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Suitability of E-Sand as Replacement for River Sand in Glass Fiber Reinforced Concrete

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Abstract
Glass Fiber Reinforced Concrete (GFRC) is being used extensively nowadays due to growth of urbanization. Due to increase in use of conventional material like river sand for production of GFRC has increased the cost of production and also has negative effect on environment due to excessive mining and use of this material for the production of GFRC. In the present work, an experimental study was made to assess the suitability of Fly Ash and E-Sand as replacement for cement and river sand respectively. Mix design for M25 grade was done utilizing 0.3% of glass fibers. E-Sand was added as replacement in 0%, 25%, 50%, 75% and 100% to determine the ideal replacement level also cement was replaced partially with fly ash by constant 30% for all mix variations. Strength tests were done for 7, 14 and 28 days. Experimental study demonstrated that E-Sand up to 100% substitution level gave satisfactory results when compared with conventional concrete.
Keywords: *Glass Fibers, Fly ash, E-Sand, River Sand*

1. Introduction

Concrete is the most widely used material in construction industry. Concrete with high strength along with long term durability, serviceability are the need of the day. Glass Fiber Reinforced Concrete consists of hydraulic Portland cement, coarse and fine aggregates along with alkali resistant glass fiber as reinforcement material. River sand is preferred for concrete but excessive mining of river sand has caused environmental degradation. So, search for alternative to river sand has already begun. E-Sand a by-product obtained from crushed rock during aggregate production can be used as fine aggregate replacement. Also fly ash which has cementitious property obtained from thermal power plant can be used for replacement of cement in concrete up to certain extent. Experimental studies of previous researchers have shown that addition of glass fibers enhances strength properties of concrete.

2. Problem Context and Definition

Concrete as a construction material has a large potential all over the world and next only to the consumption of water. Aggregates contributing about 60-70% of concrete mass, hence there exists a vast demand for aggregates. The fast and vast infrastructural developments in India demand huge quantity of natural sand for concrete, as fine aggregate. Dwindling sand resources in river beds pose environmental problem and hence government has imposed restriction on the usage of sand. The huge demand due to fast development in infrastructure, scarcity of natural sand in river bed and also due to government restriction on quarrying of sand, have has led to the increase in the cost of natural sand. This not only has increased the cost of the construction but also delays the construction in few places due to the non-availability of natural sand. The raw material used for the manufacture of cement has depleting day by day. This motivates researches for alternative material to replace the natural sand. Substitution of raw materials constituents with alternatives is an important eco efficiency driver and is need of the hour. It reduces use of natural resources and offset traditional materials thus conserving non-renewable natural resources contributing to sustainable construction and allowing for the recovery of both energy and material from selected waste.

In this experimental investigation, strength aspects of glass fiber reinforced concrete is to be studied with e-sand as replacement to river sand with percentage variation of 0%, 25%, 50%, 75% and 100% by weight of sand and cement is partially replaced by fly ash at constant 30% replacement level for all mix variations. Fly ash from Raichur Thermal Power Station (RTPS), Karnataka, was taken for the study. The tests are conducted in order to study strength characteristics such as cube compressive strength, splitting tensile strength and flexural strength. The results obtained will be compared with normal mix.

3. Previous Works

Crushed rock powder as partial replacement of fine aggregate was experimentally studied [1] and found that crushed rock powder can be replaced 40% without reduction of strength of concrete. Concrete with crushed sand as fine aggregate replacement was studied [2], which indicated that crushed sand can be replaced up to 100% without any adverse effect on the strength of concrete. Crushed rock sand as partial replacement of fine aggregate in concrete was experimentally evaluated [3]; results showed that crushed rock powder can be replaced up to 60% without reduction in strength properties. Use of crushed sand as fine aggregate replacement in concrete was studied [4], and results indicated that crushed sand can be replaced up to 50% also reducing the cost of fine aggregate for the production of concrete. Fine aggregate replacement by m-sand was experimentally carried out [5], and results showed that m-sand can be effectively replace natural sand in concrete. Very few literatures are available regard to the use of e-sand. The present study examines the possibility of using e-sand as partial/full replacement of fine aggregate. Also fly ash as replacement of cement by constant 30% for all variations with 0.3% of glass fibers as reinforcement material.

4. Materials Used

4.1 Cement

The cement used was ordinary Portland cement of 53 grade with specific gravity of 3.14. The initial and final setting time of cement was 46 minutes and 192 minutes respectively.

4.2 Fly Ash

In this study, fly ash is used as replacement of cement by constant 30% for all variations and is collected from Raichur Thermal Power Station, Karnataka. It has specific gravity of 2.1 and normal consistency of 31%.

4.3 Coarse Aggregate

The coarse aggregate of 20mm and below size were used in study.

Table 1: Properties of Coarse aggregate

Particular	Coarse Aggregate
Shape	Angular
Bulk density of compacted aggregate	1562 kg/m^3
Bulk density of loose aggregate	1368 kg/m^3
Specific Gravity	2.67
Water absorption	0.2%

4.4 River Sand and E-Sand

The river sand and e-sand used in the present study conforms to IS: 2368-1968. The e-sand was supplied by Bharathi Cements, Bangalore.

Table 2: Properties of River Sand & E-Sand

Particular	River Sand	E-Sand
Bulk density of loose sand	1428 kg/m^3	1898 kg/m^3
Bulk density of compacted sand	1624 kg/m^3	1645 kg/m^3
Specific Gravity	2.62	2.61
Water Absorption	0.9%	3.6%
Zone	II	II

4.5 Fibers Used

In the present work, Cem-Fil anti crack glass fibers of length 12mm and aspect ratio 58 is used.

4.6 Water

Ordinary potable water was used for mixing and curing purpose.

4.7 Super Plasticizer

Glenium 8233 is used for the work. The percentage of super-plasticizer is 0.35% of total cementitious quantity.

5. Methodology

Design mix concrete is preferred to nominal mix. Mix is designed following the stipulations laid down in IS 456:2000 with respect to minimum cement content, maximum water to cement ratio and minimum grade of concrete for various exposure conditions and guidelines. Mix is designed as per IS 10262:2009 - BIS method of Mix design.

Mix Ratio = C: FA: CA: w/c

Mix ratio = 1: 1.60: 3.02: 0.4 (0.5% of Super plasticizer)

Table 3: Details of Test Specimens

Mix	C + F (%)	FA (%)		CA (%)	w/c	SP (%)	GF (%)
		R S	E S				
CC	100+0	100	0	100	0.50	0.35	0.30
A0	70+30	100	0	100	0.50	0.35	0.30
A25	70+30	75	25	100	0.50	0.35	0.30
A50	70+30	50	50	100	0.50	0.35	0.30
A75	70+30	25	75	100	0.50	0.35	0.30
A100	70+30	0	100	100	0.50	0.35	0.30

C=Cement, F=Fly ash, R S=Sand, E S=E-Sand GF= Glass fiber, SP=Super plasticizer, CA= Coarse aggregate

6. Results and Discussions

6.1 Slump Test

Slump test was done for CC, fly ash as a partial replacement for cement at constant 30% for all variations and e-sand as replacement for river sand at 0%, 25%, 50%, 75% and 100% with addition of 0.3% of glass fibers by volume fraction of concrete.

Table 4: Slump Value for Concrete Mixes

Mix	Slump in mm	% of SP
CC	105	0.30
A0	98	0.32
A25	95	0.35
A50	92	0.40
A75	90	0.43
A100	95	0.45

6.1.1 Observation and Discussion on Workability

For the conventional concrete the slump value was found to be 105 mm then when glass fibers were mixed with concrete, the slump value decreased along with the increase in percentage of e-sand. As the percentage replacement level of e-sand is increased. The required slump value is achieved by increasing the percentage of super plasticizer. The reduction in slump with the increase in percentage of e-sand is due to the water absorption by e-sand, since it have more water absorption capacity than river, which hinders the hydration of cement due to lack of water content and also glass fiber content could be the reason because it cause hindrance to the aggregates to freely slip past the next to be aggregate because of their geometry in concrete.

6.2 Compressive Strength

Compressive strength of concrete mixes with cube specimen of size 150x150x150 mm, made with fly ash as a partial replacement for cement at constant 30% for all variations and e-sand as replacement for river sand at 0%, 25%, 50%, 75% and 100% with addition of 0.3% of glass fibers by volume fraction of concrete was determined at 7, 14 and 28days.

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Table 5: Compressive Strength Results in N/mm^2

Mix	Compressive Strength		
	7 days	**14 days**	**28 days**
CC	18.46	22.15	27.45
A0	19.32	22.89	29.93
A25	20.67	23.85	30.74
A50	21.56	24.89	32.22
A75	23.04	26.37	33.63
A100	24.37	27.88	35.11

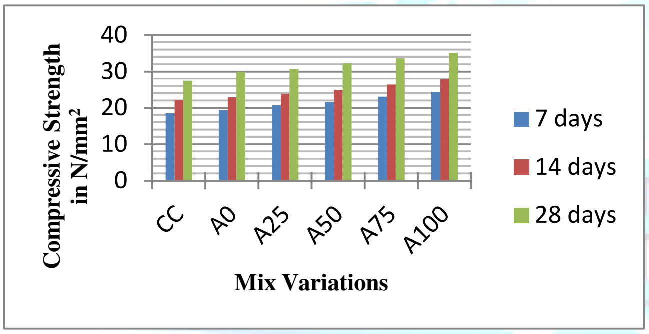

Fig. 1 Compressive strength test results in N/mm^2

Table 6: Split Tensile Strength Results in N/mm^2

Mix	Split Tensile Strength		
	7 days	**14 days**	**28 days**
CC	1.34	2.18	2.72
A0	1.48	2.20	2.98
A25	1.77	2.33	3.05
A50	1.89	2.41	3.19
A75	2.05	2.48	3.24
A100	2.11	2.57	3.37

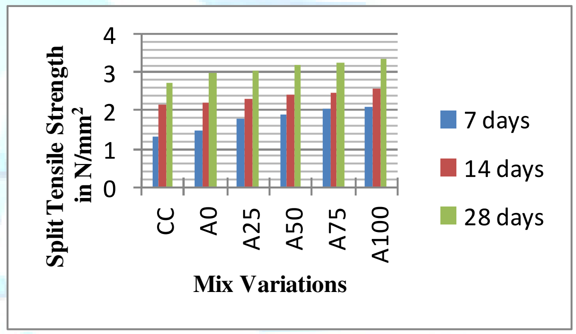

Fig. 2 Split tensile strength test results in N/mm ^{2}

6.2.1 Observation and Discussion on Compressive Strength

There is increase in compressive strength by the addition of glass fibers. The 28 days target compressive strength is achieved for the replacement level up to 100%. The compressive strength slightly increases with addition of 0.3% glass fibers. The strength achievement is delayed due to addition of fly ash as replacement of cement, which delays the early age strength achievement. At 28 days, for 100% replacement by e-sand maximum compressive strength is achieved.

6.3 Split Tensile Strength

Split strength of concrete mixes with cylinder specimen of size 150mm diameter and 300mm in height, made with fly ash as a partial replacement for cement at constant 30% for all variations and e-sand as replacement for river sand at 0%, 25%, 50%, 75% and 100% with addition of 0.3% of glass fibers by volume fraction of concrete was determined at 7, 14 and 28days.

6.3.1 Observation and Discussion on Split Tensile Strength

The split tensile strength for CC was obtained as 2.72 N/mm^2 at 28 days. For glass fiber reinforced concrete, strength increased by 17.01%. The split tensile strength of the concrete increases with increase in percentage of e-sand. The optimum replacement level for e-sand is up to 100%. The increase in tensile strength is due to addition of glass fibers which acts as crack arrester.

6.4 Flexural Strength

Flexural strength of concrete mixes with beam mould of size 700x150x150 mm, made with fly ash as a partial replacement for cement at constant 30% for all variations and e-sand as replacement for river sand at 0%, 25%, 50%, 75% and 100% with addition of 0.3% of glass fibers by volume fraction of concrete was determined at 28days.

Table 7: Flexural Strength Results for 28 days in N/mm^2

Mix	Flexural Strength for 28 days in N/mm²
CC	3.88
A0	4.15
A25	4.37
A50	4.55
A75	4.88
A100	5.05

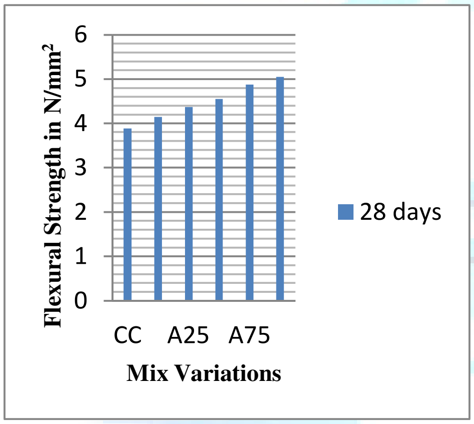

Fig. 1 Flexural strength test results in N/mm²

6.4.1 Observation and Discussion on Flexural Strength

The flexural strength for CC was obtained as 3.88 N/mm² at 28 days. For glass fiber reinforced concrete, strength increased by 30.15%. The flexural strength of concrete increases with increase in percentage of e-sand. The optimum replacement level for e-sand is up to 100%. The increase in flexural strength is because e-sand which contains silica improves the pozzolanic action.

7. Conclusions

The test results obtained can be concluded as:

- The workability of glass fiber reinforced concrete has been reduced with the increase in percentage of e-sand.
- The compressive strength of concrete for 28 days with various % replacement of e-sand has been increased and has achieved target strength for 100% replacement for GFRC.
- The split tensile strength of concrete for 28 with various % replacement of e-sand has been increased and has achieved target strength for 100% replacement for GFRC.
- The flexural strength of concrete maintained good result up to 100% replacement with e-sand along with addition of glass fibers.
- By the addition of glass fibers, compressive strength, split tensile strength and flexural strength has been improved slightly.

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