A study on workability of silica fume and iron dust added concrete

Bhupesh Jain\textsuperscript{a}, Vaibhav Jain\textsuperscript{a}, Gaurav Sancheti\textsuperscript{a}\textsuperscript{*}\textsuperscript{1}

\textsuperscript{a}Manipal University Jaipur, Dehmi Kalan, Off Jaipur-Ajmer Expressway, Jaipur, Rajasthan-303007, India.

\begin{abstract}
Workability of concrete is one of the important parameters which decide flowability and ease of placing the concrete. This is influenced by various factors such as shape and gradation of aggregate, water to binder ratio, admixture dosage, supplementary cementitious material, mixing time, rate of mixing, etc. Generally, slump cone test is used to decide the workability of concrete. In this paper, the effect on the workability of concrete after replacing cement with silica fume and sand with iron dust is discussed. Silica fume is replacing cement in the range of 2.5\% - 15\% and iron dust with sand in the range of 5\% - 30\% respectively. Also, the combined effect of silica fume and iron dust on the workability of concrete is discussed.

Keywords: Concrete; Workability; Slump cone test; Silica fume; Iron dust
\end{abstract}

1. Introduction

Portland cement is the most common binding material to prepare the concrete. Total production of concrete is around 4.6 Gt/year around the world [1]. The production of cement is associated with the emission of carbon dioxide and hence it is necessary to find other suitable materials that could replace cement partially or fully. In this way, impact on the environment can be reduced to some extent. There are several industrial waste materials that have shown cementitious properties like fly ash, silica fume, rice husk ash etc. [2–4]. These materials are termed as supplementary cementitious materials (SCMs) and can be used for partially replacing the cement. However, the fact that each material has its own influence on the concrete matrix, cannot be ignored. As such, it becomes quite essential to evaluate the concrete made from these SCMs. In this research work, properties of fresh concrete in terms of slump is evaluated for different mixes, prepared by replacing cement and sand with silica fume and Iron dust, respectively. Individual and combined effect after replacing cement and sand on workability of concrete is studied.

2. Literature Review

Alkali activated slag concretes (AASC), has generally slump of 60-120mm. Slump value between 55-180 mm can be obtained by changing the Percentage of Na\textsubscript{2}O and SiO\textsubscript{2}/Na\textsubscript{2}O ratio. With an increase in the percentage of Na\textsubscript{2}O from 4\% to 8\% slump value increased from 55 to 70 mm. After 8\%, further increase of Na\textsubscript{2}O is not allowed as per BS 8500-1:2015 and hence SiO\textsubscript{2}/Na\textsubscript{2}O ratio is increased to reach a slump value of 180 mm [5]. Slump of a concrete depends upon quality of aggregate, strength of cement, water content and water-to-cement ratio. To analyse the effect of these properties on workability of concrete, different analytical equations were formed and then regression analysis was performed. A rational equation not available which can easily be used for this purpose [6]. One of the study found that mixing time have significantly affects the workability and slump value. For plain concrete, if mixing time is increased from 7 min to 67 min, then slump value decreases from 205 to 160mm. Further rate of mixing also affects slump value, for the same number of rotations 10mm more slump is observed in higher rate of rotation [7]. Adding high range water reducing admixture like Glenium 7710 and Viscocrete retard the hydration and pozzolanic reactions and thus offset the performance benefits of concrete hence slump should be maintained in the range of 15-25mm [8]. Another, study of the rheological property of silica fume added concrete is studied with the help of workability of

\textsuperscript{*}Gaurav Sancheti. Tel.: +91-9694727780; fax: +91-141-2520879

\textit{E-mail address:} gaurav.sancheti@jaipur.manipal.edu
concrete. Seven different series with varying percentages of silica fume from 2% to 16% is used. It was observed that as the percentage of silica fume increased the workability of the concrete decrease [9].

3. Materials and Methodology

3.1. Materials

For this research work Ordinary Portland Cement (OPC) 43 grade cement and good purity Silica fume (silica >85%) is used as shown in Fig.1(a). Iron dust [Fig.1 (b)] is collected locally from rolling mills in Jaipur. Good quality aggregate and properly graded sand is used to prepare concrete.

![Fig. 1. (a) Silica Fume (SF); (b) Iron Dust (ID)](image)

3.2. Methodology

Nineteen different series were casted including control mix, in which percentage of silica fume varies from 2.5% to 15% and iron dust from 5% to 30%. Indian standard IS 10262: 2019[10] is used to design the control mix concrete. From Clause 7.1 of IS 456: 2000[10], low degree of workability is used, for which slump lies between 25-75mm. Different dosage of superplasticizer is used to maintain the slump range. The water to binder ratio (w/b ratio) is kept constant of 0.5 for all the nineteen series. Workability of concrete is measured with the help of slump cone test as per IS 1199-1959[11]. Fig. 3 shows the slump cone test of control Mix, silica fume series(S6), Iron dust series(I6) and combined series (C6).
4. Results and Discussion:

The slump value at different replacement percentages of silica fume and iron dust is shown in Table 1. Superplasticizer is added in the required amount to maintain slump range. As the % of replacement of cement with silica fume increases then the dosage of superplasticizer also increases to maintain slump because particles of silica fume are very fine (refer Fig. 2) as compared to cement particle and hence silica fume have very large surface area which reduces workability.

Table 3. Mixture proportion of concrete

| Series Name | Silica fume (kg/m³) | Iron dust (kg/m³) | Superplasticizer (kg/m³) | Slump (in mm) |
|-------------|---------------------|-------------------|--------------------------|--------------|
| CC          | 0                   | 0                 | 0                        | 35           |
| SF1         | 2.5                 | 0                 | 0.05%                    | 55           |
| SF2         | 5                   | 0                 | 0.1%                     | 45           |
| SF3         | 7.5                 | 0                 | 0.125%                   | 45           |
| SF4         | 10                  | 0                 | 0.15%                    | 40           |
| SF5         | 12.5                | 0                 | 0.175%                   | 45           |
| SF6         | 15                  | 0                 | 0.2%                     | 40           |
| ID1         | 0                   | 5                 | 0.10%                    | 45           |
| ID2         | 0                   | 10                | 0.075%                   | 40           |
| ID3         | 0                   | 15                | 0.05                     | 45           |
| ID4         | 0                   | 20                | 0.025                    | 50           |
| ID5         | 0                   | 25                | 0.01%                    | 45           |
| ID6         | 0                   | 30                | 0%                       | 50           |
| SI1         | 2.5                 | 5                 | 0.025%                   | 50           |
| SI2         | 5                   | 10                | 0.05%                    | 45           |
| SI3         | 7.5                 | 15                | 0.075%                   | 50           |
| SI4         | 10                  | 20                | 0.075%                   | 55           |
| SI5         | 12.5                | 25                | 0.075%                   | 45           |
| SI6         | 15                  | 30                | 0.05%                    | 50           |

CM – Control Mix, S – Silica fume, I – Iron dust, C – Combined Mix
Fig. 4. Variation of Slump with different Mix

On the other side, Iron dust particles have a smooth surface and don’t absorb water which result in increased workability of the mix. Therefore, simultaneous replacement of cement and sand with silica fume and iron dust respectively will compensate the effect to some extent and reduce the demand of superplasticizer. From the Fig. 4, it can be seen that for all the series slump is maintained between 25mm to 75mm.

5. Conclusion

The results show that replacing of only silica fume will decrease the workability and increase the demand of superplasticizer. However, replacing silica fume and iron dust simultaneously can achieve good workability with limited superplasticizer. Concluding recommendations that can be drawn from this research work are:

- Recommended dosage of superplasticizer ranging between 0.05% to 0.2% for the replacement of cement with silica fume up to 15%.
- Recommended dosage of superplasticizer ranging between 0% to 0.1% for the replacement of sand with iron dust up to 30%.
- Recommended dosage of superplasticizer ranging between 0% to 0.075% for the combined replacement of cement with silica fume and sand with iron dust up to 15% and 30% respectively.

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