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SUPER PLASTICISER:
CEMENT: MORTAR

EFFECT OF VARIOUS SUPERPLASTICIZERS ON RHEOLOGICAL PROPERTIES OF CEMENT PASTE AND MORTARS

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ABSTRACT

The effect of eight commercial superplasticizers including one developed from Cashew Nut Shell Liquid (CNSL) at CBRI on the rheological properties viz. viscosity and flow of cement paste and mortars have been investigated. The viscosity measurements have been made at various shear rates (5 - 100 rpm). It is found that at higher rates (100 rpm) even with the low concentration of superplasticizers (0.1), the viscosity of the cement paste is more or less same as that obtained with 0.6 % dosages of SPs at lesser shear rates. The effect of split addition (delayed addition) of superplasticizers on viscosity of cement paste and 1:3 cement sand mortar have also been studied. A decrease in viscosity due to split addition has been observed in the cement paste and there is an increase of 15-20 % in flow of mortars.

REFEREED PAPERS

Introduction

The effect of superplasticizing admixtures on the rheological properties, namely viscosity, has been studied by many workers (1-10). The improvement in the fluidity of the mix depends upon many factors e.g. the nature and concentration of the superplasticizing admixture, optimum time of addition of admixture (11), composition and temperature of mix and type of cements (12). The effect of split/delayed addition of admixture in cement paste and concrete has been studied and higher workability has been observed (11). In all eight superplasticizers have been used to study the viscosity and flow properties at various water-cement ratios and doasge levels. However, not much information on effect of admixtures on the rheological properties of cement pastes and mortars when split addition is adopted is available in literature.

The object of the present work was to study :

(a) the effect of various superplasticizing admixtures on rheological properties namely, viscosity and flow of cement paste and mortars, and

(b) the improvement in the fluidity of cement paste and mortars due to split addition of superplasticizers.

EXPERIMENTAL PROCEDURES

Cement

Ordinary portland cement with a composition CaO = 61.94, SiO_2 = 21.92, Al_2O_3 = 4.97, Fe_2O_3 = 4.06, MgO = 2.82, LOI = 1.44, SO_3 = 2.22, others = 2.35, Fineness = 2481 cm^2/gm in accordance with IS:269-1989 has been used for the present study.

Admixtures

In all, eight superplasticizers have been used during this study. The seven superplasticizing admixtures had been obtained from the Indian manufacturers/market and designated as (A1-A7) and one prepared at this Institute designated as CBRI-SP based on Cashew Nut Shell Liquid. The description of the admixtures is as follows:

A1 - Blend of speciality organic polymers conforming to ASTM C-494 - Type A.
A2 - Same as A1 obtained from a different manufacturer
A3 - Synthetic dispersion, ASTM C-494 - Type G.
A4 - Organic polymer having retarding effect
A5 - Speciality organic polymers, ASTM C-494 - Type F.
A6 - Brown liquid, ASTM C-494
A7 - Brown liquid, ASTM C-494 obtained from a different manufacturer
CBRI-SP - Synthesized at the CBRI laboratory.

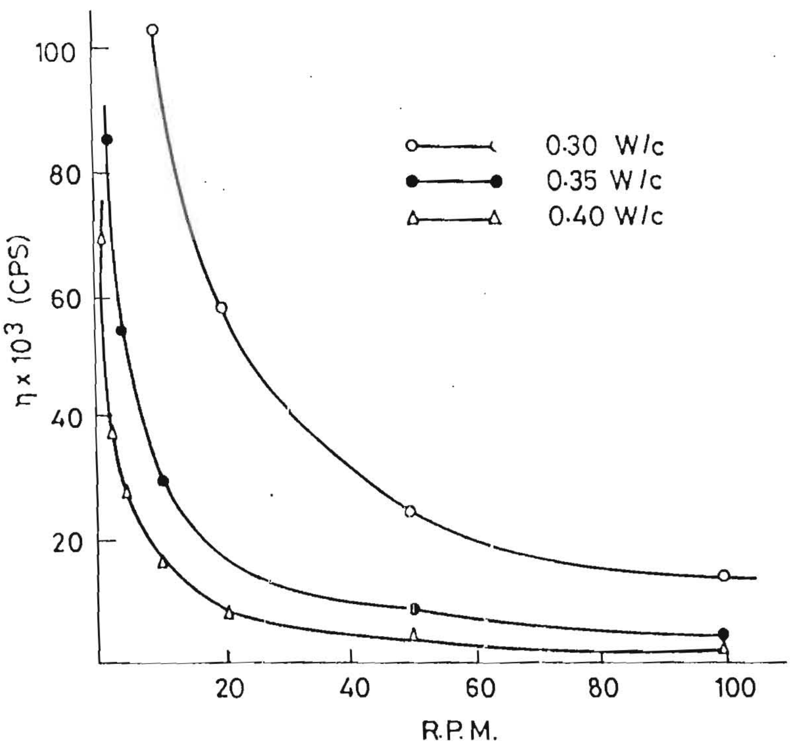

FIG. 1
Effect of Water Cement Ratio on the Viscosity of Cement Paste

Sand

Standard Ennore sand in accordance to Indian Standards Specification (650/1991) containing equal fractions of three grades of particles sizes 2 mm - 1 mm, 1 mm-0.5 mm and 0.5 mm to 0.09 mm.

Apparatus and Preparation of Cement Paste :

The rheological measurements were made with Brookfield DV-II model viscometer. T-bar spindle No. 95 using helical path was used.

- Prestipulated quantity of water was added to a given weight of cement in a beaker and mixed thoroughly with the help of a rod for five minutes and tapped for one minute to remove any entrapped air in the beaker.
- Measurements were made at a spindle rotational speed of 5, 10, 20, 50 and 100 rpm sequentially. A 75 second lapse period was followed by measurements involving successively increasing shear rates at 30 second interval.
- All measurements were made in the constant temperature room maintained at 27 ± 2°C.

The flows of 1:3 cement-sand (Ennore) mortar were determined by using the flow table according to IS-5512(1983) and by varying the dosages of superplasticizers.

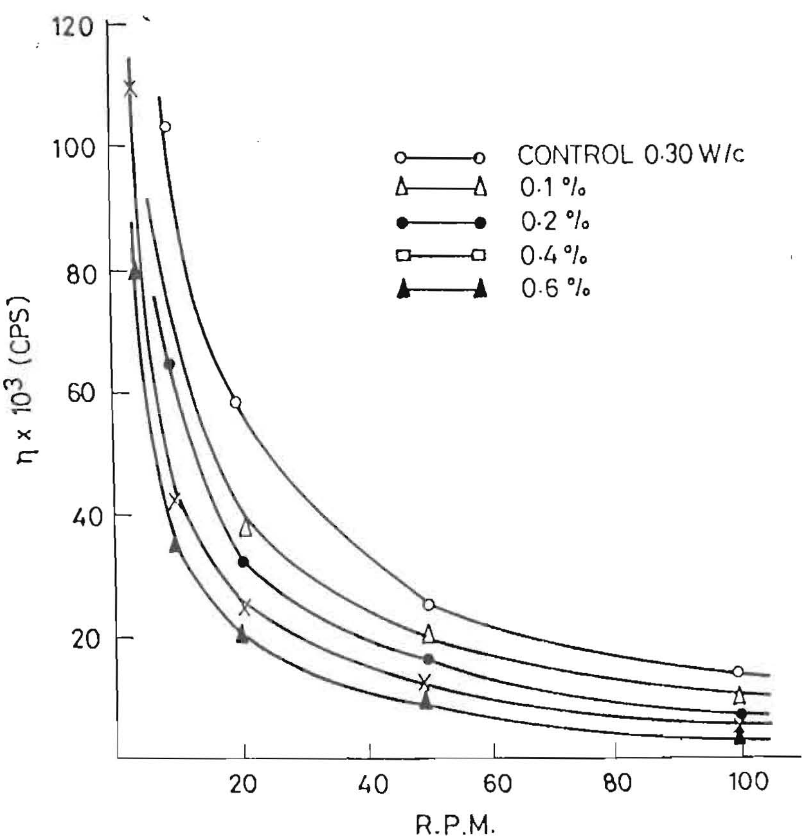

FIG. 2

Effect of Added Amount of CBRI-SP on the Viscosity of Cement Paste

RESULTS AND DISCUSSION

In Fig. 1, the typical variation of cement paste viscosity with various water-cement ratios (0.30, 0.35 and 0.40) at shear rates (5, 10, 20, 50 and 100 rpm) is shown. As expected the viscosity decreases as the water content is increased and the shear rate is increased.

In Figure 2, the effect of dosage of CBRI-SP on cement paste with shearing rate is indicative of the fact that with increasing concentration of superplasticizer, there is decrease in the viscosity. This may be due to the electrostatic repulsion of more anions adsorbed on the surface of cement paste (15) at higher dosage of superplasticizer causing decrease in viscosity. The 0.6% dose provide a considerable decrease in viscosity in comparison to control at respective shear rates.

Figure 3 represents the expected trend of decrease in viscosity of pastes (W/C = 0.30) with increasing shear rates in presence of diferent superplasticizers at a given dosage (0.6%) level. It has been observed that almost all the superplasticizers provide

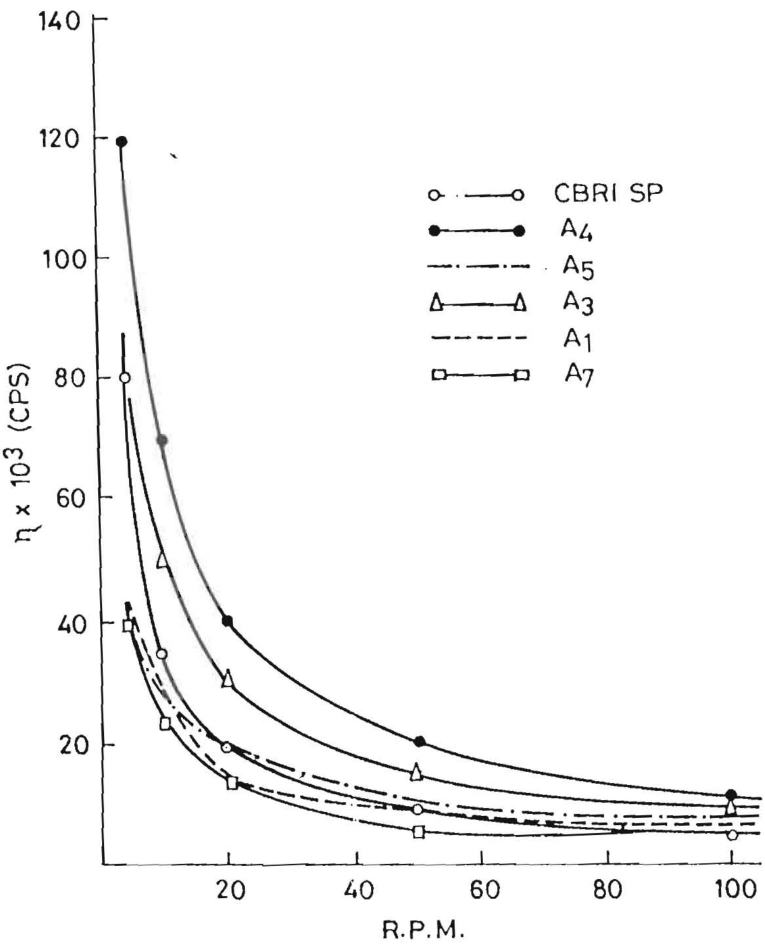

FIG. 3
Effect of Various Superplasticizers (0.6%) Dose on the Viscosity of Cement Paste at 0.30 W/C Ratio

more or less the same viscosity at highest shear rate applied (100 rpm), indicating that if sufficient vibration is provided in cement paste the viscosity is the same for all the superplasticizers studied. At a lower shear rate, viz. 20, the CBRI-SP has similar effect as A1, A3 & A5. This is evident from Fig. 4, where viscosity variation at different dosage levels of CBRI-SP (W/C = 0.30) has been plotted at different shear rates. It is clear from the plot that at the maximum shear rate (100 rpm) the variation in the viscosity is negligible irrespective of dosages of 0.2 to 0.6% (CBRI-SP) or the type of the superplasticizer. At other shear rates, there is a continuous decrease in viscosity with increasing dose level. This decrease in trend is desirable and is expected. However, care has to be exercised that the admixture/ superplasticizer should not entrain air beyond a limited extent within the levels as required by the International Standards. Higher entrainment of air will be harmful to the benefit expected of the superplasticizer on strength, permeability etc.

Fig. 5 is similar to Figure 4 but with W/C ratio of 0.35. From Figure 5, it is clear that when the water-cement ratio is sufficient to make the paste fluid, there is hardly any contribution

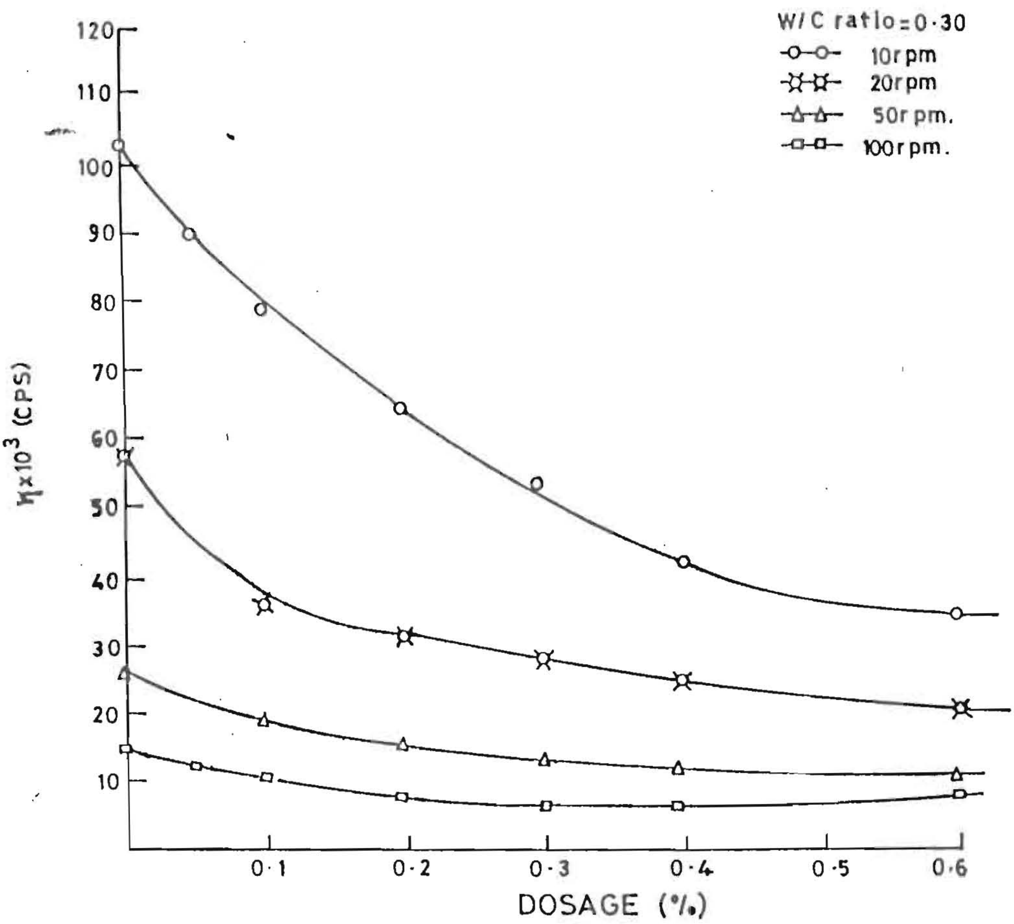

FIG. 4
Effect of Shear Rates on the Viscosity of Cement Paste with the Addition of CBRI-SP at 0.30 W/C Ratio

in the fluidity of cement paste with the addition of superplasticizers. This corroborates with the general observation that in practice the beneficial effects of superplasticizers are particularly evident in low slump and low w/c ratios. Similar trends were observed by the authors in some of their studies on mortars and concrete published elsewhere (13, 14).

The effect of split/delayed addition of various superplasticizers on the viscosity of cement paste has been plotted in Fig. 6(1-8). It is clear from the figures that with the split/delayed addition, there is decrease in the viscosity (compare the continuous curve with dotted line) or in other words there is more dispersion of the cement paste. The dispersive action of the superplasticizer is related to its interaction with cement and cement components. This increase in dispersion or workability has also been observed by many workers through Zeta Potential measurements (15), when superplasticizer is added a few minutes after mixing with water. The large negative values of the Zeta potential are observed (16) for the system but somewhat higher values result by delayed addition. It has been suggested that a certain number of sulphonic groups linked to the polymer is essential to give rise to flat adsorption and efficient dispersion. The enhanced effect of superplasticizer due to split/delayed addition can be explained as follows. When superplasticizer solution is added in the cement, it is rigidly attached to the C_3A - gypsum mixture

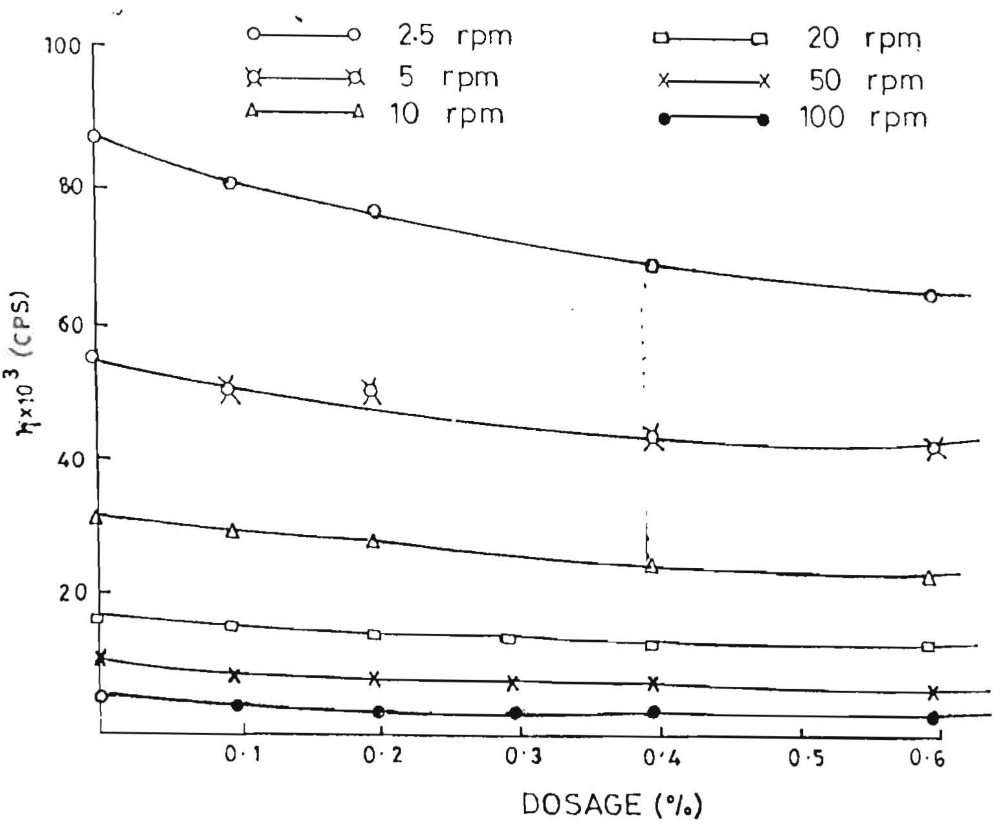

FIG. 5
Effect of Shear Rates on the Viscosity of Cement Paste with the Addition of CBRI-SP at 0.35 W/C Ratio

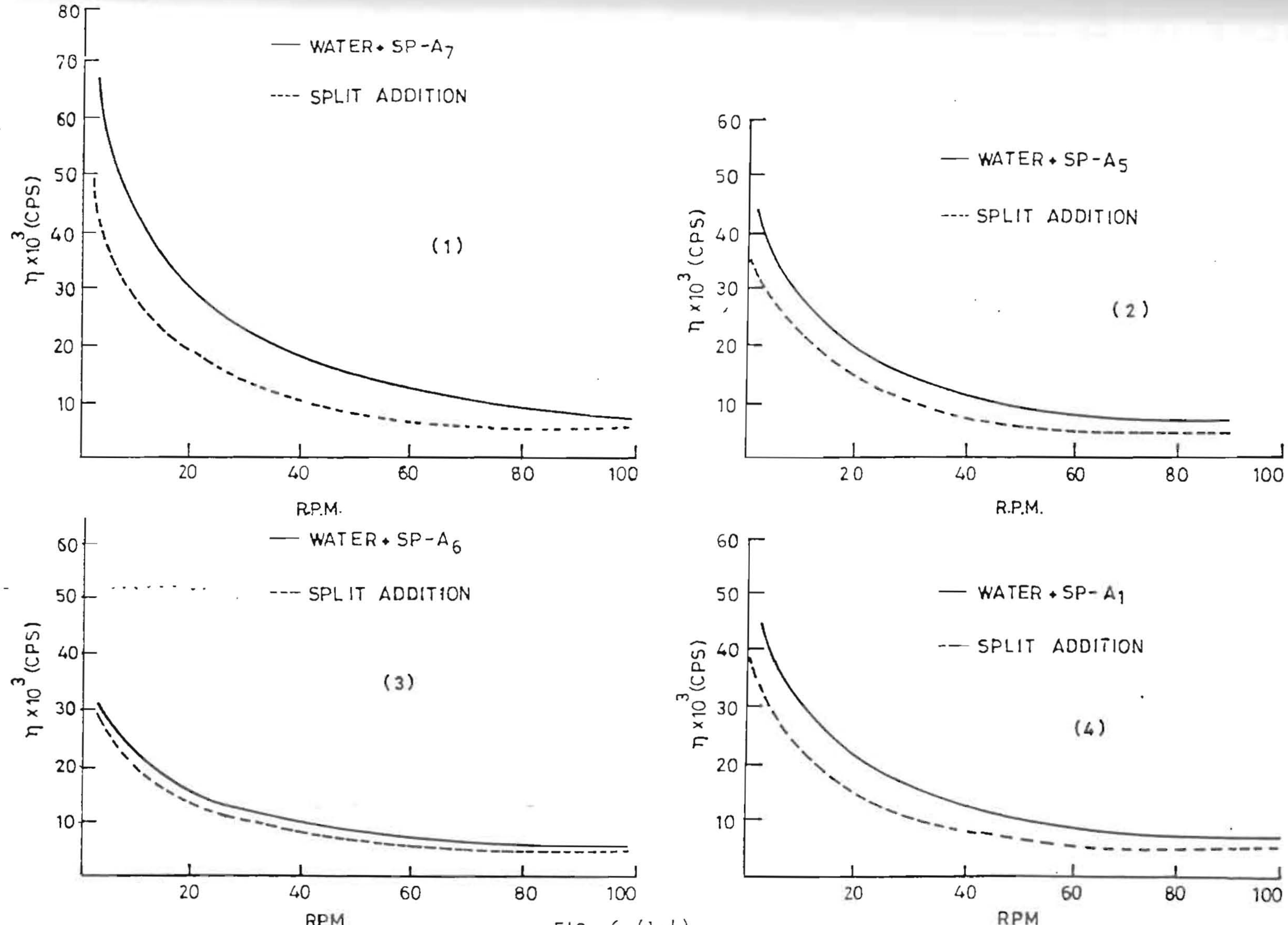

FIG. 6 (1-4)
Effect of Split Addition of Superplasticizers on Viscosity of Cement Paste at 0.30 W/C Ratio

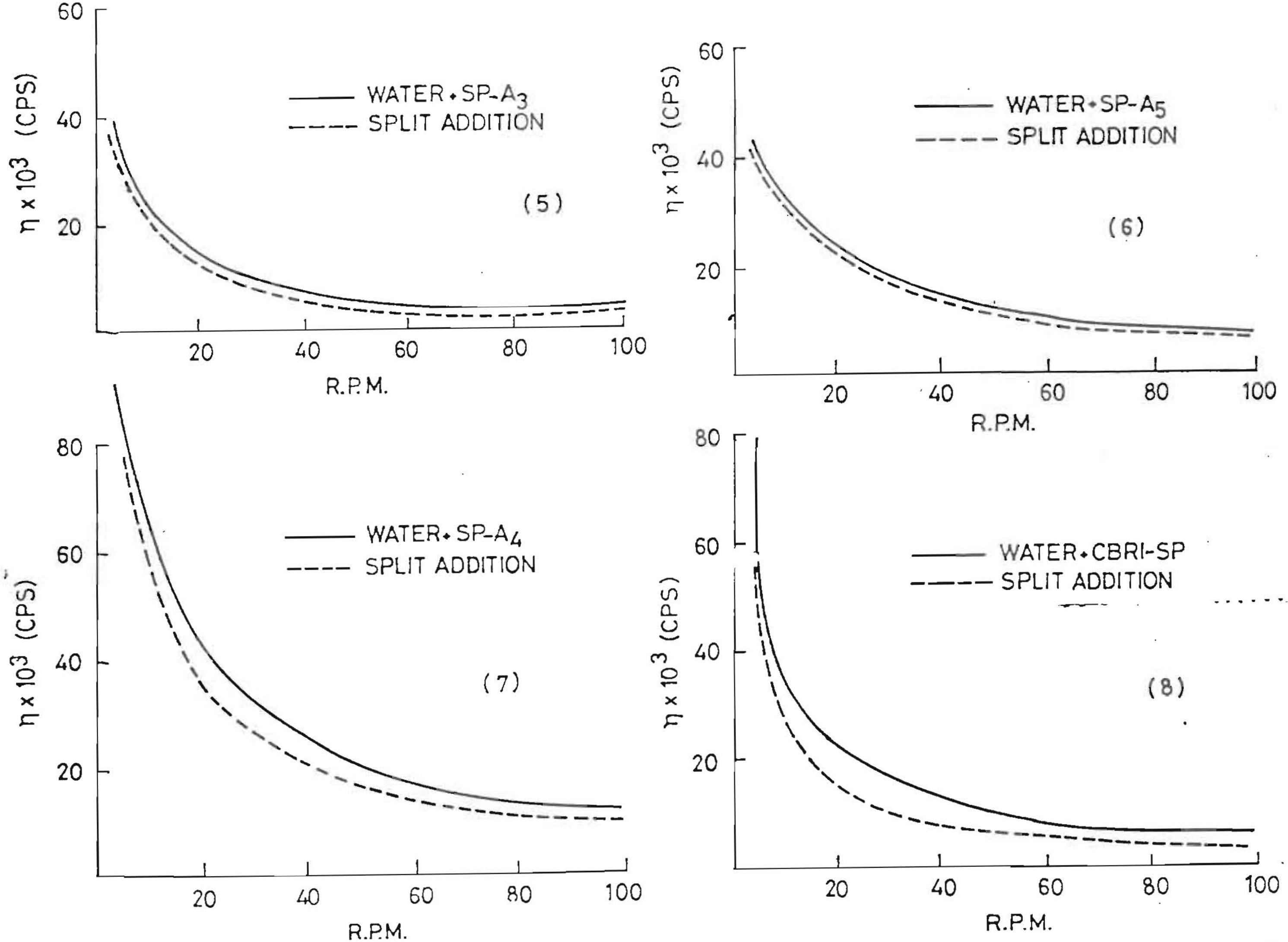

FIG. 6 (5-8)
Effect of Split Addition of Superplasticizer on Viscosity of Cement Paste at 0.30 W/C Ratio

leaving only small amounts for the dispersion of C-S-H phases. However, when split/delayed addition is made the superplasticizer is adsorbed to a lesser extent on the C_3A-gypsum mixture already undergoing hydration and ettringite formation and enough of the superplasticizer is left to promote the dispersion of the C-S-H phases and lower the viscosity of the system. Further, it has been observed (11,17) that the adsorption of superplasticizer is virtually terminated after 1.0 to 2.0 minutes of mixing and as such a great part of superplasticizer is adsorbed on the hydrated products, so that the dispersing effect of the admixture is greatly reduced.

Now, if the time of addition of the superplasticizer corresponds to the beginning of the dormant period of hydration of cement pastes without admixture (1 minute in the present study), the adsorbed superplasticizer is able to break down the aggregates of

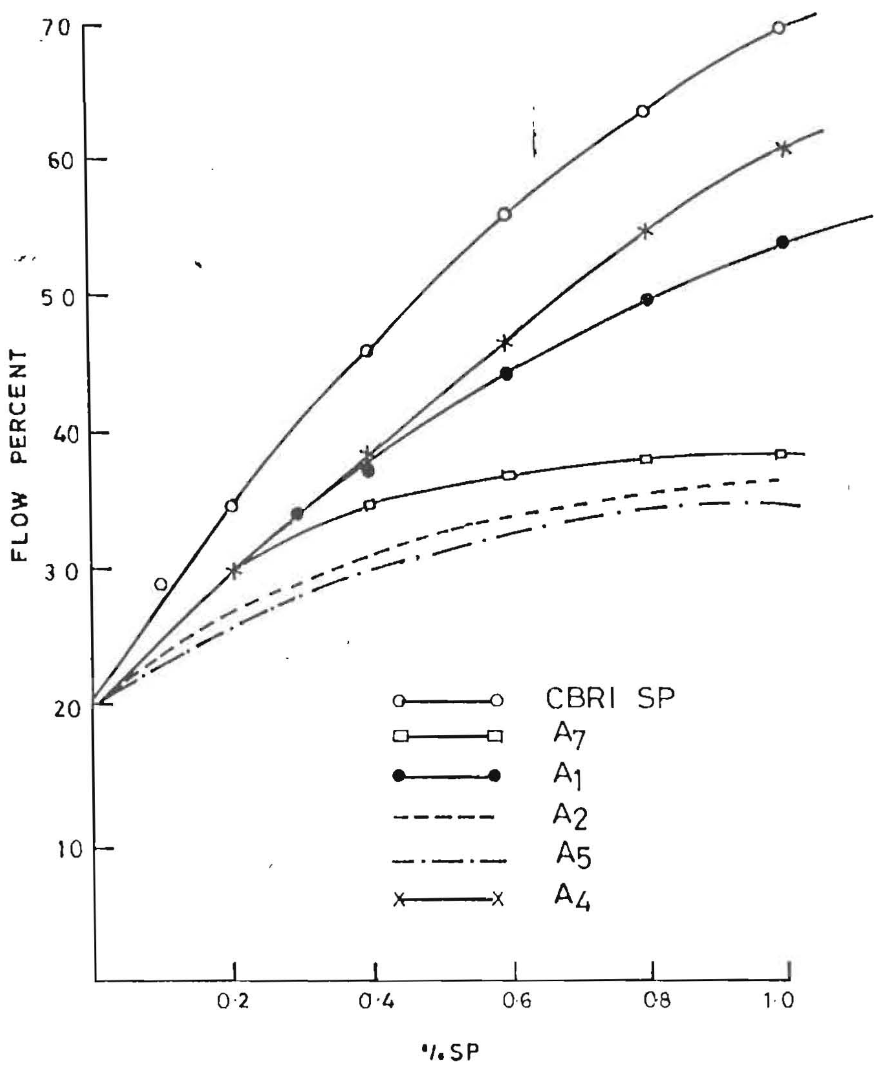

FIG. 7
Variation of Flow of 1:3C:S Mortar of Different Superplasticizers with Concentration

particles, without interfering with the dormant period of hydration (11). This adsorbed superplasticizer is able to disperse the cement particles, therefore causing higher fluidity of pastes, when there is split addition.

Figure 7 shows the effect of variation of dosages of superplasticizers on the flows 1:3 cement sand mortar determined according to IS-5512/1983

The above split addition studies were extdended to mortars (1:3 cement Ennore sand at W/C = 0.45) for various superplasticizers and at various dosage levels (Figure 8). It has been found that

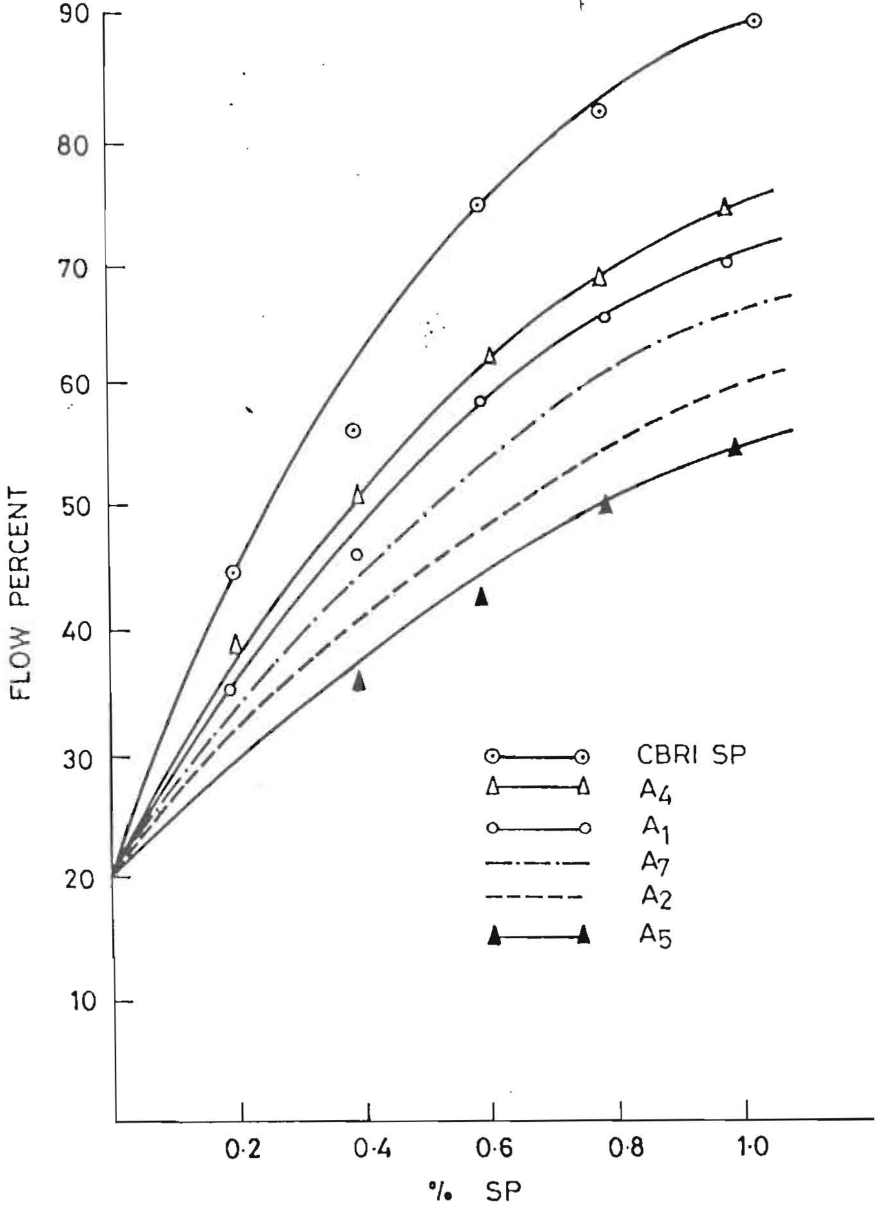

FIG. 8
Effect of Split Addition of Various Superplasticizers on the Flow of 1:3C:S Mortar

there is 10-15 % increase in the flow percentage when the split addition is made (Compare to Fig. 7).

CONCLUSIONS

1. The fluidity of the cement paste is greatly influenced by all types of superplasticizers studied. Thus the study of rheological properties, namely viscosity, can help in determining the efficacy of a superplasticizer.

2. The fluidity of the cement paste has been found to depend upon the shear rate. Thus even at low concentration of superplasticizer and higher shear rate, it is possible to achieve the same fluidity as obtainable with higher concentration and at low shear rate.

3. Each superplasticizer affects the viscosity differently and thereby the dosage level varies from product to product.

4. When the w/c ratio of the cement paste is enough to impart sufficient fluidity, further addition of superplasticizers will have less effect. Adjustments of low w/c ratio and shear rate will not only give desired fluidity but also a compact and dense mass. The results of these studies can be extdended to predict the behaviour of zero slump concretes under the influence of superplasticizers.

5. The split/delayed addition of superplasticizers imparts 10-15% increase in the flow per cent value. This increased workability/slump can be found useful where concrete has to be transported to a distant place or used in tropical regions.

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