Concrete Beton

Number 121
April 2009

The Official Journal of
The Concrete Society
of Southern Africa

Accredited technical paper:
Self-consolidating mortars using various secondary raw materials

Technical paper:
Self-compacting concrete

Concrete News and Events

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Cover picture

The beautiful Tenerife Concert Hall was designed by architect, Santiago Calatrava. The all-concrete building is characterised by the dramatic sweep of its roof. Rising off the base like a crashing wave, the roof soars to a height of 58m over the main auditorium.

President's Message

In the words of Mick Hucknall of Simply Red: *"Money is too tight to mention..."* Every time one turns a page in a magazine or newspaper or flicks on the TV, one is bombarded with reports referring to 'the global credit crunch', 'the impending recession', 'crashing industries' and 'major job losses which are looming or have already taken place'.

Things appear to be quite dire for the near future, with the developed nations of Europe, North America and even the East being hard hit by this phenomenon. Most economists are predicting an upward turn in the global economy sometime in 2010, some even being so bold as to put dates of late 2009 forward. They all maintain that the halcyon days that we have been experiencing over the last several years are a thing of the past.

Where does this leave South Africans?

According to our local financial experts, our particular picture does not seem all that gloomy compared to other countries. The South African construction industry has weathered the fiscal storm with varied success. As you know, certain sectors of the market have slowed or even come to a standstill due to the noticeable cuts in developmental spending in the mining and some commercial and industrial fields. The middle to upper income housing markets have shown a significant slowdown because of sentiment amongst developers.

Globally, governments have produced financial rescue plans in an attempt to produce some measure of damage control. These so called 'stimulation packages', which amount to large sums of cash being thrown at the respective economy, are akin to a kind of economic 'toe in the proverbial dyke', aimed at halting the financial decay and then rekindling economic growth. A high proportion of these economic encouragement initiatives entail large-scale government spending on infrastructure projects. The problem with this is that there will always be a time lag from inception to implementation, and ultimately the fiscal spend.

As for the South African industry, and particularly the construction industry, our saving grace appears to be coming from government spending on infrastructure projects currently taking place. The marked difference between our situation and the rest of the world's rescue package is that the South African government spending taking place here is not part of a 'bail-out' plan.

The projects currently embarked upon by our government departments and parastatal organisations were conceived over sufficient time with adequate care and consideration, which will contribute to their sustainability and success.

We are talking about projects such as the Gautrain Rapid Rail Link, the various stadiums constructed for the upcoming 2010 FIFA World Cup, SANRAL's Gauteng Freeway Improvement Project, various power station upgrades, as well as the enormous national Expanded Public Works Programme. The economist talk appears to be that, although progressing at a notably slower rate than previous years, these ventures should see our construction industry through to 2012 and beyond.

Hopefully, South Africans can weather the storm during this period and the world economy recovers by then.

What are we as the South African construction industry in general and the concrete and cement industry, in particular, to do?

Well, we all know it is time to tighten the monetary belts – which brings me to the gist of this President's message.

Historically, South Africans are tenacious beings – we rise up in the face of adversity and often have innovative solutions to problems, whether practical, technical, social or political.

This is particularly true with regard to cement and concrete practitioners, where one has just to look at the list of phenomenal entries received for the upcoming Fulton Awards.

I would like to point out the important role of the Concrete Society of Southern Africa in all of this. The Society must be seen as a forum for its members to network and brainstorm with peers, to ultimately develop new technologies, different applications and come up with innovative, economic, durable and environmentally friendly solutions to problems, while taking cognisance of global fiscal trends.

After all, our mission statement says, we are here *"....to promote excellence and innovation in the use of concrete and to provide a forum for networking and for the sharing of knowledge and information on concrete."*

Lastly, I would like to rally your support for the *Concrete Beton* publication. This periodical is an important weapon in the arsenal of the Society, providing its networking and technical information dissemination function. Collated by technical people for technical people, the Beton is the only accredited technical journal dealing solely with cement and concrete technology in Southern Africa.

This publication is distributed to approximately 646 members and 4750 other industry participants – many of whom are industry decision makers. So we urge you, the members, to recognise the value of the *Concrete Beton* by supporting it with content, comments and financial support, through advertising. This is your journal, please become involved with it!

In closing, I would again like to remind members of the upcoming Fulton Awards, the premier construction industry awards, which will be highlighting the superlative cement and concrete related projects completed by our local industry colleagues over the past two years. This event is scheduled for the 19th to 21st June 2009 and promises to be outstanding, so book your tickets early to avoid disappointment.

In summary, I suggest that we, in the meantime, prepare and strengthen ourselves technically and augment our networking so that we will be ready for the next economic resurgence.

Francois Bain Pr.Eng

President:
The Concrete Society of Southern Africa

Letter to the Editor

Discussion on paper in Concrete Beton Paper titled: 'Practical Consideration and Constraints in Durability Testing', by R Page and S Badenhorst. The authors are to be thanked for providing this useful set of practical considerations on durability index (DI) testing.

We would like to raise a number of points from the paper, discussed below:

1. It has been decided to change the standard thickness of a specimen from 25 mm to 30 mm. This is to accommodate the generally larger maximum aggregate sizes now being used in industry.
2. Chloride conductivity: It has to be pointed out that this is not an accelerated diffusion test *per se*, but a migration test, however, the relationship between migration and diffusion can be used.
3. It is important to distinguish the difference between durability testing and index testing. Tests such as accelerated carbonation and chloride profiling (from, for example, a bulk diffusion test) are durability type tests, while the DI tests as well as the Torrent test are index type tests, in the sense that the test parameter is an index of potential durability and, if the test is well constituted, can also be used for purposes such as specification and service life prediction.
4. As mentioned in the paper, the OPI cell design and construction has been improved very recently so that leaks should now be eliminated.
5. The paper mentions that the variability (average standard deviation between four samples of the same concrete) was significantly higher than that reported by Standish. Standish's tests actually used variability values based on the standard deviation of the means of sets of results, which will obviously produce a lower value.
6. It is important to quote units when giving values for test results. Thus sorptivity takes the unit mm/$h^{0.5}$. Nominally, the OPI value does not have a unit because it is a log value.
7. In Table 1, the duration of each test is mentioned. It is noted that the samples to be tested with the Torrent meter were only cured for seven days, while samples to be tested using the OPI equipment were cured for 28 days. Comparing test results obtained from the same concrete using two different methods (OPI and Torrent meter) however, should be based on the same curing duration. The 'Total time to results' listed in the table appears to be skewed by the shorter curing duration of the Torrent samples, which needs to be considered when drawing conclusions on time allocation for the various test methods.
8. The authors discuss the observed pressure loss in their OPI pressure cells and state how they adjusted the test results to the observed pressure loss. The methodology used raises concerns about the validity of test results. In principle, test results must not be obtained with leaking pressure cells. The only correct way to handle leaks in pressure cells is to repair the cells to eliminate leaks. The paper authors have adopted a method of 'adjusting the OPI index' to the pressure loss. This is scientifically incorrect as the pressure loss under real testing conditions (for example, using a permeable concrete sample) will be different than that observed in a calibration test (using an impermeable sample).
9. In view of the above point, test results obtained in the study appear somewhat questionable, which may explain the high standard deviation in OPI values observed by the authors (0.22). A recent study on 60 different concrete mixes cast, cured and tested at the University of Cape Town (UCT) yielded an average standard deviation of 0.12. In another recent project at UCT, approx. 20 site-cured concrete mixes were tested, resulting in an average standard deviation between four samples of the same mix of 0.13. These values are considerably lower than those reported by the authors.
10. Based on the high variability of their OPI test results, the authors suggest increasing the diameter of concrete samples tested for OPI. In view of the above discussion, this suggestion may need further consideration. It is our view that an increase in sample diameter will not result in a lower variability of test results.
11. In conclusion 1. in the paper, the authors state that the Torrent meter is a less 'onerous' test compared to the OPI test. However, it needs to be considered that permeability test results obtained with the Torrent Meter need careful interpretation by the operator as the moisture content of the concrete has a large influence on the test results.
12. In conclusion 4. the authors state that the observed leakage in the pressure cells did not significantly influence the test results. In view of the above discussion, this conclusion may need further consideration.

Prof M G Alexander and
Dr H Beushausen
University of Cape Town
(Abridged version)

Author's Reply:
No objections, all valid points
Regards
Sebasti Badenhorst, Pr.Eng

Brian Perrie

Armand van Vuuren

Councillor Election Results

The Concrete Society of Southern Africa would like to congratulate Brian Perrie and Armand van Vuuren on being elected as council members of the Society for the 2009/2010 term. The Society's Council would like to thank all members who voted.

Cementitious pastes

Author George Fanourakis' technical paper, '*The influence of slag fineness on the workability of cementitious pastes*' assisted by R J Page, was well received.

CSSA asked the author what we could expect from him in the future.

In the past, Fanourakis focused on teaching concrete technology and geotechnical engineering. But since the merger between RAU, Vista in Soweto and the TWR, his primary focus is on research. "Creating a research culture among students is to be encouraged," he says.

His next research paper will be on '*Quality control during concrete placement in large diameter bored piles*'. This paper will be co-authored by Peter Day and Graham Grieve. This research assessed the effects of the free fall technique as well as varying amounts of water and/or spoil in the pile hole, on the quality of the concrete at the end of the pile shaft.

George Fanourakis of the University of Johannesburg

The results of this investigation dispel the myth that the free fall placement of concrete in clean, dry pile holes has a detrimental effect on the degree of compaction and compressive strength of the concrete. Furthermore, as little as 100 mm of water in the bottom of the pile hole resulted in approximately 50% decrease in the strength of the concrete.

As little as 50 mm of dry spoil at the bottom of the pile hole negated all direct contact between the pile concrete on the underlying founding stratum. Wet spoil was more readily displaced by the concrete but still resulted in significant reductions in base bearing area mainly around the perimeter of the pile base

All of these issues will be dealt with in his new paper which is expected to contribute towards the formation of a guideline for the industry.

Self-consolidating mortars using various secondary raw materials

by Syed Ali Rizwan and Thomas A. Bier

The reported study was conducted by Syed Ali Rizwan and Thomas A. Bier on 15 series of self-consolidating mortars (SCMs) using different types of secondary raw materials (SRMs) at high replacement levels of cement.

Study

SRM particle characterisation and the flow behaviour, strength development, microstructure and early volume stability of SCMs are reported.

A simple procedure has been suggested for strength quantification of SCMs using various SRMs. The study demonstrates that shape, size, and surface morphology and porosity of SRMs play a very significant role in determining the water and high-range water-reducing admixture (HRWRA) demands of SCMs.

SRM characterisation also helps to understand various test results routinely performed on SCM systems. Based on the comparative tests, limestone powder (LSP) alone is not the best SRM for self-consolidating cementitious systems (SCCS). Suitable blends of fly ash (FA) and silica fume (SF) or LSP can be good SRMs for an improved overall response of SCMs using well-graded aggregates.

Keywords: microstructure; porosity; raw materials; self-consolidating mortars.

Introduction

Self-consolidating mortar (SCM) systems are an exciting category of self-consolidating cementitious systems (SCCSs) frequently used in specialised placements and repairs.

These systems use chemical and mineral admixtures to obtain high flow values greater than 10.24 in. (260 mm) for mortars using Hagerman's mini-slump cone. Simultaneous use of such admixtures drops the water demand and improves flow, strength, and durability of such systems in addition to improving other parameters. Suitable mineral admixtures—secondary raw materials (SRMs)—are essential components of SCCS and are described in the literature.[1] The desired flow of SCCS is obtained by using a suitable high-range water-reducing admixture (HRWRA), and high segregation resistance is obtained either by using low water-powder ratio (w/p) or by using a moderate w/p along with a viscosity enhancing agent (VEA). In this investigation, low w/p was used to ensure adequate segregation resistance by using well-graded aggregates. Three types of cements and five different types or combinations of SRMs were used in SCM systems.

These five SRMs included limestone powder (LSP), ASTM Class F fly ash (FA), and FA with 20% of its mass replaced by two rice husk ashes (RHA and RHAP—amorphous and crystalline, respectively) and by as-produced dry powdered silica fume (SF). FA alone, when used as an SRM in large quantities, will retard the system considerably. SCM systems containing FA plus other SRMs taken equal to 20% mass of FA were also investigated with a view to suggest a better SRM system for SCCS. The selected flow level was 12.20 ± 0.79 in. (310 ± 20 mm). LSP is considered relatively inert[2] and has been very extensively used in SCCS in Europe and Canada. SF, FA, and FA plus its 20% by mass pozzolanic replacements with other SRMs result in complex binder systems (ternary binder systems) of varying degrees of activity having complex and not yet fully understood hydration mechanisms. A 20% FA replacement level was chosen because a smaller amount of powder has an optimum efficiency and results in a large increase in compressive strength, whereas the use of a large amount of powder has a smaller effect.[3]

Research on high-performance concrete (HPC) systems using a similar level of cement replacement by SRMs consisting of FA and SF combination has been reported in the literature,[4] although parameters studied were different and it was stated that use of FA in SF concrete offsets the effect SF has in increasing the dosage of HRWRA to achieve a given workability.[4] This is in line with another work[5] and is attributed to shape similarity between the two SRMs, which affords a ball bearing effect during flow of SCCS and to hydrophobic glassy surface of spherical FA particles of varying sizes.

The SRM particle shape, morphology, and internal porosity are of great importance, and these parameters help understand the water/ HRWRA demand of cement-based systems and to explain the results of various tests performed on SCCS.[5] RHA has also been used in high-performance concrete (HPC) and showed excellent resistance to chloride ion penetration and freezing and thawing, and higher compressive strengths than control concrete.[6] Another work[7] states that HRWRA favours entrapment of air during mixing and an increased HRWRA content increases both entrapped air and shrinkage.

Some of the entrapped air escapes during the process of self-consolidation. It is also documented in the literature[8] that use of SF or RHA significantly reduces the mortar bar expansion. The improvement in the properties of cementitious materials containing RHA is due to the reduction of average pore diameter of RHA-containing cementitious systems, reduction of practical w/c of RHA-based systems due to adsorption and uptake of a portion of free water in great numbers of mesopores existing in RHA particles, and more C-S-H gel and less portlandite within such systems.[9]

Considering SCM systems containing LSP as the base line, the strength increments of SCMs using other pozzolanic SRMs or their combinations can be easily obtained. It forms simple overall strength quantification attributable to any particular SRM system in SCMs and is due to both physical and chemical effects.

Research Significance

SCCS reported in the literature[11-22] contained LSP or FA or their combinations, but no literature is available on the comparative response of various SRMs or their combinations to finally suggest a better single or blended SRM. This work demonstrates that, although LSP has been extensively used in SCCS in Europe and Canada, it is certainly not the best SRM. SRM particle characterisation details contained in this paper, seldom focused on in the published literature, are very helpful in understanding and explaining the test results. A simple procedure for strength quantification of SCMs using different SRMs is also suggested.

content. Saturation point approximation can also be made by consulting relationships shown in Fig. 1, which appears to be HRWRA content of approximately 0.30% by mass of cement. Table 1 gives the physical and chemical properties of the powders used in this study.

CEM I 42.5R can be considered ordinary portland cement, whereas CEM II/A-LL 32.5R is a blended cement and can have 6 to 20% LSP. CEM III/B 32.5

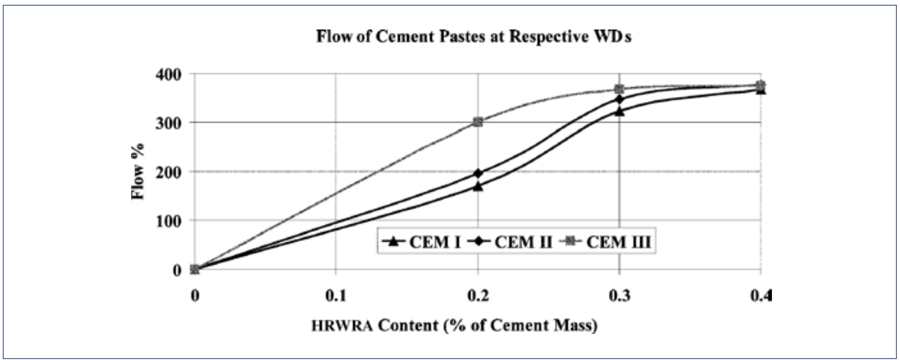


Fig. 1—Flow of three cement pastes with high-range water-reducing admixture content.

Experimental Investigation

Materials

Three types of cements—CEM I 42.5R, CEM II/A-LL 32.5R, and CEM III/B 32.5 N-NWHS/NA—were used. The SRMs used consisted of LSP, FA, and FA plus 20% by mass replacement with SF and two rice husk ashes—RHA and RHAP.

The natural sand used had a fineness modulus of 2.39 and was locally available with 0.00 to 0.08 in. (0 to 2 mm) particle size range. The HRWRA used was PCE based (total solid contents of 30% by mass) with a pH of 5.8 and a density of 0.0375 to 0.0390 lb/in.3 (1.04 to 1.08 g/cm3). It had low charge density, which produces lesser system retardation and is adsorbed slightly late to retain slump.

The authors used several types of cements in underground tunnel placements of SCC in Germany. The flow response of SCC made with different cements having similar clinker content using the same HRWRA did not differ very much for a given formulation. The total clinker content and its composition, sulphate content of cement, mixture proportions, and type and content of SRM seem to determine the amount of HRWRA required for a given flow target. Flow dependence of cement pastes on dry powder type HRWRA at mixing water equal to the system's water demand is shown in Fig. 1.

Flow seems to depend on the cement particle size and its surface area (refer to Table 1) in addition to the total clinker N-NW/HS/NA had 20 to 34% portland cement clinker and 66 to 80% ground granulated blast furnace slag (GGBFS). LSP had 92% calcium carbonate content (by mass).

Sample preparation

SCM systems had 1:1:2 by mass proportions (cement:SRM:sand) with a w/c of 0.40 and w/p of 0.20. The literature mentions various mixing regimes[22]; after experimenting with mixers of different capacities and with different initial and final mixing water contents, a slightly different mixing regime was adopted for the sake of efficiency.

It consisted of 30 seconds of dry mixing of materials at slow speed (900 rpm) in a 610.24 in.^{3} (10,000 cm^3) mixer followed by 80% of the total water addition and mixing at slow speed for 30 seconds and then for 60 seconds at fast speed (1800 rpm).

The interior walls of the mixer were then cleaned and the remaining 20% water containing HRWRA was then added. After that, three minutes of additional mixing at fast speed was completed, resulting in total mixing time of five minutes.

Testing

Flow

Literature suggests that the indexes of deformability and segregation resistance of SCCS are slump cone spread and V-Funnel time.[23,24] The flow target was achieved by using the previously mentioned HRWRA. Different HRWRAs produce different rates of production of hydrates, both the amorphous C-S-H and especially the crystalline phases.[25]

The flow behaviour of the SCM systems was characterised using the Hagerman's mini-slump cone (with dimensions 2.36 x 2.76 x 3.94 in.3 [60 x 70 x 100 mm^3]) spread—the time it takes to reach a 9.84 in. (250 mm) diameter spread[5]— and also by the mortar V-funnel flow time. The mini cone was filled with the SCM formulation and was moved upward simultaneously, starting the stopwatch and noting the time in seconds needed by SCM to reach a diameter of 9.84 in. (250 mm) (T25 cm time). The average of orthogonal diameters of two measurements was taken as the spread. The mortar funnel had 10.63 x 9.45 x 2.36 in.^{3} (270 x 240 x 60 mm^3) dimensions with 1.18 x 10.63 in.^{2} (30 x 270 mm^2) opening at the top end and a square section bottom opening of 1.18 x 1.18 in.2 (30 x 30 mm^2) with 2.36 in. (60 mm) height, making the total height of the funnel 9.45 in. (240 mm).

ACI member Syed Ali Rizwan is a Professor of Civil Engineering at the School of Civil and Environmental Engineering, National Institute of Transportation, National University of Science and Technology, Islamabad, Pakistan. He earned his BSc in civil engineering from the University of Engineering & Technology, Lahore, Pakistan and then his MSc in structural engineering from University of Surrey, UK. He obtained his PhD from Technical University, Freiberg, Germany.

He is a member of ACI Committees 237, Self-Consolidating Concrete, and E803, Faculty Network Coordinating Committee. His research interests include modern concrete technology; self-consolidating concrete; and repair, rehabilitation, and strength assessment of structures.

Thomas A. Bier is a Professor of Construction Materials Technology at Technische Universität Bergakademie, Freiberg, Germany. He received his PhD in Carbonation of Concrete in 1982. His research interests include microstructure, hydration and rheology of hydraulic binders, high-performance concrete and mortars, monolithic castables, and sophisticated dry mortars.

The funnel was filled with SCM formulation and then the lower gate was opened and the stopwatch started simultaneously. The time required to obtain seizure of flow after opening the lower gate was obtained. Seizure of flow is considered to happen when light is seen at the bottom of the funnel while viewing from the top. The average of two measurements of the same SCM formulation was taken as the funnel time.

Strength

Specimens of dimensions 1.57 x 1.57 x 6.30 in.3 (40 x 40 x 160 mm^3) were cast, cured, and tested as per EN 196-1 of 1994. The curing consisted of putting the molds in moist air at 293.15 K (20 °C) with 90%+ relative humidity immediately after casting for the first 24 hours after which they were demolded, weighed, and placed into water at 293.15 K (20 °C). Specimens were tested for compression and bending in saturated surface-dry condition at the prescribed ages.

The microstructure was studied by scanning electron microscopy (SEM) and mercury intrusion porosimetry (MIP) techniques. An environmental scanning electron microscope with field emission gun (ESEM FEG) was used to study the surface characteristics of SRMs and SCM specimens.

The sample preparation was carried out in the laboratory after stopping hydration by oven-heating the samples, broken in flexure, at 378.15 K (105 °C) for 24 hours. Oven heating does cause some damage to the microstructure but can be used for comparison of results of different formulations.[26] Carbon coating was then applied. MIP was also done on similar specimens with the help of a porosimeter.

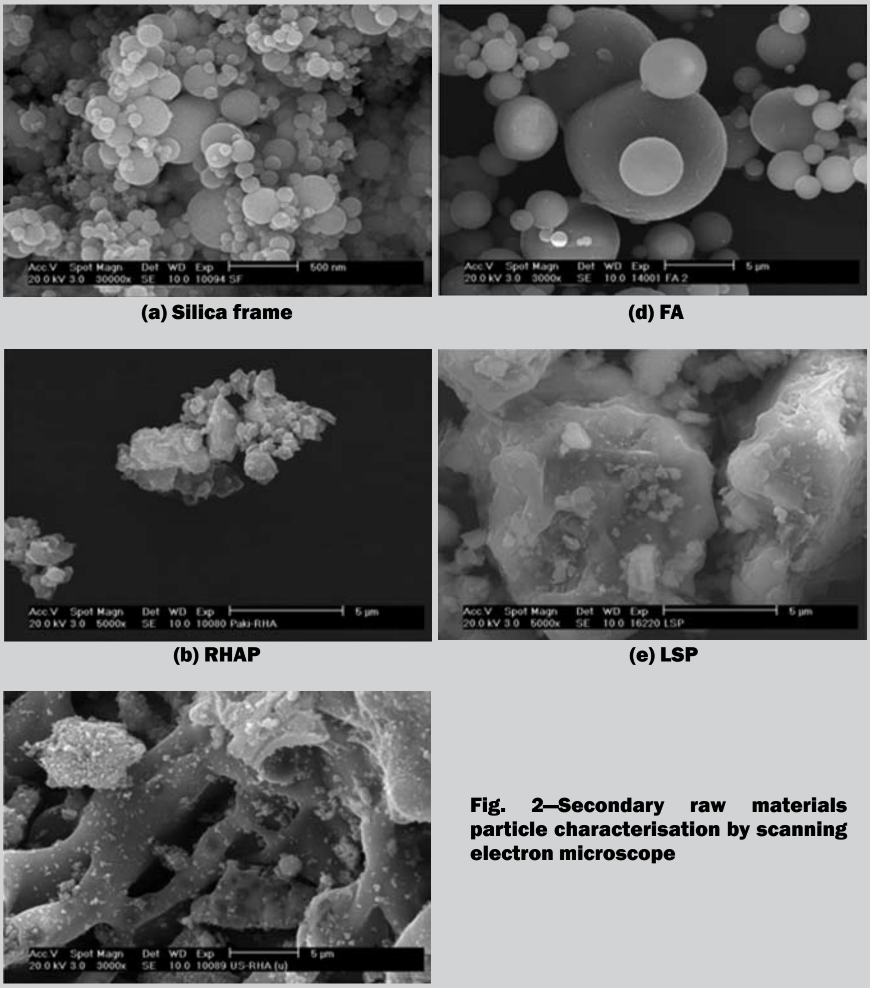
The contact angle was 140 °. MIP was used to determine partial and cumulative pore size distributions of hardened mortars and SRM powders. The radius corresponding to the maxima in differential distribution was also used to characterize the microstructure of samples.

Water vapour sorption isotherms of powders were measured at 293.15 K (20 °C) using a dynamic vapour sorption (DVS) system. Starting with dry powders, the relative humidity was stepwise increased and the adsorbed amount of water was gravimetrically determined at equilibrium. After the adsorption cycle, humidity was again stepwise decreased to obtain the desorption isotherm.

	Powders							
Oxides	RHAP	RHA	HRWRA	FA	LSP	CEM I	CEM II	CEM III
SiO_2, %	87.96	90.0+	95	51.44	7.07	18.92	18.74	31.01
Fe_2O_3, %	1.67	0.32	0.05	5.55	0.88	2.27	2.23	0.89
MgO, %	0.90	0.37	0.40	2.51	1.13	1.72	1.38	7.50
CaO, %	1.49	0.60	0.25	4.03	48.57	63.18	58.97	44.90
Al_2O_3, %	3.73	<0.01	0.20	26.13	2.53	5.09	4.78	8.86
Na_2O, %	0.78	0.14	0.10	1.23	0.47	1.48	1.25	0.86
K_2O, %	1.26	2.30	1.20	2.63	0.68	1.35	1.01	0.70
Loss on ignition, %	0.28	4 to 6	–	2.71	38.32	2.34	7.09	0.19
SO_3, %	0.21	0.14	–	–	0.28	3.48	3.20	3.76
D_{50}, in.	0.24×10^{-3}	0.27×10^{-3}	0.34×10^{-3}	1.05×10^{-3}	0.28×10^{-3}	0.74×10^{-3}	0.67×10^{-3}	0.47×10^{-3}
BET area, $in.^2/lb$	1.78×10^6	20.33×10^6	14.38×10^6	1.16×10^6	3.51×10^6	0.57×10^6	0.95×10^6	1.16×10^6
Density, $lb/in.^3$	0.0885	0.0816	0.0849	0.0835	0.0994	0.1145	0.1124	0.1077

Notes: — = not measured; RHAP = crystalline rice husk ash; RHA = amorphous rice husk ash; HRWRA = high-range water-reducing admixture; FA = fly ash; LSP = limestone powder; 1 in. = 25,000 μm; 1 in.2/lb = 1.42 × 10–6 m^2/g; and 1 lb/in.3 = 27.78 g/cm^3.

Table 1—Physical and chemical analysis of powders used (percentage)



(a) Silica frame **(d) FA** **(b) RHAP** **(e) LSP** **(c) RHA**

Fig. 2—Secondary raw materials particle characterisation by scanning electron microscope

Results

Characterisation of SRMs' particle shape by SEM

The SRM particle shape and size is very important for the response of SCM systems. Fig. 2 shows the ESEM photographs of the various SRMs used.

SF is a submicron-sized SRM, as seen in SEM shown in Fig. 2, with spherical particles. The average size (D50) measured by laser technique is that of a primary group of SF particles that adhere to each other due to electrostatic forces.

RHAP (imported from Pakistan) was found to be crystalline, based on X-ray diffraction (XRD), and showed reduced internal porosity and the pozzolanic activity. The surface of RHA (imported from the U.S.), an amorphous ash obtained at low temperature combustion 723.15 to 823.15 K (450 to 550 °C) with suitable hold time and environment,[5] shows clearly visible internal porosity that is reduced after milling. The FA was ASTM Class F with glassy, spherical, and hydrophobic particles. LSP has a very rough, irregular surface texture and morphology that needed very high HRWRA content to overcome internal friction during flow and to fill its peculiar voids. Most of the SRMs except FA and SF had almost similar particle size (D50). Surface morphology and internal porosity of SRMs also affects early volume changes of SCM systems using such SRMs.[27]

Porosity by MIP

The internal porosity of SRMs was studied by MIP. Fig. 3 shows the cumulative and differential relative pore volume curves as a function of pore radius for these SRMs. In addition to cement grains, powder particles also adsorb HRWRA and water. The internal powder pores of bottleneck type usually result in higher HRWRA demand.[27]

It can be seen that SF particles had the lowest pore size and FA particles had the highest pore size (maxima in differential curves). LSP and the two rice husk ashes had almost similar pore sizes and were between the two extremes. Higher mercury intrusion in SF particles showed that it had various small and closely spaced pores. Table 2 shows the total MIP porosities of the SRMs and their combinations used in SCM systems. The HRWRA demands of resulting SCM systems using such SRMs or their combinations with CEM I for a target flow of 12.20 ± 0.39 in. (310 ± 10 mm), obtained by varying HRWRA dose, have also been given. LSP needed the highest HRWRA content, whereas FA required the lowest. Surface properties of various SRMs, as determined by water vapour sorption isotherms, are shown in Fig. 4.

Characterisation of mortars

Flow properties—Table 3 gives the flow response of SCM systems obtained by using various SRMs for a target flow of 12.20 ± 0.39 in. (310 ± 10 mm). A flow of approximately 10.24 in. (260 mm)

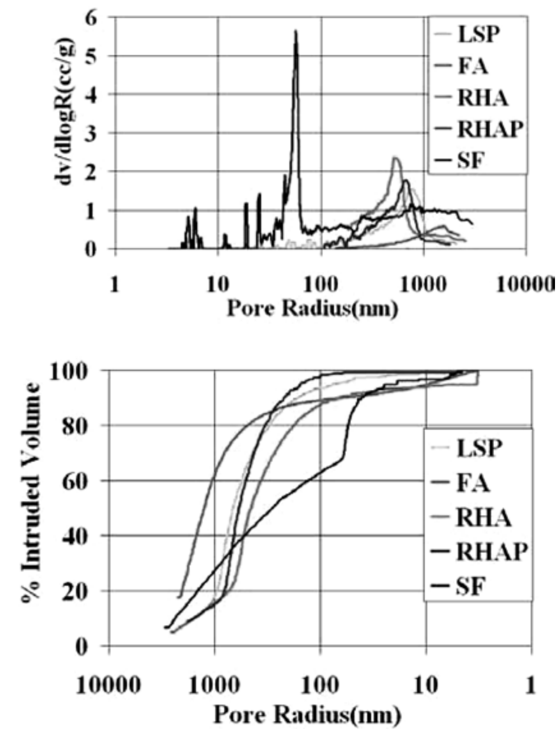


Fig. 3—Differential and cumulative mercury intrusion porosimetry pore size distribution curves of secondary raw materials (Note: 1 cm³/g = 28 in.3/lb; and 1 nm = 40 × 10⁻⁹ in.)

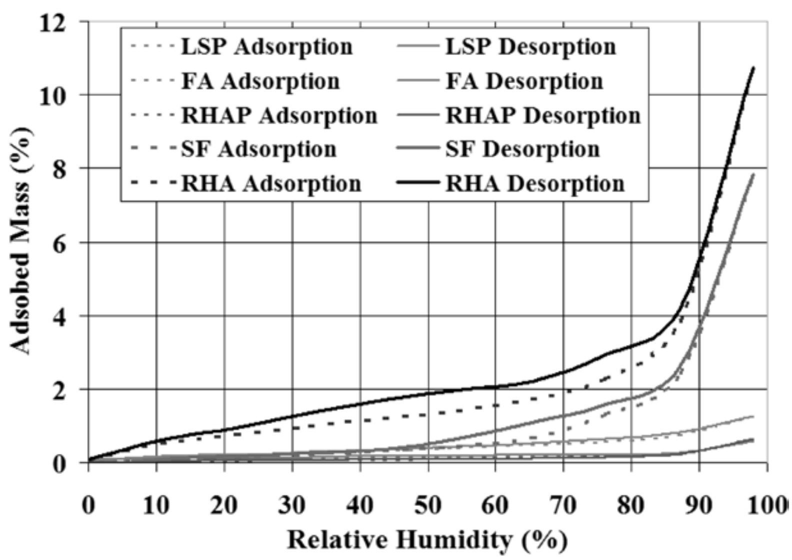


Fig. 4—Water vapour sorption isotherms for secondary raw materials

SRM	MIP porosity, in.³/lb (cm³/g)	SRM combination	MIP porosity, in.³/lb (cm³/g)	HRWRA/C, %
LSP	29.064 (1.050)	100% LSP	29.064 (1.050)	8.27
FA	14.006 (0.506)	100% FA	14.006 (0.506)	2.90
RHA	32.330 (1.168)	80% FA + 20% RHA	17.660 (0.638)	5.43
RHAP	23.722 (0.857)	80% FA + 20% RHAP	15.944 (0.576)	3.02
SF	27.818 (1.005)	80% FA + 20% SF	16.774 (0.606)	3.68

Notes: SRM = secondary raw material; MIP = mercury intrusion porosimetry; HRWRA = high-range water-reducing admixture; and C = cement.

Table 2—HRWRA content of SCM systems and their dependence on SRM porosity

SRM type used in SCM system	CEM I			CEM II			CEM III		
	P/C, %	T25, seconds	Funnel time, seconds	Funnel time, P/C, %	Funnel time, T25, seconds	seconds	P/C,%	T25, seconds	seconds
LSP	8.27	13.12	20.10	6.66	10.55	18.65	7.50	13.08	18.91
FA	2.90	13.63	22.00	2.78	8.96	14.05	2.54	8.36	14.92
FA + RHA	5.43	12.97	23.70	4.05	13.65	23.10	4.05	14.20	28.50
FA + RHAP	3.02	12.78	25.00	3.03	10.61	19.13	2.80	9.05	17.98
FA + SF	3.68	14.46	17.70	3.28	11.85	12.60	3.05	9.80	13.02

Notes: SRM = secondary raw material; and SCM = self-consolidating mortar.

Table 3—Flow response parameters of SCM systems

SRM type	CEM I, psi (MPa)		CEM II, psi (MPa)		CEM III, psi (MPa)	
	Flexure	Compressive	Flexure	Compressive	Flexure	Compressive
LSP	1443.17 (9.95)	11,188.21 (77.14)	1293.74 (8.92)	9524.63 (65.67)	1531.60 (10.56)	9157.68 (63.14)
FA	1720.15 (11.86)	17,024.53 (117.38)	1417.02 (9.77)	14,634.31 (100.90)	1782.51 (12.29)	14,503.77 (100.00)
FA + RHA	1840.53 (12.69)	18,173.23 (125.30)	1898.54 (13.09)	16,281.94 (112.26)	1824.57 (12.58)	15,461.02 (106.60)
FA + RHAP	1849.23 (12.75)	16,722.85 (115.30)	1646.18 (11.35)	14,184.69 (97.80)	1933.35 (13.33)	13,720.57 (94.60)
FA + SF	2500.45 (17.24)	19,031.85 (131.25)	2171.14 (14.97)	17,358.12 (119.71)	1826.03 (12.59)	14,866.37 (102.50)

Notes: SRM = secondary raw material; LSP = limestone powder; FA = fly ash; RHA = amorphous rice husk ash; RHAP = crystalline rice husk ash; and SF = silica fume.

Table 4—Twenty-eight-day strength of SCM systems with various SRMs and three cements

spread of mini-slump cones would characterise a mortar as self-consolidating.[28] Taking analogy from the bottom diameter of Abram's cone and measurement of T50 cm time in SCC, it is proposed to measure T25 cm time for self-consolidating pastes and mortars for comparing their rheological properties.[5] T25 cm time is thought to be a function of viscosity of a system, whereas the total spread is a function of yield stress of such systems.[29] Various sources[30] recommend that for stability of SCCS, the sand content used is an important parameter and approximately 75% of fines passing a 0.04 in. (1 mm) sieve should be able to achieve it.

P/C in Table 3 is the ratio of HRWRA to cement mass. In SCM systems, FA requires the least HRWRA content, whereas LSP needs the highest amount of HRWRA for the target flow with all cements. Despite a slight reduction in HRWRA demand with other cements with respect to CEM I, the particle shape, morphology, and porosity of SRMs seem to be the governing parameters for HRWRA requirement of SCM systems for a target spread.

Funnel times with 20% by mass replacement of FA with other SRMs in 80% FA increase (with respect to pure FA) in the case of the two rice husk ashes and decrease only in the case of SF addition.

This is due to shape compatibility resulting in lower flow resistance of such a blended SRM. The role of HRWRA, especially regarding flow, is very important; however, all good poly-carboxylate ester (PCE)-based HRWRAs should give insignificant difference in flow response of a given SCCS system at similar HRWRA content.

For the same efficiency and degrees of activation of various HRWRAs, their flow times and total cone spreads may be equal for similar formulations.

Strength response—Table 4 gives 28-day flexural and compressive strengths of SCM systems. Specimens composed of 1.57 x 1.57 x 6.30 in. (400 x 400 x 1600 mm) dimensions and were cast, cured, and tested as per EN 196-1.

Considering LSP as a relatively inert SRM,[2] the strength values of corresponding SCM systems can be considered a baseline. All other SRMs and their combinations when used in SCM systems exhibited strength increases as compared with baseline systems. For all series, the increases in strength were the highest when FA + SF or FA + RHA blended SRMs were used. A maximum increase of approximately 7250 psi (50 MPa) could be reached, whereas the use of FA or FA + RHAP increased the strength by approximately 5800 psi (40 MPa). More research is needed to understand the complex hydration mechanisms of SCM systems using secondary and ternary binder systems.

Microstructure of mortars—Pore radii at the maximum intruded volume of mercury in differential MIP pore size distribution curves for SCM with CEM II and two sands are shown in Fig. 5. It is seen that LSP gives the maximum pore radius, with both sands, compared with other SRMs or their combinations at the ages investigated. SCM systems with FA + RHA or FA + SF show the lowest and comparable pore radii at three days and beyond.

S2 in Fig. 5 is coarser sand consisting of 80% mass of 0 to 0.0787 in. (0 to 2 mm) grain size (S1) plus 20% mass of 0.0787 to 0.1575 in. (2 to 4 mm) aggregate size fraction.

More details regarding microstructure of such systems can be seen elsewhere.[31]

Discussion

SRM particle characteristics

Fig. 2 and 3 provide considerable information about the nature of SRM particles. SF and FA particles are circular and have particle size differences. SF particles were clearly at a submicron level as seen in SEM. If intruded mercury volume is taken as the measure of SRM porosity, SF possesses high porosity.

In addition, the MIP pore size (threshold radius) was much lower for SF but

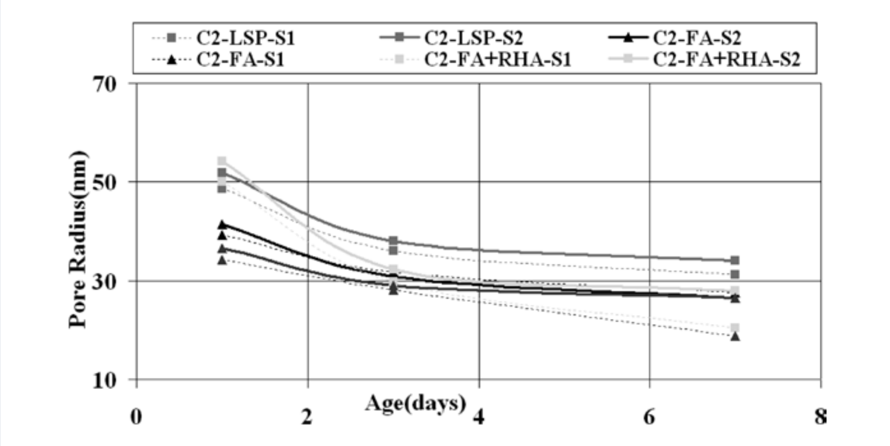


Fig. 5—Pore radii as function of age in self-consolidating mortar (CEM II, four secondary raw materials, two sands) (Note: 1 nm = 40 × 10–9 in.)

the pore volume was significantly higher than that of FA and other SRMs used. The BET specific surface area of SF was one order of magnitude higher. The BET area was higher for SRMs having internal porosity. Fig. 3 showing vapour sorption isotherms confirms these features, as a much higher amount of water was taken up by RHA and SF in the area of capillary condensation greater than 90% relative humidity.

The second group of particles (LSP, RHA, and RHAP) showed angular particle shapes. LSP had low BET specific surface areas, whereas RHA has MIP porosity close to SF.

RHAP (crystalline due to higher temperature burning) exhibited rather little MIP porosity and, hence, a lower surface area than RHA and SF. RHAP showed low water adsorption in the isotherms.

Its specific surface area was comparable to FA and confirms that surface area was mostly made up of typical external surfaces and/or surfaces with large internal pores. SF, when seen at 100,000× magnification, showed a rather spongy type of external surface with numerous closely spaced internal pores that just sucked in water when added.

It explains the higher water adsorption in isotherms and the absence of bleeding as well as higher shrinkage when SF was used in cement-based materials.

Similarly, RHA shows the highest internal porosity (MIP), which was responsible for its higher BET surface area and the highest water adsorption in the isotherms.

Flow of SCM systems

It is also reported in the literature[32] that some type of HRWRA is adsorbed on the specific mineral component more than on the others and the value of HRWRA adsorption decreases when the sulphate ion is supplied from gypsum to a higher concentration. The mixing time for HPC or SCCS was higher than that for normal concrete for obvious reasons and is reported elsewhere.[33]

HRWRAs belonging to different generations require different HRWRA content to achieve target flow, which is also dependent on the time and shear rate. It is mentioned in the literature that for better workability retention, HRWRA in a single dose should be added.[23]

The slump retention was influenced by the amount of dispersant remaining in the aqueous phase. The literature states that higher rates of slump loss were observed with a dispersant that was rapidly adsorbed from the aqueous phase, whereas better slump retention was observed with a dispersant that was adsorbed more slowly from the aqueous phase, and dispersant depletion levels were higher for concrete compared with the paste system.[34]

Table 2 shows, in addition to cement type and its content, the amount of HRWRA needed for a target flow of SCM system also depends on the MIP porosity of SRM particles and their shape, surface texture, and morphology. LSP with a very high MIP porosity exhibited the highest HRWRA demand of resulting SCM. The FA, with the lowest MIP porosity and lowest BET specific surface, showed the least HRWRA demand of the resulting SCMs.

RHA, with the highest MIP porosity, the highest specific BET surface area, and the highest water vapour adsorption, did show a significantly lower plasticiser demand when 20% of it was added to FA for making SCM. This meant that the physical properties, chemical makeup of the SRM is also very important.

Table 3 also shows that a combination of SF and FA reduces the funnel time with all cements used in SCM systems, indicating lesser internal friction offered during flow. The spherical particles of various sizes of these two SRMs get easily adjusted within themselves during flow and produce a ball-bearing effect. This effect can also be seen in some other materials and can generally be attributed to an optimised slope of an Andreasen particle size distribution, indicating optimised packing by the addition of nano-sized material.

Strength of SCM systems

Table 4 shows that SCM systems using LSP as SRM gave the lowest 28-day compressive strength with all cements and also showed the largest pore sizes, as presented in Fig. 5, compared with those of other SCMs using different SRMs or their combinations with two sands at the age of three days and beyond. This higher maximum pore size of LSP-based SCMs translates into their lowest strengths.

SCM systems using LSP can be considered as a baseline for determining the strength increase of other SCM systems using different pozzolanic SRMs or their combinations.

The strength increase could be attributed to the type of SRM keeping other parameters constant. It therefore suggests a simple strength quantification process, without finding the strength contribution of the mechanisms related to physical and chemical parameters.

This type of quantification is simple and is of interest to structural and construction engineers.

In summary, the strength increases shown by various SCM systems using different SRMs or their combinations can be attributed to better pore refinement effect, filler action, and SRM's particle characterisation.

The highest strength increase in SCM systems can be observed for 20% FA substitution by SF and RHA, followed by those using FA and RHAP. The higher water uptakes by RHA and SF with respect to other SRMs in sorption experiments and the highest BET specific surface area explains why the obtained strength increases are due to enhanced pozzolanic activity of these amorphous SRMs.

Early volume stability

For high-performance self-consolidating cementitious systems, the first 24 hours of shrinkage is very important.

The early linear shrinkage of SCM systems using the aforementioned SRMs has been measured by the au-

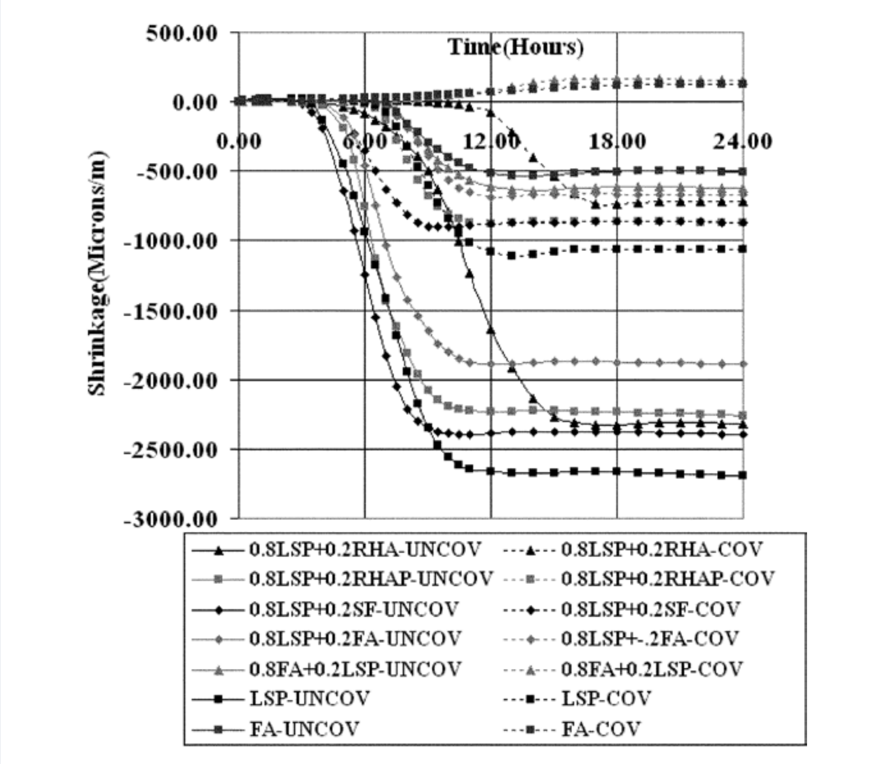


Fig. 6—Linear early shrinkage of self-consolidating mortar systems using various secondary raw materials in covered and uncovered conditions (Note: 1 micron/m = 1.22 ×10–5 in./ft.)

thors and the results are contained elsewhere.[27,31] A more comprehensive presentation is given in Fig. 6, however, which shows early linear shrinkage of SCMs containing various SRMs.

For the measurement of shrinkage, a modified version of a German shrinkage channel apparatus measuring 1.57 x 2.36 x 9.84 in. (40 x 60 x 250 mm) interfaced with a computer was used at 293.15 ± 1 K (20 ± 1°C) and 31 ± 5% relative humidity.

The shrinkage of specimens was measured in uncovered and then in fully covered conditions, with the two possible exposures in actual placements, obtained by using plastic sheet and adhesive tape. The duration of measurement time was the initial 24 hours.

It has been demonstrated in Fig. 6 that SCM systems using LSP as SRM gave maximum early shrinkage values in both covered and uncovered conditions.

FA, when used as the only SRM, shows the lowest early shrinkage in uncovered conditions coupled with a delayed setting. A combination SRM consisting of 80% LSP and 20% FA gives next-to-lowest early shrinkage in uncovered conditions. Time zero is very important with regard to shrinkage measurements, and various methods including Vicat set, imaging techniques, and ultrasonics have been used.

A side investigation showed that time-zero-based early linear shrinkage measurements were almost identical with those of non-zeroed measurements as expected. It can therefore be easily concluded that by decreasing LSP and by increasing FA, the early shrinkage can further be decreased and the set time would increase. A close to ideal condition may be when both SRMs are approximately 50% each by mass in a combination SRM.

Summary and conclusions

The role of SRMs in the overall response of SCCS is very significant. Before using any SRM in SCCS, its particle characterisation is essential, as all aspects such as water demand, HRWRA demand, strength, flow, early volume stability, and microstructure of SCM systems, depend on it and this characterisation helps in understanding and explaining the results of other routine tests. Suitable SRMs or their combinations should be used for typical applications considering ease in placement, adequate flow, enhanced strength, formwork removal, and durability.

From this research on SCM systems using high SRM content, it can be said that the shape, size, surface morphology, and porosity of SRMs plays a very significant role regarding the water demand and HRWRA demand for the target flow and for the overall response of a typical SCM formulation. It is expected that different SCM formulations may give different responses. For a given formulation, the HRWRA demand of SCM systems for a target flow is not only dependent on the type of cement used, but is also dependent on the type, porosity, and surface morphology of SRMs.

In general, for a similar formulation using pozzolanic SRMs or their combinations, the HRWRA content needed to give the target flow seems to depend on the clinker content of various cement types used. At similar cone flow values (comparable yield stress), the v-funnel times, however, seem to depend on the particle shapes of SRMs with regular and circular shapes giving lesser times as these get adjusted quickly to a continuously narrowing section without offering much frictional resistance to the flow.

The quantification of strength increase of SCM systems having similar mixture proportions with different SRMs can be ascertained by considering a relatively inert SRM-containing SCM systems as the baseline.

Considering flow, strength, microstructure, HRWRA demand, and early volume stability[26,30] of SCCS, it can be stated that LSP alone is not the best SRM for such systems at higher replacement levels. LSP's major contribution is the increase of segregation resistance. It appears from a side investigation by the authors that approximately 50% by mass replacement of FA with SF or LSP may result in a good blended SRM for SCM system in terms of overall response.

For those parts of the world where high-quality SF is not economically available, equal amount of amorphous RHA may be used instead, keeping in mind that flow times would increase slightly.

Acknowledgements

The authors are thankful to Karl Kiser, plant manager, Agrilectric International Technologies, Lake Charles, LA, for providing the amorphous RHA used in this investigation. Gratitude is also expressed to Javed Bashir Malik, Associate/ Structural Group Leader, Carter & Burgess, Houston, TX, for bearing the expenses of the ash transportation to Germany. Thanks are also due to Muhamad Sharif Nizami of PCSIR Laboratories, Lahore, Pakistan, for providing the crystalline rice husk ash used in this investigation.

ACI Materials Journal, V. 106, No. 1, January-February 2009. MS No. M-2007-215.R2 received May 26, 2008, and reviewed under Institute publication policies. Pertinent discussion including authors' closure, if any, will be published in the November-December 2009 ACI Materials Journal if the discussion is received by August 1, 2009.

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Eastern Cape: As 2008 drew to a close it marked the end of an eventful year in the life of the CSSA Eastern Cape Branch. The New Year started off with a bang with a list of exciting and interesting events lined up.

January was a quiet month with nothing planned. February has proved busy and exciting. The CSSA EC Branch AGM was held on 19th February 2009 with guest speaker Mr Odwa Mtati, the CEO of PERCCI (Port Elizabeth Regional Chamber of Commerce and Industry). He talked about the economic challenges that lie ahead. The national Self Compacting Concrete (SCC) Seminar was held in PE on 23rd February 2009 in Port Elizabeth. Attendance at the event in Port Elizabeth was staggering with 84 delegates registering to attend (the highest number for the country). The outcome of the event was extremely positive with top national speakers sharing and imparting valuable knowledge.

AGM Inland Branch 2009: The Inland Branch AGM was held on 5th March 2009 at the Midrand Protea Hotel. The AGM, which was an integral part of a breakfast gathering for members, was well attended. The guest speaker was Dr Llewellyn Lewis. He is the sole proprietor and principal consultant of BMI-BRSCU. Lewis is a well renowned highly respected consultant in the building industry. With twenty years experience he offered an insight into the future of construction and the building industry. His positive outlook, and views on how we can re-invent the way that we look and do business for the future were inspiring. For CSSA members, copies of his presentation can be obtained from John Sheath at johns@cnci.org.za

The Office Bearers for the Inland Branch Committee were also confirmed for 2009: On behalf of the Concrete Society, the Inland Branch would like to thank Trevor Sawyer for his three year tenure as the Inland Branch Chairman. Under his leadership, significant success has been achieved in branch events, specifically his dedication to student participation in the concrete boat race and the increasing emphasis on technical seminars rather than social events.

Inland Branch Committee for 2009:

Zoë Schmidt - Branch Chairman
Johan van Wyk - Vice Chairman
John Sheath Secretary / Treasurer
Trevor Sawyer
Hanlie Turner
Colin Kalis
Hannes Engelbrecht
Bernice Baxter

The President and Council of the Concrete Society of Southern Africa cordially invite you to the 30th year celebrations of the Fulton Awards!

Venue: Champagne Sports Resort, KZN Drakensberg
Date: Weekend, 19-21 June 2009
Book in Time: 14:00 on Friday, 19 June 2009
Check out Time: 10:00 on Sunday, 21 June 2009
Dress Code for Gala Evening: Black Tie, Formal.

Kindly RSVP to:
Natasja Pols (CSSA Administrator)
Tel: 012 348 5305
Fax: 012 348 6944
Email: admin@concretesociety.co.za

(A weekend brochure will be made available, shortly, with further information and booking forms or you can contact the CSSA Administrator for further info.)

CELEBRATING 30 YEARS OF EXCELLENCE
FULTON Awards
1979 - 2009

Please diarise the following dates for 2009 Fulton Awards Branch Review events:

DURBAN:
Tuesday, 23 June 2009
PORT ELIZABETH:
Wednesday, 24 June 2009
CAPE TOWN:
Thursday, 25 June 2009

Western Cape: The Western Cape Branch Annual General Meeting was held at the University of Cape Town, 19 February 2009. Subsequently to a brief overview on 2008 activities and developments, Chairman Lawrence Hendricks thanked the members for their support and handed over chairmanship to Billy Boshoff, who promised to take the Western Cape Branch to new heights in the coming two years.

Following administrative matters, the meeting proceeded with a technical presentation by Professor Jan Wium, University of Stellenbosch. The presentation dealt with seismic design principles for reinforced concrete structures, including design philosophy, structural systems and construction details. Excellent catering concluded the meeting and encouraged members to prolong the evening with discussions on concrete-related and other topics.

The CSSA Western Cape Branch Annual Golf Day was held on 19 March 2009 at Parow Golf Club. Even though it was windy, the players enjoyed the welcome break from the normal working routine. Perhaps the sponsored 'Wet Holes' helped with lifting the spirits. Over 120 players competed for the PPC floating trophy and once again the winner was chosen on a count out. Congratulations to Graham Balharry and Ismail Devage who won with a total of 44 points. Second place went to J Esterhuizen and H Emandien and Clint Wicomb and Irvin Kellerman came in third.

Golf day winners from left to right: Billy Boshoff WC Branch Chairman, Clint Wicomb (PPC), Graham Balharry winner, Ismail Devage winner.

Thanks to all the sponsors and a special thank you to PPC who was the main sponsor of the Golf Day.

Western Cape Branch Committee for 2009:

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Sand – cement mixes (Part 2 Tip 9) -

Introduction

Serviceability failures of sand-cement floor screeds are, unfortunately, fairly common. Typical problems include de-bonding, cracking, crazing, softness, poor abrasion resistance and unacceptable surface finish. In all cases the failures can be traced to one or more of:

- Incorrect application
- Inadequate specifications
- Poor materials selection
- Incorrect mix proportions
- Poor site practice and bad habits

Incorrect application

Sand-cement floor screeds are suitable only for light duty use. The commonest application is as a levelling layer under some type of covering, for example, tiles, carpet or vinyl. Sand-cement screeds are not suitable for use under abrasive traffic or heavy point loads.

Concrete toppings are recommended for use under abrasive conditions. Table 1 of SANS 10109-2:2004 'Finishes to concrete floors' gives detailed recommendations.

What is not generally realised is that, in terms of materials costs, a 30 MPa concrete topping is often cheaper than a sand-cement screed.

Specifications

Traditionally, sand-cement mixes have always been specified in terms of mix proportions by volume and not by performance. This is still almost universal practice in South Africa.

SANS 10109:2004 specifies mix proportions for sand-cement floor screeds of one 50 kg bag of cement to 130 litres of sand measured damp and loose. The reason for this is that sands bulk appreciably when damp and serious inconsistencies will occur if the sand is batched by volume without due regard to its moisture content. For example the mass of 130 litres of dry sand is about 210 kg, while the mass of the sand component of 130 litres of damp sand is about 150 kg. This Code of Practice (SANS 10109:2004) gives detailed recommendations for finishes for concrete floors and is well worth consulting.

Materials selection

Cements:

The following cements are suitable for use in sand-cement screeds:

- CEM I
- CEM IIA
- CEM IIB
- CEM IIIA

Strength grade should be 32,5N MPa or higher, bearing in mind that the lower grade cements have lower early strengths. The cements are listed above in order of increasing sensitivity to curing.

Floor screeds

Admixtures and additives

Generally speaking, admixtures are not commonly used in screeds. Sometimes bonding aids, water-proofing agents, or pigments are used. The use of pigments is becoming more common and it is strongly recommended that the manufacturer's instructions are closely followed. Bonding aids must also be used in accordance with the manufacturer's instructions.

Sand

Sand should be a well graded concrete sand of average to low water requirement. Plaster sands should not be used as they tend to have higher water requirements. A higher water content weakens the mix and increases the drying shrinkage.

Mix proportions

Mix proportions in the literature vary from 100 to 130 litres of damp sand per 50 kg bag of cement. As mentioned above, SANS 10109:2004 recommends 130 litres of sand. Sufficient water should be added to make a plastic, workable, cohesive mix – a little drier than mortar or plaster (drier mixes may be used if mechanical compacting equipment is used).

Poor practice

Poor site practice is the cause of many screed problems. Some of these practices are:

- Incorrect use of bonding aids
- Poor surface preparation, dirty concrete
- Making the mix too dry and not being able to compact the screed fully
- Floating a cement-water slurry into the surface of the screed to 'improve' the finish
- Floating neat cement powder into the surface to dry it and 'improve' the finish
- Mixing too much screed mix at one time. Screed mix should be used within an hour of mixing
- Inaccurate and inconsistent batching

Testing of floor screeds

A unique test method was developed by the Building Research Establishment (BRE) in the UK because of the problems experienced with sand-cement floor screeds. They developed the 'BRE screed tester' which is a penetrometer type device where a 4 kg mass is dropped four times at the same spot from a height of 1 m on to a circular foot-piece. The penetration of the foot-piece into the screed is measured and compared to various acceptance limits. The device, and the test, is described in the second reference below.

References/further reading

1. SANS 10109:2004 Code of practice for concrete floors Part 2 – Finishes to concrete floors, Pretoria, South African Bureau of Standards, 1992.
2. Addis, B.J. Sand-cement floor screeds, Midrand, Cement and Concrete Institute, 1996.

Cement and Concrete Institute pamphlets can be downloaded from their web site at www.cnci.org.za

Or email the author, Steve Crosswell, PPC Technical Support Manager scrosswell@ppc.co.za

Self-compacting concrete

The SCC Overview technical paper, by Petrus Jooste, was presented at SCC Seminars around the country.

Fig. 1: Bridge 2235

Abstract

Self-compacting concrete (SCC) is becoming a popular form of concrete usage in a range of applications throughout the world. This new concrete type has also found application in South Africa with great success in contracts such as the Nelson Mandela Bridge. The first formal application of self-compacting concrete occurred in Japan in 1988, and was driven by a shortage of skilled workers to place concrete at the job site and the resultant inadequate compaction and finishing of the concrete.

The response was to develop a concrete that flowed easily around obstacles into all the corners of the formwork without the need for compaction. This, together with the need for fewer skilled construction workers, made the construction of concrete structures much quicker.

This article considers the development of the technology and use of self-compacting concrete, addressing the benefits as well as the disadvantages. Importantly, the article aims to highlight the opportunities for using self-compacting concrete in South Africa.

SCC characteristics

SCC is a specialised concrete designed to flow freely around obstacles, completely fill formwork and enclose all reinforcing bars without segregation or bleeding.[1] The three key properties of SCC are filling ability (highly fluid to ensure flow under self weight), passing ability (passing around obstacles without blocking) and resistance to segregation (no separation of phases during flow or at rest after placing). As the name indicates, this concrete type requires no external consolidation effort while still fulfilling all the requirements of conventional concrete.

Mixture design requirements

Various mixture design methods have been developed throughout the world to design SCC mixtures. Unfortunately no universal SCC mixture design method can be produced, because of regional variability and availability of concrete materials. The main criterion for a SCC mixture is the self-compactability, i.e. good filling ability and passing ability without segregation or bleeding. These properties are only possible when a new generation super plasticiser is used. SCC is very sensitive to both the water content and the super plasticiser dosage. This creates a fine line between a mixture with the required properties and a mixture that segregates. A viscosity modifier can be used to assist with this problem but then the cost is increased and workability retention is shorter.

Domone[2] undertook a study on the commonly available mixture design methods and concluded that there is a wide range of mixture proportions that can be used to produce SCC. The key factors, expressed in volumetric terms are as follows:

- 30-34 % of the concrete volume to be coarse aggregate
- 0.25-0.5 as the water to powder ratio and mixtures with values at the upper end of this range require a viscosity modifier to enhance the viscosity
- 155-175 l/m³ water if no viscosity modifier is used and up to 200 l/m³ with a viscosity modifier
- 34-40 % of the concrete volume to be paste
- 40-50 % of the mortar volume to be fine aggregate

These volumes can be expressed

Constituent	Typical range by mass (kg/m³)	Typical range by volume (litres/m³)
Powder	380-600	
Paste		300-380
Water	150-210	150-210
Coarse aggregate	750-1000	270-360
Fine aggregate (sand)	Content balances the volume of the other constituents, typically 48 - 55% of total aggregate weight.	
Water/Powder ratio by Vol		0.85 - 1.10

Table 1: EFNARC typical range of SCC mix composition[3]

as approximate proportions by weight as follows:

Coarse aggregate	750 - 920 kg/m^3
Fine aggregate	710 - 900 kg/m^3
Powder	450 - 600 kg/m^3
Water	150 - 200 kg/m^3

The European Federation of Specialist Construction Chemicals and Concrete Systems (EFNARC) suggests a typical range of constituents in The European Guidelines for Self-Compacting Concrete.[3] These proportions, which are in no way restrictive, are given in Table 1. The EFNARC guidelines also recommend a maximum aggregate size of 12-20mm[3].

Benefits of using SCC

The most valuable benefit when using SCC is that no compaction of the fresh concrete is required. This leads to reduced energy requirement in the placing and finishing of the concrete. Placing is quicker and easier, the construction time is reduced and workers can be used more effectively. This was evident in the construction of the anchorage of the Akashi-Kaikyo Bridge, where the use of SCC reduced the total construction time from 30 to 24 months. Another project where the use of SCC reduced the construction time from 22 to 18 months was the wall of the liquid natural gas tank for the Osaka Gas Company[1].

The high flowability of SCC makes alternative placing methods possible, like pumping the concrete continuously from the bottom of the structure. This method was used in the filling of the pylons of the Nelson Mandela Bridge.

The high flowability and elimination of the need for compaction make the use of special designs and shapes possible. With conventional concrete, designs were restricted to shapes where concrete could be placed manually and where compaction equipment could reach. The Science Centre in Wolfsburg, Germany[4], the façade of the National Theatre in The Hague[5] and the pylons of the Nelson Mandela bridge are examples where the use of conventional concrete would not have been possible. SCC lends itself to creative shapes and innovative construction systems. Designs with very congested reinforcing are also acceptable, since SCC can flow around these and external compaction is not required.

With the reduction of the noise levels (about 93 dB when compacting conventional concrete) the working environment is safer and the noise is reduced in built-up areas. When using SCC the noise level can be brought well below 80 dB. Intensities higher than 80 dB can cause deafness, stress and fatigue[5]. With lower noise, no ear protection is needed and communication on site is easier. Vibration above 0,25 m/s^2 causes pain and stiffness in limbs, back and neck[5]. A more serious ailment caused by continuously using the poker vibrator (vibration levels from 0,75 to 4 m/s^2) is known as 'white fingers' which affects the blood circulation of the vibrator operator[4].

Fig. 2: The Nelson Mandela Bridge

With well compacted concrete, the possibility of air voids is reduced, which increases the strength and density of the concrete. The bond between the concrete and the reinforcing steel is improved and there is a reduced chance of bleed water lenses beneath reinforcing and aggregate.

The off-shutter finish when using SCC is also very good. The chances of honeycombing and blow holes are very slim. The use of admixtures assures thorough mixing since all the cement particles are better dispersed throughout the mixture, resulting in a more homogeneous concrete. This was evident in the concrete finish achieved with the construction of Bridge 2235.

The properties of SCC are well suited to produce good quality precast elements, reducing energy consumption in the production process. The energy required is not just the power to operate the plant, but also labour and equipment efficiency. Cycle time of the moulds is shorter because the admixtures used in the mixture can accelerate the hydration process which accelerates strength development. There is also less wear and maintenance on the mixing equipment.[6]

Disadvantages of using SCC

The biggest disadvantage of SCC is the cost involved in making this type of concrete. The material cost is higher since admixtures must be used. The aggregate also needs to be a smaller size, which can be more expensive and not readily available. The mixture requires a large percentage of fines and filler material to avoid segregation. SCC is sensitive to variation in the aggregate and this needs to be well controlled for consistent quality and grading.

The material sensitivity of SCC means that strict quality control is necessary at the batching and mixing operation. The material used in the mixture needs to conform to a very narrow specification. This necessitates careful grading and washing of sand to control the fines content of the mixture. If the fines content of the sand is not controlled, the water demand and admixture content will be affected and the end product can not be predicted. This could lead to a mixture that either segregates or does not flow satisfactorily. Mixer operators must be well trained and always aware of the sensitivity of this product.

Furthermore, special formwork is required when using SCC. The formwork must be stronger to support the concrete at early ages since form pressure is higher than with conventional concrete. Formwork needs to be near watertight to prevent loss of fines from the concrete mixture.

Development of SCC

SCC was first developed in 1988 by Okamura[7] at Tokyo University and its use has gradually increased. Okamura develops SCC to accomplish more durable and reliable concrete structures. The lack of skilled workers for compaction work and the misunderstandings between designers and construction engineers emphasised the need for SSC.

From Japan, the use of SCC spread through Asia and in 1993 it was also used in Europe. In North America the use of SCC grew from an insignificant amount in the year 2000 to more than a million cubic metres in total at the end of 2002. SCC was first used in South Africa in 2002. In Britain the Ready Mixed SCC usage show a 10% growth year on year and increased from near zero in 2000 to 400 000m^3 in 2008. Even though much research has been done across the world, further research is still required.[9]

Applications

Japan

One of the first big projects undertaken in Japan using SCC was the anchorage (83 m long, 63 m wide and approximately 45 m high) of the Akashi-Kaikyo Bridge. This project is a very good example of where the use of SCC reduced the total construction time from 30 to 24 months. Another project where the use of SCC reduced the construction time from 22 to 18 months was the 0.8 m thick wall of the liquid natural gas tank for the Osaka Gas Company[1]. More recent applications of SCC in Japan are lattice work (thin ribs), casting without a pump (discharging concrete from the truck and allowing it to flow freely to fill the formwork) and tunnel linings. SCC is used in lattice work because conventional concrete cannot be vibrated in this manufacturing process. To prevent cold joints in tunnel linings, SCC is used because it limits bleeding or laitance at joints.[7]

Fig. 3: The Akashi-Kaikyo Bridge

Fig. 4: Spiral staircase

Sweden

Sweden started to develop SCC in 1993 with a project where walls were cast using different materials as fillers in the mixture designs. In 1998 a monolithic frame bridge was constructed in Kjula using SCC. This was the first bridge outside Japan where SCC was used for the whole structure.[1] Since then, SCC has been used in bridges, box tunnel monoliths, rock lining monoliths (Sodra Lanken), tunnel entrances, headwalls, foundations and frame supports. The current use of SCC in Sweden's precast and ready mix concrete industry is about 10% of the total concrete usage.[8]

Netherlands

The development of SCC is particularly favoured in the precast concrete industry. Some precast concrete producers in the Netherlands only use SCC in the manufacture of their products.[5] Through this extensive use of SCC, much experience has been gained and SCC is now used in pre-cast slabs, beams, walls, columns, arches and bridge elements. SCC has also been used *in situ* but only in special cases. The first major project was the façade of the National Theatre in The Hague where only SCC could be used to fill the tiny ribs (8 mm deep). In some tunnel walls SCC was used because of the possibility of remote casting techniques. At the Rotterdam Zoo the heavily reinforced walls of a large fish pond were constructed with SCC to ensure a homogeneous watertight structure. The design and shape of the bridge piers for the 'South Tangent' traffic connection between Haarlem and Amsterdam was of such a nature that only SCC could be used. In this project 1800 m^3 of SCC was used. The most recent development in the Netherlands is self-compacting fibre reinforced concrete. This is used to produce floor elements that are thinner and lighter.[5]

America

Further examples of SCC applications are the steel form columns at Toronto International Airport and the outrigger columns at Wall Centre in Vancouver. A more interesting application is in the construction of houses in Houston where the exterior walls and slabs were cast monolithically out of SCC. The walls are textured and stained on the outside to resemble brick and have a polystyrene foam core for insulation. These houses are designed to withstand tornados and hurricane winds in excess of 218 km per hour.[(10)]

South Africa

The Nelson Mandela Bridge Project was the first project where SCC was used in the construction in 2002. This bridge (see Fig. 2) is the largest cable-stayed bridge in South Africa, connecting Braamfontein with Newtown and spanning the Braamfontein rail shunting yards. Newtown is the centre of the cultural precinct and the bridge provides access from the northern side of Johannesburg to this area.

A serious challenge during this project was the placing of the concrete inside the hollow steel pylons. The pylons were constructed from 20 mm (southern pylons) and 40 mm (northern pylons) thick steel plate, rolled to produce 1.35 m diameter steel pipes, which had to be filled with concrete to provide the required stiffness. The southern and northern pylons are respectively 31.1 m and 43.9 m high. This created difficulty with concrete lifting and placing, due to the free fall limits, access constraints (due to operating railway lines) and stressing chambers at the top of the pylons.[11] In addition, mechanical vibration was impossible due to limited access. External vibration was inappropriate because of the large amount of energy needed to overcome the pylon inertia. To overcome this it was decided to pump SCC into the pylons from the bottom. The concrete was pumped through a special pipe and valve arrangement at the bottom of each pylon.

Bridge 2235

Bridge 2235 forms part of an off-ramp from the Bakwena highway. The Bakwena highway, which extends from Pretoria to Botswana, is part of the east-west link across the southern part of Africa. The bridge deck is a post-tensioned two-cell box girder type structure, unlike the conventional metal drum void formers used in similar bridges. To save time and labour costs, it was decided to cast the deck of Bridge 2235 in one operation. Since compaction and placing was a problem in the reinforcing congested bottom slab, it was decided to use SCC.

When the first trial was poured, the concrete showed signs of segregation and too much mortar. Adjustments to admixture/binder proportions were made and the trial was repeated the following day. The second attempt was successful and the concrete stayed in suspension and flowed from the one upstand through the bottom slab shutter filling both upstands to their full height.[12] The bridge deck was then cast successfully with very little trapped air voids visible.

Spiral Staircase

In 2003, a spiral staircase at an office building in Pretoria was constructed using SCC. The position and geometry of this staircase made vibration impossible. It also had to be cast in one operation since no joints were allowed. At first, the formwork was not strong enough to withstand the concrete pressure, and adjustments to the formwork were required. With the formwork problems solved, the construction of the staircase was successful and the appearance acceptable.[13]

Fig. 5: Repaired culvert in Cape Town

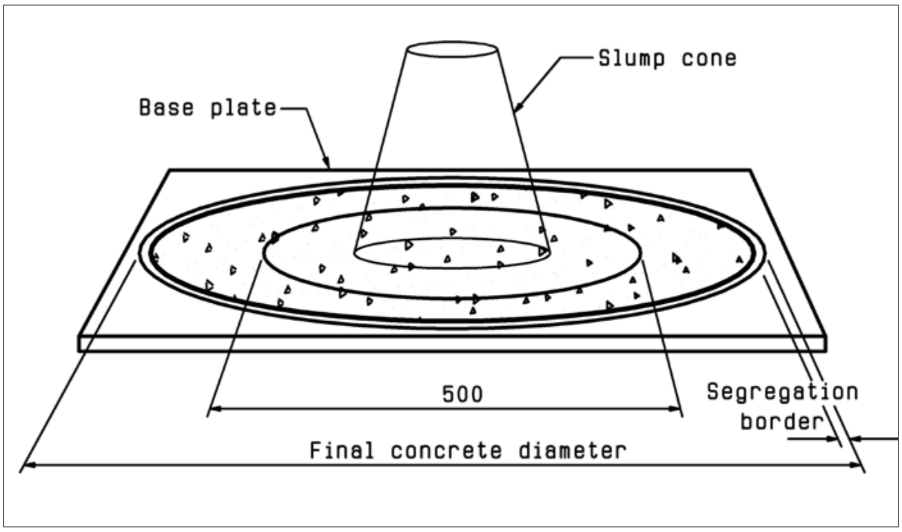

Fig. 6: The Slump flow test[(1)]

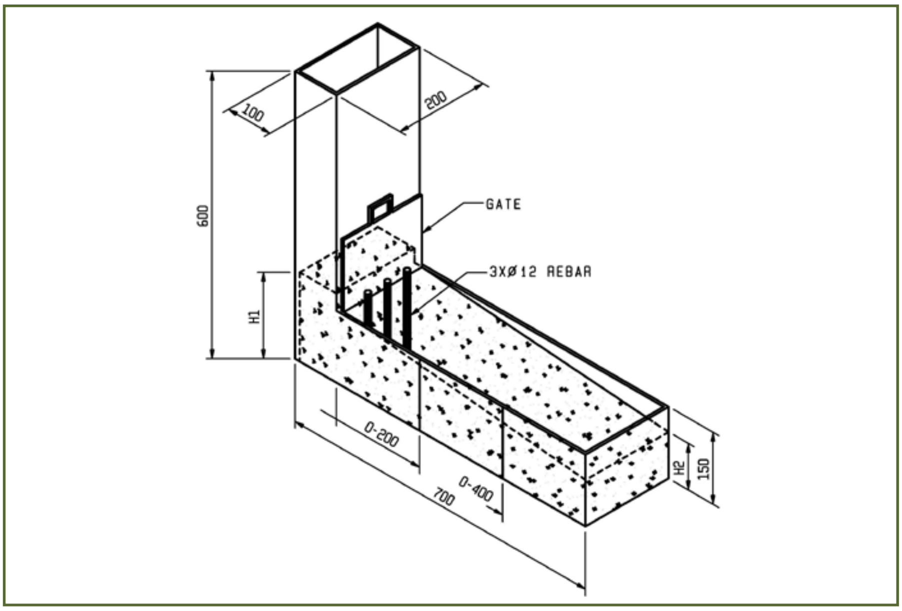

Fig. 7: L-box dimensions

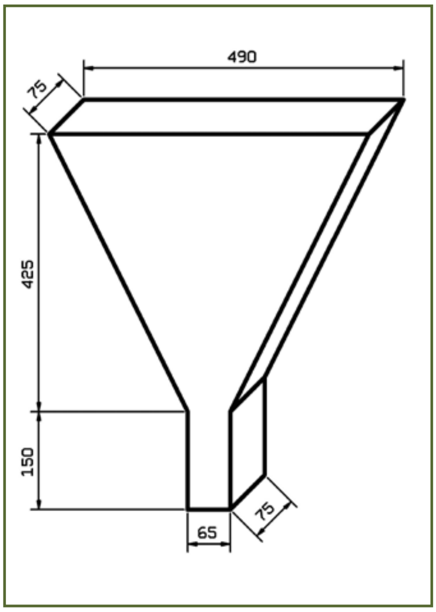

Fig. 8: V-Funnel

Culvert repair

In 2004 SCC was used on a project close to Cape Town for the repair of a culvert where the soffit had deteriorated to the extent that the reinforcing steel was exposed. To repair this, timber shuttering was placed below the soffit leaving enough room for extra reinforcing steel and concrete. SCC was placed through openings drilled from the top.

Inspection openings were also provided at the other end of the slab to check if the space had been filled completely. The operation was completed quickly and successfully. The only problem that was encountered was that rain affected the mixture on one of the days and the super plasticiser dosage had to be adapted. An alternative to using SCC in this case was to build a detour and rebuild the culvert. With the use of SCC the problem was solved in a shorter time and more cost effectively.[4]

Workability test methods

To determine the appropriate self-compacting properties, e.g. good passing ability, filling ability and resistance to segregation, various test methods are used. The three key properties cannot be described adequately with one method and a combination of tests is required. In 2001 a European project, Testing SCC, was started to investigate and establish suitable test methods to assess the three key properties of SCC.[14] The test methods selected in the European project include the slump flow, the L-box, the V-funnel, the U-test, The Oriment, the 'static sieving' test and the J-Ring. Individually, these tests cannot assess all three properties and the resistance to segregation simultaneously and therefore rheology is required to describe the properties of SCC fully. The European project did not only focus on the test methods but also related the results to fundamental rheological measurements. These rheological measurements will establish a scientific basis for the recommended properties.[14]

Rheology is the science that describes the flow and deformation of matter. The method used in South Africa to measure the rheology of concrete is the Tattersall Two Point Test. From the test methods selected in the European project, the slump flow, the L-box and the V-funnel are used to measure the workability of the concrete mixtures. These methods are used because of their stated suitability in other projects and, importantly, the availability of the equipment to perform these tests. All these methods are described in more detail below.

The Tattersall Two Point Test

This test is used to measure shear resistance at two shear deformation rates. The yield stress ($\square_o$) and plastic viscosity (μ) can therefore be calculated from the speed and torque measurements and used in the Bingham equation ($\square = \square_o + \mu\gamma$) to determine the shear resistance of the concrete under investigation.

The Tattersall Two Point Tester measures the pressure in a variable hydraulic transmission when turning an impeller in concrete at different speeds. Measurements at seven speeds are sufficient to calculate the intercept and reciprocal slope of the torque against speed relationship.

The slump flow test

The slump flow test is used to evaluate the flowability, deformability and stability of SCC. Included in this test is the T50 value, which describes the viscosity. A conventional slump cone is used in this test. The test is performed on a 900 mm x 900 mm base plate with a 500 mm φ circle drawn on the surface for the measurement of the T50 time.

Testing procedure: [15]

- ❑ While pressing the cone down firmly, fill the cone continuously with SCC to the top, without consolidating the concrete and level off
- ❑ Remove the slump cone immediately and perpendicular to the base plate, starting the stopwatch as the lifting begins
- ❑ Record the time the concrete takes to reach the 500 mm φ circle (T50)
- ❑ Measure the final diameter of the concrete as soon as it stops flowing. Assess the concrete for segregation and bleeding

The V-funnel test

This test is used to evaluate the passing ability and segregation resistance of SCC.

Testing procedure:[15]

- ❑ Fill the V-funnel continuously with SCC to the top, without consolidating the concrete
- ❑ Wait one minute for the concrete to settle and observe for segregation and bleeding
- ❑ Open the gate and start the stopwatch simultaneously
- ❑ Record the time when the concrete

Slump flow	650 - 800 mm
T50 slump flow	2 - 5 sec
V Funnel	6 - 12 sec
L Box	H2 / H2 = 0.8 - 1.0

Table 2: EFNARC Specifications for SCC workability tests[3]

has flowed out of the V-funnel (flow time = t_0)

The L-box test.

The L-box test is based on the L-flow test developed in Japan for underwater concrete. Peterson[(15)] developed the L-box test to assess the through-flow ability and filling ability of SCC. The L-shaped box (as shown in Fig. 10) is 700 mm long and 600 mm high with reinforcing bars placed in front of the gate.

Testing procedure: [15]

- ❏ Fill the vertical section of the L-box continuously with SCC to the top, without consolidating the concrete
- ❏ Wait one minute for the concrete to settle and observe for segregation and bleeding
- ❏ Open the gate and start the stop-watch simultaneously, allowing the concrete to flow into the horizontal part
- ❏ Measure the time it takes the concrete to reach the 200 mm (T_{20}) as well as the 400 mm (T_{40}) markings
- ❏ Measure the H_1 and H_2 distances as soon as the concrete stops flowing

Table 2 provides a summary of the EFNARC[3] specifications for the workability tests described above.

Fig. 6: Tattersall Two Point Tester

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SCC seminar report

The Concrete Society of Southern Africa (CSSA) held a national seminar showcasing Self Compacting Concrete (SCC) during the last week of February.

The events were hosted at the NMMU Conference centre in Port Elizabeth, Assegay in Durban, the University of Johannesburg and at Quickslab in Cape Town. The informative programme included a demonstration of SCC at various venues.

The idea for the seminar arose out of a lack of understanding of what SCC could be used for, where it could be used and its benefits.

At first the intention was to hold a local event, but it became clear that the lack of knowledge about SCC was widespread and that this type of seminar would be better supported if led by quality speakers who understood SCC's capabilities. These seminars allowed delegates to benefit from the sharing of relevant and up-to-date information and to clear up any misconceptions about SCC.

Sponsorship was sought from industry and the events were well supported by Wiehan, C&CI, Chryso SANMMU, Lafarge, Shukuma, BASF and the NPC. The CSSA is grateful for the contributions from sponsors. Guest speakers donated their time and 262 delegates attended the SCC events. Port Elizabeth dominated with 84 participating, Durban hosted 54 delegates, Cape Town 57 participants and 67 delegates attended the Johannesburg event. The fee for CSSA members was R750 and R1 250 for non-member.

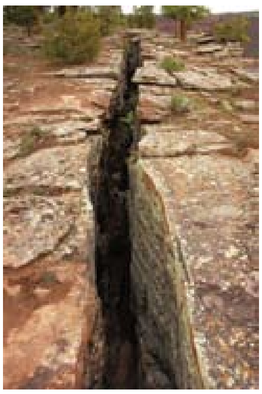
Feedback about the seminar from the CSSA SCC committee was positive. Speakers were disciplined and kept their allocated time with no significant time overruns, so proceedings ran smoothly. Content of the presentations was informative, with a reasonable balance of technical detail and qualitative overviews.

The live SCC demonstration, although not always perfect, provided an excellent opportunity to illustrate the sensitivity of the material and also how well it can perform. In general, the catering and venues were good. The sponsors received excellent exposure.

Events can be evaluated on a number of levels. The primary indicators of whether they can be considered successful are attendance numbers, sponsorship interest, discussion feedback from delegates and profitability. However, there are other non-measurable benefits from national seminars. These include: the transfer of knowledge, which has great educational value; exposure to interesting and innovative technology which is not widely known or used in the concrete industry; practical and visual demonstrations of self compacting cement video clips and how and where you can access information on SCC technology. The event was supported by CPD accredited architects.

Finally, the SCC national seminars were received well in each centre and created a good impression for the CSSA in terms of being active in seeking to inform and disseminate knowledge. In terms of organisation, a lot of work was done through the newly established administrative role and this proved critical in the successful and smooth running of the event in terms of logistics, securing seminar dates, as well as co-ordinating the run up to the event.

List of recent earth quakes in SA


Close up of a fault line or fracture in the earth

Location	Date	Magnitude (Richter)	Damage
Ceres	1969	6.3	12 killed
St Lucia	1932	6.0-6.5	Serious damage
Welkom	1976	5.2	Building collapsed
Stilfontein	2005	5.0	Damage

DATE	CONCRETE SOCIETY OF SOUTHERN AFRICA NATIONAL OFFICE PROGRAMME 2009 (March 2009)		
	MEETING/EVENT	VENUE	CONVENOR
Mid April 2009	Concrete Beton Issue 121	Distributed to all members	Crown Publications
14 April 2009 – 15 May 2009	Judging of Fulton Awards Project Entries	National	Fulton Awards Judges: Francois Bain CSSA President Elsabe Kearsley SAICE President Al Stratford SAIA President
28 May 2009	CSSA Council Meeting	CSSA National Office, Lynnwood, Pretoria	Francois Bain President of CSSA
19 June 2009 – 21 June 2009	Fulton Awards Weekend	Champagne Sport Resort, Drakensburg, KZN	Fulton Awards Organising Committee
23 June 2009 – 25 June 2009	Fulton Awards Roadshow	Durban, Port Elizabeth, Cape Town	Respective Branch Committees
Mid September 2009	Concrete Beton Issue 122	Distributed to all members	Crown Publications
17 September 2009	CSSA Council Meeting	O.R. Tambo Airport Conference Facilities, Johannesburg	Francois Bain President of CSSA
17 September - 19 September 2009	ACM Conference	Stellenbosch University, Stellenbosch	ACM Organizing Committee
Mid November 2009	Call for Councillor Nominations	Distributed to all members	Natasja Pols Administrator of CSSA
Mid December 2009	Concrete Beton Issue 123	Distributed to all members	Crown Publications

DATE	CONCRETE SOCIETY OF SOUTHERN AFRICA INLAND BRANCH PROGRAMME (March 2009)		
	MEETING/EVENT	VENUE	CONVENOR
15 May	Egg Protection Device Competition - function	To be advised	Johan van Wyk
04 June	Branch Committee meeting	C&CI, Waterfall Park, Midrand	John Sheath
19-21 June	Fulton Awards weekend	Champagne Sports Resort, Drakensberg	CSSA Head Office
02 July	Branch Committee meeting	C&CI, Waterfall Park, Midrand	John Sheath
23 July	Mini-seminar - *In-depth look at aggregates*	To be advised	Hanlie Turner
06 August	Branch Committee meeting	C&CI, Waterfall Park	John Sheath
03 September	Branch Committee meeting	C&CI, Waterfall Park, Midrand	John Sheath
19 September	Annual Concrete Boat Race Day	Victoria Lake Club, Germiston	Trevor Sawyer/ Zoe Schmidt
01 October	Branch Committee meeting	C&CI, Waterfall Park, Midrand	John Sheath
15 October	Mini-seminar - *Architectural concrete*	To be advised	Hanlie Turner
05 November	Branch Committee meeting	C&CI, Waterfall Park, Midrand	John Sheath
06 November	Chairman's Breakfast with Guest Speaker	To be advised	Johan van Wyk

DATE	CONCRETE SOCIETY OF SOUTHERN AFRICA EC BRANCH PROGRAMME 2009 (March 2009)		
	MEETING/EVENT	VENUE	CONVENOR
	These are preliminary dates. The final dates must still be confirmed.		
May 2009	Coega Bridge Site Visit	To Be Confirmed	To Be Confirmed
May 2009	NOSA Occupational Health and Safety	To Be Confirmed	To Be Confirmed
July 2009	Duty of Care of Professionals	To Be Confirmed	To Be Confirmed
August 2009	Concrete Mix Design and Specification	To Be Confirmed	To Be Confirmed
September 2009	Design of Post Tensioned Concrete Structures	To Be Confirmed	To Be Confirmed

DATE	CONCRETE SOCIETY OF SOUTHERN AFRICA WC BRANCH PROGRAMME 2009 (March 2009)		
	MEETING/EVENT	VENUE	CONVENOR
23 April 2009	MTM - Temporary Support Structures	University of Cape Town	Hans Beushausen
21 May 2009	Site Visit - Harbour - Civils and Coastal	Cape Town Harbour	Jerome Fortune
25 June 2009	Fulton Awards	T.B.A	Antony Venier
16 July 2009	Site Visit - Emplast - Concrete Wine Tanks	Emplast	Antony Venier
20 August 2009	MTM - Composite Structures	University of Cape Town	Kevin Kimbrey
17 September 2009	Site Visit - Koeberg Interchange	Koeberg Interchange	Riaan Brits
17 September 2009	Concrete Comp. Casting Date		Heinrich Stander
15 October 2009	Concrete Comp. Prize Giving	T.B.A.	Heinrich Stander
22 October 2009	MTM - Mick Latimer - M5 Upgrading	University of Cape Town	Jerome Fortune
17 to 19 Nov 2009	ACM Conference	Stellenbosch	Billy Boshoff
19 November 2009	Cocktail Party	CPUT Hotel School, Granger Bay	Heinrich Stander

DATE	INTERNATIONAL EVENTS CALENDAR		
	MEETING/EVENT	VENUE	CONVENOR
28 – 29 April 2009	Africa CemenTrade	Tunis, Tunisia	CMT
06 - 07 May 2009	QMS/ISO 9001:2000 for SMME's Workshop	Bryanston, Johannesburg	CESA
01 – 02 June 2009	Accounts Assistant Course	Bryanston, Johannesburg	CESA
24 – 25 September 2009	Central European Congress on Concrete Engineering – "Innovative Concrete Technology in Practice"	Baden, Austria	Austrian Institute for Concrete
17 – 19 September 2009	Concrete 09	Luna Park, Sydney, Australia	Concrete Institute of Australia

Advanced Concrete Materials

Important Deadlines

Submission of full paper - 30 June 2009
Review comments - 15 August 2009
Camera ready manuscripts - 30 September 2009
Final Registration - 30 September 2009
(Registration details can be found on the conference website)

Advanced Concrete Materials

International Conference, Stellenbosch, South Africa, 17-19 November 2009

Conference Chair
Prof Gideon van Zijl, Stellenbosch University, Concrete Materials

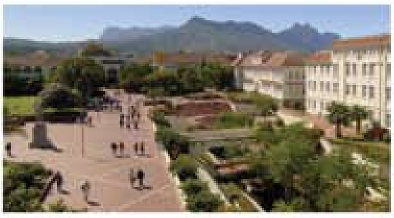
Organizing committee
This conference is organised by the Concrete Society of Southern Africa (CSSA) and Stellenbosch University (SU) and supported by the Cement and Concrete Institute (C&CI), represented by the members:

Dr Billy Boshoff	Chair person, Stellenbosch University (SU)
Mrs Natasja Pols	Co-chair, Concrete Society of Southern Africa (CSSA)
Mr Francois Bain	President, CSSA
Mrs Amanda de Wet	SU
Ms Natalie Scheepers	SU
Mr John Sheath	C&CI
Mrs Hanlie Turner	C&CI
Miss Jeanine Kilian	CSSA

Conference contact details
Web site:www.concretesociety.co.za/acm2009
Email: admin@concretesociety.co.za
Telephone: +27 (0)12 348 5305
Fax: +27 (0)12 348 6944

International Conference, Stellenbosch, South Africa, 17-19 November 2009.

Call for Papers



Organised by the Concrete Society of Southern Africa and Stellenbosch University

Supported by the cement & concrete institute

Registration Fees

	*	●
INTERNATIONAL DELEGATES		
International author	€400	€400
International delegate	€450	€500
International student	€300	€350
LOCAL DELEGATES		
Local author	R3000	R3500
Local delegate	R3500	R4000
Local student	R1500	R2000

* Registration before 31 July 2009

● Registration after 31 July 2009

This International Conference aims to bring together international and local experts and practitioners in concrete materials from the broad spectrum in the Civil Engineering industry including academics, consultants, contractors, scientists and suppliers. It provides a forum for the exchange of the latest research results, design and application procedures, methods for structural analysis and case studies on advanced concrete materials.

In the current strong infrastructure investment phase in South Africa, the various advances in these construction materials hold key potential. Relatively recent advances such as high performance concrete, high performance fibre reinforced concrete and self compacting concrete, are being introduced into Civil Engineering industries internationally.

Locally these advances are not yet exploited to their full potential, which is a main objective for this event.

Conference Scope and Themes

- Fibre reinforced concrete
- High performance concrete
- High performance fibre reinforced concrete, including:
  - Strain-hardening cement composites
  - Ultra-high performance fibre-reinforced concrete
- Self compacting/leveling concrete

In order to reach the conference goal of furthering application of these materials in industry, it is envisaged that papers are presented on the above materials from perspectives of fundamental development and characterisation, through constitutive modelling to standardisation, structural design, application and performance.

Pre- and Post Conference Seminars and Meetings

To exploit the gathering of local and international experts and role players, short pre- and post conference seminars and meetings are encouraged. The concluding meeting of RILEM Technical Committee HFC 208 on strain-hardening cement composites (SHCC) will be hosted by the chair of this conference on 20 and 21 November, directly after this conference. This will bring leading international researchers on these materials to the conference and post-conference meeting, under chairman Prof VC Li of Michigan University and subcommittee chairs Prof Henrik Stang (Standard test methods), Prof Folker Wittmann (Durability Design) and Prof Keitetsu Rokugo (Application and Design).

Conference programme Outline

A three day technical programme is envisaged from Tuesday 17 November to Thursday 19 November 2009. In addition, a reception will be held on Monday evening 16 November 2009, and an excursion followed by the conference dinner on the evening of Wednesday 18 November 2009. An accompanying persons program will be arranged.

Accommodation

The picturesque town Stellenbosch offers a variety of accommodation, with internationally renowned guest house hospitality and three to five star hotels. Information will be posted on the conference web site soon.