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# Effect of Admixtures on Durability of Self-Compacting Concrete

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***Abstract*: Self-Compacting Concrete is an innovative concrete that does not require vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in present of congested reinforcement. One of the disadvantage of self-compacting concrete is its cost, associated with the use of high volumes of Portland cement and use of chemical admixtures. One alternative to reduce the cost of self-compacting concrete (scc) is the use of mineral admixtures such as fly ash, calcite, ground granulated blast furnace slag and micro silica, which is finely, divided material added to concrete during mixture procedure. When mineral admixtures replace a part of Portland cement, the cost of self-compacting concrete will be reduced especially if the mineral admixture are waste or industrial by-product. The lower water content of the concrete leads to higher durability, in addition to better mechanical integrity of the structure. This paper presents an experimental investigation on strength aspects like compressive and flexural strength of self-compacting concrete (SCC) containing different mineral admixtures, workability tests by slump flow, T50cm slump flow, V-funnel, V-funnel at T5min. and J-ring test. and the durability of concrete by pH test for different mineral admixtures are carried out. About 20% fly ash and 0%,10%,15% calcite are used as a partial replacement for cement.**

***Keywords*: Self-Compacting Concrete(SCC), Durability, Workability, Fly ash, Calcite.**

## 1. Introduction

Self-compacting concrete (SCC) is an innovative concrete that does not require vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. The hardened concrete is dense, homogeneous and has the same engineering properties and durability as traditional vibrated concrete. The powder content present in the self-compacting concrete is relatively higher than the other type of concrete and also fine aggregate to course aggregate ratio is more in it. In several studies it is seen that use of mineral additives have been widely replace form Ordinary Portland cement in many applications because of its effective properties which include cost-reduction, reduction in heat evolution, decreased permeability, increased chemical resistance and requirement of cement becomes less than other concrete. Self-compacting concrete offers a rapid rate of concrete placement, with faster construction times and ease of flow around congested reinforcement. The fluidity and segregation resistance of SCC ensures a high level of homogeneity, minimal concrete voids and uniform concrete strength, providing the potential for a superior level of finish and durability to the structure. SCC is often produced with low water-cement ratio providing the potential for high early strength, earlier demoulding and faster use of elements and structures. The elimination of vibrating equipment improves the environment on and near construction and precast sites where concrete is being placed, reducing the exposure of workers to noise and vibration. The improved construction practice and performance, combined with the health and safety benefits, make SCC a very attractive solution for both precast concrete and civil engineering construction.

### *A. Fly ash*

Fly ash, the fine particulate waste material produced by pulverized coal-based thermal power station, is an environmental pollutant, it has a potential to be a resource material. It is nowadays used in cement, concrete and other cement based application in India. The use of fly ash as concrete admixture not only to extend technical advantage to the properties of concrete but also contribute to the environmental pollution control. High fineness, good reactivity, low carbon content are essence of good ash. Since fly ash is produced by rapid cooling and solidification of molten ash, a large portion of component comprising fly ash particles are in amorphous state. One of the significant characteristics of fly ash is the spherical form of the particles. This shape of particle increases the flow ability and reduces the water demand.

Fig. 1. Fly ash sample

### *B. Calcite*

Calcite is a rock-forming mineral with a chemical formula of $CaCO_3$. It is extremely common and found throughout the world in sedimentary, metamorphic, and igneous rocks. Some geologists consider it to be a "ubiquitous mineral" one that is found everywhere. The properties of calcite make it one of the most widely used minerals. Calcite as Limestone and Marble Limestone is a sedimentary rock that is composed primarily of calcite. It forms from both the chemical precipitation of calcium carbonate and the transformation of shell, coral, fecal and algal debris into calcite during diagenesis. Limestone also forms as a deposit in caves from the precipitation of calcium carbonate. Marble is a metamorphic rock that forms when limestone is subjected to heat and pressure. A close examination of a broken piece of marble will usually reveal obvious cleavage faces of calcite. The size of the calcite crystals is determined by the level of metamorphism. Marble hat has been subjected to higher levels of metamorphism will generally have larger calcite crystals. Calcium carbonate is naturally inorganic material widely available in the form limestone, chalk or marble. Calcium carbonate is obtained from its various natural mineral bases by processing and mining. Calcium carbonate powder can also be created from the reaction of carbon dioxide with calcium hydroxide. Calcium carbonate is the filler material improves the hydration rate of cement compound and consequently increase the strength at early ages. It don't have any pozzolonic properties but it react with alumina phases to form calcium monocaboaluminate hydrate (Afm) phase to change in strength of concrete. A beneficial influence of powder calcite on sulphate resistance. Calcite affect not only the permeability of concrete but also the chemical structure of paste in concrete. Calcite control the bleeding of concrete with low cement content and low susceptibility of the lack curing.

Fig. 2. Calcite sample

## 2. Aim & objective

- *Aim:* To study the effect of admixture on durability of self-compacting concrete.
- *Objective:* To improve the Workability of concrete.

1. To check the effect of water cement ratio on Workability.
2. To check the effect of admixture cement ratio on Workability.

To improve the durability of concrete.

## 3. Characteristics of material

*A. Cement*

Fineness – 9%
Normal consistency – 29.5%
Specific gravity – 2.93
Soundness – 4
Compressive strength at 3 days – 34.98 Mpa
Compressive strength at 3 days – 45.27 Mpa
Compressive strength at 3 days – 58.05 Mpa

*B. Coarse aggregate*

Specific gravity – 2.85
Fineness modulus – 7.50
Water absorption – 0.81%

*C. Fine aggregate*

Specific gravity – 2.64
Fineness modulus – 2.4
Water absorption – 0.8%

*D. Fly ash*

Table 1
Characteristics of fly ash

| Test Conducted | Test Result | Requirement as per IS3812 (part I)-2003 |
|---|---|---|
| Consistency (%) | 27.5 | - |
| Specific gravity | 2.2 | - |
| Initial setting time (min.) | 55 | - |
| Final setting time (min) | 225 | - |
| Soundness test (mm) by Autoclave expansion method (%) | -0.0516 | Max. 0.8 |
| Fineness % by weight by sieving (% retained on 45 micron sieve) | 45.55 | Not more than 34 |

*E. Calcite*

Table 2
Characteristics of Calcite

| Grade | 10 Micron (un-coated) |
|---|---|
| Appearance | Super fine powder |
| Colour | White and Bright |
| Whiteness | 97% |
| Residue (45 Micron Sieve) | 0.01% |
| %CaCO3 | 99.00% |
| %MgCO3 | 0.30% |
| %Fe2O3 | 0.01% |
| %HCL insoluble matter | 03 Max |
| Moisture | 0.5 Max |
| Oil absorption (ISO 787/5) | 17 g/100g |
| Ph (10% Soln.) | 9 |

## 4. Procedure for mix design

A procedure for efficiently designing SCC mixes is shown below. It is based on a method developed by Okamura. It is important to appreciate that this method may result in parameters.

The sequence is determined as follow.

*A. Defining desired air content*

Air content may generally be set at 1 per cent, or a higher value specified when freeze thaw resistant concrete is to be designed.

*B. Determination of coarse aggregate volume*

Coarse aggregate volume is defined by bulk density. Generally coarse aggregate content should be between 50 per cent and 60 per cent. When the volume of coarse aggregate in concrete exceeds a certain limit, the opportunity for collision or contact between coarse aggregate particles increases rapidly and there is an increased risk of blockage when the concrete passes through spaces between steel bars. The optimum coarse aggregate content depends on the following parameters-

- Maximum aggregate size. The lower the maximum aggregate size, the higher the proportion of coarse aggregate.
- Crushed or rounded aggregates. For rounded aggregates, a higher content can be used than for crushed aggregates.

### *C. Determination of sand content*

Sand, in the context of this mix composition procedure is defined as all particles larger than 0.125 mm and smaller than 4 mm. Sand content is defined by bulk density. The optimal volume content of sand in the mortar varies between 40 – 50% depending on paste properties.

### *D. Design of paste composition*

Initially the water powder ratio for zero flow (βp) is determined in the paste, with the chosen proportion of cement and additions. Flow cone tests with water/powder ratios by volume of e.g. 1.1, 1.2, 1.3 and 1.4 are performed with the selected powder composition for typical results. The point of intersection with the y - axis is designated the βp value. This βp value is used mainly for quality control of water demand for new batches of cement and fillers.

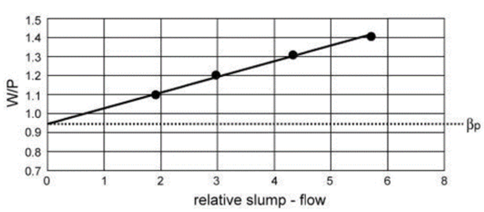


Fig. 3. Relative slump flow

### *E. Determination of optimum volumetric water/powder ratio and super plasticizer dosage in mortar:*

Tests with flow cone and V-Funnel for mortar are performed at varying water/powder ratios in the range of [0.8 – 0.9]. βp and dosages of super plasticizer. The super plasticizer is used to balance the rheology of the paste. The volume content of sand in the mortar remains the same as determined above. Target values are slump flow of 24 to 26 cm and V-Funnel time of 7 to 11 seconds. At target slump flow, where V-funnel time is lower than 7 seconds, then decrease the water/powder ratio. For target slump flow and V-funnel time in excess of 11 seconds, water/powder ratio should be increased. If these criteria cannot be fulfilled, then the particular combination of materials is inadequate. A trial with a different super plasticizer is the preferred alternative.

## 5. Testing and analysis

Following are the some short for different mixes of M50 Grade of self-compacting concrete.

Mix-A - without replacing by admixtures.

Mix-B - Cement replacing by 10% Calcite + 20% fly ash

Mix-C - Cement replacing by 15% Calcite + 20% fly ash

*Workability :* Workability is property of freshly mixed concrete or mortar that determines the ease with which it can be mixed, placed, consolidated and finished to a homogenous condition.

Fig. 4. slump flow test

Fig. 5. J-ring test

Fig. 6. V-Funnel test

### *A. Workability test result*

Table 3
Workability of SCC

| S. No. | Workability Test | Mix Designation | | | | Accepted Value as Per EFNARC | |
|---|---|---|---|---|---|---|---|
| | | Unit | Mix-A | Mix-B | Mix-C | Min. | Max. |
| 1 | Slump Flow | mm | 690 | 705 | 720 | 650 | 800 |
| 2 | $T_{50cm}$ Slump Flow | Sec | 3.25 | 3.11 | 2.93 | 2 | 5 |
| 3 | J-Ring | mm | 8.75 | 6.25 | 5.25 | 0 | 10 |
| 4 | V-Funnel | Sec | 11 | 10.87 | 10.33 | 6 | 12 |
| 5 | V-Funnel at $T_{5min.}$ | Sec | 13 | 12.30 | 12.15 | 0 | +3 |

*B. Compressive Strength Test Result on Hardened Concrete of Self-Compacting Concrete*

*Observation of Compressive Strength:*

Table 4
Compressive strength test result

| Type of concrete Mix | 7 Days ($N/mm^2$) | 14 Days ($N/mm^2$) | 28 Days ($N/mm^2$) |
|---|---|---|---|
| Mix-A | 35.92 | 46.96 | 56.22 |
| Mix-B | 34.70 | 48.14 | 59.33 |
| Mix-C | 34.22 | 49.30 | 61.48 |

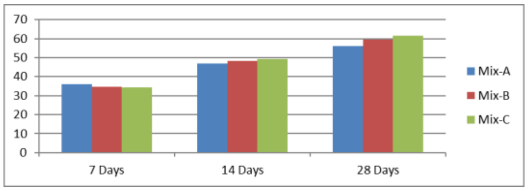


Fig. 7. Comparison of average compressive strength

*Discussion:* As per the requirement of IS code the Flexural Strength of concrete is 10% of the compressive strength result.

*C. Flexural Strength Test Result of Self-Compacting Concrete*

*Observation of Flexural Strength:*

Table 5
Flexural strength test result

| Type of concrete Mix | 7 Days ($N/mm^2$) | 14 Days ($N/mm^2$) | 28 Days ($N/mm^2$) |
|---|---|---|---|
| Mix-A | 3.50 | 4.22 | 6.16 |
| Mix-B | 3.36 | 4.34 | 6.50 |
| Mix-C | 3.32 | 4.43 | 6.73 |

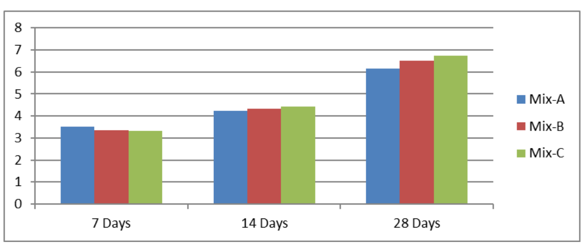


Fig. 8. Comparison of average flexural strength

*D. $P^H$ Test Result of Self-Compacting Concrete*

Fig. 9. $P^H$ test result

*Observation of pH test:*

Table 6
pH test results

| Type of concrete Mix | $P_h$ |
|---|---|
| Mix-A | 11.19 |
| Mix-B | 11.51 |
| Mix-C | 11.71 |

## 6. Conclusion

As the three different self-compacting concrete mix design for M-50 grade are prepared using 0%, 20% fly ash and 0%, 10%, 15% calcite proportions following points are concluded.

- In self-compacting concrete replacement of mineral admixture with cement is increase the powder content in concrete.
- At the water/cement ratio of 0.35, Slump flow test, $T_{50cm}$ Slump flow test, V-funnel test, V-funnel at $T_{5min}$ test, J-ring test results were found to be satisfactory, i.e. passing ability, filling ability and segregation resistance are well within the limits.
- As the increasing percentage of calcite from 0-15 and fly ash constant at 20 percent, the Slump flow test, $T_{50cm}$ Slump flow test, V-funnel test, V-funnel at $T_{5min}$ test, J-ring test of workability for self-compacting concrete are increasing because increase in powder content in concrete.
- The earlier test results of 7 days for Mix-B and Mix-C are lower than mix-A, because of siliceous material present in fly ash that react with calcium hydroxide to form a cement this pozzolonic process takes time to gain strength.
- From an experimental investigation it was observed that compressive strength of Mix-C which contain 20% fly ash and 15% calcite gain better strength than other mixes.
- According to tested results for self-compacting concrete of flexural strength are gradually increase for Mix-C which contain 15% calcite and 20% fly ash are better than other mixes.
- The SCC with various Partial replacement of cement by Fly Ash and Calcite Shows that the 20% replacement of Fly Ash, 15% replacement of Calcite shows maximum durability factor.
- It may be said that although fly ash and calcite are industrial waste, there use in concrete significantly improve the long term strength and durability and reduce heat of hydration. In other words, fly ash and calcite will be an indispensable mineral admixture for self-compacting concrete.

## 7. Future scope

The following experiments can be conducted in future with respect to self-compacting concrete.

- The use of different admixture in self-compacting concrete which help to reduce cost of construction.
- We can increase percentage of calcite and fly ash to check strength and durability of self-compacting concrete.
- The other hardened concrete tests such as split tensile, rapid chloride penetration and water absorption can also be done.

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