Characteristics of SCC with Fly Ash and Manufactured Sand

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Abstract: Self compacting concrete (SCC) of M40 grade was designed. The binder in SCC consists of OPC and fly ash in the ratio of 65:35. River sand was replaced by manufactured sand (M-sand) at replacement levels of 20,40,60,80 and 100%. An attempt was made to evaluate the workability and strength characteristics of self compacting concrete with river sand and manufactured sand as fine aggregates. For each replacement level, constant workability was maintained by varying the dosage of superplasticizer. T50 flow time, V Funnel time, V-funnel T5 time as well as compressive, split tensile and flexural strength of SCC were found at each replacement level of M-sand. They were compared to SCC with river sand. Results indicate favourable use of M-sand in preparation of Self Compacting Concrete.

Keywords: M-sand, Self compacting concrete, Admixture, Workability, Strength, Sustainability.

1. Introduction

Concrete is a widely used construction material all around the world due to its wide ranging performance characteristics, suitability and the ease in regional production. Usage of concrete worldwide is second, next to water. According to Plunge [1], one ton of concrete is produced every year per person on this planet. Another estimate reveals that approximately 17,000 million tonnes of concrete is produced world-wide annually [2]. With the growing infrastructure development and booming housing sector, the demand for concrete is bound to shoot-up. Concrete is associated with Portland cement, the main ingredient of conventional concrete, fine aggregates and coarse aggregates. Fine and coarse aggregates occupy nearly 75 percent of volume of concrete. Cement consumption in India in 2013-14 was of order of 300 million tonnes (MT) and requirements of aggregates for concrete and mortar was around 1500 MT [3]. Conventionally sand obtained from river banks is being used as fine aggregate for manufacturing of concrete, but due to ever increasing demand for river sand, supply of good quality sand to meet the demands of construction industry cannot be guaranteed [5]. Unauthorised extraction of sand from river beds has resulted in several serious environmental issues including erosion of river beds, lowering of underground water table level, destruction of flora and fauna and thereby ecological imbalance [6]. There is a great challenge in obtaining good quality natural fine aggregates due to restrictions on extraction of river sand and engineers are forced to look into alternative materials [3] without compromising in the characteristics of cement concrete to achieve sustainability in construction. The construction industry is uniquely positioned to meet the
challenges of sustainable development [8] by reducing the quantity of cement in concrete and by using alternate building materials. M-sand is one of such material, which is permitted as an alternative to river sand by IS 383:1970[9] for use in cement composites as fine aggregates. The effects of particle texture and shape of fine aggregates are more predominant than effects of coarse aggregates in concrete. M-sand has more angular and cubical shaped particles when compared to that in river sand. Angular shaped of fine aggregates when used in concrete lead to improved strength due to better interlocking of particles [7].

Conventional concrete even if, highly workable, fails to fill the formwork in reinforced concrete members with congested reinforcement. In such situations, use of Self Compact Concrete (SCC) is preferred because of its advantages as well as economical benefits [4]. SCC is a concrete having high workability, with which it will be able to flow under its own weight and completely fill the formwork, even in the presence of congested steel reinforcement, without requiring vibration, whilst maintaining uniformity and homogeneity[10]. Self compacting concrete is very sensitive to properties of fine aggregates which directly affect the quality paste [11]. M-sand, when used in SCC, imparts numerous advantages, including contributions from finer particles as filler content, which results in enhancement of strength as well as durability[12].

Properties of concrete can be improved and embodied green house gas (GHG) emissions can be reduced by substituting portland cement with flyash, which is a marginal product obtained from coal fired thermal power stations [13]. Fly Ash is used as a pozzolana in concrete and can easily used as 15–35 percent substitute for cement in concrete mixes without reduction of strength[14,15]. Further, fine particles present in M-sand and fly ash with their spherical shape as well as glassy nature, behaves like ball bearing which improves the packing of the concrete and thereby results in reduction of voids[16].

Reported research on SCC with replacement of natural sand completely by M-sand [10,12] is silent about the characteristics of self compacting concrete with flyash and partial replacement of natural sand by M-sand. Hence an attempt was made in present study to determine the characteristics of self compacting concrete with flyash and at various replacement levels of M-sand.

2. Objectives and scope of the research
The Objective of the present study is to determine the properties of self compacting concrete prepared by river sand (NS) as fine aggregates and at various replacement levels of M-sand. The properties of self compacting concrete with river sand and M-sand fine aggregate are compared to evaluate the effect of replacement of river sand by M-sand.

3. Materials and mix design
Following materials were used in the preparation of self compacting concrete
(i) Ordinary portland cement and class F fly ash
(ii) River sand and M-sand
(iii) Coarse aggregates
(iv) Superplasticizer
(v) Tap water

Ordinary portland cement of 53 Grade satisfying the requirements of IS 12269:1987 [17] and Class F fly ash obtained from Raichur thermal power station were used as binders. The specific gravity of cement and fly ash were 3.12 and 2.42 respectively. Natural sand and M-sand are used as fine aggregates(F.A). Properties of fine aggregates are as shown in Table 1. Both the fine aggregates belong to zone II of IS 383:1970[9].
| Property                  | River sand | M-sand |
|--------------------------|------------|--------|
| Specific gravity         | 2.64       | 2.65   |
| Fineness modulus         | 2.7        | 2.8    |
| Moisture content(%)      | 0.41       | 0.34   |
| Water absorption(%)      | 1.21       | 1.11   |
| Loose bulk density(Kg/m³)| 1351.53    | 1691.34|
| Compacted bulk density(Kg/m³)| 1504.66 | 1771.71|
| Zone as per IS 383;1970[9] | II        | II     |

Grain size distribution curves of natural sand and manufactured sand are shown in Figure 1. The grading curves for river sand (NS) and M-sand(MS) are almost similar and both are well graded.

![Figure 1. Grain size distribution curves of Natural sand and Manufactured sand](image)

Locally available coarse aggregates(C.A) derived from granite rock having specific gravity of 2.61 were used in the investigation. Moisture content and water absorption in coarse aggregate were 0.4 and 0.71% respectively. Tap water satisfying requirements of IS 456-2000[18] and commercially available carboxylic ether based superplasticizer having a specific gravity 1.22 conforming to IS: 9103:1999[19] and BS: 5075-3:1985 [20] were used in the investigation. M40 grade self compacting concrete was designed as per specifications of EFNARK [4]. Mix design was finalised after extensive trials. The ratio of OPC and fly ash was maintained as 65:35. The final mix proportion is given in Table 2.

| Ratio of cementitious materials | Cement | Fly ash | F.A | C.A | Water/Binder ratio |
|---------------------------------|--------|---------|-----|-----|-------------------|
|                                  | 0.65   | 0.35    | 2.388 | 2.188 | 0.36              |
4. **Methodology**

SCC was prepared using river sand as fine aggregate to obtain a slump flow of 650mm. River sand was replaced by M-sand at 20, 40, 60, 80, 100% replacement levels. The dosage of superplasticiser was adjusted to get the desired slump flow. Fillability, flowability and segregation resistance of SCC were evaluated as per EFNARK 2005[4]. Concrete Cubes of size 150mm, cylinders of 150mm dia and 300mm height, beams of size 100mm x 100mm x 500mm were cast and cured for 28days. Compressive, split tensile and flexural strength of SCC were determined as per IS 516:1959[21].

5. **Results and Discussion**

Water Various tests were conducted on SCC to evaluate properties in fresh state and hardened state as discussed above and the results are presented in this section.

5.1 **Fresh properties of SCC**

Variation of dosage of superplasticizer with percentage replacement by M-sand is shown in Figure 2. Reduction in dosage of superplasticiser was observed with increase in replacement level of M-sand to attain a slump flow of 650mm. The dosage of superplasticiser with 100% replacement by M-sand is about 27% less when compared to dosage required for SCC with natural sand. The trend is in line with the results obtained by Nagendra and Sharada Bai [11]. This may be due to presence of fine particles in M-sand which results in better particle packing. Ball bearing action by the fly ash particles also contributes to the increased workability [16, 22, 23].

![Figure 2. Variation of dosage of Superplasticiser with percentage replacement by M-sand](image)

The variation of slump flow T50 time with replacement levels of M-sand in self compacting concrete is shown in Figure 3. It can be noted that, T50 time reduces linearly upto 80% replacement by M-sand and later it remains constant. T50 time of 2-5 seconds is suggested for good self compacting concrete [4]. The range of T50 time was within the range specified by EFFNARK [4], having least time as 2.2 sec for 80% replacement by M-sand. This indicates good filling ability and resistance to segregation of M-sand SCC.
Variation of V Funnel time and T5 time with percentage replacement of M-sand for SCC is shown in Figures 4 and 5 respectively. It can be observed that V Funnel time of SCC decreases with increase in percentage replacement by M-sand. For all values of replacement levels, range of V funnel time and V funnel T5 time were 6-12 seconds and 9-15 sec respectively as per EFNARK [4] specifications.

Figure 3. Variation of T50 flow time of SCC with percentage replacement by M-sand

Figure 4. Variation of V-funnel time of SCC with percentage replacement by M-sand
5.2 Properties of SCC in hardened state

The variation of compressive strength of self compacting concrete with percentage replacement of manufactured sand is shown in Figure 6. The compressive strength increases with increase in replacement of M-sand for all replacement levels at all the ages. For 100% replacement by M-sand the compressive strength was 14.27% higher when compared to that with SCC with river sand. This indication boosts the morale of site engineer to use M-sand in place of natural sand completely.

The variation of split tensile strength of self compacting concrete with percentage replacement of M-sand is shown in Figure 7. Split tensile strength increases with the increase of replacement levels of M-sand, in line with the compressive strength. Maximum split tensile strength was observed in concrete with 20% river sand and 80% M-sand, which is 8.70% higher compared to concrete with natural sand. For SCC with 100% replacement by M-sand, the split tensile strength is 7.21% higher compared to concrete with natural sand. The increase in strength of concrete with M-sand may be due to the rough surface texture of M-sand when compared to natural sand. More angular and cubical
shaped particles with rough surface texture results in better bonding and interlocking characteristics, results in enhanced strength.

![Figure 7. Variation of Split Tensile strength of SCC at 28 Days](image1)

The variation of flexural strength of SCC with percentage replacement of manufactured sand is shown in Figure 8. The variation of flexural strength with various replacement levels of M-sand when compared to concrete with natural sand is marginal. Hence M-sand can be used for pre casting concrete pavement slabs.

![Figure 8. Variation of Flexural strength of SCC at 28 Days](image2)

6. Conclusions

Based on the limited experimental study, following conclusions can be drawn.

i. For obtaining a constant slump flow of SCC, the dosage of superplasticiser decreases with increase in percentage replacement by M-sand.

ii. Fresh properties of SCC can be improved with addition of M-sand and fly ash.

iii. Compressive and split tensile strength of SCC increase with replacement by M-sand, whereas flexural strength remains almost constant.
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