STUDY ON STRENGTH PROPERTIES OF GLASS FIBER REINFORCED CONCRETE MADE USING METAKAOLIN AND WASTE FOUNDRY SAND AS PARTIAL INGREDIENTS

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Abstract

In this investigation M30 grade of concrete is considered for the study. Here cement is constantly replaced with metakaolin by 15% and fine aggregate is partially replaced with WFS in various percentages such as 5%, 10%, 15%, 20% and 25% and using glass fibers 0.5% by weight of cement. The result shows that the concrete with 0.5% glass fibers, 15% constant replacement of cement by metakaolin and 10% replacement of fine aggregate with WFS gave maximum strength.

Keywords: *Metakaolin, Waste foundry sand, Glass fibers, M30 Grade concrete*

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1. INTRODUCTION

In today's world demand for cement and natural aggregates is more and simultaneously there is an increase in cost. The smart and effective solution for this is to using of locally available byproducts from the industries such as WFS, fly ash, bottom ash, silica fume, saw dust, GGBS etc. as a replacement for natural materials which results in critical improvements in industries energy efficiency and environmental performance.

1.1 Waste Foundry Sand

In foundry industry large amount of byproduct is generated by the casting process. About 3/4th of the total byproduct consists of sand which in turn called as WFS. Foundry industries use high quality silica sand, this sand is of good quality compared to natural sand. WFS is a waste material obtained from ferrous and non-ferrous metal cast industries. Approximately 100 MT of foundry sand is used for manufacturing process in metal cat industries. Foundries recycle and reuse the sand many times, this causes reduction in strength it is then removed which is called as WFS. WFS are waste byproducts which has the potential to partially replace natural sand in concrete, by partially replacing natural sand with WFS without sacrificing or even improving strength and durability, there are clear economic and environmental gains.

1.2 Metakaolin

Metakaolin is a fine natural white clay produced by heating of kaolin, which is most abundant mineral. Kaolin is a fine material which has been used as coating for paper. Siliceous content is more in Metakaolin and it is also called as High Reactivity Metakaolin. Metakaolin is not a waste product like fly ash, silica fume, GGBS etc. which is generated by industries. Metakaolin is produced for a specific purpose under controlled conditions. Manufacture of metakaolin is done by heating kaolin at the temperature of 650^{0}C-900^{0}C. This heat treatment breaks down the structure ofikaolin, hydroxyl ions are removed and disorder among layers of silica and alumina yields a highly reactive amorphous material and latent hydraulic reactivity which makes metakaolin suitable for cementing application. Partial replacement of cement with metakaolin may improve both mechanical properties and durability of the concrete.

1.3 Fiber Reinforced Concrete

For the most part, concrete is strong in compression and week in tension. Concrete is brittle and will crack with the application of increasing tensile force. When concrete cracks it can no more carry tensile load. With a goal to make concrete capable for carrying tension at strains more prominent than those at which cracking starts, it is important to increase the tensile strength. To increase the tensile and flexural strength, fibers are included concrete. The inclusion of fibers to concrete will bring about a composite material that haspropertiesnotquitethesameasthoseofiun-reinforcedconcrete.Theextentofthis variety depends on the type of fibers, as well as on the dosage offiber.

2. OBJECTIVES AND METHODOLOGY

2.1 Objectives

The aim of the present investigation is to study,
1. The mix design for M-30 grade of concrete.
2. The performance of fresh & hardened glass fiber reinforced concrete containing 15% constant replacement of metakaolin with cement & partial replacement of foundry sand (5%, 10%, 15%, 20% and 25%) withFA.

3. The mechanical properties such as,
   - Compressive strength.
   - Split tensile strength.
   - Flexural strength.
4. To compare test results of produced concrete with conventional concrete.
5. To draw down the conclusions based on the test results.

2.2 Methodology

The project is to study the mechanical and durability properties of glass fiber reinforced concrete by 15% replacement of cement by Metakaolin and fine aggregate by waste foundry sand.

1 The materials such as glass fibers, Metakaolin, foundry sand, cement, fine aggregate, coarse aggregate are gathered and the properties are found in research laboratory.
2 With the obtained properties of material, mix design is prepared with suitable water-cement ratio for M-30 grade of concrete. The slump value is obtained by using slump cone test.
3 The compressive strength obtained by using 150mmx150mmx150mm size of cube specimens, are tested at 7, 28 and 56 days of age in compression testing machine with a capacity of 2000kN. The compressive strength value is obtained by average of three specimens at every age of curing.
4 Cylinder specimens of 150mm dia and 300mm height are used to study the split tensile strength of concrete. The specimens are tested at 7 and 28 days age, with the help of hydraulic compression machine. The split tensile strength is determined by taking average of three cylinder specimens at everyage.
5 100mm x 100mm x 500mm size of beam specimens are casted to study the flexural strength. The test specimens are tested at 28 and 56 days to determine the flexural strength.
6 The beams are tested under two points loading system in a universal testing machine and the loads are recorded.
7 From the outcomes of test carried out charts and tables are prepared.
8 From the outcomes conclusions are made.

3. MATERIALS PROPERTIES

3.1 General

It is required to test the materials before using in concrete to suit the requirements of various IS codes. Some of materials required, for example, cement, fine aggregate, coarse aggregate, water, metakaolin, glass fibers and WFS.

3.2 Cement

The OPC 53 grade Birla super cement was used in this study. The cement was tested according to IS:12269-1987. Different tests were carried out on the cement to ensure that it confirms to the requirements of the IS: 12269-1987specifications.

Table-1: Physical Properties of OPC

Property	**Results**
Specific gravity	3.14
Normal Consistency	33%
Final testing time	410 min
Initial testing time	45 min

3.3 Fine Aggregates: Natural Sand

Locally available river sand is used as FA. The various tests are conducted on fine aggregate and the results obtained are tabulated below. The tests are conducted as per IS:2386-1963.

Table-2: Tests on Fine Aggregate

Properties	**Results**
Specific gravity	2.64
Fineness modulus	2.64
Water absorption	1.05%

Sand Conforms to Zone-II as per IS383:1970.

3.4 Coarse Aggregate

In this investigation 20mm downsize for coarse aggregates have been used and they are tested as per IS 2386:1963. The properties shown in table below.

Table-3: Tests on Coarse Aggregate

Properties	**Results**
Specific gravity	2.68
Fineness modulus	2.92
Water absorption (%)	0.36%

3.5 Water

The clean consumable water was utilized for mixing and curing of concrete. In this test work, common consumable tap water accessible at research facility was utilized for mixing and curing of concrete specimens. Water is important as it contributes in chemical reaction with cement. Water should be clean & free from salt, acids alkalis & other destructive materials.

3.6 Waste Foundry Sand

Foundry sand contain high silica. Waste foundry sand gathered at peenya industrial zone Bangalore. It is having particle size passing 4.75mm sieve size.

Table-4: Physical Property of WFS

Property	**Result**
Specific property	2.75
Water absorption	0.45%
Fineness modulus	2.74

Table-5: Chemical Compositions of WFS

Constituents	Values in%
CaO	0.14
SiO_2	87.91
Al_2O_3	4.7
MgO	0.30
P_2O_5	0.01
Fe_2O_3	0.94
K_2O	0.25
Na_2O	0.19
LOI	5.15

3.7 Metakaolin

Metakaolin was brought from Golden Micro Chemicals Pvt Ltd Vadodra. Metakaolin which is manufactured by the calcinations of pure or refined kaolinitic clay at a temperature of somewhere around 650^0C and 850^0C, followed by grinding to accomplish a fineness of 700-900/kg exhibits high pozzolanity. At the point when utilized as a part of concrete it will fill the void space between cement particles bringing about a more impermeable concrete

Fig-1: Metakaolin

Table-6: Chemical Composition of Metakaolin

Composition	Values in %
SiO_2	52.8
Al_2O_3	36.3
Fe_2O_3	4.21
MgO	0.81
CaO	<0.10
K_2O	1.41
LOI	3.53

Table 4.9: Physical Property of Metakaolin

Property	Result
Specific Gravity	2.1
Water absorption	0.5

3.8 Glass Fiber

On a particular strength to weight premise, glass fiber is one of the robust and most commonly utilized auxiliary materials. There are numerous sorts of glass fiber with distinctive substance compositions providing the particular physical properties. The glass fiber utilized as a part of this study has following properties as provided by the supplier.

Fig-2: Glass fibres

Table-7: Properties of Glass Fibers

Sl. No.	Properties of Glass fibers	
1	Length of Fiber (mm)	12
2	Diameter (µm)	20
3	Specific Gravity	2.68
4	Sofetening(%) point	3.6
5	Moisture	0.3% max
6	Tensile Strength (MPa)	1700

3.9 CONPLASTSP430

Conplast SP430 is a super plasticizing admixture. Conplast SP430 is a Sulphonated naphthalene polymer based admixture and is supplied as a brown fluid immediately assorted in water. Conplast SP430 has been manufactured to give high water reductions to 25% without loss of workability and produce high quality concrete of reduced permeability.

Table-8: Specifications of Conplast SP430

Properties	Result
Appearance	Brown liquid
Specific gravity	1.18 @ 22^0 C ± 2^0 C
Water soluble chloride	Nil
Alkali contents	Typically less than 55g Na_2O equivalent/litre of admixture

4. EXPERIMENTAL INVESTIGATIONS

4.1 Workability Test

This test was conducted for deciding the workability of cement. The measurement of the cone is shown in figure 5.1. The inside surface of the mould was cleaned before and put on even metal plate. The mould was held unbending while concrete is filling. The mould was filled in four layers. Each layer was stamped with tamping bar. The mould was separated from the concrete by pull up gradually. Slump was measured instantly by deciding the differentiation between the height of the mould and that of maximum point of the specimen being tested. The operation need to execute at a spot free from vibration and inside a time of two minutes after sampling.

4.2 Compressive Strength

Thistestwasconductedfordecidingthecompressivestrengthofconcrete.Theamount of cement aggregates, water and super plasticizer for every batch are weighed. Mixer machine is utilized for mixing the concrete. Coarse aggregates are initially poured into the drum. After that cement and fine aggregates are poured respectively. Mix the all materials for one minute in dry state. Then add required quantity of water into the drum. After uniform mixing, add super plasticizer into the drum. 150x150x150mm size of cube mould wasused.

Compressivestrengthtestsofthesecubesareconductedat7,28and56days.The test specimens are removed from water tank after curing period. Universal testing machine was used fortest.

Compressive Strength = P/A N/mm^2

where
P = Cube Compressive load causing failure in N
A = Cross sectional area of cube in mm^2

Fig-3: Compressive Strength Test

4.3 Split TensileStrength

The cylinder specimen of 150x300mm size are casted and cured for 7 and 28days. After curing period, specimen's are tested in compression testing machine by keeping the cylinder in longitudinal direction between the steel plates. The split tensile strength corresponding to failure of the specimen is calculated using the formula.

Split Tensile Strength = 2P/ πd*l*N/mm^2

Where
P is the load at failure in N.
D is the diameter of the specimen in mm
L is the length of the specimen in mm.

Fig-4: Split Tensile Strength

4.4 Flexural Strength

The flexural strength of concrete is determined by using 150x150x700mm beam. The test specimens are moulded and cured for 28 and 56days. After curing periods specimens are tested in UTM of 50 ton capacity under uniform load.

Flexural Strength = PL/bd^2 N/mm^2

Where
P is the load at failure in N.
L is the length of the specimen in mm.
b is the diameter of the specimen in mm.
d is the length of the specimen in mm.

Fig-5: Flexural Strength Test

4.5 Mix Design of M-30 Grade Concrete

Test data for Materials

a. Cement: Birla Super 53 grade
b. Specific gravity of cement:3.14
c. Chemical admixture: Super plasticizing confirming to IS9103
d. Specific gravity of CA:2.68
e. Specific gravity of FA:2.64
f. Water absorption of CA:0.36%
g. Water absorption of CA:1.05%
h. Water cement ratio:0.42
i. Free moisture (surface moisture) CA & FA:Nil
j. Sieve analysis CA confirming to Table 2 ofIS-383
k. FA confirming to Zone II ofIS-383

Determination of Target Mean Strength for Proportioning

$$f'_k = f_{ck} + 1.65s$$

Therefore, target strength = 30+1.65 x5 = 38.25 N/mm^2

Selection of water/cement ratio
Adopt water/cement ratio = 0.42

Water content for 100mm slump = 186+ (6/100) ×186 = 197.16 litres.

Reduction in water content with the usage of super plasticizer = 197x0.8 = 157.6liters

Calculation ofoCement Content
Water-cement ratio = 0.42

Cement content = 157.6/0.42 = 375.23 kg/m^3

Table 6.1: Mix Proportion Ratio

M30 Grade Conventional Concrete Mix Proportion	
Cement	375.23 kg/m^3
Water	157.6kg/m^3
FineAggregate	722.3kg/m^3
CoarseAggregate	1196.35kg/m^3
Chemical Admixture	3.009kg/m^3
Water Cement Ratio	0.42

MIX	**Mix proportions in kg/m^3**		**Wc ratio=0.42**		
	C	**MK**	**FA**	**WFS**	**CA**
CC	375.23	0	722.3	0	1196.35
S	318.95	56.28	722.3	0	1196.35
S1	318.95	56.28	686.19	36.11	1196.35
S2	318.95	56.28	650.07	72.23	1196.35
S3	318.95	56.28	613.97	108.33	1196.35
S4	318.95	56.28	577.86	144.44	1196.35
S5	318.95	56.28	541.75	180.55	1196.35

5. RESULTS AND DISCUSSIONS

5.1 Slump Test

Slump test was done for concrete with and without of metakaolin and waste foundry sand, with varying percentage of super plasticizer as shown in table below.

Mix	**Slump Value (mm)**
CC	105
S	101
S1	98
S2	94
S3	91
S4	88
S5	87

When 15% metakaolin was replaced with cement, the slump obtained was 101mm with 0.8% super plasticizer. This shows that the presence of metakaolin in concrete decrease the workability compared to CC. The results explain a continuous decrease in slump value of concrete by partial replacement of sand with waste foundry sand when compared with conventional concrete. Decrease in workability is caused due to presence offineparticlesintheWFS.SoasthepercentageofWFSincreasest hereisadecreasein workability.

5.2 Compressive Strength Test

CompressivestrengthofCCandconcretemixwithmetakaolinan dwastefoundry sand replacement were determined at 7, 28 and 56 days. The test results are shown below.

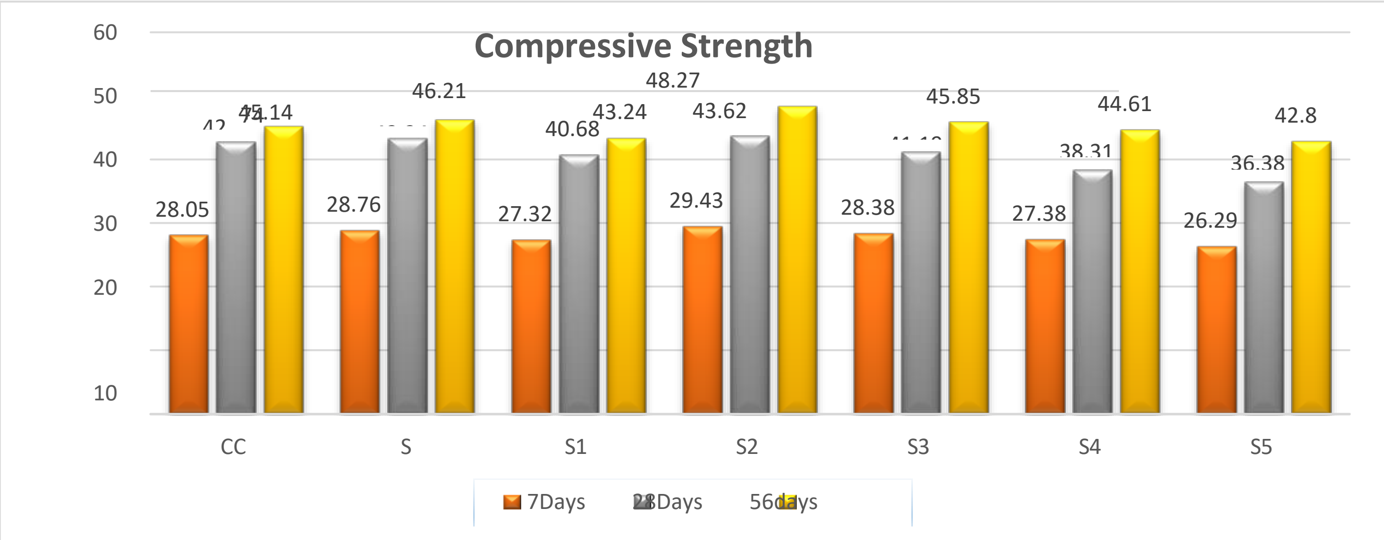
Mix	Load (P) kN	Area m^2	7D Compressive Strength N/mm^2	Average Compressive Strength N/mm^2
CC	632.5	22500	28.11	**28.0**
	626.5		27.84	
	634.5		28.20	
S	641.5	22500	28.51	**28.7**
	649.2		28.85	
	650.9		28.93	
S1	618.2	22500	27.47	**27.3**
	611.3		27.17	
	615.2		27.34	
S2	655.3	22500	29.12	**29.3**
	661.4		29.39	
	670.5		29.8	
S3	643.7	22500	28.06	**28.3**
	646.2		28.72	
	638.2		28.37	
S4	621.2	22500	27.60	**27.3**
	615.3		27.34	
	612.2		27.20	
S5	597.3	22500	26.54	**26.2**
	588.4		26.15	
	589.5		26.2	

Mix	Load (P) kN	Area mm^2	28D Compressive Strength N/mm^2	Average Compressive Strength N/mm^2
CC	962.5	22500	42.77	**42.7**
	964.8		42.88	
	958.2		42.58	
S	973.9	22500	43.28	**43.24**
	976.8		43.41	
	968.3		43.03	
S1	915.2	22500	40.67	**40.6**
	920.8		40.92	
	910.2		40.45	
S2	979.4	22500	43.52	**43.6**
	981.1		43.60	
	984.3		43.74	
S3	922.3	22500	40.99	**41.1**
	926.8		41.19	
	931.3		41.39	
S4	876.5	22500	38.95	**38.3**
	849.5		37.75	
	860.3		38.23	
S5	825.3	22500	36.68	**36.3**
	820.4		36.46	
	810.3		36.01	

Mix	Load (P) kN	56D Compressive Strength N/mm^2	Average Compressive Strength N/mm^2
CC	1015.3	45.12	**45.14**
	1011.8	44.96	
	1020.3	45.34	
S	1035.8	46.03	**46.21**
	1040.9	46.26	
	1042.8	46.34	
S1	973.8	43.24	**43.24**
	968.5	43.04	
	975.4	43.35	
S2	1077.8	47.90	**48.27**
	1092.5	48.55	
	1085.3	48.23	
	1025.8	45.59	

S3	1038.3	46.14	**45.85**
	1031.5	45.84	
S4	1003.8	44.61	**44.61**
	1009.5	44.86	
	998.5	44.37	
S5	968.9	43.06	**42.8**
	959.3	42.63	
	961.5	42.73	

The compressive strength of various mix proportion at different curing days are found out. The strength increases from 28.05 N/mm2 to 29.43 N/mm2 for 7 days, 42.74 N/mm2to43.62N/mm2for28daysand45.14N/mm2to48.27N/mm2for56days.Inthis investigation S2 (10% WFS) achieved maximum strength at all days of curing but it also replaceable up to 20% as the strength is more than the required strength. The strength obtained by S2 mix is 4.9%, 2.05% and 6.9% more than the CC. The addition of Metakaolinshowsasmallincrementinthestrength.Thewastefoundrysandcontainhigh percentage silica which forms good calcium silicate hydrate (C-S-H) gel. This gel increases the compressive strength of concrete. Reduction in compressive strength with the inclusion of WFS more than 20% could probably due to increase in surface area of fine particles led to the reduction the water cement gel in matrix.



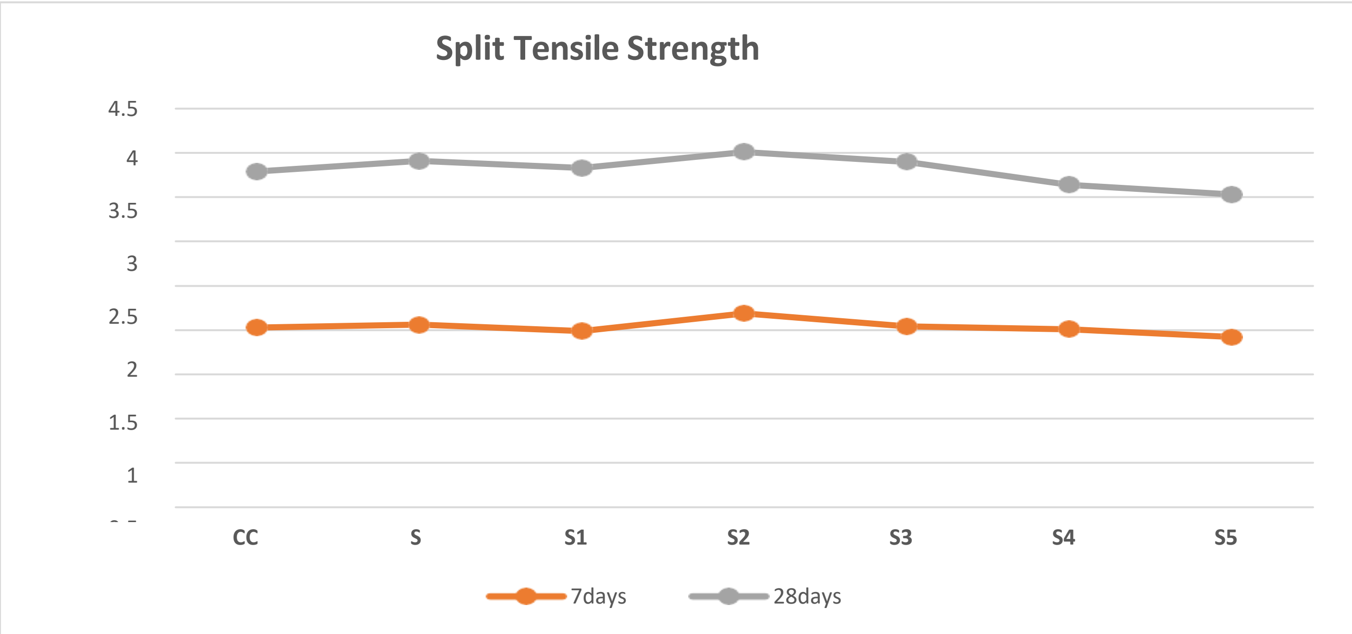
5.3 Split Tensile Strength

The test results of split tensile strength of M30 grade concrete in which cement replaced by metakaolin and fine aggregate by waste foundry sand are given in the tables below.

Mix	Load (P) kN	7D Split Tensile Strength N/mm2	Average Split Tensile Strength N/mm2
CC	140.8	1.99	**2.03**
	143.2	2.05	
	145.3	2.05	
S	141.8	2.00	**2.06**
	146.3	2.06	
	150.3	2.12	
	142.6	2.01	
S1	140.3	1.98	**1.99**
	141.8	2.00	
S2	152.6	2.15	**2.19**
	155.1	2.19	
	158.2	2.23	
S3	146.9	2.07	**2.04**
	143.1	2.02	
	144.8	2.04	
S4	141.5	2.00	**2.01**
	142.2	2.01	
	143.8	2.07	
	138.1	1.95	

S5	133.2	1.88	**1.92**
	136.5	1.93	

Mix	**Load (P) kN**	**28D Split Tensile Strength N/mm^2**	**Average Split Tensile Strength N/mm^2**
CC	265.3	3.75	**3.79**
	272.3	3.85	
	268.5	3.79	
S	280.3	3.96	**3.91**
	278.5	3.93	
	272.5	3.85	
S1	267.2	3.78	**3.83**
	271.9	3.84	
	275.5	3.89	
S2	286.5	4.05	**4.01**
	283.7	4.01	
	281.8	3.98	
S3	279.5	3.95	**3.90**
	277.6	3.92	
	270.9	3.83	
S4	261.3	3.69	**3.64**
	257.5	3.64	
	255.4	3.61	
S5	253.8	3.59	**3.53**
	248.7	3.51	
	246.8	3.49	



The split tensile strength for CC was obtained as 2.03 N/mm2 and 3.79 N/mm2 at 7 and 28days. An increment in strength was observed with the addition of metakaolin. The combination of metakaolin and waste foundry sand with glass fibres shows increase in strength compared to CC. Raise in strength while compared with CC was observed for both 7 and 28 days at 10% replacement of WFS. S2 mix gave split tensile strength of 7.8% and 5.8% more than CC. The reduction in strength was observed at 15%, but strength value was higher than CC.

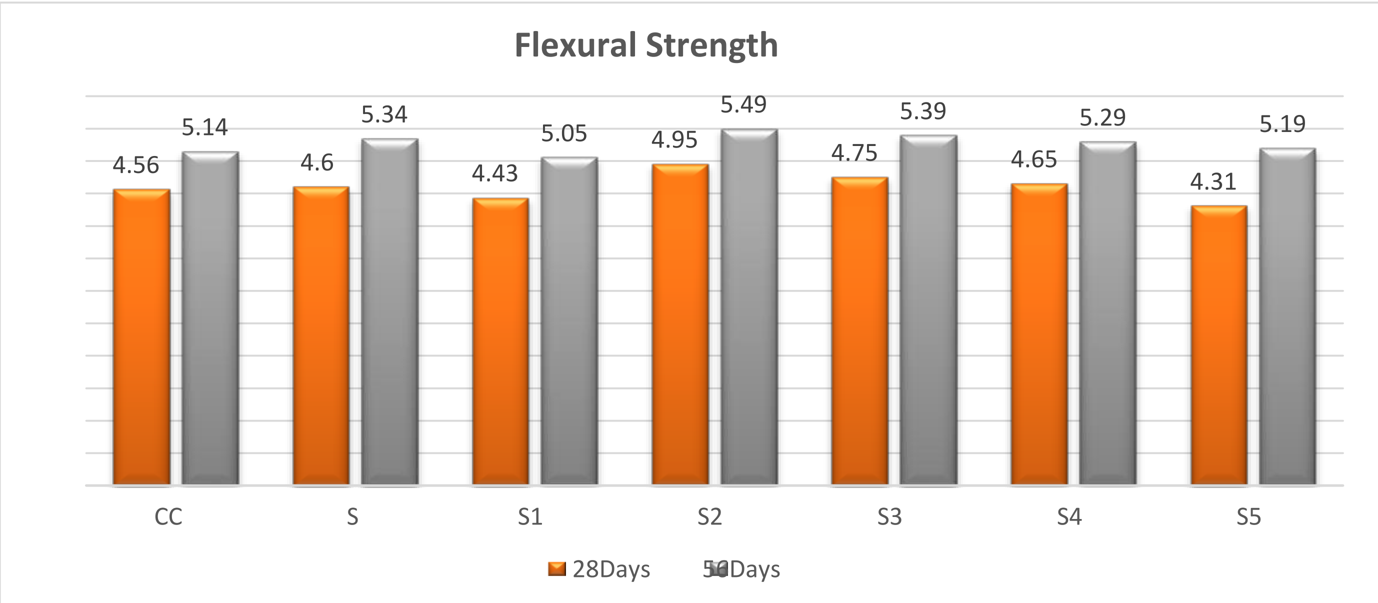
5.4 Flexural Strength Test

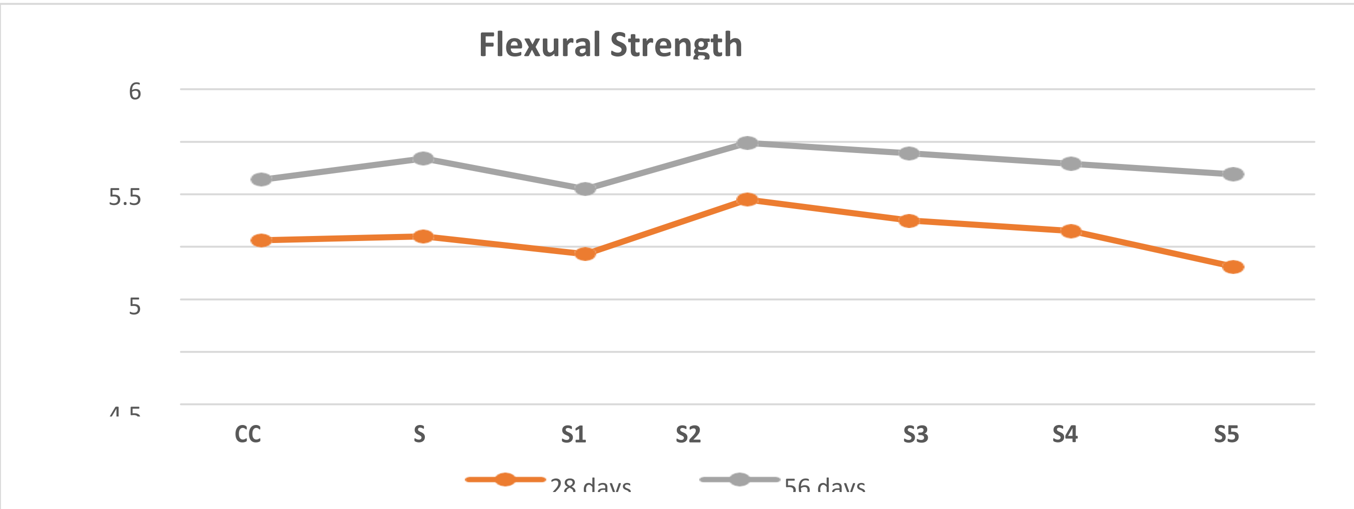
The flexural strength of M30 grade of concrete with and without metakaolin and waste foundry sand were found after 28 and 56days of water curing. The beam size 100mm x100mm x500mm was used for this investigation. The values are shown in table.

Mix	Experimental peak load in kN	Flexural Strength for 28 days (N/mm^2)
CC	9.12	4.56
S	9.21	4.60
S1	8.87	4.43
S2	9.90	4.95
S3	9.51	4.75
S4	9.31	4.65
S5	8.62	4.31

Flexural strength of concrete was tested at 28 and 56 days of curing. The concrete containing 0.5% glass fibers mixed with metakaolin and waste foundry sand in six proportions were compared with conventional concrete. A maximum strength value of 4.95 and 5.49 N/mm2 for both 28 and 56 days respectively was achieved at 10% replacement.S2mixgainedstrengthwhichis8.55%and6.8%morethanthatofCC.For all mixes, the strength obtained was higher than conventional concrete.

Mix	Peak load	56D Flexural Strength (N/mm^2)
CC	10.29 kN	5.14
S	10.68 kN	5.34
S1	10.10 kN	5.05
S2	10.98 kN	5.49
S3	10.78 kN	5.39
S4	10.59 kN	5.29
S5	10.39 kN	5.19





6. CONCLUSION

- The concrete formed using metakaolin as a replacement of cement is found to have high workability when compared to other mixes with WFS.
- The use of waste foundry sand as a substitute of fine aggregate gives low slump value as percentage of waste foundry sand increases. Therefore super plasticizer is used to maintain workability.
- Thecompressivestrengthvariesfrom28.05N/mm^{2}to29.43 N/mm^{2}for7days, 42.74 N/mm^2 to 43.62 N/mm^2 for 28 days and 45.14 N/mm^2 to 48.27 N/mm^2 for 56 days.
- Maximum compressive strength was observed for mix S2, 29.43 N/mm^2 for 7 days whichismorethanCC,43.62N/mm^{2}for28dayswhichismorethanCCand48.27 N/mm^2 for 56 days which is more than CC.
- The combination of metakaolin and waste foundry sand with various percentages shows a raise in split tensile strength when compared with CC it gives maximum strength 4.01 N/mm^2 for 28 days for S2 mix which is more than CC.
- A maximum flexural strength value of 5.49 N/mm^2 was achieved for S2 mix which is more than CC for 56days.
- The combination of metakaolin and waste foundry sand with glass fibres shown a rise in strength parameters and the highest strength was obtained at 10% replacement in all cases, although required strength was attained for 15% and 20% replacement also.
- Test result shows that 15% constant replacement of cement with metakaolin and 10% replacement level of fine aggregate with waste foundry sand, 0.5% of glass fibres by weight of cement gives satisfactory result.

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