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STUDY ON EFFECT OF INDUSTRIAL WASTES IN MECHANICAL PROPERTIES OF STEEL FIBER REINFORCED CONCRETE

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Abstract: The porous concrete matrix is greatly strengthened when reinforced with steel fibres that are divided equally throughout its whole mass, causing the matrix to behave drastically differently from traditional concrete with regard to its qualities. Owing of the significant benefits brought about by incorporating fibres to concrete, Fibres Reinforced Concrete (FRC) may be used wisely and advantageously in several applications. In India, these fibres have been utilized in the past employed in several sizable projects for the building of highway overlays, pavements, industrial floors, etc.

The experimental findings, concrete with SFRC with metakaolin and glass powder admixtures were the main focus of this study. In this project, concrete M30 quality with SFRC percentages of volumes 1%, 2%, 3%, 4%, 5% and 6% was utilized. Cement and fine aggregate were also substituted with kaolinite and glass powder in amounts of 5 percent, 10 percent, 15 percent, 20percent, 25 percent & 30 percent. The water to cement ratio should be

0.38. For the purposes of this project, 63 cubes, 63 cylinders, and 63 beams were cast with the aforementioned percentage of steel fibre, metakaolin & glass powder and they were put through compression, flexural and tensile tests. The result is evaluated against conventional concrete.

The compressive, flexural & split tensile loads of concrete at a water-cement ratio of 0.38 very slightly increased when steel fibres were employed. Steel fibres can therefore be utilized to prevent concrete cracks and drying shrinkage.

Index Terms – Industrial Wastes, Metakaolin, Glass Powder, Steel fibers.

1. Introduction

The most typical material used in civil engineering constructions is concrete. Tocreate high-quality concrete, several categories of materials are needed. Concrete is comprised concrete, fine aggregate, rough aggregate, mineral admixtures, chemical admixtures, and water. Since it holds the aggregates together and resists air action, the biggest factor is cement component ingredient. However, for every tonne of cement produced, roughly 0.8 tons of CO_2 are released into the environment.

1.1 Need for the Present Study

1. Due to fibre bridging processes that bridge the fracture surface, SFRC is a structural material that exhibits high residual tensile strength in the post-cracking zone and improved capacity to absorb strain energy.
2. SFRC is utilised in buildings including flooring, housing, precast, bridges, tunnelling, heavy duty pavement, and mining for improving long-term behaviour, boosting strength, toughness and stress resistance.

2. LITERATURE REVIEW

Naser Kabashi. et. al., [1] (2018) examined the impact of various polypropylene and fibers of steel percentages on the beam strength of concrete. During this test, steel and polypropylene fibres were employed to reinforce concrete specimens, and the outcomes were compared without fibre addition, with steel fibre in 0.5%, 1%, and with polypropylene fibre in 0.025%, 0.05%, concrete specimens are prepared. The fracture force increased by 9.6% for 1% more steel fibre, even if there weren't much advancement in brittle failure. Because the longevity of the wires was too short, raising the rigid strength by 0.050% of polypropylene had no effect on brittle failure, and they advise adopting longer fibres, preferably ones that are approximately 40mm in length, to increase ductility.

T. Mythili. et. al., [2] (2017) investigated the characteristics of M40 grade concrete with 5%, 10% & 15% to 50% via mass binder replacement Glass powder particles used as cement, fine aggregate, and coarse aggregate, respectively, range in size from less than 10, 4.75 mm to 0.15 mm, and 12 mm to 4.75 mm. In order to produce concrete with an appropriate range of strengths, his paper recommends replacing fine and coarse aggregate by 50% and cement by 30% glass powder.

Narmatha. M. et. al., [3] (2017) presented the findings the outcome of the experiment of substituting 5%, 10%, 15% & 20% metakaolin for cement. As said by them research, altering cement with more metakaolin boosted tensile and crushing value up to 15%.

Anwar A. et. al., [4] (2016) investigated the qualities of concrete of grade M40 with binder replacements of 5%, 10% and 15% to 50% by mass. The strongest material discovered to be 10% substituted, which would increase computing force by 17%, breakdown strength by 8% and rupture modulus by 7%. substitution of cement & F.A by glass powder in concrete.

Dinakar. et. al., [6] (2013) conducted explore the replacement of metakolin in various percentages to the mass of cement for concrete of grade M20 revealed that 10% replacement of metakolin produces the greatest tensile strength & compressive strength togenerate high performance together with high-strength concrete.

Ms. Shrawasti. D. Kamble. et. al.,[7] (2019) Conducted the experimental research of fiber-reinforced cement concrete employing M-sand in addition to metakaolin is described in this work. In the current study, an experimental inquiry was conducted utilising M60 mix with metakaolin additions of 5%–25% and crimped steel fibre additions of 2%–10%, with an 85 aspect ratio. Additionally, the consequence of FRMCon fresh concrete's workability, temperature, dry density & compression force was investigated.

3. OBJECTIVES AND METHODOLOGY

3.1 Objectives

1) To collect the materials and analyse basic properties.
2) Mix design of concrete of the M30 grade by using IS 10262: 2019
3) Workability for fresh concrete by using slump cone test method.
4) Test on hardened particular features such as Compressive strength, Flexural Strengthand Splitting Tensile Strength test.
5) To determine the water absorption of concrete.
6) Investigate concrete's hardening characteristics with glass bottle powder incorporated as a fine aggregate replacement and metakaolin utilized as a cement replacement.
7) To find out the optimum amount of replacement in percentage of glass powder and metakaolin in concrete.

3.2 Methodology

The methodology has been adopted to test the hardened characteristics of concrete incorporated with metakaloin and bottle glass powder. The study work includes following procedure. The M30 grade was prepared by using as per IS 10262-2009 codal provisions. The concrete mixes prepared varying the amount metakaloin and bottle glass powder of different percentage by volume in additive to concrete. The prepared mixes studied for hardened properties.

The methodology of this experimental work is represented in below.

- Collection of materials
- conducting preliminary tests on materials
- Mix design for concrete of grade M30 in accordance with IS 10262:2019
- Calculating quantity of materials for cubes, cylinders, beams
- Casting a specimens and placing for curing at 7days and 28days
- Workability of fresh concrete by slump test.
- Testing of specimens
    - Workability test.
    - Compressive strength test.
    - Split tensile strength test
    - Flexural strength test.
    - Water absorption test.
- Results
- Conclusions

4. MATERIAL CHARACTERIZATION

4.1 Materials Used for Conventional Concrete

Materials used for conventional concrete are:

- Cement
- Aggregate
    - ✓ Fine aggregate
    - ✓ Coarse aggregate
- Water
- Superplasticizers

4.2 Metakaolin

A by-product is not metakaolin. It is made by calcining pure or refined Kaolinite clay between 650^0C and 850^0C, then grinding the resulting material to a finesse of 700- 900 m^2/kg. Subsequently serves as a top-notch pozzolonic substance that is blended with cement to raise the resilience of concrete. It will cover the gaps between cement particles when applied in concrete, making it more impermeable.

Fig. 4.1: Metakaolin

Table 4.1: Physical Properties of Metakaolin

Sl No.	Properties	Values
1	Specific gravity	2.55
2	Color	Off white, Gray to Buff
3	Physical Form	Powder
4	Fineness	10000 m^2/kg

Table 4.2: Chemical Properties of Metakaolin

Sl No.	Chemical properties	Mass %
1	Silica (SiO_2)	51.5
2	Al_2O_3	42.05
3	CaO	18
4	Fe_2O_3	2
5	SO_4	0.3
6	K_2O	35

4.3 Glass Powder

Glass is a very clear substance created by melting a silica, soda, ash, and CaCO3 mixture at a huge temperature, then cooling the molten mixture to solidify without crystallisation. Glass is a widely used material that comes in several different shapes and sizes, including bottles, jars, windows and windscreens, bulbs, cathode ray tubes, etc. However, as a result of not biodegradable, disposing of solid trash becomes problematic.

Fig. 4.2: Glass Powder

Table 4.3: Physical Properties of Glass Powder

Sl No.	Properties	Values
1	Specific gravity	2.58
2	Color	Grayish white
3	Physical Form	Powder
4	Fineness	300µ

Table 4.4: Chemical Properties of Glass Powder

Sl No.	Chemical properties	Mass %
1	Silica (SiO_2)	70
2	Al_2O_3	3.00
3	CaO	10
4	Fe_2O_3	1.05
6	K_2O	0.8

5. RESULTS AND DISCUSSIONS

5.1 Compressive Strength Test

Compressive force strength is a material's or a structure's capacity to support loads placed on its surface without cracking or deflection. When a substance is in tension, its size elongates while it is in compression size reduces.

Table 5.1: Compressive Strength at 7, 14 and 28 days.

Mix	Metakaoli (%)	Glass Powder (%)	Steel Fiber (%)	Average Compression Strength (N/mm²) 7 Days	Average Compression Strength (N/mm²) 14 Days	Average Compression Strength (N/mm²) 28 Days
M0	0	0	0	34.46	39.97	43.06
M1	5	5	1	36.13	40.53	43.19
M2	10	10	1	38.48	41.43	43.50
M3	15	15	1	39.99	42.28	44.52
M4	20	20	1	40.41	43.09	45.10
M5	25	25	1	40.21	42.53	44.68
M6	30	30	1	39.97	42.09	44.34

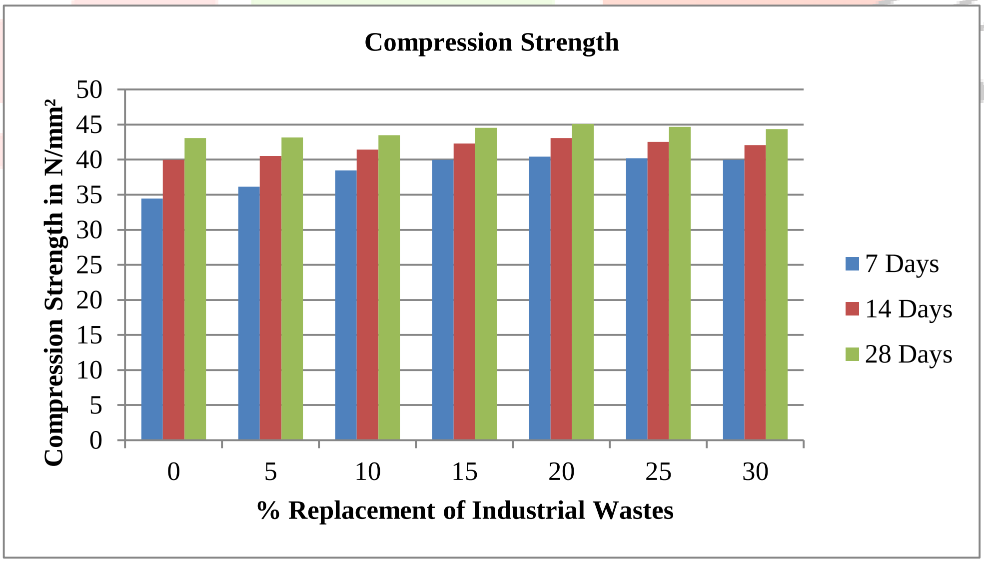

Fig. 5.1 : Compressive Strength of Concrete

On 7, 14 & 28 days, the crushing strength of M4 mix was found to be 40.41N/mm^2, 43.09 N/mm^2 and 45.10 N/mm^2 respectively. In contrast, the crushing strength of M5 mix has been declining recently, with values of 40.21 N/mm^2, 42.53 N/mm^2 and 44.34 N/mm^2.

From study its observed that, the compressive strength is continued to increase with replacement of industrial wastes upto 20% along with 1% constant steel fibers. Behind 20%, the compressive strength starts to drop.

When 20% cement content was swapped out for metakaolin and the fine aggregate with glass powder, the crushing load of the exmpler increased by 5% over the course of 28 days. With a rise in the proportion of metakaolin and glass powder behind 20%, discernible decrease in crush strength was absorbed.

5.2 Flexural Strength Test

Flexural bending strength tests in compliance with IS 516: 1959 tests on M30 grade concrete produced with and without industrial wastes such as metakaoline, glass powder and steel fibre of w/c ratio 0.38. Flexural strength increased when industrial wastes were included to the normal mix at levels of 7 days, 14 days and 28 days, up to 30%.

Table 5.2: Flexural Strength at 7, 14 and 28 days.

Mix	Metakaolin (%)	Glass Powder (%)	Steel Fiber (%)	Average Flexural Strength (N/mm²) 7 Days	Average Flexural Strength (N/mm²) 14 Days	Average Flexural Strength (N/mm²) 28 Days
M0	0	0	0	5.01	5.18	5.41
M1	5	5	1	5.27	5.38	5.45
M2	10	10	1	5.67	5.78	5.87
M3	15	15	1	5.91	6.77	6.84
M4	20	20	1	7.06	8.06	8.80
M5	25	25	1	6.55	7.36	7.75
M6	30	30	1	6.00	6.89	7.14

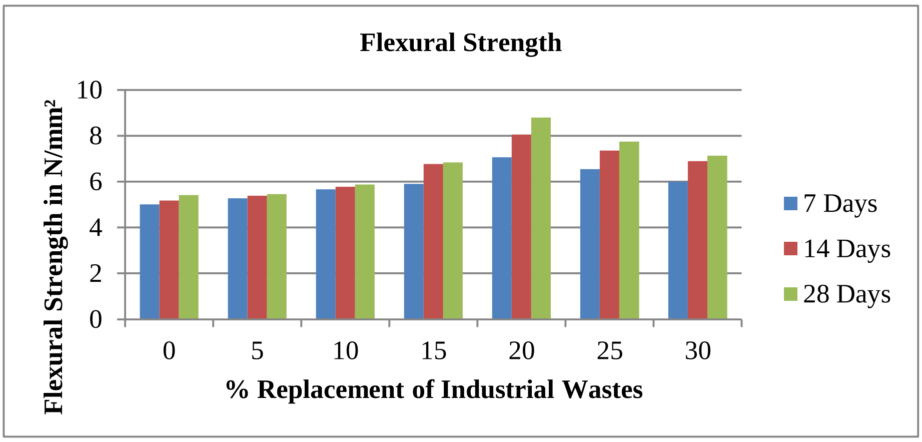

Fig. 5.2 : Flexural Strength Test of Concrete

The flexural test setup is shown in Fig 7.2 illustrates the fluctuation in bending strength results for 7, 14 & 28 days with cement replacement by metakoalin & F.A replacement by glass powder. It is evident that, over the course of 28 days, the beam strength of concrete that had 20% of the cement replaced with metakoalin & F.A. replaced with glass powder increases over control concrete. Flexural strength begins to deteriorate with a replacement rate of 25% for industrial waste.

Flexural strength at 28 days with 20% replacement was 8.80 N/mm^2, while 7.75 N/mm^2 was obtained with 25% replacement.

5.3 Split Tensile Test

On concrete of the M30 grade, both with and without industrial wastes such metakaoline, glass powder, and steel fibre of a water-to-cement ratio 0.38, splitting tensile strength tests were performed in accordance with IS 5816:1999 standards. Industrial wastes injected at levels of 7 days, 14 days and 28 days enhanced the tensile stiffness strength by up to 30%.

Table 5.3: Split Tensile Strength at 7, 14 and 28 days.

Mix	Metakaolin (%)	Glass Powder (%)	Steel Fiber (%)	Average Flexural Strength (N/mm²) 7 Days	Average Flexural Strength (N/mm²) 14 Days	Average Flexural Strength (N/mm²) 28 Days
M0	0	0	0	1.60	2.14	3.17
M1	5	5	1	1.65	2.28	3.20
M2	10	10	1	1.66	2.36	3.24
M3	15	15	1	1.70	2.49	3.33
M4	20	20	1	1.92	2.69	3.61
M5	25	25	1	1.90	2.65	3.55
M6	30	30	1	1.79	2.51	3.43

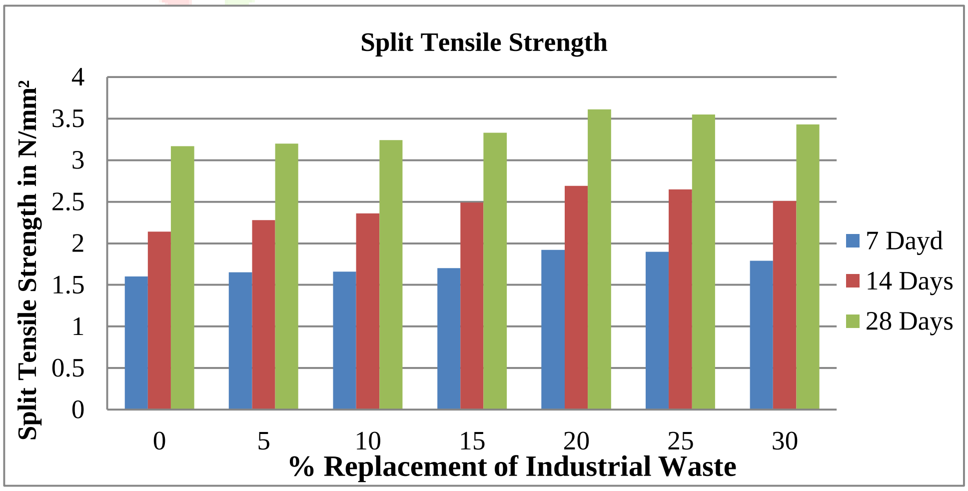

Fig. 5.3 : Flexural Strength Test of Concrete

The tensile strength result exhibits greater values than typical concrete at this time, with M4 following the same pattern as compressive strength. At 25% replacement, the tensile strength starts to decline. Tensile strength was determined to be 3.61 N/mm^2 with a replacement rate of 20%, however it dropped to 3.55 N/mm^2 at a replacement rate of 25%.

When 20% of the substitute for cement and fine aggregate is metakaolin and glass powderrespectively, the split tensile stress is found to improve by 14%.

6. CONCLUSIONS AND SCOPE OF FUTURE WORK

6.1 Conclusions

Consequently, the present experimental investigations the outcomes are as follows.

1. Workability declines as steel fibre and metakaolin are added to concrete mixtures at higher percentages.
2. Upto 20% replacement of metakoline and glass powder along with 1% constantreplacement of steel fibers, the compressive strength increases.
3. When 20% cement content was swapped out for metakaolin and the fine aggregate with glass powder, the crushing load of the exmpler increased by 5% over the course of 28 days. With a rise in the proportion of metakaolin and glass powder behind 20%, a discernible decrease in crush strength was absorbed.
4. Flexural strength improves when the metakaoline and glass powder replaced to 20% along with 1% of steel fibers.
5. The replacement of metakaolin and glass powder along with 1% of steel fiber increases the flexure strength about 60% than the conventional concrete.
6. In the flexural zone, beam failure occurred. When steel fibre is used instead of regular steel, the crack's breadth is less.
7. The substitution of industrial wastes upto 20% boosts the split tensile strength. Beyond 20%, the tensile strength begins to fall.
8. When 20% of the substitute for cement and fine aggregate is metakaolin and glass powder respectively, the split tensile stress is found to improve by 14%.
9. There is a systematic reduction in water absorption by capillary action with increase in metakaolin content in concrete.
10. The pozzolanic reaction between metakaolin and calcium hydroxide produces calciumsilica hydrate along with the formation of Friedel‟s salts, which resulted in improved compressive, flexural and tensile strength.

11. The compressive, flexural & split tensile loads of concrete at a water-cement ratio of

0.38 very slightly increased when steel fibres were employed. Steel fibres can therefore be utilised to prevent concrete cracks and drying shrinkage.

6.2 Future Scope of Studies

1. Metakaolin and glass powder are examples of industrial waste that reinforce concrete by up to 20% replacement.
2. We can try these experiments for other industrial wastes also.
3. This study can be employed on M-50, M-60 and other higher grades of concrete.
4. Using metakaolin and glass powder, we can try for durability properties of concrete such as shrinkage, resistance to weathering actions etc.,
5. Thus, our proposal asserts that the utilization of metakaoline and glass powder can strengthen concrete, turning industrial by products into something valuable. The employment of additional cementitious materials, such as matakaolin, can offset the negative effects that cement manufacture has on the economy and the environment.

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