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Effect of Polymeric Admixtures on Self-Compacting Concrete

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ABSTRACT: A recent new development in admixture technology has opened up remarkable possibilities for the use of concrete as a novel material in the modern concrete industry. Polycarboxylic Ether (PCE), a new generation superplasticiser, whose action mechanism is different, giving cement dispersion by steric stabilization, instead of electrostatic repulsion. This form of dispersion is more powerful in its effect and gives improved workability retention to the cementitious mix. The availability of PCE admixtures has been essential to the development and acceptance of Self-Compacting Concrete (SCC). The effective use of Viscosity Modifying Admixtures (VMA) is to ensure stable and fully cohesive mixture even when subjected to variations in the site conditions such as accidental excess water, ambient temperature, humidity and others. This paper presents a comparative study on PCE based and Melamine Sulphonate Formaldehyde (MSF) based admixtures with VMA in the production of SCC.

KEYWORDS: Self-compacting concrete, Super-plasticizing admixture, Viscosity Modifying Admixtures, Polycarboxylic Ether, Melamine Sulphonate Formaldehyde, Steric hindrance effect

I. INTRODUCTION

SCC has evolved as an innovative technology, capable of achieving the status of being an outstanding advancement in the sphere of concrete technology. No vibration is necessary for SCC which can flow around obstructions, encapsulate the reinforcement and fill up the formwork completely under its own self-weight (Okamura, H, 2001). The workability and water retention properties of SCC are achieved by the use of super plasticizers. Polycarboxylic Ether (PCE), a new generation superplasticiser is not only chemically different from sulphonated melamine and naphthalene based products but its action mechanism is also different, giving cement dispersion by steric stabilization, instead of electrostatic repulsion. SCC offers a uniquely high flow in conventional concrete, without the problems of bleeding and segregation that would normally be associated with high levels of workability. The viscosity and there by cohesiveness of the mix can be modified using poly saccharide based VMA (Khayat, K, 1997).

The development of this new high fluidity self-compacting, superplasticizing admixture, based on polycarboxylic ether (PCE), will significantly increase the options available to engineers, not only in terms of design of new structures, but also in repairing and upgrading existing structures with concrete in order to meet current needs (Kleen, 2001). In addition, SCC has been shown to produce excellent surface finish, free of significant air voids and other defects. SCC is cohesive, in spite of its very high fluidity and is relatively tolerant of imperfectly sealed small gaps in the shuttering. The viscosity and there by cohesiveness of SCC can be modified using Viscosity Agents (resins, colloidal matter).

II. LITERATURE REVIEW

Self-Compacting Concrete (SCC)

Self-compacting concrete (SCC) was originally developed at the university of Tokyo, Japan during the year 1986 (Ozawa, K , 1989) due to the reduction in skilled labour force and also to improve the quality of construction and the prototype for structural application was first completed in 1988. The development of this technology was driven with regard to the homogeneity and consolidation of cast in-place concrete in highly reinforced structures.

To achieve a high flow rate and avoid obstruction by confined zone of reinforcement, SCC is designed with limits on the nominal maximum size of the aggregate, amount of aggregate and aggregate grading. However when the flow rate

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is high, the potential for segregation and loss of entrained air voids increases. These problems can be alleviated by designing a concrete with a high fine to coarse aggregate, low water – cement ratio, good aggregate grading and high range water reducing admixtures. Viscosity modifying admixtures are also used to reduce the tendency for segregation and enhance a stability of the air-void system.

Mechanism of Superplasticizers

In general, traditional Super-plasticizers such as Melamine Sulphonate Formaldehyde condensate, which are formed by a backbone with negative functional groups attached to it, act through a mechanism of adsorption of the molecules onto the cement particles. This creates an electrostatic repulsive effect which results in the dispersion of cement particles. However, because of the hydration process, the molecules are subsequently covered by the crystals of the hydration products thus causing a decrease of the repulsive effect and loss of workability over time. The polycarboxylic ether based super-plasticizers available are characterized not only by the presence in their structure of electrical charges but also of side chains. The side chains improve not only the water reducing effect but, especially the workability retention properties due to their steric hindrance effect (Samir Surlaker, 2002). As stated earlier, the usual tool to control the rate of absorption and workability retention of a state of the art polycarboxylic polymer is the ratio between the negative charges and the side chains which affect also, the water reduction capability.

The special molecular shape of the PCE based polymer can produce water reduction as high as 40% and can take care of high amount of fine in the mix.

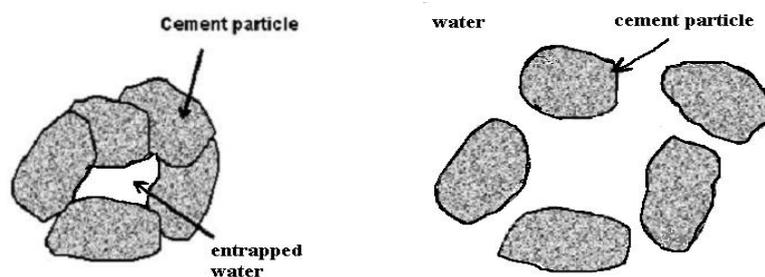


Fig. 1- Action of Super-plasticizers

High Range Water Reducing Admixture (HRWRA)

Super-plasticizers are powerful dispersing agents and are high range water reducers. The water/cement ratio can be as low to produce flowing concrete, which can have high strength. The use of super-plasticizer in concrete is an advancement of concrete technology. Polycarboxylic Ether Super-plasticizers represent a major breakthrough in concrete as they provide 40% water reduction and impart tremendous workability. Super-plasticizers can be broadly classified as, Modified Ligno Sulphonates (MLS) Melamine Sulphonate (MSF) Naphthalene Sulphonate (NSF) and Acrylic polymer (AP)

Mechanism of Polycarboxylic Ether (PCE) based Super-plasticizers

The dispersion mechanism of MSF & NSF based super-plasticizers is the electrostatic repulsion between the cement particles negatively charged by the adsorption of the anionic polymer molecule onto the cement surface. It is measured by the magnitude of zeta potential (Ramachandran, V.S 1995). The dispersion mechanism of PCE is due to the electrostatic repulsion induced due to the adsorption of the negative charge provided by the carboxylic group and steric hindrance effect from the trunk polymer (main chain) and grafted polymer chains (side chains). This comb-like structure is depicted in fig.2. The electrostatic repulsive force for PCE super-plasticizers is half of the value measured for MSF super-plasticizers and the dispersion is mainly due to the very strong steric hindrance effect that “pushes” the particles of cement apart (Ohta, A. 1997). Slump retention depends on the ability of the admixture to keep the cement particles apart. It is possible to provide a time release component through the use of cross-linked polymers.

Advantages of PCE based SP

- Significant reduction of the water demand of the mix

- Short setting time
- High early strengths
- Low tendency to segregation.

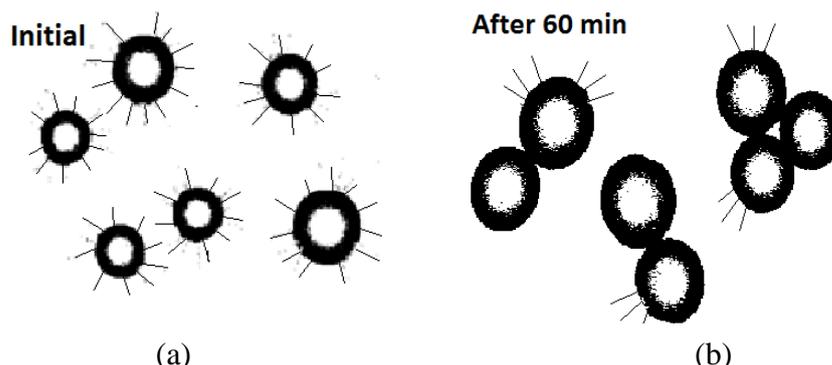


Fig. 2 Steric hindrance effect of PCE based Superplasticiser.(a)Intra molecular cross linked polymer(b) Cross linked polymers unfold and re-disperse the flocculated particles

III. EXPERIMENTAL INVESTIGATION

Optimization of super-plasticiser dosage

Optimum dosage is the minimum dosage of super-plasticizer (SP) that gives maximum flow characteristics. The optimum dosage of SP is obtained by conducting Marsh cone test. The flow time is an inverse measure of the fluidity. The measurements were taken for varying SP /cement dosages. The optimum dosage for PCE based SP is found to be 0.4 % of the total binder content and that of MSF based SP is found to be 2.4 % of the total binder content.

In the present investigation the mix proportion for SCC for a grade of 50 MPa is taken from the literature (Indumathi, 2006). Here the mix proportion for SCC is arrived by the rational mix design method by incorporating the particle packing theory and material properties. The fresh concrete properties and hardened concrete properties of SCC are compared with PCE based and MSF based super-plasticisers. Workability tests as per specification (EFNARC, 2001) were carried out for both the mixes. The test results show that the fresh concrete properties such as slump flow, filling ability, passing ability, segregation resistance etc. are within the prescribed limits as per the specifications for SCC produced using PCE based super-plasticisers. For MSF based SP the maximum horizontal spread is only 480 mm which does not satisfy the requirement of SCC. No other acceptance tests for SCC are satisfied for concrete with MSF based SP

Table 1:Mix Proportions of SCC for a grade of 50 MPa

| Component | Weight/m ³ | |
|----------------------------------|-----------------------|-----------|
| | PCE based | MSF based |
| Cement | 357 | 357 |
| Fly Ash | 153 | 153 |
| Filler (crusher dust) | 60 | 60 |
| Fine Aggregate | 828 | 828 |
| Coarse Aggregate | 759 | 759 |
| Water/powder ratio | 0.33 | 0.33 |
| Super-plasticizer in % of binder | 0.4 | 2.4 |
| VMA in % of binder | 0.1 | - |

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Fig.3 Slump Flow of SCC with PCE based super-plasticisers.

Standard specimens were tested for compressive strength after 12hrs, 18 hours, 1 day, 3days, 7 days, 21 days and 28 days of curing the as per IS : 456 – 2000 for both MSF based and PCE based concrete. It was possible to remove the mould only at the third day in the case of MSF based concrete whereas moulds were removed after 12 hours in the case of PCE based concrete.

IV. RESULTS AND DISCUSSIONS

Test results on the fresh concrete property such as slump flow are shown in table-2. The test results indicate that PCE based admixtures even with a lesser dosage produce very good flow and satisfy the requirements of SCC. Whereas even with a higher dosage, MSF based admixtures could produce a maximum horizontal spread of only 480 mm, which is less than the minimum requirement of SCC. PCE based SP shows better workability retention whereas workability is drastically reduced with time for MSF based SP. Table 3 shows the results on the compressive strength of PCE based and MSF based Superplasticizers. It was not possible to remove the moulds before 3 days because of the higher dosage of SP in the case of MSF based concrete and also the 28 day strength is found to be less than the designed strength. But it was possible to remove the mould after 12 hrs in the case of PCE based concrete. Compressive strength of PCE based concrete is found to be same as the designed strength. Also the rate of gain in strength at the early ages is found to be satisfactory.

Table 2:Slump flow of PCE and MSF based SP with time

| SP | Time in min. | 0 min | 30 min | 60 min |
|--------------------|--------------|-------|--------|--------|
| | | in mm | | |
| 0.4 % of PCE based | | 750 | 760 | 715 |
| 2.4 % of MSF based | | 480 | 390 | 240 |

Table 3:Compressive Strength of concrete with PCE and MSF based SP

| Days of curing | 12 hours | 18 hours | 1 day | 3 day | 7 day | 21 day | 28 day |
|----------------|----------|----------|-------|-------|-------|--------|--------|
| PCE based | 5.4 | 7.8 | 9.7 | 22.0 | 34.6 | 48.8 | 52 |
| MSF based | - | - | - | 16.4 | 28.2 | 40.2 | 46.5 |

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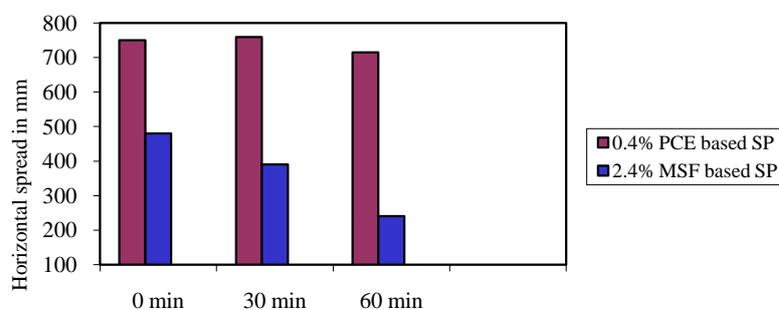


Fig.4 Comparison of workability of PCE and MSF based SP

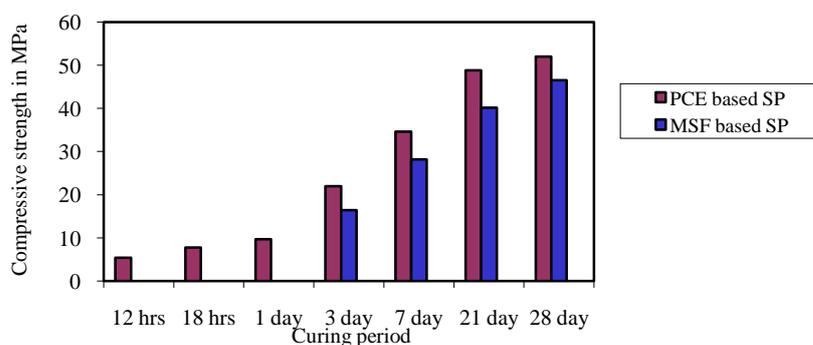


Fig.5 Comparison of compressive strength of PCE based and MSF based SP

Cost Analysis

Even though the cost of PCE based SP is more than double that of MSF based SP, the total production cost /10 m³ of concrete with PCE based SP is less than that with MSF based SP. It is found that there is a saving of nearly 12% by the use of PCE based SP.

V. CONCLUSIONS

- The optimum SP dosage for PCE is found to be 0.4 % and that of MSF is 2.4 %. Six times higher that of PCE based SP.
- Poly Carboxylic Ether based superplasticiser produces better dispersion, flow characteristics and water retention compared to MSF based superplasticiser.
- Even with a higher dosage (six times that of PCE), MSF based SP could produce an initial horizontal spread of only 480 mm which is less than the minimum requirement of SCC.
- MSF based concrete does not show self compactability and needs vibration for compaction.
- Compressive strength of MSF based concrete at 28 days is found to be less than the designed strength.
- The removal of formwork is found to be difficult before 3 days because of the higher dosage of SP in the case of MSF based concrete.
- Compressive strength of PCE based concrete is found to be same as the designed strength. Also it is possible to remove the mould after 12 hrs in the case of PCE based concrete with a satisfactory rate of gain in strength at the early ages.
- Even though the cost of PCE based SP is nearly double that of MSF based SP, there is a saving of nearly 12 % in the cost of production / 10 m³ of concrete with a better performance with respect to flow and workability retention characteristics by the use of PCE based SP compared to MSF based SP.

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