Concrete Beton

The Official Journal of
The Concrete Society of Southern Africa

TECHNICAL PAPER
- Fibre Reinforcement – Steel versus Macro (Structural) Synthetic

CONCRETE CHATTER
- KZN Branch – Concrete Achiever Award 2006
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LAUNCH OF SELF COMPACTING CONCRETE

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Contents

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CONCRETE SOCIETY OF SOUTHERN AFRICA

President: D.C. Miles

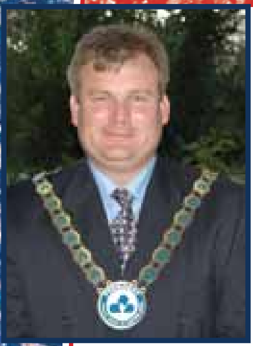
Vision

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



The Fulton Awards 2007, held over a weekend at Champagne Sports Resort, was a resounding success. We can proudly reflect on what was generally believed to have been the best Fulton Awards that we have ever had. The weekend event was attended by over 400 people partaking in more than 500 activities, like golf, bird-watching, helicopter flips, spa treatments and horse riding. It appears that everybody enjoyed the new format and many have encouraged us to follow the same format in the future. This we will gladly endeavour to do if our sponsors support us again. Some have already indicated that they want to be part of the next Fulton Awards event. We also welcome new sponsors who would want to be actively involved with the Concrete Society and especially the Fulton Awards.

It was an honour and pleasure to be able to attend the branch reviews as well. Unfortunately I do not get the opportunity to attend branch functions often and it was very pleasing to meet so many members of the Concrete Society.

I wish to extend to the winners of Fulton Awards 2007, on behalf of the Concrete Society of Southern Africa, sincere congratulations. All of you deserved the accolades that you received. You will notice that in this edition of Concrete Beton we have started a series of articles on the project winners of the Fulton Awards. We believe that this will give our members far more insight into each of the winning projects. We hope that you will enjoy these series of articles.

It is with great sadness that I must announce that our administrator, Irma Dyssel, after 13 years with the Concrete Society, has decided to pursue other interests. Irma has done extensive work for the Society and we will really miss her. Irma will be leaving us at the end of September. On behalf of Council and the members, I would like to thank her for all her hard work, dedication and loyal service to the Society and wish her well for the future.

A replacement for Irma is being sought and we will communicate these details to you as soon as they are available.

We are in the process of organizing a national seminar on 'Durability' in conjunction with the Cement and Concrete Institute. This should take place in October this year. Your respective branches will be communicating with you shortly regarding the exact details of this seminar. Considering how lively the last seminar on 'Durability' was, you would not want to miss this one!

We hope that you will enjoy this edition of Concrete Beton.

Dave Miles
President 2006/2007

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.

KZN Branch

Concrete Achiever 2006

One of the highlights of the year for the KZN CSSA branch is always the presentation of the Concrete Achiever of the year award. This year the KZN Branch Committee had no hesitation in recognising Mr Corrie Meintjes as the most worthy recipient of this award for his significant contribution towards the promotion of concrete during 2006.

Mr Corrie Meintjes, senior partner of Jeffares & Green, has been involved in the design of concrete structures for more than 30 years. In this time he has been involved in key projects such as elevated motorways, incrementally launched bridges and various other types of concrete structures.

Recently, he was involved with, and responsible for, the concept and design of the Mkomaas River Pedestrian Bridge in the Squandulweni area. This bridge was commissioned by the KwaZulu - Natal: Department of Transport. It came to their attention that children in the area were often unable to attend school due to dangerous water levels denying them access to the school on the opposite bank of the river. The construction of a bridge over the Mkomaas River would resolve this problem, as well as being of long-term benefit to the community in general.

Mr Meintjes determined that the most practical design for crossing the Mkomaas River was to construct a single span bridge. This would obviate the need for piers, thereby eliminating any structural obstruction in the watercourse, as well as any potentially dangerous construction work, which would have to take place within the river basin. This choice was justified, as from January to March 2006, during the period of construction of the bridge, high water levels in the Mkomaas River made it difficult for the contractor to cross the river, let alone construct within its basin.

Several types of bridges such as cable stay, suspension and a hybrid between these are capable of the required 150m single span. However, in recently constructed suspension structures, the local communities have expressed their concern about the movement of these structures under load. Mr Meintjes therefore looked to a more innovative design concept. His investigations lead him to investigate the prestressed concrete ribbon bridge, a practical and cost effective design in this context.

A prestressed concrete ribbon bridge consists of a ribbon of precast concrete elements that are post tensioned to induce continuity in the deck, and are designed to remain in compression under design loads. The use of precast concrete elements was also beneficial as these could be constructed concurrently with the abutments, thereby reducing the overall construction time. Precast elements have the added benefit of being cast in a casting yard and transported to the site. This would present fewer challenges for the contractor to face in the rural setting of the Mkomaas River Pedestrian Bridge.

This construction method has been successfully used in the northern hemisphere. The Mkomaas River Pedestrian Bridge is a first of its kind in South Africa and its clear span of 150m is equal to the world record for this type of pedestrian bridge (as far as could be determined, the current world record of 150m is held by a similar bridge over the ship canal in Plovdiv, Bulgaria). Mr Meintjes was therefore presented with design and construction challenges which have never previously been attempted in this country.

In catenary type structures such as stress ribbon bridges the deflections are large, therefore conventional software is unable to analyse these structures as it assumes deflections are small relative to the structures dimensions. In order to analyse the structure, independent, self-generated spreadsheets were developed in house by Jeffares & Green. Then, due to the novelty of this concept in South Africa, the Institute of Civil Engineering at the University of Stellenbosch was commissioned to do a finite element analysis of the bridge using a sophisticated computer package. This analysis confirmed the in-house results obtained. An external wind expert was also asked to assess the behaviour of the structure under various wind loadings and determined that the design was safe. Even under high wind conditions, in which people would not venture outside, the structural integrity of the bridge is not compromised.

The Mkomaas River Pedestrian Bridge is environmentally friendly in that there are no elements that interfere with the flow of the river, and the vertical curvature of the structure is aesthetically pleasing and compliments the rural landscape.

Congratulations once again to Corrie and we trust that this project will inspire the industry even further, especially with the amount of interesting and challenging work to be done before 2010. The KZN Branch looks forward to some tough decisions for this annual award in the next few years.

Eastern Cape Branch

Student Award

The Eastern Cape Branch presented a student prize to Regardt Strydom. He completed his National Diploma Building at N.M.M.U. at the end of 2006 and was top of his class in concrete and structures for which Concrete Society awarded him a cheque for R250-00 , a Fulton Concrete Technology text book and a Concrete Society membership. Regardt is currently working for MCM Property Developers.

From left to right
Regardt Strydom and Eastern Cape Chairman Louis Visser

Inland Branch

Concrete Boat Race Day

COME ALONG FOR A FUN-FILLED FAMILY DAY !!
Many boats already entered!!
Date: Saturday 15th September 2007
Time: Approx. 08h00 to 15h00
(to be confirmed nearer the day)
Venue: Victoria Lake, Germiston
Contact: Zoe Perks, e-mail: zoe.perks@holcim.com
by 31 August 2007

The Inland Branch will, once again, be hosting the celebrated Annual Concrete Boat Race Day competition. This occasion is intended to bring together members from various disciplines that consititute the Concrete Society, as well as students from the various tertiary education institutions' built environment departments.

The event serves to introduce the student to the cement and concrete industry and facilitate networking between the various interest groups in a 'fun' atmosphere. This is an ideal opportunity to offer your employees a family fun day, a reward, an inter- departmental challenge, a team-building exercise, and more.

Please note that the format will be the same as last year's. The boat must be a one-man craft which will be raced on a 4-person relay basis. Please ensure there are four people available to take part in each race. Inland branch looks forward to see you there.

Honorary Award

Honorary Membership conferred on Prof Mark Alexander

In recognition of his outstanding commitment and dedication to the Concrete Society, in particular the Western Cape Branch, and its objectives over many years, Professor Mark Alexander from the University of Cape Town has been awarded Honorary Membership of the Society.

At a special function held in Cape Town recently , the president of the Concrete Society, Mr Dave Miles, presented the Honorary Membership certificate to Professor Alexander, stating that the award was also made in appreciation of his academic career and contribution in guiding engineers as well as the greater construction industry.

Prof. Alexander, currently Deputy Dean of the Faculty of Civil Engineering at the University of Cape Town, has published widely and presented numerous papers at conferences and symposia both locally and overseas.

CONCRETE SOCIETY
OF SOUTHERN AFRICA

FULTON Awards 2007

Review of Gala Event

The Fulton Awards 2007 Gala function was held at the Champagne Sports Resort in the Drakensberg on 8-10 June 2007. Approximately 400 people attended this event and judging by all the tremendous feedback that was received, it is evident that everyone really enjoyed the weekend.

The main aim of the weekend was to give far greater exposure to the nominated projects, contractors, suppliers and our sponsors. It also provided an opportunity for guests to network in a relaxed atmosphere. The Concrete Society is proud to confirm that these objectives were achieved. Written and verbal feedback confirm that the Industry at large regards this event as the best Fulton Awards function ever.

An informal dinner on Friday evening, 8 June, started the weekend's proceedings. After a hard week and a long drive the food, entertainment and music were enjoyed by all.

The Fulton Golf Challenge took place on Saturday morning with a field of 96 golfers. Various other organised activities also took place, such as Spa Treatments, a presentation by Michelle McLean, Birds of Prey outing, helicopter flips and horse riding. For those who did not feel too energetic, the beautiful view from the Hotel, together with inviting log fires was the ideal way to relax.

The project stand competition created considerable interest, especially since the first prize was a trip for 2 people to Dubai.

The Black Tie Gala Event took place on Saturday evening and provided the perfect culmination to an exciting weekend. The Fulton Award Winners and Commendations were announced at a glittering event that had a very professional and personable Michelle McLean as MC for the evening. The Concrete Institute of Australia gave a short and informative presentation by Dr.Daksh Baweja, President of CIA and Mr. Ian Booth CEO of CIA.

After the Fulton Golf Challenge prizes were presented the party started with the great entertainment of Danny's Angels and for quite a few people, the evening lasted until the early hours in the cosy Cathkin's Bar.

The Concrete Society of Southern Africa wishes to congratulate all the project winners and those who received commendations. We wish to extend our sincere appreciation to all the Sponsors, who helped making this event possible.

Fulton Awards 2009, quo vadis?

Fulton Judge Neil Macleod with Michelle McLean

Fulton Judge Hassan Asmal with Michele McLean

Fulton Judge & CSSA President Dave Miles with Michelle McLean

Winner of the Project Stand Competition Mrs Michelle Theodosiou. She and her husband Gary Theodosiou, from C&CI, won a tip to Dubai.

Fulton Awards

Civil Engineering

Fulton Award for Civil Engineering and Commendation for Construction Techniques, Impala Platinum No16 Shaft

Commendation, Maguga Dam Regulating Weir, Power Station, Foundation & Superstructure

Building Projects

Fulton Award, Athlone Soccer Stadium East Stand

Commendation, Walter Sisulu Square of Dedication

Aesthetic Appeal

Fulton Award, Bosmansdam Road Pedestrian Bridge

Commendation, L'Ormarins Exposed Aggregate Roads

Construction Techniques

Fulton Award, Durban Harbour Services Tunnel

Commendation, Cradock to Tarka Bridge Road Rehabilitation

Design Aspects

Fulton Award, Mkomaas River Pedestrian Bridge

Commendation, Mondi Secondary Effluent Treatment Plant.

Special Recognition

Fulton Award, Spoornet Universal/ Infrabolt Concrete Sleeper Project

FULTON Awards 2007

Winner Design Aspects

Project Motivation For The Mkomaas River Pedestrian Bridge

ABSTRACT

Jeffares & Green was appointed by the KwaZulu-Natal Department of Transport to design a pedestrian bridge over the Mkomaas River in the Sisonke District Municipality.

As the client was experiencing problems with the resonant behaviour of cable supported pedestrian bridges, Jeffares & Green was asked to investigate alternatives that will render a more stable walkway for a long-span bridge such as that required over the Mkomaas River. After considering various alternatives the consultant proposed a pre-stressed concrete ribbon type structure for this site.

Typically pre-stressed concrete ribbon bridges consist of pre-cast concrete elements suspended from cables tensioned between abutments. These elements are then joined and stressed along the length of the bridge by tensioning a second set of cables placed in ducts through the elements. Compression stresses induced this way compensate for tensile stresses resulting from subsequent live loads. As far as can be ascertained, the construction method used for the Mkomaas River pedestrian bridge is a first in Africa and the length of its clear span equals the world record of 150 meters set by the Plovdiv footbridge over a ship canal in Bulgaria.

This innovative all-concrete design is cost effective, aesthetically pleasing, highly functional and environmentally friendly in so far as it does not interfere with the flow of the river in any way, neither does it have towers, stabilisers or large abutments that impose on the rural landscape.

PRELIMINARY DESIGN / CONCEPT DESIGN

In August 2004 the mayor of the Sisonke District Municipality wrote to the KwaZulu-Natal MEC of Transport requesting assistance in respect of the difficulties faced by children crossing the Mkomaas River to and from school. According to him during the wet season and when the level of the river rises, even fractionally, these children were denied access to their school, sometimes for many days at a time. Shortly thereafter Jeffares & Green was appointed by the provincial regional engineer for the design and construction monitoring of a pedestrian bridge over the river at this site. In particular, the consulting engineer was cautioned against the use of cable supported bridges, as the department of transport has experienced problems with people refusing to make use of bridges that resonate in response to live loads.

The consulting engineer nevertheless favoured the concept of a single long span bridge over the river due to environmental and construction constraints. In this case the construction of single long-span bridge will not impede the river's flow and therefore cannot be classed as an activity listed in terms of GN No. R1182 of 5 September 1997 and therefore does not require environmental authorization in terms of Section 22 of the Environmental Conservation Act, 1989 (Act No. 73 of 1989) and no delay was experienced in waiting for a record of decision from the KZN Department of Agriculture and Environmental Affairs.

Due to its large and relatively steep catchment area the Mkomaas River is known for its fast flowing waters and flash floods. And as the construction of a bridge this size would require several months it was inevitable for some of the work to take place in the rainy season. Therefore, the river's potential for flooding also influenced the choice of a single-span bridge and proved to be correct, as during the period of January until March of 2006 the level of the river was so high that the contractor had great difficulty in crossing the river, let alone construct anything in it.

The consulting engineer also considered the use of pre-cast concrete elements beneficial, as it reduced the time for construction in so far as tasks may overlap. That is, deck panels could be manufactured before the abutments were in place. The use of pre-cast panels also reduced the concrete work required on site, under difficult circumstances, and therefore a pre-stress concrete ribbon type bridge seemed like the logical choice.

This is a catenary type bridge, which found favour with some designers in Europe, Asia and North America. As yet the consulting engineer could not find evidence to suggest that this method of construction has ever been used before on the African continent, or elsewhere in the southern hemisphere. The following construction sequence is typical for this type of bridge:

- First abutments are built and anchored back to rock on either side of the river (see fig. 1 a and b).
- Main bearer cables are then placed and stressed between the two abutments (see fig. 1 c).
- Pre-cast concrete elements are manufactured and suspended from these cables and slid across the river on these cables to their respective positions along the length of the bridge (See fig. 1 d).
- These pre-cast deck elements are then joined by lapping reinforcement and placing insitu concrete in order to render the deck into a continuous ribbon running from one abutment to the other (see fig. 1 e).
- Longitudinal post-tension cables are then placed along the length of the bridge, in ducts inside the elements and tensioned in order to provide sufficient compression stresses to compensate for live load induced tensile stresses within the elements (see fig. 1 f).
- Handrails and other finishing then follow before the bridge is commissioned (see fig. 1 g).

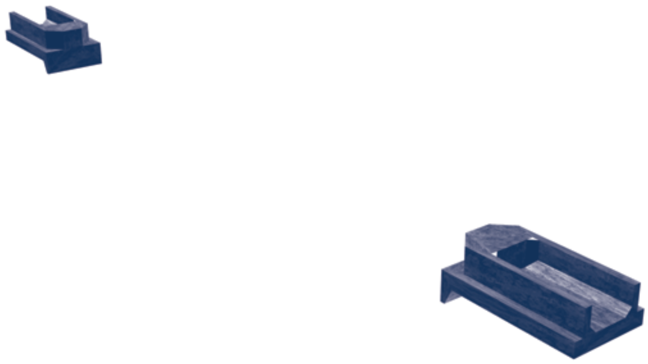
The other long-span alternative considered was a suspension bridge. This type of bridge is often used for pedestrian bridges, pipe bridges and other light structures in South Africa. On the negative side the client had experienced problems with people refusing to make use of such bridges, as they tend to resonate while pedestrians are crossing. Even the introduction of stabilisers to dampen this resonance proved only moderately successful. Their towers also tend to impose on a rural landscape and are largely steel structures, which are relatively expensive to maintain.

The stress ribbon bridge was determined to be the more viable option, in terms of meeting the design requirements, cost effectiveness and time constraints.

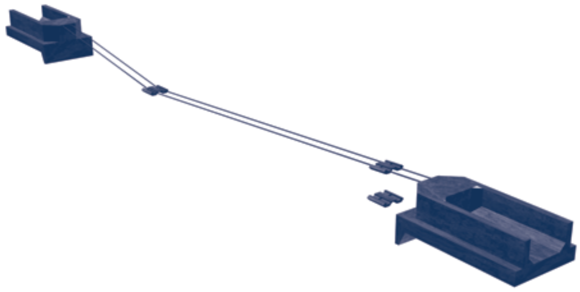
DESIGN

Geometric conditions

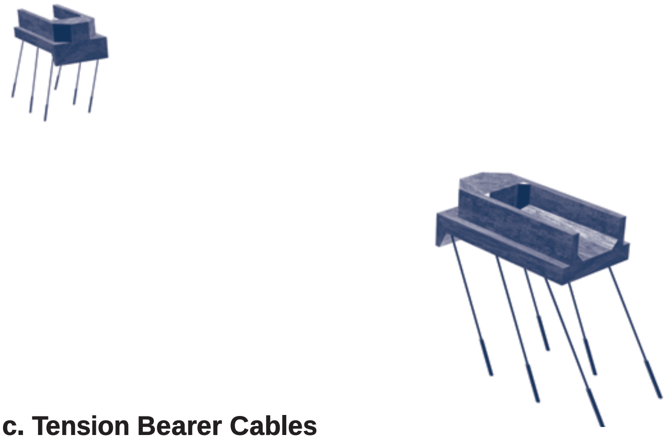
The maximum slope of the bridge was limited in the design to 1:8 as per the SABS specifications (refer SABS 0400-1990, Part D paragraph 3). Figure 2 is an exaggerated diagram of the bridge profile used in determining the geometric conditions for design.



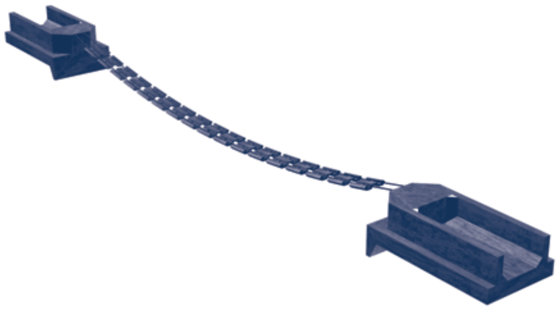
a. Cast Abutments



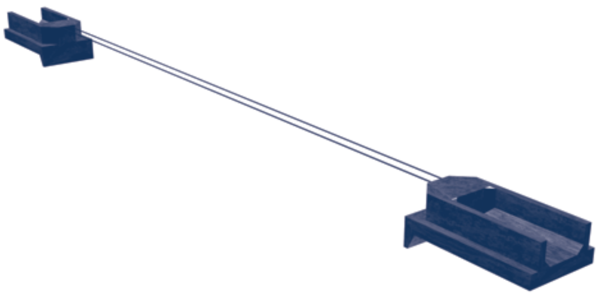
b. Add Rock Anchors



c. Tension Bearer Cables

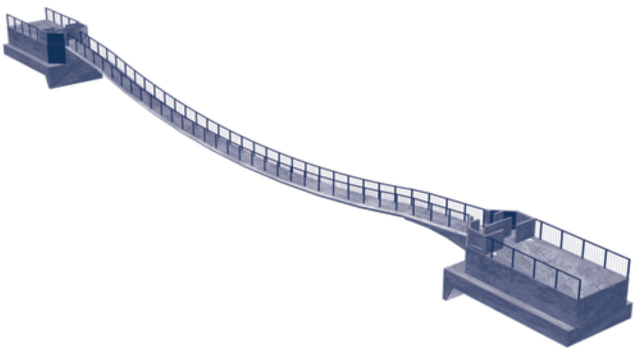


d. Add Precast Deck Elements



e. Add Insitu Concrete

f. Post-Tension



g. Final Product

Figure 1: Construction sequence of stressed ribbon bridges

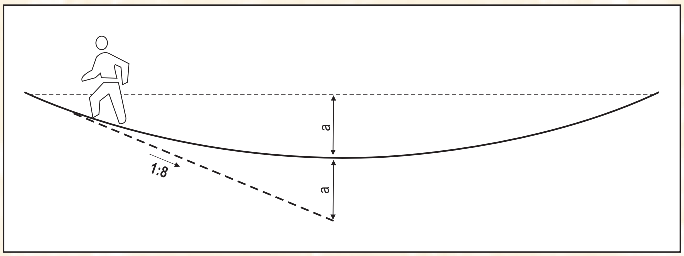


Figure 2: Geometry of stress ribbon showing apex height (a)

The cross sectional geometry of the deck is given in figure 3. Voids were provided underneath each deck panel to reduce the static load imposed on the cables.

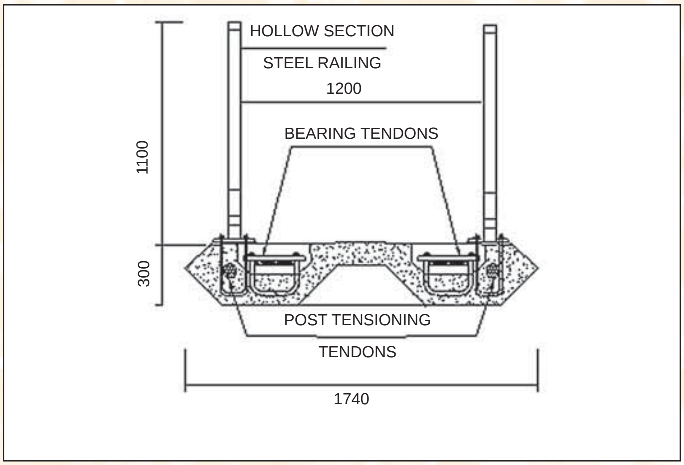


Figure 3: The deck section of the Mkomaas River Pedestrian Bridge

Analysis of stress ribbon

As conventional software packages are based on the assumption that plane sections remain plane and that deflections are small in relation to actual dimensions, these are unable to analyse catenary type structures, where deflections are large. Therefore the design was done on self-generated spreadsheets based on first principles.

The in-house analysis began by examining a catenary with an assumed nadir depth ("a", as shown in figure 2) with the ultimate goal of minimising the slope such that the bridge could accommodate pedestrians as per the SABS stipulation. Knowing the length and shape of the catenary it was possible to calculate the tensile stress in the cables, and derive from this calculation the stress in the cables with a hypothetical zero loading (straight cable). This same zero loading had to hold for subsequent loadings. Obviously the work included a fair amount of examination by trial-and-error.

It is common for tensile stresses to generate below the deck near the abutments when the post-tension force is applied to the structure. However, these stresses were reversed by the introduction of haunches at the two abutment ends and a lowering of the post-tension cable in this area.

Later on the Institute of Civil Engineering at University of Stellenbosch was commissioned to conduct finite element analysis on the bridge by using the sophisticated Diana Finite Element Structural Analysis Package. The results obtained from this analysis confirmed those determined by the self-generated spreadsheets described above, and dynamic loads would have a negligible influence on the bridge's behaviour.

Walls built at the front of the abutment were introduced to prevent cattle from being driven over the bridge as such an action could over-load the structure.

Wind effects

The CSIR's Dr. Adam Goliger, was employed to visit the site, to assess the local conditions, and to advise the consulting engineer on anticipated wind loadings. His report provided an extensive review of literature pertaining to wind loading on similar bridges and stated that in the case of the Mkomaas River Bridge it is unlikely that wind will play a significant role in the lifespan of the bridge. The report mentioned that it is not normal for people to venture outside during winds with speeds exceeding 80 km/h and are therefore not likely to be on the bridge when such a wind is blowing. For wind speeds less than 80 km/h aeroelastic excitations of the bridge will be insignificant. Under extreme wind loads (with return periods in the order of 1:250 years and gusting up to 150 km/hr) the bridge will resonate moderately, but the structure will remain intact.

Apart from an extensive literature search, Dr. Goliger conducted an analysis using a computer model of the bridge and a physical water tunnel test.

Geotechnical Design

The maximum horizontal force that could be applied to each of the abutments under working loads is in the order of 10 MN, which meant that the abutments had to be securely anchored.

After preliminary assessments of both the site and the intended design, two possible options were evaluated for anchoring the abutments. The first was the use of a dead man anchor located in the alluvial soils and the second was the use of anchors drilled and grouted into the underlying rock.
Under the design loadings the size of the dead man anchor block was determined, using conventional earth pressure analysis, to be 25 metres wide for a 9 metre deep block. The required volume of concrete exceeds that of the abutment itself and was considered uneconomical.

As competent rock (charnockite with a compressive strength of approximately 50 Mpa) was discovered on site, the use of rock anchors became a technically feasible option. Preliminary investigations suggested that the anchor interface required for the estimated load of 10 MN was in the order of 20 square metres. This was based on the side resistance of the hard rock being about 5% of the compressive strength of the rock (Williams et al, 1980) and using a factor of safety of 5 due to the "fail-unsafe" mode of failure.

Eventually rock anchors were used, as it was more cost-effective than dead man anchors.

The analysis of the movement of the base assumed a stressing sequence beginning with the front anchors, then the middle, followed by the back anchors. The settlement and horizontal movement of the base was calculated at each stage. It was noted that, if the preloading of the anchors was left at the maximum level then the application of the prestressing to the bridge cables led to an overload on the back anchors. The required loads were therefore calculated for the anchors ranging from 250 to 2000 kN such that once the deck loads were applied, the loads in all the anchors would be the same.

During construction, the rock strength parameters determined in the geotechnical investigation were confirmed, to ensure that the assumed conditions are similar to the actual conditions. Cement based grout was used to bond the anchor cables to the rock. The performance of the anchors was evaluated as part of the construction phase.

As the design of a Stress Ribbon Bridge is a new concept in the African context, it was decided by the Engineers involved, that the loads experienced by the anchors should be monitored and compared with the design values. The Mechanical Engineering School at the University of KwaZulu-Natal was commissioned to design and construct load cells to measure the maximum stresses imposed on the anchors. The load cells were constructed from a "smart" material of which magnetic properties change under stress, and the measurement and interpretation of these properties determine the maximum stress exerted on the material.

Construction

Construction of the Mkomaas River Pedestrian Bridge commenced in November 2005 and was completed in December 2006 and, remarkably, it is the first bridge that this contractor was ever commissioned to build.

Difficulties were encountered in installing rock anchors through a 4 m deep boulder layer on the south abutment, but once that was completed the work went ahead without major incident.

The launching rate of the deck elements exceeded the designers' best expectations as up to twenty-four elements were launched in a single day making the launching of the ninety-three deck elements no more than a five day operation.
The leading quantities for this bridge are 190m^3 of concrete, 37t of steel reinforcement, 2500 MNm prestressing tendons and 31.5 MN prestressing anchorages.

The tendered price for the Works (including VAT) was R3,53 million, which was well within the client's initial estimate of R5,0 million.

The main Contractor was:
Somerset Oaks Trading 19 (Pty) Ltd

And sub-contractors included:

Infraset	Manufacture and supply of pre-cast concrete deck elements
Esor	Installation of ground anchors
Freyssinet	Pre-tensioning and post-tensioning operations

SUMMARY

The Mkomaas River Bridge presented the designers with challenges that have never been attempted before in Africa, as it is the first pre-stressed concrete ribbon bridge built in the country and its clear span of 150 meters equals the world record for this type of footbridge.

It is an honest structure without imposing towers that will detract from the rural landscape in which it was built. Its walkway is also its main structural member that spans clear across the river without props, piers or stabilisers that could impeded the flow of water under the bridge.

The design was sensitive to the many challenges faced by a contractor when building a bridge over a large river in a remote area of KwaZulu-Natal. It made use of pre-cast concrete deck elements which reduced the amount of construction required on site thereby alleviating some of the burden on the contractor to produce a quality product under difficult circumstances. The use of a single span Stress Ribbon Bridge also did not require the contractor to work inside a river notorious for its flash floods.
The extensive use of concrete elements makes this a bridge that will serve its purpose virtually maintenance free for many years.

Various stages of the construction of the Mkomaas River Pedestrian Bridge

Launch of Self Compacting Concrete

Lafarge Aggregates & Readymix has announced the launch of the Lafarge Ultra Series SCC, a new range of innovative self compacting concrete. This product is specifically aimed at providing maximum performance and quality for demanding construction requirements and designed to save time in the overall construction process.

This is according to Maxime Sibille, National Marketing Manager, Lafarge Aggregates & Readymix, who says that this new product range offers a new innovative concrete mix design, backed by 10 years of intense worldwide research and development (R&D) into cement, aggregates and admixtures.

“This has resulted in one of Lafarge’s most important innovations in the readymix arena to date,” says Sibille. “Among other things, the new range offers excellent strength, quality and durability, ease-of-use and eliminates many steps in the construction process and is more economical than traditional concrete solution resulting in reduced costs.”

Because of its self compacting design, application times are dramatically cut compared to the application of traditional concrete, resulting in cost savings of up to 70%, depending on the individual job site. “It creates value for the client due to the reduction in labour requirements, application time, pumping costs, hiring of equipment and overall construction costs,” he says.

Its fluidity enables it to fill in all corners and areas in the formwork or mold, spreading easily and quickly throughout. “Furthermore, the high fluidity of the product means that the traditional requirements for noisy vibrations in order to compact concrete, is eliminated providing a healthier work environment for construction workers,” says Sibille. “Ultra Series SCC is quick and easy to place and moves effortlessly through highly congested re-enforced areas with no bleeding or segregation and provides the best quality.”

Faster, unassisted placing means lower site costs with reduced risks and exposure to move and vibration.

“Pumping costs can be reduced by up to 60% because of the product’s high fluidity and the superior flow and quality with the resulting superior finish significantly reduces the need for time consuming and costly patching,” he adds. “Other benefits include labour cost savings, as less labour time is required due to the increase of speed of casting and pouring.”

With regard to coverage, 1 cubic metre of Ultra Series SCC will cover an area of 10 square metres at a 100mm thickness.

The Ultra Series SCC range of concrete can be used for different applications Ultra Series SCC Vertical for columns, walls, and all areas with heavily re-enforced structures and Ultra Series SCC Horizontal for flatworks and foundations in housing, commercial and industrial applications.

Sibille says that Ultra Series SCC also provides a better quality surface finish than conventional concrete, with excellent strength and improved durability. “It is particularly suitable for mass concrete pans, bridge decks, walls, columns, slabs, trenches and pre-cast applications and all areas with re-enforced structures.”

“More complicated design options and shapes that were previously technically difficult to create with traditional concrete are now easy to construct,” he adds. “This is due to the product’s fluidity and improved ability to completely fill previously difficult areas, allowing for the design of more complex shapes and forms to be created.”

Ultra Series SCC is part of the new range of Lafarge readymix concrete Ultra Series. Product ranges include fibre concrete, early strength, flowable, waterproof, pool, foam, ultra light, industrial floor solutions and aqua floor concrete for under water construction.

“It’s the best thing since sliced bread and the right solution for easy, fast and demanding construction in South Africa providing an ultra performance, ultra quality and ultra innovation,” Sabille concludes.

Top: Maxime Sibille, National Marketing Manager A&C

Left: rom left to right- Dennis Berthon, Regional President Aggregates and Concrete; Maxime Sibille, National Marketing Manager, Aggregates and Concrete; Ulrich Aumuller, MD Aggregates and Concrete and model.

FIBRE REINFORCEMENT
STEEL VERSUS MACRO(STRUCTURAL) SYNTHETIC

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Introduction

Around the millennium, suppliers of micro synthetic fibres started to offer macro synthetic fibres, with the typical marketing approach being that they can provide the same performance as steel fibres at a lower cost per cubic metre and with enhanced durability (no rusting). Interestingly, the performance established for steel fibres using the EFNARC(1996) panel test to a mid point deflection of 25mm and the correlating 40mm mid point deflection of the newly introduced ASTM C-1550(2005) test was taken by the early suppliers of macro synthetic fibres to be the bench mark by which macro synthetic fibres should be compared to steel, despite the fact that the shapes of the curves for each type of fibre are markedly different with no work having been undertaken to establish the relevance of a performance test determined for steel fibres when using macro synthetics.
This is not to say that macro synthetic fibres do not have their applications, a number of fibre suppliers actually sell both steel and synthetic. This paper has been written to provide what will hopefully be perceived as an unbiased assessment of the true comparative performance of steel and macro synthetic fibres.

Background on steel fibres

Steel fibre reinforced concrete (SFRC) was introduced into the European market in the second half of the 1970's. No standards, nor recommendations were available at that time which was a major obstacle for the acceptance of this new technology. In the beginning, steel fibres were mostly used as a substitute for secondary reinforcement or for crack control in less critical parts of the construction. However, over time, SFRC came to be applied in many different construction applications, such as in tunnel linings, ground support in mines, floors on grade, floors on piles and prefabricated elements, to the point where, nowadays, steel fibres are widely used as the main and unique reinforcement for industrial floor slabs, shotcrete and prefabricated concrete products. Steel fibres are also now being considered for many structural purposes contributing to the construction's strength, stability and durability in:-

- foundation piles
- pile supported slabs
- precast tunnel segments
- concrete cellars and slab foundations
- pre-stressed construction elements as shear reinforcement

This evolution into structural applications was mainly the result of the progress made in SFRC technology, as well as the research done at different universities and technical institutes in order to understand and quantify the material properties. In the early nineties, recommendations for design rules for steel fibre reinforced concrete started to be developed. Since October 2003, RILEM TC 162-TDF(2003) recommendations for design rules have been available for steel fibre reinforced concrete.

Background on macro (structural) synthetic fibres

Micro synthetic fibres are typically 6 to 12 mm long and have a diameter of 16 to 35 micron, and are widely used to reduce plastic shrinkage cracks, as well as to reduce concrete spalling during a fire. As Young's modulus for a polyolefin is typically around 3,000 to 5,000 MPa, it is generally understood that the reinforcing effect of these fibres is gone after a couple of hours of hardening of the concrete, as hardened concrete typically shows a Young's modulus of around 30,000 MPa.
Macro synthetic fibres typically have dimensions equal to steel fibres, with length varying from 15 to 60 mm, and diameters from 0,4 to 1,5 mm. Macro synthetic fibres are to be considered as a relatively new construction material, but are often marketed as being equal to steel fibres on the basis of their performance in toughness tests. But is this a reasonable proposition?

Fibre Reinforcement.

Fibres have typically been added into the internal matrix of other materials to form a composite material of enhanced robustness that will perform better in terms of its load carrying characteristics. Typical well established examples are horse hair or straw added to mud bricks, asbestos or cellulose fibres added to cement sheets (FRC), glass fibres or mats inside a polymer matrix (fibreglass) and glass fibres added to cement or cement sand mortars(GFRC). In all these cases the primary aim is to either increase the load carrying capacity of the parent material or make it less prone to damage during installation.
When it comes to cementitious materials, the aim has typically been to enhance the inherently low tensile strength of the parent matrix when subjected to either direct tensile or flexural strain actions. This is typically achieved by targeting one of the three load/deflection or tensile stress/strain response graphs shown in Figure 1.

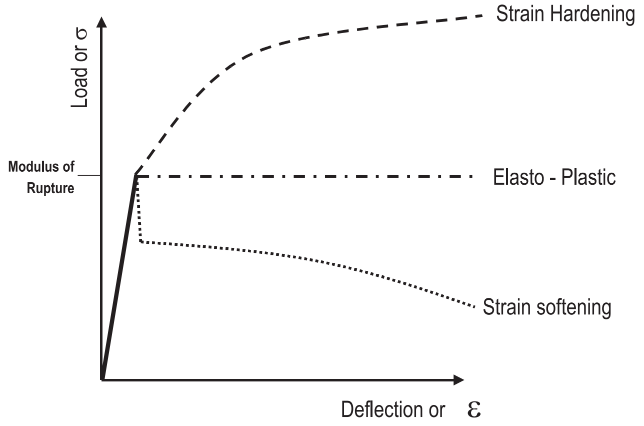


Figure 1: Load/Deflection responses for a cementitious composite

Perfect elasto-plastic behaviour as depicted in Figure 1 is a concept rather than an achievable performance when dealing with real materials. It is, however, certainly feasible to achieve either strain softening or strain hardening behaviour dependent on the type and dosage of fibres. In a statically determinate element such as a simply supported beam or a round panel supported on three points, as in the ASTM C1550 test mentioned earlier, it is obviously necessary to provide strain hardening behaviour rather than strain softening behaviour if the element is not to suffer catastrophic failure once the parent material cracking load or modulus of rupture is reached.

The way this is avoided when testing strain softening materials is to rapidly reduce the applied load, a scenario not often encountered in the real world. Similarly, if true elasto-plastic behaviour could be achieved the cracking load could continue to be supported but only at the expense of ever greater rotations and deflections in the supporting element, not usually a viable option from the point of view of serviceability.

The problem is, that in order to achieve strain hardening behaviour it is normally necessary to use quite high dosages of fibres and although this might be cost effective and practically achievable in very thin, low volume, light elements such as used in Glass Fibre Reinforced Cement and Fibre Reinforced Cement applications, it is neither economically viable nor practically achievable in the field when using large volumes of bulk materials like concrete or shotcrete.

If then, the achievement of strain hardening in full scale concrete and shotcrete elements is economically uninteresting and practically problematic how can the use of fibre reinforced concrete be justified in real life applications? The answer is quite simple, use SFRC in statically indeterminate applications, where the ability of the structural element to redistribute loads after cracking can result in strain hardening behaviour as shown in Figure 2, despite using exactly the same SFRC.

The types of structural elements where static indeterminacy can be relied on to provide load redistribution and strain hardening behaviour are typically slabs on ground, pipes, shotcrete for ground support and in fact many other common applications used in everyday construction - it is not an uncommon phenomenon.

The ability of SFRC to provide strain hardening behaviour depends, not only on providing continuity in the loaded element but on the performance of the fibre reinforcement, where the performance of the fibre reinforcement is in turn a function of the dosage and physical properties of the fibres used.

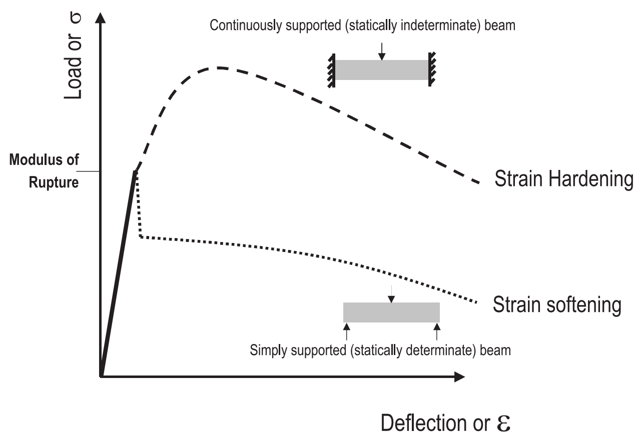


Figure 2: Effect of fixity on strain hardening behaviour of the same shotcrete

STEEL VERSUS MACRO SYNTHETIC FIBRES

There are two main differences between steel and macro synthetic fibres in terms of the load carrying capacity provided in fibre reinforced concrete(FRC) as follows:-

1. Young's modulus

Steel fibres combine a high tensile strength (typically 800-2000MPa) with a Young's modulus of around 210,000MPa, whereas polyolefin fibres have more moderate tensile strengths(300-600MPa) coupled with a quite low modulus of typically 3,000 to 5,000MPa. Compare these modulus values to that of concrete, which is typically around 30,000MPa.

What this means in practical terms for SFRC is that steel fibres tend to pick up load at very small crack widths and hence deflections/rotations for the parent concrete, thereby providing the ability for load redistribution to occur and the potential for a strain hardening load carrying capacity to be exhibited at quite low dosage rates. Synthetic fibres on the other hand start working at significantly larger crack widths, so that where the optimal performance for steel fibres is typically in the crack width range of 0.3-1.0mm the optimal performance for synthetic fibres does not normally occur until crack widths of at least 3mm are achieved. This difference in load carrying behaviour for beam tests can be seen in Figure 3 for synthetic fibres at a dosage of 1% by volume(9.1kg/m^3) and steel fibres at 0.5% by volume(40kg/m^3). These volume percent dosage rates were chosen in order to provide reasonably equivalent fibre counts per cubic metre.

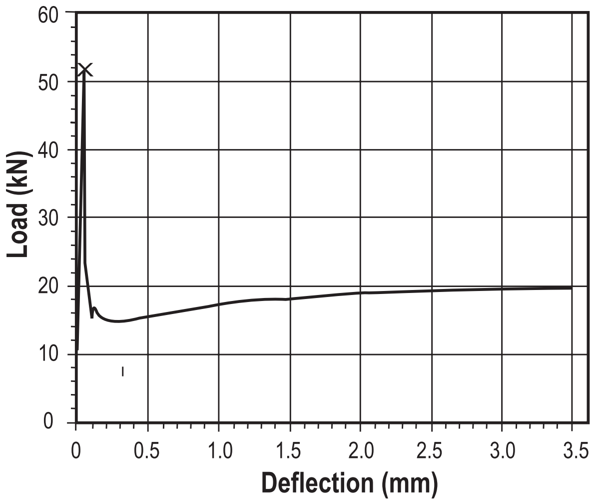


Figure 3a: Typical Load v Deflection curve for 1% by volume macro synthetic

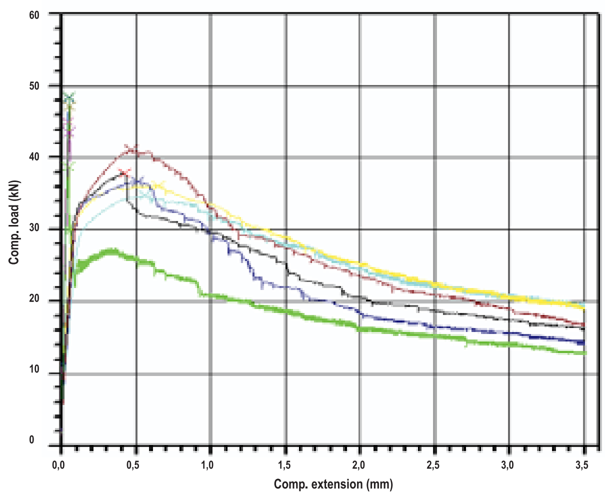


Figure 3b: Typical Load v Deflection curve for 0.5 vol % of hooked end steel fibres

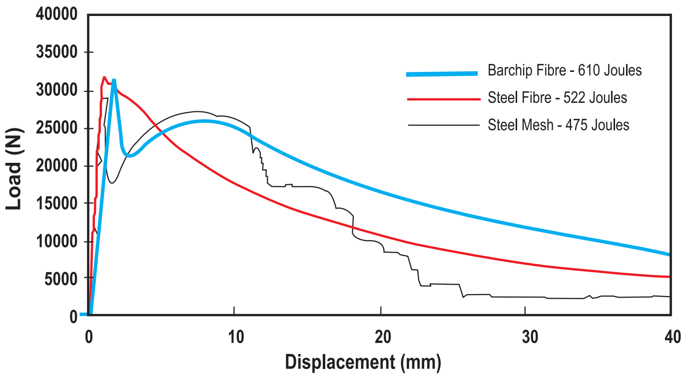
The load that can be supported when a FRC is used in a statically indeterminate element is determined by many factors, including the following:-

1. The distance between supports - the bending stress in an element spanning between supports increases as the square of span, so that for all else remaining equal doubling the span will quadruple the bending stress in the shotcrete.
2. The occurrence of cracking and the subsequent strength of the cracked concrete – in strain softening concrete the strength after cracking is lower than before cracking with this strength being a function of the fibre dosage and the tensile load in the individual fibres spanning the crack. In turn the tensile load in each individual fibre spanning a crack is determined by its Young's modulus times its strain(a function of the crack width at each fibre).
3. The rate and extent of crack development – at the earliest stage of cracking of strain softening concrete in a statically indeterminate system the concrete will work to redistribute the stresses in it from cracked to uncracked sections. If the consequential build up of stress at an uncracked section becomes great enough then cracking will occur there also. This process proceeds with continued deflections and rotations in the concrete until the final crack pattern is fully established, at which time the ultimate load capacity of the concrete is achieved and after which the load carrying capacity of the concrete will reduce(refer Figure 2).

Items 2 & 3 together explain the phenomenon of strain hardening in concrete that spans continuously past supports even though it would exhibit strain softening behaviour in a statically determinate beam or ASTM C1550 round determinate panel test i.e. as the first cracks develop the load carrying capacity is determined as a function of both the cracked and uncracked strength, only to revert to strain softening behaviour once the full crack pattern is established and the load carrying capacity is determined as a function of the cracked strength only. This progression in the load carrying capacity will be much as represented in Figure 2 and is typical of the load/deflection graphs produced when performing the EFNARC square panel test referred to earlier.

Concrete is a brittle material. Consequently, it only takes relatively small deflections and rotations to cause cracking. For this reason, to get the optimum strain hardening performance, the maximum cracked capacity needs to be mobilised at relatively small crack widths, exactly what occurs with steel fibres due to their high Young's modulus. With synthetics however, due to their low Young's modulus, the full crack pattern is typically established before the full strength of the cracked section can be mobilised and the strength provided by the cracked section during the strain hardening phase is well below optimum. Refer to the load capacity provided in Figures 3 & 4 at a deflection of less than 1mm. NB a 100mm thick continuous concrete slab supported at 2 metre centres will crack over the supports at a mid support deflection of less than 0.3mm, so it doesn't give a lot of leeway for the maximum cracked strength to be mobilised before another crack forms.

Interestingly, at this point in time in the mining industry, the effectiveness of a fibre reinforced shotcrete in terms of ground support is seen in terms of the toughness or energy absorption being provided in an ASTM C1550 round determinate panel test to a mid point deflection of 40mm, with the graph in Figure 4 (downloaded from the internet with the crack width information added) being a typical example of this approach. The argument is made, based on the graph information, that "synthetic fibre reinforced shotcrete is capable of sustaining superior energy absorption values when compared to steel fibre or steel mesh reinforced shotcrete and is undoubtedly the most suitable reinforcement selection where high ground deformations are expected".



Mesh - F41; Steel fibres - Hooked end @ 40 kg/m^3; Structural synthetic - 48mm macro synthetic @ 10 kg/m^3

Figure 4: Comparison of performance for RDP tests

There is no argument that macro synthetic fibres can provide a sufficient level of reinforcement, provided the dosage is adequate, to ensure strain hardening behaviour can be achieved, at least in the short term. The problem is, that the basis for comparison between steel and macro synthetic fibres being used to justify quite low dosages of macro synthetic fibres is currently the toughness (or area under a load/deflection graph) determined to very high deflections and crack widths. The relevance of this approach seems very dubious if the importance of load carrying capacity or strain hardening behaviour is accepted and serviceability requirements, in regards to deflections, rotations and crack widths are not being overlooked. It is also in disagreement with the approach taken by RILEM(2003) and many other international performance standards, where the typical approach is to use the results from beam tests up to a maximum crack width not exceeding 4mm to determine the capacity of fibre reinforced concrete or shotcrete.

The relative importance of load carrying capacity at small crack widths, and hence small deflections and rotations, is of recent times, assuming much greater importance to the designers of civil engineering tunnels in Australia. Even though the specified test of choice is typically the ASTM C1550 round determinate panel test, the specifications now require the performance to comply with mid point deflections between 0.72mm and 7.5mm, instead of, or in conjunction with, the overall toughness to a mid point deflection of 40mm. The mid point deflections nominated are in fact chosen on the basis of correlating back to equivalent crack widths used in third point loaded flexural beam tests.

2. Creep

It is one thing to achieve a certain level of load capacity or strain hardening but it can be quite another to maintain it, especially if the element carrying load is quite prone to creep. For this reason it is important to understand the creep properties of both steel and macro synthetic fibres. A perceived lack of definitive test information along with the lack of a standard test procedure led Lambrechts(2005) to publish the results of some in house creep tests performed at NV Bekaert in Belgium and the results are shown in Figure 6.

Macro synthetic fibres type1 and type 2 were added at a dosage of 4,55 kg/m3 (0,5 vol%). Dramix RC-65/35-BN steel fibres were dosed at 20 kg/m3(0.25 vol%). As there is no standard test method it is worthwhile summarising the main features of the test procedure adopted as follows:-

1. The long term load chosen to establish the creep behaviour of the beams was taken as 50% of the residual load capacity measured at a deflection of 5mm in a standard displacement controlled beam test - It is known that increasing the long term load as a percentage of a sections measured load capacity will tend to increase the amount of creep measured.
2. The residual strength at a deflection of 5mm was established for each beam using a standard test method, at which point the beam test was stopped. 50% of this load was then applied to that beam in the same four-point bending configuration used in the beam test - In this way the tensile stress in each fibre crossing the crack under the long term load was targeted to be 50% of what it was for a 5mm deflection in the beam test. Hence every fibre beam tested was targeted to have exactly the same relative starting point in terms of the stress in the fibres – 50% of their actual capacity.
3. The resulting creep deflection was measured at regular intervals for a period of over 1 year. The results achieved were recorded in 1/100mm increments as per the Y-axis of Figure 6.
4. No effects of temperature or humidity variations were taken into account.

As can be seen from Figure 6, the polypropylene fibres tended to creep 7 to 20 times more than the steel fibres after 1 year. Moreover, the creep of the macro synthetic fibres was continuing after one year i.e. the creep curve for the macro synthetic fibres and hence the crack widths, rotations and deflections had not stabilised. Therefore considerably higher creep was still expected for the macro synthetic fibres over time, perhaps eventual rupture.

What this means in terms of FRC using macro synthetics as the sole reinforcement, is that if there is a sustained load on a structural element, there will be a marked tendency for the deflections, crack widths and rotations in that element to significantly increase over time.

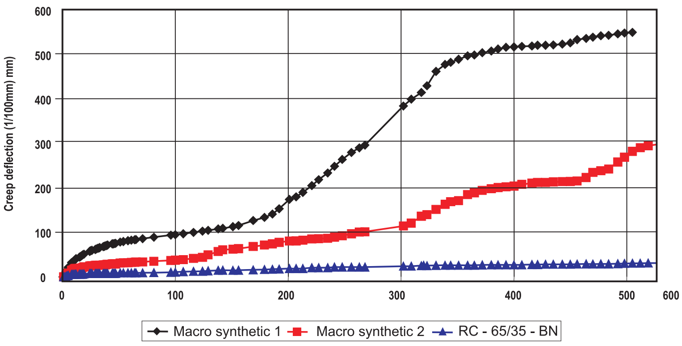


Figure 5 Creep deflection (in 1/100mm) versus time (days)

Conclusions

The actual performance level required of FRC in most, if not all, structural applications, is to provide an increasing level of load carrying capacity after cracking initiates i.e. strain hardening behaviour. If this cannot be achieved, either by virtue of the level of reinforcement or the use of statically indeterminate elements, then the FRC should be designed as plain concrete.

In terms of quantifying the structural capacity of FRC it is necessary to utilise guidelines such as RILEM TC 162-TDF(2003), which are based on the results of beam tests where the crack widths do not exceed 3.5mm.

The comparative performance of steel fibre and macro synthetic fibres when used to produce FRC should never be done on the basis of the toughness (area under the load/deflection graph) produced for crack widths exceeding 3-4mm unless the shape of the graphs are also considered.

The propensity for synthetic fibres to creep should be considered when the applied loads are to be sustained over extended periods.

References

ASTM C 1550-05. “Standard Test Method for Flexural Toughness of Fiber Reinforced Concrete (Using Centrally Loaded Round Panel)”. Published by ASTM International in 2005(latest version).

EFNARC (European Federation of Producers and Applicators of Special Products for Structures) (1996). “European Specification for Sprayed Concrete”. ISBN 0 9522483 1 X

Lambrechts A. N. (2005). “The Technical Performance of Steel and Polymer Based Fibre Concrete”. Concrete for a New World - The Institute of Concrete Technology/Annual Technical Symposium/5 April 2005.

RILEM TC162-TDF: “Test and design methods for steel fibre reinforced concrete”, TC Membership, Chairlady L. Vandewalle, Materials and Structures, Vol 36, October 2003, P560-567

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New publications available from the Cement & Concrete Institute's information centre:

1. Anna Maria Workshop 2006 – sustainability in the cement and concrete industry at Holmes Beach, Florida, 25-27 November 2006.
2. Walloon Ministry of Infrastructure and Transport. Bituminous and continuously reinforced motorways: an economic comparison, Namur:Belgium, 2006.
3. Cheng, F-T and Olsen, E. Concrete at home, Newtown: Taunton, 2005.
4. Delft University of Technology. Fundamental modeling of design and performance of concrete pavements, pre-proceedings of the 6th International DUT workshop held in Old-Turnhout, Belgium, 15-16 September 2006.
5. Febelcem, Glance at the Belgian experience in concrete pavements special edition on the occasion of the 10th International Symposium on concrete roads, Brussels, 2006.
6. Balazs, GL Keep concrete attractive , proceedings of the FIB symposium held in Budapest, Hungary, 23-25 May 2005
7. Law-Viljoen, B Light on a hill: Building the Constitutional Court of South Africa, Johannesburg: David Krut, 2006.
8. Precast/Prestressed Concrete Institute, PCI design handbook: precast and prestressed concrete, Chicago: PrCI, 2004.
9. Kovacs, I. Structural performance of steel fibre reinforced concrete, Budapest: Budapest University of Technology, 2004.
10. American Concrete Institute, Superplasticizers and other chemical admixtures on concrete, proceedings of the 8th CANMET/ACI international conference, Sorrento, Oct 2006.
11. BRE, Great practice guides for in-situ concrete frame buildings: early striking and improved backpropping for efficient flat slab construction, Crowthorne, BCA, 2001.
12. BRE, Great practice guides for in-situ concrete frame buildings: rationalization of flat slab reinforcement, Crowthorne, BCA, 2000.
13. Concrete Centre, Concrete framed buildings: a guide to design and construction, Camberley,Surrey: Concrete Centre, 2006.
14. Martin, R Guide to surface finishes of concrete slabs on ground, St Louis,Missouri: ASCC, 2006.
15. ICCX Cape Town2007: International conference and exhibition, Cape Town, 14-16 February 2007.
16. ACPA, Stormwater management with pervious concrete pavement, Skokie, ACPA, 2006.
17. The Concrete Centre, Sustainable concrete: the environmental, social and economic sustainability credentials of concrete, Camberley;Surrey: Concrete Centre, 2006.

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Proportioning of Concrete Mixes

History

The Romans were probably the first to exploit the properties of concrete in a systematic manner, although earlier examples of construction with concrete and mortar are known. In any event, many Roman concrete structures have endured for 2000 years. The Romans certainly knew the value of producing workable concrete which could be thoroughly compacted. They had recipes for proportioning mixes, they used pozzolanic materials such as volcanic ash and trass, used lightweight aggregates, and utilised hoop iron for reinforcement.
Knowledge of concrete construction was evidently available throughout their area of influence as ruins from all parts of their Empire show.
In Roman times the mix ingredients would undoubtedly have been batched by volume, the volumes of the ingredients being determined by experience.

Nominal volumetric proportions of the 1:2:4 type

This state of affairs persisted until relatively recently. The second report of the Concrete Committee of the Royal Institute of British Architects (RIBA), issued in 1911, stated that the minimum cube strength of a “1:2:4” mix should exceed 1800 pounds per square inch (psi) (12 MPa), and right up until the 1970’s British Standard Code of Practice 114 continued to prescribe mixes by volume. CP 114 also reflected minimum concrete strengths and maximum water/cement ratios. The strength of a “1:2:4” mix was taken to be 3000 psi (21 MPa) with a water: cement ratio of 0,60. Nowadays an equivalent mix would have a characteristic strength of around 30 MPa.

This method of proportioning mixes was based on experience with aggregates in the United Kingdom where the coarse aggregates were well-graded gravels with high bulk densities and the sands were fairly consistent. It was based on the volume of a 94-lb. (42,7 kg) cement bag which was taken as 1 cubic foot (28,3 litres). A 1:2:4 mix was therefore 1 bag of cement to 2 cubic feet of sand to 4 cubic feet of well-graded stone. What is not generally realised is that the sand volume referred to dry sand and that allowance still had to be made for bulking of the sand when damp. CP 114 mentioned this in the small print, as well as the fact that one could adjust the sand to stone ratio as long as the overall ratio of cement to aggregate remained at 1 to 6. The small print was often overlooked which resulted in the batching and placing of harsh, under-sanded mixes which were difficult, if not impossible, to compact thoroughly.

A more fundamental problem with this type of mix is that it is impossible to prescribe mix proportions, and water/cement ratio, and minimum strength, and slump simultaneously. The reasons for this are that no account is taken of the water requirement of the aggregates or the strength characteristics of the cement. For example a “1:2:4” mix could give characteristic strengths ranging from 20 to 35 MPa depending on the water content of the mix, the binder type and whether or not chemical admixtures are used in the mix.
It follows that the control of concrete quality on site is extremely difficult. (A fairly common mistake, still evident today, was mixing 1 bag of cement to 2 wheelbarrows of sand to 4 wheelbarrows of stone. This is in fact a 1:4:8 mix as the volume of a level wheelbarrow is equivalent to the volume of two bags of cement).

In 1918 Duff Abrams published his findings on the relationship between compressive strength of fully compacted concrete and water/cement ratio. This became, in retrospect, the foundation for a more rational method of mix design, leading in turn to a move away from volume batching to batching by mass.

Now, of course, all concrete for important work is batched by mass, while volume batching is still used extensively for low strength concrete (and mortar, plaster and floor screeds) in housing.

Tables of standard mixes

A variation on the use of nominal mixes is the use of standard mix design tables which are available from a number of sources. Normally the tables cater for different coarse aggregate sizes, different compressive strengths, sand size and quality, and concrete workability. Generally speaking standard mixes are given for compressive strength requirements only and durability criteria are ignored. Different tables are required for different cement types and the tables do not, as a rule, cover the use of chemical admixtures.
To use these tables the user needs to be able to distinguish whether the sand to be used is coarse, medium or fine and whether it has a high, average or low water requirement.
Mix design tables are drawn up by making assumptions about the aggregate and binder properties. It is important that the user understands the underlying assumptions.
These tables, which give mixes both by volume and by mass, can be very useful at the estimating or tendering stage to get a quick estimate of concrete material costs.

The "eye-ball" method of mix design

Despite the title, this method of mix design can produce good results and is a very useful method if one has to design a mix on-site in a hurry. The only information needed by the mix designer is the required water/binder ratio of the concrete (and the knowledge that the available aggregates are suitable for use in concrete). The designer does not need to know any of the physical properties of the aggregates.
It is also a useful method for designing unusual mixes. The first trial mixes for the exposed aggregate paving at the V&A Waterfront in Cape Town were carried out on site using this method.

The procedure is as follows:

- Weigh out cement (and extender if required) and water to satisfy the water/binder ratio requirement
- If applicable measure the required amount of chemical admixture
- Weigh out excess quantities of air-dry sand and stone
- Batch the binder, water, admixture, and some of the sand and stone into the mixer and mix thoroughly
- Add sand slowly until the slump is estimated to be about 150mm
- Add stone and more sand until the slump and stone content appear more or less correct, carrying out slump tests as necessary
- Weigh the left-over sand and stone
- Calculate the concrete mix proportions

The Cement and Concrete Institute method of mix design

This method is based on the American Concrete Institute standard ACI 211.1-91 (1997) Standard practice for selecting proportions for normal, heavyweight, and mass concrete. The method is described in detail in chapter 11 of the eighth edition of Fulton's concrete technology (Cement and Concrete Institute, Midrand, 2001).
This method is the most versatile (and rational) mix design method and is the method which leads to the optimum mix with the least amount of trial and error.
This method is based on the following 4 principles:

- The compressive strength (and for that matter durability) of fully compacted concrete depends on the water/binder ratio and the type of binder
- For a given set of aggregates and a given workability, the water requirement of the mix will be substantially constant
- There is an optimum stone content which is a function of the workability of the mix, the bulk density of the stone and the fineness of the sand
- The volume of a cubic metre of fully compacted concrete is the sum of the solid volumes of the constituent materials

It is therefore necessary to know the strength and durability characteristics of the available binders and their relative densities, and the relative and bulk densities of the aggregates and the grading characteristics of the sand before one can apply this method. One also has to have a fairly good guestimate (gained by experience) of the water requirements of the available aggregates.

Site adjustment of mixes

Irrespective of the mix design method used, it is nearly always necessary to adjust mixes on site to compensate for variations in aggregate properties, cement strength and so on. The adjustment of mixes in this way is part of normal site practice.

Economics

Having touched on how mixes can be proportioned, it is instructive to look at the economics of concrete mixes.
Many contractors' buyers shop around for aggregate prices and tend to purchase the cheapest sand and stone available, but when costing concrete mixes it is important to realise that **the combination of the cheapest available materials does not necessarily produce the cheapest combination of materials**. The reason is that the water requirement of the aggregates affects the cement content of the mix and hence the cost.
For example if there are two sands available with costs of R30 and R45/m3 and water requirements of 200 and 180 litres/m3 respectively, the cost of the sands would be R18 and R27 per cubic metre of concrete respectively, i.e. R9 in favour of the cheaper sand.
The difference in cement content would be 1,7*(200-180) = 35 kg (roughly) for a 30 MPa mix. This equates to a saving of about R21 per cubic metre in favour of the more expensive sand.
Assuming the stone contents of the two mixes is the same, one cubic metre of concrete with the expensive sand would be R12 cheaper than one cubic metre of concrete made with the cheaper sand.
It is therefore imperative that concrete is costed on a cubic metre basis.

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Steve Crosswell

Pr Eng MICT – PPC Cement

Chemical admixtures for use in concrete

Introduction

Chemical admixtures have been used in concrete for many decades but have often been regarded with suspicion, particularly by specifiers (and cement producers for that matter).

The truth is that the appropriate use of admixtures has greatly extended the range of concrete products and applications, for example air-entraining agents provide resistance to freezing and thawing that would otherwise be unachievable, and superplasticisers are used to achieve strengths that would have been impossible two decades ago.

This TIP describes the basic types of admixtures, their uses and side effects.

"Accidental" admixtures are also touched on.

Admixture manufacturers can provide detailed information on their particular products.

Admixture types

The five basic categories of admixtures are, by function:

- Accelerators, either set accelerators or hardening accelerators
- Retarders, which retard setting time
- Air-entraining agents (AEA)
- Concrete plasticisers (also known as Water-Reducing Agents (WRA))
- Superplasticisers (also known as High Range Water-Reducing Agents (HRWRA))

Admixtures with combined functions are also available, for example air-entraining plasticisers.

In the past many of these materials were based on waste products from other industrial processes, for example ligno-sulphonates derived from timber processing were (and still are) used as retarders and plasticisers. Nowadays, however, many admixtures are tailor-made for specific applications.

There is no South African Bureau of Standards specification for chemical admixtures and most comply with the relevant American (ASTM) or British (BS) standard.

Many specialised types of admixture are also available, some of which are:

- Anti wash-out admixtures for placing concrete underwater
- Pumping aids which modify the rheology of the concrete
- Expansive admixtures for grouts
- Stabilising admixtures for grouts
- Admixtures for gunite (shotcrete)
- Admixtures for dry-mix concrete (as used in brick and block manufacture)

These are outside the scope of this TIP and admixture manufacturers should be contacted for details.

Accelerators

Accelerators are used to accelerate the setting time or the rate of strength development of concrete, mortar or grout. Generally they are used in precast operations where rapid turnover of moulds is required, or in cold weather, or in repair materials.

The commonest (and one of the most effective) is calcium chloride, but this chemical also acts as a catalyst in the corrosion of reinforcement and is not permitted in reinforced and prestressed concrete.

A specific use of calcium chloride is in shaft sinking in mines where high early strengths are required in order to strip formwork safely.

Set accelerators, which can cause setting within a few seconds, are available for repair work and for use in gunite for rock stabilisation in tunnels and underground shafts.

High Alumina Cement (HAC) is a very effective accelerator for Portland cement concrete (and vice versa), but the mix ratio is critical.

Side effects of accelerators include lower ultimate strength, increased efflorescence and increased drying shrinkage.

Generally speaking, the use of accelerators in structural concrete in South Africa is highly unusual.

Retarders

Retarders are used to retard the setting time of concrete in hot weather, or where long hauls or delays in placing are anticipated. They are used in pump mixes in hot weather and are also sometimes used in concrete placed by tremie to reduce the risk of the tremie pipe becoming stuck in the concrete.

Chemically most retarders are ligno-sulphonates with high sugar contents.

The main side effect is excessive retardation if overdosed. If excessive retardation does occur, the concrete will set and harden normally eventually, but it must be protected from drying out until it does set.

Retarders do not affect concrete strength adversely and there is evidence that compressive strengths are in fact slightly increased.

Contrary to popular belief retarders do not reduce the heat of hydration of the concrete but they do reduce the rate of heat evolution at early ages and hence delay the temperature peak.

Air-entraining agents

Air-entraining agents produce millions of small, stable air bubbles in the cement paste. In hardened concrete the two major benefits of air-entrainment are vastly improved resistance to freeze-thaw exposure conditions and, paradoxically, decreased permeability (the air bubbles block capillary pores and are discontinuous). In fresh concrete the benefits are reduced bleeding and increased workability.

The only side effect of excessive air-entrainment is reduced strength.

The amount of air entrained by a particular air-entraining agent is highly dependant on the sand grading, and the cement type, and the extender (if any) and site trials must be carried out to determine the air content of the concrete. The air content of concrete is measured with a piece of equipment known as, logically enough, an air meter. Air meters are expensive and are not generally available on site.

Air-entraining agent dosages are small and it is easy to overdose the admixture. Air-entraining plasticisers are less sensitive to mis-use and are recommended if available.

Plasticisers

Plasticisers, or water reducing agents, are the most commonly used admixtures in concrete. When concrete is mixed the cement grains flocculate to some degree, trapping some of the mixing water in the floc. Plasticisers are dispersants which disperse the cement flocs, releasing the trapped water. Typically the water content of the concrete can be reduced by 10 to 15 litres per cubic metre.

Plasticisers can be used in one of three ways:

- To increase the workability and maintain the strength of the concrete at constant water and cement contents
- To increase the strength of concrete by reducing the water content of the concrete at a constant workability
- To make more economical concrete by reducing the water and cement contents of the mix while maintaining the required workability.

The main side effect of plasticisers is retardation of set if overdosed. This can be used to advantage in hot weather or where delays in placing are anticipated.

Concrete plasticisers and mortar plasticisers are not the same. Mortar plasticisers are in fact air-entraining agents and will seriously weaken the mix if used in concrete.

Superplasticisers

Superplasticisers, or high range water reducers, are chemically distinct from plasticisers and can be used at much higher dosages as they do not have the side effect of excessive retardation. Water reductions of up to 20% (40 litres/cubic metre) or more are possible.

Their two main uses are the manufacture of very high strength concrete, particularly when condensed silica fume is used in the mix, and the manufacture of flowing, self-compacting concrete.

Early superplasticisers suffered from poor workability retention (the effect wore off after 30 minutes or so) but this has been largely overcome with subsequent generations of the admixtures.

The main side effect is the increased possibility of segregation of the mix.

Accidental "admixtures"

Experience has shown that accidental admixtures sometimes get into the mix.

These include:

- Sugar which causes severe retardation of set, discolouration and reduction of long term strength
- Urine, which contains sugars, see above
- Seeds which cause popping of the surface of the concrete
- Organic impurities, normally in the sand, which may cause severe retardation, but usually without the discolouration associated with sugar
- Small roots in the sand which cause localised retardation and discolouration
- Chlorides which cause increased efflorescence and increase the risk of reinforcement corrosion.

Use of admixtures – practical tips

The following tips may seem obvious but...:

- Above all else, use manufacturers whose products comply with recognised quality standards and who can demonstrate compliance with a recognised quality assurance programme and who can supply expert technical back up.
- Follow the manufacturer's instructions with regard to storage, use and dosage.
- Use calibrated dispensing systems (which the manufacturer will supply).
- Design the concrete mixes to incorporate the admixture, this is especially important in the case of air entraining agents and superplasticisers.
- Do not mix different admixtures in the same concrete mix without consulting the manufacturer/(s). Even if supplied by the same manufacturer different admixtures are not necessarily compatible.
- Check the admixture is compatible with the cement and/or extender being used.
- Be aware of possible side effects of the admixture.
- Train staff on use of admixtures and the consequences of both over- and under-dosing.

Acknowledgement:
Compiled for ConQuest by:
Steve Crosswell Pr Eng MICT – PPC Cement

Branch Calendars

INLAND BRANCH EVENTS CALENDAR Chairman: Trevor Sawyer, Cell: 082 851 1531		
DATE	**MEETING/EVENT**	**VENUE**
02 Aug	Branch Committee meeting	C&CI, Waterfall Park, Midrand
23 Aug	Concrete Cube Competition - Casting	Not applicable
30 Aug	Concrete Cube Competition - Crush-in	To be advised
06 Sep	Branch Committee meeting	C&CI, Waterfall Park, Midrand
15 Sep	Annual Concrete Boat Race Day	Germiston Lake Club
04 Oct	Branch Committee meeting	C&CI, Waterfall Park, Midrand
18 Oct	Durability Workshop	TBA
01 Nov	Branch Committee meeting	C&CI, Waterfall Park, Midrand
09 Nov	Chairman's Luncheon	To be advised

WESTERN CAPE BRANCH EVENTS CALENDAR Chairman: Lawrence Hendriks, Tel: 021 556 3255 Cell: 082 578 8264		
DATE	**MEETING/EVENT**	**VENUE**
07 Aug	Branch Committee meeting	3rd Floor, Ninham Shand Building
16 Aug	Monthly Technical Meeting/Site visit	To be confirmed
30 Aug	Concrete Cube Casting date	Not applicable
04 Sep	Branch Committee meeting	3rd Floor, Ninham Shand Building
20 Sep	Monthly Technical Meeting/Site visit	To be confirmed
27 Sep	Concrete Cube Crush-in and Branch Social	To be confirmed
02 Oct	Branch Committee meeting	3rd Floor, Ninham Shand Building
11 Oct	Durability Workshop	TBA
18 Oct	Monthly Technical Meeting/Site visit	To be confirmed
06 Nov	Branch Committee meeting	3rd Floor, Ninham Shand Building
15 Nov	Annual Cocktail party	To be confirmed
04 Dec	Branch Committee meeting	3rd Floor, Ninham Shand Building

KWAZULU NATAL BRANCH EVENTS CALENDAR Chairman: Ken Brown, Tel: 031 205 2707 or Cell: 082 554 5460		
DATE	**MEETING/EVENT**	**CONVENOR**
16 Aug	Case Study - Durban Harbour Tunnel Project	TBA
21 Sep	Cements - Specifications and Selection	Rolf Schutte
17 Oct	Durability Workshop	TBA
18 Oct	Site Visit - 2010 Soccer Stadium	Garth Gamble
Oct	Egg Protection Device Competition	Lyn/Rolf
Oct	Strongest Cube Competition	Raj Naidoo

EASTERN CAPE BRANCH EVENTS CALENDAR Chairman: Louis Visser, Tel: 041 453 2813 or Cell: 082 491 8562		
DATE	**MEETING/EVENT**	**VENUE**
Aug	Rocla P.E. Site Visit (Precast Concrete Systems)	TBA
Sep	Bort Longyear Technical Talk	TBA
Sep	Golf Day	TBA
10-Oct	Durability Workshop	TBA
Nov	Year End Function	TBA

Diary of Forthcoming Events

Diary 2007

15-17 August	Sandton	The Water, Energy, Earth and Air Exhibition
27-29 August	Singapore	32nd Conference on our World in Concrete & Structures
3-5 September	Ghent, Belgium	5th International RILEM Symposium on Self Compacting Concrete
4-6 September	Dundee, Scotland	7th International Congress on Concrete: Construction's Sustainable Option
10-12 September	Cape Town	3rd International Conference on Structural Engineering, Mechanics and Computation
19-21 September	Maryland, USA	1st International Conference on Recent Advancement in Concrete
10-12 October	Yantai, China	9th International Conference on Steel, Space & Composite Structures
14-15 October	Beijing, China	9th International Conference on Steel, Space & Composite Structures
17-19 October	Beijing, China	7th International Conference on Shock & Impact Loads on Structures
18-20 October	Adelaide, Australia	Concrete 07, Design, Materials & Construction
28-30 November	Changsha, China	2nd International Conference on Geotechnical Engineering
2-5 December	Kingdom of Bahrain	4th Middle East Nondestructive Testing Conference & Exhibition 2007

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

DURABILITY ROAD SHOW IN OCTOBER 2007 !

CONCRETE SOCIETY OF SOUTHERN AFRICA

The Concrete Society of Southern Africa will be hosting Durability Workshops at the four main centres across the country in October 2007. A number of key speakers will be presenting the latest information. Following the success of the last seminar, this event is not to be missed. CPD certificates will be issued to registered professionals who book in advance of each function.

The dates are as follows:

10 October 2007 - Eastern Cape Branch – Port Elizabeth
11 October 2007 - Western Cape Branch – Cape Town
17 October 2007 - Kwa-Zulu Natal Branch – Durban
18 October 2007 - Inland Branch – Johannesburg

Times and venues will be communicated to our members in due course.

CONCRETE SOCIETY OF SOUTHERN AFRICA

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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