Advanced performance of fly ash co-mixtured self-compacting concrete

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Abstract. The enormous production of CO2 as a by-product of cement manufacturing results in heavy environmental pollution, and needs to be checked suitably. Accordingly, the present work was aimed at conducting an experimental research towards the use of partial replacement of cement by fly ash and use of suitable super plasticisers as admixture in producing the most appropriate self-compacting concrete as well as thoroughly studying its effects on the properties of such a concrete in fresh condition. Different percentages of replacement ranging from 5 to 35% were adopted and European Federation of National Associations Representing for Concrete (EFNARC) was followed for mix designing purpose. Various relevant tests were conducted on the plasticity properties on such concrete samples with varying percentage of fly ash to work out optimum and effective mix for SCC. Important tests such and ultra sound pulse velocity (USPV), water absorption, drying shrinkage along with slump tests were carried out. Although there exists a close approximation between the performance of the various mixes, but 30% replacement of cement content by fly ash was found to be the most suitable mix for a concrete mixture with high workability and flow ability vital for SCC.

Keywords: self-compacting concrete, Compaction, Fly ash, Fresh properties, Compressive strength.

1. Introduction
Concrete being a versatile and low cost construction material is, therefore used most widely for civil engineering projects, thus playing an important role in the construction industry world over. However, use of concrete for civil construction works in extremely large quantities is also associated with several problems, namely, emission of carbon-di-oxide (i.e. through manufacturing of cement), depleting natural river sand and difficulties in achieving desired compaction required for its efficient performance etc. Most of these problems can be solved by partially replacing cement with some other cementitious material like fly ash [1-9]. Self-compacting concrete is an extremely fluid mixture that can flow very easily within and around the densely reinforced members. It does not require any vibration or tamping after pouring and is thus able to consolidate under its own weight without undergoing any significant segregation. Thermie’s method has been extensively used by previous researchers for under water concrete placement[10-12]. There are few areas where self-compacting concrete may find vital usage and application such as exceptionally large areas to be concreted, dense reinforcement to be concreted (where manual methods of compaction would be difficult to implement), situations where segregation and bleeding would adversely affect the strength gain properties, etc.

The strength properties of SCC are reported to be low by previous researchers. This research paper aims at studying the influence of fly ash on the properties of freshly mixed concrete. Various tests such as slump tests. Drying shrinkage, ultrasonic pulse velocity, water absorption etc. are conducted to get a complete picture of the performance of freshly placed concrete. Superplasticisers are also used to improve the workability of the concrete mix. The results are expected to provide useful guidelines for implementation in real practice.
2. Materials, Mix Proportions and Tests

2.1. Cement:
Properties of cement such as strength and durability were the basis on which the Grade of cement conforming to 43 Grade suitable for this particular research was considered.

| S. No | Physical Properties       | Results obtained | IS:8112-1989 Specifications |
|-------|---------------------------|------------------|------------------------------|
| 1.    | Fineness of Cement %      | 8.2%             | 10%                          |
| 2.    | Normal Consistency %      | 32%              | -                            |
| 3.    | Vicat Initial Setting Time (Minutes) | 35 | 30 (min)                  |
| 4.    | Vicat Final Setting Time (Minutes) | 317 | 600 (max)                |
| 5.    | Specific Gravity          | 3.15             | -                            |

2.2. Aggregates:
Codal guidelines necessitate the maximum permitted size of coarse aggregate to be restricted to 20mm. Accordingly coarse aggregate of size 20mm and fine aggregate of size 4.75mm were chosen with properties as found in Table 2

| Physical Properties | Fine Aggregates | Coarse Aggregates |
|---------------------|-----------------|-------------------|
| Specific Gravity    | 2.65            | 2.76              |
| Fineness Modulus    | 2.54            | 6.7               |
| Bulk Density (kg/m³) | 1424            | 1498              |

2.3. Fly Ash:
Fly ash conforming to class F was used as partial replacement of cement with specific gravity of 2.89 in the present work.

2.4. Water:
Water used was fresh, colourless, odourless and free from any type organic matter.

2.5. Admixture:
For the purpose of maintaining desired workability, Superplasticiser was used. Locally available superplasticisers, namely, CONPLAST SP 430 G8 was used in appropriate proportion.

2.6. Mix Proportion:
As there exist no particular standards for mix proportioning of SCC, mixes based on [10] was adopted. Total 7 different Mixes including one control mix (i.e. without SCC). Complete detail of these Mixs are given in Table 3.

| S. No | Trial Mix | Cement (kg/m³) | Fly Ash (kg/m³) | Fly Ash (%) | F.A (kg/m³) | C.A (kg/m³) | Water (kg/m³) | W/P | SP |
|-------|-----------|----------------|-----------------|-------------|-------------|-------------|---------------|-----|----|
| 1.    | Control   | 440            | -               | 0           | 924         | 772         | 189           | 0.43| 5.26|
| 2.    | 5%        | 396            | 44              | 5           | 924         | 772         | 189           | 0.43| 5.26|
| 3.    | 10%       | 374            | 66              | 10          | 924         | 772         | 189           | 0.43| 5.26|
| 4.    | 15%       | 352            | 88              | 15          | 924         | 772         | 189           | 0.43| 5.26|
| 5.    | 20%       | 330            | 110             | 20          | 924         | 772         | 189           | 0.43| 5.26|
| 6.    | 25%       | 308            | 132             | 25          | 924         | 772         | 189           | 0.43| 5.26|
| 7.    | 30%       | 288            | 154             | 30          | 924         | 772         | 189           | 0.43| 5.26|
S. No. | Trial Mix | Cement (kg/m³) | Fly Ash (kg/m³) | Fly Ash (%) | F.A (kg/m³) | C.A (kg/m³) | Water (kg/m³) | W/P | SP
---|---|---|---|---|---|---|---|---|---
8. | 35% | 254 | 176 | 35 | 924 | 772 | 189 | 0.43 | 5.26

2.7. Slump Flow Test:
Slump flow tests were carried out to select the mix ideal for self-compaction purposes. The results are given in Table 4.

| S. No | Trial Mix | Slump Flow (mm) Acceptance range 650-800mm | T₅₀ Slump Flow(sec) Acceptance range 2-5sec |
|---|---|---|---|
| 1 | Control | 653 | 4.3 |
| 2 | 5% | 678 | 3.5 |
| 3 | 10% | 706 | 3.8 |
| 4 | 15% | 669 | 3.3 |
| 5 | 20% | 666 | 4.5 |
| 6 | 25% | 635 | 3.0 |
| 7 | 30% | 690 | 3.0 |
| 8 | 35% | 710 | 3.3 |

The mix with 30% of fly ash was found to be ideal through the Slump flow tests.

2.8. V-funnel Test:
This test was performed to assess the flow ability and stability of SCC. V-funnel test was carried out on freshly mixed SCC. The results are given in Table 5

| S. No | Trial Mix | V-Funnel (Sec) Acceptance Range(Sec) |
|---|---|---|
| 1 | Control | 11 | 8-12 |
| 2 | 5% | 10.2 |
| 3 | 10% | 9.8 |
| 4 | 15% | 10.47 |
| 5 | 20% | 10.5 |
| 6 | 25% | 10.35 |
| 7 | 30% | 9.0 |
| 8 | 35% | 9.66 |

2.9. L-box Test:
As per EFNARC, the minimum value of H₂/H₁ can be 0.8 and the max value 1.0. In the present study, the L-box ratio for all the mixes were above 0.8, which is as per EFNARC standard [15]. Thus from the passing ability test results of SCC mixes it can be concluded that with the increase in fly ash content the passing ability also increases. The results of L-box test are given in the Table 6.

| S. No | Trial Mix | L-Box Acceptance Range |
|---|---|---|
| 1 | Control | 0.92 |
| 2 | 5% | 0.95 |
| 3 | 10% | 0.87 |
| 4 | 15% | 0.91 |
| 5 | 20% | 0.85 |


| Mix | Water Absorption (%) | Ultrasonic Pulse Velocity |
|-----|-----------------------|---------------------------|
| 6   | 25%                   | 0.9                       |
| 7   | 30%                   | 0.93                      |
| 8   | 35%                   | 0.98                      |

2.10. Water Absorption:
Figure 1 shows variation of water absorption in different mix samples. The water absorption of the concrete cylindrical specimens was determined according to conventional method as per IS1199. Water absorption tests were taken up after 28 days of curing.

2.11. Drying Shrinkage:
Drying shrinkage test was conducted on three prisms for different percentages of fine aggregate replacement by CBA. The results of this test are shown in Figure 2.

2.12. Ultrasonic pulse velocity:
The test involves determination of pulse velocity through concrete as per procedure given in ASTM [16]. Fig. 3 shows the variation of ultrasonic pulse wave in different mix samples.
3. Conclusions

The present experimental research work was aimed to study effects on the properties of fresh self-compacting concrete by using fly ash as partial replacement of cement together with super plasticisers as admixture. The main conclusions drawn from the results are summarized as under:

- The initial setting time of all mixes were well within the limits of the codal guidelines.
- By carrying out slump flow test it was found that percentage replacement by weight 25-35% were the best among the 7 trial mixes. It is suggesting that further studies in smaller ranges be carried out for improved accuracy in determining the optimum percentage of fly ash.
- All trial mixes satisfied the criterion in the V-funnel test, however the mixture with 30% replacement showed to have the best results. Similarly, the L-box test results were almost the same for all mixes satisfying the limits.
- By observation of test results of USPV, drying shrinkage and water absorption, the trial mix with 20% replacement shows the best results.

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