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Effect of Waste Foundry Sand, Waste Glass, and Glass Fiber on Mechanical Properties of Concrete

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Abstract- *The proposed study present behaviour of concrete with inclusion of waste foundry sand (WFS), waste glass, and glass fiber in different concrete trial mixes. Waste foundry sand (WFS) is basically by-product formed from metal casting industries ferrous or non-ferrous, which due to rapid concrete construction in world used as an alternative of sand. Waste glass can be used in concrete in crushed form as a replacement of aggregate or in powdered form as a replacement of cement, the only problem with waste glass is it is prone to alkali-silica reaction due to different composition of different types of glasses. Glass fiber is added with waste glass and waste foundry sand (WFS) to increase strength. Normal concrete grade M25 (1:1:2) is used for this experimental purpose, different concrete trials were casted which consist of replacement of sand with waste foundry sand in different proportion (0%, 10%, 20%, and 30%). Next trial consists of optimum value of (WFS) with different proportion of waste glass (0%, 10%, and 20%, 30%) as a replacement of fine aggregate. Final trial consists of addition of glass fiber (0%, 0.25%, 0.50%, and 0.75%) in optimum value of second trial. Mechanical properties of concrete compressive strength, split-tensile strength, flexural strength was examined at 7, 14, 28, and 56 days curing period.*

Keywords: *waste foundry sand (WFS), waste glass, glass fiber, alkali-silica reaction*

I. INTRODUCTION

Concrete is composite man-made materials and is widely used building material for construction purposes, it is a mixture cement sand and aggregate and admixture sometime. With rapid construction going on at very fast pace in the world we need to look for alternative of these materials which can partially replace or fully replaced these materials to some extent and have same or better strength. Waste foundry sand is generally waste produced by casting industries, all casting industries reuses sand many times for core making and moulds making process when sand cannot be reused by industries it is termed as waste foundry sand (WFS). Waste glass which is usually dispose in landfill can be used as an alternative of aggregate and cement in concrete in crushed form or powdered form, concrete made with waste glass have strength greater than conventional concrete only problem arises that it gives rise to alkali-silica reaction which will deteriorate concrete in hardened state.

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Both these material waste foundry sand (WFS) and waste glass are waste and dispose in landfill as both these materials are non-biodegradable, they will be hazardous to environment, both these materials can be used in making good concrete. Glass fiber due to its light weight is best reinforcement provided for concrete durability.

A. Waste foundry sand (WFS)

Around 5000 foundry unit in India which produce more than 7.5 million tonnes per annum foundry sand, in 2018 production was high more than 11 million tonnes WFS was produces. With ongoing development in India, it is estimated foundry industries produce more than 13.08 billion tonnes during period of 2020-2023. Waste foundry sand is by-product of ferrous and non-ferrous metal casting industries. Foundries effectively reuse and use sand ordinarily in a foundry when the sand can never again be utilized in the foundry, it is discarded from the foundry and is named as waste foundry sand. Colour wise WFS is in black colour and is finer than sand. WFS is classified on the basis of binder and binder system, mostly two types are there.

- Clay bonded sand
- Chemically bonded sand

B. Waste glass

In India only 45% of waste glass is recycled and 55% are dispose in landfill. Waste glass is result of supercooling blend containing sand (silicon dioxide) and soda ash (sodium carbonate) procedure of supercooled material does not permit to solidify and hold interior structure of liquefied fluid. Many types of glasses are there but mostly used type of glasses are soda-lime, lead, boro-silicates, barium they are used in production of sheets, container. Composition of soda lime glass is around 70% SiO_2, 15% Na_2, and 12 % CaO, it will make it pozzolanic cementitious material.

C. Glass fiber

A glass fiber or fiberglass consisting of number of very high fibers of glass or it is a type of fiber where reinforcement is specially glass fiber. The basic component of glass fiber is silica. According to the need of the fiberglass, the glass fiber can be made of different types of glass. Glass fiber is lightweight, durable and less brittle. The glass fiber can easily get moulded in various geometric shape. By addition of glass fiber it prevents concrete from shrinkage and eliminates the cracks.

II. MATERIALS AND TRIALS

A. Cement: Ordinary Portland cement 43 is used, all test is carried were carried out as per recommendation of IS: 12269-1989.

Its properties are shown in Table 1.

Table No.1. physical properties of cement

SN.	Property	Results
1.	Specific gravity	3.3
2.	Normal consistency	30.5
3.	fineness	2.27
4.	Initial setting time	28 min
5.	Final setting time	232 min

B. Aggregate: Locally available aggregate having size 10mm and 20mm were used in this work, the vital parameter has been studied as per procedure laid down in IS: 2386 (Part 1-8) for testing of aggregate for concrete. The physical properties are shown in Table 2 & 3.

Table No.2. properties of coarse aggregate

SN.	Property	Results (10mm)	Results (20mm)
1.	Specific gravity	2.64	2.79
2.	Fine modulus	6.36	8.09

Table No.3. properties of fine aggregate

SN.	Property	Results
1.	Specific gravity	2.61
2.	Fine modulus	3.22

C. Waste foundry sand (WFS): Waste foundry sand (WFS) was locally attained from Boparai metal casting industries. The physical properties of Waste foundry sand are shown in Table 4 and chemical composition in Table 6.

Table No.4. physical properties of WFS

SN.	Property	Results
1.	Specific gravity	2.97
2.	Fine modulus	2.56

Table No.5. chemical property of WFS

Constituents	Value (%)
Sio_2	87.91
Al_2O_3	4.70
Fe_2O_3	0.94
CaO	0.14
MgO	0.30
SO_3	0.09
Na_2O	0.19
K_2O	0.25
TiO_2	0.15
P_2O_5	0.00
Mn_2O_3	0.02
SrO	0.03
LOI	5.15

D. Waste glass: Window glass, beer bottle, were locally obtained and crushed and finally pass through 4.75mm sieve and retained on 2.36 mm. the physical properties is shown on Table 6.

Table No.6. properties of waste glass

SN.	Property	Results
1.	Specific gravity	2.56

E. Glass fiber: AR glass fiber is used, properties are shown in Table 7.

Table No.7. properties of glass fiber

SN.	Property	Results
1.	Type	AR
2.	Length	6=12mm
3.	Specific gravity	2.25

F. Trial mixes: Four concrete trial mixes were made with different proportion. 1st trial mix was made as conventional concrete M25 (1:1:2). 2nd trial mix waste foundry sand is replaced with sand in different proportion 10%, 20%, and 30%. After tracing optimum value of WFS waste glass in crushed form (passed through 4.75mm) is added along with WFS in 3rd trial as replacement of fine aggregate in different ratio 10%, 20%, and 30%. In 4th trial, after obtaining maximum value of 3rd trial glass fiber in different proportion 0.25%, 0.50%, and 0.75% is added as weight of cement in concrete mix.

Table No.8. trials

Trials	Mixture	Specimen
1st Waste foundry sand (WFS)	M1	0% WFS
	M2	10% WFS
	M3	20% WFS
	M4	30% WFS
2nd (20% WFS + waste glass varied %)	M5	0% waste glass
	M6	10% waste glass
	M7	20% waste glass
	M8	30% waste glass
3rd (20% WFS + 10% waste glass + glass fiber varied %)	M9	0% glass fiber
	M10	0.25% glass fiber
	M11	0,50% glass fiber
	M12	0.75% glass fiber

G. Casting of specimen: For compressive strength 150×150×150mm cube were casted, 150×300mm cylinder for split tensile strength, 500×100×100 beams for flexural strength. After casting proper finishing of specimen were done. Specimen were stored at room temperature of 21 ^{0}C in casting room for 24 hours after that specimen were demoulded and were put in water curing pond.

III. RESULTS AND DISCUSSION

A. Compressive strength: Compressive strength for concrete for different trial mixes made with waste foundry sand, waste glass and glass fiber was evaluated at 7, 14, 28, and 56 days. First trial made with waste foundry sand result shown in Fig. 1. Compressive strength was increased in first trial made with different proportion of WFS. At 28 days mixture M-1 (0% WFS) showed compressive strength of 27.22 N/mm^2, and other proportion M-2 (20% WFS), M-3 (30% WFS), and M-4 (30% WFS) achieved compressive strength of 32.06, 33.79, and 32.65 N/mm^2. Compressive strength also increases with ages (from 28 to 56 days).
Second trial consist of WFS and waste glass (crushed form) show better results than conventional concrete. Second trial made with waste glass shown in Fig.

2. Compressive strength marginally increases for concrete with different proportion of waste glass. At 28 days M-5 (0% waste glass) showed compressive strength of 27.22 N/mm^2, and other mixes M-6 (10% waste glass), M-7 (20% waste glass), and M-8 (30% waste glass) achieved compressive strength of 31.01, 27.89, and 25.88 N/mm^2. There was also increase in strength with ages (from 28 to 56 days). Last trial made with glass fiber, waste foundry sand and waste glass compressive strength were evaluated for concrete for different curing period. Result for third trial is shown in Fig. 3. At 28 days mixture M-9 (0% glass fiber) achieved compressive strength of 27.22 N/mm^2, and other proportion M-10 (0.25% glass fiber), M-11 (0.50% glass fiber), and M-12 (0.75% glass fiber) achieved compressive strength of 35.09, 23.94 and 22.69 N/mm^2 at 28 days. Increment in strength with ages (from 28 to 56 days) was observed.

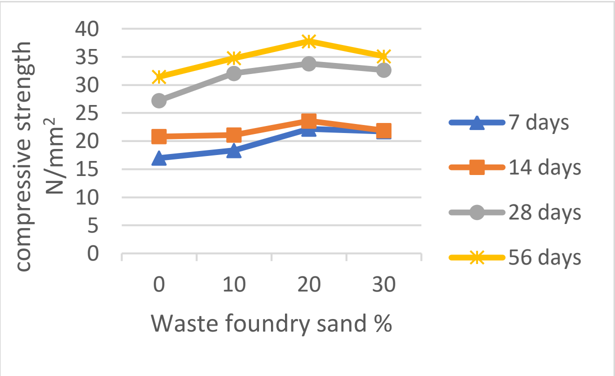

Fig. 1. Compressive strength in relation with waste foundry sand content and curing age.

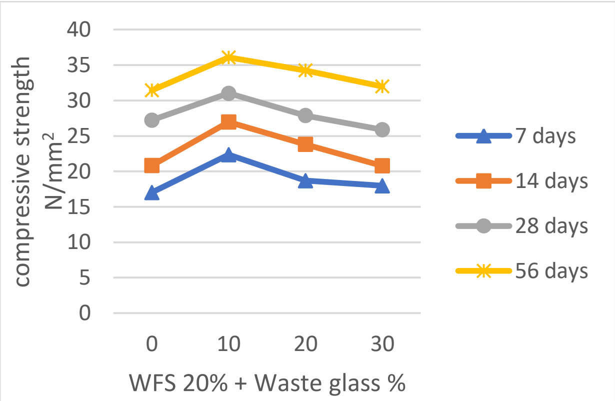

Fig. 2. Compressive strength in relation to waste glass content and curing age.

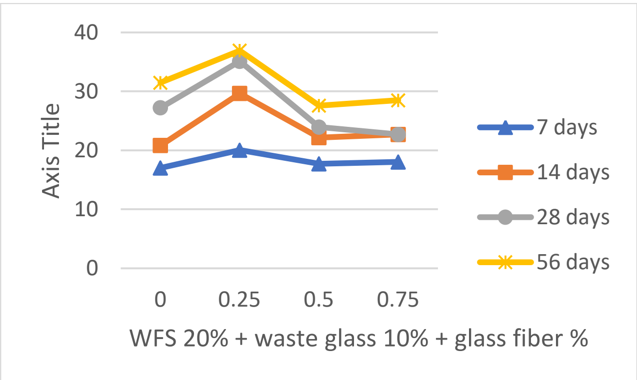

Fig. 3. Compressive strength in relation to glass fiber content and curing age

B. Split tensile strength: Split tensile strength for concrete for different trial mixes made with waste foundry sand, waste glass and glass fiber was measured at 7, 14, and 28 days. First trial made with waste foundry sand result shown in Fig. 4. Split tensile strength was increase in first trial made with different proportion of WFS. At 28 days mixture M-1 (0% WFS) showed split tensile strength of 1.98 N/mm^2, and other proportion M-2 (20% WFS), M-3 (30% WFS), and M-4 (30% WFS) achieved split tensile of 2.11, 2.97, and 2.21 N/mm^2.

Second trial made with WFS and waste glass (crushed form) split tensile was shown in Fig. 5. Split tensile strength marginally increases for concrete with different proportion of waste glass. At 28 days M-5 (0% waste glass) showed split tensile strength of 1.98 N/mm^2, and other mixes M-6 (10% waste glass), M-7 (20% waste glass), and M-8 (30% waste glass) achieved split tensile strength of 2.82, 2.48, and 2.61 N/mm^2.

Last trial made with glass fiber, waste foundry sand and waste glass, split tensile result for third trial is shown in Fig. 6. At 28 days mixture M-9 (0% glass fiber) achieved split tensile strength of 1.98 N/mm^2, and other proportion M-10 (0.25% glass fiber), M-11 (0.50% glass fiber), and M-12 (0.75% glass fiber) achieved split tensile strength of 2.67, 2.52 and 2.49 N/mm^2 at 28 days.

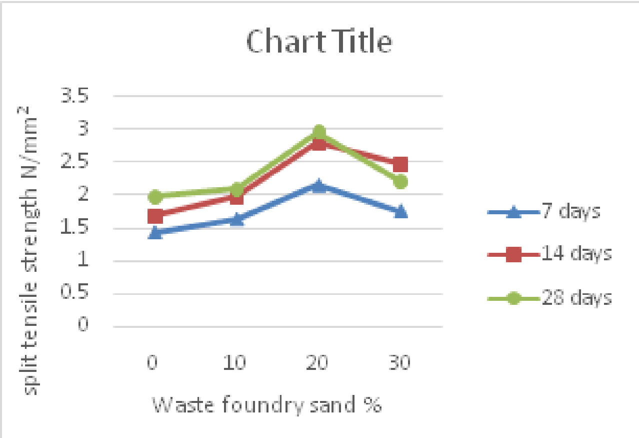

Fig. 4. Split-tensile strength in relation to waste foundry sand content and curing age

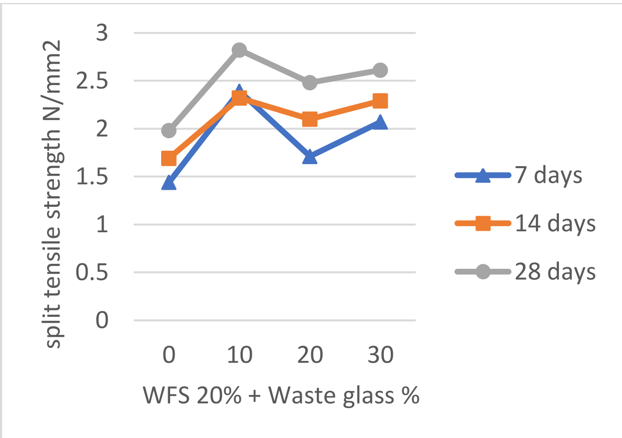

Fig. 5. Split-tensile strength in relation to waste glass content and curing age.

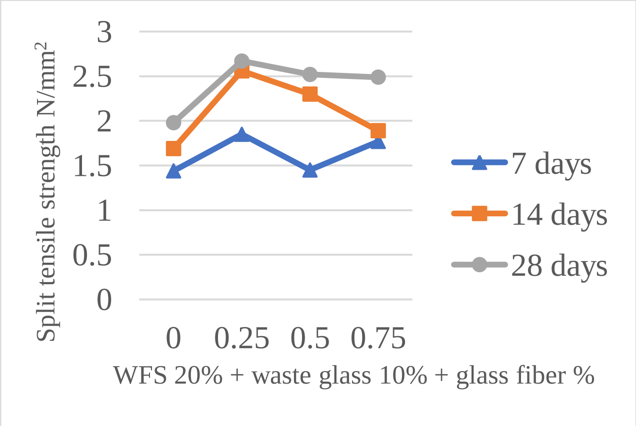

Fig. 6. Split-tensile strength in relation to glass fiber content and curing age.

C. Flexural strength: Flexural strength for concrete for different trial mixes made with waste foundry sand, waste glass and glass fiber was evaluated for 28 days only. First trial made with waste foundry sand result shown in Fig. 7. There was increase in flexural strength of concrete in first trial made with different proportion of WFS. At 28 days mixture M-1 (0% WFS) showed flexural strength of 5.25 N/mm^2, and other proportion M-2 (20% WFS), M-3 (30% WFS), and M-4 (30% WFS) achieved flexural strength of 5.77, 7.35, and 6.3 N/mm^2.

Second trial consist of WFS, waste glass (crushed form), flexural strength result shown in Fig. 8. Flexural strength marginally increases for concrete with different proportion of waste glass. At 28 days M-5 (0% waste glass) showed flexural strength of 5.25 N/mm^2, and other mixes M-6 (10% waste glass), M-7 (20% waste glass), and M-8 (30% waste glass) achieved flexural strength of 8.4, 6.82, and 6.3 N/mm^2.

Last trial made with glass fiber, waste foundry sand and waste glass flexural strength result shown in Fig. 9. At 28 days mixture M-9 (0% glass fiber) achieved flexural strength of 5.25 N/mm^2, and proportion M-10 (0.25% glass fiber), M-11 (0.50% glass fiber), and M-12 (0.75% glass fiber) achieved flexural strength of 8.92, 7.35 and 6.3 N/mm^2 at 28 days.

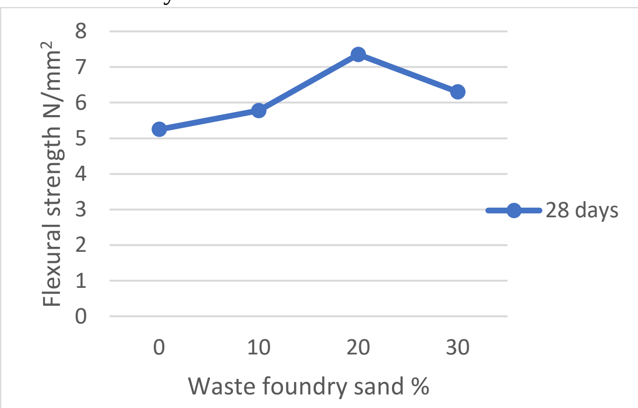

Fig. 7. Flexural strength in relation to waste foundry sand content and curing age

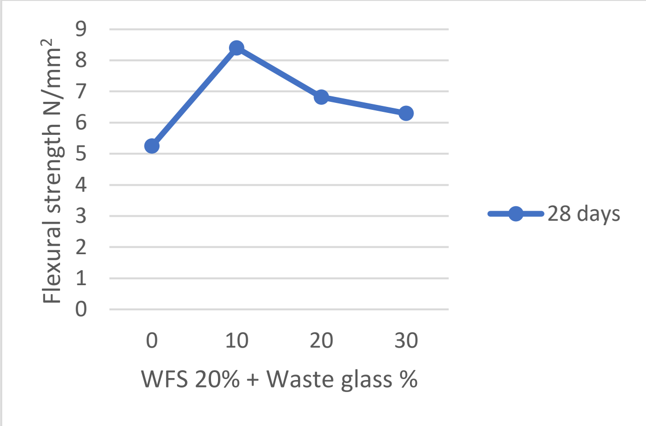

Fig. 8. Flexural strength in relation to waste glass content and curing age.

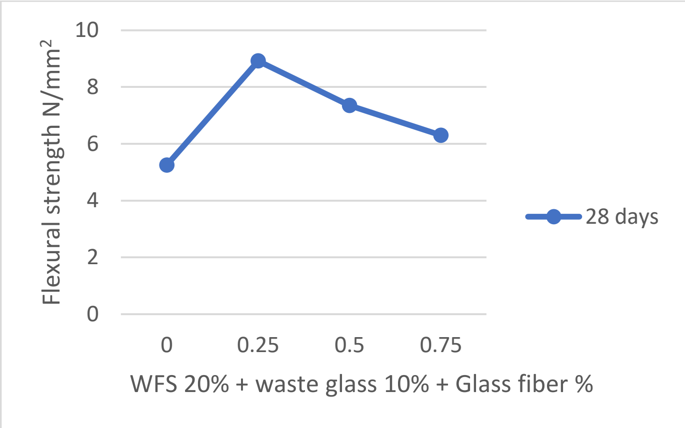

Fig. 9. Flexural strength in relation to glass fiber content and curing age.

IV. CONCULSION

Following conclusion can be drawn from the purposed study

- Waste foundry sand can efficiently improve mechanical properties of concrete. At 28 days compressive strength was found to be 33.79N/mm^2 maximum at 20% WFS replacement with sand. Moreover, compressive strength was marginal increase with ages from (28-56 days) 56 days show compressive strength of 37.76 N/mm^2.
- Split-tensile, flexural strength for concrete containing WFS was increased than conventional concrete. Split tensile strength and flexural strength for 28 days cure concrete show maximum value of 2.97 N/mm^2 and 7.35 N/mm^2 at 20% WFS replacement.
- 20 % Waste foundry replacement was found to optimum after that strength progressively decreases.
- Concrete containing waste glass show significant improvement in properties of concrete. Compressive strength for 28 days cured concrete show maximum value of 31.01 N/mm^2 at 10% replacement of waste glass with sand. Also, strength continuously increases with ages, compressive strength for 56 days cured concrete was 36.08 N/mm^2.
- Split-tensile strength, flexural strength of concrete containing waste glass show value of 2.82 N/mm^2 and 8.4 N/mm^2 at 10% replacement for 28 days cure concrete.

- 10 % waste glass replacement was found to be maximum after that strength continuously decreases.
- Waste glass can be used for making good concrete only problem rises it give rise to alkali-silica reaction in concrete containing waste glass, we have to add supplementary material like fly sash, silica fume and waste foundry sand etc.
- Glass fiber addition in concrete improves concrete overall strength. Compressive strength for 28 days cured concrete containing glass fiber was 35.09 N/mm^2 maximum for (0.25% GF) addition, there was little increases in compressive strength for 56 days for concrete incorporated with glass fiber with maximum 36.91 N/mm^2 at (0.25% GF).
- Split-tensile strength, flexural strength for concrete containing glass fiber was found to be 2.67 N/mm^2 and 7.35 N/mm^2 maximum at (0.25% GF) for 28 days cured concrete.
- 0.25 % glass fiber addition was found to be maximum after that strength decreases but it somehow remains higher than conventional mix

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