² And For 28 days, the nominal mix split tensile strength value is 2.92 N/mm².

Table - 15: split tensile strength values of 0.45 w/c ratio.

GGBS In %	7 days ,N/mm^2	28 days ,N/mm^2	M K In %	7 days N/mm^2	28 days N/mm^2	GGBS and Metakaolin	7 days N/mm^2	28 days N/mm^2
10 %	1.88	3.18	5 %	1.74	2.97	10%GGBS + 5% MK	1.83	3.06
20%	1.78	3.11	10%	1.83	3.11	20%GGBS +10% MK	1.79	3.01
30%	1.69	3.06	15%	1.78	2.87	30%GGBS+15% MK	1.60	2.97





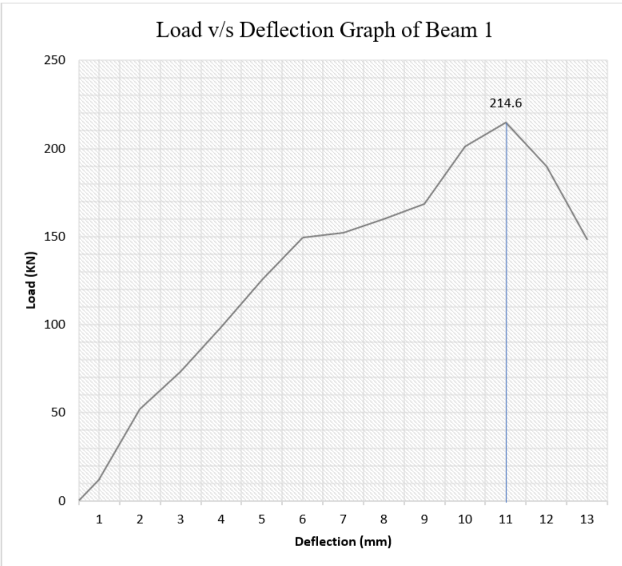
8.4.1 FLEXURE TEST

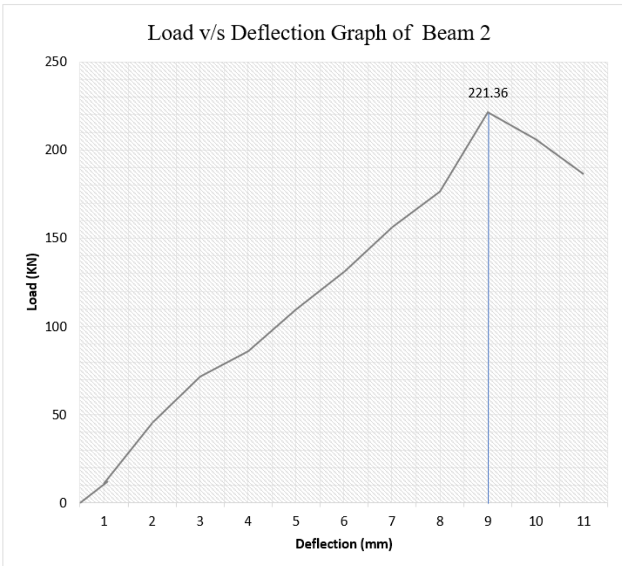
The flexure tests have been carried out for nominal beam (beam 1) and admixtures added beam (beam 2). The beams are tested by applying a load to a loading frame using a hydraulic jack having a capacity of 2000 KN. Hydraulic jacks are used to provide two-point loading on a beam with a constant moment. The beam was supported by two basic supports that rested on steel plates measuring 200mm x 100mm. The beam's effective length is 1000mm. To get deflection values, the deflection gauge is mounted at the bottom of the specimen along the depth of the beam.
The beams (2 no's) of size: 1500 mm x 250 mm x 150 mm have been tested under two-point loading. The load deflection characteristics, failure mechanisms, and load capacity curve are analysed. After applying the load uniformly cracks are developed in beam. Flexure fractures appear first in the middle of the span, followed by diagonal cracks. Later, these cracks spread to the spot where load was applied.

1. BEAM 1: M40 grade concrete, 0.4 water cement ratio.
2. BEAM 2 : M40 grade concrete, 0.4 W/C ratio, 10% GGBS and 10% Metakaolin replacement of cement, 0.5 % Steel fibres added.

Fig -4: placing of specimen on loading frame.

Fig -5: specimens after testing in loading frame





9. RESULTS AND DISCUSSIONS

9.1 Workability

- Table 8.1 shows that as the amount of GGBS is raised, the slump increases as well. It may be inferred that the higher the percentages of GGBS, the more workability.
- As can be seen in table 8.1, the slump decreases as the proportion of Metakaolin increases. It may be deduced that the higher the amount of Metakaolin, the less workability.
- From table 8.1 it is observed that workability for10 % GGBS & 5% Metakaolin mix slump is maximum, hence the optimum mix is 10% GGBS & 5 % MK for good workability.
- The GGBS shows high workability because it contains calcium silicate hydrate (CSH) which has a high dense and is less porous.
- The metakaolin shows less workability when compare to an a GGBS material because the Metakaolin has high absorption of water due to the manufacture processing is done in temp of 650-900 ℃.

9.2 Compressive strength and Split tensile strength

- When comparing the compressive strength and split tensile strength of concrete created by replacing cement with GGBS and Metakaolin (10%), the compressive strength and split tensile strength of the concrete produced by replacing cement with GGBS and Metakaolin (10%) shows the highest strength.
- The GGBS of 10% shows high compressive strength, and high split tensile strength, when compare to the 20% & 30% of GGBS because the chemical reaction takes place at the addition of 10% GGBS only, for further percentages chemical reaction is not fully completed.
- The clinker dilution effect reduces the both strengths of metakaolin by 5% and 15%, respectively, when compared to 10% metakaolin. The diluting effect occurs when a portion of the cement is replaced with the same amount of metakaolin. The filler effect, pozzolanic reaction in metakaolin with calcium hydroxide, and compounding effect respond oppositely to the dilution effects in metakaolin concrete. As a result, there existed an optimum metakaolin substitute for metakaolin concrete.
- In comparison to Nominal concrete, the concrete produced by substituting cement with GGBS (10%) and metakaolin (10%) showed better compressive strength and split tensile strength.

9.3 Flexure test

- The load v/s deflection graph of beam 1 has obtained maximum load of 214.6 KN and 11 mm deflection.
- The load v/s deflection graph of beam 2 has obtained maximum load of 221.36 KN and 9 mm deflection.
- It is observed that beam 2 shows more strength when compared to the beam 1. Because the beam 2 consists of 10% GGBS, 10%metakaolin and 0.5 %, of steel, fibres.
- The flexural, strength of beam 2 was increased, by 3.15 % when compare to the nominal concrete.

10. CONCLUSION

- Higher compressive and tensile strength may be achieved when the cement is partially, replace by 10% GGBS and 10% metakaolin with a water cement ratio of 0.4.
- Concrete workability is greater for water cement ratios of 0.4 than the ratio of 0.43 and 0.45.
- 7 days compressive, strength of 10% GGBS and 10% metakaolin is found to be 37.33 N/mm^2 and 36.33 N/mm^2 and is optimum, when compared to nominal concrete of strength 35.33 N/mm^2.
- 28 days compressive strength of 10% GGBS and 10% metakaolin is found to be 53 N/mm^2 and 52 N/mm^2 and is optimum, when compared to nominal concrete of strength 50.33 N/mm^2.
- 7 days Split tensile strength of 10% GGBS and 10% metakaolin is found to be 1.98 N/mm^2 and, 1.97 N/mm^2 and, is optimum, when compared to nominal concrete of strength 1.9 N/mm^2.
- 28days Split tensile strength of 10% GGBS and 10% metakaolin is found to be 3.34 N/mm^2 and 3.29 N/mm^2 and is optimum, when compared to nominal concrete of strength 3.11 N/mm^2.
- Finally, the compressive strength, and split, tensile strength achieved is high with the, replacement of 10% GGBS and 10% metakaolin compared to nominal mix concrete.
- The load v/s deflection graph of beam 1 has obtained maximum load of 214.6 KN for 11 mm deflection.
- The load v/s deflection graph of beam 2 has obtained maximum load of 221.36 KN for 9 mm deflection.
- It is observed that beam 2 shows more strength when compare to the specimen beam 1. Because the beam 2 consists of 10% GGBS, 10%metakaolin and 0.5 % 0f Steel fibres.
- When compared to the nominal concrete, the flexural strength of specimen of beam 2 increases by 3.15 %.

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