# Concrete Beton

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**Accredited technical paper:**

## The influence of slag fineness on the workability of cementitious pastes

**Technical paper:**

## Practical consideration and constraints in durability testing

## Concrete bridge elements of the Gauteng Freeway Improvement Project

# Contents



***Front cover photograph: Richard Jansen van Vuuren***
*The photograph shows steel reinforcing which used in the upgrading of the N1 /R21 interchange where six existing bridges will be upgraded and four new bridges will be constructed.*

CONCRETE SOCIETY
OF SOUTHERN AFRICA

# President's Message

Well, notwithstanding the global downturn in the economy, this has been a seriously busy year for most of us, by all accounts. As I am writing this message, I am sure the majority of members are frantically winding up the last bits of business and looking forward to a well deserved December break.

Please come back well rested, because we are planning a very busy calendar of events for next year.

There are a myriad of branch activities planned – too many to discuss in this forum – and I implore you to refer to the various preliminary branch calendars for particulars of their events planned for next year. I would like to take this opportunity to thank the branch committees and chairpersons for their commitment and wish them well with their activities for next year.

Our newly appointed administrative assistant, Jeanine Kilian, will, amongst her responsibilities, have an event's coordinator function and will be directly responsible for coordinating branch events. In doing so we will be able to stage more branch events of high quality and with a common CSSA feel to all of them. I also take this opportunity to welcome Jeanine to the CSSA.

It is with great excitement that we announce that we have no less than four large national events planned for 2009. Please make a note of these dates and jot these down in your year planners.

We start off with a Self Compacting Concrete (SCC) Seminar in late February 2009. This will be a travelling "road show" type event and will visit the major centres, being the Eastern Cape, KwaZulu-Natal, Western Cape and Inland branches.

The subject of SCCs is a hot topic, but we have found that generally practitioners, consultants and contractors are still a bit in the cold with regards to issues such as why to use it, how to use it, its advantages, its disadvantages, possible problems that may be encountered and precautions related thereto. In essence the idea is to try to get concrete practitioners a little more familiar with the realities of SCCs.

This is followed by the much anticipated biennial Fulton Awards weekend, which is scheduled for the 19th to 21st June 2009. This will be followed by the Fulton Awards Road Show week where, as per usual, we visit the various branches showcasing the winners. Although still following the same concept, we have a few tricks up our sleeves which will be sure to enhance the event.

You have probably seen the calls for nominations and sponsorship. Interest is already peaking and we can confirm that we have received what appears to be a record amount of entry packs drawn. Enquiries are still pouring in.

Again, there are several high level advertising opportunities with great brand exposure. Please contact our head office directly in this regard.

A further two to three months on, we are planning to host, with the support of the C&CI, two 2-day seminars in acknowledgement of the C&CI's 70'th anniversary.

The venues will be in the Western Cape and Gauteng. It is our intention to tie-up these events with site visits to some of the significant projects currently taking place. We will also involve undergrad and post-grad students, and in so doing involve young engineers. Although still in the planning stages, we will be releasing more information on this event shortly.

The last national event being planned for the year 2009 is the Advanced Concrete Materials Conference. We will host this event with Stellenbosch University. This will be an International conference with Rilem support and is scheduled for the week of 17th to 19th November 2009 in Stellenbosch.

Obviously all these technical events will qualify for CPD points. Generally all our technical talks and site visits, at branch level, also qualify for CPD accreditation. In so doing the society prides itself on providing the necessary high level technical support that the membership requires.

By the time you receive this copy of the Concrete Beton, many of our members would already have been approached or have received correspondence related to the proposed new membership strategy and configuration.

Council has completed the process of structuring the tiered corporate and individual membership packages and has also generated descriptive information packs. You will also receive further information with the renewal notices. Please take time to peruse and give some serious thought to this matter. There are some significant benefits to your company should you be interested in the Corporate Membership option.

Should you require more clarity on this matter please do not hesitate to contact me or any of the CSSA councillors or your local branch chairperson, all of whom will be eager to assist you.

I am proud to say that this is the next step the Council has embarked upon to provide you, the member, with a 'new look', relevant and financially self-sufficient Society.

We would like to thank Crown Publications for coming on-board and producing such a high end product. Crown has produced the two preceding- and this current issue of Concrete Beton, as well as this year's CSSA Source Book. I am sure that you will all agree with me that these publications are of a superb quality. I would like to urge members to please support Crown Publications in terms of advertising and advertorials.

Please don't forget that the Concrete Beton is the only accredited technical journal dealing with cement and concrete in Southern Africa. This publication is now distributed to the majority of local professionals, specifiers and contractors who are your actual target audience. In a nutshell, should you wish to highlight your high level technical products or services, then the Concrete Beton should be your advertising medium.

Please also remember that an edition of the much sought after Fulton Awards Beton will be published next year, so keep a little in reserve in your advertising budget for this publication as well.

Lastly, I would like to thank all CSSA councillors and the Administrator for the hard work, dedication and many hours they have put in on behalf of the Society this year – your efforts are highly appreciated.

Before signing off, on behalf of Council, the Administration and myself, I would like to wish all our Society members a pleasant festive season and a very prosperous new year.

Should you be driving over the holidays, we wish you a safe journey.

**Francois Bain PrEng**
**President, CSSA**

# Inland Branch Concrete Boat Race 2008

On the 13 September, the CSSA Inland Branch held its Annual Concrete Boat Race Day at the Victoria Lake Club in Germiston, near Johannesburg. Each year sees an improvement in the event, and this year was no exception with more than 70 boats taking to the water and well over 1 300 supporters cheering the rowing team of their choice.

Support from the local Universities was very good and, as in the past, they had included the boat construction as a project management exercise in their student syllabus. Success on the day was due largely to the financial and other support from industry representatives. Special thanks therefore go to the following companies and organisations:

| | |
|---|---|
| **Afrimix** | **Chryso SA** |
| **AfriSam (Pty) Ltd** | **Infraset** |
| **Ash Resources** | **Lafarge** |
| **BASF Construction Chemicals (Ptry) Ltd** | **PPC** |
| **Basil Read** | **Rocla Poles** |
| **Blitz Concrete** | **W R Grace** |
| **Cement and Concrete Institute** | **Gauteng Lifesaving** |

Judging for the Student Construction Award was carried out by Francois Bain of Shabalala Bain Infrastructure Consultants and President of the Concrete Society, and Carl Schmidt. Many entries in this competition were of very high quality. After much deliberation, the judges decided upon the following winners in the students construction category:

| Category and position | Boat name | Team |
|---|---|---|
| Student construction | | |
| 1st | Lady Lochs | University of Pta |
| 2nd | C.O.W | University of Jhb |
| 3rd | | Tshwane University of Technology |

Additional prizes (compliments of PPC Cement) were awarded to Deon Kruger for the lecturer that registered the largest number of boats on behalf of the University of Johannesburg and to Chris de Jager for the greatest increase in the number of boats and students compared to the event in 2007.

The overall results for the day were as follows:

| Category and position | Team |
|---|---|
| **Students race** | |
| 1st | University of Johannesburg |
| 2nd | University of Pretoria |
| **Industry race** | |
| 1st | Barloworld Logistics |
| 2nd | Ash Resources |
| 3rd | Ash Resources |
| **Ladies race** | |
| 1st | PPC Cement |
| 2nd | Chryso SA |
| 3rd | Barloworld Logistics |

*Seen with Marelene Corrie of PPC Cement and Francois Bain, the National President of the CSSA at the CSSA Inland Branch Annual Concrete Boat Race Day, were:*

*Winners of the Construction Award.*

*Winners of the Student Race.*

*Winners of the Ladies Race.*

*Winners of the Industry Race.*

## Inland Branch visit to FNB Stadium (Soccer City)

More than 20 members attended a recent site visit organised by the Inland Branch of the Concrete Society to the construction site of the FNB Stadium, south west of Johannesburg.

The tour began with an overview of the project given my Mike Moody, Project Director from Grinaker-LTA. He explained that construction was being carried out by a joint venture between Grinaker-LTA (50% Building and 50% Civil) and Interbeton. The client is the City of Johannesburg.

Visitors were shown the original design, which was tabled as part of the South African bid for the Soccer World Cup 2010, and the subsequent changes to this after South Africa had been chosen to host the event. The final design mirrors the shape of an African bowl. Key statistics of the project were outlined and included:

- Current project cost: R2,6 billion
- 70,000 m$^3$ of concrete
- 1 200 piles
- 8,5 million bricks
- Completion date: April 2009

Details of the use of self compacting concrete (SCC) for the project were described by George Evans, also of Grinaker-LTA, although the concrete itself was produced by W G Wearne. Focus centred on the eccentric columns surrounding the stadium, which are to support the final shell of the structure. The challenge was to get the concrete to flow and consolidate with 860 kg per m$^3$ of reinforcing steel present.

Evans went on to explain the differences between high slump concrete, self levelling concrete and self compacting concrete. He explained why only self compacting concrete could have achieved the excellent results that were obtained, and paid tribute to W G Wearne for these. The advantages of using SCC on site were cited as:

- Consistent production, supply and performance
- Consistent consolidation and off shutter finish
- Reduced variability
- Improved construction joints
- Extended workability of the concrete
- High early strength

The party was then given a guided tour of the site, which was impressive in terms of the logistics, layout, scale and the progress made to date. The Inland Branch extends its thanks to Grinaker-LTA/Interbeton joint venture for being gracious hosts and for allowing its members to visit the site.

Drinks and snacks were served at the end of the tour courtesy of Sika South Africa.

The off-shutter finishes are of excellent quality.

A close up view of the reinforcing steel detail.

The magnitude of the project is apparent when viewed from a distance.

One of the eccentric columns at the stadium.

The tour group discusses the details of the project at the end of the site visit.

# KZN Branch: 2007 Concrete Achiever of the Year Award

Clive Wilson, of geotechnical engineers Wilson and Pass Inc, won the 2007 Concrete Society of Southern Africa (KwaZulu-Natal Branch) 'Concrete Achiever of the Year Award' for his company's innovative usage of a 'Top Down' method of construction used to provide a three-level parking basement below the new wing of Umhlanga Hospital.

This is the first time that such a method of construction has been used in KwaZulu-Natal (and perhaps South Africa) and aside from its novelty factor, proved to be highly cost-effective. A saving of about three months on the overall project programme was due largely to the construction method, allowing the simultaneous construction of the superstructure and the basement. The method also reduced the cost of lateral support because ground anchors or temporary internal props were omitted.

Another distinguishing factor of the 'Top Down' method was its broad use of concrete, specifically in the lateral and foundation support piling, floor slabs and the shotcrete that was applied over both the lateral and column support piling. In other countries structural steel is used to fulfil one or more of these functions.

As it pertained to this contract, the 'Top Down' method involved installing contiguous, augered concrete piles some 10-16 m deep around the periphery of the area that would serve as the basement for the hospital. Thereafter, having first excavated some 7.5 metres down, column support piles were installed from the (B1) upper level of the future basement, to support the columns that would later be constructed above. A floor slab was then cast across the entire area at B1 level, incorporating the tops of the column support piles.

At this stage the 'Top Down' description comes into play. While the remaining lower part of the basement (from B1 to B3) was then excavated to a depth of six metres – with the subsequent construction of the B2 suspended floor slab and B3 surface bed floor slab – the construction of the superstructure above the B1 floor level could continue apace.

*Dion Kuter (left) CSSA: KwaZulu-Natal branch chairman presenting 'The 2007 Concrete Achiever of the Year Award' to Clive Wilson.*

Some of the factors that weighed in favour of using this method of construction and the exclusive use of concrete, included:

i) AFRIPILE's importation of modern piling rigs that allowed for the installation of larger diameter concrete piles – and to greater depths. Such piles provided **(a)** lateral support to the initial stage of this exceptionally deep excavation without ground anchors, and **(b)** supported the heavily loaded columns beneath this six-storey structure, as single units, or in pairs. This limited the space they occupied as finished columns in the parking basement.

ii) The contiguous concrete piles around the sides of the basement also formed part of the permanent structure. This eliminated the need for permanent secondary internal retaining walls, as well as temporary shoring often provided by either steel sheet piles or timber.

iii) The 800 mm diameter concrete column support piles were sufficiently robust to withstand limited impacts by front-end loaders and dump trucks used to excavate the basement while the piles supported the superstructure above, despite being exposed and unbraced over a height of 6 m below floor B1. Whereas structural steel piles/columns or steel column inserts in the tops of piles may have exhibited equivalent strength and would have occupied less space, the risk of damage to them during basement excavation would have been intolerable.

iv) It was relatively simple to attach the suspended basement floor B2 to the piles, and to connect pairs of piles to form rectangular columns through the basement, by reshaping the piles by chipping away concrete to expose "pull-out" reinforcement, and/or by grouting bars into holes drilled through the piles.

**PROFESSIONAL TEAM:**

**AFRIPILE:** Design and construction of the basement; installation of column support piles and lateral support piles.

**AFRISTRUCT PROJECTS:** Management of bulk excavation; construction of floors, walls, columns within the basement.

**WILSON & PASS:** Consulting geotechnical and structural engineers. Proposed and detailed the 'Top Down' method, including detail design of the piles and lateral support.

| CONCRETE SOCIETY OF SOUTHERN AFRICA KWAZULU-NATAL BRANCH PROGRAMME FOR 2009 | | | |
|---|---|---|---|
| MONTH | DATE | EVENT/TOPIC | CONVENOR |
| Jan 09 | 19 | Call for Nominations for the Concrete Achiever of the year award. | Garth / Dion |
| Feb 09 | 19 | Tilt up Technologies (UKZN) | Raj |
| Mar 09 | 11 | National and Regional AGM / KZN Achiever | Dion & Garth |
| Apr 09 | 16 | Braamhoek Power Station | Patrick |
| May 09 | 21 | Ash Resources | Raj |
| May 09 | 28 | KZN Golf Day | Garth / Patrick |
| Jun 09 | TBA | Gautrain Presentation (UKZN) | TBC |
| Jun 09 | 19 - 21 | Fulton Awards – Main Event (Champagne Sports Resort – Drakensberg) | Philip Ronne |
| Jun 09 | 23 | Fulton Awards – Regional Roadshow (Venue TBC) | All |
| TBA | TBA | New Durban Airport Site Visit | Rolf/Rowan |
| Aug 09 | 20 | Interpretation of Concrete Tolerances | Garth |
| Sept 09 | TBA | Reinforced Concrete Design Course | Greg |
| | | | |

# CSSA National Office events diary for 2009

| Date | Venue | Event |
|---|---|---|
| 23-26 Feb 09 | PE / JHB / DBN / CT | SCC Road Show |
| 11-12 March 09 | DBN | AGM – National |
| 19-21 June | Champagne Sports Resort KZN | Fultons Awards |
| 23-25 June 09 | DBN / PE / CT | Fultons Awards Road Show |
| Sep-Oct 09 | JHB / CT | Celebrating Concrete |
| 17-19 Nov 09 | Stellenbosch | Advanced Concrete Materials Conference |

# Eastern Cape Branch report back on 3rd quarter of 2008

## Coega Harbour site visit

The CSSA Eastern Cape Branch held a site visit and discussion at the Coega Harbour on 2 September hosted and presented by Transnet. Although attendance at this event was limited to 30 people, over 70 people applied for inclusion on the attendance list. Unfortunately not all could be accommodated and a second visit is being organised. Once again attendees consisted of consulting engineers, architects and suppliers and afforded all a chance to learn more about what is going on at Coega as well as what their future plans are.

The CSSA wishes to thank Transnet, and Gerrit du Plessis and Fazeel Christian in particular, for sponsoring the event and delivering the presentation (the snacks and drinks were very much appreciated by all). Furthermore the branch thanks Renee de Klerk for her contribution on the environmental issues. It also thanks those who attended as well as those who expressed interest but were not able to attend since your support and interest has been very encouraging.

The branch also thanks all who contributed by filling in their feedback forms since this provides valuable information for us in terms of arranging and benchmarking future events. The results of the feedback will be place on the CSSA Eastern Cape website once it is up and running.

## Radisson Hotel site visit and technical discussion

The branch also held a site visit and technical discussion at the Radisson Hotel site on 14 October. The number of people in attendance was approximately 50 and they were taken on a tour of the building to about the 10th level and shown some of the interesting parts of the project. Those attending included professionals (engineers, architects and quantity surveyors), contractors and suppliers.

The event was hosted by the contractor WBHO who, besides providing the venue and snacks, were part of the presentation. The branch wishes to extend a massive thank you to WBHO for opening up their site and for their honesty in sharing some of their challenges, mistakes and successes on the project. The tour group was very fortunate and grateful to also have the structural engineers (Esais Koen from Elwandle Projects) and the architects (Lloyd Pringle from Stauch Vorster) present.

## Wiehahn presentation

The branch also held a successful and interesting presentation on formwork systems and design as well as a light weight flat slab design, specifically discussing the innovative Cobiax flooring system on 6 November at St Georges Park Cricket Ground.

The presentation was hosted and presented by Wiehahn who sponsored the entire event. Andrew Rowe went through some of the issues related to formwork design; drawing particular attention to the handbook produced by Peri in this regard which can act as a useful guide to contractors as well as formwork designers. Riaan Brits introduced the cobiax system. In this presentation he discussed design considerations and benefits, construction issues as well as possible costs savings in designing in this manner. A design guide on the system was also made available and can be requested directly from Wiehahn.

The branch thanks Wiehahn for the material they provided and in particular Dean Sandells (the local technical representative).

## Overview of the Eastern Cape Branch 2008

2008 has been an eventful year for the CSSA – Eastern Cape Branch. It has been able to arrange a number of interesting technical events and attract a diverse grouping of people. Site visits and technical discussions have been attended by consulting engineers, architects, quantity surveyors, contractors and suppliers within the concrete and construction industry. Not only have the events been well organized and well attended but the quality of technical input has been high.

The first issue of the branch's newsletter went out in August. The aim of the newsletter has been to showcase local projects, local issues and local successes. The branch aims for the newsletter to be a platform for all parties involved in the industry to communicate with each other and learn from each other. Another issue is being planned for issue before the end of the year.

### Events planned for 2009:

| | |
|---|---|
| February | **SCC Road Show** |
| March | **CSSA Eastern Cape Branch AGM** |
| April | **Coega Bridge – Site Visit** |
| May | **NOSA – Occupational Health and Safety** |
| July | **Duty of Care Professionals** |
| August | **Concrete mix design and specification** |
| October | **Design of post tensioned concrete structures** |

# The influence of slag fineness on the workability of cementitious pastes

**R J Page**
*Laboratory Manager: Afrisam Product Technical Laboratory, Alrode (Slagment).*

**G C Fanourakis**
*Associate Professor: Department of Civil Engineering Technology, University of Johannesburg.*

*In South Africa the fineness of Ground Granulated Blastfurnace Slag (GGBS) has remained the same for nearly forty years. In 1999, producers of GGBS were considering the use of relatively finer ground GGBS with a view to improving the strength performance of concrete.*

*The concomitant increase in compressive strength of concrete with an increase in GGBS fineness was confirmed in an extensive investigation carried out by Slagment (Pty) Ltd (Slagment, 1999). However, the effect of relative fineness of South African GGBS on the workability of concrete mixes had not been assessed.*

*This paper discusses the results of an investigation that was aimed at quantifying the influence of finer ground GGBS on the workability of concrete, based on the work of Page (2001). Traditionally, GGBS was ground to a fineness of 3 600 cm²/g, GGBS (3600), and it was proposed to increase its fineness to 5000 cm²/g, GGBS (5 000).*

*The experimental programme included four binder types, namely, CEM I 42,5 alone or in combination with either GGBS (3 600) or GGBS (5 000) or Fly Ash (FA). To eliminate the effects of aggregates on workability, only binder pastes were tested.*

*The results revealed that, as expected, the binder containing the Fly Ash was the most workable.*

*In general, the finer slag, GGBS (5 000), exhibited a higher viscosity and hence lower workability than the GGBS (3 600), due to its relatively higher surface area.*

## INTRODUCTION

The results of an investigation, in 1999, conducted by Slagment (Pty) Ltd, showed the strength of concrete to improve with the use of relatively finer ground Ground Granulated Blastfurnace Slag (GGBS) (Slagment, 1999). However, the effect of GGBS fineness on the workability of concrete was not determined.

The fineness of cementitious material is normally indicated by the surface area of the material, which is generally determined by the Blaine method. Traditionally, GGBS was ground to 3 600 cm²/g (Blaine) and the proposed finer material investigated was ground to a fineness of 5 000 cm²/g.

There is another school of thought that advocates that a more accurate assessment of the fineness can be determined from a particle size analysis. The characteristic parameters generally adopted for this distribution are a position parameter 'X' and the slope (n-value) of the distribution function according to the Rosin, Rammler, Sperling and Bennett (RRSB) distribution (Blunk et. al., 1989). A high value of n (slope of the distribution curve) indicates a narrow particle size distribution which will result in a higher water requirement. Lower n-values should result in a reduced water demand.

Patzelt (1993) stated that the water requirement for GGBS even when finely ground should be the same in comparable systems. Hence, the water requirement can be altered by altering the particle size distribution of the material.

Fujiwara and Dozono (1997) carried out a study on the effect of Blaine and n-value on viscosity and on the yield stress. Fifty one types of powder were tested with Blaine values ranging between 3 500 and 7 500 cm²/g and n-values ranging from 0,7 to 1,1. The results of their tests showed the following:

- the n-value has a definite effect on the yield stress. As the n-value decreases the yield stress decreases. When the n-value is below 0,8 the yield stress increases as the n-value decreases
- when the Blaine is less than 4000 cm²/g, the n-value has a strong influence on the viscosity (viscosity decreases as the n-value reduces). When the Blaine is greater than 4000 cm²/g the influence of the Blaine, rather than the n-value, is greater (as the Blaine increases the viscosity increases).

The purpose of the investigation reported here (based on the work of Page, 2001) was to determine the influence of GGBS fineness on the workability of cementitious pastes. This research was based on the premise that there is a direct correlation between the workabilities of concrete and the included paste. The effect of both Blaine and n-value on workability was considered.

The experimental programme included four binder types, namely, CEM I 42,5 alone and in combination with either GGBS (3 600) or GGBS (5 000) or Fly Ash (FA). Fly ash (FA) was included in the binders tested in order to provide another reference. To eliminate the effects of aggregates on workability, only binder pastes were tested. Commonly used blending proportion ratios were adopted.

The Standard Consistency, Flow Table, Viscosity over Time (Single Speed) and Rheology of Mortar (Variable Speed Viscometer) tests were carried out on all the mixes.

## EXPERIMENTAL DETAILS

### Materials

#### Portland Cement - CEM I 42,5

For the purposes of this project, cement from only one supplier (PPC) was considered. The cement was a CEM I 42,5, which complied with SANS EN 197-1 (2000). The cement had a specific surface area of 3 468 $cm^2/g$ and a mean particle diameter of 30,13 µm.

#### Ground Granulated Blastfurnace Slag - GGBS

The Ground Granulated Blastfurnace Slag was taken from the same source for the two samples tested. The GGBS (5 000) was ground finer than the GGBS (3 600) by being subjected to a longer period in the mill. Both Samples of GGBS complied with SANS 1491-1 (2005).

The GGBS (3600) was the traditional slag used in the South African market. This material was ground to a Blaine of 3 600 $cm^2/g$, had a specific surface area of 4 630 $cm^2/g$ and a mean particle diameter of 19,76 µm.

The GGBS (5 000) was the finer ground slag proposed for the market. This material was ground to a Blaine of 5 000 $cm^2/g$, had a specific surface area of 5 613 $cm^2/g$ and a mean particle diameter of 13,39 µm. This material was produced as a once-off run and hence is not currently available.

#### Fly ash

The FA conformed to SANS 1491-2 (2005) and was obtained from a local supplier. The FA was classified by a 12,5 % residue on a 45 µm sieve.

### Particle Size analysis

The results of particle size analyses that were carried out on the CEM I 42,5 and on the GGBS samples are shown in Figure 1:

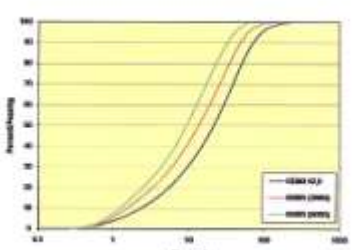

*Fig. 1 - Particle size analyses*

In summary, the GGBS (5 000) had 100 % of the particles smaller than 60 µm and in the case of the GGBS (3 600) the equivalent figure was 100 µm. The three curves show the three binders getting progressively coarser with the Portland cement being the coarsest.

The surface area of the material increased by 16% from the CEM I 42,5 mix to a 50/50 CEM I/ GGBS (3 600) blend and a further 12% in the case of 50/50 CEM I/ GGBS (5 000) blend. Table 1 shows n-values for the cementitious materials included in this investigation (excluding the FA).

Table 1: N-values of CEM I and GGBS

| Cementitious Material | n-value |
|---|---|
| CEM I 42,5 | 1,14 |
| GGBS (3600) | 1,22 |
| GGBS (5000) | 1,36 |

### Chemical analysis

The results of a chemical analysis of the CEM I 42,5, GGBS (3 600) and GGBS (5 000) are shown in Table 2. This analysis was carried out by the X-ray Fluorescence (XRF) technique by PPC (Pty) Ltd.

Table 2: Chemical analysis

| Chemical | Cementitious Material | | |
|---|---|---|---|
| | CEM I 42,5 | GGBS (3600) | GGBS (5000) |
| $SiO_2$ | 22,6 | 35,6 | 34,80 |
| $Al_2O_3$ | 4,00 | 15,00 | 14,20 |
| $Fe_2O_3$ | 2,32 | 1,00 | 0,97 |
| $Mn_2O_3$ | 0,33 | 1,21 | 1,16 |
| $TiO_2$ | 0,27 | 1,23 | 0,56 |
| CaO | 66,30 | 33,50 | 37,00 |
| MgO | 2,70 | 10,60 | 8,50 |
| $P_2O_5$ | 0,03 | 0,00 | 0,01 |
| $SO_3$ | 1,92 | 1,77 | 1,66 |
| $K_2O$ | 0,38 | 0,80 | 0,84 |
| $Na_2O$ | 0,00 | 0,23 | 0,12 |
| LOI | 0,00 | 0,00 | 0,00 |
| Total | 100,90 | 100,90 | 99,80 |

Referring to Table 2, the CaO content of the GGBS (5 000) is higher than the GGBS (3 600). This difference, which may have a significant affect on strength, is probably attributed to a difference in the chemical composition of slag from different blastfurnaces.

### Laboratory procedures

#### Paste mix proportions

The four binder types shown in Table 3 were used for the test programme. The proportioning was done on a mass basis.

Table 3: Paste mix proportions

| Binder | CEM I 42,5 (%) | GGBS (3600) (%) | GGBS (5000) (%) | FA (%) |
|---|---|---|---|---|
| PC | 100 | | | |
| PC/SL | 50 | 50 | | |
| PC/SL | 50 | | 50 | |
| PC/FA | 70 | | | 30 |

### Paste preparation

The cementitious pastes were weighted as indicated below. The pastes were made up using a Hobart mixer with a standard mixing time of two minutes at the lowest speed (to prevent air entrainment/ entrapment in the mix). The water was first placed into the mixer followed by the binder. After 45 seconds of mixing, the mixer was stopped for 10 seconds to scrape-off the material deposited on the sides of the bowl.

### Tests

The binder pastes which are listed in Table 3, were subjected to the following tests.

Standard consistency tests

The tests were carried out in accordance with SANS EN 196-3 (2005). The materials were weighed out with 500 g of binder and the relevant amount of water required to obtain the specified workability. The Vicat apparatus with the plunger (50 mm long and 10 mm in diameter), which is shown in Figure 2, was used for this test.

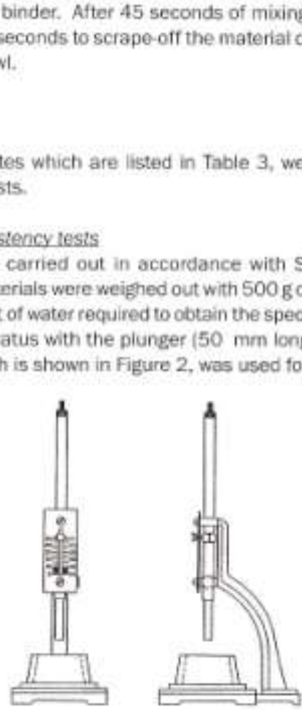

*Fig. 2 – Vicat apparatus*

This test entails allowing the plunger to vertically penetrate a 40 mm deep paste (in a 75 mm average diameter mould) under its own weight. The standard consistency is defined as the consistency at which a penetration of 33 to 35 mm is achieved.

The results are expressed in terms of the moisture content, expressed as a percentage of the mass of the binder, at which the standard consistency was obtained and the actual penetration recorded. The penetration result is recorded as the distance between the plunger face and the bottom of the mould. Therefore, for example, a penetration of 35 mm into the paste would be recorded as a result of 5 mm (40 mm minus 35 mm).

Flow table tests

Three tests were carried out on each binder type in accordance with SABS Method 1153 (1989).

Figure 3 shows a flow table with the accompanying mould. The mould is 50 mm high and its diameters at the top and bottom are 70 mm and 100 mm, respectively.

*Fig. 3 – Flow table*

The total binder used for each test was 770 g. After filling, tamping and lifting the mould, in accordance with the test method, the table is raised and dropped (through a height of 12,7 mm), 25 times within a 15 second period.

The average diameter of the spread is determined from measurements of the diameter taken at four approximately equally spaced intervals. The flow of the mortar is defined as the increase in diameter expressed as a percentage of the original diameter of the bottom of the specimen (100 mm). The test is repeated at various water contents until a flow of 100 to 110 % is obtained.

The results are expressed in terms of the water content that produced the 100 to 110 % flow, and the average diameter of the flow.

Viscosity with time tests

In the absence of a test specification, the tests were conducted as follows.

Three samples of each binder type were tested at each of three different water/binder (w/b) ratios (0,4;0,5; and 0,6). These w/b ratios are the usual ratios used, as mentioned by Ish-Shalan and Greenberg (1960). Before the pastes were tested in the viscometer, the temperature was recorded. An initial viscosity reading was taken and then readings were recorded at 1, 2, 3, 4, 5, 10, 15 and 20 minutes. The test was stopped and the temperature was re-recorded.

The viscosity was measured using a VT-04 Portable Viscotester, manufactured by the Rion Co. Ltd, shown in Figure 4. This instrument determines the viscosity of the paste by rotating a rotor in the sample which causes viscous resistance.

*Fig. 4 – Viscometer*

The results from this test are expressed in deci Pascal seconds (d Pa s). One d Pa s is a tenth of a Pascal second (Pa s) which is identical to a kilogram per metre second (kg/m s). At 20 ° C, water and olive oil have approximate dynamic viscosity values of 0,01 and 0,84 d Pa s, respectively. The viscosity of cementitious pastes generally varies from 1 to in excess of 50 d Pa s.

Rheology – Variable speed viscometer

Figure 5 shows the variable speed viscometer. The test method used was that of Banfill (1990).

*Fig. 5 – Variable speed viscometer (Visco-Corder)*

The material was tested in a cup which was rotated at various speeds, whilst a stationary paddle, which was located inside the cup, measured the torque created by the rotating sample. The torque was relayed, through a spring, to a pen which recorded the measurement on a chart that moved at a constant rate.

The results were presented in the form of a flow curve where torque versus speed was plotted. The y intercept and slope of a flow curve represented the yield value and plastic viscosity of the material, respectively.

In the case of this investigation, the mix preparation differed from the general procedure described above. The mixes were weighed and prepared according to DIN 1164 (1998). This entailed placing water into the mixing bowl before adding the binder. The cementitious paste was mixed for 30 seconds before the graded sand (as specified by the test procedure) was added, after stopping the mixer. The mixer continued at 140 rev/min to complete one minute. The mixer was stopped and the speed adjusted to 285 revs/min, mixing took place for a further minute. The total mixing time was two minutes. The standard sand used, which had the particles greater than 1 mm removed by sieving, was expected to have very little influence on the workability. The Visco-Corder cup was then filled to the indicated position and the testing started within one minute after completion of mixing. The total approximate duration of each test was about two and half minutes. The total period for each test varied because the speed adjustment was manual, making it difficult to keep the interval period from one speed to the next exact. However, preliminary trials conducted to determine the influence of varied duration at the specified speed indicated that these varied durations had little effect on the results achieved.

## RESULTS AND DISCUSSION

### Standard consistency tests

The results of the Standard Consistency Tests are shown in Table 4.

Table 4: Standard consistency test results

| Binder | Water Required | Penetration |
|---|---|---|
| PC | 135,02 | 5 |
| PC/SL | 137,08 | 5,6 |
| PC/SL | 137,04 | 5 |
| PC/FA | 128,01 | 7 |

Referring to Table 4, it is evident that both the slag blends (PC/SL) required approximately 1,5 % more water than the PC mix to achieve the same workability. In the case of the PC/FA blend, the water content was reduced by 5,2 % relative to the PC.

### Flow Table Tests

The first trial was done to determine the water required to achieve a flow of 100 to 110 % (diameter of 200 to 210 mm). Then two more mixes were made using the same amount of water and the flow was measured. Table 5 shows the average flow of three samples of each of the mixes with the same amount of water.

Table 5: Flow table test results

| Binder Type | Water that produced 100 to 110% Flow (g) | Measured Flow (mm) |
|---|---|---|
| PC | 245 | 202,8 |
| PC/SL | 239 | 200,8 |
| PC/SL (F) | 240 | 198,1 |
| PC/FA | 231 | 204,9 |

With reference to Table 5, there is a reduction in water for the slag mixes compared to the PC mix. However, it must be noted that the average flow for the slag mixes was less than that for the PC mixes.

The water reduction and flow of the binder types containing slag or Fly Ash relative to the PC is shown in Table 6.

Table 6: Water reduction and flow differences relative to PC

| Binder Type | Water Reduction Relative to PC (%) | Flow Difference Relative to PC (%) | Water Reduction/ Flow Difference |
|---|---|---|---|
| PC/SL | 2,4 | -0,98 | -2,45 |
| PC/SL (F) | 2,0 | -2,32 | -0,86 |
| PC/FA | 5,7 | +1,04 | 4,80 |

As expected, the Fly Ash mixes yielded the highest water reduction/flow ratio (4,80). This means that this mix provided the most flow with the least amount of water.

Comparing the two slag blends, it is evident that the blend with the finer ground slag, PC/SL (F) yielded a lower workability.

### Viscosity with time tests

The results of the viscosity with time tests, for the three w/b ratios (0,4; 0,5 and 0,6) are shown in Figures 6 to 8. The results shown in each figure are based on the average of three tests carried out on each binder type. Details of the test data are included in the work of Page (2001).

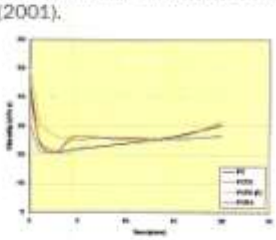

*Fig. 6 – Viscosity with time for a w/b ratio of 0,4*

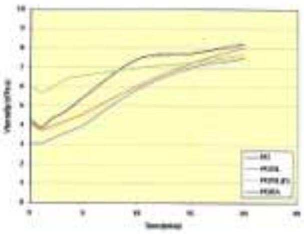

*Fig. 7 – Viscosity with time for a w/b ratio of 0,5*

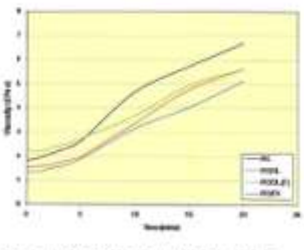

*Fig. 8 – Viscosity with time for a w/b ratio of 0,6*

With reference to Figures 6 to 8, as expected, for each of the blends, viscosity decreased with increasing w/b ratio. Furthermore, for each w/b ratio, the viscosity during the initial test period (up to 3 to 8 minutes) decreased due to gypsum going into the solution in the order PC/SL (F), PC, PC/SL and PC/FA. The PC/SL (F) was the most viscous of the binders during the abovementioned early period probably due to its relatively high surface area.

In the case of the w/b ratios of 0,5 and 0,6 (Figures 7 and 8), the viscosity of the PC binder mix increased and exceeded that of the other binders, after the early period. This was probably due to the fact that this mix contained more Portland cement than the other mixes and hence, in the presence of sufficient water, hydration occurred and resulted in a relative increase in viscosity.

The rate of increase in viscosity was of a similar magnitude in the case of all the w/b ratios. Table 7 below shows the average rate of increase of all the binders, from 5 to 20 min, for each of the w/b ratios.

Table 7: Rate of increase in viscosity

| Water Binder Ratio | Rate of Increase (d Pa s/min) |
|---|---|
| 0,4 | 0,23 |
| 0,5 | 0,18 |
| 0,6 | 0,23 |

The only consistent trend common to all three w/b ratios was that the FA blend had a lower viscosity (better workability) than all the other mixes.

The lack of prominent trends in the test results may be attributed to the following inaccuracies associated with the coaxial viscometer (Banfill,1973).

- Slippage - slippage on the surface of a smooth cylinder. Although the instrument used had a roughened surface there was no evidence to prove that slippage did not occur with a roughened surface.
- Sedimentation - the w/b ratio should be kept below 0,4 with this type of equipment to ensure a maximum 10 % error. Only one set of mixes had this value.
- Plug flow - at no time was it monitored and confirmed that total shear flow was present in the sample being tested.

## Rheology – variable speed viscometer

The results shown below in Table 8 are average results from three sets of tests. The detailed data are included in the work of Page (2001).

The flow curves for the binders are shown in Figure 9.

Table 8: Summary of results for variable speed viscometer

| Rev/ min | Average Torque (g cm) | | | |
|---|---|---|---|---|
| | PC | PC/SL | PC/SL (F) | PC/FA |
| 250 | 393,3 | 383,3 | 431,7 | 245,0 |
| 200 | 350,0 | 346,7 | 386,7 | 211,7 |
| 150 | 311,7 | 301,7 | 343,3 | 185,0 |
| 100 | 271,7 | 260,0 | 298,3 | 156,7 |
| 50 | 225,0 | 215,0 | 248,3 | 128,3 |

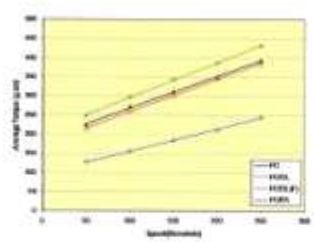

*Fig. 9 – Flow curves for the binders*

The equation below (Bingham model) shows the relationship between shear stress (τ) and shear rate (γ), and indicates that two parameters are required to characterize a material, namely yield value ($\tau_o$) and plastic viscosity (μ).

$$\tau = \tau_o + \mu \gamma$$

For the purposes of this investigation, a large emphasis was placed on the yield stress, which indicates the mobilizing force required for the movement of the material. According to Neville (1995), this value is a good indicator of the workability of concrete.

The viscosity and yield stress values pertaining to the flow curves in Figure 9 are shown in Table 9.

Table 9: Viscosity and yield stress values

| Binder Type | Viscosity (μ) | Yield Stress (γ) |
|---|---|---|
| PC | 0,83 | 185,8 |
| PC/SL | 0,85 | 174,3 |
| PC/SL (F) | 0,91 | 205,2 |
| PC/FA | 0,58 | 98,8 |

With reference to Table 1 (containing the n-values) and Table 9 (containing the yield stresses) the following observations were made from this investigation.

- No relationship was found to exist between the n-value and the yield stress of a material. This is in disagreement with Fujiwara and Donozo (1997) who found that, for n-values of 0.8 and greater, a positive correlation existed between the n-value and the yield stress of a material. However, as the particle shape of a material has an effect on the yield stress, the n-values and yield stresses of PC pastes should not have been compared with those of the blended pastes. Therefore, when the n-values and yield stresses of the two PC/SL pastes were compared, the trend established by Fujiwara and Donozo (1997) was confirmed.
- The n-value had a strong influence on the viscosity (viscosity decreased as the n-value decreased. This trend was in agreement with the work of Fujiwara and Donozo (1997).

## SUMMARY OF RESULTS

The results from the different tests are summarised in Table 10 below. For each test the results of the PC were considered as the reference for this relative comparison of results obtained by the other blends. Therefore, a relative decrease in percentage indicates a relative increase in workability.

Table 10: Summary of relative workability results

| Binder | Variable Speed Viscometer (Yield stress) | Variable Speed Viscometer (Viscosity) | Coaxial Cylinder Viscometer (Viscosity @ 3 mins) | Flow Table Variation in water requirement | Standard Consistency Variation in water requirement |
|---|---|---|---|---|---|
| PC | 100% | 100% | 100% | 100% | 100% |
| PC/SL | 94% | 102% | 103% | 98% | 101% |
| PC/SL (F) | 110% | 110% | 126% | 98% | 101% |
| PC/FA | 53% | 70% | 100% | 94% | 95% |

As expected, the mix incorporating the FA had the lowest yield stress and viscosity and hence the best workability.

With regards to the two mixes containing GGBS, the results of the yield stress correlated well indicating a decrease in workability when the finer ground GGBS was used. Furthermore, the viscosity (μ) also increased when moving to the finer material. This means that once the material is mobilized more energy is required to maintain the flow.

## CONCLUSIONS

The standard common workability tests such as the slump test and the flow table test measure one parameter whereas the variable speed viscometer can solve for the yield stress and the viscosity of the material.

The variable speed viscometer was the most sensitive test in determining the difference between the various blends.

The results of the yield stress correlated well indicating a decrease in workability when the finer ground GGBS is used.

From these results it can be inferred that the finer ground GGBS will reduce the workability of concrete. For the purposes of concrete mix design there will be an increase in water requirement for an equivalent slump when moving to a finer ground GGBS.

Based on the above it is recommended that further workability tests be carried out on various finenesses of GGBS (between 3 600 – 5 000 cm2/g) with different n-values. It is also recommended that more than one source of CEM I 42,5 be included in any further research. The workabilities and corresponding strengths achieved should be compared in order to optimize the effect of finesses on the workability and strength.

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The lighter side of concrete.


Why did the Chicken cross the Mafia?

# Practical consideration and constraints in durability testing

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*This paper describes the practical issues that were encountered during a large scale durability test programme conducted at the Slagment laboratory. Various durability tests were conducted that are described in the paper.*

*The main concerns were the time and resources required for preparation of the samples and the testing. With the exception of the Torrent permeability test, durability testing is onerous and requires attention to detail. Another concern was the high variability observed in samples of the same batch. In the case of the Torrent Permeability tester this was mainly attributed to variations in moisture contents of the concrete at the time of testing. In the case of the oxygen permeability tests it may be due the relative small sample size. Both these issues require further investigation.*

## INTRODUCTION

During the period of March 2006 to September 2006, Slagment Alrode Laboratory was tasked to carry out durability testing on 135 concretes. The concretes were made up from various binders, aggregates and w/c ratios. The results from these tests were to be used for the modelling of durability in concrete based on the parameters of binders, aggregate and w/c ratios.

Durability index testing(1) (oxygen permeability, water sorptivity and chloride conductivity) were done as well as non destructive permeability tests (Torrent Permeability Tester)(2), accelerated carbonation (Fib Model Code 2006)(3) and accelerated chloride penetration (NT Build 443)(4) .

The objective of this paper is to describe the various practical issues that had to be considered during the course of these tests. It also investigates the impact of these practicalities on the usefulness of these tests in terms of modelling durability and quality assurance on site. The variability of the test results has a major influence on their usefulness. The higher the standard deviation the greater the uncertainty in the interpretation of the test results. Some of the practical issues may influence the standard deviation of the tests.

## DESCRIPTION OF TEST METHODS

### Durability index testing[1,5]

Three accelerated tests, the oxygen permeability, water sorptivity and chloride conductivity, were developed by Alexander, Ballim, Mackechnie and Streicher that respectively measured the transport mechanism of gas, fluid and chloride ions into concrete. The philosophy is that these tests could be used as an index to quantify the susceptibility to attack of the covercrete of site concrete. The test are briefly described below and the full test methods described in Durability Index Testing Procedural Manual(1), May 2005 available at www.civil.uct.ac.za

#### Oxygen permeability

The D'Arcy coefficient of permeability is determined by placing 67 mm diameter by 25 mm thick oven-dried concrete samples (representing the cover layer of concrete) in a falling head permeameter (see Figure 1). The samples are obtained either from cubes made in the laboratory or cores drilled from structural elements.

*Fig. 1 – Oxygen permeability test*

The falling head permeameter applies an initial pressure to the concrete sample and allows the pressure to decay with time. The pressure decay with time is measured and is converted to a linear relationship between the logarithm of the ratio of pressure head vs time, from which the D'Arcy coefficient of permeability (k) is determined. The coefficient of permeability (k) is a clumsy exponential number and therefore is simplified by defining the permeability index (OPI):

$$OPI = -\log_{10} k \;.\;.\;.\;.\;.\; (1)$$

#### Water sorptivity

Through the action of capillary forces, fluid is drawn into porous, unsaturated material. The amount of water drawn into the concrete under capillary suction is determined by carrying out a water sorptivity test. The test faces of oven-dried concrete samples, 67 mm diameter by 25 mm thick (representing the cover layer of concrete) are placed in a few millimetres of water. The test face represents the side of the sample that would be exposed to wetting and drying cycles. At regular intervals the specimens are removed from the water and the mass of water absorbed is determined by weighing the sample. Measurements are stopped before saturation is reached, and the concrete is then vacuum-saturated in water to determine the effective porosity (see Figure 2).

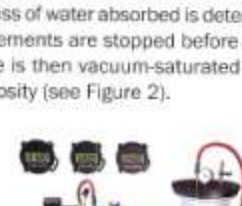

*Fig. 2 – Water sorptivity test apparatus*

A linear relationship exists between the mass of water absorbed and the square root of time. The sorptivity index is determined from the slope of the straight line produced.

### 2.1.3 Chloride conductivity

Diffusion is the process during which liquid, gas or ions move through porous material under the action of a concentration gradient. Diffusion occurs in partially- or fully-saturated concrete and is an important transport mechanism for most concrete structures exposed to salts. High surface salt concentrations are initially developed by absorption. This salt subsequently migrates by diffusion towards the low concentrations of the internal material. The chloride conductivity test is an accelerated diffusion test using an applied potential difference to accelerate migration of chlorides in concrete to obtain quick results in the laboratory. Normally laboratory samples are tested. The results of the test are related to chloride ingress into the concrete (see Figure 3).

*Fig. 3 – Chloride conductivity test apparatus*

## Torrent permeability tester(2)

The torrent permeability tester is a non-destructive air-permeability test method.

The distinctive characteristic features of this method are a two-chamber vacuum cell and a regulator that balances the pressure in the inner (measuring) chamber and in the outer (guard-ring) chamber (Figure 4). The cell is placed on the concrete surface and a vacuum is created with the pump in both chambers. Due to the external atmospheric pressure and the rubber rings the cell is pressed against the surface and thus both chambers are sealed, making the cell self-supported. After 1 min stop- cock 1 is closed, which insulates the inner chamber system. From this moment on, the pressure in the inner chamber starts to increase, as air is drawn from the underlying concrete. The rate of pressure raise, which is directly related to the permeability of the concrete, is recorded. As the vacuum pump continues to operate on the outer chamber, through the pressure regulator; the latter ensures that the pressure in the outer chamber is kept always equal to the pressure in the inner chamber. Thus, the outer chamber acts as a "guard-ring", creating a controlled, unidirectional air flow into the inner chamber. That makes it possible to calculate the coefficient of permeability kT [$m^2$], on the basis of a theoretical model. A correction is applied if the results of the resistivity (measured by the Wenner method) are too low, indicating a Manufacturer's web page: www.proceq.com

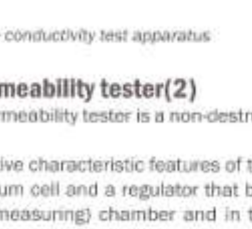

*Fig. 4 – Torrent Permeability Tester*

*Fig. 5 – Torrent Permeability tester used on site*

## Accelerated carbonation testing

The accelerated carbonation test is conducted to determine the resistance of concrete to carbonation by increasing the concentration of $CO_2$ the concrete is exposed to. The accelerated carbonation test was conducted in accordance with the guidelines given in the Fib Model Code for Service Life Design(3). The test is conducted in a relative humidity and temperature controlled chamber with the concentration of $CO_2$ at 2%. Concrete cubes are wet-cured for seven days, after which it was left to dry in a controlled environment of 50-60% relative humidity and temperature of 22 to 25°C until 28-days old. It was then placed in the $CO_2$ chamber for 28 days. After 28-days exposure in the $CO_2$ chamber the cubes were split phenolftailen was sprayed on the freshly broken faces and the depth of carbonation measured.

## Build 443 Accelerated Chloride penetration(4)

This Nordtest method specifies a procedure for the determination of penetration parameters for estimating the resistance against chloride penetration into hardened concrete or other cement-based materials. The resistance against chloride penetration is determined by accelerated testing. A water-saturated concrete specimen is on one plane surface exposed to water containing sodium chloride. After a specified exposure time thin layers are ground off parallel to the exposed face of the specimen and the chloride content of the layers, Cx, is measured. The original (initial) chloride content of the concrete, Cj, is measured at a suitable depth below the exposed surface. The effective chloride transport coefficient, De, and the boundary condition of the chloride profile at the exposed surface, Cs, are calculated. This is done by using the related values of measured depth below the exposed surface, x, and measured chloride content, Cx. The penetration parameter, KCr , is calculated for a selected chloride concentration, Cr The influence of De, Cs, Ci, and Cr is combined in the calculation of KCr, which facilitates comparison of the results.

## COMPARISON OF COST TO CONDUCT THE VARIOUS TESTS

The costs to conduct the tests include equipment, maintenance of equipment and labour.

## Time and Resource allocation for durability testing

During this investigation the following samples were made from 35 litre concrete mixes.

- 15 x 100 mm cubes
- 3 x 150 mm cubes
- 1 x 300 mm beams
- 1 x 500 mm beams

The 150 mm cubes were used for the Torrent permeability tester. The cubes were utilized to determine compressive strength, accelerated carbonation and accelerated chloride penetration. The beams were used to obtain 12 x 68 mm diameter x 25 mm thick samples for durability index testing.

Total duration of mixing and casting was 15 weeks with a staff compliment of one supervisor and three laboratory staff. The duration of mixing, casting and stripping were 45 working days (average three mixes per day) and the total man hours were 720 hours. Table 1 indicates duration of preparation and testing for each test.

Table 1: Duration of each test

| Test | Casting and Curing (days) | Sample Preparation (days) | Testing (days) | Total time to results (days) |
|---|---|---|---|---|
| OPI Test | 28 | 8 | 1 | 37 |
| Water Sorptivity | 28 | 8 | 2 | 38 |
| Chloride Conductivity | 28 | 9 | 1 | 38 |
| Torrent meter | 7 | - | 27 | 34 |
| Chloride Profiling | 28 | 47 | 2 | 77 |
| Accelerated Carbonation | 28 | 28 | 1 | 57 |

The chloride profiling grinding of concrete is by far the most onerous test from the point of view of time and resources. The sample preparation is made up of the following activities:

- saturation calcium hydroxide - 4 to 5 days
- drying and coating with epoxy - 3 days
- re-saturation with calcium hydroxide - 2 days
- exposure to sodium chloride - 35 days
- grinding (3 samples) - 2 days

## Maintenance of Equipment

The only main real maintenance issue with the durability index equipment is the continued leak detection of the OPI equipment. Test procedure requirement is that cells should not lose any pressure over a 24 hour period at a starting pressure of 100 kPa. Slagment Alrode Lab has 11 OPI test cells. The original manufacturers of these cells include 3 various suppliers (University of Cape Town, University of Witwatersrand and Liftfab). It has been an ongoing struggle to find and block leaks in nearly all the OPI cells and various methods have been trailed as described below.

Leak Detection Method I: Submerge the OPI cell into a bath of water.

The problems associated with this method are:

1. It is a time consuming procedure, OPI cell must be removed from housing stand and all connections removed.
2. Automated pressure transducers don't like water and should be removed or sealed.

Leak Detection Method II: Snoop leak detector

The product is a clear liquid which is squirted over a possible leak area and noticeable bubbles (almost fizzing) appear if leaks are picked up.

The problems associated with this method are:

1. Snoop did not always pick up the leaks on many connections which were clearly leaking (as picked up in the first method - OPI cell in water bath).
2. Snoop cannot be used to detect leaks on the outlet side of ball values used. Leaking values were only noticed when OPI cells were placed in water baths

The following leak spots were identified on the OPI cells:

1. Outlet test face of OPI cylinder - The diameter of outlet hole on the test face of the OPI cylinder was not a standard size and varied between groups of test cells. The equipment with the larger diameter caused a problem in that it would cut into the side of the silicone rubber ring. Due to the location of this damage it could not be determined if this was a definite leakage spot.
2. Inlet/Outlet connections - connection between values and cell are made up of a threaded steel pipe, connected to cell and valve on either side. Plumbing tape has been used on thread to make this air tight. Many of these connections have shown leaks when tested in the water baths. Similar connections used for the pressure gauges also showed leaks. In some cases where leaks were detected it was necessary to make a number of attempts to seal the connection with plumbing tape. Where possible these connections must be designed out, replacing a threaded connection with a welded connection. Where threaded connections are necessary, a flange and rubber o-ring should be introduced to the threaded pipe.
3. There were instances where the ball valve showed leaks.

General wear and tear on the profile grinding equipment was a further issue. The housing bracket of the profile grinder was made up with very soft metal and with all the vibration during grinding the handle on the equipment has stripped the threads. The equipment is now made up from stainless steel.

## Cost of equipment and maintenance

The cost of equipment reflected here is an estimate that is based on experience. It assumes that the laboratory has to procure all equipment required by the test method other than a cube crushing machine as this is generally standard equipment.

Table 2: Cost of maintenance and equipment

| | Equipment required | Initial cost of equipment | Maintenance cost per year |
|---|---|---|---|
| Durability index testing | **a)** Water-cooled diamond tipped core barrel with a nominal inner diameter of 70 mm, attached to a suitable coring drill.<br>**b)** A holding device in which cubes can be clamped firmly and securely to ensure they remain in position while coring takes place.<br>**c)** A water-cooled moveable bed diamond saw.<br>**d)** Permeability test arrangement in Figure 1.<br>**e)** Compressible rubber collars with Shore Hardness 39A<br>**f)** Standard grade 99.8% oxygen supply and regulator capable of regulating pressure to 120 kPa.<br>**g)** Automating cylinders<br>**h)** Vacuum saturation facility for sorptivity<br>**i)** Vacuum saturation facility for chloride<br>**j)** Conduction cell<br>**i)** DC power supply 0-12 Volt,<br>**k)** Digital voltmeter and ammeter (two multi-meters), 4 digits, 0-20 V range, 0-300 mA, rated accuracy 0.1 % R30 000 | R30 000<br>R10 000<br>R30 000<br>R20 000<br>R240 each<br>R500 per cylinder<br>R40 000 for set of four<br>R800<br>R800<br>R2 000<br>R2500<br>R500<br>**Total 140 000** | R10 000 |
| Torrent Permeability Tester | **a)** Air permeability test equipment as supplied by Proseq<br>**b)** Wenner probe as supplied by Proseq | R100 000 incl vacuum pump<br>R10 000<br>**Total R110 000** | No routine maintenance required |
| Accelerated carbonation testing | **a)** Relative humidity controlled chamber<br>**b)** $CO_2$ cylinder<br>**c)** $CO_2$ measuring equipment<br>**d)** $CO_2$ regulator<br>**e)** Roller pin for splitting cubes<br>**f)** Phenolftalien spray<br>**g)** $CO_2$ cylinder | R100 000<br>R5 000<br>R2 500<br>R500<br>R700<br>**Total R110 000** | R3 000 |
| Built 443 test | Water-cooled diamond saw<br>Temperature controlled curing bath resistant to chlorides<br>Equipment for grinding off and collecting concrete powder from thin concrete layers (less than 2 mm)<br>Equipment for chloride analysis according to applied test method | R30 000<br>R5 000<br>R30 000<br>**Total R110 000** | R3 000 |

## GENERAL PRACTICAL ISSUES

### Practicalities of Cutting and Coring

Customized equipment was made for drilling and cutting at Alrode Laboratory. (Figure 6 and 7). A running table was developed for the diamond tipped saw, which included a clamping bracket to hold samples when cutting. A portable drilling rig which secures the drill and core barrel which includes a clamping device for the concrete samples was also made .

Issues experienced with this activity were:

1. Sliding tables and spinning blades introduced a safety risk . A safety procedure was introduced for this equipment and equipment may only be manned by trained personal.
2. Noise and water pollution – Slagment Alrode Laboratory is situated in an office park thus this activity is not well received. We have since moved the activity to our manufacturing plant in Vanderbiljpark, where are busy setting up a specific area to facilitate this activity.
3. Vertical drilling of samples – It was noticed from many samples drilled that these were not vertical and had a slight slant on the side. The causes from this were, movement on the bearings of the core drilling machine, and flexibility of the upright support of the drill. The deflection of the upright support is a function of the applied pressure by the drilling hand and also the length of the core barrel (pushes the drill further up the shaft increasing the lever-arm on upright support). In addition to training of operator to drill slower an attempt to eliminate the flexibility of the shaft is to reduce the length of the core barrel from 450 mm (standard length) to 200 mm.
4. Spalling of cut edges of samples – In many cases stones were situated on the outside of the core sample on the cutting edge. If this stone is on the tail end of cutting, it will break out of the sample leaving rough jagged edges on the test specimen. Specific procedures have been introduced to eliminate this and are as follows:

- Lab test samples – cutting and coring to follow the following sequence. 5 mm cover to be cut off cube or test beam exposing outer face of test specimen. Coring drilling then takes place on exposed surface. A 25 mm slice (measured from exposed surface) is then taken which cuts the completed test specimens from cube or beam.
- Insitu site samples- core sample is taken from site as per test procedure, sample must then be cut on either side to make test specimen. To ensure that the cutting blade does not reach the tail end of the specimen and tear out the coarser aggregates in the concrete, the test specimen must be rotated while cutting. Care must be taken to keep sample in-line to keep a smooth cutting face.

*Fig. 6 – Equipment for drilling*

*Fig. 7 – Equipment for cutting*

## Determining the effects of leaks on

### OPI test results

A comparison between results as shown below for pressure loss in OPI pressure cells show that cell 2 & 3 have minimal pressure loss due to leaks. Pressure cells 1 & 4 have shown gradual loss in pressure when tested over a period of 24 hours or more.

Summary of results for Pressure loss test:

| | |
|---|---|
| Cell 1 – Date 6 and 7 October 06<br>0 hrs – 103.4 kPa<br>12 hrs – 101.1 kPa<br>24 hrs – 97.9 kPa | Cell 1 – Date 21 & 22 January 06<br>0 hrs – 94.4 kPa<br>12 hrs – 92.4 kPa<br>24 hrs – 88.7 kPa |
| Cell 2 – Date 6 and 7 October 06<br>0 hrs – 105.6 kPa<br>12 hrs – 106.5 kPa<br>24 hrs – 106.8 kPa | Cell 2 – Date 21 & 22 January 06<br>0 hrs – 103.3 kPa<br>12 hrs – 104.3 kPa<br>24 hrs – 102.8 kPa |
| Cell 3 – Date 6 and 7 October 06<br>0 hrs – 102.9 kPa<br>12 hrs – 103.3 kPa<br>24 hrs – 101.2 kPa | Cell 3 – Date 26 & 27 January 06<br>0 hrs – 106.2 kPa<br>12 hrs – 107.2 kPa<br>24 hrs – 106.3 kPa |
| Cell 4 – Date 6 and 7 October 06<br>0 hrs – 104.4 kPa<br>12 hrs – 98.7 kPa<br>24 hrs – 95.0 kPa | Cell 4 – Date 26 & 27 January 06<br>0 hrs – 102 kPa<br>12 hrs – 93.3 kPa<br>24 hrs – 94.2 kPa |

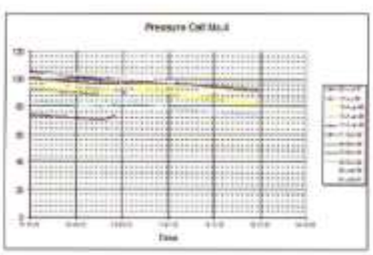

*Fig. 8 – Drop in pressure of cells*

From the above it is assumed that cell 4 is the "worst" cell for pressure loss due to leaks and cell 2 is the best, using this we can make some assessment of the effect of pressure loss on the actual test results.

Cell 4 lost a pressure of 5,7kPa and 8.8 kPa due to leaks in the first 12 hrs of each test. Graphs above show a linear fall in pressure over time. As the test results for mix A, cell 2 (below) were accumulated over a period of 6 hrs we can thus add a pressure loss of 4.4 kPa over the full period of testing (0.18kPa per 15 mins). By applying this loss in pressure to the permeability calculation the adjusted OPI index will be 10.24

## VARIABILITY OF THE TESTS

### Durability index testing

In this project the samples were cured for seven days before being placed in a 50 - 60% relative humidity at 22 to 25°C until 28 days old, and then tested. The average OPI for all concretes tested were 9.86, the average standard deviation between four samples of the same concrete mix was 0,22. These results were significantly higher that those reported by Standish(6) in the industry round robin of November 2004. The concretes tested in this program were generally of lower strength, and cured for seven days whereas the concrete in the industry round robin was cured for 28-days. The graph (figure 9) indicates the relationship between the average OPI obtained and the standard deviation between individual results obtained from the same sample of concrete. It indicates a trend that as the average OPI reduces, the standard deviation between samples of the same mix increases.

It is possible that the variation in results observed may be due to the small sample size and this needs to be investigated.

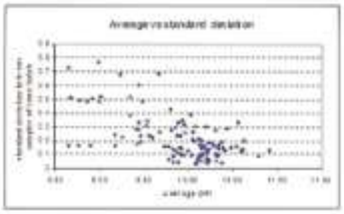

*Fig. 9*

The sorptivity samples were cured in the same manner as described above. The average sorptivity was 9,11 and the average standard deviation between samples of the same mix was 0,82.

In this investigation the chloride conductivity was 1,11 the average standard deviation was between samples from the same batch was 0,111.

## Torrent permeability

In this investigation the Torrent meter tests were conducted on a 150 mm cubes. The cubes were mostly water cured for seven days before being placed in a 50 - 60% relative humidity chamber at 22 to 25°C until 28 days old, and then tested.

The average Torrent reading for all samples tested was 1,02 x $10^{-16}$ the average standard deviation was 0,486x$10^{-16}$. As for the OPI, the standard deviation is related to the test average as indicated in Figure 10. A possible explanation of the variation observed in the results may be because of the variation in moisture content between different samples. It is recognized that the moisture content influences the Torrent permeability readings. The more moisture present in the sample the better the result. Although the samples were cured and dried in the same manner, it is possible that not all samples had the same moisture content.

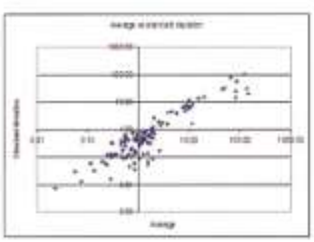

*Fig. 10 – Variation of Torrent permeability*

## Accelerated carbonation testing

The variation in results between samples of the same batch of concrete was not determined as not enough specimens were tested.

## Build 443 Accelerated Chloride penetration

The variation in results between samples of the same batch of concrete was not determined as not enough specimens were tested.

## CONCLUSIONS

Based on our experiences with durability testing the following conclusions are made:

1. With the exception of the Torrent permeability Tests all other durability tests conducted during this program were onerous tests that required attention to detail and more time and resources and that is required for normal strength testing.
2. The variation in test results of samples of the same batch of is often large, a general trend was observed that indicated the variation in results between samples of the same batch increases as the permeability increases.
4. The leaking of the OPI equipment was problematic but did not significantly influence the results. It may be that the relatively small sample size contributes to the variations observed in the OPI tests.
5. Variations in moisture content could have influenced the variations observed in the Torrent permeability test.
6. The Build 443 test is especially onerous and lengthy and is unpractical for quality control purposes.
7. Recommendations

To try and reduce the variation of test results of samples of the same batch of concrete the following may be considered:

1. Suggested improvements on OPI equipment is that the Inlet/Outlet connections should, where possible, be designed out. Threaded connections should be replaced with a welded connection. Where threaded connections are necessary, a flange and rubber o-ring should be introduced to the threaded pipe.
2. The moisture content of the samples tested with the Torrent Permeability tester needs to be estimated and corrections need to apply. A procedure for CEM I concretes does exist however this needs to be extended to concretes containing mineral components.
3. In the case of the durability index tests, bigger sample sizes should be investigated.

## References


**1.** Durability Index Testing Procedural Manual, May 2005, available at www.civil.uct.ac.za

**2.** fib, Model Code for Service Life Design, Luzern, International Federation of Structural concrete, 2006

**3.** RILEM TC 189-NEC, Non-destructive evaluation of the concrete cover: Comparative Test, unpublished PAPER SUBMITTED TO MATERIALS AND STRUCTURES

**4.** Nordtest NT build 443, Concrete, Hardened: Accelerated chloride penetration, published by Nordtest, Finland, 1995

**5.** Holcim South Africa, Materials Handbook of Holcim South Africa, Johnson Hydenbry Afrika, second Edition, January 2006


**Paper postscript by Sebasti Badenhorst, who since co-authoring the paper, has joined Grinaker-LTA:**

*Since this paper was written, improvements have been made to the OPI cells and it did solve the problem of leaking of cells. The work of the Durability Focus Group under the auspices of the Cement and Concrete Institute is ongoing. The objective is to obtain SANS status for the test methods and accreditation for the laboratories doing the tests. The test methods are currently being applied at the Gauteng Highway Improvement Scheme and valuable practical experience in using and interpreting the tests are being obtained by consultants and contractors involved in the project.*

# Bridge elements in the Gauteng Freeway Improvement Project

The Gauteng Freeway Improvement Project (GFIP) is an ambitious project that will ultimately contribute R29-billion the national GDP by the end of 2009, and it estimated that it will create 30 000 direct employment opportunities with in the region of another 130 000 indirect jobs.

The GFIP comprises seven work packages, phase one, will run from July 2008 to May 2010. Most of the road works will be completed by the time South Africa hosts the 2010 FIFA World Cup, however if some work packages are unfinished, then construction will cease for a period of three months and the roads will be put in serviceable condition for the duration of the competition.

Phase two of the GFIP will involve the building of new freeway sections, completing a second ring road, providing alternatives to the current freeway system, and opening up new areas for development.

Concrete Beton spoke to three consulting engineers regarding their involvement in the project, specifically regarding bridge elements in various work packages within the project.

UWP Consulting is working on the upgrading of the N12-18 highway between the Reading and Elands Interchanges through the construction of additional lanes and improvements to Reading and Voortrekker Interchanges through the construction of a new partial interchange at the N12/N17 intersection.

Concrete structures include:

Two new bridges at Reading Interchange (box type structures);

One new bridge with precast beams at N12/N17 interchange;

Two new incrementally launched structures at N12/N17 interchange; and

The widening of an existing bridge on the R59 near Reading interchange.

Long sections of concrete retaining walls will be constructed where the two carriageways are in close proximity with a level difference in the carriageways.

All work is due to be completed by May 2010 at a cost of approximately R695-million (VAT included).

The contractor working on the project is Siyavaya Highway Construction Joint Venture that is a joint venture of five companies namely: Group 5 Civil Engineering; Power Construction; Bophalong Construction; Umso Construction and Liviero Construction.

The primary suppliers are Afrimix for concrete and Much Asphalt for the road surfacing material.

UWP explains the significant challenges to project as being working around the existing Rand Water pipeline that runs parallel to the N12-18 from Voortrekker Interchange to the northern end of the contract as it has a serious impact on the project and sections of the pipeline need to be relocated.

In addition thousands of cubic metres of rock need to be removed from directly adjacent to the highway causing several logistical problems with traffic accommodation.

Approximately 20 000 $m^3$ of concrete will be during construction on this section of the GFIP.

Africon Bridge Engineering Division is responsible for the Upgrading of the N1/R21 section between the Brakfontein Interchange (km 14.000) and the Flying Saucer Interchange (km 23.000).

It is responsible for the widening of six existing bridges and the constructing of four new bridges.

The new bridges consist of one 240 m long 9 span incrementally launched bridge and two three span continuous voided slab bridges at the Flying Saucer Interchange. There is one new three span continuous voided slab bridge on ramp C1 at the John Vorster Interchange.

The construction period allocated to this section is 24 months with some aspects only being completed after 27 months. The contract start date was 27 May this year.

The main contractor is BRCD Joint Venture of which consists of Basil Read; Roadcrete and Dip Civils.

Other sub-contractors are Stefanutti Stocks and Civilcon.

Africon describes the significant challenges to their work package as being the accommodation of traffic. This is being resolved by keeping three lanes in both directions on the N1 and R21 open at all times except for certain special cases on a Saturday or Sunday where the number of lanes could be reduced to one or two.

Another challenge is working in close proximity to the Gautrain project. This handled by working in other areas first and then going back after the Gautrain work group have finished their work in their section.

In terms of concrete use on the work package self compacting concrete is being used for piles and three of the six bridge widenings make use of precast beams.

BKS is overseeing the improvements to N1 route 1, sections 20 and 21: Buccleuch interchange to Brakfontein interchange (Package C of the GFIP – better known as the Ben Schoeman highway).

The upgrading is being done at a cost of approximately R1,7-billion Rand and will take two years to complete. An additional traffic lane in each direction between Brakfontein and Buccleuch is being constructed as well as additional lanes between consecutive interchanges. Extensive upgrading will be done to the 21.2 km long section of road, its five access interchanges and the two system interchanges.

The most significant of the upgrading is done at the Allandale Interchange at a cost of R350-million. This upgrading consists of a totally new interchange, which caters for free traffic flow in all directions, which means that there will be no traffic lights at the terminals. After the upgrading the Allandale interchange will be similar to a systems interchange such as Buccleuch or Brakfontein. Five new bridges will be constructed at the new Allandale interchange.

Construction has began in June 2008 and most of the planned work will be completed within two years after which an additional six months will be required to complete the finishing and smaller works.

Package C of the GFIP is structure-intensive. Nine new bridges are to be constructed, while four existing bridges are to be widened.

Bridge B0025 is located at the new Allandale Interchange. It will carry the M39 (Allandale Road) Westbound carriageway over the N1 Section 20 at km 54,243. The Westbound carriageway of Allandale Road over the bridge consists of 3 lanes of 3,5 m each and shoulders of 2.8 m resulting in a total carriageway width of 16.1 m.

The bridge is a four span continuous deck with main spans of 22,2 m and end spans of 13,35 m. The main spans consist of precast pre-stressed M-beams in a pseudo box girder configuration. The end spans are in-situ reinforced concrete voided slab decks. The elevation of the bridge deck will be enhanced by the use of precast concrete panels. The end span elevation will be grooved to simulate the main span panels.

Substructure for this bridge comprises multiple column type piers and wall type abutments with return walls. The columns and abutment walls will be provided with fluting to form an aesthetic finish. Due to the very high abutments, buttress walls are recommended instead of tapered walls for structural and economic reasons.

Bridge B0026 is located at the new Allandale Interchange. It will carry the M39 (Allandale Road) Eastbound carriageway over the N1 Section 20 at km 54,314. The existing bridge B446 will be demolished due to insufficient span length to accommodate the widened N1 cross section. The Eastbound carriageway of Allandale Road over the bridge consists of 5 lanes of 3,5 m each, a median of 5,1 m and shoulders of 2,0 m resulting in a total carriageway width of 26,6 m.

The bridge is a four span continuous deck with main spans of 22,2 m and end spans of 13,35 m. The main spans consist of precast pre-stressed M-beams in a pseudo box girder configuration. The end spans are in-situ reinforced concrete voided slab decks. The elevation of the bridge deck will be enhanced by the use of precast concrete panels. The end span elevation will be grooved to simulate the main span panels.

Substructure for this bridge comprises multiple column type piers and wall type abutments with return walls. The columns and abutment walls will be provided with fluting to form an aesthetic finish. Due to the very high abutments, buttress walls are recommended instead of tapered walls for structural and economic reasons.

Bridge B0027 is located at the new Allandale Interchange. It will carry the M39 (Allandale Road) Westbound carriageway over the N1 Northbound Off-Ramp at km 54,263. The Westbound carriageway of Allandale Road over the bridge consists of 2 lanes of 3,5 m each and shoulders of 2,8 m resulting in a total carriageway width of 12,6 m.

The bridge deck is a pre-stressed concrete continuous voided slab type deck, which can be cast in-situ and on conventional falsework. The main span is 22,146 m and the end spans 13,257 m and 13,443 m. The aesthetic appearance of the bridge deck is enhanced by the use of long cantilevers.

Substructure for the bridge comprises multiple column type piers and perched abutments with return walls. The columns will be provided with fluting to form an aesthetic finish.

Bridge B0028 is located at the new Allandale Interchange. It will carry the M39 (Allandale Road) Westbound carriageway over the R101/N1 Southbound on-ramp at km 54,233. The Westbound carriageway of Allandale Road over the bridge consists of 2 lanes of 3,5 m each and shoulders of 2,8 m resulting in a total carriageway width of 12,6 m.

The bridge deck is a continuous reinforced concrete slab, which can be cast in-situ and on conventional falsework. The main span is 13,8 m and the end spans 8 m each. The reinforced concrete deck is both aesthetically pleasing and cost effective to construct

Substructure for this bridge comprises multiple column type piers and wall type abutments with return walls. The columns will be provided with fluting to form an aesthetic finish.

Bridge B0029 is located at the new Allandale Interchange. It will carry the M39 (Allandale Road) Eastbound carriageway over the R101/N1 Southbound on-ramp at km 54,300. The Eastbound carriageway of Allandale Road over the bridge consists of 4 lanes of 3,5 m each, a taper from the N1 South-bound off-ramp of 1,4 m and shoulders of 2,0 m resulting in a total carriageway width of 19.4 m.

The bridge deck is a pre-stressed concrete continuous voided slab type deck, which can be cast in-situ and on conventional falsework. The aesthetic appearance of the bridge deck is enhanced by the use of long cantilevers. The main span length is 23 m and the end spans 13,8 m each.

Substructure for the bridge comprises multiple column type piers and wall type abutments with return walls. The columns will be provided with fluting to form an aesthetic finish.

Bridge B0030 A&B is located at the crossing of Le Roux Avenue over the N1. It will carry both carriageways of Le Roux Avenue over the N1 Section 20 at km 55.217. The new bridge will replace the existing Le Roux Overpass bridge, which has insufficient span lengths to cater for the widened N1 carriageway. Both carriageways of Le Roux Avenue consist of 2 lanes of 3.5 m wide each, with shoulders of 1.5 m and 1.7 m for the fast and slow shoulders respectively. A pedestrian walkway of 2 m wide is provided on each bridge deck, separated from the traffic lanes by an 800 mm high F-shape barrier.

*Construction activities on the N1 / R21 Interchange during peak traffic times are being deftly managed.*

**Photograph: Richard Jansen van Vuuren**

*Concrete support pillars under construction. Note plastic wrapping to aid curing.*

**Photograph: Peter Butler Photography**

The carriageway width for road traffic is 10.845 m.

The bridge is a two span continuous deck with span lengths of 30,4 m. Precast M-beams are used in a pseudo box girder configuration. The elevation of the bridge deck will be enhanced by the use of precast concrete panels.

Substructure for the bridge comprises multiple column type piers and wall type abutments with return walls. The columns and abutment walls are provided with fluting to form an aesthetic finish in line with the Allandale Interchange bridges. Due to the very high abutments, buttress walls are recommended instead of tapered walls for structural and economic reasons.

Bridge B0031 is located South of Brakfontein Interchange. It will carry the K54 (Nelmapius road) over the N1 Section 21 at km 11,361. The existing bridge B462 will be demolished due to insufficient span lengths to accommodate the widened N1 cross section. Nelmapius Road, which passes over the bridge, consists of 2 lanes of 3,7 m each and shoulders of 1,7 m resulting in a total carriageway width of 10,8 m. Pedestrian walkways of 1,5 m and 1,94 m are provided on the North and South sides respectively. When the future second carriageway is constructed, the South walkway will be removed, which will result in a standard Gautrans 13 m wide carriageway.

The bridge is a four span continuous pre-stressed concrete voided slab. The main spans are 31,25 m long and the end spans of 18,75 m and 22,450 m respectively. The deck will be constructed by means of overhead structural steel gantries supporting the formwork and wet concrete. The aesthetic appearance of the bridge deck is enhanced by the use of long cantilevers.

The substructure comprises multiple column type piers. The western abutment consists of a perched wall type structure with a pile cap just below the natural ground level. The eastern abutment is a frame type abutment behind a reinforced earth wall, which is an extension of the reinforced earth wall of the proposed Gautrain Bridge.

Bridge B460 is located at the Olifantsfontein Interchange. It carries the R562 (Olifantsfontein Road) over the N1 Section 20 at km 3,77. The existing bridge is widened by the addition of a second bridge deck to upgrade the Olifantsfontein Interchange. Olifantsfontein Road, which passes over the widened bridge, consists of 5 lanes of 3,5 m each and shoulders of 2,0 m and a 600 mm wide median island, resulting in a total carriageway width of 21,1 m. Pedestrian walkways of 2 m wide each are provided, protected from the traffic by F-shape barriers.

The bridge is a four span continuous pre-stressed concrete voided slab with main span of 24,384 m and end spans of 8,724 m. Aesthetically the bridge deck is provided with long cantilevers to suit the existing bridge.

Substructure for the bridge comprises multiple column type piers and spill through abutments founded on spread footings. The circular columns of the existing bridge will be modified to suit the columns of the new bridge. The modified columns will also be used to jack the existing bridge deck to increase the substandard vertical clearance.

Bridge B454 carries the N1 Section 21 over Maxwell Drive (R564) at km 51,137. Bridge B454 is being widened by 3 m on the west side of the existing bridge only. The total carriageway width becomes 50,87 m, comprising 12 traffic lanes of 3,4 m, a median width of 600 mm and shoulders of approximately 2 m. The west shoulder is 3,7 wide due to the addition of a structurally stable deck width of 3 m in stead of the 1,5 m required.

The widening consists of a three span continuous reinforced concrete voided slab deck with span lengths of 11,2 m, 15,9 m and 11,68 m. The substructure consists of reinforced concrete spill through abutments and circular reinforced concrete columns to suit the existing bridge. The structure is founded on spread footings.

Bridge B455 carries the N1 Section 21 over the Jukskei River at km 52,560. Bridge B455 is being widened by 7,790 m on each side of the existing bridge. The total carriageway width after widening is 49,8 m, comprising 12 traffic lanes of 3,4 m each, inside shoulders of 1,6 m, outside shoulders of 2,5 m and an 800 mm wide median barrier.

The widening consists of two additional three span continuous pre-stressed concrete box girder bridge decks with span lengths of 25,6 m, 32,92 m and 25,6 m. The substructure comprises frame type spill-through abutments and single column type piers to suit the existing bridge.

Bridge B458 carries the N1 Section 20 over Alexandra Avenue at km 56,902. Bridge B458 is being widened by 4,930 m on each side of the existing bridge. The total carriageway width of the widened bridge is 43,0 m comprising 10 traffic lanes of 3,4 m, inside shoulders of 1,6 m, outside shoulders of 2,5 m and an 800 mm wide median barrier.

The widening consists of two single span reinforced concrete voided slab decks spanning 14,875 m. The substructure comprises wall type abutments on spread footings.

Bridge B463 carries the N14 Southbound Carriageway over the N1 Section 20 at km 1,322. Bridge B463 is widened by 4,175 m on the north side of the existing bridge only.

The widening consists of a four span continuous pre-stressed concrete voided slab type deck with span lengths of 19,565 m, 21,045 m, 20,505 m and 19,67 m. The substructure comprises spill-through abutments and single column piers.

The amount of structural concrete envisaged on the bridge works on Package C is shown below.

| **Structure** | **Start** | **Finish** | **Concrete ($m^3$)** |
|---|---|---|---|
| Brakfontein | Jan 2009 | Oct 2009 | 580 |
| Nelmapius | Jun 2008 | May 2010 | 2 051 |
| Olifantsfontein | Aug 2008 | Apr 2010 | 1 173 |
| Le Roux | Dec 2008 | May 2010 | 1 455 |
| Alexandra | Aug 2008 | Jul 2009 | 415 |
| Allandale B0025 | Aug 2008 | Jun 2009 | 2 080 |
| Allandale B0026 | Jul 2009 | May 2010 | 3 380 |
| Allandale B0027 | Aug 2008 | May 2009 | 955 |
| Allandale B0028 | Sep 2008 | Apr 2009 | 1 172 |
| Allandale B0029 | Jun 2009 | May 2010 | 1 590 |
| Jukskei River | Aug 2008 | Oct 2009 | 1 420 |
| Maxwell Drive | Mar 2009 | Sep 2009 | 203 |
| **TOTAL** | | | **16 474** |

# Events diary: International

**26 – 28 February 2009**
China International Concrete Technology & Equipment Expo.
International Exhibition Centre, Beijing, China.

**17 – 19 September**
Concrete 2009
Luna Park, Sydney, Australia

**24 – 25 September 2009**
Central European Congress on Concrete Engineering – 'Innovative Concrete Technology in Practice'.
Baden, Australia.

# 2009 ACI calendar of events

JANUARY

Launch of ACI eLearning program

FEBRUARY

2-6: World of Concrete – Las Vegas Convention Center, Las Vegas, Nev.
3: ACI and SDC joint World of Concrete press conference

MARCH

Early: Announcement of ACI's spring seminar program schedule
15-19: ACI Spring 2009 Convention – Marriott Rivercenter, San Antonio, Texas
19: Appointment of new ACI Board members and officers

APRIL

Early: Release of 2009 edition of Manual of Concrete Practice (MCP)

MAY

21-22: SDC (www.concretesdc.org) #25 Session – Washington, DC

JUNE

11-13: 22nd Annual ASCE National Concrete Canoe Competition (co-sponsored by ACI) – University of Alabama, Tuscaloosa, Ala.

AUGUST

Early: Announcement of ACI's fall seminar program schedule

OCTOBER

All month: 105-year anniversary of ACI

NOVEMBER

8-12: ACI Fall 2009 Convention – Marriott New Orleans, New Orleans, La.
11-13: USGBC GreenBuild International Conference & Expo – Phoenix, Ariz.

# CSSA Inland branch calendar of events

| Date | Event | Venue | Organiser |
|---|---|---|---|
| Thursday 5th Feb | Committee meeting | C&CI offices | John Sheath |
| Thursday 5th Mar | Committee meeting | C&CI offices | John Sheath |
| 11 – 12 March | AGM - National | Durban | Natasja Pols |
| Thursday 2nd Apr | Committee meeting | C&CI offices | John Sheath |
| Thursday 7th May | Committee meeting | C&CI offices | John Sheath |
| Friday 15th May | Egg Protection Device function | To be advised | Johan van Wyk |
| Thursday 28th May | Branch Golf Day | Rand Park Golf Club | Hannes Engelbrecht |
| Thursday 4th Jun | Committee meeting | C&CI offices | John Sheath |
| 19th-21st Jun | Fulton Awards weekend | Champagne Sports Resort, Drakensberg | CSSA Head Office |
| Thursday 2nd July | Committee meeting | C&CI offices | John Sheath |
| Thursday 23rd Jul | QTM – In depth look at aggregates | To be advised | Hanlie Turner |
| Thursday 6th Aug | Committee meeting | C&CI offices | John Sheath |
| Thursday 3rd Sep | Committee meeting | C&CI offices | To be advised |
| Saturday 19th Sep | Boat Race Day | VLC, Germiston | Trevor Sawyer |
| Thursday1st Oct | Committee meeting | C&CI offices | To be advised |
| Thursday 15th Oct | QTM - Architectural Concrete | To be advised | Hanlie Turner |
| Thursday 5th Nov | Committee meeting | C&CI offices | To be advised |
| Friday 6th Nov | Chairman's Breakfast | To be advised | Johan van Wyk |

# Sand – cement mixes (Part 1 Tip 8): Mortars and plasters

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## Introduction

Large quantities of cement are used in sand-cement mixes, even more, probably, than in concrete and serviceability failures of these mixes are fairly common, particularly with plasters and floor screeds. Typical problems include de-bonding, cracking, crazing, softness, poor abrasion resistance and unacceptable surface finish. As far as mortar is concerned a common problem is leaching of lime from the mortar in face brick masonry.

In all cases the failures can be traced to one or more of:

- Inadequate specifications
- Poor materials selection
- Incorrect mix proportions
- Poor site practice and bad habits

This tip covers mortars and plasters. Part two (TIP 9) will cover sand-cement floor screeds.

## Specifications

Traditionally sand-cement mixes have always been specified in terms of mix proportions by volume and not by performance. This is still almost universal practice in South Africa. The exception is SANS 10164:1980 'The Structural Use of Masonry' which specifies mortar mixes by compressive strength in Table 1 and then goes on to suggest suitable mix proportions which should satisfy those strength requirements in Appendix C-2.

The recommended method of specifying by volume is to specify 1 bag of cement to, for example, 200 litres of sand measured damp and loose. The reasons are that specifying a mix as 1:6 by volume is open to serious misinterpretation (e.g. 1 bag of cement to 6 wheelbarrows of sand) and the fact that sands bulk when damp, often by as much as 30% by volume. To put some numbers on bulking, 200 litres of dry sand would typically weigh about 320 kg whereas the sand component of the same sand in a damp condition could weigh as little as 205 kg if the sand bulks 30%.

In terms of mass the mix proportions could therefore vary from 1:6,4 to 1:4,1depending on the moisture content of the sand.

## Materials selection

### Cements:

The following cements are suitable for use in mortars and plasters:

- CEM I
- CEM IIA
- CEM IIB
- CEM IIIA
- MC 12,5

(Fulton's Concrete Technology, 8th edition)

### Lime:

Builders Lime (complying with SANS 523:2007) is used to improve workability, plasticity and water retentivity of mortars and plasters. Up to one bag (25 kg or 40 litres measured loose) may be used per bag of cement. The quantity added depends on the fines content of the sand.

- Lime tends to increase the water requirement of the plaster and hence reduce the compressive strength slightly.
- The improved workability and water retention result in better bond and impermeability.
- Lime must not be used with Masonry cements.

### Chemical admixtures and additives:

These include plasticisers, retarders, accelerators, bonding aids, water proofing agents and pigments. There is a huge range of proprietary admixtures and additives available and it is obviously not possible to cover them in any depth in a short TIP.

Generally speaking the manufacturers' instructions should be followed closely and expert advice should be sought if in doubt.

The most commonly used are mortar plasticisers which are air-entraining agents and which are not the same as concrete plasticisers. Their use in concrete will seriously affect the compressive strength of the concrete. Mortar plasticisers must also not be used with Masonry cements.

### Sand:

The quality of the sand is the main determinant of the quality of the mortar or plaster. Sand for use in mortar and plaster is specified in SANS 1090:2002. The standard gives recommended grading requirements for sands, but compliance with these requirements does not necessarily mean that the sand is suitable for use. The converse also applies. Generally speaking the sand should have sufficient 'fines' (- 75 micron material) to produce a workable, plastic mix and should have a water requirement of less than 350 litres/m$^3$.

The best indicator of sand quality, apart from experience, is a simple field test:

- Dry approximately 50 kg of the sand (air dry is sufficient)
- Weigh out 5 kg of cement and 25 kg of the sand and measure 5 litres, 1 litre and 1,5 litres of water in separate containers
- Mix the sand and cement to a uniform colour
- Mix in the three quantities of water, one after another, until the mix is workable enough for use as plaster

If 5 litres of water is enough, the quality of the sand is good; if 6 litres is required the quality is average and if 7,5 litres is required the sand is poor quality. If more than 7,5 litres is required the sand is very poor.

Good quality sand is suitable for all grades of mortar and plaster. Average quality sand is suitable for mortar and interior plaster. Poor and very poor quality sands should not be used if at all possible.

Sands should of course be clean and free of seeds and organic matter such as small pieces of root.

### Mix proportions:

Mortar and plaster mixes are normally in the range of 1 bag of cement to 200 to 300 litres of damp sand. Mixes richer than this 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.

A common problem with plasters is the use of too rich a mix. Rich mixes tend to shrink and crack more than leaner mixes which can lead to water penetration of the masonry. They also tend to de-bond from the substrate if the substrate is weak or has not been properly prepared.

A less common problem is the use of too lean a mix which results in soft, friable plaster.

The National Home Builders Registration Council (NHBRC) recommends mortar and plaster mixes for house construction but these recommendations are currently under revue.

#### Poor practice:

Poor site practice is the cause of many plaster problems. Some of these practices are:

- Floating neat cement into the surface of the plaster to "improve" the finish
- Mixing too much mortar or plaster at one time – this results in re-tempering of the mix, sometimes even on the following day. Plaster and mortar should be used within two hours of mixing
- Adding gypsum based plaster (e.g. Cretestone, Rhinolite, and similar products) to the mix. This is done to get the mix to stiffen quickly when plastering door and window reveals. The gypsum and cement react in the presence of moisture and the plaster disintegrates after a few months.
- Adding extra cement to the mix to improve workability
- Inadequate preparation of the substrate, particularly concrete surfaces
- Inaccurate and inconsistent batching
- Over-reliance on the abilities of bonding aids

Sand – cement mixes (Part 2 Tip 9): floor screeds

## Introduction

Serviceability failures of sand-cement floor screeds are, unfortunately, fairly common. Typical problems include de-bonding, cracking, crazing, softness, poor abrasion resistance and unacceptable surface finish.

In all cases the failures can be traced to one or more of:

- Incorrect application;
- Inadequate specifications;
- Poor materials selection;
- Incorrect mix proportions;
- Poor site practice and bad habits.

#### Incorrect application:

Sand-cement floor screeds are suitable only for light duty use. The commonest application is as a levelling layer under some type of covering, for example tiles, carpet or vinyl.

Sand-cement screeds are not suitable for use under abrasive traffic or heavy point loads.

Concrete toppings are recommended for use under abrasive conditions. Table 1 of SANS 10109-2:2004 "Finishes to concrete floors" gives detailed recommendations.

What is not generally realised is that, in terms of materials costs, a 30 MPa concrete topping is often cheaper than a sand-cement screed.

## Specifications

Traditionally sand-cement mixes have always been specified in terms of mix proportions by volume and not by performance. This is still almost universal practice in South Africa.

SANS 10109:2004 specifies mix proportions for sand-cement floor screeds of one 50 kg bag of cement to 130 litres of sand measured damp and loose. The reason for this is that sands bulk appreciably when damp and serious inconsistencies will occur if the sand is batched by volume without due regard to its moisture content. For example the mass of 130 litres of dry sand is about 210 kg, while the mass of the sand component of 130 litres of damp sand is about 150 kg.

This Code of Practice (SANS 10109:2004) gives detailed recommendations for finishes for concrete floors and is well worth consulting.

## Materials selection

#### Cements:

The following cements are suitable for use in sand-cement screeds:

- CEM I
- CEM IIA
- CEM IIB
- CEM IIIA

Strength grade should be 32,5N MPa or higher, bearing in mind that the lower grade cements have lower early strengths.

The cements are listed above in order of increasing sensitivity to curing.

#### Chemical admixtures and additives:

Generally speaking, admixtures are not commonly used in screeds. Sometimes bonding aids, or water-proofing agents, or pigments are used.

The use of pigments is becoming more common and it is strongly recommended that the manufacturer's instructions are closely followed.

Bonding aids must also be used in accordance with the manufacturer's instructions.

#### Sand:

Sand should be a well graded concrete sand of average to low water requirement. Plaster sands should not be used as they tend to have higher water requirements. The higher the water requirement the weaker the mix and the greater the drying shrinkage.

### Mix proportions:

Mix proportions in the literature vary from 100 to 130 litres of damp sand per 50 kg bag of cement. As mentioned above, SANS 10109:2004 recommends 130 litres of sand.

Sufficient water should be added to make a plastic, workable, cohesive mix – a little drier than mortar or plaster. (Drier mixes may be used if mechanical compacting equipment is used)

### Poor practice:

Poor site practice is the cause of many screed problems. Some of these practices are:

- Incorrect use of bonding aids
- Poor surface preparation, dirty concrete
- Making the mix too dry and not being able to compact the screed fully
- Floating a cement-water slurry into the surface of the screed to "improve" the finish
- Floating neat cement powder into the surface to dry it and "improve" the finish
- Mixing too much screed mix at one time. Screed mix should be used within an hour of mixing
- Inaccurate and inconsistent batching

### Testing of floor screeds:

Because of the problems experienced with sand-cement floor screeds, a unique test method was developed by the Building Research Establishment (BRE) in the UK.

They developed the "BRE screed tester" which is a penetrometer type device where a 4-kg mass is dropped 4 times at the same spot from a height of 1 metre on to a circular foot piece. The penetration of the foot piece into the screed is measured and compared to various acceptance limits.

The device, and the test, is described in the second reference below.

## References and further reading

**1.** SANS 10109:2004 Code of practice for concrete floors Part 2 – Finishes to concrete floors, Pretoria, South African Bureau of Standards,1992.

**2.** Addis, B.J. Sand-cement floor screeds, Midrand, Cement and Concrete Institute, 1996.

**3.** Concrete Beton Bulletin 8, December 1971 "Mortars – Mixes, Yield and Strength", Concrete Society of SA

Fulton's Concrete Technology, 6th edition, 1986 (the "red book"), Portland Cement Institute, Midrand.

*Cement and Concrete Institute pamphlets can be downloaded from their web site at www.cnci.org.za*