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Experimental investigation on self-compacting concrete by using fly ash

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ABSTRACT

Self-compacting concrete is a fluid mixture suitable for placing in structures with congested reinforcement without vibration. Self-compacting concrete development must ensure a good balance between deformability and stability. Also, compactibility is affected by the characteristics of materials and the mix proportions; it becomes necessary to evolve a procedure for mix design of SCC. The paper presents an experimental procedure for the design of self-compacting concrete mixes. The test results for acceptance characteristics of self-compacting concrete such as slump flow; J-ring, V-funnel and L-Box are presented. Further, compressive strength at the ages of 7, 14, and 28 days was also determined and results are included here. For SSC, it is generally necessary to use superplasticizers in order to obtain high mobility. Adding a large volume of powdered material or viscosity modifying admixture can eliminate segregation. The powdered materials that can be added are fly ash, silica fume, lime stone powder, glass filler and quartzite filler. Since, self-compactability is largely affected by the characteristics of materials and the mix proportions, it becomes necessary to evolve a procedure for mix design of SCC.

Keywords: *Self-compacting Concrete, Fly ash, Silica fume, Mix Design, Fresh Properties, Hardened Concrete Properties, Compressive Strength.*

1. INTRODUCTION

Today concrete is most widely used construction material due to its good compressive strength and durability. Depending upon the nature of work cement, fine aggregate, coarse aggregate and water are mixed in specific proportions to produce plain concrete. To make durable concrete structures, sufficient compaction is required. The use of self-compacting concrete (SCC) is spreading worldwide because of its very attractive properties in the fresh state as well as after hardening. The use of SCC will lead to a more industrialized production, reduce the technical costs of in situ concrete constructions, improve the quality, durability and reliability of concrete structures and eliminate potential for human error.

Self-Compacting Concrete (SCC) is a new generation concrete, which has generated tremendous interest since its initial development in Japan by Okamura [1] in the late 1980's in order to reach durable concrete structures. SCC has gained wide use for placement in congested reinforced concrete structures with difficult casting conditions. For such applications, fresh concrete must possess high fluidity and good cohesiveness. SCC is considered as a concrete which can be placed and compacted under its self-weight with little or no vibration effort, and which is at the same time, cohesive enough to be handled without segregation or bleeding. It is used to facilitate and ensure proper filling and good structural performance of heavily reinforced structural members. SCC development is a desirable achievement in the construction industry in order to overcome problems associated with cast-in-place concrete. SCC is not affected by the skills of workers, the shape and amount of reinforcing bars or the arrangement of a structure and, due to its high-fluidity and resistance to segregation it can be pumped longer distances.

The main advantage of SCC is to shorten construction period and to assure compaction in the structures especially in the confined zones where vibration and compaction is difficult.

1.1 Advantages of SCC

- It eliminates noise due to vibration.
- It provides high stability during transport and placement.
- It provides uniform surface quality and homogenous.
- It provides greater freedom for design
- It is useful for casting of underwater structures.

1.2 Development of SSC

The main motive for development of SCC was the social problem on durability of concrete structures that arose around 1983 in Japan. Due to a gradual reduction in the number of skilled workers in Japan's construction industry, a similar reduction in the quality of construction work took place.

1.3 Mechanism for achieving SCC

The method for achieving SCC involves not only high deformability of paste or mortar, but also resistance to segregation between coarse aggregate and mortar when concrete flows through the confined zones of reinforcing bars. Okamura [1] and Ozawa [2] have employed the following methods to achieve self-compactability.

- Limited aggregate content.
- Low water-powder ratio.
- Use of super plasticizer.

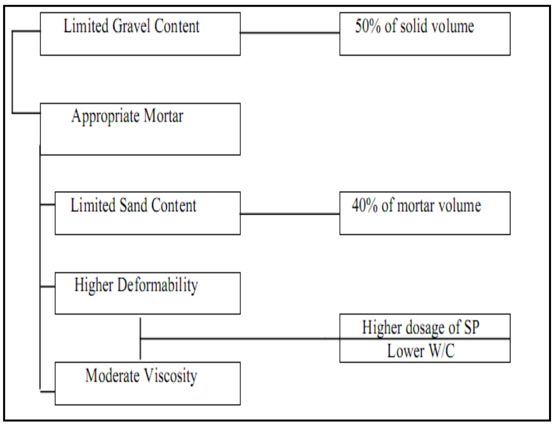

Fig 1 Methods for achieving Self Compactability

1.4 Composition of SCC

SCC is a fluid mixture, which is suitable for placing in difficult conditions and in structures with congested reinforcement, without vibration. In principle, a self-compacting or self-consolidating concrete must:

- Have a fluidity that allows self-compaction without external energy,
- Remain homogeneous in a form during and after the placing process, and
- Flow easily through reinforcement.

2. EXPERIMENTAL STUDY

2.1 GENERAL

The program consisted of casting and testing 60Mpa Self-Compacting and self-curing Concrete. The dosage of super plasticizer was kept at 0.5%, 1.0%, 1.5% & 2.0%.Based on studies available in the literature. Therefore optimum dosage of superplasticizer at 1.1% to achieve required fresh properties of SCC. Self-curing compound poly ethylene glycol-600 of different dosages 0%, 0.5%, 1.0% and 1.5% was added to high strength SCC. A total of 60 cube specimens were casted.12 cubes were casted in each proportion and tested after 7, 14, 21 and 28 days, all 12 cubes in each batch are used for taking weight loss at 3,7,14,21 and 28 days.

2.2 MIX DESIGN

The mix design methodology adopted was modified Nan Su method. The details of the specimens cast is shown in table 1 and 2.

Table 1 Details of Cubes casted

S. No	MIX Designation	Dosage of PEG-600	No. of Cubes casted and tested at days of curing				
			7 DAYS	14 DAYS	21 DAYS	28 DAYS	TOTAL
1	B-0(W)	0	3	3	3	3	12
2	B-0(I)	0	3	3	3	3	12
3	B-0.5	0.5	3	3	3	3	12
4	B-1.0	1	3	3	3	3	12
5	B-1.5	1.5	3	3	3	3	12

Table: 2 Details of Cylinders & Prisms casted

S. No	MIX Designation	Dosage of PEG-600	No. of Cylinders casted and tested at age of curing	No. of Prisms casted and tested at age of curing
			28 DAYS	28 DAYS
1	B-0(W)	0	3	3
2	B-0(I)	0	3	3
3	B-0.5	0.5	3	3
4	B-1.0	1	3	3
5	B-1.5	1.5	3	3

3. MATERIALS USED

- **Cement**
  The cement used in the investigation was 53 Grade Ordinary Portland cement confirming to IS: 12269[19]. The specific gravity of cement was 3.14 and specific surface area of 225 m^2/g having initial and final setting time of 40 min and 560 min respectively.
- **Fine aggregates**
  The fine aggregate that falls in zone-II conforming to IS 383-1970 was used. The fine aggregate used was obtained from a nearby river coarse**.** The sand obtained from quarry was sieved through all the sieves (i**.e.** 4.75mm, 2.36mm, **1.1**8mm, 600µ, 300µ and **1**50µ). Sand retained on each sieve was filled in different bags and stacked separately for use. To obtain zone- II sand correctly, sand retained on each sieve is mixed in appropriate proportion.
- **Coarse Aggregate:** Crushed granite was used as coarse aggregate. The coarse aggregate was obtained from a local crushing unit having 20mm nominal size, well graded aggregate according to IS: 383.The specific gravity was 2.8, while the bulk density was 1487 kg/m^3. The coarse aggregate used is from a local crushing unit having 20mm nominal size. 20mm well-graded aggregate according to IS-383 is used in this investigation. The coarse aggregate procured from quarry was sieved through all the sieves (i.e. 20mm, 16mm, 12.5mm. 10mm and 4.75mm). The material retained on each sieve was filled in bags and stacked separately. To obtain 20mm well-graded aggregate, coarse aggregate retained on each sieve is mixed in appropriate proportions.
- **Mineral admixtures**
  a) Fly ash
  Fly ash is a by-product obtained during the process of combustion of pulverized coal in electric power generating plants. Fly ash produced from Meenakshi thermal power plant.

  b) Silica fume

  The silica fume was used in this experiment conforms to ASTM C 1240 and IS 15388:2003 [8]. The silica fume is in white colour powder form. Silica fume has been procured from Astra chemicals Ltd-Chennai.

4. CALCULATION

4.1 Coarse aggregate and Fine aggregate

The content of fine and coarse aggregates can be calculated as follows (Eqs. (1) and (2))

$$W_{ca} = PF * W_{lca} * (1 - \frac{s}{a}) \quad (1)$$

$$W_{fa} = PF * W_{lfa} * \frac{s}{a} \quad (2)$$

Where,

W_{ca}= Content of coarse aggregates in SCC (kg/m^3);

W_{fa}= Content of fine aggregates in SCC (kg/m^3);

W_{lca}= Unit volume mass of loosely piled saturated surface-dry coarse aggregate in air (kg/m^3);

W_{lfa}=Unit volume mass of loosely piled saturated surface-dry fine aggregates in air (kg/m^3);

PF = Packing factor;

$\frac{s}{a}$ = volume ratio of fine aggregates to total aggregates.

4.2 Calculation of Cement Content

To secure good flowability and segregation resistance, the content of binders (powder) should not be too low. According to the ‘‘Guide to Construction of High Flowing Concrete’’, the minimum amount of cement to be used for producing normal concrete and the high durability concrete are 270 and 290 kg/m3, respectively.

However, too much cement used will increase the drying shrinkage of SCC. Generally, HPC or SCC used in Taiwan provides a compressive strength of 20 psi (0.14 MPa)/kg cement. Therefore, the cement content to be used is (Eq. (3)):

$$C = \frac{f_c{}'}{0.14} \quad (3)$$

Where, C= cement content (kg/m3); f’c= designed compressive strength (MPa).

4.3 Water content required by Cement

The relationship between compressive strength and water/cement ratio of SCC is similar to that of normal concrete. The water/cement ratio can be determined according to ACI 318 or other methods in previous studies. The content of mixing water required by cement can then be obtained as follows (Eq. (4)):

$$W_{wc} = W/C * C \quad (4)$$

Where, W_{wc} = content of mixing water content required by cement (kg/m3);

W/C = water/cement ratio by weight, which can be determined by compressive strength.

5. CONCLUSIONS

- All the mixes fresh properties values are nearer to range of EFNARC [6] specifications.
- The Fresh Properties of SCSCC were more reliable and satisfied values as per EFNARC [6] specifications at a dosage of 1.1% of Super plasticizer with 0.5% of PEG-600.
- Hence the optimum dosage of Super Plasticizer compressive strength point view of SCC is 1.1%.
- After 7 days, weight loss rate is considerably decreased in the mixes B-0.5 and B-1.0 compared to other mixes.
- After 28 days, Percentage weight loss is minimum in the mix B-0.5 than other mixes.
- This is attributed due to low water cement ratio or better sealing capacity of PEG-600. So, it is concluded that the optimum dosage of SCC specimens with PEG-600 is 0.5%.
- The capillarity suction of water is increasing with increase in percentage dosage of PEG-600. Optimum dosage of PEG-600 is B-0.5 among other mixes.
- At 7 days curing, SCC with PEG-600 of 0.5% (B-0.5) shown maximum compressive strength compared with other mixes of PEG used specimens. But this compressive strength less than B-0 (W). It is concluded that B-0.5 achieved better earlier strength.

- At 28 days curing, SCC with PEG-600 of 0.5% (B-0.5) shown maximum compressive strength compared with other mixes of PEG used specimens. But this compressive strength reached the wet curing specimens strength.
- It imports that better filling ability, less porosity and hence better hydration, which leads to better formation of C-S-H gel, due to this gain more strength.
- The compressive strength of B mixes was increases up to optimum dosage of Self curing compound and then decreases.

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