TO DEVELOP SELF-COMPACTING CONCRETE OF GRADE M25, M30 AND M35 USING COMPOSITE CEMENT

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Abstract: Both fly ash and slag are industrial by-products and their disposal has become a serious environmental problem. Considering their excellent cementitious properties, their utilization in the cement industry becomes crucial. Because of the significant contribution to the environmental pollution, over dependency on cement has to be reduced. There is a need to economize the use of cement, thus, the concept of composite cement becomes necessary. In this study, Fly Ash (FA) and Ground Granulated Blast Furnace Slag (GGBFS) were used as partial replacement of cement to improve the properties of self-compacting concrete (SCC). Three SCC grades viz., M25, M30 and M35 were made in the laboratory. For all the three grades, two variations were considered. Case 1 included 65% Ordinary Portland Cement (OPC), 15% FA and 20% GGBFS while case 2 included 85% OPC and 15% FA. In order to improve the workability of SCC, certain amount of super-plasticizer was added in the design mix. V-funnel, L-box and slump flow tests were conducted on fresh SCC whereas compressive strength, flexural strength and split tensile tests were performed on hardened SCC. The results showed that the optimum admixture content was used their respective grades and cases leading to negligible segregation. Moreover, all the design mixes satisfied the SCC workability conditions comfortably. It was concluded that by replacing cement partially with fly ash and GGBFS in percentages mentioned in cases 1 and 2, the tensile strength of SCC could improve. From the 28 days results obtained from the compressive strength test, it was inferred that 15% fly ash and 20% GGBFS could be partially replaced with cement for all the grades i.e., M25, M30 and M35. This, could help in reducing the reliance on cement, and utilizing the industrial by-products in a better way.

Keywords*:* Self-Compacting Concrete (SCC); Fly Ash (FA); Ground Granulated Blast Furnace Slag (GGBFS)

1. Introduction

A concrete mix can only be classified as self-compacting if it has the following characteristics: Filling ability; Passing ability and Viscosity. This concrete mix is highly workable facilitating faster placement of concrete.

When we look at ordinary concrete, it is a dense material when mixed and requires the use of vibration or other compacting techniques to remove air bubbles and honeycomb-like holes, especially at the surfaces, where air has been trapped during pouring. These air particles trapped on the concrete surface are not desired and weaken the concrete if left. Vibration is a laborious task and takes time to remove such particles. Improper or inadequate vibrations lead to undetected problems later. Additionally some complex forms cannot be easily vibrated. These problems aggravate during the construction of large structures with congested and isolated reinforcements. Thus, in such scenarios, the concept of Self-Compacting Concrete (SCC) comes in handy. When placed, due to its own weight, the concrete gets compacted easily without the help of any compacting media and without much segregation. For such seamless compaction, stricter monitoring and high precision measurements of SCC become necessary for large construction activities.

2. Literature review

P. Dinakar et al (2013) worked on the influence of including fly ash (FA) on the properties of self-compacting concrete (SCC). Portland pozzolana cement (PPC) was partially replaced with fly ash. Workability, strength and durability properties were studied in this experiment. The results indicated that fly ash along with PPC could be used in SCC to produce high strength high performance concretes. High absorption values were obtained with increasing amount of FA, however, all the SCCs exhibited initial absorption values of less than 3%. The water penetration depths in SCCs were lower at 10% and 30% replacements of fly ash but remained higher at 50% and 70% replacements. There is a systematic reduction in the chloride permeability of SCCs at 30% replacement of fly ash.

3. Experimental work

3.1. Materials

Cement, fly ash and GGBFS:

The cement which was used in the experimentation work was Ordinary Portland Cement (OPC), 43 grade, of Ultratech conforming to BIS: 269 - 2015. Fly ash and GGBFS that were used for the thesis work conform to BIS: 3812 (Part 1) - 2013 and BIS: 12089 - 1987 respectively. The specific gravities of cement, fly ash and GGBFS were calculated to be 3.13, 2.2 and 2.88 respectively. The color of fly ash was light grey while the color of GGBFS was dark grey.

Cement, fly ash and GGBFS were added together in the proportions as mentioned above i.e., case 1 and case 2. The composite cement thus obtained was mixed with water to form a composite cement paste. This paste was then tested for important parameters of Indian Standard Code. Their results are given in the table below.

Table 1. Properties of composite cement paste

Variation	Standard Consistency (P) in %	Initial Setting Time (min.)	Final Setting Time (min.)
Case 1	33	180	460
Case 2	31	170	445

Coarse aggregates:

10 mm nominal size aggregates were considered for the mix design of SCC. They were naturally occurring with well-defined angular edges and rough planar surfaces. The specific gravity of coarse aggregates was calculated to be 2.68.

Fine aggregates:

Natural sand was used as fine aggregate. Its specific gravity was evaluated and was found to be 2.65. The percentage silt content of sand was observed to be 7.15 percent.

Admixture:

The admixture used for the enhancing the workability of SCC was MasterEase 3504, a product of Master Builders Solutions. It is a super-plasticizer, which improves the rheological properties of SCC, significantly facilitating its pump-ability and placement. The colour of the liquid was reddish-brown and its specific gravity was found to be 1.08.

3.2. Replacement of cement with fly ash and GGBFS

The gradations of SCC viz. M25, M30 and M35 were designed with the help of Indian standards by replacing cement with composites in the following variations: case 1: (OPC – 65%, GGBFS – 25%, FA – 15%); case 2: (OPC – 85%, FA – 15%)

3.3. Mix Proportion

Table 2. Quantities of mixing materials per m^3 for Case 1

Materials	M25 grade mix	M30 grade mix	M35 grade mix
Cement	308.75 Kg	352.85 Kg	390 Kg
Fly ash	71.25 Kg	81.43 Kg	90 Kg
GGBFS	95 Kg	108.57 Kg	120 Kg
Admixture	5.225 Kg	6.514 Kg	7.2 Kg
Fine aggregate	803.90 Kg	754.77 Kg	724.21 Kg
Coarse aggregate	880.75 Kg	860.76 Kg	848.78 Kg
Water	190 litres	190 litres	190 litres

Table 3. Quantities of mixing materials per m3 for Case 2

Materials	M25 grade mix	M30 grade mix	M35 grade mix
Cement	403.75	461.4	510
Fly ash	71.25	81.45	90
Admixture	5.7	7.33	8.1
Fine aggregate	805.18	758.14	721.76
Coarse aggregate	805.18	864.60	845.91
Water	190 litres	190 litres	190 litres

4. Results

4.1. Compression test

Compressive strength test was done on cubical moulds, where the test specimen was subjected to a compressive force at a loading rate of 140 Kg/sq cm/min. The loading capacity of the compressive testing machine is 3000 KN. The code followed for this test was BIS: 516 - 1959. Higher compressive strength correspond to better durability of the specimen. This test was conducted for specimens having curing age of 7, 14, 28 and 56 days. A set of three cubes were tested for each mix and the average value was considered.

Table 4. Compressive test results of three grades for both cases

Curing Age (days)	Compressive strength of M25 (N/mm^2)		Compressive strength of M30 (N/mm^2)		Compressive strength of M35 (N/mm^2)	
	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
7	24	25.77	25.54	34.22	33.77	38.22
14	27.55	29.12	31.96	35.56	38.67	44
28	31.95	35.89	39.38	42.2	46.2	46.67
56	38.23	39.68	43.56	45.67	49.3	50.2

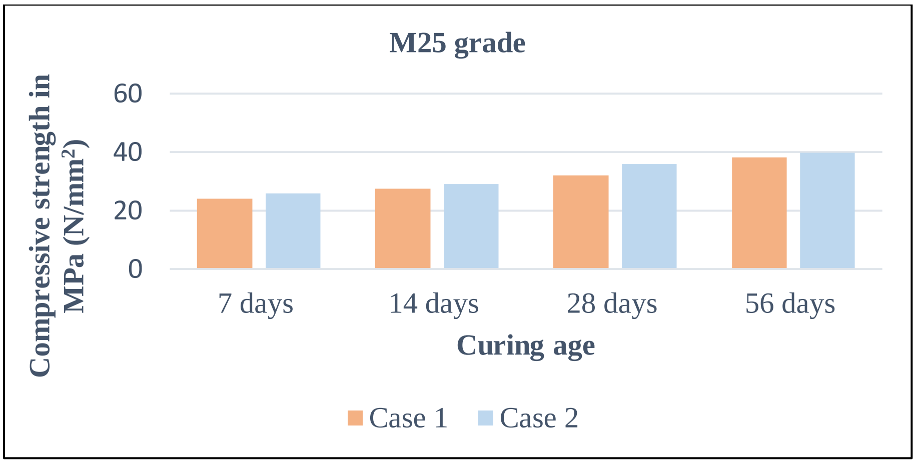

Figure 1. Compressive test results of M25

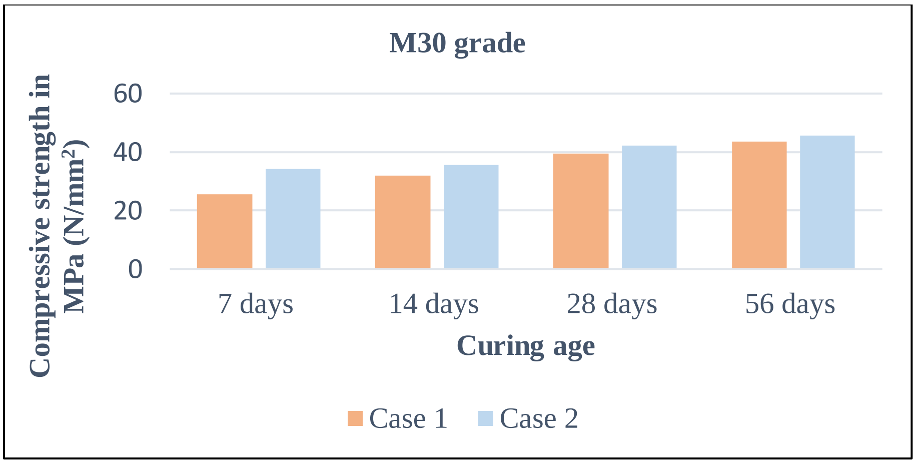

Figure 2. Compressive test results of M30

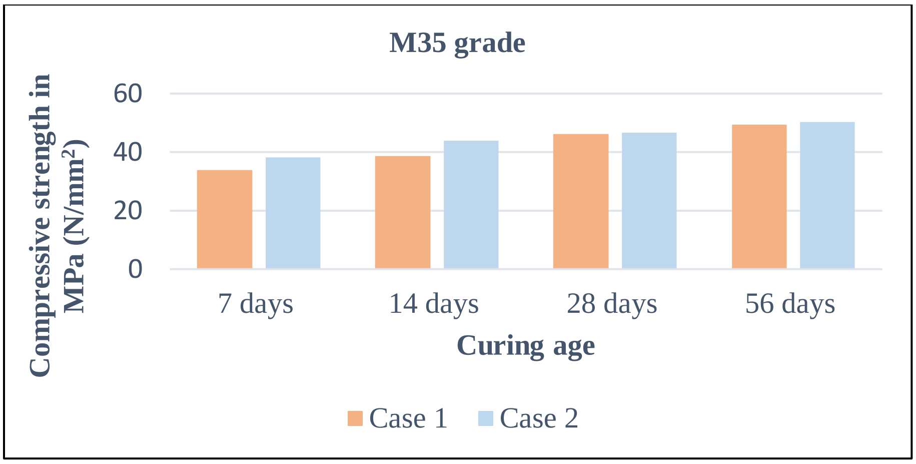

Figure 3. Compressive test results of M35

4.2. Flexural test

Flexural strength test was done on beam moulds. In this case the specimens were removed after 3 and 7 days curing and were subjected to a symmetrical two point loading with a loading rate of 7 Kg/sq cm/min. It is important to know the tensile strength of concrete since it is weak in tension. Tensile strength determines the load under which the cracking would develop. The absence of cracking is of considerable importance in maintaining the durability of concrete. The code followed for this test was again BIS: 516 - 1959.

Table 5. Flexural strength test results of three grades for both cases

Curing Age (days)	Flexural strength of M25 (N/mm^2)		Flexural strength of M30 (N/mm^2)		Flexural strength of M35 (N/mm^2)	
	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
3	5.61	5.72	5.69	5.71	6.34	6.39
7	6.74	7.31	6.235	7.6	7.97	8.06

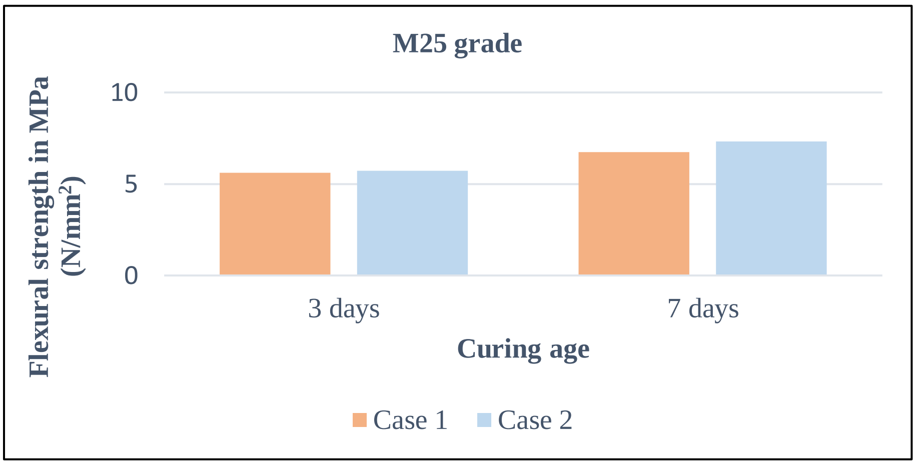

Figure 4. Flexural test results of M25

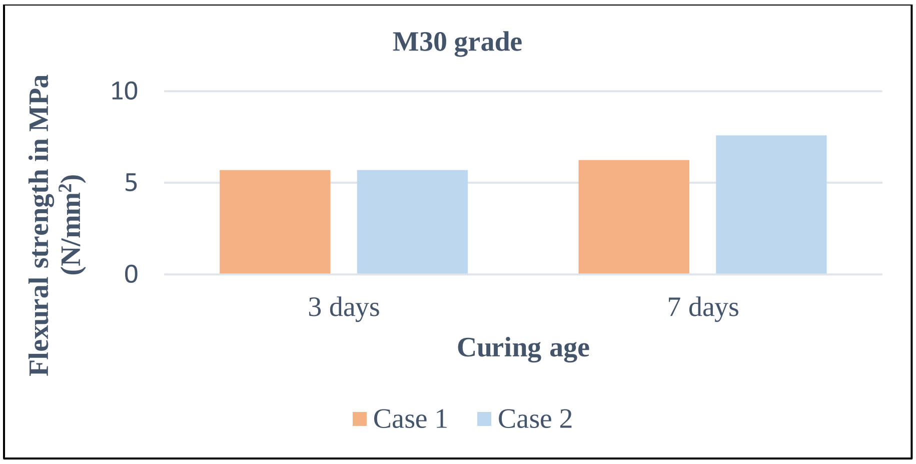

Figure 5. Flexural test results of M30

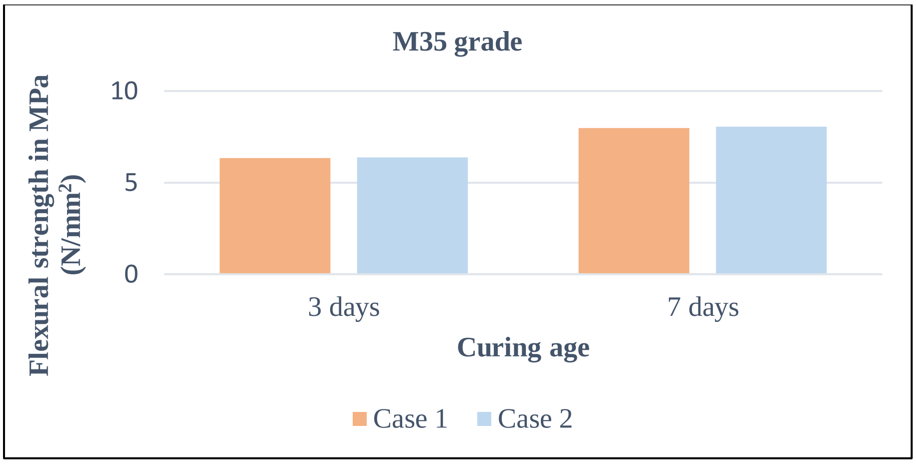

Figure 6. Flexural test results of M35

4.3. Split tensile test

Split tensile strength test was done on cylindrical moulds. In this case the specimens were removed after 7, 14 and 28 days curing. Using a special gear consisting of steel loading pieces (as per the codal provisions), the split tensile testing was done. These loading pieces were placed in compressive testing machine. The loading rate for the testing was 140 Kg/sq cm/min. The reason for calculating split tensile strength is similar to flexural testing. BIS: 5816 - 1999 was referred for this test.

Table 6. Split tensile strength test results of three grades for both cases

Curing Age (days)	Split tensile strength of M25 (N/mm^2)		Split tensile strength of M30 (N/mm2)		Split tensile strength of M35 (N/mm2)	
	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
7	2.652	2.758	2.865	3.183	2.865	3.819
14	2.971	3.077	3.183	3.501	4.297	4.138
28	3.395	3.607	3.819	4.138	4.35	4.562

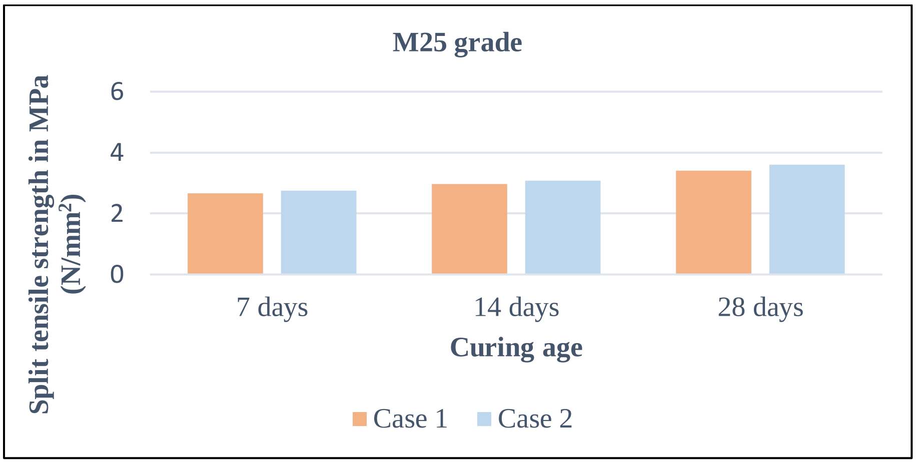

Figure 7. Split tensile test results of M25

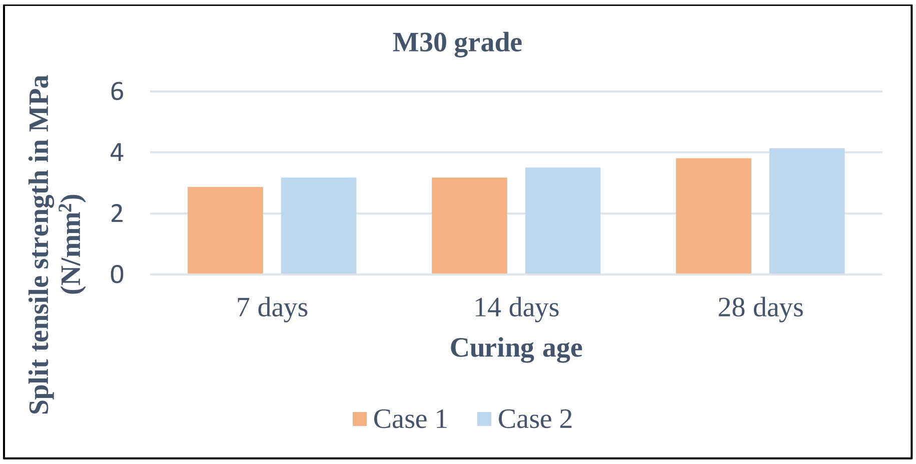

Figure 8. Split tensile test results of M30

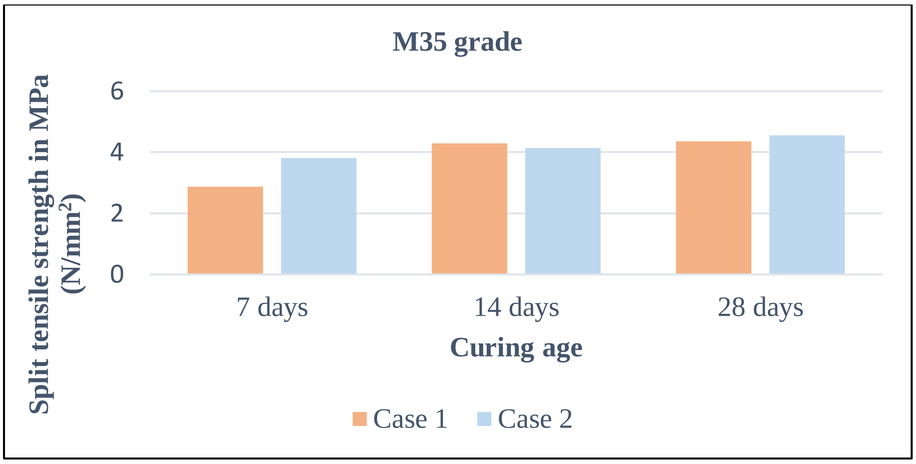

Figure 9. Split tensile test results of M35

5. Conclusions

The following conclusions were drawn from the experimentation work:

- The normal consistency of the composite cement paste for case 1 (OPC – 65%, Fly ash – 15% and GGBFS – 20%) had an increment of 6.45% as compared to case 2 (OPC – 85% and Fly ash – 15%).
- The initial setting time of case 1 was 5.88% more than case 2 and the final setting of case 2 was 3.37%. The reason for higher initial and final setting times for case 1 as compared to case 2 could be due to the presence of pozzolanic materials (35%).
- The admixture content used was optimum for their respective grades and cases. Not much segregation was observed in the SCC mixes.
- Since all the design mixes i.e., cases 1 and 2 of M25, M30 and M35, were categorized under V2 class for viscosity flow tests, from BIS: 10262 – 2019, it could be assumed that the mixes would be viscous with less segregation.
- As per the codal provisions for slump flow test, the concrete mixes were categorized under SF2 class. The code states that, these mixes could be used for normal concreting works.
- After analysing the results of flexural strength test and split tensile strength test, it can be concluded that, by replacing cement partially with fly ash and GGBFS in percentages mentioned in cases 1 and 2, the tensile strength of SCC could improve.
- From the 28 days results obtained from the compressive strength test, it can be inferred that cement can be partially replaced with 15% fly ash and 20% GGBFS for all the grades i.e., M25, M30 and M35. This, could help in reducing the dependency on cement, and utilising the industrial by-products in a better way.

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