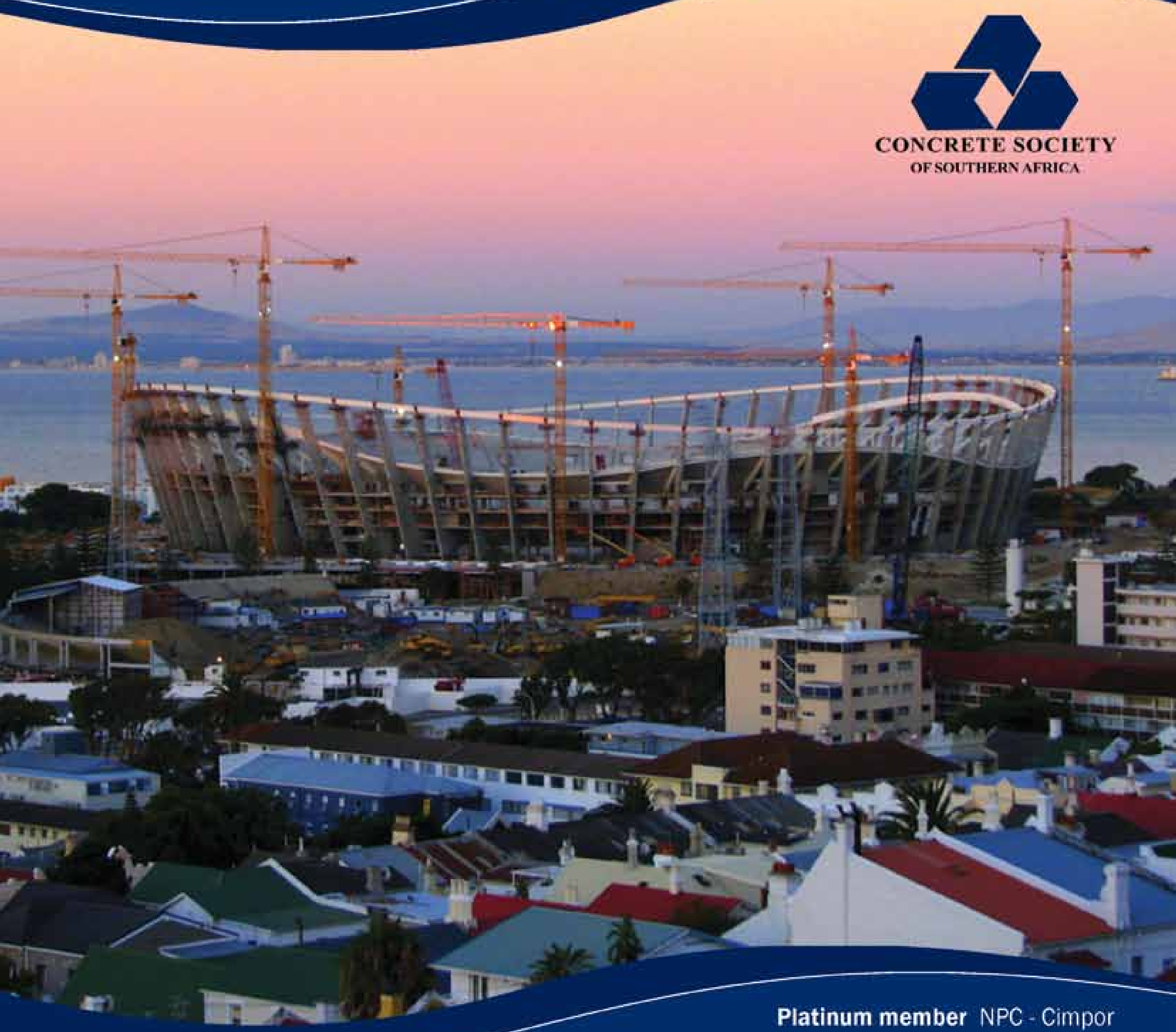
Concrete Beton

Number 122
August 2009

The Official Journal of The Concrete Society of Southern Africa

CONCRETE SOCIETY OF SOUTHERN AFRICA



Platinum member NPC - Cimpor

Accredited technical paper:
Importance of Processing in Advanced Cement-Based Products

Technical paper:
Self-compacting concrete
Specification, Testing and Performance

Concrete News and Events

President's Message

It is hard to believe that we have already passed the mid-point of this year.

My own life, over the last six months, has been a complete whirlwind. The major influencing factor obviously has been my involvement with the bi-enniel Fulton Awards which, after much planning and an intense adjudication process, culminated in the glamorous award ceremony weekend, held at the Champagne Castle Sports Resort over the weekend 19th – 21st June 2009.

I would like to once again thank all involved in arranging the event, from the highly effectual Fulton Awards Committee to the Society's administration. Our gratitude is also extended to the entrants who show-cased their marvellous projects.

The event was world class and I take this final opportunity to congratulate all the winners. Apart from the most important function of celebrating the finest achievements in the Concrete Construction Industry over the last two years, the Fulton Awards weekend also serves the purpose of both a highly effective networking opportunity as well as a weekend outdoors to spend quality time with the family. From what I saw this ideal was successfully achieved.

The Society's Council and Administration are already hard at work with the planning for the next Fulton Awards, the ceremony of which will take place mid-2011.

We look forward to seeing many of the significant projects currently on the drawing board or computer screen entered into the next session of this pinnacle event.

I would like to take this opportunity to yet again fondly congratulate and welcome our two new elected Councillors; Bryan Perrie of the C&CI and Armand van Vuuren from Chryso to serve for two years on the Society's Council. The skills of these two highly esteemed individuals augment well with those of the other council members and I am proud to be surrounded by such a strong team.

Looking forward to the always frenetic last half of the year, the Society will still be very busy. The next few months up to year-end are highlighted by a number of high profile events.

Most significant is the Advanced Concrete Materials International Conference scheduled to be held in Stellenbosch from the 17th November to the 19th November 2009. This promises to be a highly valuable session, especially for those interested in modern and futuristic concrete products, techniques, applications research and development.

I urge members to consider becoming involved as the topics covered will inevitably become main-stream in the near future and relate in particular to the civil and structural engineering industry.

We can confirm that the branches also have fairly full calendars for the remainder of the year. With the high quality of these events, be certain not to miss them. In particular are the Inland Branches ever popular concrete boat races, taking place on Saturday the 19th September 2009. This event attracts in excess of one thousand people to the shores of the Germiston Lake. This year promises to have a bumper attendance yet again.

More information on your local branch events, or the events being planned by any other branches should you find yourself in another city for a while, can be obtained from the Society's website. We look forward to seeing many of you at these events.

Francois Bain Pr Eng
President:
The Concrete Society
of Southern Africa

Cover: WSP Group Greenpoint Stadium in Cape Town. The roof area is 37 000m^2 with 9 000 glass sheets. Mass of roof steel and glass is 4 500 tonnes. There is 7,4 km of steel cabling in the roof. Seating capacity is 68 000.

Cold Weather Concreting

Bateman Engineering projects took the top honours in the Fulton Awards Construction Techniques category for the Letseng Diamond Mine project, in Lesotho. The Client: Letseng Diamonds, Principal Agent: Bateman Engineering Projects, and Contractor: Stefanutti Stocks Civils.

The diamond mine is located in the Maluti mountains 3 100 m above sea level. The project presented challenges for the team of design engineers and construction management.

The on site team had the task of ensuring the quality of concrete being produced and cast at temperatures – 20° C to meet the stringent quality controls under difficult conditions.

Bateman Engineering Projects is a project management and engineering company specialising in providing its clients with a full range of projects involving hydrometallurgical, pyrometallurgical, mineral processing plants etc.

The Letseng Diamond Mine Project entailed the engineering, procurement and construction management of a green fields, diamond processing facility located within an existing mining complex located in the Lesotho mountains.

The basis of the design was a mass dry process achieved by gravity alone. This approach was favoured over the standard slurry pumping (wet process) due to the high rate of damage to large diamond sizes experienced in the wet process. Bateman was responsible for the design and offered a process guarantee that an average of 350 tons per hour would be achieved by the plant. All associated support including civil and structural engineering had to ensure that this was met.

Letseng Mine is situated in Lesotho on the Buthe-Buthe/Oxbo road, approximately 450 km from Johannesburg and +/- 120 km from the Cledonspoort border post (near Fouriesburg). It is located at an average elevation of 3 100 m above mean sea level in the Maluti mountains of Lesotho.

The plant, inclusive of a stockpile tunnel, conveyors and MCC buildings, was constructed on an existing ground slope of 17 degrees to facilitate the gravity fed process plant, which resulted in four stepped terraces to assist in the design for this requirement.

The blasting process yielded an over excavation ranging in heights from two to five metres.

The over blasting necessitated introducing retaining walls to the process building and together with the redesign of building foundations due to increased column heights, it ultimately resulted in the proposed construction schedule extending into the winter months. This resulted in cold weather concreting being undertaken in temperatures ranging from a maximum of 20°C to a minimum of -20°C.

Some forward planning was required to take the necessary precautions against the cold weather during concreting operations which entailed the following procedures: tarpaulins used to protect aggregates, use of flood lights to heat the aggregate, pre-heating of aggregates and water, measures put in place to control mixing of concrete, controls put in place with placing of concrete and controls to ensure curing of concrete.

Cold Weather Concreting Judges' Citation

It impressed the judge that this design engineer/contractor combination worked so well together in order to perform a project that many of their contemporaries deemed impossible during winter in the highlands of Lesotho. In so doing they provided an economically viable solution to the client.

Among the noteworthy challenges that were overcome successfully by this team were working at altitude, working on steep inclines, problems with the availability of cement, suitable aggregates, access, manpower and most significantly mixing and placing concrete in very low temperatures.

The technical specification that was developed, including daily time regimes, was regarded by the judges as groundbreaking in Southern African terms.

This project proves that with good adherence to specifications, good management and excellent quality control on site, very difficult technical goals can be achieved.

The project is one the entire team should be proud of.

Cold weather concreting on the Lestseng Diamond Mine Project in Lesotho is a worthy recipient of the Fulton Award for Construction Techniques category for 2009.

Importance of Processing in Advanced Cement-Based Products

by KG Kuder and SP Shah

The design versatility of cement-based composites continues to make them attractive for a variety of specialised applications. Advanced processing techniques, including Hatschek's, extrusion, self-consolidating concrete and slipform-cast concrete paving, offer great promise for improving innovation in the modern construction world. However, to advance the state-of-the-art of cement-based products, the fresh state characteristics of these materials need to be well understood.

Synopsis

Processing has a significant impact on composite performance, affecting fresh and hardened state properties as well as overall cost. In spite of its importance, relatively little is known about the relationship between processing and composite performance.

Recent work at the Centre for Advanced Cement-Based Materials (ACBM), at Northwestern University, has focused on developing a better understanding of this critical relationship. The results indicate that overall composite performance can be enhanced by controlling fresh state properties. This paper presents a review of these studies and discusses ongoing research to link composite performance to microstructural changes.

Keywords: Extrusion, flocculation, fresh state properties, Hatschek-process, processing, self-consolidating concrete, slipform casting.

Processing of Hatschek-produced Composites

Introduction

The Hatschek-process is currently used to manufacture fibre-reinforced cement board (FRCB) for non-structural elements in residential construction. The composites are an attractive alternative to wood because they are more fire resistant, can better withstand fading, are not susceptible to insect attack and are more durable. Despite these advantages, use of Hatschek-produced FRCB in colder climates has been limited due to its vulnerability to freeze-thaw attack.

Hatschek process

Figure 1 presents a schematic of the Hatschek formation process. A dilute slurry of cement, silica, water and cellulose fibres is contained in a series of bins. Screens pass through these bins, collecting a monolayer of the material, which is then vacuumed to remove excess water. The monolayers are added to each other as the conveyor belt continues on to subsequent bins. This series of monolayers come together to form a single layer of the FRCB. Multiple layers are gathered on the accumulator role until the desired thickness is attained. At this point, the composite is then autoclave cured. The resulting FRCB is a laminated composite that is composed of a large volume of cellulose fibers, approximately 30%.

The freeze thaw-durability of FRCB produced by the Hatschek process is poor due to its high porosity, the organic cellulose fibres that reinforce it and its laminated structure. To overcome these weaknesses, some manufacturers have started pressing the FRCB after it is formed, expelling excess water and possibly improving the interlaminar bond (ILB). Research has shown that applying pressure to FRCB improves its mechanical performance[1,2,3]. The effect of pressure on the freeze-thaw durability of FRCB was investigated, with particular attention to the role of the ILB[4].

Experimental programme and results

Commercial Hatschek-produced FRCB that were 8 mm(5/16 inch) thick, reinforced with cellulose fibres and autoclave-cured were investigated. Immediately after the boards were formed, external pressure was applied at varying levels: 0, 10, 20 and 30 bars. Mechanical testing indicated that pressure increases the flexural strength, decreases flexural toughness (quantified as area under flexural stress – displacement curve) and increases interlaminar tensile strength.

Figure 2 presents the ILB as a function of pressure. ILB increases by 200% from 0 to 30 bars of pressure. Microstructural analyses were conducted using scanning electron microscopy and mercury intrusion porosimetry. These results suggest that the application of pressure improves the fibre-matrix bond and the interlaminar tensile strength by reducing the interlaminar space and the area between the fibers and the matrix[4,5].

To assess the freeze-thaw durability of the FRCB, specimens were subjected to as many as 300 accelerated freeze-thaw cycles according to a modified version of ASTM Standard C1185 Standard Test Methods for Sampling and Testing Non-Asbestos Fibre-Cement Flat Sheet, Roofing and Siding Shingles, and Clapboards[6]. Flexural performance and the interlaminar properties of the FRCB were evaluated after 50, 100, 150, 200 and 300 cycles. The results showed that flexural strength decreases after freeze-thaw conditioning. After 50 cycles, flexural strength improves with increasing pressure treatments. However, after more than 50 cycles, pressure treatments do not affect the flexural performance.

Figure 3 presents the ILB strength as a function of freeze thaw cycles and indicates that there is a significant decrease in strength (at least 80% for all materials) after only 50 cycles. However, despite this breakdown of the material structure, there is still a difference in the ILB strength for the different pressures. Even after 200 cycles, the ILB strength of the 30 bar material is twice that of the 0 bar, indicating that pressure may improve the ILB strength. Visual observations also suggest that

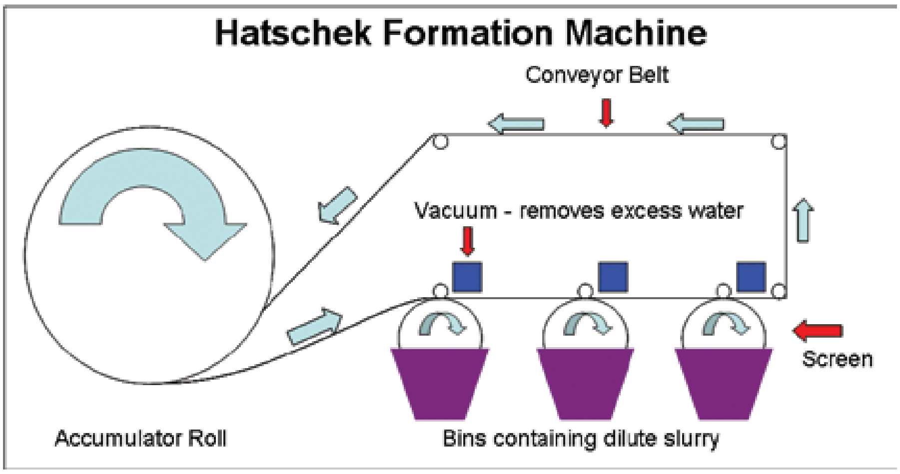


Figure 1 – Schematic of Hatschek slurry-dewatering process.[4]

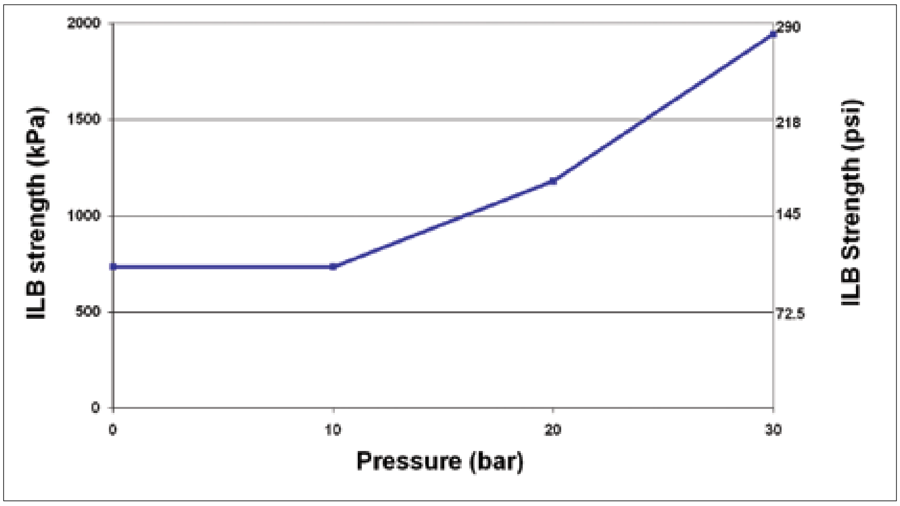


Figure 2 – Interlaminar tensile bond (ILB) strength as a function of pressure.[4]

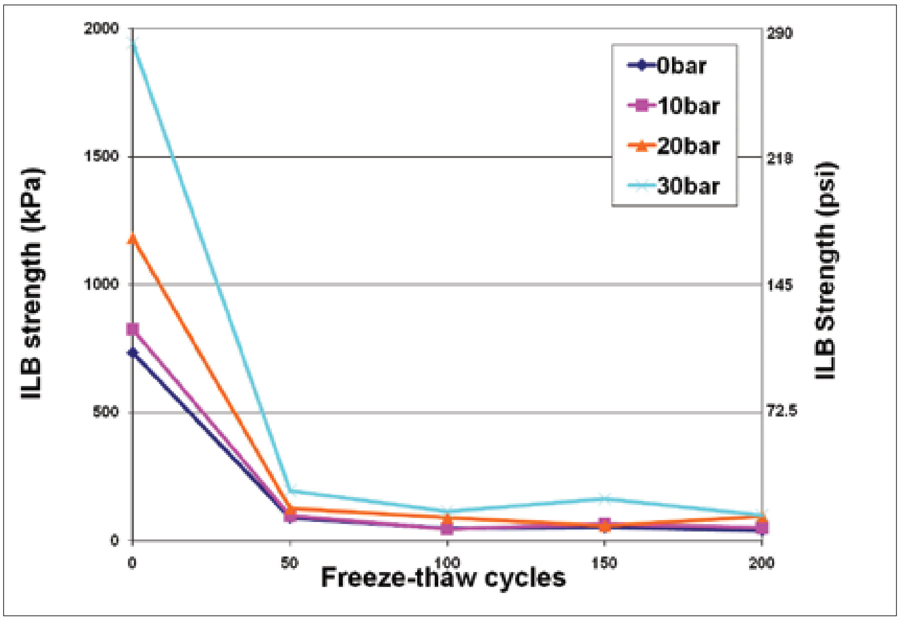


Figure 3 – Interlaminar tensile bond strength (ILB) as a function of freeze-thaw cycles for different pressure treatments.[4]

pressure treatments do improve the ILB and, consequently, the freeze-thaw durability of the FRCB.

Figure 4 shows 20 and 30 bar materials that have been subjected to 200 freeze-thaw cycles during the three-point bend test. A delamination failure is seen with the 20 bar material, whereas the layers remain in tact for the 30 bar material.

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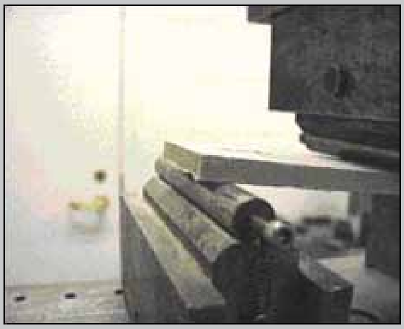
(a)



(b)

Figure 4 – FRCB specimens during three-point bend test after 200 freeze-thaw cycles for pressure treatments of: (a) 20 bar; and (b) 30 bar.[4]

Summary

Overall, the results indicate that modifications to the processing of FRCB can improve the performance of FRCB. Pressure can be applied to freshly formed FRCB to increase the density, improve the fibre-matrix bond, reduce porosity and improve interlaminar tensile strength. FRCB undergoes severe degradation due to exposure to freeze-thaw conditioning; however, the research suggests that some improvement in performance is seen with composites that were pressed.

Processing of Extruded Composites

Introduction

Extrusion is an advanced processing technique that is used to produce high-performance, fibre-reinforced cementitious composites (HPFRCC). Extruded HPFRCC are excellent candidates to replace currently-used building enclosure products. Compared with conventional materials, extruded composites can be stronger, more durable, more ductile, more environmentally friendly, cost effective and offer more design flexibility and improve safety in the event of natural hazards. In addition to enhanced mechanical performance, composites demonstrate a significant improvement in durability due to the high density that results from the extrusion technique[7,8]. Despite the great potential of extrusion technology, it has not been widely adopted by the North American concrete products industry. One reason for this limited use is that expensive cellulose ether processing aids are needed to control the fresh state properties of extruded materials.

Extrusion Technique

In the extrusion process, composites are formed by taking stiff cementitious dough and forcing it through a die of desired cross section with either an auger or a ram. Mix formulations and processing parameters (extruder barrel and die size, extrusion velocity, etc) must be carefully designed to optimise fresh state properties. In the fresh state, extruded composites should be sufficiently soft to flow through the die (minimising extrusion pressure), yet rigid enough to maintain shape upon exiting the die (shape stable). These fresh state properties will in turn affect hardened state properties, including fibre dispersion, composite density and the fibre-matrix bond. Currently, the fresh state properties of extruded composites are controlled using cellulose ethers. These materials are expensive. ACBM investigated the effects of processing aids on the extrusion process using extrusion rheology, with an aim at reducing the overall processing aid cost[9].

Extrudability

Extrudability was evaluated by extruding open cross-sections, using a cellular die, with two cells, that had a total length of 25.4 mm (1 in), a width of 15 mm (0.59 in) and a wall thickness of 3.25 mm (0.13 in). Specimens were extruded by a piston extruder at a rate of 1 mm/s (0.04 in/s). If poor shape stability, phase migration, an excessively high extrusion pressure, or surface defects (usually edge tearing) was observed, the material was considered not extrudable. It is important to note that extrudability is related to extrusion velocity as well as to the shape being extruded. The minimum amounts of binders defined here are dependent on the velocity and die used.

The matrix composition used, by volume, consisted of 33% Class F fly ash (produced by Dynegy Midwest Generation, Inc, mean particle size = 10 μm), 12% silica fume (WR Grace Force 10,000), 14% cement (Lafarge Type I), 39% water and 1% high-range-water-reducing admixture (Daracem 19). Two different cellulose ethers, Methocel (D) and Walocel (W), and two different clay types, Concresol (C) and Metamax (M), were studied.

The properties of the cellulose ethers and clays are given in *Table 1*.

Table 2, respectively. Mix designs are described with the binders of the mix described by weight percentages. For example, W0.25C0.25, contains 0.25% Walocel and 0.25% Concresol. Mixes were prepared using a planetary (Hobart) mixer. A piston extruder, mounted in a closed-loop, MTS hydraulic testing machine with a 24 kN (5.4 kips) load cell, was used with a barrel diameter of 38.1 mm (1.5 in) and a length of 125 mm (4.92 in).

Table 3 summarises the extrudable mixes. In the absence of clay binders, half the amount of W was required compared to D.

Figure 5 shows the effect of clay on extrudability. Once 0.3% of the clay was added, an extrudable mix was achieved. Similar results were found when either C or M was added. However, if all the cellulose ether was removed, the material was no longer extrudable. These results indicate that it is important to find the most effective type of cellulose ether (here twice as much D is needed, compared to W, while the costs are comparable) and that cellulose ethers can be partially replaced with clay binders.

Capillary Rheology

Capillary rheology was used to describe the fundamental flow properties of the extruded mixes. The analysis assumes that flow is laminar (Reynolds number

Trade name	Producer	Chemical designation	Specific gravity g/cm³ (lb/in³)	Viscosity Pa*s (psf*s)
Methocel 4fm*	Dow Chemical Company	Hydroxypropyl methylcellulose	1.3 (0.05)	2.3-3.8 (0.05-0.08)
Walocel M-20678**	Wolff Celulosics	Methylhydroxyethy 1 cellulose	3.2-4.0 (0.12-0.14)	10.4-12.4 (0.22-0.26)
* Viscosity determined for 1% solution, 20°C, Rolovisko rheometer ** Viscosity determined for 1% solution, 20°C "by rotation"				

Table 1 – Properties of cellulose ethers

Trade name	Producer	Mineral Composition	Mean particle size mm (min)
Stephan Schmidt Concresol	kaolinite (45%), mica (35%) Group	and free silica (20%)	= 0.5 (20)
Metamax HRM	Engelhard	calcined kaolinite	1.2 (47.2)

Table 2 – Properties of clay binders

< 2000), is fully developed and that there is no slip at the wall. The apparent shear stress (τ_{app}) and shear rate ($\dot{\gamma}_{app}$) are given in Equation (1) and (2), respectively.

$$t_{rx} = t_{app} = \frac{PD}{4L} \quad (1)$$

$$\dot{g}_{app} = \frac{8V}{D} \quad (2)$$

Where P is the extrusion pressure (kPa or psi), V is the mean extrudate velocity in the capillary (mm/s or in/s), L is the capillary length (mm or in) and D is the capillary diameter (mm or in). End effects are taken into consideration using Bagley's end correction [10], which determines the true wall shear stress in the capillary, τ_w, by: Where N is the end correction factor for the imaginary extension of the capillary length.

$$t_w = \frac{PD}{4(L+ND)} \quad (3)$$

Capillary analysis was conducted by extruding mixes through three different die lengths at six different velocities. Three die lengths (giving L/D = 1, 2 and 4) and six piston velocities, 0.2, 0.5, 1, 2, 3 and 5 mm/s (0.008, 0.020, 0.040, 0.079 and 0.197 in/s), which correspond to extrudate velocities of 1.8, 4.5, 9, 18, 27 and 45 mm/s (0.071, 0.178, 0.354, 0.709, 1.063 and 1.772 in/s), respectively, were used.

Figure 6 presents an example of a rheometric curve obtained using capillary analysis. Yield stress (τ_0) was approximated using the lowest two data points and extrapolating to the y-axis. Using the differential viscosity versus apparent shear rate curve, an equilibrium viscosity ($\eta_{equilibrium}$) was defined as the differential viscosity at which the system equilibrated.

Figure 7 presents the two parameters plotted together, for both the extrudable and not extrudable mixes, and demonstrates that, when considered together, τ_0 and $\eta_{equilibrium}$, can be used to evaluate extrudability. *Figure 7* suggests that an extrudable mix is one in which the yield stress is reasonably low (facilitating extrusion) and the equilibrium viscosity (probably related to thixotropy) is high. It is interesting to note that the zone of extrudability, with low yield stress values and high viscosities, is similar to the zone of rheological parameters required for self consolidating concrete[11],

(a) D		(b) W	
Material	**Extrudable**	**Material**	**Extrudable**
D0.5		W0.25	
D1	x	W05	x
D2	x	W1	
D0.5/C0.15		W0.25/C0.15	
D0.5/C0.3	x	W0.25/C0.3	x
D0.5/C3		W0.25/C3	
D0.5/M0.15		W0.25/M0.15	
D0.5/M0.3	x	W0.25/M0.3	x
D0.5/M3		W0.25/M3	

Table 3 – Extrudable mixes

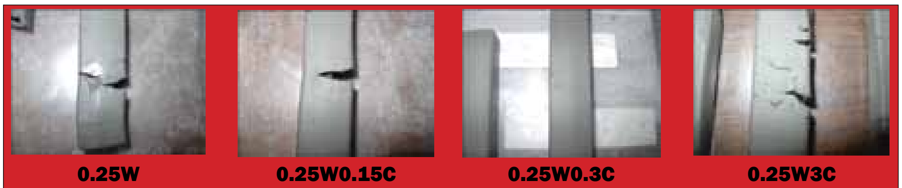


Figure 5 – Example of effect of clay on extrudability (Walocel and Concresol combinations shown here).[9]

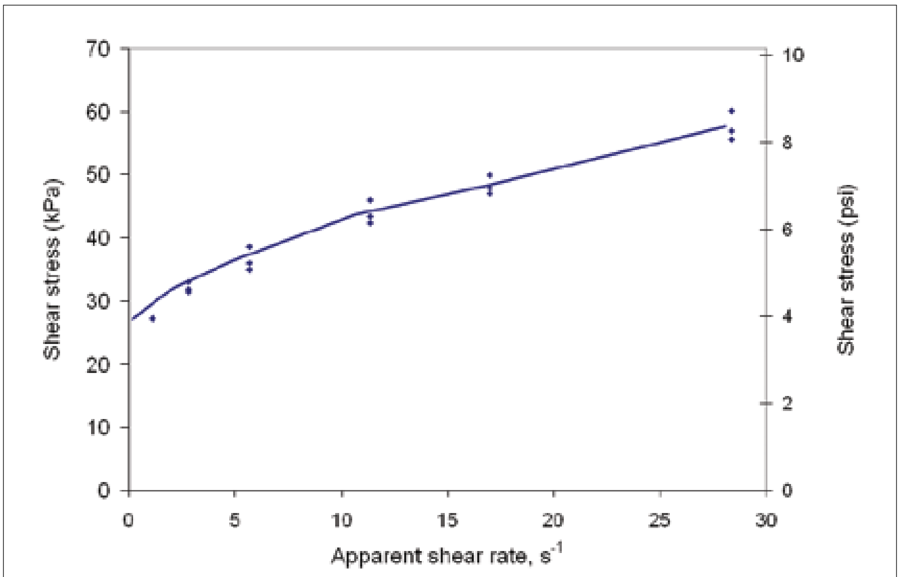


Figure 6 – Example of shear stress versus apparent shear rate (Walocel 0.5 shown here).[9]

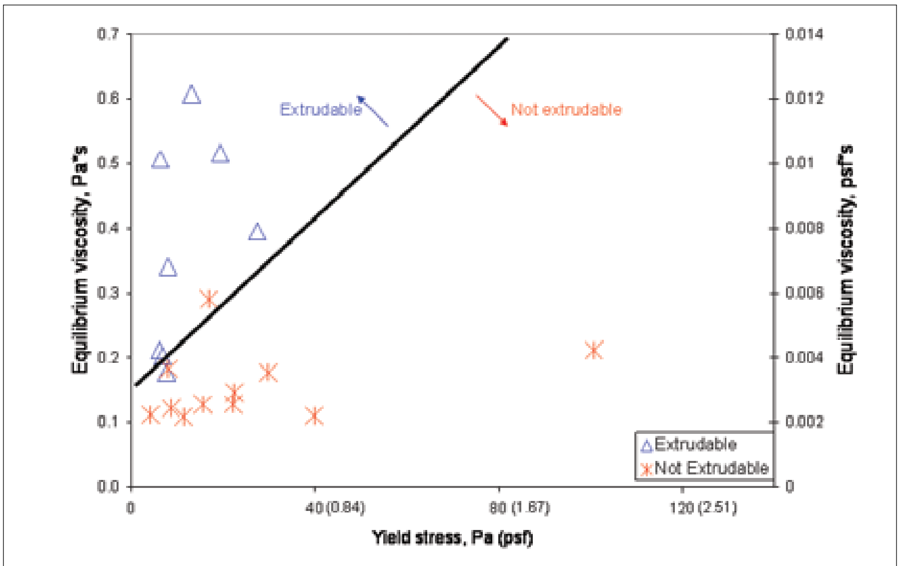


Figure 7 – Equilibrium viscosity versus yield stress for extrudable and nonextrudable mixes.[9]

which requires a low yield stress and a high viscosity. The similarities with these rheological parameters suggest that both the yield stress and viscosity (related to cohesion) are important factors to describe flow behavior.

Summary

Clay binders were found to be suitable partial replacements for cellulose ethers, significantly reducing the cost of the extruded composite. Capillary rheology was used to describe the fresh state properties for extrusion and showed that extruded HPFRCC have high equilibrium viscosities and low yield stresses.

Fibre-reinforced Self Consolidating Concrete

Introduction

Self consolidating concrete (SCC) is concrete that is highly deformable in the fresh state, flowing under its own self weight without segregating. This technology is suitable for applications in which complicated shapes are being formed and in cases where congested reinforcement is used. SCC eliminates the need for external vibration, reducing labour and energy costs. When properly designed, the hardened state properties of SCC can be superior to conventional concrete, with a more homogeneous matrix and better bonding to reinforcement. The extension of this technology to fibre-reinforced self consolidating concrete (FRSCC) offers great promise, likely producing composites that exhibit superior mechanical performance and durability due to the enhanced fibre-matrix bond and greater compactness. Recent research efforts have focused on developing methodology to design fibre reinforced SCC to optimize fresh state properties, which should in turn enhance hardened state properties[12].

Rheological paste model – solid skeleton grading

The 'rheology of paste' model developed by Saak and colleagues[13] has been modified to account for fibre reinforcement. The model determines the minimum volume of cement paste needed to allow for the required deformability and segregation resistance by analysing the optimum grading for the solid skeleton system. The average aggregate spacing, d_{ss}, which is twice the thickness of the excess paste layer coating the aggregates, is determined according to: Where d_{av} is the average diameter of the solid skeleton particles, V_{paste}, V_{void} and $V_{concrete}$ are the volumes of the paste, voids and concrete, respectively. Fibres are treated based on an "equivalent spherical particle" fraction based on the specific surface of the fibres such that an equivalent diameter, $d_{eq\text{-}fibres}$, can be calculated by:

$$d_{ss} = d_{av}\left[\sqrt[3]{1+\frac{V_{paste}-V_{void}}{V_{concrete}-V_{paste}}}-1\right] \quad (4)$$

Where d_{av} is the average diameter of the solid skeleton particles, V_{paste}, V_{void} and $V_{concrete}$ are the volumes of the paste, voids and concrete, respectively. Fibres are treated based on an "equivalent spherical particle" fraction based on the specific surface of the fibres such that an equivalent diameter, $d_{eq\text{-}fibres}$, can be calculated by:

$$d_{eq-fibres} = \frac{3L_f \quad g_{fibre}}{1+2\dfrac{L_f}{d_f} g_{aggregate}} \quad (5)$$

Where d_f and L_f are the diameter and length, respectively, of the fibres, g_{fibre} is the specific weight of the fibres and $g_{aggregate}$ is the weighted average of the specific weight of all the aggregates. Finally, the average equivalent diameter of the solid particles, d_{av}, is determined:

$$d_{av} = \frac{\Sigma\, d_i m_i + d_{eq} m_{fibres}}{\Sigma m_i = m_{fibres}} \quad (6)$$

Where d_i is the average diameter of the aggregate fraction (defined as the average size opening of two consecutive sieves), m_i is the mass of the aggregate fraction and m_{fibres} is the mass of the fibres.

Rheological Characterisation

The rheology of the cement paste is characterized using the mini slump-cone test and rheometer tests. Mini slump-cone tests were used to determine flow diameter (related to yield stress) and rheometer tests employing a concentric cylinder geometry, along with equilibrium shearing protocol, indicated the apparent viscosity. These two parameters were considered jointly using the ratio of the flow diameter/apparent viscosity.

Application of model

The optimum flow diameter/viscosity ratios for self compactability were determined as a function of the average aggregate spacing, d_{ss}, as is shown in *Figure 8*. Three zones are shown: segregation, allowable (self consolidating) and poor deformability. These zones were determined based on experimental data using regression analysis. Fibre dispersion was analysed by evaluating the amount of fibres in the top, middle and bottom thirds of cylindrical specimens and the effects included in the model based on segregation tendencies. The model lines show that minimum and maximum flow diameter/apparent viscosity of the cement paste are needed to achieve sufficient deformability and prevent segregation, respectively. As the average aggregate spacing decreases, the required flow diameter/viscosity increases, suggesting a greater flow diameter and lower viscosity are needed for self consolidation. Furthermore, a larger range of possible flow diameter/viscosity exists for larger average aggregate spacing, indicating more design flexibility.

The concept of optimum limiting values of flow diameter/viscosity for varying average aggregate spacing can be used to design FRSCC. Rheology tests are used to analyse the cement paste, while the grading of the optimum solid skeleton is determined through the measurement of the average diameter of the particles and the void ratio. The correlation between cement paste rheology and solid skeleton grading is then determined. Based on this relationship, the allowable values for the average spacing of solid particles as well as the cement paste rheology and solid skeleton grading can be determined.

The proposed model was used to design three FRSCC containing the same cement paste and 50 kg/m³ of steel fibres (Dramix 65/35), but which fell within the different mix design zones – poor deformability, self-compacting and poor segregation resistance for mixes A, B and C, respectively.

Figure 9 presents the results of this analysis. The cement paste had a flow diameter/viscosity of 650, V_p varied from 0.32, 0.36 and 0.40, and d_{ss} ranged from 0.272, 0.360, and 0.460, corresponding to mixes A, B and C, respectively. Slump tests, a visual segregation index and the T_{50} slump flow test (time required to reach 50 mm diameter spread) were used to assess and verify that the intended fresh state properties were achieved. These results indicate that a rational method can be used to design FRSCC.

Summary

A methodology has been developed to design FRSCC that considers the effect of the cement paste rheology and the solid particle skeleton (considering the contribution of the fibres via an equivalent spherical particle fraction) on fresh state properties and fiber dispersion. The results indicate that through the use of optimum limiting values of slump flow diameter/viscosity for varying average aggregate spacing, mixes that exhibit self consolidating behavior can be achieved.

Slipform Paving

Introduction

Currently, concrete pavement is placed using a slipform paving machine. Slipform paving is a continuous process in which the concrete is poured, consolidated and finished as the paving machine moves at a constant rate over the fresh concrete. The concrete is a low slump concrete (less than 5 cm [2in]) that maintains its shape without edge support once placed. To consolidate the concrete, equally spaced internal vibrators are used. However, if the frequency is not properly selected, or if the paving machine moves too slowly, the concrete can become over-vibrated. The result of this over vibration is aggregate segregation, a reduction in air-entrainment and vibrator trails that are a source of inherent weakness. To resolve this issue, a low compaction energy concrete has been designed that does not require vibration[14]. The concrete demonstrates both a high workability and a high shape stability.

Strategy

Figure 10 depicts the strategy adopted to produce low compaction energy concrete. A typical SCC mix design (eg one with high workability) was taken and modified using various mineral (fly ash, clays) and chemical (plasticizers, viscosity modifying admixture) admixtures to achieve shape stability. Flowability was evaluated using a flow test and a drop table test. Results from the drop table test were also used to assess shape stability. In addition, compression strength tests were conducted on freshly-mixed concrete samples to determine green strength. Finally, a model paver that was constructed to simulate the slipform paving process in the laboratory was used to evaluate the compaction ability of the concrete.

Experimental Results

The effect of plasticizers and fine materials on the flowability and green strength of concrete was determined.

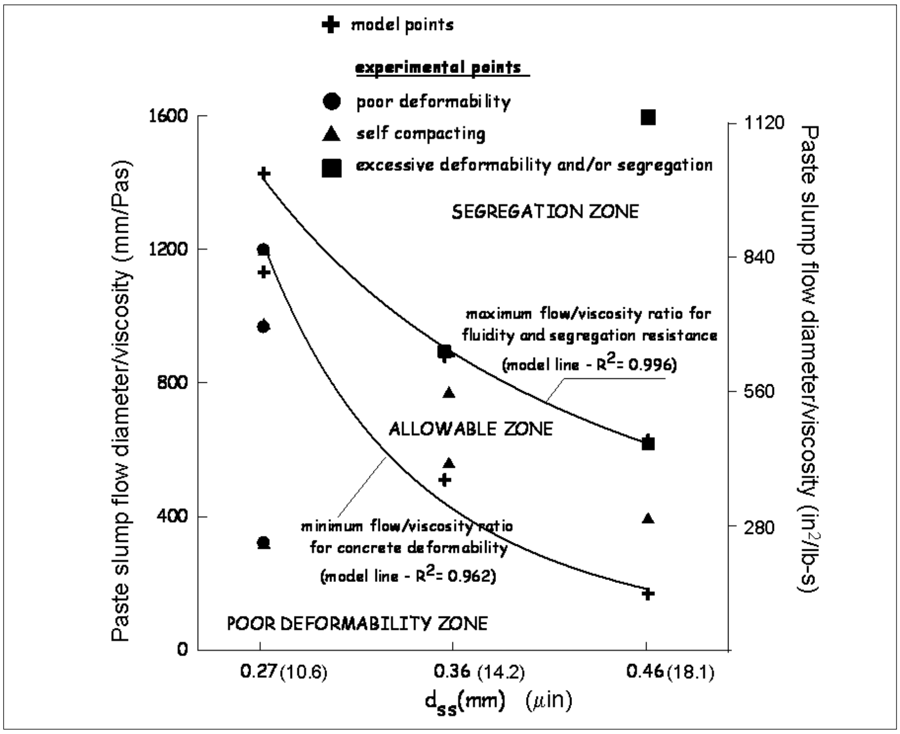


Figure 8 – Paste slump flow diameter/ viscosity ratio as a funciton of average aggregate spacing, dss (model lines and experimental data).[12]

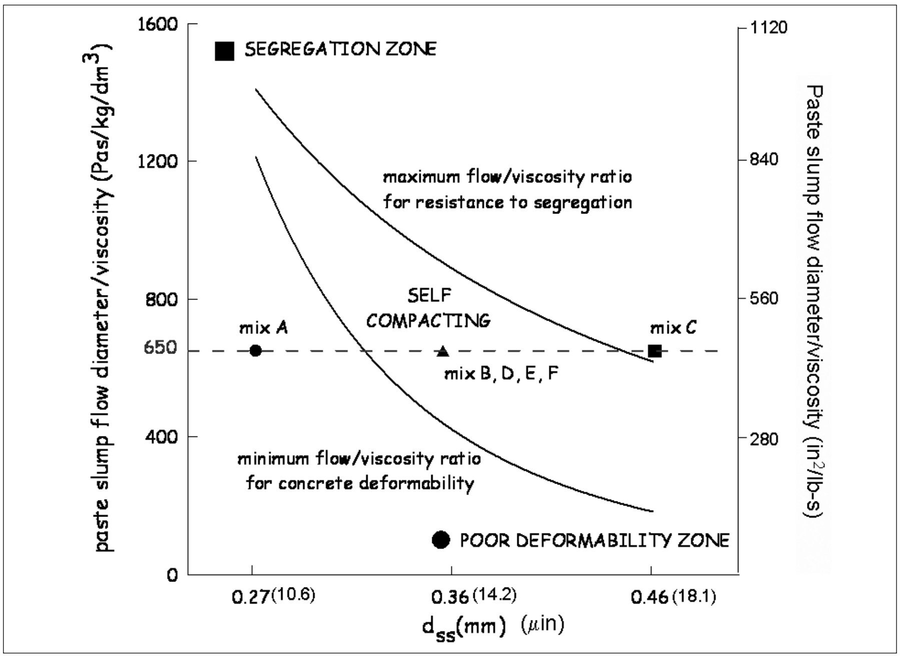


Figure 9 – Paste slump flow diameter/ viscosity ratio as a funciton of average aggregate spacing, dss, for three concrete mixes with different deformability to demonstrate model effectiveness.[12]

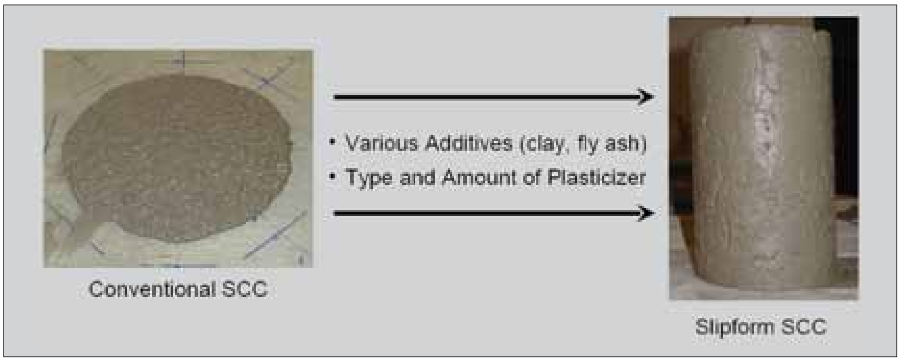


Figure 10 – Concept of producing low compaction energy slipform paving concrete.

The results are presented elsewhere, but summarised here[14]. The amount of additive needed to achieve a flow ratio of zero (i.e. shape stability) was obtained by beginning with a typical SCC mix design and then reducing or increasing the amount of plasticizer or fine material, respectively. Flowabilty and green strength of the shape stable mixes were then evaluated using the drop table tests. These results show that by properly tailoring the type and amount of plasticizer and fine material(s) in a mixture, both shape stability and flowability can be achieved.

The relationship between green strength and the flow ratio after 25 drops is presented in *Figure 11*. As expected, a general trend exists whereby green strength reduces dramatically with the flow ratio. However, it is interesting to note that some mixes do not follow this trend. These mixes contain the naphthalene-based plasticizer, or fine materials (clay or fly ash). Further research is needed to understand this trend.

Figure 12 shows different mixes that were cast using the laboratory-scale slipform paver for four different mixes: typical slipform, modified plasticizer (naphthalene-based), and two with clay additives. The last three of these are mixes that were shown to have desirable flowability and shape stability. These composites demonstrate excellent shape stability, edge stability and flowability when cast without vibration.

Summary

Concrete mixes were successfully designed for slipform paving applications that can be cast without applying vibration. Mixes were developed using the concept of SCC and modified to obtain shape stability. The effect of additives on the flowability and shape stability was evaluated. A good correlation was observed between high flowability, shape stability and the ability to be formed without vibration using a simulated slipform paver.

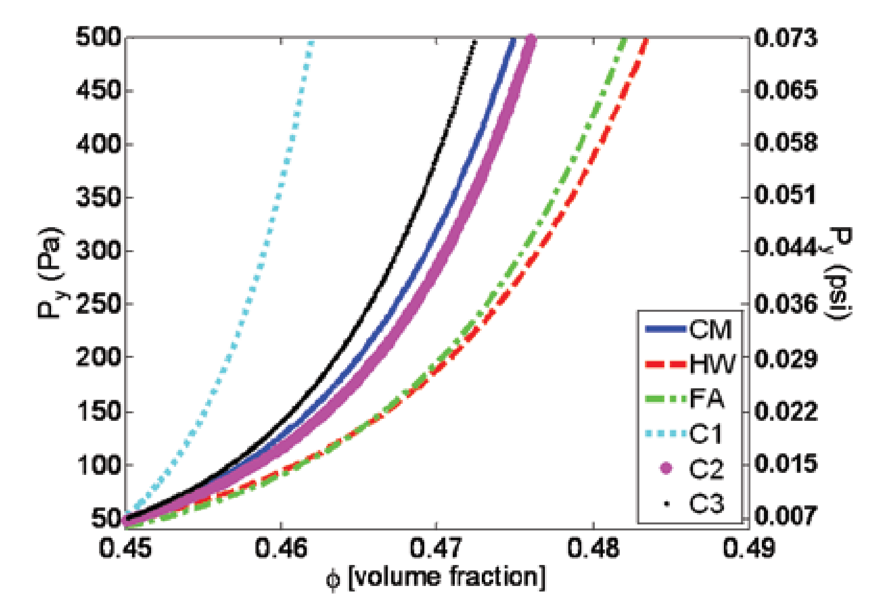


Figure 13 – Compressive yield stress as a function of local volume fraction of cement paste for control (CM), superplacicizer (HW), fly ash (FA), purified magnesium almino silicate clay (C1), kaolinite, illite, quartz clay (C2) and kaolinite clay (C3).

Future Directions: The Study of Flocculation

Introduction

Advanced processing techniques rely on microstructural changes that occur during the first few hours of the life of concrete. Applications such as extru-

Figure 12 – Concrete slab in fresh state produced with model laboratory paver without internal or external vibration for: (a) typical slipform paving concrete; (b) modified SCC with napathelene-based plasticizer; (c) SCC with 0.32% volume Metamax; and (d) SCC with 0.32% volume Concresol.

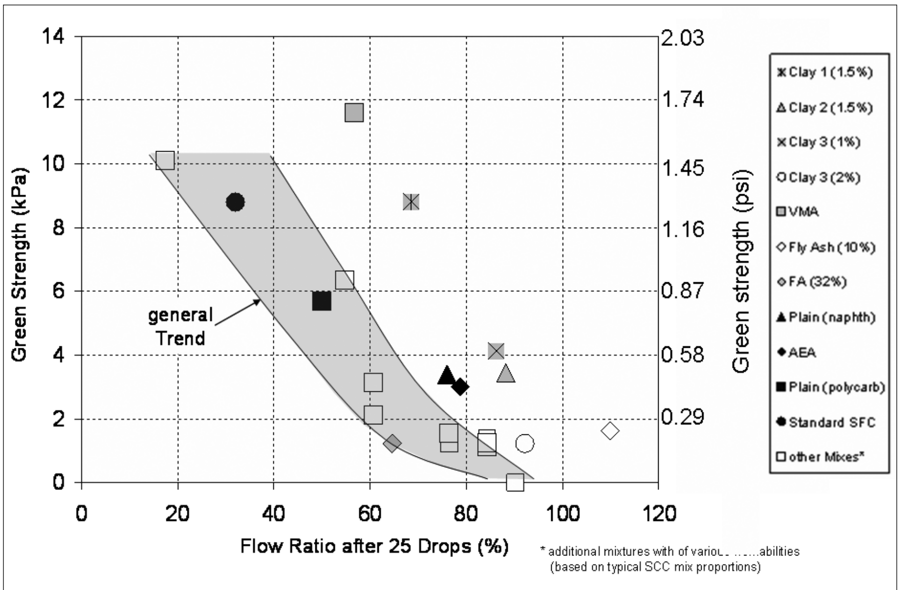


Figure 11 – Green strength as a function of flow ratio for variety of mixes.[14]

sion, self consolidating concrete and slipform casting require cementitious systems that are highly flowable yet shape stable. Ongoing work at ACBM is investigating how admixtures, including plasticizers, clays and fly ash, affect the flocculation behavior of cement paste. It is hypothesized that flocculation is related to shape stability (green strength).

Compressive Rheology and Green Strength

The flocculation behavior and green strength of different cement pastes were investigated. Flocculation behavior was examined using the centrifugal approach in which the compressive yield stress is measured as a function of local particle volume fraction. In addition, green strength was measured. Six different mixes were investigated: control (CM), cement and Class C fly ash (FA), cement and napathalene-based plasticizer (HW), cement and purified magnesium alumino silicate clay (C1), cement and kaolinite, illite, quartz clay (C2) and cement and kaolinite clay (C3). The water/binder ratio was approximately 0.40.

Figure 13 presents the compressive yield stress of the six different mixes as a function of local volume fraction. These results show that the HW and FA mix are more compressible than the control (CM), whereas C1, C2 and C3 have a higher compressive yield stress. These findings correlate well with green strength testing, which shows that the HW and FA have green strengths that are lower than the CM, while the C1, C2 and C3 have a greater green strength than the CM. Flocculation appears to be related to green strength.

Summary

Enhanced fresh state properties have been achieved by controlling workability and green strength. The flocculation of particles in the cement paste mixes was studied using compression rheology and shows good agreement with green strength. These results suggest that flocculation is an important mechanism to understand and control for the processing of advanced cement-based composites.

Conclusion

Recent work at the Centre for Advanced Cement-Based Materials (ACBM), at Northwestern University, demonstrates the potential of cement-based composites to be used in a variety of specialised applications. The success of these new technologies relies on advanced processing techniques in which the fresh state properties must be controlled and optimised. The role of processing on composite performance has been examined for the Hatschek process, extrusion, self consolidating concrete and slipform-cast concrete paving. The results indicate that overall composite performance can be enhanced by controlling fresh state properties. Furthermore, ongoing research suggest that by studying the behaviour of the microstructure at early ages, in particular with respect to flocculation, the mechanisms by which enhanced fresh state properties are achieved can be understood.

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DATE	INTERNATIONAL EVENTS CALENDAR 2009/2010		
	MEETING/EVENT	VENUE	CONVENOR
17 – 19 September 2009	Concrete 09	Luna Park, Sydney, Australia	Concrete Institute of Australia
19 - 26 September 2009	Managing Projects with MS Project Course	CESA Training Centre, Bryanston, Johannesburg	CESA
24 – 25 September 2009	Central European Congress on Concrete Engineering – Innovative Concrete Technology in Practice	Baden, Austria	Austrian Institute for Concrete
15 October 2009	Construction Charter - Rules, Verification Methodology and Evidence Checklist	King's Tide Boutique Hotel, Summerstrand, Port Elizabeth	CESA
16 October 2009	Construction Charter - Rules, Verification Methodology and Evidence Checklist	Blue Lagoon Hotel, Blue Bend Place, Beacon Bay, East London	CESA
14 – 16 April 2010	Design and Construction of Safe and Sustainable High-rise Stuctures	Technical University, Munich, Germany	Prof HR Viswanath

Eastern Cape

The first six months of this year have been an exceptionally busy time for the branch committee members in terms of work commitments. The net result is that the planned events have been delayed for later in the year.

Following on the SCC seminar and AGM, the branch enjoyed a Fulton Awards Dinner at the King Edward Hotel at the end of June.

Rod Stellebrass gave guests an insight into the Coega Terminal Project, one of the entrants in the Fulton Awards. The evening culminated in the announcement of the winners and commendations and an entertaining speech by the current CSSA president, Francois Bain. Local comedians, Boet n' Swaer, provided the laughs and entertainment.

The branch will send out a newsletter soon to give updates on what's happening in the region.

Western Cape

A number of successful events were held over the past months and the increase of memberships is reflected in the good attendance of all the events.

During April, Riaan Brits discussed the principles and common pitfalls of temporary support structures at the monthly technical meeting.

The Regional Fulton Awards event, hosted at the Kelvin Grove, reflected the true goal of the Fulton Awards to celebrate the excellence and achievement of the concrete industry in South Africa.

The Western Cape Branch invites everyone involved in the concrete industry in the Western Cape to consider entering their current projects for the next Fulton Awards to be held in 2011.

At the Concrete Flooring seminar in Stellenbosch, 100 members and guests listened to Kevin Dare, Executive Director of the CoGri Group (UK) on specification and construction of industrial concrete floors.

Dare is a founder member and on the board of governors of the UK's Association of Concrete Industrial Flooring Contractors (ACIFC) and was a member of the working group who were instrumental in developing the flatness specifications in the Concrete Society's Technical Report 34.

Inland Branch

The Inland Branch has seen some changes over the past month or so with the Chairperson, Zoe Schmidt, emigrating to Australia. The Secretary/Treasurer, John Sheath has subsequently been elected as the new Chairman, with Johan van Wyk continuing as Vice-Chairman. Trevor Sawyer has taken over the responsibilities of Treasurer and Bernice Baxter is now the Branch Secretary.

The Branch held a special mini-seminar in July in conjunction with the Cement and Concrete Institute (C&CI) and Royal Consulting, to coincide with the visit of Kevin Dare, Chairman of the CoGri Group in the UK. The event was attended by more than 150 delegates including 86 non-members at the Midrand Protea Hotel.

The focus of the seminar was 'trouble free concrete floors – fact or fiction?' Proceedings were started by the Chairman with an overview of the Concrete Society and the benefits it can offer. This was done specifically due to the high numbers of non-members present, but will be repeated at all future meetings in an effort to boost both individual and company membership.

Bryan Perrie, MD of C&CI presented an overview of the current concrete flooring market in South Africa which included details of common failures in concrete floors and designing and specifying to prevent them.

Kevin Dare presented two papers – one on the design process and detail design and the other on performance-based specifications. Many references were made to the latest edition of the Concrete Society UK's Technical Report TR34 with which he had particular involvement in developing the flatness specifications.

Proceedings were brought to a close with a short talk by Ian Buchanan of Royal Consulting who presented a case for setting up a South Africa Association of Industrial Flooring Contractors.

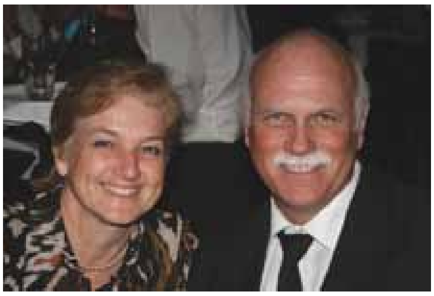
Arrangements are now well under way for the Branch's regular quarterly meeting at the end of July, which covers all aspects of aggregates, from quarrying to recycling from five speakers.

John Sheath

Kevin Dare

KZN CSSA Committee from the left Dion Kuter, Wayne Milligan, Ken Brown, Garth Gamble, Jason Callister, Phil Everitt, Greg Parrot, Rowan Scully, Raj Naidoo, Francois Bain and Patrick Flannigan.

KwaZulu- Natal



Rolf and Sheila Schutte

Dion Kuter and Garth Gamble

The KZN branch organised yet another successful Regional Fulton Awards Evening in celebration of the 30 year anniversary of this prestigious event. This year the committee decided to change the venue to the Suncoast Casino on Durban's Golden Mile.

President of the CSSA, Francois Bain attended the evening. The venue proved the key to the smooth running of the evening and strategically placed screens offered the 160 guests excellent views of the Fulton presentations.

Self Compacting Concrete

Specification, Testing and Performance

The Self Compacting Concrete Specification, Testing and Performance paper is presented by George Evans, Concrete Services Manager for Grinaker-LTA Civil Engineering.

Introduction

Self Compacting Concrete has unique plastic properties that exceed the traditional parameters of Ordinary Concrete consistencies, making it possible to place and consolidate concrete into difficult forms or heavily reinforced sections without the use of form or internal vibrators. Consolidation of ordinary concrete is of paramount importance to achieve the desired finish, strength and durability properties in its hardened state. The compaction effort is normally variable and applied by inexperienced or untrained labour that aligns the consolidation effort with horizontal flow as an indication of adequate compaction. The homogeneity of ordinary concrete is highly dependent on the consolidation technique employed, and most often, when using a poker vibrator, it varies according to the placement, depth and compaction effort of the vibrator during the compaction process. As the consolidation is 'blind', inconsistencies are normally only noticed upon the removal of formwork, (vertical structures) or at commencement, during and after surface finishing (horizontal structures).

Facade columns

The development of Self Compacting Concrete during the late 1980s was primarily as a result of poor durability of concrete structures in Japan, mainly associated with poor consolidation of the concrete. High slump concrete used in piling applications is not SCC, and is only self-compacting by nature of its placement. SCC is defined as a concrete that is able to flow under its own weight and completely fill the formwork, even in the presence of dense reinforcement, without the need of any vibration, whilst maintaining homogeneity. It is a unique material that should be designed to meet specific application criteria.

Material requirements

The basic materials used to produce SCC are not significantly different to that used in the production of conventional concrete, except that the proportions are different, and the plastic concrete performance is unusual. The constituent materials, used for the production of Self-Compacting Concrete (SCC) should generally comply with the requirements of SANS 2001-CC1:2006 Concrete Works (Structural) because conventional concrete is placed using external energy. There is no need for specific rheological characteristics. The intensity of energy applied in the consolidation process is adjusted to compensate for most plastic property variations. A slump window requirement is generally enough, in conjunction with good consolidation practices, to lead to dense concrete elements in most applications.

Other rheological requirements are needed for SCC, as no additional placing or consolidation operations will compensate for any lack of rheological performances. The self-consolidation of SCC is mainly governed by its yield stress, while the viscosity will affect the homogeneity and the ability to flow through reinforcement without hindrance or segregation. The SCC viscosity can therefore be adjusted depending on the application, but the yield stress must remain significantly lower than other types of concrete in order to achieve self-consolidation.

Specification

As SCC is a sensitive material and the success of an application will be governed by the consistency of the rheological properties, the specification for SCC should therefore be performance based, permitting the manufacturer/supplier/constructor to demonstrate their technical capability.

Performance

The workability of SCC is higher than the highest class of consistence prescribed for conventional concrete and can be characterised by the rheology. Various mix design methods have been proposed in order to obtain the unique rheological performances of SCC which may lead to different mix designs for a given application. The performance criterion is the only objective means to evaluate the adequacy of an SCC mix. Since criterion relates to measurements, a number of rheology test procedures have developed. A concrete mix can only be classified as Self-Compacting Concrete if the requirements for all three characteristics, namely; filling ability/flowability, passing ability and segregation resistance are fulfilled.

Testing

Several tests have already been developed to characterize the performance of a fresh self-consolidating concrete.

Self Compacting Concrete

Note: The typical requirements for each test method are based on current knowledge and practice.

Some common test methods are briefly discussed

a. Slump-flow or Spread Test

This procedure relies on the use of the slump cone. The cone is filled in one layer without rodding, and the diameter, instead of the slump of the concrete sample, is measured after the cone has been lifted. This test is mostly used for evaluating the SCC'S filling ability and ultimately, self-compact ability as it mainly relates to its yield stress. Monitoring the time it takes for the concrete to reach a spread of 500 mm T_{50}° can also be used as an evaluation of SCC viscosity.

b. L-Box, U-Box

These two tests simulate the casting process by forcing an SCC sample to flow through obstacles under a static pressure. The final height H and H2/H1 for the U-Box and the L-Box respectively are recorded. They provide indication on the static and dynamic segregation resistance of an SCC as well as its passing ability (ability to flow through reinforcement).

c. V-Funnel and Orimet

By monitoring the time it takes for the SCC to flow through an orifice under its own weight, these two test methods give an indication of its viscosity. Both tests are used in the field and are sometimes used as acceptance tests.

d. GTM Screen Stability

This procedure is used to evaluate the resistance to static segregation of an SCC. A sample of concrete is poured over a 4.75 mm sieve and the amount of mortar passing through the sieve in a two-minute period is measured.

The above tests do not measure the bleeding or settlement of SCC which are critical components in the overall evaluation of static segregation resistance. Although slight bleeding of SCC is advantageous in horizontal applications, it is undesirable in vertical structures and should therefore also be included in the suite of rheological tests. ASTMC 232 may be used for this purpose, except that the container shall be filled without rodding or vibration of the SCC.

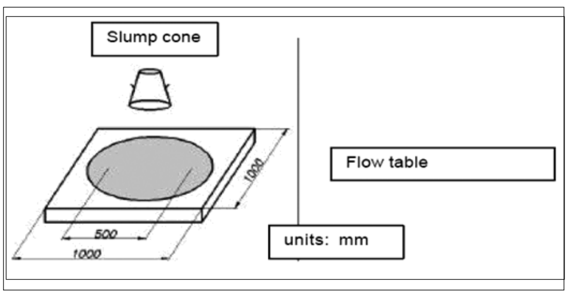
Facade columns

Rheological considerations

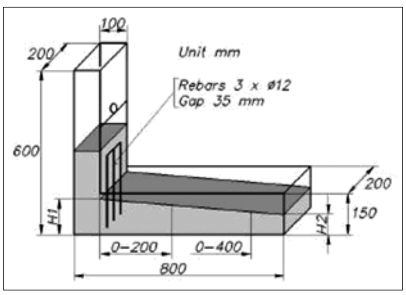
It is logical to contest that the ability of the fines fraction to carry coarse aggregate is the backbone to developing a successful SCC. Consider the influence of the paste on a macro scale:

No Fines Concrete – Maximum coarse aggregate fraction - (SCS = 1.0). Fines deficient – No Flow – Very low water content and very low shrinkage.

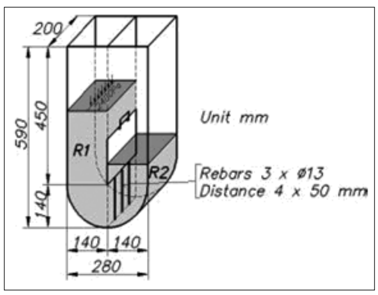
Normal Concrete – Sufficient fines to slightly over-fill voids and just enough to promote flow. The coarse aggregate fraction is optimized – (SCS 0.7 - 0.85).



a) Slump-flow



b) L-box



b) U-box

The water content is approximately 190ℓ/m³, contributing towards higher shrinkage.

SCC – Requires excess fines to carry coarse aggregate – coarse aggregate held in suspension (SCS 0.4 - 0.7). Water content rarely exceeds that of conventional concrete. What is the effect on shrinkage?

The incorporation of one or more powder (< 100 µm) materials having different morphology and grain size distribution can improve particle packing density and reduce inter-particle friction and viscosity, improving deformability, self-compactability and stability.

While considering the above, the basic requirement stated in SANS 2001-CC1 and 10100 for transporting and placing of conventional concrete remains a significant requirement for the performance of SCC: "Discharge the mixed concrete from the mixer and so transport it to its final position that segregation, loss of ingredients and adulteration are prevented, and that the mix is of the required workability at the point and time of placing."

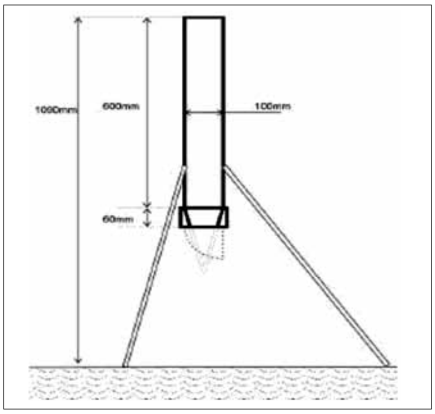
A practical application of SCC

SCC was used for Soccer City's 16,5m high columns which are curved and cantered away from the base by 6m. The bottom section of each column is 2m x 600mm reducing to 600 x 800mm at the top. Each column is heavily congested with 860kg/m³ reinforcing steel which prohibited the use of poker vibrators inside the column.

What made the Self-Compacting Concrete for Soccer City unique is that it was combined with conventional materials – commercial aggregates, cement, extenders and fillers - that were correctly and consistently proportioned on site to achieve the desired rheology parameters. These included a slump flow of 700-750mm, a V-funnel flow of 6-8 seconds, with no segregation, settlement or bleeding in order to maintain its homogenous concrete properties after placement and passing through the heavily congested reinforcement. Due to the high cementitious content, the compressive strength development permitted the early removal of formwork which was specially designed to resist high pressures and eccentric loading whilst exhibiting the finesse of recesses and curvature.

Congested reinforcement

The success of this and other applications must also be attributed to the in-situ trials to evaluate the performance of such a unique material. The trials should embrace the transportation, discharge, placement method, rate of placement, protection, curing and form release agents.



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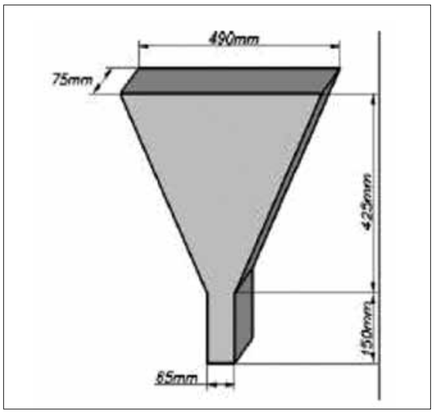

V-funnel

Facade columns

The use of hydrated lime in masonry construction

A brief history of lime

Lime (Calcium oxide, or CaO) has been used as a binder. It is derived from burning limestone ($CaCO_3$) at temperatures in excess of 900°C. The burning process, known as 'calcining', drives off the carbon dioxide to leave the calcium oxide behind in lump form. At this stage the lime is 'unslaked'. When water is added it reacts vigorously giving off heat and forms hydrated or slake lime, calcium hydroxide ($Ca(OH)_2$). Hydrated lime is a fine material, substantially finer than Portland cements.

The same process is used to make dolomitic (ie contains magnesium oxide) limes. Dolomitic lime is slow to hydrate and hydration is normally carried out in an autoclave. It is possible to produce lime by burning sea shells and this process was used in early lime kilns in South Africa at Kalk Bay and Yzerfontein and used until recently.

Hydraulic limes contain a proportion of clay which supplies aluminates and silicates.

From ancient times, up until fairly recently, lime mortars were made either by mixing 'unslaked' lime with sand and water, by leaving the mixture overnight for the lime to hydrate, or by hydrating the lime and then mixing with the sand. The mix was then remixed with additional water and used as bedding mortar. Lime mortars harden very slowly through the recombination of the hydrated lime with carbon dioxide from the atmosphere. This process is called carbonation and the hydrated lime converts back to limestone, releasing water in the process. The slow rate of hardening in those days was often advantageous as the mortar was relatively flexible and tolerated more movement than with stronger, more rigid mortars.

Portland Cements

With the introduction of Portland cements it became possible to produce mortars which hardened relatively quickly and which developed more strength than the lime mortars used previously. This had advantages as it was then possible to build much more quickly. Portland cement mortars largely supplanted lime mortars and the benefits of using lime in mortars were neglected. It was assumed that mortars with high compressive strengths performed better than those with lower compressive strengths, and the use of high strength cement mortars was, and still is, commonplace. The most important properties of hardened mortar in load bearing masonry are good bond strength to the masonry units, low drying shrinkage, and low permeability, not compressive strength. Best practice is to utilise the setting and hardening characteristics of Portland cement in combination with the beneficial effects of lime.

The effects of lime on plastic mortar

Plasticity – lime acts as a plasticiser and makes mortar mixes fattier and more workable. This in turn makes the mix friendlier for the mason and it is easier to bed the masonry units and control the thickness of the masonry beds and perpends. In the case of plaster mixes it is much easier to trowel the plaster on to the wall and to achieve the required finish.

Cohesion – lime mortars are more cohesive which means they are easier to use and there is less wastage as they adhere better to the masonry units and the masons' trowels and floats.

Water retention – lime retains moisture in the fresh mortar and plaster because of its fineness. This means that the masonry units cannot suck the moisture from the mortar so easily and the cement has more moisture available to hydrate properly. Common problems with mortar and plaster are poor strength and durability caused by rapid drying.

'Finishability' – because lime retards the set of cement slightly it is easier for the mason to achieve the required finish, on both masonry joints and plaster.

The effects of lime on hardened mortar:

Permeability – mortars containing lime are generally less permeable. This is partly a result of their superior workability and water retention. Denser mortars are obviously desirable, especially in single skin masonry in high rainfall areas.

Less efflorescence – contrary to popular belief the use of lime in mortars does not cause efflorescence, it actually

reduces it. The reasons are that mortars containing lime are less permeable and lime hydrate, particularly dolomitic lime, is not particularly soluble in water.

Recommended mixes

Mortar and plaster mixes are normally in the range of one bag of cement to 130 to 300 litres of damp sand. Rich mixes are typically used where masonry is highly stressed or where plaster is subject to impact, for example squash court walls. Leaner mixes are used on soft, friable surfaces such as poorly baked and sun-dried bricks. In some cases, mixes as lean as one bag of cement to four bags of lime to 600 litres of sand have been used successfully.

SANS 10164 recommends the mixes, in the table below, which will give adequate strength and durability, providing average or good quality sands are used. A simple field-test for sand quality is described in PPC Tip 8. For further information contact Steve Crosswell, Technical Support Manager at PPC, email scrosswell@ppc.co.za

Mortar Class	Cement*	Lime**	Sand (Damp and bulked)
I	1 bag	0 – 10 litres	130 litres
II	1 bag	0 – 40 litres	200 litres
III	1 bag	0 – 80 litres	300 litres

* CEM I, II or III/A and strength class 32,5N or higher.
** A 25-kg bag of lime contains a nominal volume of 40 litres of lime

The Gautrain and The Concrete

Cyril Attwell, chief concrete technologist on the Gautrain project for Murray and Roberts, shared the technology and mixes developed for use in the country's first 100 year durability project with Concrete Beton's editor, Carol Dalglish. The giant South African construction company used the EN206, European specifications on the Gautrain. Attwell controlled and designed the concrete works, reviewed repair method statements, methods of testing for quality control and quality assurance systems to ensure consistent production and quality.

Advanced Re-crystallisation Technology

The Advanced Re-crystallisation Technology (ARC) is basically the process where the chemistry of concrete is used to synergise the strength and durability.

ARC takes into account the chemistry of the aggregate, as well as the chemistry of the cement and any extenders, chemical or mineral, PFA and slagment. By putting everything together rather than looking at purely the physical aspects in conventional concrete technology, one can get a considerable amount of extra strength, which increases the durability and strength while minimising costs, says Attwell.

At the beginning, the quality control and assurance programme was based on conventional concrete cube testing and the limitations were soon realised.

A concrete test cube sample is taken that is representative of the concrete used in a pre-cast element or balanced cantilever, the concrete test cube is stored at a consistent temperature of 22° to 25°, but the actual concrete in the element is undergoing an entirely different exposure, the ambient temperature and its own heat of hydration. This reaction is strongly exothermic - almost like a snake eating its own tail. Thus it keeps building on its thicker section. The elements are at a considerably higher temperature than the 22° – 25° of the cubes and the thinner elements may be lower than that. A thermal analysis will show the exact strength of all the points in the elements, and the element can be lifted at the right time.

Nurse-Saul Testing

There were approximately 46 maturity testing functions researched and conducted to define which maturity function best suited the mix design. The Nurse-Saul function as detailed in ASTM C1074, American Standards Test Method, was found to be the most suitable. It is generally used in pre-cast concrete or in high early strength concrete with low quantities of extender.

The iconic project used 93 mixed designs which were split into six main sections: Rosebank; Park 2Stations; Marlborough; Midrand; Centurion; and Pretoria.

Cement and binders

The concrete and shotcrete split approximately 50% between north and south, 400 000m^3 of concrete was supplied

SA's first 100 year durability project

for the southern section with another 48 000m^3 remaining. The northern section has used 260 000m^3 with 160 000m^3 remaining.

Initially the pre cast design utilised 500kg per cubic metre of cementitious binder, 90% of it 52,5RCEM1, but availability was a problem. Murray and Roberts had to consider 42,5CEM1 which was used extensively throughout the rest of the project.

The binder content has been cut to approximately 400kg per cube at a cementitious split of 70% of 42,5CEM1 and 30% pulverized fly ash (PFA), which is slightly out of the ordinary for a precast application.

Strength

At a water to cement ratio of 0.45, an average strength between 68 and 74 mpa, (measure of strength of concrete), was achieved. The expected strength using a 0.45 water cement ratio and a 70/30 split of binder is approximately 40 - 45mpa concrete with a nominal safety factor. The 25mpa difference between theoretical and actual can be related back to the ARC process.

Cement & Aggregates

Attwell used PPC cement and both aggregates and cement from AfriSam across the project. He says, "The cement suppliers produced a world-class service on the Gautrain and the consistent supply and quality in the concrete has been exceptional."

In the pre-cast design from the initial design to full production the saving on 42,5CEM1 per cube is approximately 150kg per cubic metre. The 42.5 Cem1 was replaced by the waste material, pulverised fly ash.

Weird & Wonderful

ARC technology was first developed for Grootvlei prison in Bloemfontein, to facilitate the fast-track building of the multi-storey prison. Attwell says that 12mpa was required at 12 hours, at minus 8 degrees, to build the bottom cells and the top layer the following day. Conventionally, an accelerator is used to achieve that result but chemically it stunts the crystal formation in the concrete.

Environment

We have instituted re-using the wash water that is used in concrete batches and ready-mix trucks. By pumping it back as concrete mixing water strength is gained in the concrete, which allows for further reduction of cement content. This benefits the environment. Previously the water was collected in a sump and directed at great expense through sewer or storm water systems. This way money is saved and is great for the environment. "Greenpeace were astounded when I told them what we were doing – this has never been done anywhere else in the world." This is good news for cement manufacturers as cement is the second highest contributor to green house gases.

"You can imagine reducing your cement by a third on a major project from 450 to 500kg of cement to 300kg. This will have a huge impact on the environment."

Testing

The concrete has been looked at in a holistic manner. It is pointless looking at only one aspect. We used concrete test cubes on the 400 elements and had two failures, which is acceptable in the normal circumstances. The two failures were due to the in-situ concrete actually having a lower strength and the concrete test cubes being kept in ideal conditions.

Due to lifting or release of tension on a cable the concrete element failed. When the new maturity quality control systems were put in place for in-situ testing on 3500 elements, there were no failures.

Maturity tests

Using the maturities relationship of heat of concrete, over time, directly relates to the strength. The heat evolution of concrete is directly proportional to its strength. Using that concept, we applied maturity testing and sped up production by 150% through eliminating quality control risks, found with concrete testing cubes. For the first 400 elements, (approximately 2 – 3 months), we ran the two testing regimes parallel – cubes and maturity. A large deviation was found depending on the concrete element dimension. The deviation was anything from 50% to 200%.

Explanation

What happens in summer when the concrete temperature is between 23° to 30°, the ambient temperature generally in the same ball park, and evening temperature is around 20°. In these circumstances the concrete elements generate excess heat, easily 55 to 60° centigrade, while the cubes are kept at a constant 22° to 25°. Concrete at higher temperature would be a lot stronger. An additional concern is that if the 70°/75° centigrade point is exceeded, the water molecules start becoming vapour, causing internal stresses in the concrete. The cube showed results of 12 to 15mpa and maturity 18 to 24mpa. In winter you have the reverse, the cubes showing a minor drop of early strength and the concrete maturity a considerable drop if the concrete is un-insulated.

Thermal differentials

Polyfoam was used on the steel shutters. The windchill factor at the yard lowered the concrete temperature and in doing so lowered the strength of the concrete. The Polyfoam insulation made a large difference on the thinner sections of the elements.

The other thing that was picked up using maturities was the strong effect of thermal differentials within a concrete element.

The allowable thermal differential was higher than the considered norm of 20° centigrade - dolomite and lime stone being 34.4°. Using maturities, thermal stresses were noted in different concrete structures, and construction practices were revised to deal with these differentials.

Torrent Permeability Meter

The Torrent Permeability meter is used as a durability testing device to check if the concrete meets a durability specification. On this project Murray and Roberts used it as a training tool to elevate different construction teams and continuously improve on their abilities. Using different compaction methods and construction practices on a single element, the best construction practice can be clearly defined using the Torrent permeability test. Concrete in its hardened state can speak volumes about the construction method applied, the concrete design and its own future, says Attwell.


Cyril Attwell

Concrete is like a woman

He firmly believes concrete is like a woman. Every single batch, even from the same design behaves differently – exactly like a woman. The time of day, the ambient temperature, the volume of the concrete, the attention applied to the concrete can all change the personality of the concrete. He says that anyone who says they have ultimate understanding of concrete can't be truthful. Even although you have consistency, there are still consistent deviations.

In trying to control or change it - variables like the ambient temperature, the volume of concrete, changes in the aggregates, (grading and the mineralogy), alter the chemistry of concrete. So over time, like the chemistry changes in women, understanding the concrete changes when they happen, and having all the method statements and procedures in place when those things do occur is, he believes, the answer.

"Knowing that we can guide the concrete but not control it,will have some people up in arms."

Concrete and the Human Body

Attwell is a maverick when it comes to concrete technology. Expanding on his chemistry background "Concrete is like the human body – its rather frightening. Just like concrete the human body ages, sometimes the worse for wear. The bones can become arthritic exactly in the same way concrete corrodes with steel. You have other external effects. Carbonisation and chloride attack is similar to the effect of smoking or drinking on the human body. When we realise how close concrete and the human body are we will have a deeper understanding of concrete design and durability.

Attwell is passionate about concrete and he believes strongly in innovation – the technology has hardly developed in the last 6 000 years. "Sure we have developments in additives, but not the huge jump as in medical technologies."

2010 Final Countdown

The final eight cubic metres of production for the civil works were scheduled for March 2010, but this could shift a month or two because of certain delays on the project.

Shotcrete Tunnel Lining and Centre Wall

The Gautrain is one of the largest and most impressive construction projects in South Africa. Bombela Civils Joint Venture chose Chryso Southern Africa to supply admixtures for the Shotcrete tunnel lining as well as for the construction of the centre tunnel wall.

This is the first construction of its kind to use a full Shotcrete lining without any concrete backing. The Shotcrete was specifically designed so that a concrete backing that was usually placed on the surface would not be necessary. This was achieved by applying a safety layer first, followed by the insertion of bolts, and then smoothing layer to cover the bolts and finally applying the finishing layer. Joining layers were added where necessary. This innovation was necessitated because large volumes of Shotcrete were used. It is the first time that a sulphate resistant Shotcrete was used, as durability is vital and a design lifespan of 50 years is required.

The Shotcrete covers a total tunnel distance of 11km. Admixtures supplied by Chryso met the required specifications. A total of 81,000m^3 of Shotcrete was used in construction of the tunnels. Shotcrete strength of 25MPa was required and maintained. One of the main criteria of the concrete designed for the Shotcrete was a slump retention period of six hours.

Shotcrete was supplied from three batch plants situated in Marlboro Plants 1 & 2 - with a total capacity of 120m^3 per hour, Rosebank Plant – with a capacity of 37m^3 per hour and Park Station with the same capacity as Rosebank.

Shotcrete Mixes

The requirements of the Shotcrete mix are as follows:

Grade of Concrete (on cores in situ at 28 days) = 25MPa; Workability Slump Flow (mm) = 170mm +- 30mm; Slump Retention (min) = 6 hours; Minimum Cementitious Content (kg/m^3) = 360kg/m^3; Maximum Water Binder ratio = 0.45 These specifications are in accordance with the EN206-1 standard.

Chryso Fluid Optima 100 is specifically designed for long slump retention and was therefore the natural choice. It also assisted in achieving the required strength.

Chryso Jet 50 alkali free liquid accelerator is specifically designed for very fast concrete setting and was applied at the Shotcrete nozzle.

Centre tunnel wall

In combination with the Shotcrete lining, a centre wall had to be constructed in the tunnel. The design challenge was that the wall should not have a direct connection with the Shotcrete lining as the vibration of the moving trains may affect the Shotcrete stability. About 5000 linear metres of heavy reinforced concrete walls of 250mm thick were therefore erected with no connection to the top of the tunnel. The concrete walls had to be filled to the top by using self compacting concrete. The formwork was 12 metres long. Construction was done at high speed as every cycle took 16 hours. Construction took place 24 hours per day. A distance of 120 metres per week was completed, and stripping was achieved every 6 hours. The total volume of Self Compacting Concrete used was 15 000m^3

This centre tunnel wall is the biggest self compacting cement project done in South Africa to date.

The requirements of the SCC mix are as follows: Grade of concrete (on cores in situ at 28 days) = 40MPa; Workability Slump Flow (mm) = 600mm +- 50mm; Slump Retention (min) = 2 hours; Minimum cementitious content (kg/m^3) = 300kg/m^3; Maximum Water Binder ratio = 0.50. These specifications are in accordance with the EN206-1 standard.

Chryso Fluid Optima 175, a super plasticiser was selected for this project and is specially designed for SCC concrete. It was developed to reduce water content considerably and/or increase the workability of the concrete without compromising concrete setting times.

To date all deadlines have been met and once the entire Gautrain project is finished, it will certainly stand out as a showcase of excellence in Concrete Construction. All the companies involved will be able to look back with pride on achieving this milestone in South Africa.

Bridge over the Coega River

In 2008 the contract to build the bridge over the Coega River, including the kilometer of approaching roads was awarded by the Coega Development Corporation to the Basil Read Newport JV The three span structure of 125m comprises 2 x 37.5 Jackspans and a central span of 50m crossing the Coega River at a skew of 28° with a vertical grade of 0.31% and a cross fall of 2%.

Superstructure

The superstructure comprises two separate decks. Each deck is a 3 span continuous post tensioned, cast in situ beam and slab structure. Each of the decks has three 900mm wide beams with parabolic curved soffits. The overall deck depth varies from 3,5 – 1,7m.

Substructure

The abutments are conventional perched solid wall cantilever type, founded on piles. Wall type piers with rounded ends and aligned in the direction of flow are specified.

Basil Read Newport Construction JV decided to invest in new formwork systems for this bridge, and for future infrastructural work. This included a Heavy Duty Shoring system combined with a flexible soffit system and a lightweight walling system. They chose Doka systems, Staxo, HD Shoring, Dokaflex Slab Formwork and the Frami Lightweight walling system.

Gert Duvenhage, Project Engineer for the JV says that the Coega River Bridge project is unique. Various aspects of the project demand distinctive characteristics from the formwork system. "The Doka system has definitely provided a sound foundation for this project in terms of support, practicality, accessibility and safety. Its vast range of equipment and staff expertise offered this project a solution for the support of the Arch Beams as well as for some unique sloping ground condition."

The Staxo towers are assembled on the ground in a horizontal position, using minimal labour force and then hoisted into position by crane. Ladders form an integral part of the frame, hence easy and quick access for the riggers.

These towers have a load-bearing capacity of up to 70KN per leg which conforms to the requirement of this project because of the slopping ground on the abutments, the different ranges of the screw jack footings have facilitated assembly of the towers.

The Arch Beam soffit tables are manufactured by using a jig, supplied by Doka, as a guide. These tables are straightforward as the various components offer minimal handwork and drilling. This equipment normally arrived on site in practical containers, making transport fairly easy.

The 'Frami' shutters selected for this project were easy to assemble and achieved an acceptable off-shutter finish.

"Doka's onsite support gave the site staff the opportunity to understand this simple system. It also contributed to the progress on site once the workers overcame the learning curve and we are on track," says Duvenhage.

Company Membership Details

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Shukuma Flooring	Mr A Stücki	PO Box 15552 Emerald Hill 6000	041 372 1933	041 372 1944
Lategan & Bouer Engineers	Mr K Lategan	PO Box 1251 Secunda 2302	017 634 4150	017 634 4188
Scribante Concrete	Mr S Scribante	PO Box 2179 North End 6056	041 484 7211	041 484 6231
Quickslab (Pty) Ltd	Mr J Coetzee	PO Box 9 Brackenfell 7560	021 982 1490	021 982 1492
Empa Structures	Mr CA Bain	PO Box 3846 Durbanville 7551	021 988 8840	021 988 8750
Doka South Africa	Mr U Meyer	PO Box 8337 Halfway House 1685	011 310 9709	011 310 9711
Jeffares & Green (Pty) Ltd	Mr CJ Meintjies	PO Box 13009 Cascades 3202	033 347 1841	033 347 1845
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Silver	**Principal Member**	**Address**	**Tel No**	**Fax No**
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MAPEI	Mr C van der Merwe	PO Box 365 Brakpan 1540	011 876 5336	011 876 5160
Chryso SA (Pty) Ltd	Mr NS Seymore	Postnet Suite 59 Private Bag X1 East Rand 1462	011 395 9700	011 397 6644
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BKS Engineering & Mangement (Pty) Ltd	Mr PD Ronné	PO Box 112 Bellville 7535	021 950 7500	021 950 7502
Platinum	**Principal Member**	**Address**	**Tel No**	**Fax No**
NPC-Cimpor (Pty) Ltd	Mr P Strauss	PO Box 15245 Bellair 4006	031 450 4411	086 535 2772

DATE	CONCRETE SOCIETY OF SOUTHERN AFRICA NATIONAL OFFICE 2009		
	MEETING/EVENT	VENUE	CONVENOR
17 September	CSSA Council Meeting	OR Tambo Airport Conference Facilities, Johannesburg	Francois Bain President of CSSA
Beginning of October	Membership Renewals	Distributed to all members	Natasja Pols Administrator of CSSA
17 – 19 November	ACM Conference	Stellenbosch University, Stellenbosch	ACM Organizing Committee
Mid November	Call for Councillor Nominations	Distributed to all members	Natasja Pols Administrator of CSSA
Mid December	Concrete Beton Issue 123	Distributed to all members	Crown Publications

DATE	CONCRETE SOCIETY OF SOUTHERN AFRICA INLAND BRANCH 2009		
	MEETING/EVENT	VENUE	CONVENOR
19 September	Annual Concrete Boat Race Day	Victoria Lake Club, Germiston	Trevor Sawyer
01 October	Branch Committee meeting	C&CI, Waterfall Park, Midrand	John Sheath
15 October	Mini-seminar - Architectural concrete	To be confirmed	Hanlie Turner
05 November	Branch Committee meeting	C&CI, Waterfall Park, Midrand	John Sheath
06 November	Chairman's Breakfast with Guest Speaker	To be confirmed	John Sheath

DATE	CONCRETE SOCIETY OF SOUTHERN AFRICA EC BRANCH 2009/2010		
	MEETING/EVENT	VENUE	CONVENOR
	These are preliminary dates. The final dates must still be confirmed.		
November 2009	Safety of Site - What are the Responsibilities	To Be Confirmed	To Be Confirmed
March 2010	Concrete Mix Design and Specification	To Be Confirmed	To Be Confirmed

DATE	CONCRETE SOCIETY OF SOUTHERN AFRICA WC BRANCH 2009		
	MEETING/EVENT	VENUE	CONVENOR
17 September	Site Visit - Koeberg Interchange	Koeberg Interchange	Riaan Brits
17 September	Concrete Comp. Casting Date	To Be Confirmed	Heinrich Stander
15 October	Concrete Comp. Prize Giving	To Be Confirmed	Heinrich Stander
22 October	MTM - Mick Latimer - M5 Upgrading	University of Cape Town	Jerome Fortune
19 November	Cocktail Party	CPUT Hotel School, Granger Bay	Heinrich Stander

DATE	CONCRETE SOCIETY OF SOUTHERN AFRICA KZN BRANCH 2009		
	MEETING/EVENT	VENUE	CONVENOR
	These are preliminary dates. The final dates must still be confirmed.		
15 September	Reinforced Concrete Design Course	Blue Waters Hotel	Greg
15 October	Concrete Mix Designs	University of KZN	Dion
19 November	Umgeni Viaduct Site Visit	Umgeni Viaduct Site	Dion