Effect of mineral admixtures on kinetic property and compressive strength of self Compacting Concrete

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Abstract: This paper presents experimental investigations made on the influence of chemical, physical, morphological and mineralogical properties of mineral admixtures such as fly ash, ground granulate blast furnace slag, metakaoline and micro silica used as a replacement of cement in self compacting concrete on workability and compressive strength. Nineteen concrete mixes were cast by replacing with cement by fly ash or ground granulated blast furnace slag as binary blend at 30%, 40%, 50% and with addition of micro silica and metakaoline at 10% as a ternary blend with fly ash, ground granulated blast furnace slag and obtained results were compare with control mix. Water powder ratio 0.3 and super plasticizer dosage 1% of cementitious material was kept constant for all the mixes. The self compacting concrete tested for slump flow, V-funnel, L-Box, J-Ring, T50, and compressive strength on concrete cube were determined at age of 3, 7, 28, 56, 90 days.

1. Introduction
Concrete is a construction material extensively used around the globe. Properties of concrete have changed tremendously to meet the field requirements. Adopting new technological advancements in construction industry few types of concrete have been developed to improve the various properties of concrete in fresh and harden state. Increase in the population growth necessities the need for housing and infrastructure demands leading usage of more concrete for construction industry. Recent developments in civil engineering constructions like high-rise buildings and long-span bridges necessitates the need concrete of higher compressive strength [1]. An advancement of concrete construction technology and its production has led to higher grades of concrete strength. In the pursuit of advancement of concrete construction an innovative type of concrete was used in construction such as self compacting concrete (SCC). The usage of self compacting concrete in high rise building and long span bridges has resulted in an increase in the homogeneity and better performance of the concrete structures [2]. Self compacting concrete can be use to mould the structure without the use of vibrators and consolidates by its own weight and can flow through densely and congested reinforced and complex structural elements [3]. Many researchers have conducted experimental studies made on various mineral admixtures like fly
ash, GGBS, micro silica and metakaoline incorporating in self compacting concrete. Thus incorporating high volumes of mineral admixtures can make it cost effective, increases the workability and strength at later ages. The preset research aimed to investigate the effect of chemical, physical, mineralogical, morphological properties of fly ash, ground granulated blast furnace slag, micro silica and metakaoline on the workability and compressive strength of self compacting concrete.

2. Experimental Investigation

2.1. Materials

In present study self compacting concrete was prepared with 53 grade Ordinary Portland cement confirming IS 12269-1987, Class F fly ash (PFA) in accordance to IS 3812-1981, Ground granulated blast furnace slag (GGBS) in accordance to IS 12089-1987, Micro silica (SF) in accordance to IS 15388-2003 and Metakaoline (MK). The chemical and physical properties of cement, and mineral admixtures are as shown in Table 1.

The illustrated SEM micrographs reveal that the cement particles (Figure1) are angular and non-spherical in shape, fly ash particles (Figure2) are spherical and smooth, hallow spheres called as cenospheres (microspheres) and plerospheres. GGBS particles (Figure3) are long, elongated and flaky in shape. Micro silica particles (Figure4) appear the spherical in shape and as denser particles. Metakaoline particles (Figure 5) smooth spherical shape powdered particle.

| Table 1. Chemical and Physical Properties of Cement, flyash, GGBS, SF, MK. |
|-----------------------------|----------------|----------------|---------|-------|
| Cement | Fly ash | GGBS | SF | MK |
| SiO₂ | 16.34 | 62.63 | 33.77 | 91.9 | 52.0 |
| Al₂O₃ | 6.95 | 23.35 | 13.24 | 0.4 | 42.2 |
| Fe₂O₃ | 5.38 | 3.93 | 0.65 | 0.3 | 0.7 |
| CaO | 60.84 | 2.04 | 33.77 | 0.3 | 0.08 |
| MgO | 2.32 | 0.46 | 10.13 | 0.0 | 1.76 |
| SO₃ | 1.99 | 0.53 | 0.23 | --- | --- |
| Na₂O | 1.50 | 1.35 | --- | --- | 0.07 |
| K₂O | 2.73 | --- | --- | --- | --- |
| LOI | --- | 0.39 | 0.19 | 1.7 | 0.3 |
| Specific Gravity | 3.12 | 2.1 | 2.9 | 2.45 | 2.12 |
| Specific surface (m²/Kg) | 297 | 311 | 436 | 22000 | 12000 |

X-ray diffract gram of cement shows the presence of crystalline phase of calcium, silica and alumina compounds. Fly ash is composed of 30 % crystalline compounds such as quartz, mullite, hematite, and 70% amorphous glassy material such as silica glass and glass of other oxides. GGBS shows amorphous silica, alumina and calcium. Micro silica is amorphous phase, significant presence of silica. Metakaoline is an amorphous phase of silica and alumina.

2.2. Aggregates

Manufactured sand confirming Zone II and the crushed coarse aggregate obtained from the local crushing plant are used in the present study. The properties of Coarse and Fine Aggregate are depicted in the Table 2. Super plasticizer (SP) poly carboxylic ether base Auromix 400 with specific gravity 1.08 and chloride ion content less than 0.2% and pH 6 are used. Fresh and potable water of pH 7.72 free from organic waste is used for mixing and curing of the SCC.
Table 2. Properties of fine and coarse aggregates

| Properties       | Coarse Aggregate | Fine Aggregate |
|------------------|------------------|----------------|
| Specific Gravity | 2.7              | 2.62           |
| Water Absorption | 0.8%             | 3.8%           |
| Fineness Modulus | 6.86             | 2.68           |

Figure 1. SEM and XRD images of Cement.

Figure 2. SEM and XRD images of fly ash.

Figure 3. SEM and XRD images of GGBS.
2.3. Mix proportions

Total 19 mixes with 30%, 40%, 50% replacements of fly ash or ground granulated blast furnace slag and combined with micro silica or metakaoline at 10% as a replacement of cement were cast and examined on the kinetic properties and compressive strength of self compacting concrete and compared with control mix. Table 3 represents composition of self compacting concrete of various mineral admixtures.

Table 3: Mix Proportions (Kg/m3) of self compaction concrete with different replacement of Mineral admixtures

| Mix No      | OPC  | Fly ash | GGBS   | SF   | MK   | Fine aggregate | Coarse aggregate |
|-------------|------|---------|--------|------|------|----------------|------------------|
| Control Mix | 576  | ---     | ---    | ---  | ---  | 879            | 777              |
| PFA30%      | 455  | 121     | ---    | ---  | ---  | 879            | 777              |
| PFA40%      | 415  | 161     | ---    | ---  | ---  | 879            | 777              |
| PFA50%      | 374  | 202     | ---    | ---  | ---  | 879            | 777              |
| PFA30% + SF10% | 410 | 121     | ---    | 45   | ---  | 879            | 777              |
| PFA40% + SF10% | 370 | 161     | ---    | 45   | ---  | 879            | 777              |
| PFA50% + SF10% | 329 | 202     | ---    | 45   | ---  | 879            | 777              |
| PFA30% + MK10% | 416 | 121     | ---    | ---  | 39   | 879            | 777              |
| PFA40% + MK10% | 376 | 161     | ---    | ---  | 39   | 879            | 777              |
| PFA50% + MK10% | 335 | 202     | ---    | ---  | 39   | 879            | 777              |
| GGBS 30%    | 416  | ---     | 160    | ---  | ---  | 879            | 777              |
| GGBS 40%    | 363  | ---     | 213    | ---  | ---  | 879            | 777              |
| GGBS 50%    | 310  | ---     | 266    | ---  | ---  | 879            | 777              |
| GGBS 30% + SF10% | 371 | ---    | 160    | 45   | ---  | 879            | 777              |
| GGBS 40% + SF10% | 318 | ---    | 213    | 45   | ---  | 879            | 777              |

Figure 4. SEM and XRD images of Micro silica.

Figure 5. SEM and XRD images of Metakaoline.
3. Results and Discussions

In the present study physical, chemical, mineralogical, morphological properties of mineral admixtures their effect on fresh properties and compressive strength of self compacting concrete with different replacement are studied.

3.1. Fresh properties

The workability test on self compacting concrete such as slump flow, T50, J-Ring, L-Box and V-funnel with various replacements of cement by mineral admixtures are shown in the Table 4. The slump flows of the concrete mixtures are between 630 and 750 mm. The values of slump flow improve with the increase in flyash replacement and decreases with an increase in GGBS. An addition of micro silica in flyash and GGBS blended self compacting concrete decreases the flow. But with metakaoline, flow rate increases compared to micro silica as shown in Figure 7. The V-funnel time between 12 to 6 seconds indicating increase in the flow ability of concrete and flow time decreases with an increase in fly ash compared with other type of mineral admixtures as in the Figure 8.

The value L-box is between 0.8 to 1, it increases the passing ability of self compacting concrete with different replacement of mineral admixtures as shown in Figure 9. $T_{50}$ slump flow test indicates high filling ability of concrete mixes. From Figure 10 it was observed that decrease J-ring value of SCC by increase in fly ash. It has been observed that increase in volume of fly ash increases in self compatibility properties; this is due to shape of flyash particles. Most of the particles are spherical in shape called as cenospheres or plerospheres, and amorphous glassy material such as silica glass and glass of other oxides as shown in the Figure 2. The spherical particles produce ball bearing action and take less water to wet the surface of fly ash, this result increases the workability of concrete. GGBS in concrete decreases the flow properties, as GGBS particles are flaky and elongated in shape and have larger surface area as shown in Figure 3. This results in higher water demand, and hence as a result concrete workability decreases. Introducing micro silica in concrete decreases the flow properties, due to micro silica are densified form of micro pellets and very larger surface area compared to other type of mineral admixture as shown in Figure 4. It consumes more water for wetting; this may decrease in workability of concrete. It has been observed that additions of metakaoline in the concrete decreases the flow properties due to high specific surface area, irregular particle shapes as shown in Figure 5, as increases in higher demands decreases the workability, it is comparatively higher workable than micro silica. It was also observed that increase in specific gravity of mineral admixtures decreases the flow property of self compacting concrete.
Compressive strength is evaluated for all the mixes of self compacting concrete as in Table IV. GGBS has achieved maximum compressive strength at early ages, this is due more percentage of Cao (33.77%) in GGBS that react with water resulting in formation of tobermorite, leading to higher strength at earlier ages when compare to other type of mineral admixtures. The higher compressive strength at 56 and 90 days is observed in fly ash, this is due to higher percentage of ultra fine particles, it increases the packing density of self compacting concrete at initial stage later increase in SiO2 reacting with CH obtained during hydration of cement.

The compressive strength after 28 days is increases, this was observed in the metakaoline series and this is due to content of Al2O3 which is more compared to other types of mineral admixtures, which react with portlandite which is formed during primary hydrates with cement and converts into tobermorite. This phenomenon increases the compressive strength of self compacting concrete.

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Figure 7. Slump flow test Vs Replacement of Mineral admixtures.

Figure 8. V-Funnel Test Vs Replacement of Mineral admixtures.

Figure 9. L-Box Ratio Vs Replacement of Mineral admixture

Figure 10. J-Ring Test Vs Replacement of Mineral admixtures

Figure 11. Compressive strength Vs Ages of with fly ash and GGBS.

Figure 12. Compressive strength Vs Ages of SCC with fly ash and GGBS with SF.
4. Conclusion based on the results.

The following conclusions are drawn based on the above investigations:

- The performance of self compatibility of fresh concrete can be improved by addition or replacement of cement by mineral admixtures.
- Use of fly ash in self compacting concrete increases in slump flow compared other series replacement of mineral admixtures.
- The workability of concrete depends on other factors such as specific gravity, shape, size, specific surface of mineral admixtures.
- Higher compressive strength has been obtained by 30% replacement of cement by ground granulated blast furnace slag and 10% of Silica fume series is 49.12 MPa at 28 day and this is equal to control mix. Also the increase in replacement levels has resulted in decrease in strength.

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