Durability Properties of Glass Fiber Reinforced Concrete Made using Metakaolin and Waste Foundry Sand as Partial Ingredient

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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. Water absorption was less for 10% substitution WFS, metakaolin and glass fiber as the WFS content increases Water absorption increases. As the WFS content increases loss in strength due to acid attack increases, but 10% substitution of WFS showed less loss in strength. However WFS can be replaceable up to 20% because it gave strength that is comparatively higher than CC.**

Key Words- Metakaolin, Waste foundry sand, Glass fibers, M30 Grade concrete, Durability properties

I. 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.

A. 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.

B. 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 of kaolin, 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.

C. *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 haspropertiesnotquitethesameasthoseof un-reinforcedconcrete.Theextentofthis variety depends on the type of fibers, as well as on the dosage offiber.

II. OBJECTIVES AND METHODOLOGY

A. *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%) with FA.
3. The durability properties such as
   - ✓ Water absorption test.
   - ✓ Acid Resistant test.
4. Nondestructive test such as
   - ✓ Rebound hammer test.
   - ✓ Ultrasonic Pulse Velocity Test.
5. To compare test results of produced concrete with conventional concrete.
6. To draw down the conclusions based on the test results.

B. *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.
3. By utilizing 150mm x 150mm x 150mm specimen cubes, the durability properties such as water absorption and acid resistance is conducted.
4. Rebound hammer test and UPV test are conducted to determine the surface hardness and uniformity of concrete for 28 days by using 150x150x150 mm cubes.
5. From the outcomes of test carried out charts and tables are prepared.
6. From the outcomes conclusions are made.

III. MATERIALS PROPERTIES

A. 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.

B. 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

C. *Fine Aggregates: Natural Sand*

Locally available river sand is used as FA. The various tests are conducted on fineaggregateandtheresultsobtainedaretabulatedbelo w.Thetestsareconductedasper 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.

D. *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%

E.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.

E. 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

F. 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

G. 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

H. 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.

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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

IV. EXPERIMENTAL INVESTIGATIONS

A. Mix Proportions

Concrete mix design is preferred to conventional mix proportion. The mix design is carried out as per IS 10262:2009 and IS 456-2000 method.

Mix Design of M-30Grade 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 IS 9103
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 of IS-383
k. FA confirming to Zone II of IS-383

Determination of Target Mean Strength for Proportioning
$f'_{ck} = f_{ck} + 1.65s$
Therefore, target strength = 30+1.65 x5 = 38.25 N/mm^2
Selection of water/cement ratio
Adopt water/cement ratio = 0.42
Selection of water content
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 of Cement Content
Water-cement ratio = 0.42
Cement content = 157.6/0.42 = 375.23 kg/m^3
375.23> 320 kg/m^3. Hence ok

Proportion of Volume of CA and FA Content
Volumeof CA = 0.62 = 0.62
Volumeof FA = 1 - 0.62 = 0.38

Mix calculation
a. Volume of concrete = 1 m^3
b. Volume of cement = (Mass of Cement /Specific Gravity) x (1/1000)
= (376.23/3.14) x (1/1000)
= 0.119 m^3
c. Volume of water = (157.6/1) x (1/1000)
= 0.158 m^3
d. Volume of S.P at 0.8% by mass of cementitious material
= (3.009/1.18) x (1/1000)
= 0.0025 m^3
e. Volume of all in aggregate = [a - (b + c + d)]
= 1-(0.119+0.158+0.0025)
= 0.72 m^3
f. Mass of CA = (e x volume of CA x specific gravity×1000)
= 0.72 x 0.62 x 2.68 x 1000
= 1196.3 kg
g. Mass of FA = 0.72 x 0.38 x 2.64 x 1000 = 722.3kg

Table-9 : Mix Proportion Ratio

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

Table-10: Concrete Mix Design Proportion

MIX	Mix proportions in kg/m^3, w/c ratio=0.42, SP=0.8, GF=0.5				
	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

CC: Conventional Concrete.
S: 15% Metakaolin + 0% Waste Foundry Sand.
S1: 15% Metakaolin + 5% Waste Foundry Sand + 0.5% of Glass Fibers.
S2: 15% Metakaolin + 10% Waste Foundry Sand + 0.5% of Glass Fibers.
S3: 15% Metakaolin + 15% Waste Foundry Sand + 0.5% of Glass Fibers.
S4: 15% Metakaolin + 20% Waste Foundry Sand + 0.5% of Glass Fibers.
S5: 15% Metakaolin + 25% Waste Foundry Sand + 0.5% of Glass Fibers.

Durability Test

B. Water Absorption Test

Water absorption test is conducted on 150mmx150mmx150mm cube specimen at 28 days. The cube was kept in oven at 105^{0}C. After curing the cube is taken out and weighed (W_2). After 24 hrs, the cube is removed from oven and weighed (W_1).

Water Absorption in % = [(W_2-W_1)/W_1] x 100

C. Acid Resistance Test

Cubes of sizes 150mmx150mmx150mm were cast and cured at 28 days. The cubes are allowed to dry for 24 hours and weights are taken (W_1).For acid attack 5% dilute hydro chloric acid is utilized. The cubes are dipped in acid solution for a session of 30 days. The concentration is to be maintained throughout this period. After 30 days, the cubes are taken from acid solution. The surface of cubes are cleaned and weighed. The cubes are then tested in the compression testing machine under a uniform loading. The weight loss and strength of cubes due to acid attack are determined.

Loss in Weight = [(W_1-W_2)/W_1]

Non Destructive Test

D. Rebound Hammer Test

Hold the rebound hammer instrument properly such that the plunger is in perpendicular direction to the surface of the specimen. Slowly push it on the surface of the specimen until hammer impact. Press the side button of the instruments after impact, to lock the plunger at present position. Note down the rebound hammer number on graduated scale.

Fig-3: Rebound Hammer Test

E. Ultrasonic Pulse Velocity Test

The experiment measure the strength of concrete from pulse velocity passing through the concrete specimen which is to be measured. The instrument consists of vibration frequencies of 54 kHz. The travelling time between beginning onset and the receiving of the pulse is measure electrically. The distance between transducer by travelling time of pulse gives the average speed of wave propagation. Presently, battery operated completely portable digitalized units have become accessible in U.K. According to IS: 13311-Part 1, velocity criteria were concrete quality grading is given in table 5.1.

Table -11: Ultrasonic Pulse Velocity

Sl, NO.	Pulse Velocity by cross-probing, km/sec	Concrete Quality Grading
1	Above 4.5	Excellent
2	3.5 to 4.5	Good
3	3.0 to 3.5	Medium
4	Below 3.0	Unsure

Fig-4: Ultrasonic Pulse Velocity Test

V. RESULTS AND DISCUSSIONS

A. Water Absorption Test

The water absorption of concrete cube was tested at 28 days of curing. The concrete specimens are mixed with metakaolin and WFS at different mix proportions. The results are shown in table below.

Table-12: Water Absorption of Concrete for 28 days

Mix	Average Water Absorption (%)
CC	1.8
S	1.59
S1	1.67
S2	1.75
S3	2.12
S4	2.54
S5	2.67

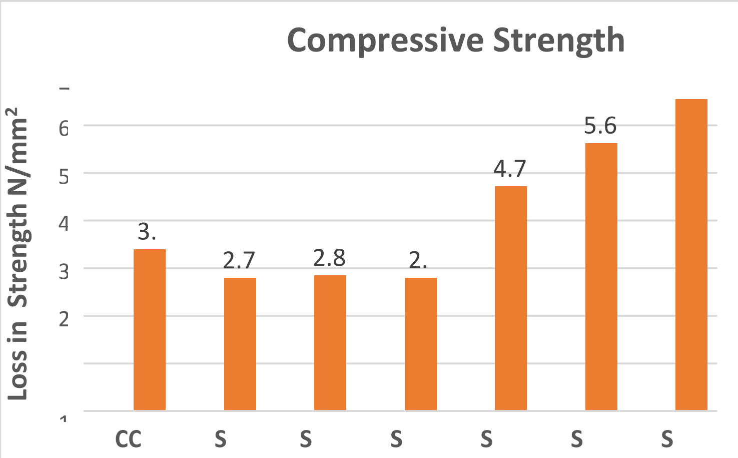
The metakaolin –WFS concrete with 0.5% glass fibers was found to have lesser water absorptions when compared to conventional concrete up to10% replacement level. It was observed that as the percentage of WFS increases, the water absorption increases.

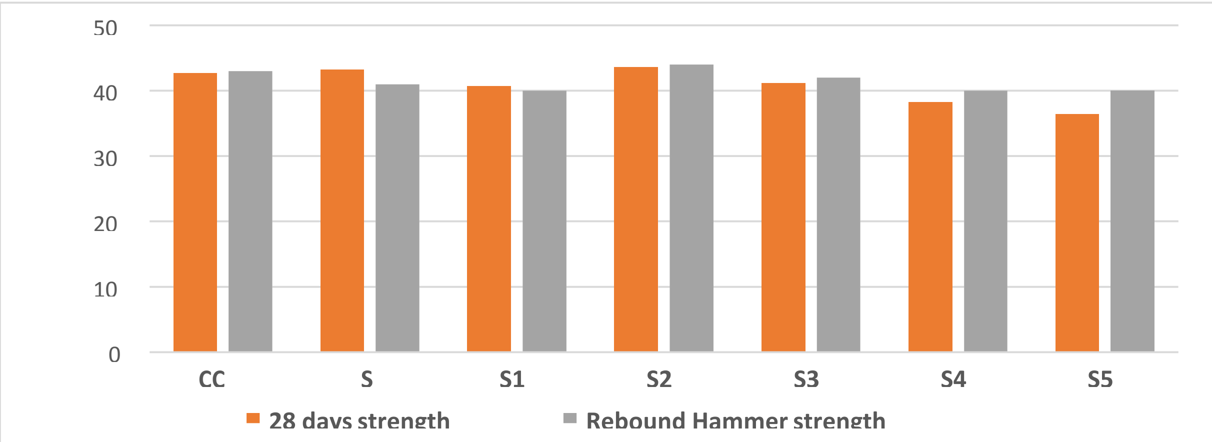
B. Acid Resistance Test

Acid test were conducted by 150mm cube specimens with the concrete containing metakaolin-waste foundry sand with 0.5% glass fibers and values were compared with the conventional concrete.

Table-13: Acid resistance of concrete for 30days

Mix	Weight (kgs) Actual	Weight (kgs) Reduced	Wt. Loss (g)	Compression Strength (N/mm²) Actual	Reduced	Strength Loss
CC	8.475	8.390	85	42.74	39.34	3.4
S	8.545	8.475	70	43.24	40.45	2.79
S1	8.360	8.315	45	40.68	37.83	2.85
S2	8.460	8.415	45	43.62	40.82	2.80
S3	8.550	8.495	55	41.19	36.47	4.72
S4	8.600	8.540	60	38.31	32.68	5.63
S5	8.410	8.335	75	36.38	29.83	6.55





Graph-1: Acid Resistance of Concrete for 30 days in HCl

The loss in weight and strength of concrete cube specimen in hydro chloric acid were found for all variations. The table 7.10 with graph 7.9 shows a better cause on acid resistance with the inclusion of metakaolin and waste foundry sand concrete. But still there is a considerable loss in compressive strength. This is due to the high dehydration rate in HCl. Mixes S, S1, S2 gave god resistance for acid attack compared to mixes S3, S4, S5 and CC. As the minimum loss in strength of 2.79 N/mm2 and 2.80 N/mm2 for mixes S and S2.

Non Destructive Test

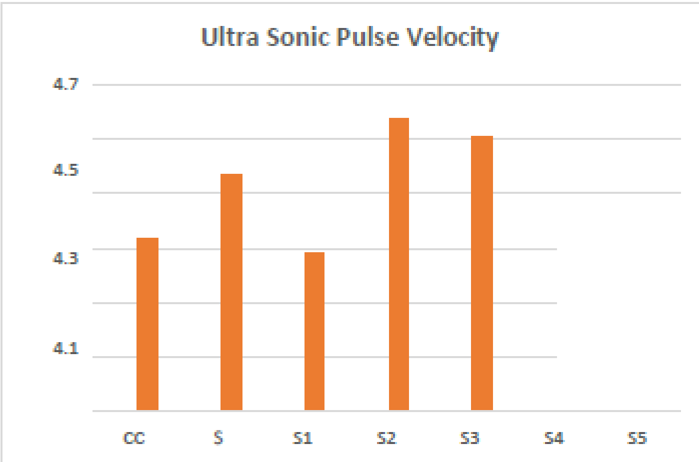
C. Rebound Hammer Test

The results of rebound hammer test on M30 grade of concrete was determined at 28 days are shown in Table below.

Table-14: Rebound Number for 28 days

Sl. No.	Mix	Rebound Number	Average Compressive strength in N/mm2
1	CC	35	43
2	S	34	41
3	S1	31	40
4	S2	37	44
5	S3	33	42
6	S4	32	40
7	S5	32	40

The increase in rebound number with percentage replacement of waste foundry sand shows a better surface hardness for glass fiber reinforced concrete with metakaolin- waste foundry sand concrete when compared with conventional concrete. The maximum rebound number is obtained for 10%replacement level.



Graph 2: Rebound Number at 28 days

D. Ultrasonic Pulse Velocity test

Graph-3: Ultrasonic Pulse Velocity at 28 days

Ultrasonic Pulse velocity valves shows quality in concrete. It was found that Pulse velocity values show a better uniformity in concrete made with metakaolin – waste foundry sand and 0.5% glass fibers when compared to conventional concrete.

This test of M30 grade of concrete was determined at 28 days results are shown in Table below.

Table-15: Ultrasonic Pulse Velocity Test at 28 days

Sl. No.	Mix	Ultrasonic Pulse Velocity (km/sec)	Concrete quality grading as per IS: 13311- Part 1
1	CC	4.130	GOOD
2	S	4.370	GOOD
3	S1	4.080	GOOD
4	S2	4.570	EXCELLENT
5	S3	4.510	EXCELLENT
6	S4	4.150	GOOD
7	S5	4.050	GOOD

VI. CONCLUSIONS

i. The concrete formed using metakaolin as a replacement of cement is found to have high workability when compared to other mixes with WFS.

ii. 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.

iii. Water absorption found to increase with increase in waste foundry sand contents.

iv. A considerable loss in compressive strength is found on the cubes immersed in HCl.

v. The increase in rebound number with percentage replacement of waste foundry sand shows a better surface hardness for metakaolin – waste foundry sand concrete when compared with CC.

vi. Pulse velocity values show a better uniformity in metakaolin – waste foundry sand concrete.

vii. 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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