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Accredited Technical Paper:
Early age cracking and capillary pressure-controlled concrete curing

Fulton Awards:
Greenstone Shopping Centre
Freedom Park Project

President's Message

The year has flown by and here we are, not many weeks away from the festive season, holidays, shutdowns and New Year resolutions. This has been a memorable year for many.

The FIFA 2010 Soccer World Cup dominated and who would have believed after all the promotion, hype and a very successful event that it has almost faded into history. However, many reminders and landmarks remain – the stadiums, the improved road infrastructure, huge retaining walls, the Gautrain, new hotels, and more.

Looking at many of these landmarks, one sees the high quality of concrete that is possible to achieve. Not only in the smooth, off-shutter finishes but also in some of the architectural aspects, which have provided very aesthetically pleasing structures.

I urge all members involved in the design and/or construction of these projects to consider entering them for the 2011 Fulton Awards. Nominations are welcome from all quarters as long as the focus is on the concrete aspects of the structure. Go to our website for details at www.concretesociety.co.za

Post World Cup has not been an easy period for the construction industry and it will not be a year of fantastic growth. Government's ability to spend some of the committed R846 billion for infrastructure projects seems to have stalled. Some of the smaller construction companies and contractors have been particularly hard hit by government's shelving of 161 construction projects.

These public sector projects are mainly at municipal level and include the development of waterworks, storm water drains, taxi routes and road works. This is problematic considering these companies and contractors were relying on government infrastructure spending to cushion them from the effects of the economic crisis. The private sector has also canned many major construction projects, due to the economic climate.

In August the Society held a successful CSE 2010 two-day symposium, 'Concrete for a Sustainable Environment', at Emperor's Palace in Kempton Park. Twenty-two papers were presented, including two from overseas speakers. The concrete industry is heavily involved in meeting new 'green' challenges and the Society's symposium was appropriate at this time.

Over 100 delegates took part in the event, which covered the whole spectrum of 'green' issues - from cradle to grave, aggregate to recycled concrete. The symposium generated interesting and lively question sessions, when considering the challenges of 2011.

As a Chartered Marketer, I am a great believer in ensuring that 'customers' are happy and receive good value for money for products and services. To this end, we will be carrying out an electronic survey amongst members shortly. We want to ensure that members are satisfied with the services of the Society in this ever-changing world.

Although I am writing this message in October, it will be the last one of the year. So I wish all members a safe, happy holiday and festive season. Enjoy the read.

Yours in concrete,
John Sheath
President

Cover: Moses Mabhida Commuter Station in Durban designed by Arup Interchange Design South Africa.

Freedom Park Project

Freedom Park Project is the culmination of former President Nelson Mandela's vision of 'a people's shrine, where we shall honour those who endured pain'. Working with rounded and curving building planes, construction materials needed to lend themselves to the undulating surfaces forming the walls and roofs of the building elements.

The South African Presidential Legacy project at Freedom Park was borne out of the Truth and Reconciliation Commission. The aim was to create a memorial commemorating those who had dedicated their lives to the struggle for freedom and democracy.

The Freedom Park Trust and the Office of Collaborative Architects briefed GAPP, its associates MMA and Mashabane Rose Architects to facilitate the design and development of an appropriate memorial reflecting South Africa's heroic rich history and untold past.

Situated on the pristine Salvokop Hill overlooking Pretoria's landmark Union Buildings, Unisa and the Voortrekker Monument, Freedom Park is being developed in five distinct phases.

A joint venture company comprising Concor Civils, Concor Building and Trencon was responsible for the Intermediary Phase. An inaugural function on Heritage Day was held by former President, Thabo Mbeki, December 16th, 2006.

The intermediary phase 'Sikhumbuto', which means elements of remembrance and 'Moshate', presidential hospitality suites, was undertaken together with the building of the ascending reeds and necessary roads and pathways.

The design team was faced with a daunting challenge, as the The Freedom Park Trust was generally unfamiliar with the technicalities of design, engineering and construction work on a project of this nature.

This meant that the Office of Collaborative Architects was forced to take the lead in the development of a design strategy that would not only incorporate modern and aesthetically pleasing built elements, but a design strategy that would pay homage to

the enduring cultural architecture that forms an integral part of South Africa's substance.

Due to the decision to adopt rounded and curving building planes, and the elimination of sharp corners and linear finishes, construction materials needed to lend themselves to the undulating surfaces forming the walls and roofs of the building elements.

Concrete was deemed as the ideal medium both for providing structural integrity to the project, and for achieving an attractive and earthy finish.

Concrete came into its own in a number of the elements and gained favour with both the designers and The Freedom Park Trust.

Large retaining walls, up to 9 metres high, were built using off-shutter concrete and provided an awe-inspiring backdrop to the equally impressive Gallery of Leaders.

In the latter form, the true inherent qualities of concrete were given full reign and resulted in an unprecedented building form that clearly encapsulates the intention of creating a lasting edifice to the tenacity of the human spirit.

Without any fixed radii and varying in height, the roof of the Gallery of Leaders stands testament to the ingenuity of the project team in pouring concrete on a varying gradient and curved surface.

The use of specially designed shutters and shutter elements allowed the team to retain the concrete within the confines of the shutter to ensure a consistent and attractive finish without compromising the structural integrity.

The team included: the principal agent: PMSA; contractor: Concor Trencon Joint Venture and subcontractors: AfriSam readymix and Lafarge.

Moses Mabhida Station

Arup Interchange Design South Africa has completed the design and construction of the Moses Mabhida Commuter Station in Durban, which is located a kilometre from Durban's newly constructed Moses Mabhida Stadium.

The commuter station is the first South African building to be added to Arup's international track record as multidisciplinary designer of some of the world's most prestigious transport buildings.

Construction began in April 2009 and the station was completed during May 2010. The clients included Passenger Rail Agency of South Africa and Metrorail.

The team was lead by project consultant Arcus Gibb and included LDM quantity surveyors and, structural engineering company, Iliso Engineers. Grinaker-LTA provided the construction.

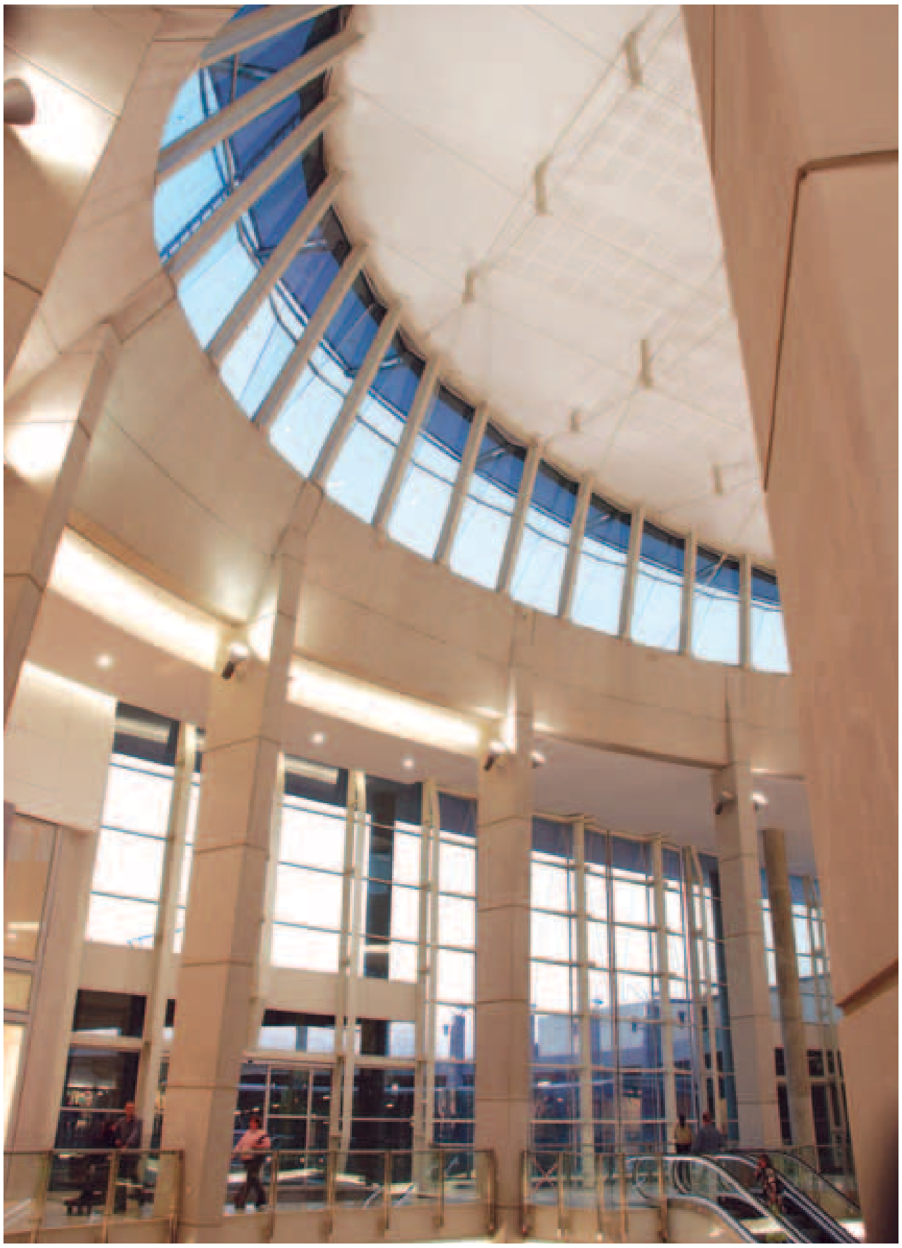
Celebrating Durban's potential and to fulfil its function as a key transport node, the station significantly improves the connectivity between the new King's Park Sporting Precinct and the broader Umgeni rail corridor.

Moses Mabhida Commuter Station will play an important part in transporting passengers to and from matches at the adjacent Moses Mabhida Stadium.

The design and form of the station resembles a ship at berth. It is tethered to its surroundings by a central pedestrian bridge, which connects and defines the station accommodation and the way it operates.The station's configuration is based on a simple, pragmatic two-level arrangement. Passengers and pedestrians approach the station from Isaiah Ntshangase Road, formerly known as the Walter Gilbert Bridge. The building's entrance and visitor reception facilities — such as ticketing facilities, turnstiles and concourse access — are located at high level. The high-level concourse provides all staff and security facilities and leads to the low-level platforms via stairs and lifts.

Caroline Sohie from Arup says that the intention behind the design is to show that public transport can have some dignity. "We have achieved our goal on this project by creating a strong identity for the station building that claims its own place next to the magnificent stadium. The design does not shirk its responsibility and nor does it overpower the landscape."


You can't see it...
but innovation is in our nature!
LAFARGE
LAFARGE
LAFARGE
RoadCem
ROAD BINDER
LAFARGE
Build crete
50 kg
GENERAL PURPOSE CEMENT
LAFARGE
bringing materials to life™



Green

The upmarket shopping precinct, which serves the residential area of Modderfontein, Edenvale, Linksfield, Linbro Park and Lombardy East, has been designed to be a state-of-the-art facility providing comfort and convenience for shoppers.

The centre court is modelled from an elliptical prism, which is projected from a point in the sky that is neither on the centre of the x-nor the y-axis of the ellipse.

Both the high concrete support structure and the structural steel elements of the roof light in the top middle section were shaped to match this complicated three-dimensional shape. The modelling was done in 3-D on Microstation. From these structural models the concrete and steel drawings were developed. The unique design, detailing and construction requirements were challenges that the team had to deal with in order to produce this spectacular, breathtaking but functional centre court.

Due to this very interesting outline each of the columns was different in size, orientation and shape. The sizes of the columns increased to the top but at different rates to match the elliptical prism profile. The contractor had to make up special shutters for each column to achieve the shape and also the required off-shutter finish.

The concrete mix design for the standard columns gave excellent results and the same mix was used in the construction of these columns.

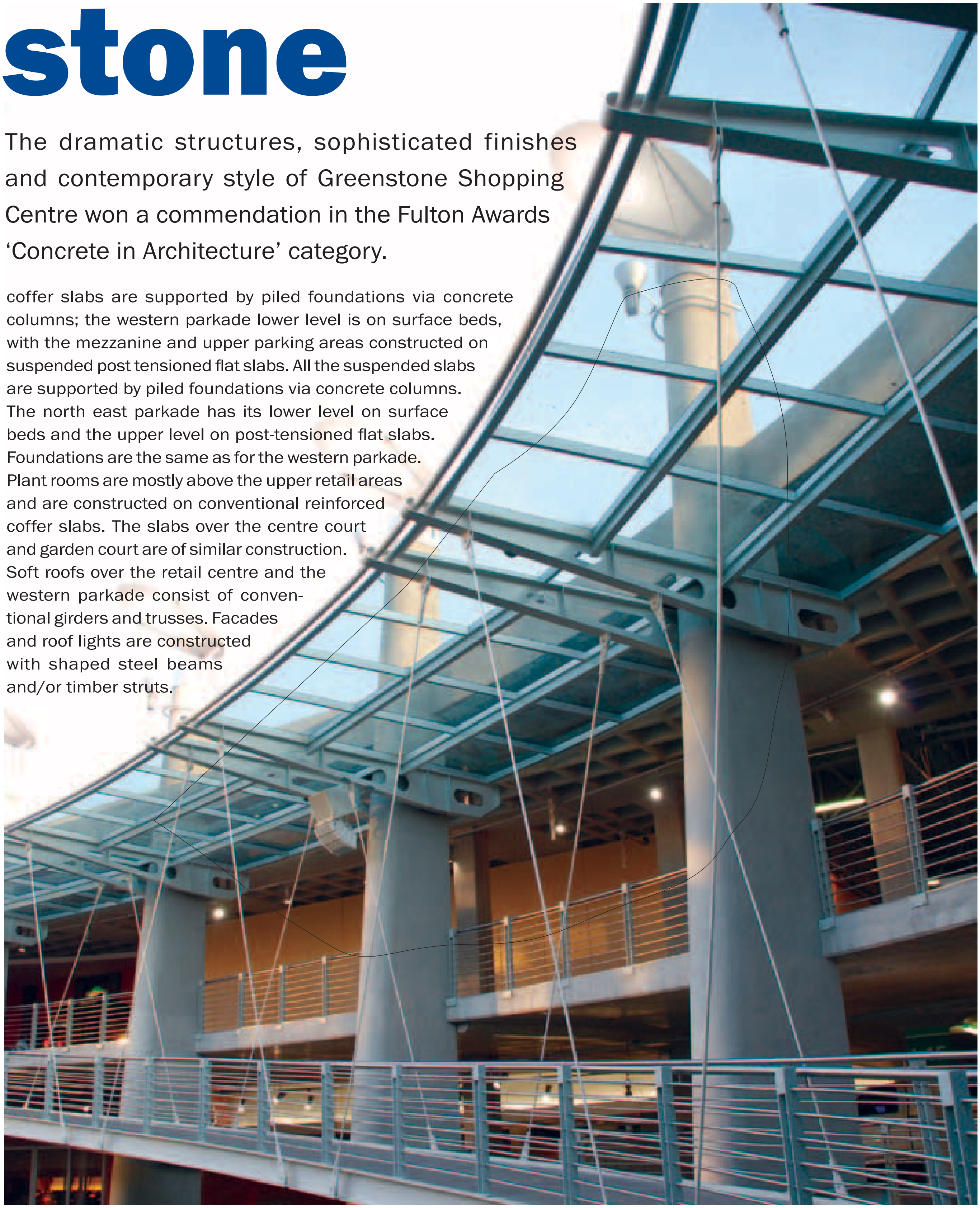
The upper retail area is on post-tensioned coffer slabs. These are supported by piled foundations via concrete columns. With the price of steel being very high, a post- tension coffer scheme as an alternative to a reinforced coffer scheme, was considered and priced in detail. In previous projects, a post-tensioned coffer solution had been less expensive. Due to cost, programme and flexibility benefits, the post-tension coffer design was used throughout for the upper retail floors.

The key elements of the shopping centre include: the lower retail area is on surface beds; the upper retail area is on post tensioned coffer slabs; the

stone

The dramatic structures, sophisticated finishes and contemporary style of Greenstone Shopping Centre won a commendation in the Fulton Awards 'Concrete in Architecture' category.

coffer slabs are supported by piled foundations via concrete columns; the western parkade lower level is on surface beds, with the mezzanine and upper parking areas constructed on suspended post tensioned flat slabs. All the suspended slabs are supported by piled foundations via concrete columns. The north east parkade has its lower level on surface beds and the upper level on post-tensioned flat slabs. Foundations are the same as for the western parkade. Plant rooms are mostly above the upper retail areas and are constructed on conventional reinforced coffer slabs. The slabs over the centre court and garden court are of similar construction. Soft roofs over the retail centre and the western parkade consist of conventional girders and trusses. Facades and roof lights are constructed with shaped steel beams and/or timber struts.



The team included: WSP Structures Africa; principal agent: Bentel Associates International; client: Sasol Pension fund; and contractor WBHO.

The judges said that the high quality off-shutter concrete finish achieved particularly on the atrium columns and roof ring beam structure, was visually stimulating, and linked well with the 'contemporary' style and aesthetic appeal adopted for the development.

The open feeling created by the tall reinforced concrete feature columns enhances the attractiveness of the shopping centre to users. The decision by the designers to leave the off-shutter post tensioned concrete coffer slabs and reinforced concrete columns in the unpainted parkade area, reveals the honesty of this particular part of the building.

Early age cracking and capillary pressure-controlled concrete curing

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ABSTRACT: Due to the evaporation of water at fresh concrete surfaces, a capillary pressure is built up in the pore system of the material leading to shrinkage deformations, ie the so-called capillary or plastic shrinkage, and possibly to cracking. By influencing the capillary pressure build-up, the risk of cracking in the very early age, ie within the first few hours after casting, may be reduced significantly. A method of controlled concrete curing is proposed. It is based on in situ measurements of the capillary pressure by using wireless sensors. If the measured pressure reaches a previously defined threshold value, the concrete surface is rewetted. Experimental and numerical results concerning the physical behaviour of drying suspensions are presented and observations made and discussed during on-site capillary pressure measurements.

1. INTRODUCTION

The presented work is aimed to reduce the early age cracking risk in concrete construction. Cracks in concrete structures may occur approximately within the first four hours after casting, ie when the material is still in its plastic stage and before it has reached a significant tensile strength. Similar phenomena as those leading to concrete cracking in this age may also be observed in drying suspensions with inert solid particles, for instance in silt. Physical processes rather than chemical reactions are the predominant reason for volume changes and cracking in plastic concrete (Wittmann 1976, Cohen et al. 1990, Schmidt et al. 2007, Slowik et al. 2008a). Therefore, drying suspensions consisting of fly ash and water may serve as model materials for studying these processes (Slowik et al. 2008a, Slowik et al. 2009). Such suspensions are characterised by a cement-like particle size distribution and by spherical particle shapes.

Planar concrete structures such as floors and roads are particularly prone to shrinkage and cracking in the plastic stage. This may be attributed to their large surface subjected to the evaporation of water. After casting, the fine solid particles, ie, those of the cement and additives are covered by a plane water film at the top face of the concrete where evaporation usually takes place. The self-weight of the solid particles may lead to a settlement of the same and, accordingly, to the transport of additional water towards the upper surface, ie to the bleeding of the concrete. Due to evaporation, the thickness of the water film reduces and, eventually, the near-surface particles are no longer covered by a plane water film. Due to adhesive forces, a curved water surface with so-called menisci in the interparticle spaces, see Figure 1, is then formed. Accordingly, a negative capillary pressure is built up in the water, the magnitude of which may be calculated by using the Gauss-Laplace equation.

$$p = -\gamma \left(\frac{1}{R_1} + \frac{1}{R_2} \right) \qquad (1)$$

The pressure p depends on the surface tension γ of the liquid phase and on the main radii R of its curved surface. It has to be considered that in cement paste water loss is not only caused by evaporation but also by the cement hydration beginning later.

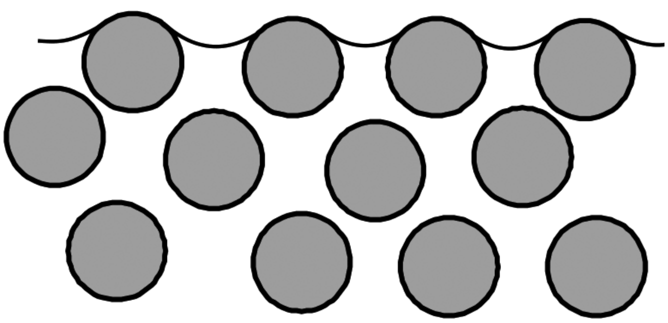

Figure 1: Curved water surface between near-surface solid particles in a drying suspension.

The negative capillary pressure results in inward forces on the particles at the surface. The microstructure is compacted, resulting initially in a measurable settlement or vertical shrinkage of the material. After the material has been separated from the side faces of the mould, or after cracks are formed, the contracting capillary forces lead also to a shrinkage strain in the horizontal direction. Up to this stage, the volume change of the material is approximately equal to the volume of the evaporated water (Grube 2003, Slowik et al. 2008a).

However, the expansion of entrapped air might cause a deviation, however. While water is evaporating, the curvature of the menisci is increasing, the absolute capillary pressure value continues to rise, and the material volume is getting smaller. Since this volume change is caused by capillary forces, plastic shrinkage of concrete is also referred to as capillary shrinkage.

At a certain material specific pressure, air penetrates suddenly into the pore system (Wittmann 1976, Slowik et al. 2008a). This is the case when the curvature of the water surface is too large for bridging all the spaces between the particles at the surface where evaporation takes place. According to the terminology used in soil physics, this pressure value is referred to as air entry value (Slowik et al. 2008a).

Air entry appears to be a local event because of the irregular particle arrangement it does not occur simultaneously in all pores. The latter are drained successively starting with the largest ones. The air entry value marks the first instance of air penetrating the pore system. If the capillary pressure is measured at a location where air entry takes place, the pressure 'breaks through' (Wittmann 1976), ie it drops down to zero.

Figure 2 shows measured curves of the capillary pressure versus time in a cement paste sample, as well as in a sample made of fly ash and water. Each of the samples was instrumented with two capillary pressure sensors at different locations, but at the same depth of 4 cm. Details of the experimental set-up are described by Slowik et al. (2008a). It may be seen that the curves obtained for different sensor positions follow the same path. The maximum absolute pressure values, however, are different.

This may be attributed to the air entry which does not happen simultaneously into all pores. For this reason, the maximum absolute pressure value measured at a certain location cannot be considered to be a material property. It depends on the sensor location. In addition, the pressure might 'break down' locally, due to air bubbles reaching the sensor tip.

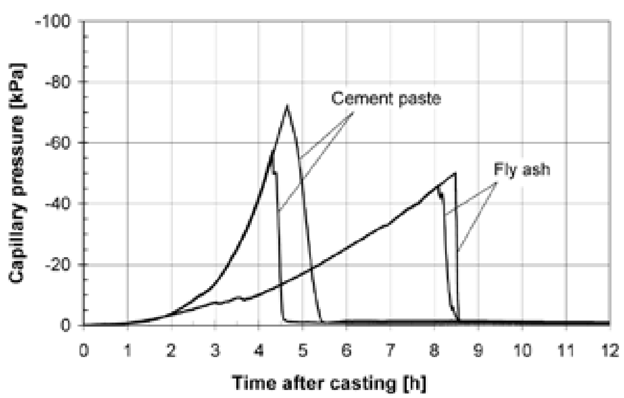

Figure 2: Capillary pressure versus time, measured at a depth of 4 cm, specimen height 6 cm.

When the concrete is in its plastic stage, all pores are interconnected and the capillary pressure is almost constant in the vicinity of the surface. According to the authors' experimental observations, this is the case up to a depth of at least 10 cm in common cementitious materials. Hydrostatic pressure differences are much smaller than the absolute value of the capillary pressure being built up.

When the air entry value is reached, the cracking risk increases significantly. The pores where air has penetrated into are weak spots at the material surface, and origins of crack initiation. This has been shown experimentally by electron microscopic observations (Slowik et al. 2008a, Schmidt et al. 2007) and by force measurements (Slowik et al. 2008b). In suspensions consisting of fly ash and water it was observed that shortly after air entry cracks were formed along a line connecting the weak spots mentioned above. Crack initiation requires air entry, whereas air entry does not necessarily result in cracking. Strain localisation and crack formation might be prevented by a limited mobility of the solid particles, although air entry takes place.

The causality between air entry and plastic shrinkage cracking led to an idea for a concrete curing concept. If the absolute capillary pressure being built up in the plastic concrete is permanently kept below the air entry value of the material, cracking can not occur. A corresponding curing method is described in section 4.

Early age cracks are not only an aesthetic problem. They also may degrade the durability of the structures. Even if they are not visible or if they have been temporarily closed during surface finishing, they do have an influence on damage processes taking place during the service life of the structure. Numerical studies into the drying shrinkage cracking of hardened concrete have shown that the obtained crack patterns are strongly influenced by pre-existing early age cracks (Slowik et al. 2008b). The latter may lead to distinct damage localisation and larger crack widths. Thus, the concrete permeability will be increased and the durability of the structure might be unfavourably affected.

2. MEASUREMENT OF THE CAPILLARY PRESSURE IN PLASTIC CONCRETE

In laboratory experiments, the capillary pressure build-up in drying suspensions has been studied (Slowik et al. 2008a). The test materials included cement paste as well as suspensions made of fly ash and water. In addition to the capillary pressure, deformations, the specimen temperature as well as the electrical conductivity in different depths were measured. For the capillary pressure measurement, miniature pressure transducers were installed outside the forms into which the specimens were cast. The connection to the water-filled pore system of the material was provided by metallic tubes having an inside diameter of 3 mm. The location of the tip of the respective tube is regarded as sensor location. In the following, some experimental observations are described.

The slope of the capillary pressure versus time curve depends on the evaporation rate and on the material characteristics. The higher the evaporation rate and the smaller the particle sizes, the steeper the increase of the absolute capillary pressure value. The last mentioned effect results from the smaller surface pores in the case of smaller particle sizes. Moreover, for smaller particle sizes higher absolute pressure values are reached. Air entry into the smaller pores requires a higher curvature of the water surface and, accordingly, a higher capillary pressure. Therefore, high-performance concrete compositions tend to be more vulnerable to early age shrinkage and cracking when compared to conventional structural concrete. This is due to the small particle sizes, the high binder contents and the low water-cement ratios. These characteristics lead to comparably high absolute capillary pressure values and shrinkage strains. Consequently, the early age cracking risk is higher. In addition, a more intense self-desiccation increases the water loss rate.

The slope of the capillary pressure versus water loss curve depends on the specimen height of the drying suspension. This effect has been extensively investigated by Radocea

(1992). The higher the specimen — the higher the potential for material consolidation. In other words, out of a higher specimen more water can be transported to the surface where evaporation is taking place.

As mentioned before, the maximum absolute capillary pressure value, the so-called 'break-through' pressure, measured in a drying suspension depends on the sensor location and may not be regarded as a material property. However, the pressure reached at the first instance of air entry into the pore system should be specific for a certain material. This pressure is called air entry value and mainly depends on the pore structure at the specimen surface and on the mobility of the particles. It has been found that under certain experimental conditions, reaching the air entry value is accompanied by a temporary maximum of the settlement, ie of the vertical shrinkage, by an increasing deviation between specimen volume change and evaporating water volume as well as by a sudden drop of electrical conductivity (Slowik et al. 2008a). On the basis of these observations, the air entry value may be identified in laboratory experiments as a material parameter for a drying suspension.

Capillary pressure measurements were also undertaken under site conditions. Figure 3 shows capillary pressure versus time curves measured on a road construction site. Two sensors were applied to an actual concrete member which was treated by using a curing agent. A third sensor was applied to an uncured reference specimen, which had the same height and was cast simultaneously. It may be seen that the capillary pressure rise was much faster in the case of the uncured concrete specimen. Obviously, the curing agent reduced the evaporation rate. Consequently, the capillary pressure increase was retarded, although not prevented. This retardation reduces the cracking risk. Due to the beginning cement hydration, the particle mobility starts to decrease resulting in an increasing mechanical resistance to the capillary pressure.

Figure 3 also shows that at two different sensor locations in the cured concrete member almost the same capillary pressure values were measured. This confirms the results obtained under laboratory conditions.

In view of a capillary pressure based concrete curing, the corresponding measuring technique had to be improved. Since cable connections usually cause technical problems during the construction process, a wireless capillary pressure sensor was developed, see Figure 4 consists of a conic

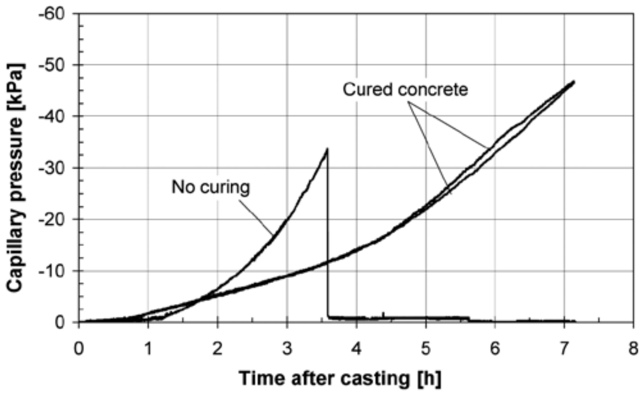

Figure 3: Capillary pressure versus time, measured at a road construction site.

Figure 4: Wireless capillary pressure sensor to be used for on-site measurements.

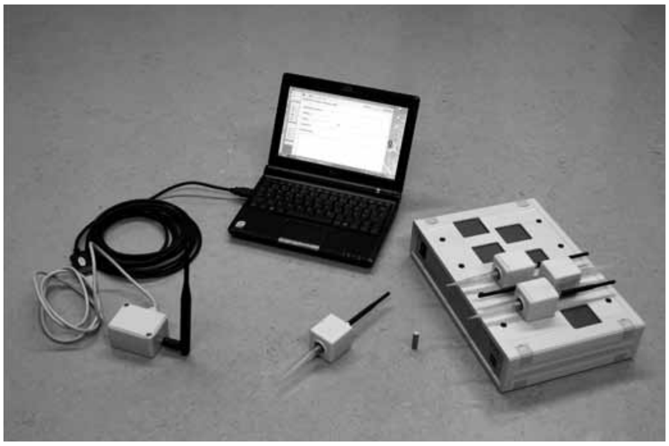

Figure 5: Measuring system for on-site capillary pressure measurements.

plastic tip, which is plunged into the concrete, a small cubic box containing the transducer as well as the radio module, and an antenna. The range of wireless transmission amounts to approximately 50 m. Prior to the sensor application; the plastic tip has to be filled with water in order to connect the sensor to the pore system of the material. After the measurement, usually after the final setting of the concrete, the sensor is simply extracted from the concrete surface and the remaining hole is closed. The plastic sensor tip may be replaced, if necessary.

Figure 5 shows the complete measuring system. It consists of the wireless sensors, the radio receiver box and a contactless battery charger. The receiver box may serve up to eight wireless sensors. In Figure 5, it is connected to a netbook via USB.

3. NUMERICAL SIMULATION OF CAPILLARY PRESSURE BUILD-UP AND CRACK INITIATION

The described capillary pressure build-up and the resulting crack initiation have been numerically simulated by using a 2D particle-based model (Slowik et al. 2009). It represents a drying suspension consisting of inert solid particles surrounded by water. Circular particles of different size are generated and placed in a rectangular specimen. The top face of the specimen is assumed to be open ie evaporation may take place. In order to simulate the loss of water, the absolute capillary pressure value is incrementally increased and the according course of the water front is calculated under the assumption of constant curvature of the water surface.

In addition to forces resulting from the capillary pressure, the solid particles are subjected to gravitational and inter-particle forces. The latter mainly include electrostatic and van-der-Waals forces. By superposition of these forces, a resulting interparticle force is obtained, see Figure 6. In the short-distance range, however, a simplified force-distance function has been adopted for computational reasons (Slowik et al. 2009).

Figure 7 contains the results of a numerical simulation of the capillary pressure build-up in a drying suspension with circular (dark colour) solid particles having a size ranging from 4 µm to 32 µm. The absolute capillary pressure value in the

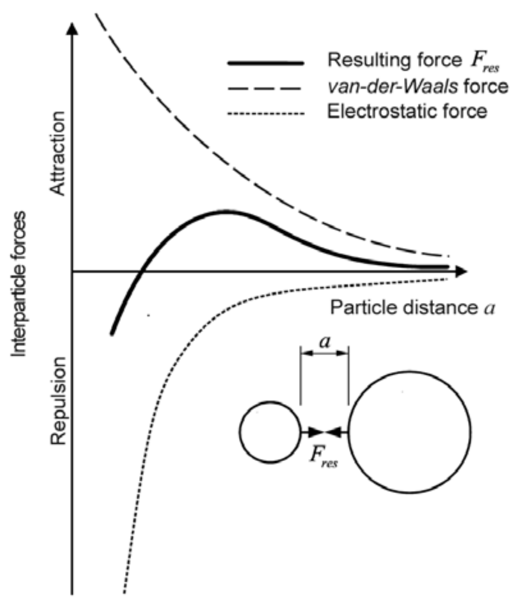

Figure 6: Interparticle forces versus particle distance (not to scale).

water (grey colour) is incrementally increased. The top figure shows the particle arrangement under zero pressure and the bottom figure for the maximum absolute pressure value reached. The latter amounted to 88 kPa. During the capillary pressure build-up ie under decreasing water content of the system, menisci are formed between the solid particles at the surface leading to downward forces and a settlement of the material. It may also be seen that the air entry into the material does not occur uniformly. Under certain conditions, strain localisation and crack initiation may be observed in such simulations. In the simulation shown in Figure 7, a 'gap' is formed on the right side of the specimen and widened by the rising capillary pressure. This phenomenon of strain localisation and separation is regarded as crack initiation.

By using the described 2D model, several influences on the capillary pressure build-up and on the early age cracking risk were investigated. The cracking risk is increased if the particle sizes are decreased. Furthermore, the capillary pressure versus water loss curve becomes steeper with decreasing particle sizes. The same effects could be observed when the portion of fine particles was increased. It was also found that the material appears to be more vulnerable to cracking in this case. These numerical results are in accordance with experimental observations.

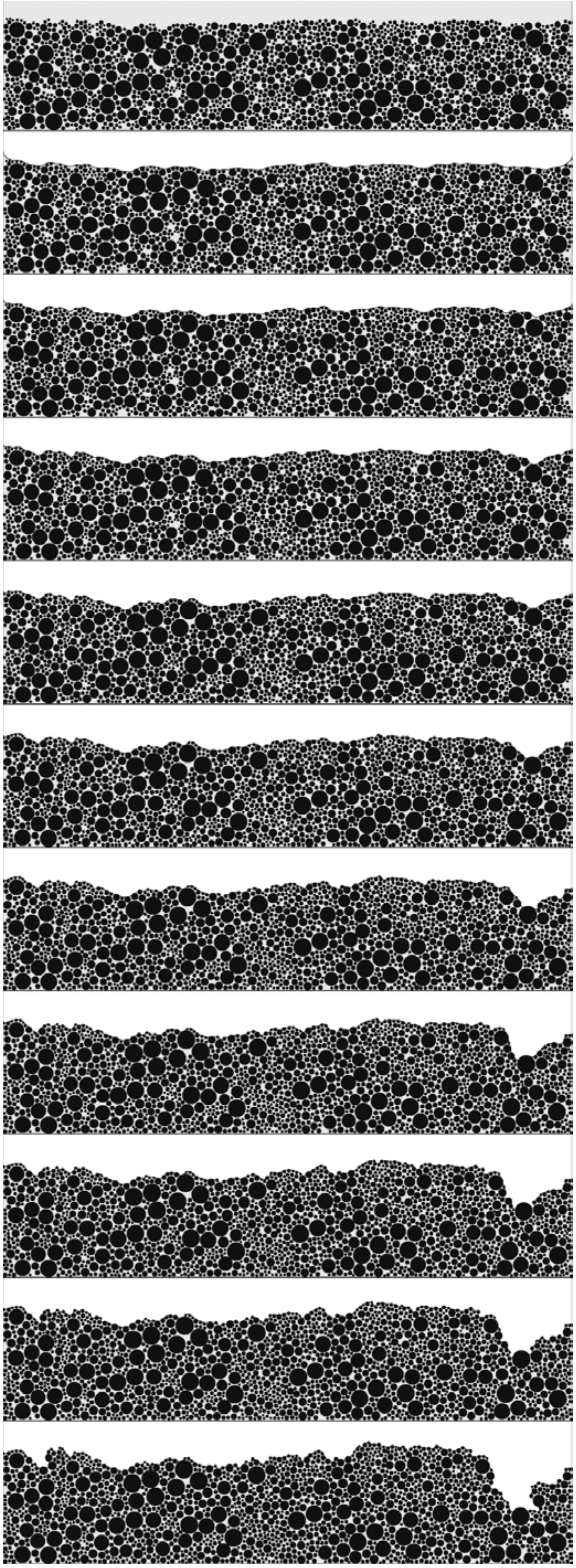

Figure 7: Simulation of the capillary pressure build-up in a drying suspension (absolute capillary pressure value increasing from top down, particles sizes ranging from 4 µm to 32 µm).

The capillary pressure values obtained in the simulations are in the same order of magnitude as those determined experimentally. The ongoing work on the simulation of capillary shrinkage cracking is aimed at a better understanding of the material based influences on the air entry value and on the early age cracking risk. Possibly, the numerical results can help to select an appropriate threshold pressure value for a closed-loop controlled concrete curing.

4. CONCRETE CURING BASED ON CAPILLARY PRESSURE MEASUREMENT

If the air entry value of a certain cementitious material is known, it is possible to define a critical absolute capillary pressure value which should not be exceeded during concrete processing. This value should be smaller than the absolute air entry value. In this way, the early age cracking risk may be significantly reduced since cracking requires air entry.

A method of closed-loop controlled concrete curing is proposed. It is based on the in situ measurement of the capillary pressure. If the measured absolute value reaches a previously defined threshold, the concrete surface is rewetted. This results in a temporary reduction of the capillary pressure. The rewetting is terminated when a lower limit is reached. It is recommended to always maintain a negative capillary pressure in order to prevent the formation of a water film on the concrete surface, which might have an unfavorable effect on the near-surface material properties. Furthermore, a moderate capillary pressure leads to an advantageous compaction of the microstructure.

Figure 8 shows the capillary pressure versus time curve measured in a concrete slab subjected to a controlled concrete curing. The corresponding curve measured in an uncured reference slab is also shown. It may be seen that the capillary pressure could be kept within a certain range between two limit values. The evaporation rate was monitored by using curing meters (Jensen 2006). An initial value of about 0.5 kg/ (m²h) has been measured, see Figure 9.

For the rewetting of the concrete surface, a commercially available fogging device was used, see Figure 10. Experience has shown that only a few seconds of fogging are required for reducing the absolute capillary pressure value down to its lower limit. The major advantage of the closed-loop control is that only the amount of water actually needed, for preventing early age cracks, is added to the concrete surface. Hence, the surface quality is not degraded by the rewetting.

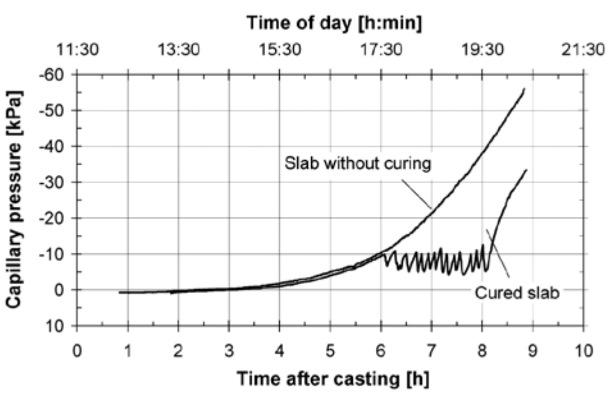

Figure 8: Capillary pressure versus time in a concrete slab under controlled curing.

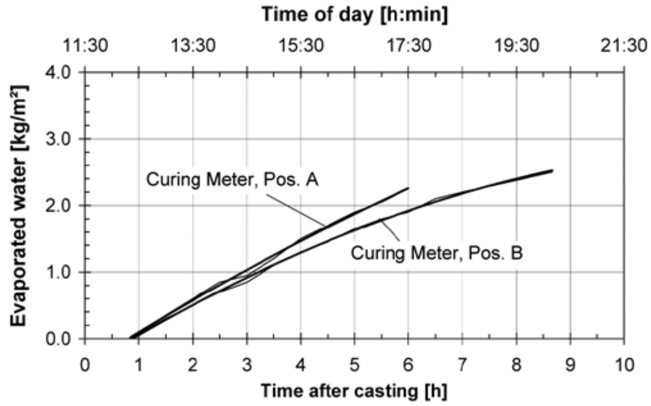

Figure 9: Evaporated water mass versus time, measured by using curing meters (Jensen 2006).

In field experiments, the effect of the proposed curing method on the crack pattern formed in the plastic stage could be demonstrated (Slowik et al. 2008b). The number of cracks as well as the total crack length was significantly reduced.

5. CONCLUDING REMARKS

Concrete in its plastic stage may be regarded as a drying suspension consisting of solid particles and water. The loss of water results in the build-up of a negative capillary pressure in the liquid phase of the material. Capillary pressure-induced local air entry into the material may then lead to crack initiation.

By keeping the absolute capillary pressure value below the value at which air entry takes place, crack initiation may be prevented. This concept requires the in situ measurement of the capillary pressure and the closed-loop controlled rewetting of the plastic concrete.

The material-dependent critical capillary pressure value and the required duration of the controlled curing will be subject to further research.

The application of the proposed curing method might be too expensive for many ordinary projects in concrete construction. Even in these cases, the wireless capillary pressure sensors might be utilised in order to obtain valuable information on the actual cracking risk and on the efficiency of curing measures. The sensors are comparably inexpensive and do not disturb the construction process.

Figure 10: Fogging device.

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Concrete’s low carbon path

Renowned concrete technologist Gordon Forrester shared his presentation on ‘Where is Concrete Headed?’ with exhibitors and delegates, at the annual Pan Mixers South Africa Trade Fair, in September.

The concrete technologist has consulted on the iconic Gautrain, South Africa’s first 100 year durability project, as a qualified Seta (Skills Education Training Authorities) assessor and accredited ACT specialist. Forrester travelled over 150 000km for the Bombela Consortium, training and visiting every single Gautrain site over a two and a half year period.

He is excited about developments for concrete’s future low carbon emission path.

Green Cement

Worldwide, cement factories produce about 5% of all carbon dioxide, (CO_2) emissions. Carbon dioxide is released as limestone ($CaCO_3$) is calcined. During calcining, when limestone is heated it produces CaO, free lime plus CO_2.

Green cement technologies have been welcomed by industry as they lower the cement producers’ carbon footprint and reduce the massive fuel and electricity input required by the plants. Pulverised coal or other fuel is required for cement clinkering and milling of clinker has high electricity requirements.

Manufacturers reduce pollution by using suitable waste products that are effective additives in concrete. This offers many benefits. Green cement reduces ‘pure’ cement need, as producers use valuable waste materials to replace a portion of the cement.

Forrester says that by taking plain cement and adding waste material such as fly ash and slag, the carbon footprint is reduced. Coal-fired boilers produce fine ash that is filtered from the boiler gases. Fly ash reacts with calcium hydroxide to produce more cementing compounds and provides some valuable concrete qualities.

Slag is produced during the steel manufacturing process. During smelting, impurities rise to the surface of the iron. The slag is tapped from the top of the molten iron in the furnace. The molten slag is granulated by being poured into cold water, where it changes to a glassy substance that has cementing properties after being ground to a powder. Slag will harden when mixed with water but hardening is a very slow process. If the slag is mixed with Portland cement, the strength gain is accelerated and the effects of both are enhanced.

Gordon Forrester

Forrester says that Self Cleaning Concrete, Pervious Paving and Autoclaved Aerated Concrete are also all classed as ‘green’ technologies.

Self Cleaning Concrete

Self cleaning concrete technology is something that could be used more in the country, says Forrester. This isn’t a futuristic idea but is a new technology that has environmental improvement capabilities.

Self cleaning concrete uses an admixture containing photo catalysts. These are based on titanium dioxide – the photo catalyst decomposes organic material such as grime, oil, bacteria and allergens on the surface of the concrete. The contaminants become easy to remove as the surface becomes hydrophilic, which causes the surface to ‘wet out’. This prevents moisture from forming beads of water on the surface, which leads to staining by attracting and holding the dirt. Water or rain rinses the contaminants away.

Titanium dioxide on the surface of the concrete creates a self cleaning material. The titanium-based catalyst is not consumed as it breaks down

Jubilee Church in Rome

pollution, but continues to work. On pavers the catalyst can nullify the nitrous oxide found in motor exhaust pipe fumes, as it catalyses the dirt and the carbon, making them water soluble, and thus easy to wash away.

Buildings stay cleaner and do not require chemical applications that are potentially harmful to the environment and this reduces maintenance costs. The technology can be applied to white or grey cement and it works with any Portland cement. It can be used in all varieties of concrete, including plaster. White self cleaning concrete was used on the iconic Jubilee Church in Rome.

Pervious Concrete

With climate change impacting on the environment – pervious concrete provides a solution.

Pervious concrete is a special type of concrete with high porosity, or concrete paving blocks in concrete flatwork applications.

Pervious concrete has little, or no, fine aggregate and has just enough cementitious paste to coat the coarse aggregate particles while preserving the interconnectivity of the voids. Typically pervious concrete has a water to cementitious materials (w/cm) ratio of 0.25 to 0.35, with a void content of 15 to 25%. Addition of a small amount of fine aggregate will generally reduce the void content and increase the strength, which may be desirable in certain situations.

The natural absorption of the systems will allow the water to permeate, either through the concrete, or between the joints of the paving and soak into the earth.

Pervious concrete is traditionally used in parking areas, areas with light traffic, residential streets, pedestrian walkways, and greenhouses. It is an important application for sustainable construction and is one of many low impact development techniques used by builders to protect water quality. Pervious concrete naturally filters storm water, can minimise traffic aquaplaning, and can reduce pollutant loads entering into streams, ponds and rivers.

Autoclaved Aerated Concrete

When mixed and cast in forms, several chemical reactions take place that give Autoclaved Aerated Concrete (AAC) its light weight. This is approximately 20% of the weight of conventional concrete. During production, aluminium powder reacts with calcium hydroxide and water to form hydrogen. The hydrogen gas foams the mix to about double the volume with gas bubbles 1-5mm in diameter. AAC can be reinforced with mesh prior to foaming. At the end of the foaming process the hydrogen escapes to the atmosphere and is replaced by air.

Before autoclaving, the malleable material is called cake. The material is cut into either blocks or panels and placed in an autoclave chamber for approximately 12 hours. During this process the temperature is raised to 190°C and vessel pressurised to 8-12 bars. The quartz sand reacts with calcium hydroxide to form calcium silica hydrate. This gives the material its unique lightweight, thermal insulation and approximately 7MPa.

Depending on its density, up to 80% of the volume of the mass is air. The low density produces a relatively low compressive strength – AAC has lower compressive strength than regular concrete and blocks have similar strength to brick masonry.

The construction benefits are immense. Forrester says “Imagine picking up a block, gluing it together with a thin cementitious paste. Grooves can be cut-out for wiring and then plastered over. It is almost like building with polystyrene blocks except that it is fireproof, non-toxic and once it is plastered it looks the same as any other building. In addition, it provides excellent thermal and sound insulation properties."

The Australian construction industry uses autoclaved aerated concrete extensively in high rise buildings. Hebel Autoclaved Aerated Concrete systems have developed flooring slabs out of lightweight material (<1000kg/m^3) with added reinforcing. In some applications it is possible to replace a heavy concrete slab — 1 cube of conventional concrete has a mass of about 2400kg — with lightweight AAC planks and the dead loading in the structure is thus reduced.

Polymer Concrete

Forrester says that polymer concrete can be used for products that are normally made of iron or steel. The material is made of resins and suitable aggregates, such as sand and stone. The resin could be polyester, epoxy or vinyl. A polymer concrete unit could have a mass of 10% of that of reinforced concrete product of a similar size. Polymer concrete has a high resistance to most chemicals, a lightweight nature, extreme temperature resistance, minimum wear from abrasion and low absorption. These characteristics make it a high quality material for pipes, door frames, window frames, electric light poles and fencing posts.

Polymer concrete won't corrode, and its light weight reduces the need for heavy lifting equipment which ultimately provides a reduced impact on the environment. It is ideal for handrails on bridges. The corrosion-resistant product could be used for pre-cast drainage channels, sewerage work and other infrastructure projects.

Reinforcement

Steel is the traditional reinforcement material but poor concrete can promote the rusting of steel. Carbon dioxide can penetrate poorly compacted concrete, which lowers the pH of concrete. This reduces the passivation of the steel. In addition, chloride penetration aids the formation of corrosion cells. Forrester says that when steel rusts, it expands. The expansion can increase the size of the steel by six times. If steel expands in concrete it creates tensile forces, which cause the concrete to crack and break.

Polymer Glass fibre rebar is a fairly recent reinforcement development. There are a number of ACI design and codes reports available eg ACI 440.5-08(2008) 'Specification for Construction with fibre-Reinforced Polymer Reinforcing Bars'. Glass Fibre Reinforcement such as the non-conductive V-Rod GFRP rebar, from America, can add durability to concrete in new aluminium smelter construction, says Forrester.

"Many years ago, extensive repairs had to be carried out at Richard's Bay aluminium smelter because of rebar corrosion. Stray currents from the melting pots, and a highly laden chloride environment, caused accelerated corrosion. Glass fibre rebar will not rust; it is impervious to salt ions, chemicals and the alkalinity loss in concrete. The glass fibre rebar is light. It weighs approximately 25% of an equivalent steel size. Glass fibre rebar is electromagnetically neutral. It does not contain metal or conduct magnetic fields. It can also be used in medical facilities or near electronic testing equipment. "Imagine being able to construct reinforced concrete without being concerned about carbonation, or concrete cover to the steel," says Forrester. Glass fibre rebar is produced using the pultrusion process.

Pultrusion

Pultrusion is a manufacturing process for producing continuous lengths of reinforced polymer structural shapes with constant cross-sections. Raw materials are a liquid resin mixture, containing resin, fillers and specialised additives and flexible textile reinforcing fibres. The process involves pulling these raw materials through a heated forming die, using a continuous pulling device, rather than pushing, as is the case in extrusion.

The reinforcement materials are in continuous forms such as rolls of fibre glass fibre, mat and fibre glass roving. The reinforcements are saturated with the resin mixture, being thoroughly 'wet-out' in the resin bath, and then pulled through the die. The gelation, or hardening, of the resin is initiated by the heat from the die and a rigid, cured profile is formed that corresponds to the shape of the die.

Forrester says that glass fibre reinforcement bars have been tested in USA since 2004. Their use has not been approved for use in structures at this point, but it is likely that the material will find its way into the South African market as its usage increases overseas.

Conclusion

The concrete technologist says, "Sometimes we close our minds and make things complex, which are not as complex as we think. Research is lots of fun and broadens my mind – keeps me thinking outside the box."

Quality Control

Quality control and laboratory accreditation, which standards are used and how often the testing facilities are audited?

These are the questions posed by Steve Crosswell, Technical Support Manager at PPC Cement. He says that specifications often state that tests must be carried out by 'an approved laboratory' and the facilities audited. But in my experience this rarely happens.

In the 1980s, the South African Bureau of Standards (SABS) adopted the Code of Practice SABS 0259, which covered the competence of laboratories. In 1990 that code was replaced by ISO/IEC* Guide 25, which in turn was superseded by SABS ISO/IEC 17025 in 1999.

This standard code of practice is still current and is entitled 'General requirements for the competence of testing and calibration laboratories'.

Accreditation to this standard is the responsibility of the South African National Accreditation System (SANAS). ISO is the International Standards Organisation, while IEC means the International Electrotechnical Commission.

Laboratory accreditation

The first step is to make an application to SANAS. The application must include a policy statement, procedures, work instructions, test methods, work sheets, sample reports, etc. Most importantly, the applicant must be able to demonstrate that the laboratory's operations substantially comply with the standard's requirements, ie it has a track record of producing reliable results and its staff members are competent.

These documents are subjected to review, and if the review is successful, an initial audit is scheduled. The audit team comprises a lead auditor and at least one technical auditor. The applicant may be required to revise or amend some of his documentation prior to the first audit.

At the first audit — the lead auditor will normally audit in compliance with the 14 Management requirements of the standard, and the technical auditor will assess the technical competence of the laboratory in terms of the 10 technical requirements of the standard. This will include checking of all equipment records, calibrations, reference tests, validations, staff competency, etc.

There are three possible results of the first audit: failure – this is rare as the document audit weeds out these applicants; conditional approval, which is subject to clearing of findings, sometimes with a follow-up audit this is the most common outcome; unconditional approval – this is rare unless the scope of accreditation is very narrow. The accreditation period is five years and it is SANAS' policy to keep the same audit team for that term.

Once a laboratory is accredited it is re-audited after six months, then a year later, then 18 months after that. At this stage, accreditation will last for two more years, when the 5-year cycle starts again with the submission of a new application and a new audit team may be appointed.

Benefits of accreditation

There are many benefits for the laboratory. The management and technical competence of the laboratory is shown to be of the highest international standard. With certification of a laboratory to ISO 9001 or ISO 9002 it becomes easy to manage the laboratory because procedures and methods are well structured, and non-conformances are easier to detect and correct.

It commits senior management to the quality system. It ensures independence of the laboratory from other company influences, for example, sales, distribution, finance, etc.

For the client the benefits include the knowledge that results are traceable to international standards and the tests have been carried out by competent staff on well-maintained, regularly calibrated equipment. The results are reliable. In the event of a dispute, the results will carry far more weight than results from a non-accredited laboratory.

It is important for the client to realise that most accredited laboratories carry out both accredited and non-accredited work. For example, a laboratory may be accredited to test concrete cubes, but not flakiness index, although it may carry out the test. It must be clearly indicated on test reports whether the test results were derived from accredited tests or not. Commonly, non-accredited test results are marked as such and results not so marked are deemed to be accredited by default. Similarly, comments, remarks and interpretive calculations are not accredited and must be marked as such.

To find out more about laboratory accreditation and SANAS, visit the SANAS website at www.sansa.co.za. The site contains all the relevant documentation and a list of accredited testing and calibration laboratories.

PPC has three SANAS accredited testing laboratories at Jupiter (Johannesburg), while Cape Town and Port Elizabeth laboratories carry out aggregate and concrete tests on a commercial basis.

Taking to the water

The Annual Concrete Boat Race Day at Victoria Lake attracted 1400 concrete enthusiasts. The event held on September 18th provided ideal conditions for entrants it was clear skies, a light wind and paddling perfect calm waters on the lake.

Scrutinising the concrete boats

A record number of 59 boats registered for the event and the Society recruited additional judges to cope with the demand. The judging panel included Inland Committee members with a wealth of experience: Colin Kalis, Hanlie Turner, Daren Jacobs and President of the Concrete Society of Southern Africa, John Sheath.

There were various categories: students, cement and concrete industry members and boat racing and boat construction. As part of the students' curriculum, the learners' applied their knowledge of project management and concrete technology to their concrete boat construction. Members of the cement and concrete industry, stakeholders and representatives from the institutes raced to the finish.

Once again, the event attracted a record number of industry companies participating in the hope of picking up a coveted medal. University of Johannesburg lecturer, Deon Kruger was awarded a special prize as the lecturer who registered the greatest number of boat entries. It is the second time that Deon has collected this prize.

President of the Society, John Sheath thanked Deon for his support of the Society and of the boat race.

Competitors test the water

Chairman of the Inland Branch, Armand van Vuuren, thanked industry supporters for their contributions to making the event a great success.

Industry supporters included: cement suppliers Afrimix and AfriSam, the country's leading supplier of fly ash, Ash Resources, international chemical group BASF Construction Chemicals, developer Basil Read, the invaluable Cement & Concrete Institute, additive specialist, Chryso Southern Africa, Duraset, Group Five, French international cement and aggregate producer, Lafarge South Africa, Mapei SA, giant cement supplier, PPC Cement, Rocla, Ulula Ash and WR Grace.

The final Quarterly Technical Seminar will be held on October 21st, with a focus on Retaining Walls in Concrete.

The Chairman's Breakfast will be held on November 5th. The guest speaker is Simon Gear, environmental specialist, weatherman and author of Going Green, published by Penguin. Gear heads up SDG Consulting, environmental and air quality specialists.

Competitors out-paddling each other

Winning team 'Agter Os' took first prize in Student Construction Award

CONCRETE SOCIETY OF SOUTHERN AFRICA NATIONAL OFFICE PROGRAMME 2011			
DATE	**MEETING/EVENT**	**VENUE**	**CONVENOR**
1st Quarter of 2011			
March 2011	Durability Roadshow Seminar	Johannesburg, Durban, Port Elizabeth, Cape Town	Armand van Vuuren
March 2011	Concrete Beton	Sent out to all CSSA Members	Crown Publications
16th March 2011	AGM	Emperor's Palace	CSSA President
16 – 17th March 2011	Council Meeting	Emperor's Palace	CSSA President
April 2011	Source Book	Sent out to all CSSA Members	Crown Publications
2nd Quarter of 2011			
3 – 5th June 2011	2011 Fulton Awards Weekend	Champagne Sports Resort	Francois Bain
June 2011	Fulton Awards Concrete Beton	Sent out to all CSSA Members	Crown Publications
30th June 2011	Council Meeting	Emperor's Palace	CSSA President
3rd Quarter of 2011			
July 2011	Concrete Beton	Sent out to all CSSA Members	Crown Publications
4th Quarter of 2011			
13th October 2011	Council Meeting	Emperor's Palace	CSSA President
November 2011	Concrete Beton	Sent out to all CSSA Members	Crown Publications
November 2011	Council Nominations	Sent out to all CSSA Members	CSSA Administration
November 2011	Concrete Flooring Roadshow	Johannesburg, Durban, Port Elizabeth, Cape Town	To be confirmed

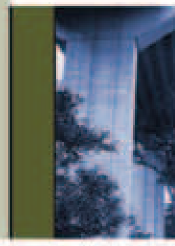
CONCRETE SOCIETY OF SOUTHERN AFRICA INTERNATIONAL EVENTS 2010			
DATE	**MEETING/EVENT**	**VENUE**	**CONVENOR**
17 – 22nd January 2011	BAU 2011	New Munich Trade Fair Centre, Munich Germany	Johannes Manager Andrea Hack
9 – 10th February 2011	Cement & Building Materials Conference & Expo	Grand Hyatt Hotel, Amman, Jordan	Strategic Business Development Company

Company Membership Details

Platinum	Principal Member	Address	Tel No	Fax No
AfriSam SA (Pty) Ltd	Mr M McDonald	PO Box 15 Roodepoort 1725	011 758 6000	011 670 5166
Lafarge Industries SA (Pty) Ltd	Mr H van Zyl	Private Bag X26 Gallo Manor Johannesburg 2052	011 257 3100	011 257 3439
Pretoria Portland Cement Company Ltd	Mr DJ Leach	PO Box 40073 Cleveland Johannesburg 2022	011 626 3150	011 677 2301
Gold	**Principal Member**	**Address**	**Tel No**	**Fax No**
BKS (Pty) Ltd	Ms S Ngebulana	PO Box 3173 Pretoria 0001	012 421 3681	012 421 3501
NPC-Cimpor (Pty) Ltd	Mr PK Strauss	PO Box 15245 Bellair 4006	031 450 4411	086 535 2772
Sika South Africa (Pty) Ltd	Mr PC Adams	PO Box 15408 Westmead 3608	031 792 6500	031 700 1760
Silver	**Principal Member**	**Address**	**Tel No**	**Fax No**
Ash Resources (Pty) Ltd	Mr GW Smith	PO Box 3017 Randburg 2025	011 886 2200	011 886 6140
Cement & Concrete Institute	Mr B Perrie	PO Box 168 Halfway House 1685	011 315 0300	011 315 0584
Chryso SA (Pty) Ltd	Mr NS Seymore	Postnet Suite 59 Private Bag X1 East Rand 1462	011 395 9700	011 397 6644
MAPEI SA (Pty) Ltd	Mr C Van Der Merwe	PO Box 75995 Garden View 2047	011 552 8476	011 552 8449
Bronze	**Principal Member**	**Address**	**Tel No**	**Fax No**
Active Scanning CC	Mr A Brown	Postnet Suite 152 Private Bag X4 Bedfordview 2008	072 627 7259	011 616 5058
Bapedi Civil & Structural Consultants CC	Mr BP Kunutu	PO Box 412689 Craighall 2024	011 326 3227	011 326 3363
CIP Penetron CC	Mr F McLennan	PO Box 149 Paarden Eiland 7420	021 551 2142	021 551 3553
Doka South Africa (Pty) Ltd	Mr U Meyer	PO Box 8337 Halfway House 1684	011 310 9709	011 310 9711
Empa Structures CC	Mr CA Bain	PO Box 3846 Durbanville 7551	021 975 7928	021 975 8225
Group Five KZN	Mr G Chambers	PO Box 201219 Durban North 4016	031 569 0300	031 569 0420
Jeffares & Green (Pty) Ltd	Mr CJ Meintjies	PO Box 794 Hilton 3245	033 343 6700	
Lategan & Bouwer Engineers	Mr K Lategan	PO Box 1215 Secunda 2302	017 634 4150	017 634 4188
Mexel Energy (Pty) Ltd	Mr J Lombard	PO Box 1862 Brooklyn Square Pretoria 0181	012 743 5999	088 684 1485
Quickslab (Pty) Ltd	Mr J Coetzee	PO Box 9 Brackenfell 7561	021 982 1490	021 982 1492
Scribante Concrete (Pty) Ltd	Mr S Scribante	PO Box 2179 North End 6056	041 406 9500	041 406 7901
Shukuma Flooring (Pty) Ltd	Mr A Stücki	PO Box 15552 Emerald Hill 6000	041 372 1933	041 372 1944
Stefanutti Stocks Civils (Pty) Ltd	Mr W Jerling	PO Box 12394 Aston Manor Kempton Park 1630	011 552 4011	011 393 2366
Structural Solutions CC	Mr R Govoni	PO Box 40295 Walmer 6065	041 581 3210	041 581 3126
UWP Consulting (Pty) Ltd	Dr A-C Brink	PO Box 13888 Cascades 3202	033 347 7900	033 347 7950
Verni Speciality Construction Products (Pty) Ltd	Mr VP Botha	PO Box 75393 Garden View 2047	086 118 3764	086 128 3764
WR Grace	Mr D van den Berg	64 Rigger Road Spartan Kempton Park 1640	011 923 4631	011 923 4672

FULTON *Awards* 2011

Call for Nominations



2011 Fulton Awards promises to, yet again, attract seriously significant entries due to the timing thereof being towards the culmination of a particularly active period in the local construction industry with some very large capital expenditure projects taking place.

The Concrete Society of Southern Africa (CSSA) is calling for nominations of projects for the prestigious Fulton Awards, presented by the Society every two years to honour excellence and innovation in construction utilizing concrete.

Awards will be made in the following 6 categories:

- OVERALL CIVIL ENGINEERING PROJECT
- OVERALL BUILDING PROJECT
- CONCRETE IN ARCHITECTURE
- UNIQUE DESIGN ASPECTS
- CONSTRUCTION TECHNIQUES
- INNOVATIVE TECHNOLOGIES

Any project completed during 2009 or substantially completed during 2010 is eligible for entry, and projects may be entered in more than one category. Closing date for nominations has been extended to 26 November 2010. The extended closing date for receipt of entry packs is 17 January 2011.

Francois Bain, Chairman of the Fulton Awards 2011 organizing committee, says: "The 2011 Fulton Awards promises to, yet again, attract seriously significant entries due to the timing thereof being towards the culmination of a particularly active period in the local construction industry with some large capital expenditure projects taking place".

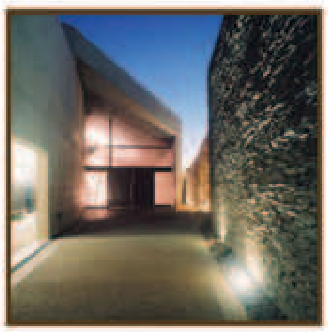
The occasion will be celebrated over the weekend of the 3rd to the 5th of June 2011 at the beautiful Champagne Sports Resort in the Drakensburg with the actual awards taking place at the exquisite gala event on the Saturday evening.

EXPOSURE FOR ALL 2011 SUBMISSIONS

The Society aims to provide increased exposure for all entrants and project submissions. As in 2009, emphasis is placed on the entries for the Fulton Awards with a special exhibition created for the nominated projects.

PUBLICATION OF ALL 2011 SUBMISSIONS

Each submission will be published in a special 2011 Fulton Awards Edition of the Concrete Beton.



cement & concrete institute

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CONCRETE SOCIETY OF SOUTHERN AFRICA

For nomination forms and entry packs, contact The CSSA Administrator on Tel: 012 348 5305 or admin@concretesociety.co.za