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CONCRETE SOCIETY
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Accredited Technical Paper:
Self-compacting lightweight aggregate concrete for composite slabs

Fulton Award Winner:
Mountain House Roofs

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President's Message

Will 2012 be the year of opportunity for the construction industry? I do hope so.

Almost without exception the first question most industry peers ask is, 'Are you busy?' I am not sure what response they expect but irrespective of workload one can always be busy - busy designing, busy supervising, busy managing staff or projects, busy tendering, busy marketing or simply busy doing nothing!

Am I busy? Yes. Doing what? All of the above... except the last one, of course.

The past year of my Presidency passed by extremely quickly. I believe that by having John Sheath as CEO, it has made it possible for me to serve my company well, and also devote time to the Society at the level expected in this position.

Certainly a highlight of the year for me was the Fulton Awards Gala Dinner in the Drakensberg. Not only did I get the chance to speak to over 400 highly respected and influential industry guests, which was a real privilege, but we viewed some extraordinary projects being showcased from around the country.

Planning for the Fulton Awards 2013 event is already underway with project nomination forms available for download from our website, or from the national office. Entries are already open, so enter, we want your projects!

Another highlight for the year was to see how the role of CEO has been unfolding. We are under no illusions that this is a process, and will take more than a year or two before we, the council and the Society, start seeing the full fruit of our investment in appointing John Sheath to this position. On a personal note, I have felt the tangible benefit of having John run the day-to-day affairs of the Society.

A final highlight for me has been the recent invitation from the Engineering Council of South Africa to represent the Society for the next four years on the 4th Council of ECSA. This invitation has been formally endorsed through a formal letter of appointment by the Minister of Public Works, Thulas Nxesi.

Over the past year a number of discussions were devoted to the goal of the Concrete Society in delivering quality seminars and conferences for members and the industry. A number of ideas were considered. The first to kick off is a national roadshow, FloorSem 2012, which took place in February.

There are a number of other topics under discussion as either regional or national events.

On a final note, I wish to thank the council and the members of the Society for allowing me the privilege of serving as President for 2011.

It has been exciting and I trust, even although I only took up the Presidential position after John Sheath relinquished it to take-over as CEO, that I have made a difference to the future sustainability of the Society.

Nick van den Berg
President
The Concrete Society of Southern Africa

COVER: The winner of the prestigious Fulton Awards 2011 'Unique Design Aspect' category, the Mountain House Roof, illustrates the versatility of concrete.

VISION: To be the most relevant forum for those who have an interest in concrete and to promote the related services of the CSSA members.

MISSION STATEMENT: 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.

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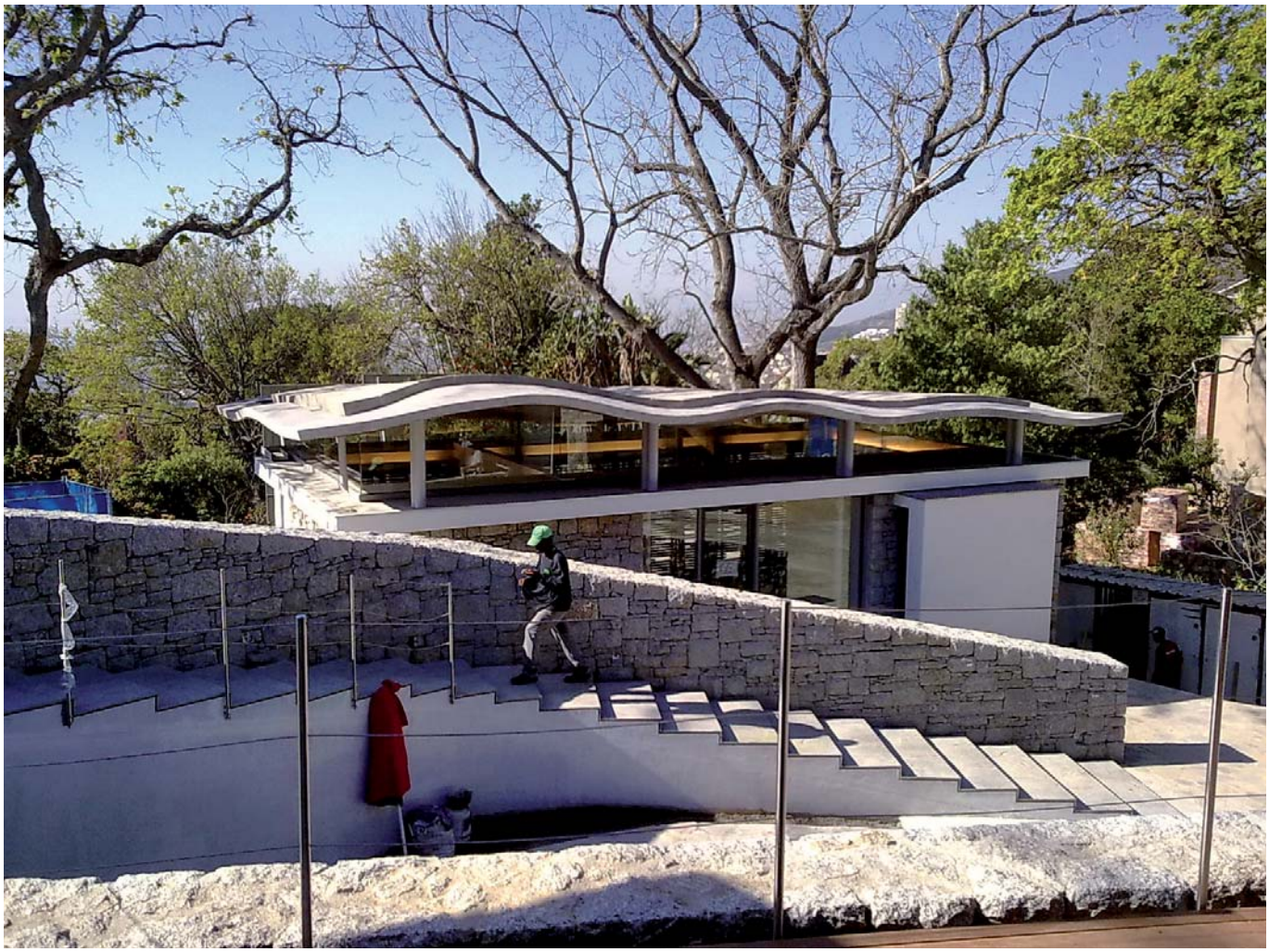
Mountain House



The Mountain House Roofs proved a worthy winner of the prestigious Fulton Awards 2011 'Unique Design Aspect' category for the organically shaped concrete roofs. The Cape Town Mountain House in Oranjezicht showcases the versatility of concrete.

The structural capacity and aesthetic qualities as well as the ability to be moulded and durability of the concrete has created a unique roof that enhances the appearance of the house. The light and delicate roof appearance is in stark contrast to the usual perception of concrete being a heavy material.

Located in the suburb of Oranjezicht it borders Table Mountain nature reserve. To the North, spectacular views from the site look across the city of Cape Town with Table Bay in the background. The owner's brief to the Architect was to design a special house that could respond to the beauty of the site and would be in harmony with its surroundings.

In the early stage, the Architects had chosen roofs with organic shapes to satisfy their vision for the house to blend harmoniously into the mountain backdrop. A second motivation was to allow the unique views of the mountain. The house was conceived as a series of five pavilions that were set into a deep cut on the site. While four of the pavilions are linked below ground, the intention was to give the appearance of separate free-standing pavilions. The five roofs vary in size from a minimum of 65 m^2 to a maximum of 150 m^2 and the maximum amplitude dimension from peak to trough was approximately 1 m.

Specialist input from a thermal expert predicted that heat gains and losses through the concrete would be unacceptably high. This resulted in insulation being specified for the tops of the roofs and to protect this insulation, concrete paving tiles were laid on top of the concrete. Since the roofs overhang the interior spaces, the insulation does not extend to the roof edges and the paving slabs are not visible unless viewed from above.

The ability to mould concrete to the organic shapes of the Architects' requirements meant that concrete, almost automatically, became the material to consider. The client had expressed a desire to see off shutter concrete as the final finish which meant that the choice

Roofs

of shuttering became an additional part of the design parameters.

While the concept of the organically shaped roofs was decided right from the outset, the choice of shuttering was not. Several shuttering ideas (including shaping sand with a mortar crust) were work-shopped to discuss the merits and to expose demerits of every proposal. A trial piece of roof was even made with a shutter consisting of a series of 22 mm boards which were cut in shapes to follow the required contours. This would see the soffit reading as a series of discreet steps which was seen as a desirable aesthetic result.

There was some concern about the possible extent of damage once the shutter increased in size to cover a full roof. The 'stepped' shutter also used a lot of timber with concomitant cost and environmental implications. The stepped shutter was then rejected and a new solution sought.

The final choice of shutter was inspired by timber boat building techniques. In this time-honoured way of building boats, frames are

Mountain House Roofs

shaped to suit the boat's final desired shape. These frames are spaced at centres to suit the cladding planking's spanning capability and planks are then fixed to the frames bending progressively to take the required shape.

For this house's roofs, the design and construction of the shutter shape followed this procedure: A plan with contour drawing of the final levels of the roof was produced by the architect. This they did by marrying the various design variables regarding the required aesthetics, views to be exploited, room sizes etc.

A shuttering layout plan was then produced which showed the progression from the flat soffited staging, to the position of the profiled ribs to the position of the boards to the edges.

The Architect's contour drawing was used to draw sections at 500mm centres. These sections were turned into a series of profiles. Drawings of these profiles were issued to the Contractor who, using the off-set dimensions provided on the drawings, was able to set the profiles out at full scale on timber boards.

Simple jig-saw cutting then allowed these profiles to turn the boards into the 'boat rib' frames. The frames were fixed at 500 mm centres to the pre-prepared and levelled flat soffit. Timber planks 200 mm wide were cut from 16 mm ply-wood and fixed to the ribs to create the shaped soffit. Edge shutters were fixed in position.

Additional challenges in the planning of the shuttering design were: That the front edges followed a wavy line in plan and that all four of the roof edges were sloped. The soffit of the slab was stepped up at the roof edges to make the slab thinner to allow the roof thickness to appear more slender. Detailed, large scale, workshop-style drawings were made of all the edges of the shuttering to ensure that the end results were exactly what were required.

The roofs were essentially designed as 200 mm thick reinforced concrete flat slabs. Angled steel columns along the front edges and vertical columns along the back edges of the roofs provided the vertical support. Lateral support was provided by short steel columns at the sides of the roofs. These short columns were fixed to the reinforced concrete slabs of the building and the design relies on diaphragm action in the slabs to transfer any lateral loads to the walls. Over and above the dead load and the statutory live load, an additional dead load for insulation and the covering concrete tiles was allowed for. The 'vaulted' profiles provided structural benefit in the one direction, (front to back). The curved shapes in the other direction do not provide flexural benefit. Conventional reinforced concrete section analyses translated the calculated bending

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Mountain House Roofs

moments from factored loads into areas of flexural reinforcing steel. Transverse forces, perpendicular to the main flexural reinforcing, as a result of the curved shapes, are resisted by closely spaced reinforcing steel clips between the top and bottom steel. These same shapes of reinforcing clips provided additional shear capacity at the column heads.

The maximum diameter of the reinforcing bars was 10 mm so as to allow the main reinforcing steel to take the shape of the shuttering without the need for special shape bending. The closely spaced bars were also desirous from a crack control point of view.

Recesses in the top of the concrete for a gutter combined with a step in the soffit at the front of the slab meant that the reinforcing across these reduced sections was congested, complicated to detail and very difficult to fix.

Together with the requirement for an off-shutter concrete, with a finish good enough to be displayed in a luxury house, came the need to ensure that all blemishes would be avoided. Great care was taken to ensure that the shutter planks were smooth and over and above the shutter being varnished, the boards were coated with shutter release oil. To avoid rain damage to the shuttering, tarpaulins were used to cover the shuttering on rainy days.

Substantial discussions and consultation were held with concrete experts to ascertain the need for a top shutter at the bottom of the troughs. These top shutters were going to add considerable extra work and there was a strong desire to avoid them. Lafarge were used as the specialist concrete suppliers and after final consultation, the top shutter was dispensed with. Lafarge provided a mix capable of being pumped, but with a low enough slump to allow the shapes to be worked, without the need for a top shutter. Over and above a water-proofing compound, the final concrete mix included Klipheuwel sand, crusher dust, 13 mm stone and an admixture. Curing was done with a spray-on curing compound.

The Contractors' team of dedicated carpenters was able to steadily improve on the time required to set up the shuttering for each roof. What initially appeared to be an out-of-the-ordinary task that intimidated this team became something that they took in their stride. Each roof

was cast individually and the concrete thickness was monitored by a simple gauging probe and the finish was produced by hand trowelling. The success of this project relied on acknowledging input from everyone on the team. Every bit of input was discussed and evaluated. This encouraged a collaborative sense of ownership which led to a collective sense of pride that was palpable amongst everyone. The team: Client: Philippe Brawerman; Principal Agent: Van Der Merwe Miszewski Architects: Subcontractor: DDC Construction; submitted by: Hulme & Associates, Consulting Structural and Civil Engineers.

Self-Compacting Lightweight Aggregate Concrete for Composite Slabs

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ABSTRACT: In the construction of high-rise buildings, very often lightweight structures are used in order to minimise costs. The application of composite slabs can be an economically advantageous construction method because of the placement of trapezoidal steel sheets, independently of the crane, and because of their simultaneous function as formwork, working platform, reinforcement and horizontal stiffeners.

This applies to the construction of new buildings and refurbishment of existing buildings that require lightweight structures. Composite slabs of lightweight concrete combine the advantages of rapid construction and extensive industrial prefabrication.

This paper describes the development of a pumpable, self-compacting, lightweight aggregate concrete (SCLC), which has optimised properties for use in composite slabs. In the first step, a few variations of SCLC with a bulk density class D1.6 were developed. These materials varied in their mechanical properties, e.g. compressive strength, tensile strength, and Young's modulus. Furthermore, different shrinkage reducing admixtures (SRA) were added to the mix of one chosen SCLC, which accordingly showed favourable mechanical properties. With the addition of SRA, shrinkage deformations in the concrete could be reduced considerably. In the next step SCLC compositions for the bulk density classes D1.4 and D1.8, respectively, were developed.

Finally, the mechanical performance of composite slabs made with the developed SCLC compositions was studied by means of four-point bend tests. Particular attention was directed at interactions between the concrete and sheet steel as well as at the failure mechanisms inherent in the slab system. The test results clearly demonstrated the relevance of concrete properties to the improvement of the performance of the composite slabs.

1. INTRODUCTION

Composite structures represent one of the most economic solutions for flooring in structural engineering. The advantages of crane-independent, rapid installation of steel decking sheets combined simultaneously with their formability, making a ready working platform available, and reinforcement and stiffening elements for horizontal loads are responsible for the success of this technology. To achieve minimal dead weight in such structures, the use of lightweight concrete is necessary. In particular, self-compacting, pumpable lightweight aggregate concrete can simplify the construction process and optimise quality as well as minimise noise generation and erection time.

The aim of the ongoing project is to develop a self-compacting lightweight concrete well suited to use in composite floors and to investigate the load-bearing behaviour of the composite slabs. Since the complex interaction of the composite members (SCLC and steel) in the adhesion, friction, sheet deformation, and clamping effect, is influenced by profile geometry and the particular properties of the SCLC, several parameter combinations have been investigated experimentally and by means of finite element analysis.

2. DEVELOPMENT OF SELF-COMPACTING LIGHTWEIGHT CONCRETE

The first SCLC compositions with commercially produced lightweight aggregates (LWA) were developed approximately 10 years ago (Mueller and Mechtcherine 2000). In the following years intensive research was undertaken in order to improve the rheological behaviour of SCLC and make it pumpable, (Mechtcherine et al. 2003; Haist et al. 2003). Although some research was also directed toward improving the ductility of SCLC by the addition of short fibres, (Mechtcherine et al. 2003), generally speaking the optimisation of the properties of this new material in its hardened state with regard to particular applications has so far never been a topic of investigation. In the framework of this project, a purposeful further development of SCLC technology has begun to take into account the special demands of construction using light composite slabs. Apart from excellent flowability and robust pumpability, such application demands high tensile strength, high stiffness, low brittleness of the concrete, and low shrinkage and also low creep deformations. Four of the SCLC compositions developed, belonging to the bulk densities classes from D1.4 to D1.8 are presented in this paper (see Table 1).

Table 1. SCLC compositions developed

Concrete Density class	SCLC-1 D1.6	SCLC-4 D1.4	SCLC-6 D1.8	SCLC-7 D1.6
Cement*	10.3	10.9	10.3	10.7
Fly-Ash	9.5	9.9	5.0	9.9
Silica Fume (solid)	-	-	0.6	0.7
Water**	15.9	16.5	17.7	15.4
SP***	0.95	0.64	0.8	1.0
VA****	0.15	0.30	-	-
LSP*****	-		5.1	-
Sand 0/2	23.7	-	-	21.5
Split 5/8	-	-	22.3	-
LWA 2/10	37.4	33.0	-	39.2
LWA 0/4	-	26.2	36.3	-

All components are given in % by volume, except SP and VA.

* CEM II/A-LL 32.5 R

** Without pre-wetting Water

*** Super plasticizer (SP) in % by mass of cement

**** Viscosity agent (VA) in % by mass of cement

***** Limestone powder (LSP)

For all compositions, expanded clay was used as LWA. The coarse LWA had a grain size of 2 mm to 10 mm. The grain size of lightweight sand ranged from 0 mm to 4 mm. Since the porous expanded clay can absorb high amounts of mixing water, which may considerably affect the consistency of fresh concrete, the expanded clay aggregates were pre-wetted with water (18.5% by mass of coarse LWA and 21% by mass of lightweight sand). This additional water did not influence the strength of SCLC negatively. However, it may have had an effect on its shrinkage behaviour.

An ELBA laboratory mixer with a capacity of 60 litres was used at the TU Dresden for the concrete development. The mixture SCLC-1 (cf. Table 1) was developed in an earlier project, (Mechtcherine et al. 2003), and used in this study as reference concrete and the basis for a further optimisation.

The total mixing time was three minutes in the preliminary tests. The reference concrete SCLC-1 showed a slump flow of 680 mm, a flow time t_{500} of 3.8 s and the V-funnel flow time of 6.3 s. During first mixings of SCLC-1 it was observed that a part of the coarse lightweight aggregates was ground, or ruptured, due to the intensive mixing process. To minimise this, the mixing intensity was reduced, but the total mixing time was still limited to three minutes. Since the super plasticiser on the polycarboxylate ether basis could not develop its full effect during this short time period, at the applied low mixing intensity, the consistency of the fresh concrete mixture became stiffer when tested directly after mixing: the slump flow decreased to 610 mm.

However, in the process of the subsequent 'post-mixing' with very low intensity, which simulated the post-mixing in a ready-mix concrete lorry, the SCLC became more workable. Figure 1 shows the change of the concrete consistency over time, which is appropriate to the application of this material as ready-mix concrete in the production of composite slabs at the construction site.

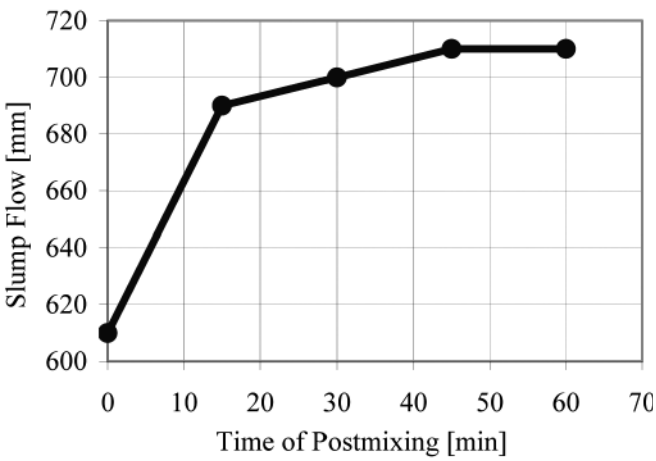

Figure 1. Change of the slump flow during the low-intensity post-mixing.

SCLC-1 was used for the production of a first series of slabs at the TU Kaiserslautern using a concrete plant mixer with a volume of 1 m³. Testing of characteristic concrete properties in the fresh and hardened state provided nearly the same values of the characteristic properties as those obtained at the TU Dresden.

Primarily based on the results of the first four-point bend tests (cf. Chapter 4), a few material parameters of SHCC were subsequently selected to be improved, in order to enhance the mechanical performance of the composite slabs. The following changes were the objective:

- extension of the range of bulk densities classes to D1.4 and D1.8,
- increase in the tensile strength,
- increase in the Young's modulus,
- reduction of creep and shrinkage deformations

To reduce the bulk density of SCLC to the density class D1.4 (mixture SCLC-4), the normal-weight quartz sand utilised in the reference mixture was substituted by lightweight sand (cf. Table 1). The mixture SCLC-6 was designed to meet the bulk density class D1.8 and simultaneously to increase the Young's modulus and the tensile strength in comparison to the reference composition. It was attained by replacing the coarse LWA by basalt split and by adding silica fume, while the quartz sand was replaced by lightweight sand (cf. mixture SCLC-6 in Table 1). The silica fume was used in the form of a colloid suspension with 50% by mass of solid material. To improve the grain size distribution, which was disturbed by the introduction of the split aggregates, some limestone powder was used additionally in the mixture SCLC-6. Finally, mixture SCLC-7 was developed with the goal of reducing the bulk density by a small amount (in order to be more secure in reaching the density class D1.6) and to increase the tensile strength. The first goal was achieved by increasing the content of LWA slightly and simultaneously by lowering the portion of quartz sand slightly. An increase in the tensile strength should be attained, similar to the SCLC-6 composition, by adding silica fume suspension (cf. Table 1).

The properties of the hardened SCLC were tested at a concrete age of 28 days according to the German standard DIN 1048. Table 2 gives the results of the mechanical tests performed. As expected, SCLC-4 (bulk density class D1.4) showed lower strength and stiffness in comparison to the reference SCLC-1 (bulk density class D1.6).

The reduction of the compressive strength was moderate; however, as a result of using LWA for all aggregate grain fractions, there was a pronounced decrease in the values of the most relevant parameters, Young's modulus and the splitting tensile strength. In contrast, the testing of the mixture SCLC-6 (bulk density class D1.8) revealed a considerable increase in tensile strength, leaving the perceptual increase in the compressive strength and Young's modulus well behind. Finally, SCLC-7 showed, again in comparison to the reference SCLC-1, a slightly lower dry density, while comparing better to the bulk density class D1.6.

The compressive strength and Young's modulus of this mixture were somewhat below the reference values, but a significant perceptual increase in the splitting tensile strength could be attained.

Table 2. Mechanical properties for different SCLC mixtures

Concrete Bulk Density Class	SCLC-1 D1.6	SCLC-4 D1.4	SCLC-6 D1.8	SCLC-7 D1.6
Dry density*	1630	1390	1765	1543
Compression strength**	40/43	34/36	46/48	39/41
Young's modulus	20000	14000	21000	18700
Splitting tensile strength	2.4	1.4	3.4	2.8

* The dry density is given in kg/m³, all mechanical properties are given in MPa.
** Compressive strength measured on cylinder/cube

Since the SLCL compositions developed have a high proportion of fines and increased total water content due to the pre-

wetting of LWA, high shrinkage deformation can be expected. In the composite slab, concrete shrinkage deformations are constrained by the profiled steel sheet, which leads to tensile stresses in concrete. This effect is particularly pronounced at the upper chord of the profiled sheet, a region where stress concentrations from mechanical loading occur as well. To decrease the shrinkage deformations and therefore to counteract early cracking, two different shrinkage reducing admixtures (SRA) and one concrete sealant agent (SA) were used as concrete additives. Their effect on shrinkage behaviour was tested on prisms made of the reference concrete SCLC-1 using the Graf-Kaufmann method (cf. Figure 2).

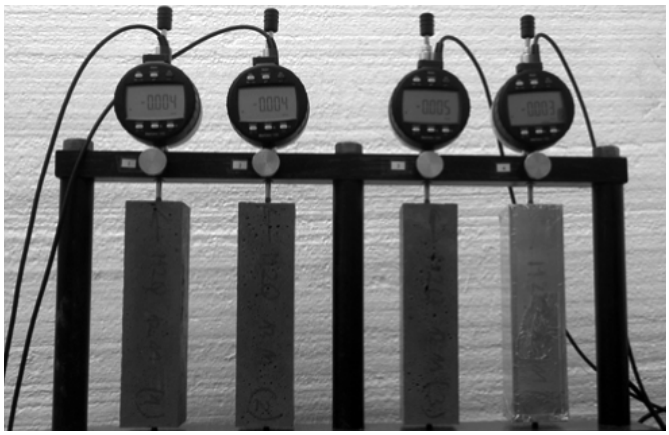

Figure 2. Equipment used for shrinkage measurements.

Figure 3 shows the test results for total shrinkage, including the autogenous and drying components. The addition of SRA resulted in a clear decrease in shrinkage deformations in comparison to the reference mixture without such additive. In contrast, the use of concrete sealant agent was not only not beneficial, but even caused some increase in shrinkage.

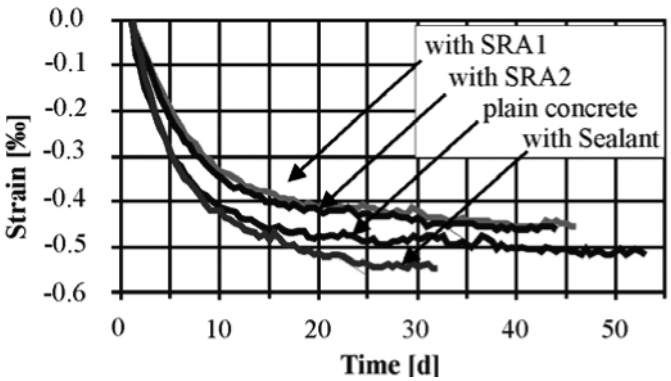

Figure 3. Development of total shrinkage strain over time for SCLC without and with shrinkage reducing additives (SRA) and sealant agent (SA), respectively.

To estimate the effect of the additives on cracking behaviour of SCLC, instrumented ring tests were performed. The setup of this test is shown in Figure 4. It consists of two steel rings of different diameter. Fresh SLCL was placed between the rings. At a concrete age of one day, the outer steel ring was removed and the circumference of the concrete annulus was exposed to desiccation at the standard laboratory climate (20 °C, 65% RH). The inner steel ring was equipped with strain gauges for measuring deformations of this ring induced by the shrinkage of the concrete annulus. From the deformation

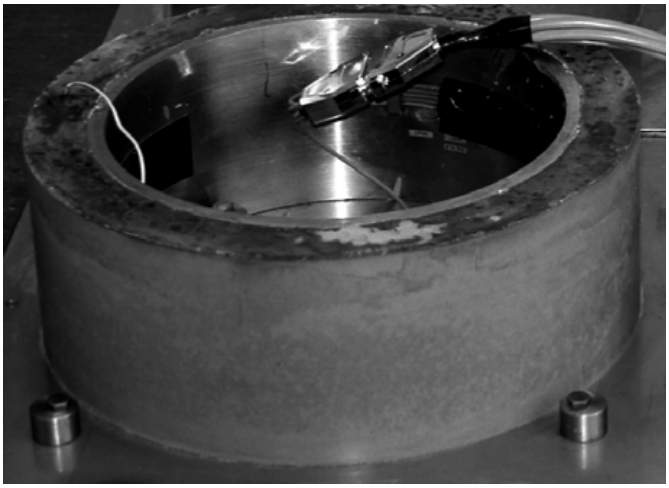

Figure 4. Instrumented ring test for estimating concrete cracking due to restraint of shrinkage deformations.

values measured, the stress in the SCLC annulus could be estimated using formula by Hossain & Weiss (2004).

Figure 5 shows typical cracks as observed in the ring test right after the crack formation in SCLC. In their tendency, the test results agree well with the findings of the shrinkage measurements. However, in the ring tests the differences were much more pronounced: while the reference concrete cracked at the age of 15 days and showed a crack width of 0.8 mm, the mixes with the additives SRA1 and SRA2 displayed considerably smaller crack openings of 0.2 mm and 0.3 mm, respectively. The cracking occurred also considerably later in SCLC-1 with SRA, at a concrete age of 27 days (SRA1) and 39 days (SRA2), respectively. The largest crack width was registered for concrete with the sealant: it was 0.9 mm right after crack formation at a concrete age of 19 days.

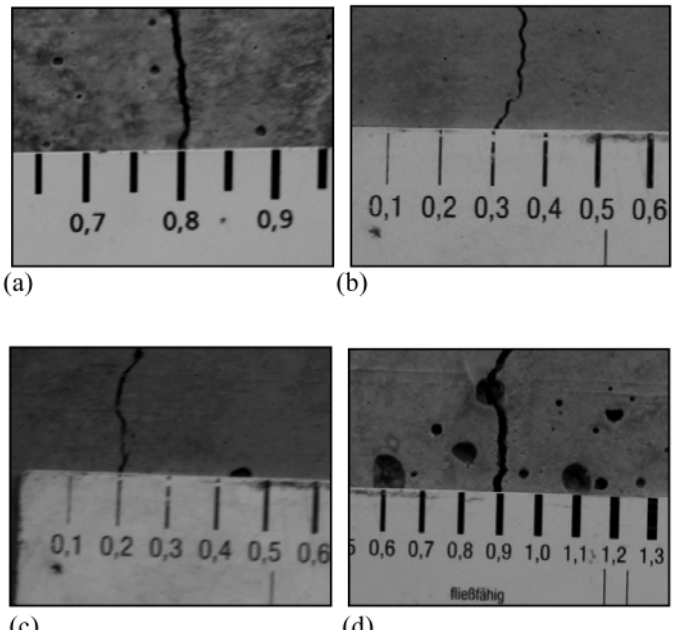

Figure 5. Crack widths observed in ring tests right after crack formation:
a) Reference composition SCLC-1, cracking age 15 days
b) SCLC-1 with SRA1, cracking age 27 days
c) SCLC-1 with SRA2, cracking age 39 days
d) SCLC-1 with sealant, cracking age 19 days.

3. TESTING THE PUMPABILITY OF SCLC

One of the key properties required for an efficient application of SLCL for the production of the composite floors is robust pumpability. This property was tested by producing 1 m³ of fresh SCLC in a regular concrete plant and pumping it in a circle for a while and subsequently casting of composite slabs with the pumped concrete. Here is one experiment, in which SCLC-7 with addition of SRA1 was pumped and will be described.

The lightweight aggregates were pre-wetted in the 1m³ mixer. Subsequently, the concrete was mixed with the same mixer. The slump flow of fresh SLCL right after mixing was 650 mm.

A truck-mounted concrete pump M28-4 from Putzmeister was used in the test. The walls of the pipe system were first lubricated by pumping an amount of a premix made of cement, sand and water. Subsequently, the pump started to deliver SCLC. After the premix and the very first portion of SCLC were pumped into the waste, the pumping process was changed to the cycle regime.

Figure 6. Casting a composite slab with pumped SCLC.

The velocity of pumping was set to 8-10 m³/h. After 10 minutes of pumping it was interrupted for a further 10 minutes to investigate the condition of the mix, then the pumping process continued. The velocity was increased to 70m³/h. The testing of the mix during the interruption showed that no segregation occurred. A significant decrease in slump flow to 490 mm was observed indicating some loss in the workability of the material. This could likely be traced back to the surplus of water absorption by LWA due to the high pumping pressure. With an addition of super plasticiser (0.2 % by mass of cement) and some water (approximately three litres) the desired consistency was reached again. The pumping test was continued for another five minutes and then finished by casting composite slabs with the pumped SCLC (cf. Figure 6).

4. TESTS WITH COMPOSITE SLABS

4.1 *Test setup and main results*

Preliminary tests with two composite slab specimens (denoted here as specimen A and specimen B) were performed, in order to obtain initial references, regarding their applicability to and behaviour of self-compacting lightweight in composite floors. The experiment setup was designed similar to previous tests on composite slabs with lightweight concrete by Faust at Leipzig University, (Faust 2002), and Kessler at the TU Kaiserslautern (Kurz & Kessler, unpubl.). According to Koenig & Faust (1997) and Kurz & Kessler (2007), the composite slabs showed ductile bearing behaviour with longitudinal shear failure in 4-point-bend tests. The specimens were approximately the same size; the tests were carried out according to Eurocode 4.

The specimens were made using a profiled sheet steel type Super-Holorib SHR51 with a nominal thickness of 1.00 mm. They had a width of 70 cm and a height of 14 cm. The length of the one specimen type was 3.40 m ('long' shear length of 90 cm) and that of the other specimen type was 2.20 m ('short' shear length of 60 cm). At the points of load application, crack-initiating sheets were installed. The same dimensions were chosen for the new specimens A and B, to be tested in this project with SCLC. The concrete composition SCLC-1 was used (cf. Chapter 2).

During the testing of specimen A (with a 'long' shear length of 90cm), the first slip appeared at the load of 58.8 kN (25.8 kNm). The maximum load was 87.2 kN (37.2 kNm), which was 48% above the load of the first slip. Thus, the load bearing behaviour can be classified as 'ductile'. Specimen B (with a 'short' shear length of 60 cm) reached a peak load of 112.3 kN (29.1kNm), while the first slip, appeared at 71.4kN (18.9 kNm). With a load increase of 57% after the first slip, the load bearing behaviour can also be classified as well as 'ductile'. The abort criterion of mid-span deflection of L/50 was insignificant for both tests.

From these maximum loads, shear strengths of 525.2 kN/m² and 512.3 kN/m², respectively, could be obtained for A and B. The calculation was done according to the regulations of Eurocode 4, without taking into account the support pressure, and under assumption of a triangular compression stress distribution (Faust 2002). The primary test results are given in Table 3.

Table 3. Test results for composite slab specimens with SCLC Specimen

Specimen		A	B
f_{vp}	[MPa]	337.8	337.8
$0.9_{fcm,cube}$	[MPa]	38.43	38.43
Length	[m]	3.4	2.2
Width	[m]	0.70	0.695
M_u	[kNm]	37.2	29.1
η	[%]	79	54
τ	[kN/m²]	512.3	525.2

4.2 Deformation and failure behaviour of the composite slabs

While the maximum loads achieved were within the expected range, the failure mode and crack pattern in part showed unusual features, which were significantly different to the well-known behaviour of normal weight concrete specimens. First cracks appeared, as expected, at the crack-initiating sheets and on the longitudinal edges of the specimen (cf. Figure 7). These horizontal, longitudinal cracks split the concrete cover at the height of the composite sheet's upper chord. In contrast to composite slabs made of ordinary concrete, an additional crack appeared with further load increases and opened within a distance of approximately 20 cm from the crack-initiating sheet, while the initial crack at the crack-initiating sheet was closed.

For specimen A this crack was vertical in the beginning and split later. One branch headed towards the load application area and the other grew between the load application and the support. With further increases in load, another crack formed in the same way at a distance from the first, equal approximately to the height of the slab. This crack ran along the compression trajectories toward load application as well. Specimen B showed only one considerably curved crack heading toward load application (see Figure 8).

Figure 7. Specimen A at the ultimate limit state.

The more the cracks opened, the more their edges shifted against each other. For Specimen B a vertical displacement of the crack edges could be recognised and local buckling of the composite sheet was observed. After cutting specimen B it could be observed that the curved crack ran through the entire width. The concrete at the lower crack edge was clearly damaged. Burls of the composite sheet left abrasion marks on the concrete, and the angle of the concrete rib was sheared off. These marks have gone undetected in tests of ordinary concretes of normal weight.

Figure 8. Specimen B at the ultimate limit state

Specimen A with its 'long' shear length and specimen B with its 'short' shear length were both split longitudinally after reaching maximum load. Each crack started at an upper chord angle of the Super-Holorib-sheet and ran inclined through the entire specimen thickness. Specimen A was split at each rib of this undercut profile (see Figure 9). The test results observed by Koenig & Faust (1997) and Kurz & Kessler (2007) with conventional lightweight concrete showed similar behaviour.

5. SUMMARY

Several SCLC compositions suitable for the production of composite slabs were developed in this investigation. The bulk density classes ranged from D1.4 to D1.8. To secure a target workability of SCLC over the delivery and casting time, LWA were pre-wetted by a defined amount of water.

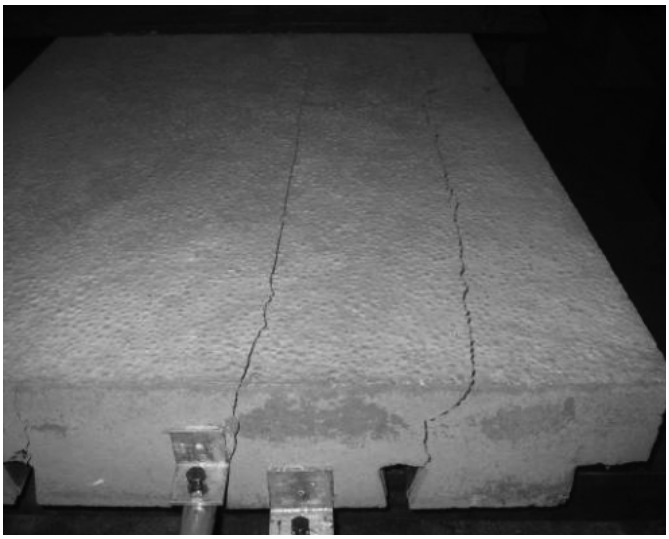

Figure 9. Longitudinal splitting cracks in specimen A.

Furthermore, it was shown that the mixing intensity and duration play a significant role with regard to concrete workability. Shrinkage measurements showed a clear, positive effect of the addition of shrinkage reducing additives, while the addition of a sealing agent led to no improvement.

These results were confirmed in the instrumented ring tests: the cracking of the specimens with SRA occurred at a higher concrete age, and crack widths were considerably lower in comparison to the specimens made without the addition of SRA. Furthermore, the pumpability of SCLC was validated by pumping tests.

Composite slabs made of SCLC showed a ductile failure in the bend tests. The crack pattern was very different to that known in the corresponding tests on composite slabs made with ordinary concrete. The observed failure mode was not only the well known and assumed longitudinal shear failure, but also a combined failure from transverse force and longitudinal shear. Investigations are in progress.

6. ACKNOWLEDGEMENTS

This research has been sponsored by the *Bundesamt für Bauwesen und Raumordnung* with funding from the initiative '*Zukunft Bau*' (reference number Z 6 – 10.08.18.7-07.9/II 2 – F20-07-19). The authors are responsible for the content of this report.

From the CEO's desk

The year has started with a flurry of activity, with the organisation of the FloorSem 2012 seminar road show, which has attracted record support from the members and industry in terms of both attendance and sponsorship. A huge 'thank you' to all those who participated – your support is greatly appreciated.

It is also membership renewal time and I appeal to those members wishing to renew for 2012 to do so as soon as possible, to ensure maximum benefit from your membership for the year. A reminder also to the professional registered engineers that your individual membership of the Society entitles you to 'partial exemption' from your annual fees to the Engineering Council of South Africa, (worth R950 in 2011/12). This is due to the fact that we are a registered Voluntary Association with ECSA. In addition, you will also automatically be awarded 1 CPD point for being a Society member.

One of the Society's main aims this year is to increase membership to ensure representation and support from all segments of the concrete and construction industry. Our drive to attract more company members has borne fruit over this past year, with several organisations joining us, but we would like to see many more enjoying the benefits that Company membership can offer.

With Fulton Awards 2013 a mere 18 months away, planning has already commenced to make it an even better event for entrants, sponsors and guests. Nomination forms are already available on the CSSA website and you are urged to complete for any project that was completed in 2011, and later on this year for any projects due for completion or substantially completed in 2012. It is far easier to nominate a project whilst the team is still together and not scattered across the industry on new projects.

A great deal of work has gone into reviewing and revising the Fulton Awards categories, criteria for entry and judges' questions. This has been done as a direct result of feedback from members after the 2011 awards and my personal experience as one of the judges.

For the record, the categories now are: Civil Engineering Structure; Building Structure; Architectural Concrete; Sustainable Concrete; Community Structure; and Innovative Construction.

We are planning to hold two more National Seminar road shows during June and October. More information will be published shortly.

Finally, a reminder to all members that March 28th marks our Annual General Meeting, which this year is to be held in Cape Town, as the new incoming president hails from the 'mother' city. Nick van den Berg will be stepping down as President as his term of office ends. I would like to take this opportunity of thanking him for the support he has given me personally, in my first year, as the CEO of the Society, and also for the direction and guidance he has given the Concrete Society as a whole.

John Sheath

Chief Executive Officer
Concrete Society of Southern Africa

Self-Compacting Lightweight Aggregate Concrete for Composite Slabs

ACCREDITED TECHNICAL PAPER

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Women rule – well they do in the Inland Branch!

John Sheath, our CEO, caught up with Hanlie Turner, after she was elected as Inland Branch Chair at their Annual General Meeting.

John Sheath: Tell me Hanlie, how does it feel to have been elected to this position?

Hanlie Turner: Being elected Chairperson of the Inland Branch of the Concrete Society is a tremendous honour for me. As you know, and to quote from the website, 'Concrete Society membership offers unique benefits to all those interested in, or having a passion for concrete'. While I cannot claim to be a concrete technologist, or having in-depth technical concrete expertise, I certainly fit the profile in terms of my passion for concrete.

John Sheath: Yes, I think many of us know of your great interest in concrete. How long have you been involved with this unique building material?

Hanlie Turner: Over my 30-year career in the broader construction industry, with Murray & Roberts, WLPU Consulting Engineers, currently known as Knight Piésold, and during the past 19 years at the Cement & Concrete Institute, I have developed a keen interest in engineering, construction and of course concrete as a sustainable material. The interest has grown to such proportions that I now come home from a holiday with no family snapshots, but photographs of interesting concrete structures. Some of my best memories of my working years include a climb up the Ergo decant tower, a visit to Katse Dam, a site visit to the Harper Road Bridge before it was swung over the freeway into its final position, and standing on the R21/N1 flyover just before a next section was being launched. How amazing to be involved, in some small way or another, with the structures that shape our skylines and cater for the ever increasing needs of our society.

John Sheath: "I think I am right in saying that your election to Chairperson of the Branch marks a first for a lady to hold this position, in what has been a very male-dominated area of the Society. Are you at all daunted by this?

Hanlie Turner: Not at all. Yes, I am the first lady to be elected chairperson of a branch, but I will not hold this position in isolation. The Inland Branch committee consists of both men and women with a passion for concrete. I know many amazing women in our industry, who are fully accepted, by all, because of their ability and commitment to the project in hand.

John Sheath: What plans do you have for the Inland Branch?

Hanlie Turner: The Inland Branch will continue to provide a forum for networking. We have an exciting programme lined up for the year, as always with the interests of our different members' groups at heart. I ask that members please support our events with their presence, their expertise as speakers, and of course with sponsorships. Above all, communicate with us, let us know what topics should be covered at our Quarterly Technical Meetings and give us feedback to help us ensure that expectations are met and that we remain relevant.

John Sheath: Do you have any views on the short term future of the greater construction industry?

Hanlie Turner: While there are early glimmers of hope that the construction industry may be picking itself up from the bottom of the current depressed cycle, let us believe that President Zuma's State of the Nation Address, which promised a renewed commitment to infrastructure spend, and the pipeline of strategic projects will herald an era of many more innovative, aesthetic and environmentally responsible, concrete structures and applications.

In her full time capacity, Hanlie Turner is Marketing Manager of the Cement & Concrete Institute in Midrand, Gauteng.

Concrete floors exposed
- at 'ultimate concrete flooring seminar'!

The latest seminar road show – FloorSem 2012 – organised by the Concrete Society saw 450 delegates, around the country, learning the latest thinking and technology in the designing, planning and construction of industrial concrete floors on the ground.

In association with the Cement and Concrete Institute, the Society ran a very successful series of seminars in Johannesburg, Cape Town, Durban and Port Elizabeth. The events featured two international and six local guest speakers, dealing with issues relating to the successful laying of concrete floors.

The event commenced with an overview of the Concrete Society by the Chief Executive Officer, who handed over the seminar to the Chairman for the day, Peter Cullinan from BKS in Durban and Bryan Perrie, of the Cement and Concrete Institute chaired the other centres.

The programme included a keynote address by Kevin Dare, Managing Director of Face Consultants, in the UK. He gave delegates a comprehensive presentation on the 'journey of compromises' when installing industrial concrete floors.

He summarised basic floor construction techniques around the world. Dare also covered structural design; detail design; construction methods including long strip, laser screed jointed, laser screed jointless and post-tensioned. The latter were compared in terms of their advantages and disadvantages. He highlighted some of the problems that stakeholders face including: Joints deterioration; Curling; Joint load transfer; Flatness not suitable; Poor abrasion resistance; Cracking; Problems at loading docks; Delamination; Overloading; Restraint issues; Fibres at the surface; Wide joints; and Use of chemical admixtures.

Dare concluded his presentation by stating that the best floor results are obtained by engaging all the stakeholders and understanding their requirements, difficulties limitations and managing expectations.

Les Greening, from LGA Fortuna Logistics Consultants, presented views from a material handler's perspective and the focus on the impact of floor tolerance and construction of efficient distribution centre operations. He offered a fascinating insight into the world of bulk handling, warehouse stock, on a massive scale using the very latest in materials handling equipment and the considerations which are necessary when designing and installing high tolerance floors.

Engineer Bertus Broekhuizen of Otec CC Consulting Civil and Structural Engineers, dealt with issues from a consultant's point of view. His presentation included all the aspects of designing and laying industrial concrete floors,

Johannesburg delegates


Durban delegates

in terms of the client and engineers' expectations, relating to suitability, serviceability and durability.

Delegates were keen to hear an engineer's take on the concrete requirements for producing a successful industrial concrete floor.

Martin Kerrigan, Projects Director of Twintec South Africa, presented a 'practical approach to 'jointless' floor construction'. His presentation included understanding floor slab design, slab joints - induced and formed, and an understanding of the materials that are used. He reviewed typical maintenance and operational requirements, and he described construction methodology using a typical case study.

A presentation on Jointless Post Tensioned Slab on Grade was given by Peter Norton of Concrete Laser Flooring (CLF) and Francois le Roux of Nyeleti Consulting.

Norton began by citing several definitions of a floor, including one by B C Crisp, an Australian engineer: "the floor is the most important part of the building. All activities occur on or near the floor and the remainder of the structure is simply a means of protecting the floor and workforce from the environment." A brief look over the past 30 years revealed that many changes have taken place in industrial flooring, particularly in warehouses –


Kevin Dare

the increase in fast moving consumer goods; larger warehouses; higher racking; more efficient distribution methods; faster forklifts and round-the-clock operations.

He posed the question: "Why do we need to reduce the number of joints? In short, the reason put forward was the many problems that jointed floors presented.

So, he concluded, post-tensioned jointless floors are the future and will enable the industry to provide the owner with a world class surface facility offering long life and low maintenance.

Francois le Roux then described, in some detail, the process by which post tensioned floors were constructed, the benefits of such floors and the applications to which they are suited, namely: Distribution Centres and Warehouses; Refrigerated stores; Bulk Solid Storage; Heavy Equipment Maintenance facilities; Freight Forwarding Centres; Container Handling facilities; Base slabs for Water Retaining structures; and Raft Slabs.

A case study was also presented featuring a project for BMW South Africa.

The seminar then turned to a very different approach – the contractor's point of view. Ian Buchanan of Royal Floors pulled no punches when he described the many challenges that face the contractor when installing an industrial concrete floor. These ranged from poor specification and quality of sub-base material to insufficient attention paid to concrete mix design and inappropriate level and flatness specifications.

"There is a far greater likelihood," he said, "of a successful outcome when there is interaction between the engineer and a specialist flooring contractor before construction commences, or better still, even before enquiry

Concrete floors exposed

- at the 'ultimate concrete flooring seminar'!

documents are issued." In conclusion he left the delegates with a few thoughts: The use of a laser screeder does not offer any guarantee of a better quality finished floor. It is a piece of kit used to place and strike off concrete usually to very accurate levels – no more – no less. It may be faster – but the final product is not necessarily more durable than floor placed conventionally. Therefore do not exclude conventional placing methods from project specifications.

Jointless floors have joints – as do post-tensioned floors - even though those joints are few and far between.

Many will be prepared to pay a premium for a jointless, or post tensioned, floor in the hope of avoiding frustrations with conventionally jointed floors.


Wynand Louw

"If this presentation made at least one person reflect why there are vast numbers of conventionally constructed concrete surface beds throughout South Africa and the rest of the world, rendering hassle-free service without maintenance – then it will have served its purpose".

Concrete Technologist, George Evans, with the Cement and Concrete Institute offered a detailed look at the materials proportions and handling for producing good, durable concrete aspects included: Mix Design: Aggregates & Cement; Concrete Plastic Properties: Mobility & Bleeding; Placing: Method, Rate, Location & Sequence; Consolidation: Effectiveness; Protection & Curing: Method & Duration; and Concrete Hardened Properties: Dimensional Stability & Durability.

The final presentation of the day focused on applied finishes and sealing of concrete floors by Wynand Louw of W Louw and Associates. The various types of coatings that are available were outlined: Toppings and Screeds; Floor hardeners; Decorative dry shakes; Thin coating systems i.e. Epoxy enamel (200-600µm); Medium to thick epoxy systems (1000-3000µm); Epoxy screeds; Polyurethane Coatings; Urethane screeds; and Polyurea spray systems.


Les Greening

The features and benefits of each coating type were presented, together with typical application areas in which they would be suitable for use. Key criteria that need to be checked before embarking upon a resinous based application were highlighted and included: Brief and expectations; Intended use of floor; History of previous spillage on floor; Surface preparation; Correct choice of joints and sealants; Maintenance and guarantee.

Louw's final word to the delegates was that if all the facts and history are not known about the floor in question – then rather walk away. Question times were lively and interesting and certainly had delegates thinking deeply about all the issues that were discussed.

In his closing addresses, Chief Executive Officer, John Sheath, thanked Bryan Perrie for his excellent chairmanship, Hanlie Turner from the C&CI for her valuable input on the organising committee, the exhibitors and sponsors for their generous support, and the delegates for their attendance.

A special mention and thanks were made to CSSA Head Office staff Natasja Pols and Jeanine Steenkamp who had organised the entire week, making an extremely successful event.


Jeanine Steenkamp, John Sheath and Natasja Pols

CONCRETE SOCIETY OF SOUTHERN AFRICA WESTERN CAPE BRANCH 2012			
DATE	**MEETING/EVENT**	**VENUE**	**CONVENOR**
23rd Feb	FloorSem 2012	Newlands Sun Hotel	John Sheath (National event)
28th March	AGM (Branch and National)	UCT Civil Engineering Building LT1	Etienne van der Klashorst (evdklash@sun.ac.za)
19th April	Technical meeting (Living with the new generation cements)	UCT Chemical Engineering Building	Ken Newton (ktw@mweb.co.za)
10th May	Annual golf day	Parow Golf Course	Riaan van Dyk (riaanvd@kls.co.za)
14th June	Site Visit	To be confirmed	Ken Newton (ktw@mweb.co.za)
26th July	Technical Meeting	UCT Chemical Engineering Building	Hans Beushausen (Hans.Beushausen@uct.ac.za)
23rd August	Site Visit	To be confirmed	Jerome Fortune (jerome@chrysosa.co.za)
Early September	Technical Meeting	UCT Chemical Engineering Building	Hans Beushausen (Hans.Beushausen@uct.ac.za)
12th Sept	Cube casting date	-	-
10th Oct	Cube crushing	To be announced with publication of event information	Ken Newton or Etienne van der Klashorst (evdklash@sun.ac.za) (ktw@mweb.co.za)
11th Oct	Cube completion prize giving ceremony	To be announced with publication of event information	Ken Newton or Etienne van der Klashorst (evdklash@sun.ac.za) (ktw@mweb.co.za)
18th Oct	Site visit	To be confirmed	Ken Newton or Etienne van der Klashorst (evdklash@sun.ac.za) (ktw@mweb.co.za)
15th Nov Date TBC	Annual Cocktail function	Granger Bay Hotel School	Christo Adendorff (christo.adendorff@af.aurecongroup.com)

CONCRETE SOCIETY OF SOUTHERN AFRICA INLAND BRANCH 2012			
DATE	**MEETING/EVENT**	**VENUE**	**CONVENOR**
19th Jan	Committee Meeting	C&CI, Midrand	Armand van Vuuren
8th Feb	Committee Meeting	C&CI, Midrand	Armand van Vuuren
24th Feb	AGM and Flooring Seminar	Premier hotel, Kempton Park	Jannes Bester/Natalie Johnson/Tina Coetzee
14th March	Committee Meeting	C&CI, Midrand	Hanlie Turner
11th April	Committee Meeting	C&CI, Midrand	Hanlie Turner
9th May	Committee Meeting	C&CI, Midrand	Hanlie Turner
16th May	Mini-Seminars - Fixings	To be advised	Jannes Bester/Natalie Johnson/Tina Coetzee
13th June	Committee Meeting	C&CI, Midrand	Hanlie Turner
11th July	Committee Meeting	C&CI, Midrand	Hanlie Turner
25th July	Mini-seminar – Sustainability	To be advised	Jannes Bester/Natalie Johnson/ Tina Coetzee

CONCRETE SOCIETY OF SOUTHERN AFRICA INLAND BRANCH 2012 CONTINUED			
DATE	MEETING/EVENT	VENUE	CONVENOR
8th August	Committee Meeting	C&CI, Midrand	Hanlie Turner
17th August	Egg protection device – Casting date	NA	Darren Jacobs
24th August	Egg protection device – 'Crush in'	PPC Jupiter works	Hanlie Turner
12th Sept	Committee Meeting	C&CI, Midrand	Darren Jacobs
29th Sept	Annual Concrete Boat Race Day	Victoria Lake, Germiston	Michelle Fick/Andrew Schmidt
10th Oct	Committee Meeting	C&CI, Midrand	Hanlie Turner
2nd Nov	Chairman's Breakfast	To be advised	Hanlie Turner

CONCRETE SOCIETY OF SOUTHERN AFRICA NATIONAL OFFICE PROGRAMME 2012			
DATE	MEETING/EVENT	VENUE	CONVENOR
First quarter 2012			
20th – 24th Feb	FloorSem 2012	Durban, Port Elizabeth, Cape Town, mJohannesburg	Bryan Perrie
28th Feb	Closing date for inclusion in Source Book 2012/2013	Attention all CSSA members	CSSA Administration
March 2012	Concrete Beton	Posted to all CSSA members	Crown Publications
28th March	Annual General Meeting	UCT	Nick van den Berg
29th March	Council Meeting	Newlands Sun	Prof Billy Boshoff
April 2012	Source Book 2012/2013	Posted to all CSSA members	Crown Publications
Second quarter 2012			
21st June	Council Meeting	Johannesburg – Venue to be confirmed	Prof Billy Boshoff
June 2012	Concrete Seminar – Topic still to be confirmed	Durban, Port Elizabeth, Cape Town, Johannesburg	John Sheath
July 2012	Concrete Beton	Posted to all CSSA members	Crown Publications
Third quarter 2012			
18th Oct	Council Meeting	Johannesburg – Venue to be confirmed	Prof Billy Boshoff
October 2012	Concrete Seminar – Topic still to be confirmed	Durban, Port Elizabeth, Cape Town, Johannesburg	John Sheath
Nov 2012	Concrete Beton	Posted to all CSSA members	Crown Publications

CONCRETE SOCIETY OF SOUTHERN AFRICA INTERNATIONAL EVENTS 2012			
DATE	MEETING/EVENT	VENUE	CONVENOR
17th – 20th June	Bond in Concrete 2012	Brescia, Italy	Dr Giovanni Metelli
18th – 21st June	1st International Congress on Durability of Concrete	Trondheim, Norway	Henny Catherine Braarud
9th – 11th July	Concrete in Low Carbon Era	Dundee, Scotland	Prof M R Jones

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FULTON Awards 2013

2013 Fulton Awards

Call For Nominations

The Concrete Society of Southern Africa (CSSA) is calling for nominations of projects for the prestigious Fulton Awards, presented every two years by the Society to honour excellence and innovation in design and use of concrete. We are proud to announce that the Cement and Concrete Institute is confirmed as the Anchor Sponsor for the 2013 Fulton Awards.

For the 2013 Awards there will be 6 categories:

CIVIL ENGINEERING STRUCTURE:

Projects where the Civil / Structural Engineer is the Principal Agent or is the Civil Engineering Project Manager or is the Lead Consultant heading up the project team and the Bill of Quantities and Contract Documentation is generally compiled by the Project Civil Engineer.

BUILDING STRUCTURE:

Projects where the Architect or a Building Works Project Manager is the Principal Agent or is the Project Manager or is the Lead Consultant heading the project team and where the Bill of Quantities and Contract Documentation is generally compiled by the Project Quantity Surveyor.

ARCHITECTURAL CONCRETE:

Architectural projects where concrete has been used as the principal construction material and which demonstrates unique and exceptional structure, surface finishes or particular details, in an aesthetic manner.

SUSTAINABLE CONCRETE:

Projects that demonstrate the innovative use of concrete through the implementation of sustainable strategies during the design, construction and use phase.

COMMUNITY STRUCTURE:

Structures that have made a significant contribution to the formation of socially viable environments and the values of communities, with a high participation of stakeholders (client, users, local communities, local authorities, non-governmental organizations and others).

INNOVATIVE CONSTRUCTION:

Structures where totally new materials / techniques / technologies / applications / design and/or analysis concepts or procedures, using concrete as the principal material, have been developed and utilized.

Any project completed during 2011 or substantially completed during 2012 is eligible for entry, and projects may be entered in more than one category.

For nomination forms, contact the CSSA Administrator:

Tel: 012 348 5305 or e-mail: admin@concretesociety.co.za or visit the Concrete Society website on www.concretesociety.co.za

Anchor Sponsor of the 2013 Fulton Awards

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Closing Date For Nominations 31 August 2012