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WATER REDUCING AGENT:
CASHEW NUT SHELL LIQUID

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A study of a water-reducing agent from cashew nutshell liquid

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Abstract – The water-reducing agent better known as superplasticizer is a recent development. A number of base materials have been used for the development of such water-reducing agents which can act better than ordinary plasticizers in concrete. The sulphonated salts of melamine, napthalene, lignin, hydroxycarboxylic acids and hydroxylated polymers are some typical compounds. Recently cashew nutshell liquid obtained from a natural product waste as a thick black phenolic compound has been converted into a water-reducing agent. This paper describes the results obtained on its effectiveness in influencing the rheological properties of flow, viscosity, particle-size distribution, etc, of cement particles in hydrating cements and the water-reducing capabilities in cement mortars and concretes.

The use of chemical admixtures for controlling concrete properties has been accepted both nationally and internationally for the last two decades [1–3]. One of the most valuable and interesting developments in admixture technology has been the evolution of superplasticizers [2]. These superplasticizer admixtures are a functional extension of normal plasticizing admixtures. The use of superplasticizers in concrete benefits the construction engineer either in saving time, improved strength and more workable concrete placement in complicated and congested reinforcements, or in the appearance of the finished structure [4]. The main role played by such admixtures is related to the dispersing capability due to the presence of surface active constituents present in them. The long chain sulphonated compounds or hydroxycarboxylic acid groups *etc* promote the surface active properties of the admixture. These properties vary with the molecular size of the compound. Since superplasticizers – unlike normal plasticizers – do not markedly lower the surface tension of the water, they can therefore be used at very high dosage levels without entraining excessive air. Hence full advantage may be obtained from the water-reducing effect in terms of high initial and subsequent strength. In addition, its use with marginal-quality cement and aggregate may help to produce both good-quality and durable concrete at low water:cement ratios as well as flyash concrete, blast furnace slag concrete, lightweight concrete and fibre–cement composites, *etc*, with reduced water requirements.

This paper describes the salient properties of a superplasticizer synthesized [5] from cashew nutshell liquid (CNSL) or fractionated CSNL by sulphonating and condensing with formaldehyde in the presence of certain additives (labelled as CBRI-SP). Some of the preliminary investigations on the properties of flow, compressive strength, viscosity of cement pastes, dispersion of cement particles, *etc*, of the superplasticizer are presented and compared with some other commercially available superplasticizers.

Experimental materials

- Cement: Ordinary Portland cement conforming to IS:269-1976 (Ordinary and low heat Portland cements).
- Sand: Standard Ennore sand conforming to IS:650-1966 (Specification for standard sand for testing of cement).
- Superplasticizers: Ten commercially available superplasticizers were procured and labelled SP-I–SP-X, omitting their trade names.
- CBRI-SP: A superplasticizer based on CNSL, synthesized at the Central Building Research Institute.

Methods

The percentage flow values of a 1:3 cement:sand (Ennore) mortar at various water:cement ratios for the control and at a water:cement ratio of 0.45 for different dosages of superplasticizer were measured according to IS:5512-1983 (Flow table for use in testing hydraulic cements and pozzolonic materials); see Table 1.

The viscosity of the cement paste was measured using a Brookfield RVTDVII, digital model. The T-bar spindle No. 95 was used and the shear rate was maintained at 100 rpm. For each measurement the cement was mixed with a predetermined amount of water for 5 minutes before the viscosity and flow were measured. For the superplasticized paste, the superplasticizer was mixed with the required quantity of water and added to the cement to obtain the paste for experimental measurements. All these measurements were made in a constant temperature room maintained at 27 ± 1°C and a relative humidity (RH) of about 50%.

In another set of experiments the flow of the cement paste only was measured using a truncated cone open at both ends (height 60 mm, base diameter 40 mm, top diameter 20 mm) and using the flow table as in IS:5512-1983 to obtain the flow values (designated as minislump by some workers [6]) at different water:cement ratios. The results of the viscosity and flow of cement paste at different water:cement ratios are given in Table 2.

The compressive strength of the concrete prepared with cement 1, sand 1.50 and aggregate 3 (< 20 mm) was determined. A comparative evaluation of slump, compaction factor and compressive strength of the M15 concrete under field conditions (used for the construction of an indoor stadium at Dehradun in India) is given in Table 3.

A Malvern (3600 Model) laser particle-size analyser was used to determine the effect of the addition of CBRI-SP on the particle-size distribution or dispersion of the cement particles. This was carried out in a non-aqueous medium (benzene) so that the change in the size of cement particles due to the small addition of water/superplasticizer solution was evident. The whole operation was automatically controlled and the final stage of the particles recorded using the analyser. The cell of the analyser was filled with about 20 ml of benzene and the instrument was set. About 0.010 g of dry cement powder was inserted in the organic liquid, stirred well and the distribution pattern recorded. Then a drop of water was added using a microsyringe, the liquid was stirred for 2 hours and the distribution pattern recorded. Similarly, the pattern was recorded after adding a solution of CBRI-SP (0.6%) to a fresh cement in benzene and stirring for 2 hours. The particle distribution patterns are given in Fig 1.

The costs of the various commercially available superplasticizers provided by suppliers were collected and are compared along with their recommended dosage in Table 4.

Results and discussion

The addition of water-reducing superplasticizing admixtures allows a similar or better workability, flow or slump, *etc* to be achieved by using less water than required for normal

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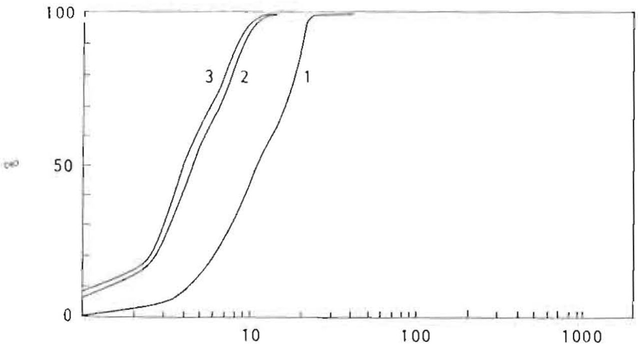

Fig 1 Particle distribution patterns: 1, cement in benzene; 2, cement, benzene and water; 3, cement, benzene and superplasticizer solution

Table 1 Comparison of flow (1:3 cement:Ennore sand) of various superplasticizers at various dosages

Superplasticizer	Flow (mm) Dosage (%)						Water: cement ratio
	0.0	0.2	0.4	0.6	0.8	1.0	
Control	120	–	–	–	–	–	0.45
	129	–	–	–	–	–	0.50
	153	–	–	–	–	–	0.54
	195	–	–	–	–	–	0.60
SP-I	120	130	135	150	157	160	0.45
SP-II	120	126	130	140	143	145	0.45
SP-III	120	130	136	145	150	155	0.45
SP-IV	120	120	130	140	140	140	0.45
SP-V	120	120	120	120	120	120	0.45
SP-VI	120	125	125	130	130	130	0.45
SP-VII	120	130	135	144	145	145	0.45
CBRI-SP	120	130	142	153	160	170	0.45

concrete. Recommended dosages allow a 5–20% reduction in water content for a specified workability. It would be reasonable to assume that the extent of water reduction by the addition of water-reducing admixtures would be markedly affected by changes in mix parameters such as cement content, aggregate size, shape, grading and the water:cement ratio. In order to establish the suitability of the product developed at our institute as a superplasticizer/water-reducing admixture, it was incorporated in the cement–water system and its rheological properties evaluated.

The relationship between flow (mm) and dosage of various superplasticizers for 1:3 cement:sand mortars at a water:cement ratio of 0.45 is given in Table 1 along with the control at various water:cement ratios.

It is clear from this table that the flow values increase with an increase in the dosage of superplasticizer. The flow value of the plain mortar (1:3 cement:sand), just after mixing, is 120 mm whereas with an addition of superplasticizers it increases up to 170 mm; the effect varies distinctly with the type and dosage of superplasticizer. It is clear also that the flow value of plain mortar (153 mm) at a ratio of 0.54 is almost the same as that of CBRI-SP (0.6%), SP-2 (0.8%), SP-4 (1%), SP-10 (1%) at a ratio of 0.45. These values indicate that a water reduction of about 18% for the same mortar and for the same workability is possible at varying dosages of superplasticizer.

The results of the viscosity n (cP) and flow for neat cement paste at different water:cement ratios, compared with the results obtained with CBRI-SP (0.6% dosage), are given in Table 2. The viscosity and flow of superplasticized cement

Table 2 Viscosity and flow of cement paste at different water:cement ratios and at 0.6% of superplasticizer

	Water:cement ratio	n (cP)	Flow (%
Control	0.30	4.7×10^3	175 (in 25 stro
	0.35	2.5×10^3	250 (in 25 stro
	0.40	1.2×10^3	Paste flows on the table
CBRI-SP	0.30	2.0×10^3	250 (in 20 stro

Table 3 Properties of M15 concrete with superplasticizer at s dosage and water:cement ratio

Mix 1:1.5:3	Water:cement ratio	Slump (mm)	Compaction factor	Compressive strength (100 mm cube (kg/cm²; 28 da
Control	0.52	100	0.91	190
0.6%	0.48	150	0.93	220
SP-X (Napthalene based)				
0.6%	0.48	162	0.94	220

Table 4 Comparison of cost of various superplasticizers

Designation	Recommended dose by wt of cement (100 kg)	Approx. cost at site (Rs/litre)	Approx. cost of superplasticizer (1:2:4 conc cement content, 64 kg in Rs
SP-I	0.6-0.162 litres	16/-	24– 44/-
SP-II	200–300 ml	40/-	88–120/-
SP-III	0.6–3.0%	38/-	64–200/-
SP-IV	0.5–3.0%	38/-	64–200/-
SP-V	0.3–0.6%	20/-	36– 72/-
SP-VI	500–700 ml	40/-	116–172/-
SP-VII	0.6–1.0 litres	48/-	116–172/-
SP-VIII	0.15–0.30%	55/-	49– 99/-
SP-IX	0.5–1.0%	47/-	117–280/-
SP-X	600–800 g	35/-	63– 87/-
CBRI-SP	1.8-2 litres	6/-	35– 38/-

paste at a ratio of 0.30 falls between the viscosity obtained at a ratio of 0.35–0.40 of the control cement paste, thus indicating the water-reducing capability of the CBRI-SP.

The slump (mm), compaction factor and compressive strength (28 days) for the M15 concrete prepared at the field site are given in Table 3. It is clear from the table that with the addition of 0.6% superplasticizer (CBRI-SP) the slump increases from 100 mm of control at a ratio of 0.52 to 162 mm with a ratio of only 0.48, whereas it increases to 150 mm on the addition of commercial superplasticizer SP-X, which is claimed to be a napthalene sulphonate formaldehyde condensate. Thus, this indicates the better fluidizing effect of CBRI-SP. However, in the case of superplasticized concrete the increase in strength is the same (220 kg/cm²) with both the superplasticizers compared with 190 kg/cm² for the unplasticized concrete.

The particle-size distribution curves 1,2,3 (Fig 1) for the neat cement, hydrating cement and superplasticized hydrating cement, respectively, clearly show that the cement undergoes dispersion on hydration but the process is slow. On the addition of superplasticizer (CBRI-SP) curve 3 shows that dispersion is increased because the number of finer and colloidal particles is apparently large.

It is clear from Table 4 that the cost of CBRI-SP is lower than that of other commercially available water-reducing/superplasticizing admixtures. CBRI-SP is based on CNSL but the base material for the other products given in Table 4 (except SP-X, which is napthalene based) is not mentioned by the manufacturers in their product catalogues. However, on the basis of the amount required for the same quantity of cement, CBRI-SP is about 30% more economical compared with the napthalene-based superplasticizer.

Conclusions

As a result of the investigations carried out using CBRI-SP and other commercial water-reducing/superplasticizing admixtures in cement pastes, mortars and concrete in order to determine viscosity, flow and strength properties, it can be said that:

(1) The viscosity obtained with CBRI-SP at a water:cement ratio of 0.3 falls between those obtained without superplasticizer at ratios of 0.35 and 0.40. The same holds for minislump.
(2) CBRI-SP produces a large flow in mortar better than all the commercially available products studied for this purpose at the same water:cement ratio and dosage level.
(3) In concrete the 0.6% dosage of CBRI-SP and the naphthalene-based commercial SP-X at a ratio of 0.48 results in a better compaction factor than that obtained in concrete without superplasticizer at a ratio of 0.52. In these cases the slump is improved from 100 mm to 150 mm and the 28 day compressive strength increases to 22 MPa compared with 19 MPa for the neat concrete.
(4) CBRI-SP behaves like the well-established sulphonated napthalene formaldehyde condensate superplasticizer.
(5) CBRI-SP is less costly and more than 30% economical than other commercial superplasticizers.

Therefore this product is recommended as a cheaper, good, water-reducing admixture/superplasticizer for commercial utilization.

Acknowledgements

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Books & Publications

Cladding directory

A TCS Programme with chartered surveyors Richard Ellis and City University has led to the publication of a specialist guide to cladding and curtain walling systems in the UK.

Richard Ellis's three-year research project with the Structures Research Centre at City University in London began in September 1989. Its main aim is to compile a comprehensive computer database for architects and other specifiers. The database classifies cladding and curtain walling systems primarily under their technical capabilities and assesses component parts against criteria such as finishes available, size of frame members, materials employed and insulation properties.

During the course of investigations there was found to be a distinct lack of guidance for specifiers of cladding systems. To alleviate this problem the researchers have compiled *The Curtain Walling and Cladding Directory*, which contains information on more than 70 manufacturers. Companies are categorized according to their primary business activity: curtain walling, composite panels, profiled metals, or concrete and stone. Each company is summarized on a separate fact sheet which details size, capabilities, products, facilities and services available.

Information can be retrieved quickly and entries cross-referenced easily. The directory, which will be updated annually from the computer database, also contains a bibliography of British Standards and Codes of Practice relevant to curtain walling and cladding.

Published jointly by Richard Ellis Building Consultancy Division and City University Structures Research Centre, the directory costs £75 and comprises 96 pages ring-bound into an A4 folder. Contact Simon Loomes at Richard Ellis, Berkeley Square House, London W1X 6AN.

Design guide for precast concrete frame buildings

Precast Concrete Frame Buildings: Design Guide provides a detailed review of the subject, promoting a greater awareness and understanding of precast frame buildings. Although written particularly for readers less familiar with this form of construction, it will be of interest to all engineers, architects and others concerned with the procurement of buildings.

The authors are Alan Tovey, Associate Director, Building and Structures, at the British Cement Association and Kim Elliott, Lecturer at Nottingham University.

There has been a wealth of general and detailed information on many structural forms but surprisingly little to help engineers and architects to achieve a full understanding of precast concrete building structures and their procurement. This new publication seeks to fill that gap.

The Guide has been prepared and published with the support of the Precast Concrete Frame Association and the Structural Precast User Group. It is available from the British Cement Association, Wexham Springs, Slough SL3 6PL, price £24.

BRE publishes reports on housing systems

The Building Research Establishment has published reports on two steel-clad housing systems (Cowieson and Weir 1920s) and on three steel-framed housing systems (Coventry Corporation, Riley and Stuart). These reports form the final part of the series of 34 reports covering BRE's investigation of the form of construction and condition of steel-framed and steel-clad dwellings, carried out on behalf of the Department of the Environment.

These reports cover about [illegible] dwellings which represent almost [illegible] of the total stock of steel-framed dwellings built in the UK between 1920 and 1975. The findings of each report [illegible] based on up to five detailed inspections, depending on the number of dwellings built and the availability of vacant properties.

Available from the BRE Bookshop, Building Research Establishment, Garston, Watford WD2 7JR. The Stuart and Weir 1920s Reports are each priced at £10,- the Coventry Corporation and Riley Reports at £5 and the Cowieson Report at £3.

Bridged in steel case study

Construction at Dumfries of three viaducts in weather-resistant steel over the River Nith is featured in the latest issue of the 'Bridged in Steel' series of case studies.

Provision of a bypass to the north of Dumfries, Scotland, which removed a bottleneck in the town centre and improved traffic flow required three crossings over the River Nith.

Comparative costings confirmed that a superstructure comprising steel plate girders acting compositely with an *in situ* concrete deck slab was the most economical solution, and weather-resistant steel without any separately applied protective coating was endorsed as an appropriate low-cost, low-maintenance structural material.

A consistency in design concept was regarded as important to convey the impression of a family of structures and the approach embankments and viaducts had to be kept low to minimize visual intrusion on the landscape.

The 12 page A4 publication, *Bridged in Steel*, No. 11, is illustrated with diagrams and colour photographs. Copies are available free from Fraser Nelson, British Steel General Steels Commercial Office – Plates, PO Box [illegible] Motherwell, Lanarkshire ML1 1AA.