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EXPERIMENTAL STUDY ON FLOWABILITY AND MECHANICAL PROPERTIES OF SELF COMPACTING CONCRETE WITH PARTIAL REPLACEMENT OF CEMENT BY NATURAL POZZOLANIC AND INDUSTRIAL WASTE BASED MATERIALS.

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Abstract

Self-Compacting Concrete (SCC) is one of the innovative product of concrete technology developed in recent years. However, many researchers are still trying to optimize the mix ratio and study the utilization of new/alternate materials into the (SCC). The typical high content of cement is one of the biggest challenges in optimizing its mix ratio. This high cement consumption increases the manufacturing cost of (SCC) and is also undesirable from an environmental point of view in terms of high carbon emissions in Portland cement manufacturing.

In this study different Pozzolanic materials were employed to lower the Portland cement content. Laboratory tests were conducted on 5 different combinations of Natural Zeolite (NZ) and Ground Granulated Blast Furnace Slag (GGBS). For all mixes binder content was maintained constant at the weight of 500 kg/m^3 for M50 grade. 50% of cement content was maintained unchanged, the rest was replaced with GGBS and NZ at different proportions of (40%+10%), (30% + 20%), (25% + 25%), (20% + 30%) and (10% + 40%) respectively. The flowability of SCC was determined as per the guidelines of EFNARC by conducting Slump flow, L box, J ring, V funnel, U box test. Mechanical properties of concrete were tested for 7, 14, 28 and 56 days by conducting Compression test, Split tensile test and Flexural test. The best results were achieved for the equal proportion of GGBS and NZ at 25% each as 62 MPa, 3.6 MPa and 10.4 MPa respectively for 56 days. While reference mix containing 100% cement content has attained 65 MPa, 4 MPa, 10.8 MPa respectively at the age of 56 days. Even though the strength gained is less than the control mix, but has achieved the designed target strength. The results are encouraging and indicate natural zeolite can be used for self compacting concrete.

Keywords: *Natural Zeolite (NZ), GGBS, Cement, Self-Compacting Concrete (SCC).*

1- INTRODUCTION

Self Compacting Concrete was developed in Japan in 1980s in order to achieve high-performance durable concrete structures, and with advancements in concrete technology its use has become widespread all over the world (Ozawa et al., 1989; Okamura and Ouchi, 2003). Self-Compacting Concrete (SCC) has an ability to flow under its own weight, and fills the required space or formwork completely and produces a dense and adequately homogenous material without a need for vibrating compaction.

Zeolites are greyish white with a smooth texture microporous, aluminosilicate minerals commonly used as commercial adsorbents and catalysts. Zeolites occur naturally but are also produced industrially on a large scale. This kind of material has the property to absorb CO_2 with incredible strength. Zeolites are widely used as ion-exchange beds in domestic and commercial water purification, softening, and other applications Maghsoudi, A. A. et al. (2018).

Zeolites are also extensively used as catalysts and absorbents. Their well-defined pore structure and adjustable acidity make them largely active in a large variety of reactions. Zeolites have the potential of providing precise and specific separation of gases, including the removal of H_2O, CO_2 and SO_2 from low-grade natural gas streams. Other separations include noble gases, N_2, O_2, Freon and formaldehyde.

Ground granulated blast furnace slag (GGBS) is a derivate of the iron and steel manufacturing process that is primarily composed of Calcium oxide, Silica, Magnesia, and Alumina as a fluxing agent, metallic ore, gangue material, and lime agent. GGBS is a latent hydraulic binder that develops binding properties when used in the manufacture of concrete. When activated by the alkaline hydration products of cement. Tavasoli S Nili M & Serpoush, B (2018).

2-MATERIALS AND METHODS

2.1 Materials Used

SCC was produced using cement, industrial residue and naturally available materials such as GGBS and Zeolite which were procured from local commercial suppliers at Bangalore, Karnataka, India. Aggregates used are M-Sand and 10mm conforming to IS 383. Super Plasticizer used is Auramix 400 conforming to IS 9103. Below are the specific gravity and bulk density of materials listed in Table1. Properties of Zeolite and chemical composition of GGBS are listed in Table 2 and Table 3 respectively.

Table 1 Properties of the materials

Sl. No	Materials	Specific gravity	Bulk Density kg/m^3
1	Cement OPC-53	3.11	1440
2	GGBS	2.89	1100
3	Natural Zeolite	2.1	1050
4	Fine Aggregate	2.62	1800
5	Coarse Aggregate	2.62	1600
6	Auramix 400	1.09	1091

Table 2 Properties of Zeolite

Properties of Zeolite	
Moisture	0.98%
Silicon Di Oxide	63.87%
Aluminum Trioxide	11.47%
Calcium Oxide	2.37%
Magnesium Oxide	1.00%
Sodium Oxide	6.81%
Potassium Oxide	0.94%
PH (5% Aq.Suspension)	8.2
Bulk Density	1.05 g/cc
Specific Surface Area	378 Sqm/kg
Water Absorption	30 ml/100g

Table 3 Chemical composition of GGBS

Chemical composition	
Calcium oxide:	40%
Silica:	35%
Alumina:	13%
Magnesia:	8%

2.2 Methodology

The study aims at investigating effectiveness of replacement of Cement with GGBS and Zeolite in order to enhance flowability and strength characteristics of self compacting concrete (SCC). Planning of experimental investigation is done as mentioned below:

- To evaluate basic tests of binder constituents, M-Sand and 10mm aggregate.
- To calculate quantity of materials required to prepare SCC.
- To prepare samples of 6 mix designs by varying binder content.
- To evaluate fresh properties of SCC by conducting Slump test, L-Box test, J-Ring test, V-Funnel test and U-Box test.
- To evaluate hardened properties of SCC by conducting Compressive strength, Split tensile test and Flexural strength test on cubes, cylinders and beams respectively casted in laboratory.

2.3 Mix design of SCC

Mix design for M50 grade self compacting concrete was done as per the IS 10262-2019. All the mix proportions are calculated based on the mix design shown in Table 4. In this research there are 6 different proportion including Control mix, C:G25:Z25, C:G40:Z10, C:G30:Z20, C:G20:Z30, C:G10:Z40 respectively shown in the Table 5. Here, cement content is kept constant to 50% of the volume of total binder content mentioned in Table 4, remaining 50% of binder content is varied with the varying amount of GGBS and Zeolite with respect to each other as (40%+10%), (30% + 20%), (25% + 25%), (20% + 30%) and (10% + 40%) respectively tabulated in the Table 5.

Table 4 Percentage of materials required per 1m^3 of concrete

Materials	Mass of the materials (Kg/m^3)	% by volume
Binder Content	500	20.6
Water	225	9.3
Fine Aggregate	960	39.6
Course Aggregate	734	30.3
AuroMix 400	6.5	0.3
Density	2425.5	100.0

Table 5 Mix proportion for different mixes

Mix	Cement (kg/m^3)	GGBS (kg/m^3)	Zeolite (kg/m^3)	Water (kg/m^3)	FA (kg/m^3)	10mm CA (kg/m^3)	Auramix 400 (kg)	% of Super Plasticizer	W/C	Density Kg/m^3
Control Mix	500	0	0	225	960	734	6	1.2	0.45	2425
C:G40:Z10	250	200	50	225	960	734	6	1.2	0.45	2425
C:G30:Z20	250	150	100	225	960	734	6.15	1.23	0.45	2425.15
C:G25:Z25	250	125	125	225	960	734	6.25	1.25	0.45	2425.25
C:G20:Z30	250	100	150	225	960	734	6.5	1.3	0.45	2425.5
C:G10:Z40	250	50	200	225	960	734	6.65	1.33	0.45	2425.65

2.4 Casting, Curing and Testings

Flowing ability and passing ability tests were conducted on each mix as per EFNARC code. For each mix 150mm x 150mm x 150mm cubes were casted to determine the compressive strength of age 7 days, 14 day, 28 days and 56 days. Cylinders of size 100mm diameter and 200mm height were casted to determine the split tensile of the concrete. Beam of size 100mm x100mm x 500mm were casted to determine the flexural strength of the concrete as shown in Figure 1.

Figure 1 Cubes, Beams and Cylinder filled with SCC.

3- RESULTS AND DISCUSSION

3.1 Fresh concrete properties testings

The results of Slump flow test, J-Ring test, L-Box test, V-funnel test and U-Box test are shown in the Table 6. It shows that flowability and passing ability of concrete decreases with increase in zeolite.

Table 6 Results of fresh concrete properties carried out

SL	MIX PROPORTIONS	SLUMP FLOW (mm)	L-BOX	J - RING (mm)	V-FUNNEL (sec)	U-BOX (mm)
1	Control mix	670	0.9	8	10	18
2	C:G40:Z10	670	0.9	8	11	20
3	C:G30:Z20	675	0.85	7.5	10.5	28
4	C:G25:Z25	672.5	0.83	6.75	10	20
5	C:G20:Z30	672	0.8	6.5	11	25
6	C:G10:Z40	660	0.85	10	12	30
Limiting values as per EFNARC		**650 -800 (mm)**	**0.8-1**	**<10 mm**	**8 - 12 (sec)**	**<30 mm**

3.2 Mechanical properties

3.2.1 Compressive strength

The compressive strength of all mix proportion were conducted in Universal Testing Machine as shown in Figure 2. Results for 7 days, 14 days, 28 days and 56 days are shown in the Figure 3. It was observed that with the percentage addition of Zeolite increases, the strength also increases till 25%, beyond it the strength gradually decreases as the percentage of GGBS increase simultaneously. Optimum mix

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proportion was C:G25:Z25 among the 5 mix proportion, as this mix only achieved the target strength of 58.25MPa. Compressive strength of the cube specimens are 65MPa and 62MPa for control mix and developed mix for the age of 56 days as shown in Figure 3.

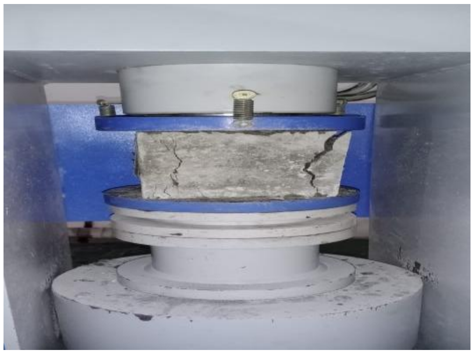

Figure 2 Compressive strength

3.2.2 Split tensile strength

The split tensile strength of all mix proportion were conducted as per IS Code. Results are shown in Figure 2. Split tensile strength of the concrete was found 4 MPa and 3.6 MPa for control mix and developed mix respectively for the age of 56 days, results for 28 days and 56 days are shown in the Figure 4.

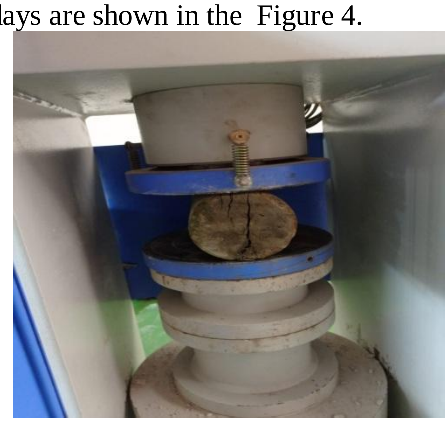

Figure 3 Split tensile strength

3.2.3 Flexural strength test

The Flexural strength of all mix proportion were conducted as per IS Codes. Results are shown in figure 2. Flexural strength of the concrete was found 10.8 MPa and 10.4 MPa for control mix and developed mix respectively for the age of 56 days. Results are shown in Figure 5.

Figure 4 Flexural strength

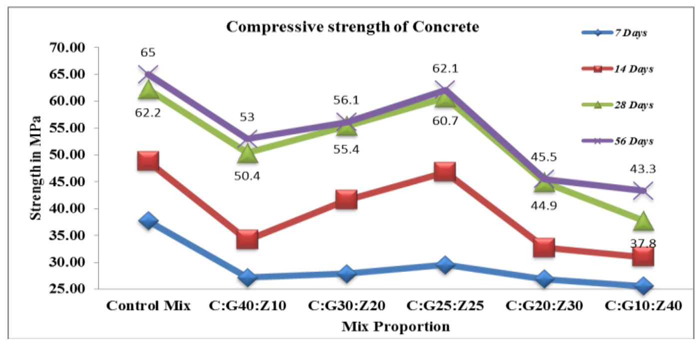

Figure 3 Results of Compressive strength

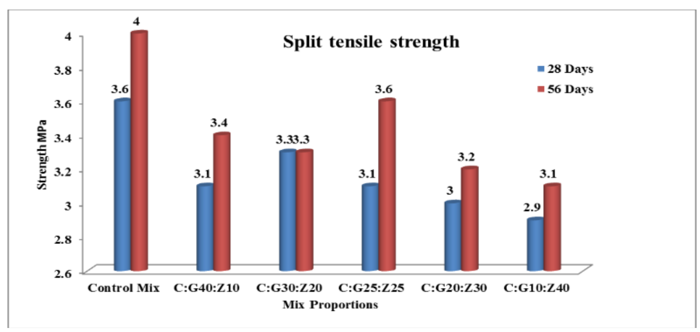

Figure 4 results of Split tensile strength

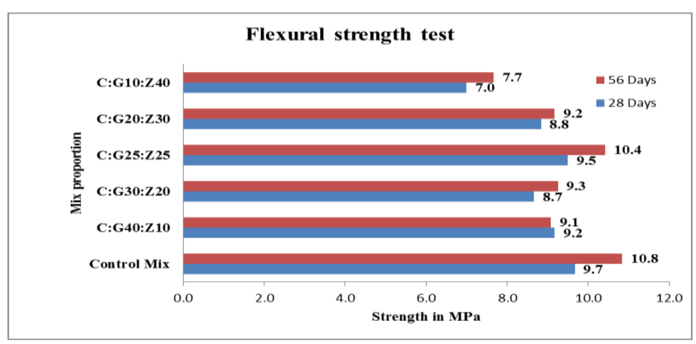

Figure 5 Results of Flexural strength test

4- CONCLUSION

By conducting the research we can come to the following conclusions.

1. Developed mix concrete showed similar workability properties as that of Control mix concrete. On the other hand s, increasing percentage of zeolite needs more superplasticiser to maintain the workability of the fresh concrete.
2. Compressive strength achieved of control mix and C:G25:Z25 mix are 11.5% and 6.4% more than the target strength for the age of 56 days curing.
3. Split tensile strength of C:G25:Z25 mix was decreased by 10 % when compared with the strength of control mix for the age of 56 days of curing.
4. Flexural strength of C:G25:Z25 mix was decreased by 3.7% when compared with the strength of control mix for the age of 56 days.

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