Concrete Beton

The Official Journal of
The Concrete Society of Southern Africa

TECHNICAL PAPER
- The Current Status of Self Compacting Concrete In South Africa
- The Development of a Probabilistic Service Life Design Model for Typical South African Concretes and Environmental Conditions

CONCRETE CHATTER
- Durability Seminar
- Boat Race

FULTON AWARDS 2007 WINNER - CONSTRUCTION TECHNIQUES
- Impala Platinum No. 16 Shaft

CONCRETE TIPS
- Cracking of Concrete in the Plastic State
- Early Age Thermal Contraction Cracking of Concrete

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CONCRETE SOCIETY
OF SOUTHERN AFRICA

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CONCRETE SOCIETY
OF SOUTHERN AFRICA

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CONCRETE SOCIETY
OF SOUTHERN AFRICA

Vision
To be the most relevant forum for all who have an interest in concrete and to promote the concrete related services of the Society's 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.

President's Message

As this edition of Concrete Beton will be the last source of communication for 2007, I feel that it would be appropriate to reflect back on some of the highlights. This year has been very exciting for the Concrete Society of Southern Africa. The Fulton Awards has without any doubt been the ultimate event.

This weekend event in the Drakensberg turned out to be a roaring success. As a result of this, Council has decided to adopt this format for the future. The Fulton Awards in 2009 will therefore be held in a similar manner. Nominations for the next event will start early in 2008.

The National Seminar on Concrete Durability that was held in October is a follow up to the seminar that we hosted five years ago. From the reports that I have received, it has been of definite benefit to all those that have attended. Concrete Durability is of utmost importance to our industry and the more knowledge that we can gain the better. I would like to urge you to support the people that are doing research into this field. Ultimately we will all benefit from this research. I would like to thank Bryan Perrie for his initiative to plan this conference, as well as all the speakers who graciously offered their time to travel around the country. A special thanks to Trevor Sawyer, Hannelie van Jaarsveld and the local branch committees for all their hard work with the organising of the road show.

All our branches were actively involved with their own events this year and I am sure that you all enjoyed the functions that were hosted by them. It is difficult to single out a particular branch, but special recognition must go to the Eastern Cape Branch. They have done a tremendous job this year. In the recent past there was very little interest from members. However, due to the hard work and diligence of Louis Visser and his team, we are seeing a huge resurrection in this branch. I would like to urge all members in the area to support Louis by attending functions and to introduce new people to the Concrete Society.

We were saddened by the decision of our Administrator, Irma Dyssel, to resign. Irma has done tremendous work for the Society over the past 13 years. Many members have come to know Irma as the voice and face of the Concrete Society. She will surely be missed by all. I would like to thank Irma on behalf of all the members for her hard and loyal work and wish her well in her new endeavors.

We have opened a new office in Randburg. The contact details for the new office are in the magazine. Lastly, I would like to urge you to become more involved in the Concrete Society. At our next AGM in March 2008, we need to elect two new councilors to serve on the Council of the Concrete Society. Should you be interested in standing as a councillor or know someone who would be interested, you are more than welcome to contact me. We look forward to your support.

I wish all of you and your families a peaceful and joyful Festive Season and a prosperous New Year and look forward to seeing you in 2008.

Dave Miles

ECSA

The Concrete Society of Southern Africa has now been registered as a voluntary association of the Engineering Council of South Africa (ECSA). Our members will derive great benefit from this development. The first of which, is that members will be able to claim CPD (Continued Professional Development) points for attending technical Society events. A reviewing committee will evaluate all technical talks, seminars and conferences before accrediting and allocating points to an event. This practice adheres to the principles of ECSA.

We trust that this will encourage professionals to become members of the Concrete Society.

For more information,
please contact the office
or visit the website at
www.concretesociety.co.za


ECSA
CERTIFICATE OF RECOGNITION
Concrete Society of Southern Africa
Voluntary Association: Category A

NATIONAL DURABILITY SEMINAR

SPEAKERS :

Edwin Kruger	Bryan Perrie	Sebasti Badenhorst	Prof. Mark Alexander	George Evans
SANRAL	C&CI	Holcim	UCT	Grinaker-LTA

The support of the Industry was overwhelming, with excellent attendance at all four centers. We would like to express sincere thanks to all the sponsors. Holcim was the major sponsor. Regional sponsors were Chryso, Sika and Xypex. This road show was also endorsed by the Cement & Concrete Institute, South African Readymix Association and the South African National Roads Agency.

The Concrete Society of Southern Africa hosted the National Durability Road Shows during October 2007. These seminars were aimed at owners of concrete infrastructure, including parastatals, national, provincial and local government departments, consulting engineers, contractors, suppliers and test laboratories.

With ten years of academic and applied research into the durability of concrete in South Africa now behind us, we have learnt a great deal about the potential of our raw materials and our concretes to perform adequately in different (often very aggressive) environments. In practice, however, it is not only the materials that affect the potential durability of concrete structures. In fact, to varying degrees and with often cumulative effects, the design and detailing of the structure; different construction practices; actual environmental conditions on site and different interpretations of variations and correlations between laboratory and site test results, all play a role.

It is vitally important to understand the influence of all the above factors in implementing durability specifications and particularly quality assurance testing. At this stage the durability index tests developed at our universities are still in development and results obtained from them should be used with circumspection and with due cognisance of the uncertainties inherent at present. In order not to disadvantage any party unfairly due to these uncertainties, financial penalties based on the durability index tests should be used cautiously and with a full understanding of the consequences of non-compliance to the specification.

The ultimate goal is the inclusion of a design approach in SANS 10100-1 and a quality assurance procedure in 10100-2 and the SANS 2001 Series together with SANS Test Methods that can be accredited.

The importance of educating all stakeholders in the latest developments cannot be overemphasised, and therefore the Durability Focus Group, established under the auspices of the C&CI, presented the workshops around the country in conjunction with the Concrete Society of Southern Africa. The objective was to make the entire subject of durability better understood by all those interested.

In the next edition of Concrete Beton, we will publish some of the material that was presented at the Seminar.

Concrete Pumped to Soaring Heights for World's Tallest Headgear

Concrete had to be pumped 109m above ground surface for the construction of what is believed to be the tallest concrete mining headgear in the world, recently completed at Impala Platinum's 16th Shaft near Rustenburg.

Ian Connellan, Site Agent for Murray & Roberts Construction, says the headgear – which has become a new landmark on the Rustenburg skyline – has a footprint of 20 by 21 metres and a total height of 132m, of which 109m is above terrace (bank) level. The wall thickness ranges from 950mm to 550mm.

"The towering headgear was constructed using unique variations on the slipform method and took a month to complete from bank to top. The concrete – mixed to a special formulation – was pumped up along the full vertical height of a 90HC towercrane. It was then placed by using a manual spreader boom, positioned in the centre of the headgear. The gap was bridged using high-pressure rubber piping, allowing for substantial amount of play.

"All the fittings for the 125mm diameter high pressure pipeline had to be imported. The pumps employed were Putzmeister units imported from Germany and the special hydraulic valve - which prevented gravitational flowback of the concrete - was also imported from Germany," Connellan stated.

To pump concrete to the challenging height of almost 110m called for a special formulation and in this respect admixtures supplied by Chryso S.A. played a vital role. The concrete mix (designed by Chryso's GM:Technical Services and Cement Division, Eddie Correia) consisted of Chrysofluid Optima 100 New Generation admixture, crusher dust, 19mm stone, riversand, and OPC 1 cement and slagment applied in a 50-50 ratio.

"The resultant - exceptionally pumpable - mix helped the sub contractors, GMBA member Renniks Construction, to pump the 7 000 cubic metres of concrete higher than ever achieved in the local mining industry in a vertical lift. The mix also allowed extended workability without negatively affecting setting time which allowed construction to proceed at a rate even faster than required," Connellan added.

The piping that carried the concrete was installed along the 90HC tower crane, secured to the structure at five tie-in points. A second tower crane (200HC) was fitted with an Alimark elevator with a climbing track raised to match the increasing height of the headgear. Fifteen of the 60 workers employed per shift were carried per trip by the elevator.

Connellan said the construction team fared exceptionally well on the project which was completed a week ahead of schedule. A 12-hour shift was in force with even longer supervisory shifts to ensure continuity in construction. "The maximum progress made in a day was 6m. A 24-hour shift on average took the structure another 4,5m higher."

The R80m contract – scheduled for completion in May next year - calls for the construction of the headgear, internal concrete floors, concrete bulk air-cooler tunnels and concrete access tunnels, as well as winder bases and ancillary earthworks. In addition to the 7 000cu m of concrete required for the slide, another 14 000cu m will be used for foundations and ancillary work.

Murray & Roberts Construction installed a laboratory on site to continuously monitor concrete strength and the performance of the additives. Chryso S.A. also had regular presence on site to provide input regarding the additives in the concrete mix.

The concrete was supplied by Qualicrete of Rustenburg which had a Karoo batch plant on site.

Work in progress on the top of the 109m tall Impala Platinum headgear near Rustenburg.

Inland Branch

Boat Race

On the 15th September 2007 the Inland Branch held their Annual Concrete Boat Race Day at the Victoria Lake Club in Germiston, near Johannesburg. Each year sees an improvement in the event and this year was no exception, with more than 50 boats taking to the water and well over a 1000 supporters cheering the rowing team of their choice.

Support from the local Universities was very good and who, as in the past, had included the boat race in their student syllabus as a project management exercise. Success of the day was due largely to the support from industry representatives who provided financial and other support. Special thanks therefore go to PPC, Cement & Concrete Institute, Holcim, Chryso SA, Blitz Concrete, Afrimix Readymix Concrete, Stefanutti & Bressan, Ash Resources and Infraset.

Judging for the Student Construction Award was carried out by Francois Bain of Shabalala Bain Infrastructure Consultants and Carl Schmidt. Many entries in this competition were of top-most quality. After much deliberation (about 3 hours in total to get through all the entries), the judges decided upon the following winners in the students construction category:

1st Prize Swordfish - “the team presented a well executed design and construction. The over-riding factor however, that eventually swayed the judges’ decision was the excellent project presentation displayed alongside the finished boat. The boat itself was finished to the same high quality. The fact that the team manufactured a “cradle” for the boat to stand on when not being used, impressed the judges and indicated the team’s care for their project. The overall quality of the finished product was exemplary and the team members showed pride in their work. Well done team “S04 - Swordfish”.

2nd Prize CT Forces - “the team used a unique, ingenious design utilising a sacrificial polystyrene mould which was eventually dissolved from within the completed boat using solvents. This rendered the boat a totally waterproof “shell” structure. A further point that impressed the judges is that the team modeled the boat on a structural design package to determine the points of stress and strain and possible weakness. They were impressed also by the well executed decoration of the completed vessel and the ingenious use of a “cooler” box, just big enough for a six-pack, sealed in to close the hole required to remove the sacrificial polystyrene mould. An excellent effort on the part of team “S23 - CT Forces”.

3rd Prize Alchemy - “The team presented a well designed and craftily constructed entry. The decoration to the outside of the vessel was superb. The judges were particularly impressed by the inflatable flotation device included in the forward compartment in the bows of the boat”.

CONCRETE SOCIETY
OF SOUTHERN AFRICA

FULTON Awards 2007

Anchor Sponsor
cement & concrete institute

Winner - Construction Techniques

Impala Platinum No. 16 Shaft

PROJECT MOTIVATION

Impala Platinum's No. 16 Shaft comprised a main shaft and a ventilation shaft with the associated winder buildings, a bulk air cooler, personnel tunnel and services duct. The main-shaft headgear was a concrete structure that was unique in the following ways:

- It is the tallest concrete head-gear in the world at a height of 108.3m above bank level. The overall height from the foundation is 132m.
- It is the first headgear slide in South Africa that was pumped, using a Putzmeister stationary pump.

This novel approach necessitated the design of a special concrete mix to enable the concrete to be pumped vertically upwards, using special additives supplied by Chryso Admixtures.

The headgear utilised the following quantities of raw materials:

- Rebar used: 1 300t of high-tensile steel
- Concrete placed in the slide: 7 000m^3
- Concrete placed in the floors (ten levels): 700m^3

The project had a four-phase approach: the first phase was the box cut and presink; the second phase was the slide, construction of the winder houses and service ducts; the third phase was the ventilation ducts and connections into the slide; and the fourth phase was the suspended floors in the slide and the cantilevered Koepe slab.

A construction programme was agreed upon by all parties concerned, which involved the construction of the shutter, transportation and assembly on-site, the first phase of the slide (base to bank level –21 metres), adjusting the shutter profile (which changed at bank level), removing the shutter and equipment from the top.

Murray & Roberts Construction, in conjunction with Shaft Sinkers, excavated the shaft using Volvo 6X6 articulated dump trucks, which enabled the shaft collar to be constructed a lot quicker than anticipated. This equated to a full two-month advance on the programme schedule. A 40 t excavator was used to load the dumpers. These were the only trucks that could remove the blasted material up a 23 degree slope fully loaded.

The slip form platform was pre-fabricated off-site to eliminate any problems on-site. The slide modules were placed on top of the collar. While the slab was being completed, the access stairway was

also in progress. This was a unique aspect of the operation in that it had to bridge over phase one of the slide, as well as provide safe access for personnel and materials while sliding the first 26 metres.

This access was also used to support the pumping column for the concrete placement. The concrete was pumped vertically downwards down to the platform. It was placed in the slip form by means of a spreader beam situated in the centre of the slip-form, and light enough to be moved by hand. This accelerated the rate of placing the concrete up to six metres of slide per 24-hour shift.

The proposed duration of the slide activity was unknown, as this was the first time this had been undertaken. Therefore a conservative rate of about 2.5 metres per 24 hours was allowed for in the construction programme. However, a rate in excess of 3 metres per shift was achieved, which resulted in the project being completed well ahead of schedule.

There were also some unforeseen problems that had to be managed. With the slide moving faster than anticipated, the tower cranes could not always be extended timeously. The higher the structure became, the more difficult it was to extend the crane in time. Taking this into consideration, two unscheduled 'labour rests' were enforced. This gave the workforce a well-deserved break from the usual 12 hour shift, as well as allowing the crane operators to catch up with the crane extensions.

It was decided to pump the concrete due to the high quantity of concrete required for every metre being slid. Without pumping, it would have been impossible to achieve the speeds required for the slip-forming due to the one-metre-thick walls. Slip-formed concrete must not only remain workable during distribution and placement, it must also be cohesive and avoid segregation and bleeding. Slide concrete must have sufficient paste to lubricate the formwork at the interface so as to prevent anything other than nominal friction.

Normally, pump and slip-form concrete will cover the same requirements, with the exception of setting time. Therefore a typical slip-form mix requires a higher volume of the material than would be required normally for maximum cement economy. This has the effect of providing a matrix in which the coarse aggregate can rotate, while also providing a zone of low shear strength at the shutter face. It must also retain the correct quantity of water for the hydration process to be completed, without any tendency to bleed. This is particularly important considering the method of vibration adopted for slip-forming.

For this particular project, the crusher sand grading was within specification, with 51% passing the 600 micron sieve and 35% passing the 300 micron sieve, which reveals it is acceptable for pumping. However, a concern was that, if the crusher sand went out of specification, then no other fine material was available in the mix with which to adjust the gradings. It was then suggested that a filler sand rather be used from the beginning of the slide, together with the crusher sand, so that if any adjustments had to be made, there would be no colour difference in the concrete. This change to the mix design ensured that a uniform colour was achieved throughout the slide.

The resultant mix was exceptionally pumpable, which helped the subcontractors, Renniks Construction, to pump the 7 000 m3 of concrete higher than ever achieved in the local mining industry in a vertical lift. The mix also allowed extended workability without impacting negatively on setting time, which allowed the construction to proceed at a rate even faster than required.

The specific requirements of Murray & Roberts Construction required a concrete mix comprising Chrysofluid Optima 100 New Generation admixture, crusher sand, 19 mm stone, river sand and a CEM I 42.5 N cement and slagment applied in a 50:50 ratio. Chryso SA supplied the specific admixtures required. A technical representative from Chryso was requested to visit the site frequently during construction in order to examine the concrete and monitor the pump pressure. This enabled Chryso SA technical staff to advise the construction team on any admixture dosage changes to keep the pump pressure at its optimum without affecting the setting time of the concrete.

Two Putzmeister stationary pumps were on-site, one electrical and the other diesel. The one was on standby. This was to ensure continuity during pumping operations.

Due to the head being pumped, in excess of 100 m, it was necessary to equip the pumps with hydraulic valves and specially-imported thick-wall, high-pressure pipes and clamps so as to be able to handle the pumping pressures.

While Shaft Sinkers sunk the 60 metres of the barrel, Murray & Roberts Construction constructed the headgear foundation – which was a daunting task from a safety point of view. The method of constructing the collar allowed simultaneous sinking of the shaft and construction of the base slab.

This called for intricate co-ordination between the sinking and construction teams. In order to speed up the operation, Shaft Sinkers built the sinking stage outside of the shaft. On the designated day, it was lowered into the shaft using a 400 t mobile crane. The shaft was suspended and then closed off.

Phase three commenced upon completion of the slide. Murray & Roberts Construction had to vacate the inside area of the shaft in order to allow the structural steel erectors to install the suspended steel beam supports for the internal floors. Once the four floors had been completed, a temporary headgear was built within the concrete headgear to facilitate early sinking.

In conjunction with this, the service ducting connections into the shaft, as well as the bulk air cooler duct, were being completed. While the temporary headgear was being installed, the construction of the three remaining suspended floors carried on. The Koepe winder level was then constructed, comprising six-metre-deep beams and a cantilever protruding six metres from the shaft face at an elevation of 92 metres.

The method used was unique. In order to construct the internal beams, the designer devised a method to pour the first metre of the six-metre-deep beam. Thereafter the support was lowered and the balance of the beam cast. This was done in order to reduce the loads on the floors below.

In order to construct the cantilever, a method was devised whereby a working platform was built on the ground from trusses. The platform weighed 34 tons. Two trusses were suspended above the Koepe level and then stressed to the six-metre-beams. Strain jacks were then used to elevate the working platform to the underside of the cantilever beams at about 91 metres. Although the platform was lifted with cables, it was supported in position in its working state with Dywag bars.

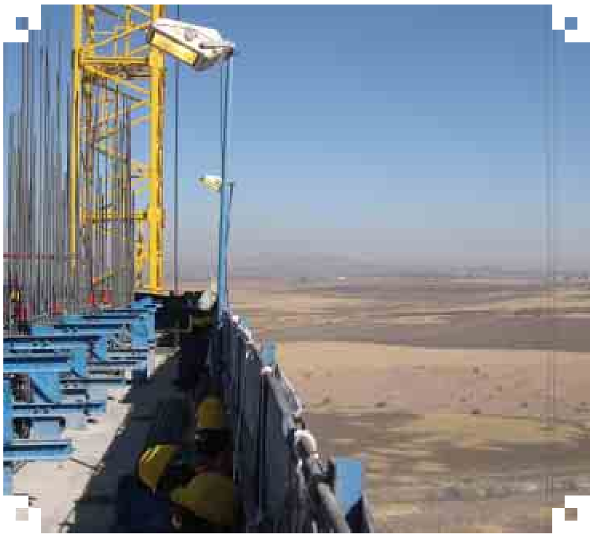
Once the platform was in position, four cantilever support beams were constructed, each three metres deep. Once these had cured, the load was transferred from the temporary trusses onto the new concrete beams. Thus the trusses themselves could be removed, allowing the Koepe slab to be completed.

Once the Koepe slab was finished, the strain jacks had to be reinstalled in order for the platform to be lowered back down to the ground. The design of the Koepe slab assisted in maintaining safe working conditions. The construction of the cantilever and Koepe slabs took about three months. Once the Koepe slab was completed, the structural steel elements of the winder house could then be completed. Only then could the single remaining tower crane be dismantled.

Tower cranage was limited to conveying reinforcing steel, cast-in items and any other materials required. The tower cranes, comprising a 90HC and 200HC Potain model, were not employed for concrete placement because there was not enough hook time due to the volumes required.

A fairly standard management structure was used on-site up until the actual construction of the slide itself. A separate specialised management team was deployed for the slide. At the peak of the project the construction team comprised 150 people, with a strong emphasis on supervisory-level personnel. This contributed to the commendable safety statistics of the project. A total of 681 621 lost-time injury-free man hours were achieved throughout the contract. The contract was completed without a single lost-time incident.

A total of 800 000 man hours were worked, with 681 621 lost-time injury-free man hours. The entire project team drove this strong emphasis on safety.



Full Impala Platinum safety specifications were adhered to, including that all on-site had to undergo medical and KBC training and TEBA registration. There was also an on-site induction for all personnel, as well as safety workshops. A refresher induction course was held during a break in the construction. A safety officer was present on each shift. Daily audits were conducted on all aspects of the construction process, together with daily ‘walkabout’ safety inspections.

Due to the fact that it was a 24-hour operation, two full crews had to operate day and night. Each shift had a foreman from Renniks Construction to monitor the sliding. The foreman’s crew comprised concrete hands, a shutter hand and steel fixers. There was a full-time surveyor on the sliding deck to monitor the movement of the slip form. This included checking and adjusting the levelling lasers placed at the bottom of the structure.

These lasers were used to ensure that the structure did not twist or pull to a side. RSV Consultants also had a designer on each shift in order to assist with any design queries that arose, as well as checking and signing off the slide logs. Special permission had to be obtained for the workforce to work extended hours, as the project exceeded the number of hours allowed per month. This entailed intricate negotiation with the Department of Labour.

Situated on the south-east corner of the Impala mining lease near No. 1 shaft, the development of No. 16 shaft is integral to Impala Platinum’s R6.6-billion expansion of its Rustenburg operations. No. 16 shaft is expected to produce 226.5 kt of reef a month from seven operational levels. The shaft will access both the Merensky and Upper-Group Two (UG2) reef horizons by means of a downcast rock and man-material shaft, together with an upcast ventilation shaft.

At No. 16 shaft the world’s tallest headgear will house two Koepe winders – one will hoist personnel and material, while the other will only hoist rock. The rock-hoist tipping arrangement will be located inside the concrete headgear to reduce noise pollution. A conveyor will transfer reef and waste from the headgear bins to a transfer tower, and then into two concrete silos.

Murray & Roberts Construction brings together a unique combination of engineering disciplines and expertise, enabling it to deliver world-class solutions to customers across the broad spectrum of building and industrial civils. It leverages this engineering expertise and industrial design competence to deliver major projects into the high-growth markets of developing economies. Its ability to innovate in order to suit the environments in which it operates has also played a role in positioning Murray & Roberts as a leading contractor in emerging and developing countries.

The Current Status of Self Compacting Concrete in South Africa

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Abstract

Self-compacting concrete requires no external vibration to achieve consolidation and generally results in savings in labour and time, improved workability, improved quality, higher durability and better surface finish. SCC is a widely accepted technology in Europe, East Asia, and North America. In South Africa, on the other hand, SCC has only been used for a relatively small number of applications and the acceptance of the new technology by the local industry is at this time very limited. A limited investigation into the South African concrete industry was performed, in addition to a market review to gain insight into the extent of use of SCC in South Africa presently. The review showed that the reluctance to accept the new technology is partly related to the limitations that presently surround the use of self-compacting concrete locally. The limitations include sparse knowledge and experience of specifying and working with SCC using South African materials and the reluctance of concrete product manufacturers to change their production processes. In addition, there is an absence of South African standards or guidelines that can be used to facilitate the design, manufacture and application of self-compacting concrete. Ongoing education efforts may result in the situation where the advantages of SCC will be applied more frequently to improve construction procedures and concrete quality in South Africa.

Introduction

Self-compacting concrete (SCC) is a relatively new concrete technology. Developed in Japan in the late 1980's, it is characterised by its ability to flow and completely fill formwork, even in the presence of dense reinforcement, whilst still retaining its homogeneity **(Figure 1)**. The fresh properties of self-compacting concrete are possible due to the use of advanced superplasticisers and re-designed mixes containing lower coarse aggregate contents and higher fines contents. Self-compacting concrete differs from traditional vibrated concrete in that it requires no external vibration to achieve consolidation. The advantages of this are economic benefits of savings in labour and time, in addition to improved quality, better surface finishes and improved workability.

Figure 1: Self compacting concrete does not need any external vibration for full compaction and filling of formwork

The acceptance of the new technology by the South African construction industry is at this time very limited, which is partly due to a limited amount of knowledge and experience of specifying and working with SCC using South African materials, in addition to an absence of South African standards or guidelines that can be used to facilitate the design, manufacture and application of self-compacting concrete. The required significant investment, both economically and in terms of education, that is necessary to successfully produce SCC leads to a consequent price premium on the final delivered product. These factors result in there being no incentive for the cement and concrete producers to market a new product. An investigation into the mindset of the South African concrete industry was performed, in addition to a market review to gain insight into the extent of use of SCC in South Africa presently.

Advantages of SCC compared to conventionally vibrated concrete

The advantages of SCC are well documented in the literature (for example RILEM, 2000). In general, the economic advantages of self-compacting concrete relate to the following factors:

- Faster construction
- Reduction in site manpower
- Better surface finishes
- Easier placing
- Improved durability
- Greater freedom in design
- Reduced noise levels
- No compaction necessary
- Safer working environment
- Less repair and making good after formwork is removed
- Risk of poor workmanship is reduced

SCC enables a faster construction time because no time is spent on consolidating the fresh concrete. This also leads to a reduction in manpower, whereby workers who traditionally vibrated the fresh concrete are no longer necessary. Most of the advantages directly relate to economic benefit (faster construction, reduction in manpower, easier placing, less repair work and improved durability), while the rest relate to aesthetics and ease of use. In how far these advantages, which were identified mainly for industrialised countries, apply to South Africa will be discussed in the following sections.

Market review on the South African mindset on SCC

A market review, conducted to gauge the level of use and understanding of SCC in South Africa, was undertaken in the form of questionnaires and personal interviews. Various construction companies, architects, consultants and concrete product manufacturers were approached and asked to fill out a questionnaire. In total, about 40 individuals were approached and 20 replied to the request and completed the questionnaire, the respondees consisting of approximately 30% contractors, 30% consultants, 20%

Readymix producers, 15% precast concrete manufacturers, and 5 % Architects. The questions focused on whether individuals had heard about self-compacting concrete and its advantages, and if they had heard about it whether they had used it in practice. The reasons for using SCC, as well as the volume and method of manufacture were also asked. If the individual filling out the questionnaire had never heard of or used SCC in practice then they were made aware of the advantages of the new technology, followed by a question as to whether they would or could use SCC in practice. Two questions aimed to gather information as to whether potential users of SCC would be more likely to use it if a practical set of guidelines existed for the design, manufacture and application of SCC in South Africa.

Awareness about SCC and its advantages

Of the twenty responses, seventeen had heard about SCC, and of those, eleven had used SCC at least once. Most of the respondents heard about SCC through international industry-related conferences or technical journals, although the respondents' knowledge of the benefits of SCC was either limited or specific to their fields. This indicates that a marketing campaign, detailing the economic, time-saving and other advantages, is necessary to educate the market and that conferences, journals and magazines have a definite role to play in advancing the use of SCC in South Africa. In order for this to happen, more articles and papers need to be written and presented. This will come about as SCC is used more in research and practice and more general awareness is generated.

Those involved in the production of SCC and its constituents have also played an important role in advancing the use of SCC in the construction industry, as a number of respondents had heard about SCC from Readymix producers or admixture suppliers.

Of those interviewed, 16 replied that they were aware of the advantages of SCC. The advantages that were listed by the respondents were as follows (the number in the brackets indicates how many respondents listed that particular advantage).

- No need for compaction (10)
- Better surface finish or improved off-shutter quality can be obtained (5)
- Reduced labour requirement on site (5)
- Intricate or complex geometric shapes can be cast (4)
- Reduced construction time, therefore labour can be used more effectively (3)
- Ease of placing / alternative placing methods are possible (2)
- No segregation (2)
- Self-levelling (2)
- Reduced noise levels (2)
- Better product can be produced (in terms of precast concrete products) (2)
- Improved durability (2)
- Reduced air voids (1)
- No vibration needed therefore health and safety benefits (1)
- Honeycombing is reduced. Concrete can be placed in restricted areas and areas with high reinforcement congestion (1)
- Concrete can be pumped long distances (1)
- Higher strengths are obtained (1)

Most of the advantages listed indicated that the respondents had a limited view of the advantages of SCC, with none of the respondents (except those involved in research and production) listing more than four advantages. The main advantage of SCC, namely that it requires no compaction, was listed as an advantage by ten respondents. Only one then went on to further analyse this advantage and relate it to the health and safety benefits of placing concrete without vibration. Reduced labour requirements were listed by five respondents as an advantage of using SCC but there were no respondents who applied this advantage, or any other, to savings in terms of cost. Three respondents listed reduced construction time as an advantage, and then went further to say that with these time savings, labour could be used more effectively or efficiently.

Application of SCC in South Africa

The areas in which SCC found application in South Africa were mainly high rise buildings and bridges, where most respondents used SCC for the technical advantages that it offers **(Figure 2)**.

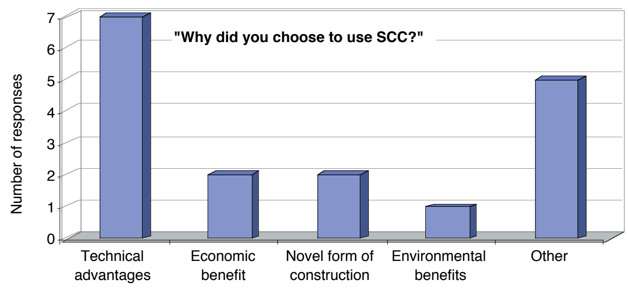

Figure 2: Market review – Reasons for using SCC

Five respondents used SCC for other reasons which are listed below:

- Trial run for future use in precast yard
- SCC used to cast a slab which was very close to the soffit of another slab. The proximity of the slab to an existing one made external compaction impossible.
- Column construction, where the limited access made compaction of traditional concrete impossible.
- SCC used for precast parapet wall infill and poured into the small gap in the parapet wall.
- SCC used to create bridge superstructure elements in the vicinity of moving trains. SCC construction techniques simplified the construction works and made the use of concrete in a restricted access site simpler.

The volumes of SCC used were generally low, where most respondents reported using up to 10 m3 of self-compacting concrete for their applications. The most used form of SCC production was Readymix. Of the benefits listed by those who had used self-compacting concrete in practice, the fact that it saved them or their company time was listed most often **(Figure 3)**.

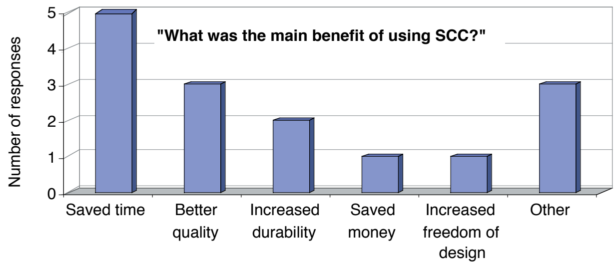

Figure 3: Market review – Main benefits resulting from the use of SCC

The advantage that self-compacting concrete gives better quality was the second most highlighted benefit that users perceived they gained by using SCC. Other reasons or benefits that users felt were that the use of self-compacting concrete gave them peace of mind and that the use of SCC benefited the customer. The advantages of increased quality and durability were not listed as often as expected, leading to the conclusion that education is needed to create awareness about these important issues.

Of those that had used SCC, all indicated that they would use it again. Of the nine who had never used SCC in practice, eight were interested in learning more about the product. There was the general feeling that SCC could be used in their field.

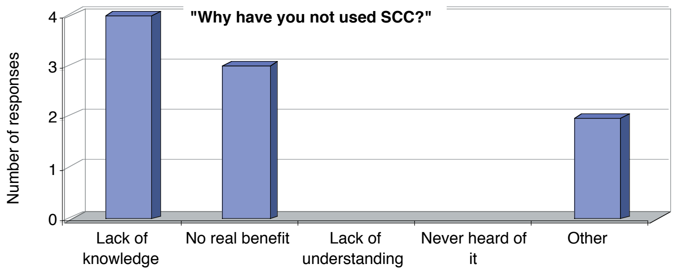

Figure 4: Market review – Main reasons for not having used SCC

Lack of knowledge was listed as the primary reason for not using SCC **(Figure 4)**, indicating that the development of a practical set of guidelines would facilitate the use of SCC in South Africa **(Figure 5)**.

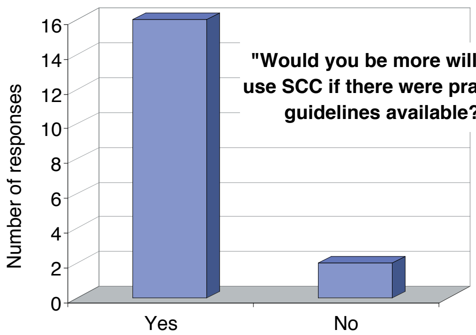

Figure 5: Market review – Potential interest of the industry to apply SCC

Most respondents were interested in learning more about SCC, and most felt that industry or professional bodies, such as the Cement and Concrete Institute, the Concrete Society of Southern Africa, or the South African Institution of Civil Engineering should be responsible for the development of such recommendations.

Materials used

According to the answers received in the questionnaire, most SCC used in South Africa is made using a coarse aggregate size of between 9 mm and 19 mm. There seems to be a preference for this size stone in SCC use, probably due to the fact that a smaller sized aggregate provides the best results for self-compacting concrete in terms of workability characteristics.

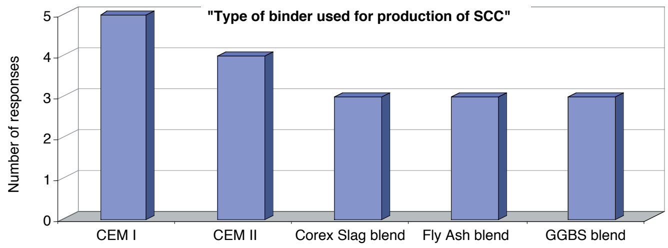

Figure 6: Market review – Type of binder used in the production of SCC in South Africa

As can be seen from **Figure 6**, Corex slag, fly ash and ground granulated blastfurnace slag have all been used in equal measure as extenders by the respondents. Admixtures used included common commercial superplasticisers and, in one reported case, a viscosity modifying agent.

Conclusions drawn from a more specific market review

As the market review process progressed it became apparent that various individuals within the concrete industry played a large role in SCC in South Africa. A second, more advanced questionnaire was therefore developed to aid in eliciting more information from those who have been instrumental in the introduction of SCC in the country, to determine whether those who had intimate knowledge of SCC felt that its benefits and advantages were applicable to South Africa. The most notable points that were highlighted by those interviewed surrounded the mindset of those in industry, the role of those involved in education and marketing, and whether there exists a viable market for self-compacting concrete in South Africa.

It was believed by most of the selected interviewees that the mindset of potential users of SCC needs to change. The mindset that presently exists is one of conservatism, traditionalism and habit. Potential users are unwilling to adopt the use of SCC in their operations simply because it is an unknown technology and the potential benefits are either not well known or not well understood. It was noted in the first questionnaire that many potential or existing users of SCC were unaware of the benefits of the product that relate to increased durability and quality. This was again highlighted in the second questionnaire, where most interviewees felt that these two benefits, while being the most important, were the least understood. Clients and specifiers of concrete and concrete products were also thought to be accustomed to a certain way of thinking that will require a determined education and marketing campaign to change.

Other reasons for the market being unwilling to accept the new technology were the higher cost of SCC, the lack of marketing and education strategies, and the belief that SCC is at the moment still a specialist concrete in South Africa. Although most interviewees felt that in South Africa there is a viable market for SCC, which has the potential to expand, the afore-mentioned issues need to be addressed. The fact that South Africa in general is seen to lag behind more advanced markets by at least five years was also seen as a reason why the use of SCC is not more widespread. It was generally believed that the use of SCC will reach the same levels as other markets such as Japan and Europe, but that this will take up to ten years.

All of the interviewees believed that education and marketing should be the main method of overcoming the various disadvantages and problems that presently surround the production and use of self-compacting concrete in South Africa. Where the interviewees differed was in their belief as to who should be responsible for such an education and marketing campaign. The authors took the view that a combined approach, involving academics, researchers, concrete producers and their suppliers, as well as official industry bodies, such as the Cement and Concrete Institute, will be the most effective in changing mindsets and educating the market.

Are the main advantages of SCC applicable to the South African market?

Most of the advantages of SCC relate directly to economic benefits (faster construction, reduction in manpower, easier placing, less repair work and improved durability), while others relate to aesthetics and ease of use. Based on the market review discussed above, the main advantages offered by SCC technology are analysed in view of their applicability for the South African construction industry.

Reduction in manpower

The labour-saving advantages associated with self-compacting concrete are a contentious issue in South Africa. The construction industry in South Africa is intentionally labour-intensive, and the government is seeking to address the current unemployment crisis by utilising the resources of the construction sector and thus supporting the use of “labour friendly” technologies. These goals are contrary to the benefits that SCC can offer and political imperatives play an important role in the current lack of acceptance of this technology.

Automation of casting processes

SCC can be pumped over longer distances and at a faster speed than conventional concrete. All major Readymix suppliers in South Africa have truck-mounted pumping equipment, but despite this, pumping is not a readily accepted form of placing concrete in South Africa. It is therefore debatable whether the advantage of self-compacting concrete in terms of automation and pumping is currently applicable to the South African market. However, with increasing construction volumes and time constraints, pumping is expected to become a more commonly used procedure for concrete placement.

Concrete durability

In South Africa, durability of concrete structures, especially on the coast, is of particular importance. As a result, durability specifications in the design process of such structures have developed to be the norm rather than the exception. The benefit of increased durability of self-compacting concrete should provide some impetus for acceptance by both developers and designers. Higher durability of SCC is generally linked to high workability and high fines contents, as well as elimination of construction errors during compaction.

Reinforcement congestion and thin sections

SCC allows for the design of thin sections and sections with congested reinforcement, which traditionally would be difficult to compact effectively. There are few applications with high reinforcement congestion requiring the use of SCC in South Africa, which somewhat eliminates this advantage. However, the use of SCC is often also of benefit in situations where the configuration of formwork or the production process makes access to the fresh concrete difficult for vibrators. Inclined formwork, beam and deck repairs and high casting heights often preclude the use of mechanical vibrators, leading to the use of SCC to solve such problems. Some contractors in South Africa have used SCC for this reason.

Architectural concrete

New developments in architectural concrete have been facilitated by the advent of SCC, enabling the design and construction of concrete facades and cladding. In South Africa there is potentially a large market for architectural concrete members. However, at present South African architects and precast concrete product producers are either mostly unaware of SCC or have yet to exploit it. The Cement and Concrete Institute of South Africa has recently significantly increased its efforts in promoting architectural concrete, thus opening new opportunities for the use of SCC.

Working environment

Traditionally, health and safety measures in many precast yards and on construction sites in South Africa have fallen short of international standards and are still not receiving sufficient attention. However, in recent years this has gradually changed and increasing awareness of safety regulations will probably promote the use of SCC in future.

Concluding remarks

Successful implementation of SCC in the South African construction industry is currently retarded by a number of factors relating to general disadvantages or challenges concerning the manufacture and use of SCC.

The South African market will require a considerable amount of education and time before the use of SCC substantially increases and it can be confidently used. Many of the difficulties associated with SCC are directly related to inadequate knowledge of the product, but these are expected to be gradually overcome by education and marketing, or by Readymix companies assuming a greater role in concrete supply. Other factors will also play a role in the acceptance of SCC, such as special formwork requirements for using SCC on site, as well as more sophisticated moisture and water control equipment needed during the manufacturing process. Precast plants may also have to investigate in how far they need to invest in plant upgrades to distribute SCC efficiently to the moulds.

Conditions on construction sites in South Africa are not ideal for the production of SCC but there are a number of relatively high-tech Readymix plants that are in a position to produce SCC. Notwithstanding the favourable economic and marketing conditions that exist for the production and provision of SCC to a wide range of clients, little use has been made of this technology so far. Very recent developments (subsequent to this study), however, show that Readymix producers are now starting to market this new technology. Economic factors will play a role in the success of SCC implementation, whereby Readymix plants in South Africa are already operating at full capacity, and local cement production is unable to supply the demand.

Precast operators, who are in full control of the process, are in the best position to reap the benefits of self-compacting concrete. The situation in South Africa currently shows that there are few, if any, precast operations making use of self-compacting concrete. Most precasters felt that changes to their production processes were not necessary, and that the advantages of SCC were outweighed by the disadvantages.

Despite the above challenges, industry demands resulting from the current construction boom and increasingly stringent regulations for concrete quality can in future be expected to shift the industry towards more sophisticated production methods for prestigious projects. This, in connection with ongoing education efforts may result in the situation where the advantages of SCC will be applied more frequently to improve construction procedures and concrete quality in South Africa. The market review revealed that one of the main reasons why SCC has not been used more extensively in South Africa is the absence of a local set of guidelines for the production and application of SCC. Therefore, if the industry is to make use of the numerous advantages of this technology, a set of relevant guidelines needs to be developed.

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The Development of a Probabilistic Service Life Design Model for Typical South African Concretes and Environmental Conditions

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Abstract

Although the design of concrete structures traditionally focuses on their structural stability, the durability of these structures plays an essential role in their economy, and impacts on the viability of the concrete industry.

This trend is recognised internationally. The International Federation of Structural Concrete (fib), is currently developing a model code for service life design (MC-SLD). The intention of the MC-SLD is to prepare a framework for standardization of performance-based design approaches to durability.

In the context of the fib MC-SLD, Holcim South Africa is in the process of developing a design tool based on a probabilistic approach to durability. This design tool will provide the engineer with guidance to enable competent decisions, based on job specific materials and environment, to assist with durability design.

The models and algorithms need verification and calibration. This is done in relation to Holcim materials and the main environmental and climatic exposures in South Africa.

This paper outlines the experimental programme, describes laboratory and field trials, and reports on the progress achieved so far in the verification of results.

Introduction

A lack of durability design

In South Africa, most structural design engineers aim to achieve an economical design by optimising the resistance of the combined materials to load. The load depends on the function of the structure but is generally attributed to the weight of the structure and any objects it needs to support, dynamic loading due to traffic or machinery and wind load. The probability of failure under load is meticulously calculated in accordance with the National Code of Practice[1] to ensure a probability of reaching the limit state of failure of one in a million that are considered acceptable to ensure public safety.

However in the long term these structures are not necessarily economical. The maintenance and repair of non-durable concrete structures becomes a large financial burden to their owners, as the cost of repair may by far exceed the cost of the original construction. This constrains funds available for new construction and expansion of infrastructure. The public sector in South Africa is particularly at risk and in the long term deteriorating infrastructure could inhibit economical growth.

The current clause in the National Code of Practice[2] allows for durability by empirical rules that define vague exposure conditions, minimum cover and maximum water: cement ratio's. There is no logical means for the designer to quantify the probability of failure based on a defined environmental exposure and to quantify the economical viability of the design over the service-life of the structure. Durability failure is not defined in terms of an acceptable service or limit state. Therefore no logical attempt can be made to define the owner's risk with current practices.

Local Developments With Regards To Ensuring Durability Of Concrete Structures

Owners of infrastructure are aware of their increasing financial risk, and in the last few years performance-based specifications for durability have become mandatory for most infrastructure projects.

The development of durability index testing

The development of performance-based specifications for durability was pioneered in South Africa by a combined research effort between The University of Cape Town and the University of the Witwatersrand.[3]. Their philosophy was that unless some relevant durability parameters can be unambiguously measured on site concrete, durability will not be achieved. Their belief was that durability is a property the client needs to pay for, just like strength, it should be engineered, appropriately specified, measured and paid for.

Three accelerated tests, the oxygen permeability, water sorptivity and chloride conductivity, were developed that respectively measured the transport mechanism of gas, fluid and chloride ions into concrete[3]. The philosophy was that these tests could be used as an index to quantify the

susceptibility to attack of the covercrete of site concrete. The results of these tests could be used as a basis of fair payment for achieving durability.
An analogy was made between the durability index tests and the compressive strength cube test. Although the cube does not resemble the concrete in the structure, experience has permitted the correlation between the results of the compression strength test and structural performance so that structure may be designed for different levels of stress. Correlation with actual structural concrete performance is therefore the foundation of the durability index test philosophy.

Mackecnhie[4] did correlate 28-day index testing on grade 20, 40 and 60 MPa concrete made with Ordinary Portland Cement (OPC), 70% OPC & 30% fly ash and, 50% OPC & 50% slag. In this experiment concrete specimens were exposed to the tidal and spray zones of Simonstown harbour and Granger Bay. Control samples were kept at the University of Cape Town laboratory. Concrete resistivity, ultrasonic pulse velocity (UPV) and chloride ingress by means of chemical analysis of powder samples at different time periods were measured. In addition sixteen grade 40 MPa concrete panels were attached to marine structures in the spray zone.

In conclusion to this study Mackechnie reported:

1. A good correlation, (correlation coefficient of 0,94) between the 28-day oxygen permeability index and the carbonation depths measured at the University of Cape Town exposure site. The carbonation depths of the concrete exposed to the tidal and splash zones were not significant because of the high moisture content of the concrete preventing carbon dioxide ingress.

2. The correlation between the chloride conductivity and the two year diffusion coefficient determined from the chloride profile (measured from the powdered samples) was poor, (correlation coefficient 0.33 to 0.6). An adjustment factor to the chloride conductivity was therefore derived by multiplying the 28-day chloride conductivity values with the chloride conductivity from wet cured concrete, to account for the long-term effects of chloride binding and cement hydration. The correlation between the two-year diffusion coefficient and the modified chloride conductivity improved with correlation coefficients between 0,75 and 0,83 and it was considered as adequate for predicting the chloride resistance of the material.

3. The rate of chloride ingress into the concrete was dependent on the severity of exposure to the marine environment and the materials properties.

As part of the above study, Mackechnie formulated a prediction model for chloride ingress for concrete in the Western Cape marine environment, considering surface concentration, two year diffusion coefficient (that was derived from the modified chloride conductivity) and severity of exposure. The model was limited to cementitious materials Ordinary Portland Cement, 30% Fly ash & 70% OPC and 50% slag & 50% OPC.

The civil engineering department of the University of Cape Town published a Microsoft Excel spreadsheet based on the above work[5] that calculated the projected durability index parameters based on grade of concrete, cementitious type, curing regimes and site control. These projected durability indexes could be entered into another worksheet that calculated the chloride and carbonation profile with time based on different exposure conditions. This was a first attempt to predict the deterioration rate of concrete based on the durability index tests. However it was based on Western Cape exposure conditions and only valid for limited constituent materials. The reliability of the prediction was also not addressed.

The Implementation Of Performance-based Specifications Based On Durability Index Testing

In 1999 durability seminars hosted by the Concrete Society were held in the major centres of South Africa where the foregoing philosophy and work were presented. A matrix of durability index parameters (Table1) was developed and presented that was based on controlled laboratory studies and site data that could be used to produce a set of acceptance criteria and rejection criteria for performance based specifications[3].

Client bodies realised the importance of performance-based specifications to protect their assets and soon ambiguous durability index criteria were incorporated into project specifications based on the excellent category in Table 1.

Durability class	OPI log scale	Sorptivity (mm/√h)	Conductivity (mS/cm)
Excellent	>10	<6	<0,75
Good	9,5 - 10	6-10	0,75 – 1,5
Poor	9,0 – 9,5	10 - 15	1,5 – 2,5
Very Poor	<9,0	>15	>2,5

Table 1:
Suggested ranges for durability classification using index values[3]

The recommended limits and specifications did not allow for different exposure conditions and cover and were therefore no better than the current national standard approach of maximum water:cement ratio. The engineer was still unable to quantify the probability of failure, and what is the implication of non-compliance in terms of service life in a rational and logic manner. The mechanisms of attack were not defined in the table and these limiting values were applied in cases where the use of the performance-based specifications was not appropriate, for example in sulphate and soft water conditions. Apart from the above, concern was raised regarding the repeatability and reproducibility of the test methods.

As a consequence more work into the durability index testing was initiated, focusing on the repeatability and reproducibility of the test methods, and defining proper exposure conditions. Consequently Grieve proposed a new set of guidelines for specifying Durability Index Limits based on the work of Alexander and Standish.[6] The principle was based on a 'deemed to satisfy' approach and the chloride ingress and carbonation model[5] largely developed based on the work of Mackechnie[4] was used to derive the recommended durability index limits based on a 50-year service life, 30mm and 50mm nominal cover for carbonation and marine conditions respectively. The cementitious types considered are CEM I 42,5 ,70% CEM I & 30% fly ash blend, 50% CEM I & 50% slag blend and 90% CEM I & 10% silica fume blend.

Although this is considered as a leap in the right direction the design is still not transparent. Engineers are still unable to define the risk to their clients, and to establish the consequence of not complying with the specification, which is essential in establishing fair payment. The problems are:

1. The serviceability and limits states of the service life design have not been defined. What will happen in 50-years, will the structure have to be repaired or will corrosion initiate.
2. The reliability of the service life prediction model used to derive the deemed-to satisfy criteria has not been defined. Therefore the clients are still in the dark on what is the probability of having a 50-year service life should the specification be met, and what is the reduction in reliability should the specification not be met.
3. The 'deemed to satisfy' approaches only refer to a limited number of cementitious binder combinations, which are not necessarily applicable for the cement types available in the area of construction. (The availability of different cementitious materials in South Africa are governed by geographical area).
4. The service life prediction model has not been calibrated for the vast number of environmental conditions occurring in South Africa. (Hot and dry conditions in the centre of the country, hot and humid conditions on the east coast and hot and dry conditions on the west coast).

Latest International Developments On Service Life Design

Outline of the fib model code for service life design

The focus in this paper will be on the recent work of the International Federation of Structural Concrete (fib) Task group 5.6. The objective of the task group was to identify agreed durability related models and to prepare a framework for standardization of performance-based design approaches. A model code for service life design (MC-SLD) is currently under development.

Outlined is the principles and philosophy of the MC-SLD as was presented by Schiessl et al at the 2005 fib symposium.[7]

A framework for standardization

The design principles of the MC-SLD are:

1. When designing for durability, the design service life should be defined and the definition given in the MC-SLD is: The design service life is the assumed period for which a structure or part of it is to be used for its intended purpose with anticipated maintenance but without major repair necessary.

The design service life is defined by:
- A definition of the relevant limit state
- A number of years
- A level of reliability for not passing the limit state during this period.

2. Durability of the structure in its environment shall be such that it remains fit for use during its design service life. This requirement can be considered in one of the following ways:

- By designing protective and mitigating systems.
- By using materials that, if well maintained, will not degenerate during the design service life.
- By giving such dimensions that deterioration during the design service life is compensated.
- By choosing shorter lifetime for structural elements, which may be replace one or more times during the design life.

All of the above approaches are possible in combination with appropriate inspection at fixed condition dependant intervals and appropriate maintenance facilities.

The flow chart in Figure 1 illustrates the flow of decisions and the design activities needed in a rational service life design process with a chosen level of reliability. The design criteria may follow one of four approaches, with different levels of sophistication, that have been verified as described.

- Full probabilistic design

In verifying service life in a full probabilistic mode, the following principles shall be followed.

The probabilistic models shall be applied that are sufficiently validated to give realistic and representative results
The parameters of the models applied and their associated uncertainty shall be quantifiable by means of tests, observations and/or experience
Reproducibility and relevant test methods shall be available to assess the action and material parameters
Uncertainties associated with models and test methods shall be considered

- Partial factor design (semi probabilistic approach)

When using the partial factor method it shall be verified that the target reliability for not passing the relevant limit state during the design life is not exceeded when design values for actions or effects and resistance are used in the design models

- Deem to satisfy rules

The deemed to satisfy is a set of rules for dimensioning, materials and product selection and execution procedures. In the MC-SLD the deemed-to satisfy design has to ensure that the target reliability of not passing the relevant limit state during the design life is not exceeded when the concrete structure or component is exposed to the design environment. The specific requirements for design, material selection and execution for the deem-to satisfy design shall be determined in either of two ways:

On the basis of statistical evaluation of experimental data and field observations according to the requirements of the of the clause full probabilistic method
On the basis of calibration to a long term experience of building tradition

The limitations to the validity of the provisions for example range of cement types covered by the calibration and national climatic conditions shall be clearly stated.

- Avoidance of deterioration

This design is the most robust solution. It represents the simple example of using stainless steel reinforcement to avoid reinforcement corrosion.

The project specification is drafted after the design process and forms part of the maintenance plan, quality plan for execution, inspection and monitoring.

The fib is working towards a full revision of the CEB/FIP Model code 90[8], where service life design based on the MC-SLD will be included. The CEB/FIB Model code 90 was the basis of the Eurocode 2[9].

Deterioration models in the MC-SLD

The following deterioration mechanisms, for which broadly accepted models exist, are treated in the MC-SLD:

- Carbonation induced corrosion
- Chloride induced corrosion
- Freeze-thaw attack with de-icing salts
- Freeze thaw attack without de-icing salts

Sulphate resistance, alkali-silica reaction and softwater attack are not covered mainly due to fact that accepted predictive models do not exist yet. It was therefore recommended that for these mechanisms of attack, traditional approaches and prescriptive specifications should be applied.

Holcim experimental program

Holcim South Africa is one of the major suppliers of cement, aggregate and ready mixed concrete in South Africa with three cement factories, one ground granulated blastfurnace slag factory, one silica fume production facility, 13 quarries and 27 ready-mix concrete plants. Holcim uses various mineral components to produce cement such as fly ash, ground granulated blastfurnace slag, limestone and silica fume(upon request). At the quarries various types of rock are mined to produce aggregate, dolomites, quartzites, andesites, granites and tillites, to just name a few. The composition of the ready mix concrete depends on the aggregate and cement available in the area, and therefore hardened and time dependent properties varies depending on the constituent materials and the environment the concrete is exposed to. Concrete and concrete materials are supplied across the country to areas with contrasting environmental conditions. The work conducted on concrete durability in South Africa, as described above, is not necessarily representative of the concrete Holcim supplies.

As part of the Holcim initiative to provide information to specifiers and structural designers regarding the performance of their products, an experimental program was launched in order to quantify the strength gain, shrinkage and durability of concrete containing Holcim materials. The intention is to use the data to calibrate existing accepted predictive models, both locally and internationally developed, and to define the reliability of the prediction.

The program consists of field and laboratory trials. The field trials focus on the performance of concrete containing different percentages and types of mineral components exposed to different environmental conditions. The environmental exposure conditions range from a hot and dry environment in the Northern Cape to a hot and humid environment along the Eastern coast. Various coastal environments are included from Cape Town to Durban. In the centre of the country environmental conditions range from hot and dry conditions, to moderate conditions and various industrial environments are included. Carbonation and chloride ingress will be monitored with time.

The laboratory program consists of defining the durability of the concrete by means of various accelerated tests, including the durability index tests. The type and percentage of mineral components, cement clinkers, concrete admixtures and aggregate types and grading are varied to assess the effect of each of these variables on the durability parameters.

The results of this experimental program will be incorporated in a design tool that may assist the design engineer the service life in association with its reliability.in relation to a defined limit state.

The experimental program is currently ongoing.

Conclusion

The financial implications of repair of concrete infrastructure justify that a service life design approach should be included into the National Code of Practice. However the current South African approach to durability needs extensive calibration to define the reliability of the prediction before any rational recommendations for a design code can be made.

The international approach driven by the fib is focused on a reliability-based concrete durability design and provides a logic framework for the standardization of service life design internationally.

Holcim South Africa is committed to contribute knowledge to establish best practices for South African service life design with its ongoing characterisation and research into the materials they supply.

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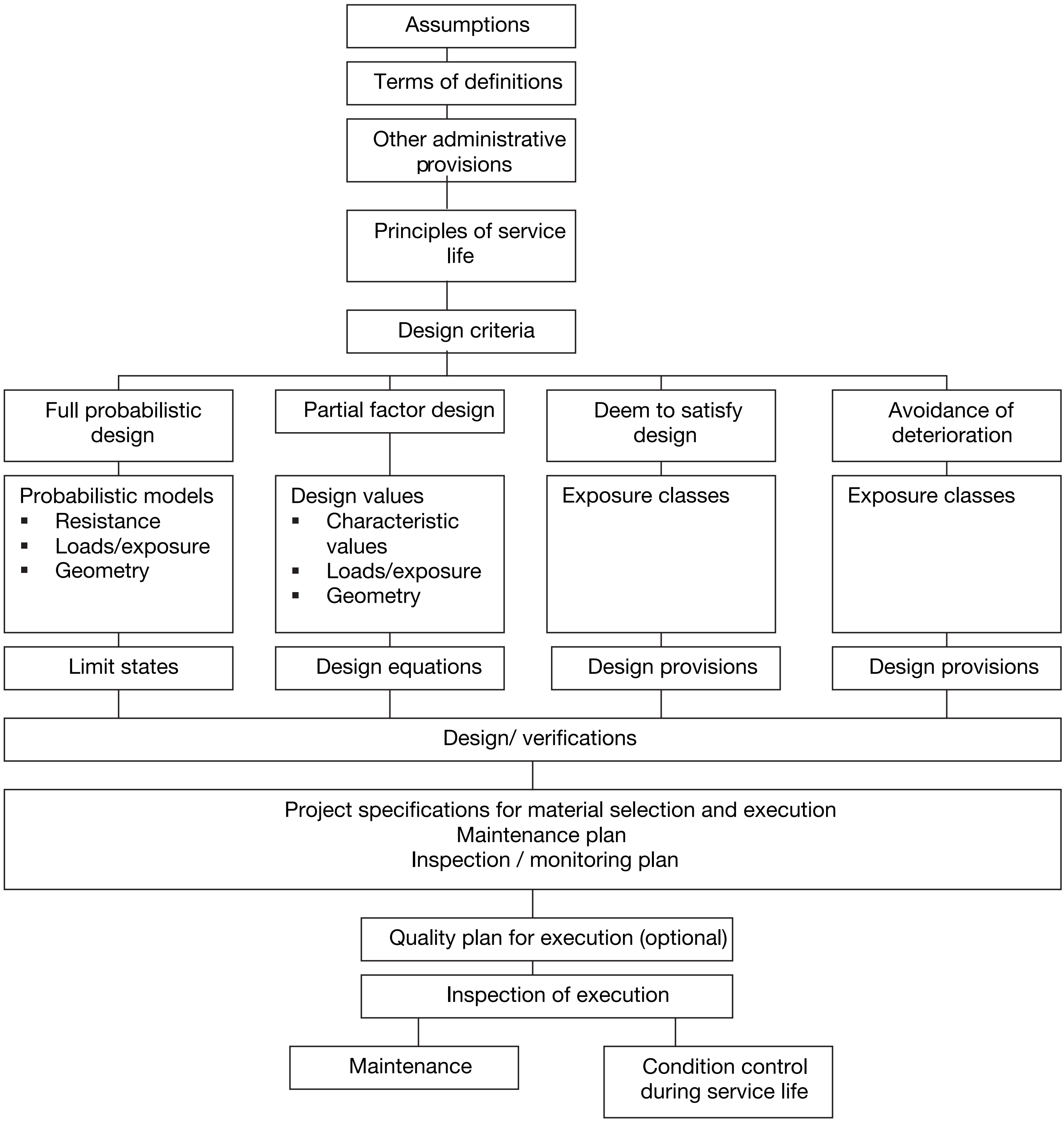
Figure 1: Flow chart of the MC-SLD [8]



Cracking of Concrete in the Plastic State

Introduction

Two common types of plastic cracking are plastic shrinkage cracking and plastic settlement cracking. Both types of cracking are related to bleeding of the plastic concrete, but in different ways. This TIP covers the causes of plastic cracking, prevention of cracking and remedial measures.

Plastic shrinkage cracking

Concrete, or more correctly cement-water paste, shrinks as it dries out. This is because the very fine pores present in the paste contract as water is lost from the paste and expand again if water is re-gained at a later stage. If shrinkage occurs while the concrete is still workable and plastic it is called plastic shrinkage. This type of shrinkage is usually restrained by reinforcement, formwork and internal friction, and cracking results. The typical crack pattern is one of random, non-continuous cracks, often parallel to each other. Cracks usually form within an hour of finishing the surface of the concrete.

Typical plastic shrinkage cracking on a suspended slab

This type of cracking is often associated with concrete slabs, but it can occur on strip footings and any other concrete where the top surface is exposed to rapid drying conditions.

Causes of plastic shrinkage cracking

Plastic shrinkage cracking occurs on concrete surfaces exposed to high surface temperatures, and/or strong wind, and/or low humidity. Any environmental factor which increases the rate of evaporation of bleed water from the surface of the concrete increases the probability of cracking. In essence cracking is likely if the evaporation rate exceeds the bleeding rate.
Concrete mix design also influences the probability of cracking. Mixes designed to be cohesive with low bleeding capacity are particularly prone to cracking if the environmental conditions are conducive. For example, cracking of pump mixes is particularly prevalent in the Western Cape in summer, as is cracking of some mixes containing very finely ground cements or extenders.
Retardation of set, from whatever cause, also increases the probability of cracking.

Preventive measures

The following preventive measures will help to reduce the occurrence of cracking:

- Pouring the concrete during a cooler part of the day
- Protecting the surface of the concrete from wind and sun with shadecloth and wind breaks
- Liberally applying a good quality curing compound immediately the surface is finished
- Protecting the surface with damp sand, hessian or plastic sheet immediately the surface is finished
- Using fog sprays to keep the surface of the concrete damp
- Delaying the finishing of the surface in order to close up any cracks that may have occurred

Remedial measures

Generally speaking this type of cracking is not serious from a structural point of view but the durability of the concrete can be affected if the cracks penetrate through the slab and the steel is exposed in a potentially corrosive environment. Remedial measures are normally restricted to filling the cracks with cementitious slurry or, in some cases, with a low viscosity epoxy resin.

Plastic settlement cracking

After concrete has been compacted, but before it sets, the solid phase of the mix tends to settle and displace water upwards. This is known as bleeding. The amount of bleeding is a function of the cohesiveness or “stickiness” of the mix. The use of single sized sands, such as dune sands, can cause severe bleeding. The results of severe bleeding include bleed channels in the paste, voids under reinforcement and coarse aggregate particles, sand streaking of off-shutter surfaces and settlement cracks.
Settlement cracks occur when the settlement of the concrete is restrained, either by the formwork, or the reinforcement or, sometimes, void formers. The picture on the following page is typical of plastic settlement cracking in a column where the settlement had been restrained by the stirrups.
When the cracks are caused by restraint by reinforcement, the crack pattern invariably follows the underlying steel and the cracks extend to the steel. In addition the concrete settles away from the steel which impairs bond. This is obviously undesirable, especially in severe environmental exposure conditions.

Plastic settlement cracking in a column

Preventive measures

Preventive measures include redesigning the concrete mix to increase cohesion and the use of revibration of the concrete.

Cohesion can be increased by blending in a finer sand, or a sand containing more fines, or by using an air-entraining agent, or by using a finely divided extender.
Alternatively it is often possible to revibrate the concrete before it sets in order to close up any cracks.

Remedial measures

In cases where potential loss of durability is important, remedial measures consist of crack injection with low viscosity epoxy resins.

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Early Age Thermal Contraction Cracking of Concrete

Introduction

Cracking due to early age thermal contraction can occur in large concrete sections (where the smallest dimension is of the order of 0,5 m or larger) and the binder content is high enough to generate a significant amount of heat during hydration. There are other contributing factors as well and this Tip discusses the phenomenon. For a detailed description the reader is referred to Concrete Society Technical Report No 22 - Non-structural cracks in concrete, pp24 – 27.

Heat of hydration

Cement hydration reactions are exothermic and heat is therefore generated during hydration. The hydration reactions of fly ash, ground granulated slag and silica fume are also exothermic to a greater or lesser degree. The critical factor is the rate of heat generation in the first 24 to 30 hours after placing. During this period the rate of heat generation exceeds that of heat lost to the environment and the temperature of the concrete rises. As a rough rule of thumb one can expect a temperature increase of 10 to 12 degrees centigrade per 100 kg of binder in the mix with the peak temperature being reached between 24 and 48 hours after placing. The timing and magnitude of the peak temperature depends on the binder characteristics and the section thickness. Typical heat of hydration figures for CEM I 42,5N from Riebeeck West, a 70/30 blend of the same cement with fly ash and a 50/50 blend with Corex slag are given in PPC TIP 4.

It is undesirable for the core temperature of the concrete to exceed 60 degrees centigrade or the temperature differential between the interior and exterior of the concrete to exceed 20 to 25 degrees centigrade.

Section size and geometry

The minimum section dimension determines the rate of heat loss of the concrete to the surrounding environment. Generally speaking heat of hydration only starts to become a problem once the minimum dimension exceeds 0,5 m. Once the least dimension exceeds about 2 metres the interior of the concrete will not get any hotter, but the section will take longer to cool down.

Initial concrete temperature

The initial concrete temperature affects the rate of heat generation at early ages, but not the amount of heat generated and the ultimate rise in temperature. The main benefit of cooling the plastic concrete, for example with ice or liquid nitrogen, is to depress the peak temperature and hence reduce the temperature differential between the concrete and its immediate environment.

Ambient conditions

While it might be expected that high ambient temperatures increase the probability of early thermal cracking, this is not necessarily the case. Moderate daytime temperatures coupled with low night-time temperatures can be a more severe condition in practice. For example, if concrete with a binder content of 350 kg/m3 is placed during the day at 20 degrees centigrade, the core temperature could reach nearly 60 degrees after 24 hours at the time of stripping. If the night-time temperature were to fall to only 10 degrees the temperature differential could be as high as 50 degrees which would cause rapid cooling of the exposed surface of the concrete and cracking caused by thermal contraction would be highly likely.

The probability of cracking is, however, a function of the restraint on the member.

Restraint

If concrete is free to contract then cracking will not occur. In reality however there is always some internal and external restraint. Examples of external restraint are if the concrete is cast onto a previously hardened base, or between or adjacent to similar elements without the provision of a movement joint.

In this case the internal restraint is the still warm interior of the concrete, which will only cool and contract later. Differential thermal strains will cause cracking, the extent being dependent on the temperature difference and strain capacity of the concrete.

Reinforcement

Reinforcement can be used to control cracking to some degree. Using small diameter bars at close centres reduces crack widths, as does the use of the minimum allowable cover.

Common examples of early thermal contraction cracks

According to the Technical Report the most common occurrence of this type of cracking is in cantilever walls in, for example, reservoirs, retaining walls, bridge abutments and basements.

They are also common in other large pours where some member dimensions may exceed 2 metres.

In either case, if the temperature differential cannot be kept below 20°C, the preferred approach is to insulate the concrete surfaces which are exposed. This has little effect on the core temperature but keeps the surfaces warm and reduces the temperature differential. Temperatures can be monitored with thermocouples and insulation removed when appropriate.

Minimising cracking

Carefully co-ordinated planning between the designer and the contractor can reduce cracking:

Design and specification:

Restraint – size of pour, joints
Distribution steel – size, spacing, cover
Heat development - section thickness, cement type and content

Construction:

Restraint – sequence and timing of pours, additional joints
Heat development – choice of concrete materials and formwork type
Cooling – striking of formwork, curing, insulation

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Diary of Forthcoming Events

Diary 2008

20-22 February	Johannesburg, South Africa	International Concrete Conference and Exhibition (ICCX)
11-16 August	Washington DC, USA	6th International Conference on Case Histories in Geotechnical Engineering
August	Singapore	33rd Conference on Our World in Concrete & Structures
24-26 November	Cape Town, South Africa	International Conference on Concrete Repair, Rehabilitation & Retrofitting

Abrasion Resistance of Concrete Paving Blocks

Introduction

Since their introduction in South Africa in the 1960's concrete paving blocks have proven themselves, on the whole, to be hard wearing and durable, but there have been problems on occasion, the most common one being excessive surface wear.
The current standard, SANS 1058, covers three block types, five paver thicknesses and two strength grades, 25 and 35 MPa. The tests prescribed in the standard only cover dimensions and compressive strength and not abrasion resistance, and this can cause contractual problems when excessive wear occurs. SANS 1058 is currently under revision and it is likely that a test for abrasion resistance will be introduced to remedy the situation.

Abrasion resistance tests

The test method most commonly used in South Africa to date has been the "wire brush" method in which a reversible electric motor drives a circular wire brush under a standard load for a standard time. The direction of rotation of the brush is reversed periodically during the test. The depth of penetration into the surface of the block is measured and an average depth reported.

Two advantages of this method are that:
- the equipment is portable and tests can be carried out in situ on both paving blocks and conventional concrete paving, and
- Visual inspection of tested blocks gives a rapid qualitative assessment of abrasion resistance

Blocks tested with the wire brush equipment –needless to say, both failed
(A very good quality block would have a penetration depth less than 1-mm)

However the method has a number of drawbacks:
- It is difficult to measure the depth of penetration accurately, and
- The tests are time consuming

Other methods are described in ASTM methods C779 (3 types of apparatus), C1138, C944 and C418, the first three tests methods being mechanical, the last being a sand-blast test.

The method being evaluated currently for inclusion into SANS 1058 is Australian/New Zealand Standard AS/NZS 4456.9:2003 – Method 9: Determining abrasion resistance. The equipment for this test is a revolving square steel container, with four circular holes on each face, containing 600 steel ball bearings of 16-mm diameter which revolves at 60 revolutions per minute. Sixteen paving blocks (or any other type of rigid paving unit such as tiles or flags) are clamped to the faces of the container and the mass loss is measured after 3600 revolutions. The samples are also weighed after immersion in water for 24 hours and again weighed underwater. The results are used to calculate the mass loss, the density of the units, and an abrasion index. It is provisionally recommended that paving units be at least 14 days old at time of test.

The South African Concrete Manufacturers' Association has recommended a maximum average mass loss of 15 grams/unit as the acceptance criterion for the time being.

AS/NZS 4456.9 Abrasion resistance test machine, PPC Laboratory, Montague Gardens

Pictured below is a wet-cast concrete cobble tested on the above machine. This particular cobble had a mass loss of less than 6 grams, indicating excellent abrasion resistance potential. Dry-cast units of equivalent quality have also been tested.

A wet-cast cobble exhibiting excellent abrasion resistance

Conclusion

In conclusion it is recommended that specifiers and suppliers of concrete block paving (and other rigid paving units) begin to pay attention to the abrasion resistance of the paving blocks, as well as the compressive strength of the units.

This will improve the quality of the units, lead to fewer customer complaints and improve the image of concrete block paving in the marketplace.

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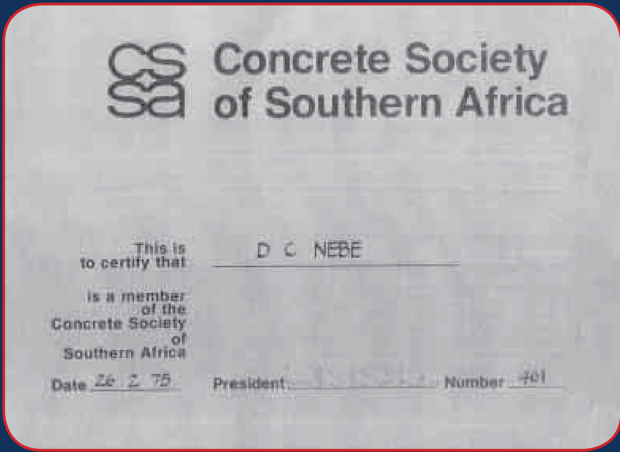
We have received substantial feedback from our long-standing members, who have supplied copies of their membership certificates.

With the Society heading for its 40th anniversary in 2009, it is always interesting to establish the history and to track the progress it has achieved over all the years.

A number of these members are still involved with the Concrete Society and we are trying to establish who is the "oldest member" – with respect!

So far Mr. DC Nebe from Paulpietersburg is the longest serving member, having joined the Concrete Society in 1975!

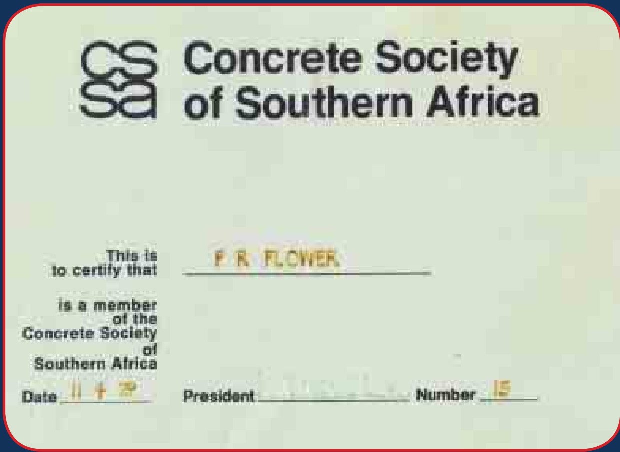


Concrete Society of Southern Africa

This is to certify that D C NEBE

is a member of the Concrete Society of Southern Africa

Date 26 2 75 President Number 401



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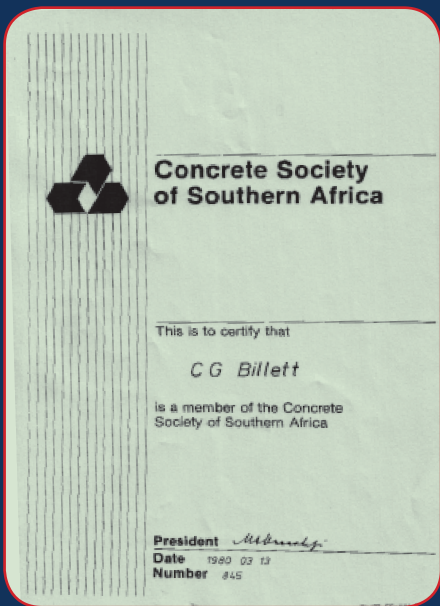
This is to certify that P R FLOWER

is a member of the Concrete Society of Southern Africa

Date 11 4 79 President Number 15



Concrete Society of Southern Africa

This is to certify that

C G Billett

is a member of the Concrete Society of Southern Africa

President

Date 1980 03 13

Number 845

Has anyone one else joined prior to that?
Please contact the office:
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Announcement

The Department of Education has again granted its accreditation to the Concrete Society of Southern Africa's journal

Concrete/Beton

Concrete/Beton, accredited under the new rules, invites academics to submit technical papers on concrete research and practice. A panel of eminent professionals will review all technical papers and on approval, the paper will be submitted for publication.

This service is free of charge and affords significant benefits for authors and their institutes:

- **Financial rewards from the Department of Education**
- **Prestige gained by peer review and industry dissemination**
- **Automatic entry for the Richard Robinson prize for the best paper published each year.**

You are invited to submit material for publishing

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