# Sulfate resistance of self compacting concrete incorporating mineral admixtures

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**Abstract - –** *A self-compacting concrete (SCC) is the one that can be placed in the form and can go through obstructions by its own weight and without the need of vibration. SCC provides better quality especially in the members having reinforcement congestion or decreasing the permeability and improving durability of concrete.*

*Chemical attacks on concrete structures causes deterioration of structure and its durability is affected. Sulphate attack is one of the most common aggressive actions leading to the deterioration of concrete.*

*The scope of the work is to develop suitable mixes containing the mineral admixtures to satisfy the requirements of SCC using local aggregates and to determine the strength and durability of such concrete exposed to sulphate attack.*

*The study showed remarkable improvements in properties of self-compacting concrete by incorporation of mineral admixtures at various proportions and improved resistance against sulfate attack. Conclusions are drawn based on the experimental results.*

***Key Words***: Self compacting concrete, mineral admixtures, sulphate attack, partial replacement by mineral admixtures.

## 1. INTRODUCTION

Self Compacting Concrete was first developed in Japan in 1988 in order to achieve more durable concrete structures by improving the quality achieved in the construction process and the placed material.

Self-compactability is largely affected by the characteristics of materials and the mix proportions.

As per the EFNARC guidelines of mix design the main difference between the normal concrete and the self compacting concrete is the incorporation of mineral admixtures. Partial replacement of cement with mineral admixtures particularly industrial waste products such as fly ash, blast furnace slag and silica fume improves properties of concrete significantly and favorably.

In this study, Self compacting concrete Specimens are designed incorporating mineral admixtures at different combinations and tested for compressive strength and splitting tensile strength and the variations in their weight and strength are noted after accelerated attack of sodium sulfate solution with 15% concentration.

## 2. Experimental Program

**Materials:**

Self compacting concrete was made with the cement, manufactured sand, coarse aggregates, water and the mineral admixtures.

Cement: Ordinary Portland cement, 43 grade confirming to IS 8112:2013.

Fine aggregate: Locally available manufactured sand confined to grading zone II of IS: 383-1970.

Coarse aggregates: Locally available crushed granite stones confirming to graded aggregates of sizes 16mm down and 12.5mm down.

Mineral admixtures: ground granulated furnace slag from Jindal steel plant, Class F fly ash, and silica fume were used as mineral admixtures.

Chemical admixtures: Glenium B233 is used as super plasticizer.

**Mix design:**

Four types of mix proportions were carried out .

| | |
|---|---|
| Mix 1 Control mix | Self compacting concrete without any replacement to cement |
| Mix 2 | Replacement of cement with Silica fume 10%, GGBS 10%, Fly ash 30% |
| Mix 3 | Replacement of cement with Silica fume 10%,GGBS 20%, Fly ash 20% |
| Mix 4 | Replacement of cement with Silica fume 10%,GGBS 30%, Fly ash 10% |

Table 1 showing different mixes.

Mix design was prepared by Okumara method. The table 2 below shows the composition of SCC mixes.

| Mix | OPC Kg/m3 | GGBS kg/m3 | Fly ash kg/m3 | Silica fume kg/m3 | Fine aggregate kg/m3 | Coarse aggregate kg/m3 | Water kg/m3 |
|---|---|---|---|---|---|---|---|
| **Mix 1** | **595.3** | **0** | **0** | **0** | **819.6** | **766.85** | **189** |
| **Mix2** | **279.7** | **51.0** | **122.4** | **40.07** | **819.6** | **766.85** | **189** |
| **Mix3** | **279.7** | **102.0** | **81.6** | **40.07** | **819.6** | **766.85** | **189** |
| **Mix4** | **279.7** | **153.1** | **40.8** | **40.07** | **819.6** | **766.85** | **189** |

Table 2 showing composition of SCC mixes

**Test methods:**

**Fresh state Properties:** Slump flow test, T5o time funnel time ,L box test, U box test, J ring tests were performed for determining the workability properties of self compacting concrete to meet the EFNARC standards.

**Hardened tests:** The hardened properties investigated in this study are compressive strength tests and splitting tensile strength test. Compressive strength test was performed on (15x15x15) cm cubes where as tensile strength was assessed indirectly by the splitting test on cylinders.

**Sulfate attack:**

The sulfate attack test was performed by immersing the cubes and cylinder specimens in 15% sodium sulfate solution for 28 days after curing of 28 days in water. This type represents an accelerated testing procedure where the higher concentration than that exists in the field is used for accelerated testing. The resistance of concrete is evaluated by noting the change in strength and weight.

## 3. Test Results

## Fresh state Properties:

Table 3 shows the results of fresh properties of Self compacting concrete mixes.

| Mix | Slump flow in mm | *T50 time in seconds* | *V funnel time in seconds* | *L box ratio* | *U box (h2-h1) in mm* | *J ring h in mm* |
|---|---|---|---|---|---|---|
| ***Mix 1*** | **650** | **4.8** | **12** | **0.82** | **19** | **10** |
| ***Mix 2*** | **690** | **3.2** | **7.8** | **0.92** | **9** | **6** |
| ***Mix 3*** | **680** | **3.9** | **8.6** | **0.89** | **13** | **7** |
| ***Mix4*** | **675** | **4** | **10** | **0.85** | **16** | **8** |

Table 3 showing fresh properties of different mixes.

In terms of slump flow, all SCC mixes exhibited satisfactory slump flows in the range of 650-690 which is a sign of good deformability.

All the fresh concrete properties were in good agreement with the range of values given by EFNARC.

## Hardened state properties:

The strength parameters were studied through compressive strength and split tensile strength.

Among the mixes, the strength in blended combination of OPC replacement with 30% GGBS, 10% FA, 10% SF is found higher than other blended combinations where as it is lesser for the control mix. The early age strength is lesser or marginally higher when compared to the control mix whereas strength exceeded at later stages for the blended mixes

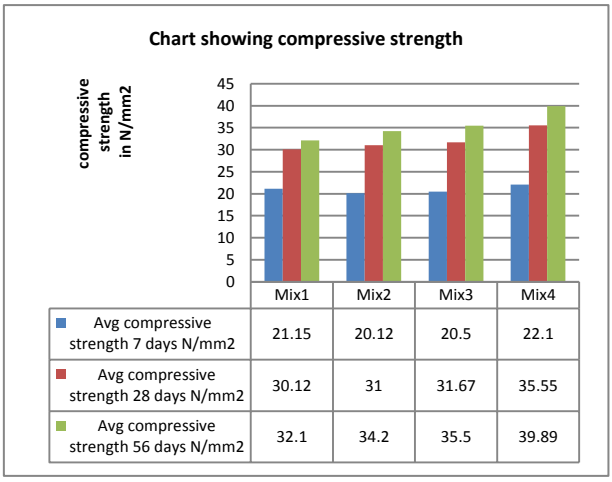


Chart 1 showing compressive strengths at various ages.

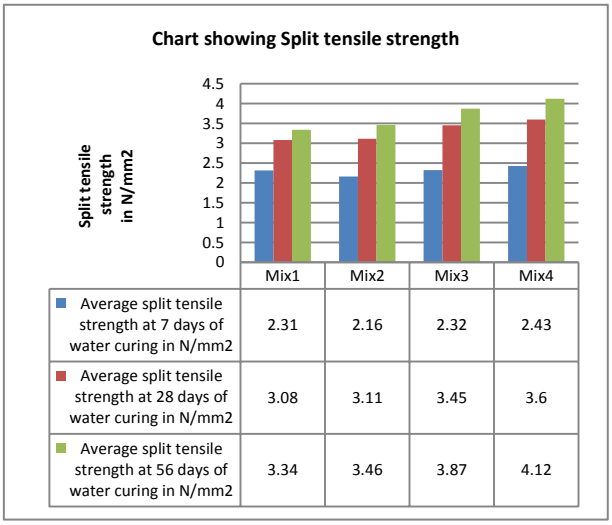


Chart 2 showing Split tensile strengths at various ages.

### Sulfate attack:

Surface deterioration was not clearly identifiable on the concrete specimens immersed in 15% sodium sulphate solution. No change in length was observed. Light whitish deposits were seen on the surface of the specimens.

When subjected to continuous exposure to sulfate all the specimens showed increase in weight. The gain in weight for Mix 1 were in the range of 0.3 and 0.38% for cubes and cylinders .Similarly the gain in weight for mix 2, 3 and 4 were 0.18 and 0.26%, 0.25 and 0.23%,0.12 and 0.19 % respectively for cubes and cylinders.

Table 4 gives the percentage weight gain for the 4 mixes after immersing in 15% $Na_2SO_4$ solution for 28 days.

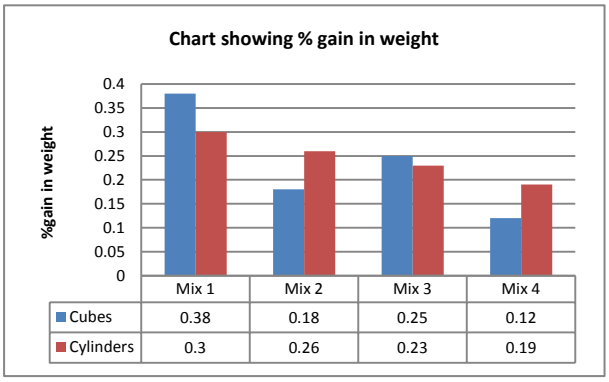


Chart 3 showing change in weight after 28 days of immersion in sodium sulfate solution

Chart 4 and 5 gives the percentage gain in compressive and splitting tensile strength gain after immersing in 15% $Na_2SO_4$ solution for 28 days after initial water curing for 28 days

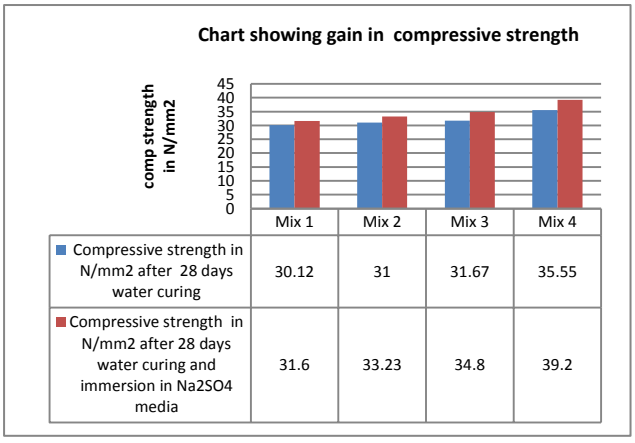


Chart 4 Percentage gain in compressive strength after 28 days sulfate exposure

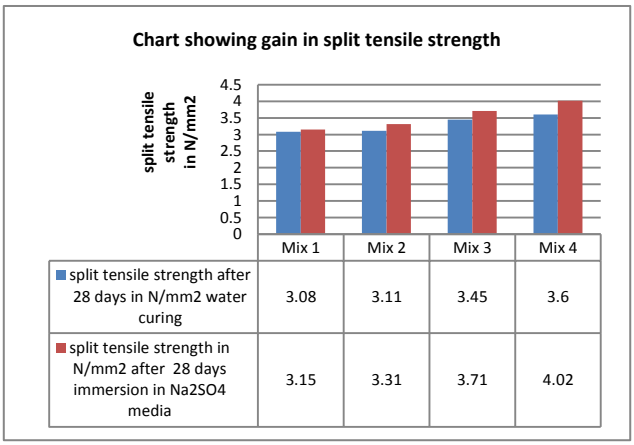


Chart 5 Percentage gain in split tensile strength after 28 days sulfate exposure

All concrete specimens showed increase in strength when compared to 28 days water cured specimens. The percentage gain in compressive strength were 4.91, 7.19, 9.88 and 10.27% respectively for mix1, mix2, mix3 and mix4. The percentage gain in splitting tensile strength was 2.27, 6.43, 7.53 and 11.66 % respectively for mix1, mix2, mix3 and mix4.

When compared to water cured specimens of same age there was decrease in both compressive and split tensile strengths as shown in the chart below.

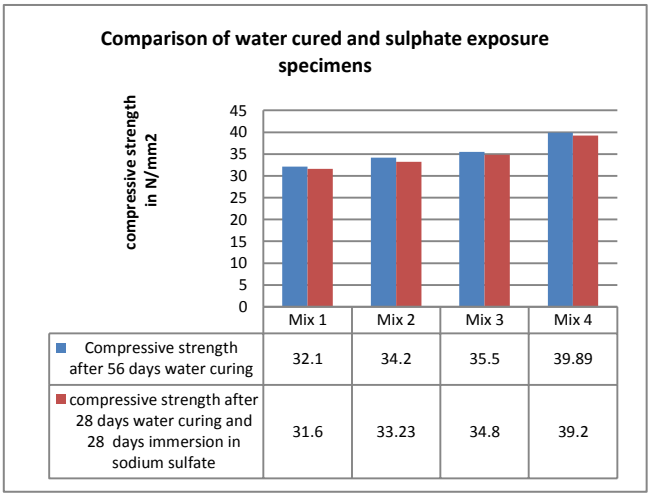


Chart 5 showing comparison of compressive strengths of specimens of same ages.

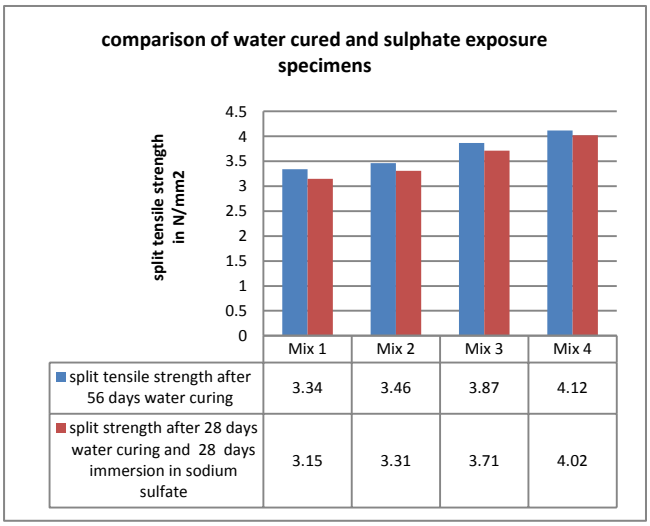


Chart 6 showing comparison of splitting tensile strength of specimens of the same ages.

## 4. Conclusions

The following conclusions were drawn from the investigations.

- ❖ All the mix proportions developed satisfied the requirements of self compacting concrete specified by EFNARC.
- ❖ From the experiments it is noticed that the blended mixes with mineral admixtures of silica fume, GGBS and fly ash showed higher workability compared to mix with 100% cement.
- ❖ It was observed that 28 days strength of blended mixes was higher when compared to control mix. The enhancement of strength may be due to increased pozzolonic reaction and synergetic effect of various admixtures used.
- ❖ Among the blended concrete mixes, Mix 4, OPC replacement with 30% GGBS,10% FA,10% SF showed higher strength when compared to combinations where as it was lesser for the control mix.

Sulphate attack on SCC Specimens:

- ❖ Surface deterioration was not clearly identifiable by visual examination of the concrete specimens immersed in 15% sodium sulphate solution. Light whitish deposits were seen on the surface of the specimens.
- ❖ It was observed that the all the specimens had shown marginal increase in mass when exposed to sulphate for 28 days after initial curing of 28 days. This may be due to deposition of reaction products such as ettrignite and gypsum which possess more volume and densification of microstructure.
- ❖ From the experiment it is found that, all SCC specimens showed increase in compressive, split tensile strength when subjected to sulphate exposure for 28 days after initial water curing for 28 days. The increase in strength may be attributed to two types of reactions:
  - The continuous hydration of cement components to form more hydration products, in addition to the reaction mineral admixtures with the free lime to form more C-S-H leading to increased strength.
  - Reaction of sulphate ions with hydrated cement components to form gypsum and etrignite .
- ❖ Loss in strength was observed when 56 days water cured specimens are compared with specimens of 28 days water cures and 28 days sulphate exposed specimens.
- ❖ The mix4 with OPC replacement by 10% Silica fume, 20%Flyash and 30%GGBS showed higher strength gain after 28 days of exposure to sulphate.
- ❖ Mixes with Higher percentages of GGBS showed better sulphate resistance.

## BIOGRAPHIES

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