



# Concrete Beton

The Official Journal of  
The Concrete Society of Southern Africa



## TECHNICAL PAPER

- Heat Curing Practice in Concrete Precasting Technology – Problems and Future Directions
- Dynamic Evaluation of the Solar Chimney

## CONCRETE CHATTER

- Inland Branch Chairman's Award 2006
- KZN Branch Egg Protection Device Competition
- KZN Branch Cube Competition 2006

## CONCRETE TIPS

- Aggregates for Concrete – Part 1 Introduction and grading requirements
- Aggregates for Concrete – Part 2 The effects of aggregate particle size, shape, surface texture and absorption on the water requirement of concrete
- Aggregate contaminants and their effects



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OF SOUTHERN AFRICA



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### Vision

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

### Mission Statement

To promote excellence and innovation in the use of concrete and to provide a forum for networking and for the sharing of knowledge and information on concrete.







## President's Message



By the time you read this copy of Concrete Beton most of you will be back at the grindstone. I am sure that 2007 will prove to be even more challenging than previous years.

The Fulton Awards 2007 will no doubt be the main focus of this year. This event occurs once every two years and is one of the most prestigious awards in the construction industry. We have received a record number of 39 nominations for the Fulton Awards 2007. I will visit all these projects personally

together with my fellow judges. This is quite a daunting task. The projects that have been nominated are spread across Southern Africa and some of them are in quite remote parts of the country. We would need to travel an excess of 12 000 km to visit all the projects. Needless to say this requires very careful planning. This is where our administrator, Irma Dyssel and her assistant, Susar van der Merwe really shine. Without their invaluable contribution it would be very difficult to organise an event of this caliber. I am really looking forward to meeting all the project teams over the next few months when we visit all the projects. Further information about the Fulton Awards 2007 Gala Event will be sent to all members during the next few weeks. I can assure you that the main event will be one of the best events that we have ever hosted and this should not be missed.

The Concrete Society plans a number of new developments this year. One which will be of great benefit to our members is an improved Concrete Beton. We aim to increase the size of the magazine as well as appeal to a broader base of our members. We will also be including a number of articles from our International partners. Another article that may be of interest, is a section of new products on the market. We will allow companies to submit editorials about new and exciting products that are being developed. Plans about other changes are in process and we are hoping to have them implemented by the middle of the year. This will include a signing of an International partnership with the Concrete Institute of Australia.

We are now registered as a Voluntary Association of ECSA (Engineering Council of South Africa). This has been of

immense benefit to all our members. As a result of this, the Concrete Society is now able to award CPD points to all our events after it has been reviewed by a technical panel. We are also qualified to award CPD points to other organisations after reviewing their event program and contents. However we were quite surprised by the amount of requests that we received from other organisations to evaluate such events for CPD points. Unfortunately our review committee was being placed under unnecessary pressure to evaluate these events. Since we had worked hard to achieve this status of reviewing all events in accordance with the ECSA guidelines, we did not want to jeopardize our acquired position. Therefore, we are only able to evaluate and allocate CPD points for Concrete Society events.

I have to take this opportunity to thank all our sponsors and we are looking forward to a continued relationship in 2007, since we are not able to run the Concrete Society without this support. Another critical part of our funding is the annual subscriptions that we receive from our members. We have managed to keep the increase in subscriptions below inflation this year and we would like to encourage prompt payment from all the members. This is also a criterion for having your listing published in our Annual Source Book.

In closing I would like to thank the Council and Branch Committees for their dedication, hard work and effort that they put into the past year to make the Society a success. Without these volunteers we would not be able to run the Society like we have. A special thanks to our administrator, Irma Dyssel, for all her hard work.

Please feel free to contact the Head Office or any one of the four branches countrywide, if you require any further information.

Thank you and I look forward to this very exciting year!

Dave Miles  
President 2006/2007



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

We trust that this will encourage professionals to become members of the Concrete Society. For more information, please contact the office.





## Concrete Chatter

### Inland Branch

#### Chairman's Award 2006

The winners of the 2006 Inland Branch Chairman's Award were announced at a special banquet held on Friday 10th November at the Country Club, Johannesburg. This year's recipients are Hanlie Turner and Ansie Martinek, Manager and Senior Information Specialist respectively, of the Cement and Concrete Institute's Information Centre, for "their invaluable support and assistance to the concrete industry over the past 15-20 years".

In announcing the winners, Trevor Sawyer, Chairman of the Inland Branch, referred to the prime motivation submitted by Paul Donoghue, Member which read as follows:

*a big smile and passion. It had been provided promptly however obscure the question and there has always been an answer".*

In support of this motivation, John Sheath, Member submitted these words to the Chairman:

*"Their passion for concrete is infectious, regularly challenging people to become more familiar with concrete - and making it a thoroughly memorable experience. Their professionalism and commitment to excellence is reflected in every aspect of their work and they are always seeking ways to enhance and add value to the services they can offer the greater concrete industry.*



*Trevor Sawyer, Inland Branch Chairman's reads the motivation for the 2006 Chairman's Award*



*This year's winners, Hanlie Turner and Ansie Martinek receive their certificates from Trevor Sawyer*

*"As a young student, I was sent to the then PCI for a week course in Concrete Technology. This course opened a whole new world and in the last 20 years I have made a career of concrete. As (I call them) the concrete literates know, concrete is a very technical, dynamic and interesting material that has many facets. Over the last 20 years I have been exposed to many of these, but however much training one has had, there has always been something new to learn or an answer looked for.*

*In all my travels to other countries and here in South Africa when I have looked for information or help, it has only been a telephone call away and has always been provided with*

*These ladies have established a reputation for being a valuable source of informed assistance, unfailing courtesy and exceptional service. They have an impeccable service ethic, witnessed by the many appreciative letters from users paying tribute to the excellence of the service that the Information Centre delivers at all times. The reputation of the Centre has grown to the extent that it is regarded as an indispensable resource by the Concrete Society members, academics, consultants, contractors and students.*

*I firmly believe that these ladies are worthy recipients of the Concrete Society Inland Branch Chairman's Award for 2006.*





## Concrete Chatter

### KZN Branch

#### Egg Protection Device Competition

Only for the second time in the 10-year history of this fun competition - open to all departments of Civil Engineering at tertiary academic institutions in KZN - has an all-girls team effectively put 'egg' on the faces of 13 other teams in the annual SAICE/CSSA Egg Protection Device Competition.

For the first time ever, even the judges had to contend with a tie for second place. They were seen delving into their wallets for cash to facilitate the equal sharing of the second prize. The carefully prepared cheques could not be torn up and shared!

This annual event, sponsored by Natal Portland Cement, always guarantees excitement for the students as they test whose precast concrete arch structure takes the most blows from an overhead weight before it cracks and breaks the egg underneath. This year's event most definitely ranked as one of the most lively and nail-biting to date.

Natal Portland Cement is proud to be associated with SAICE and the CSSA in this innovative KZN event and remains committed to continue its sponsorship with even greater plans to "take the event to a higher level" next year.



*The 2006 winners from Mangosuthu Technikon*

*L to R front row: Lirontso Qholosha, Akhona Kahlela, Palesa Mofokeng  
L to R back row: Prof Phil Everitt, SAICE Branch Chairman; Ken Brown, CSSA  
Chairman; Laurence Stevens, NPC Operations Manager and Lungisa Mzalis, SAICE*



*Mantec team 1 jubilant that their arch survived another blow*

### KZN Branch

#### 2006 Kwazulu-Natal Branch Cube Competition

The new format of the Annual Cube Competition certainly had the KZN contestants really thinking this year. The challenge was to achieve the highest strength to weight ratio using materials that are commercially available in South Africa. A maximum concrete density of 1900 kg/m<sup>3</sup> was allowed.

The formula to establish the winning entry was based on the average of three 100mm cubes: "Strength (MPa), divided by the square of the 24-hour drip-dried mass of the cube (kg)".

The challenge was thus to produce the highest strength with the lowest density. The simple example below shows how clever the contestants had to be:

Cube Strength	Cube Mass	(Cube Mass) <sup>2</sup>	Final Result
40 MPa	1.9 kg	3.61	11.1
20 MPa	1.2 kg	1.44	13.9

The results were as follows:

Contestant	Cube strength (MPa)	Cube Mass (kg)	Final Result	Position
Craig Handler	62.3	1.629	23.48	1
Themba Shezi	32.6	1.899	9.04	2
Elvis Nair	14.1	1.280	8.61	3

Well done to all 22 contestants and congratulations to the prize winners. Many thanks to Dick King Laboratory Supplies for the trophies, and to Natal Portland Cement for the generous prize money and corporate gifts.



*L to R: Ken Brown, CSSA KZN Branch Chairman; Themba Shezi (2nd), Tholulwazi; Lyn Smith, Natal Portland Cement; Elvis Nair (3rd), Natal Portland Cement; Craig Handler (Winner), Sika*

## Technical Paper

# HEAT CURING PRACTICE IN CONCRETE PRECASTING TECHNOLOGY – problems and future directions

S. O. Ekolu

*School of Civil and Environmental Engineering, University of the Witwatersrand*

*Dr. Stephen Ekolu is a Lecturer of construction materials engineering at University of the Witwatersrand. He completed his first degree in civil engineering from Makerere University. For six years, he worked as a construction engineer and later as a civil engineer specializing in construction materials and project management. In 1997, he obtained M.Sc from University of Leeds, United Kingdom and was awarded a Ph.D from University of Toronto, Canada in 2004. Dr. Ekolu has conducted teaching and research at Universities in Uganda, Canada, and South Africa. His areas of interest are materials aspects of concrete, cement extenders, concrete durability, concrete repair, petrography, evaluation methods and techniques.*



Stephen O. Ekolu

**Abstract:** *While heat curing is mostly used in the precast concrete industry, freshly cast insitu concretes can also potentially attain high temperatures even without artificial heat application. The demands of the modern construction industry coupled with advances in cement manufacture promote the use of high early strength cements and high cement contents. These factors in addition to hot weather conditions in tropical countries, and large concrete pours may raise concrete temperatures to levels similar to those of heat cured concretes.*

*This article attempts to give an overview of the modern application of heat curing practice, discusses problems associated with exposing concretes to undesirably high temperatures at an early age. Current needs and recent developments associated with delayed ettringite formation are highlighted while potential future advancements are speculated.*

## 1. Introduction

The terms *heat curing*, *heat treatment*, *accelerated curing* and *elevated temperature curing* are often used

interchangeably to mean a deliberate and defined application of some form of heat on fresh concrete with the intent of promoting rapid cement hydration. The process is a low pressure curing operation conducted in enclosed chambers, tunnels or beds where the precast elements are subjected to some form of heat exposure. Steam and radiant heat sources are often used. Steam curing refers to the application of heat by use of live steam. Radiant heat may be applied by direct electric heating elements or electric blankets, by circulating warm air around formwork, or by using pipes to circulate hot water, steam or hot oil (CSA, A23.4; Dafstb, 1989; Neville, 1996).

Concrete precasting plants often need to attain relatively high concrete strengths in a matter of hours in order to meet construction time demands (ACI, 1992). The attainment of high early strength is the main engineering benefit of heat curing and is achieved by subjecting the newly cast concrete elements to elevated temperatures. Creep and shrinkage are major contributors to prestress losses in prestressed concrete. Heat curing reduces creep and shrinkage of concrete by up to 50% and



## Technical Paper (cont.) - Heat curing practice in Concrete Precasting Technology

30% respectively, while prestress loss may reduce by up to 40% (Hanson, 1964). The use of heat curing gives precasting technology an important edge of ensuring speedy supply of elements required for construction. Common practice is that concrete elements may be heat cured overnight and demoulded the next day, ready for use. There is also the economic benefit of quick turnaround of moulds and minimization of storage space when heat treatment is used in production. These aspects have been of key contribution to the success of concrete precasting technology.

But heat curing is riddled with obscure problems and future improvements in the precasting technology might be of critical importance. From its inception, heat curing practice has been based on the basic response of portland cement to heat application. Since the second half of the last century, significant advances in cement chemistry and manufacture have occurred, and concrete mixtures have evolved. Undesirable durability-related problems attributed to heat curing have been exposed while high performance concretes are increasingly being used. These are some of the driving pressures for improvement of heat curing practice.

### 2. Problems in Heat Treatment

#### 2.1 The heat treatment cycle

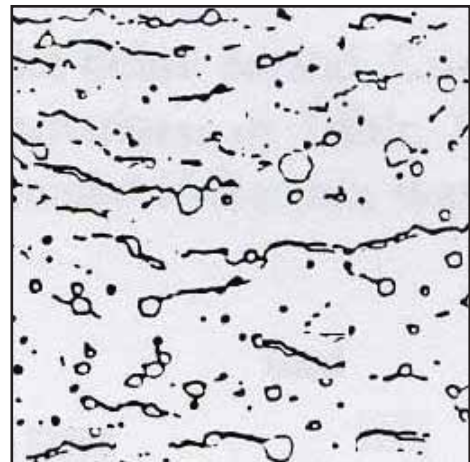
Heat is applied on fresh concrete using a carefully controlled heat cycle. European countries, USA, Canada, and South Africa have standard specifications outlining recommended practices for heat treatment of precast concretes. Most regulations (CSA A23.4; Neville, 1996; SABS 0100-2, 1992; Fulton's, 2001) recommend how long concrete must be left to hydrate before heat is applied, the rate of heating and cooling, and the maximum concrete temperature not to be exceeded.

Internal microcracking of concrete during heat treatment is a problem that might occur due to inadequate precur period, also discussed later in Section 3.1. After casting of concrete, it is usually left to hydrate for about 3 to 5 hours under normal conditions until an initial set has been attained. This precur period allows concrete to develop sufficient tensile strength required to resist pressures generated in the air pores. Figs. 1 and 2 are micrographs showing typical microcracking damage induced within the cement paste matrix during heat treatment and consequently affecting the structural integrity of the paste matrix.

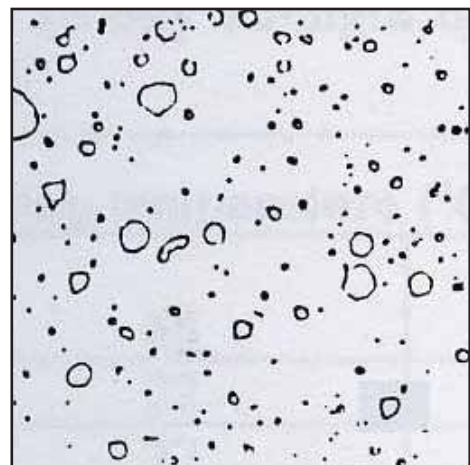
#### 2.2 Significance of the temperature threshold limit of 60 to 70°C

The maximum curing temperature limit of 60 to 70°C has

been maintained from the early use of heat curing in the precast concrete industry. These limits were fixed based on the influence of heat curing on physical properties. Whereas the main purpose of heat curing is to achieve early strength development, it is also recognized that there is reduction in long-term strength when compared to normal moist curing as shown in Fig. 3. Due to the retrogression in late strength, it has been considered that the optimum curing temperature should balance the attainment of high early strength and high late strength, thus the use of 60 to 70°C threshold temperatures. The prevailing view is that curing of concrete beyond this temperature range offers little or no benefit to engineering properties of concrete (Hanson, 1963; Pfeifer and Marusin, 1991; Kosmatka et al., 1991). This understanding was based primarily on the influence of heat curing on physical properties of concrete.



(a) Short precur period: microcracks formed in paste



(b) Adequate precur period or normal moist curing: undamaged paste matrix

Fig 1. Influence of precur period on microstructure of heat treated cementitious systems (adapted from Alexanderson, 1972)

## Technical Paper (cont.) - Heat curing practice in Concrete Precasting Technology

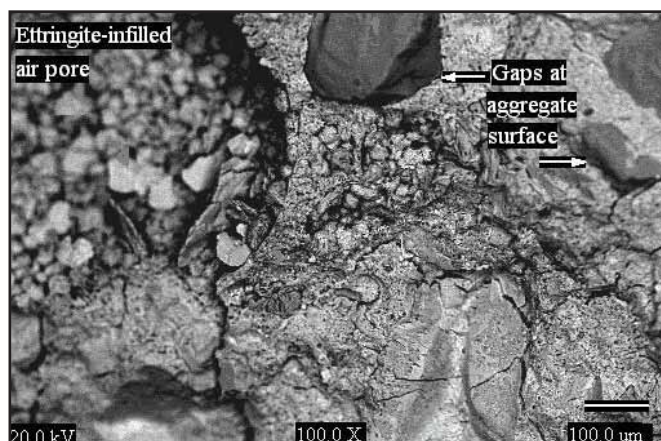
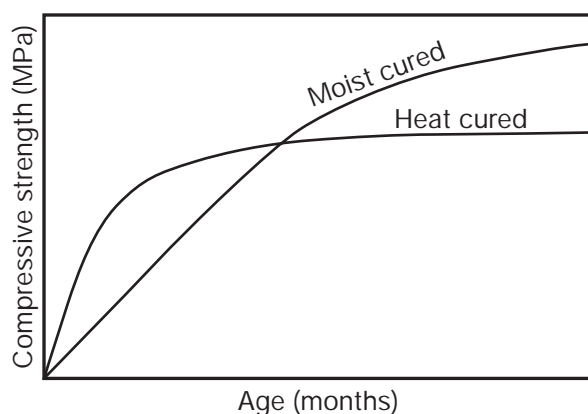


Fig. 2 Inadequate precure period results in development of microcracks and gaps around aggregates upon heat treatment (Ekolu, 2004)



(ILLUSTRATIVE ONLY)

Fig. 3 Compressive strength development for heat treated and normally moist cured cementitious systems (adapted from Dafstb, 1989).

But from the 1950's and 1960's, failures in field concretes exposed to high temperatures at early age have been experienced. Recent research has shown that the temperature range of 60 to 70°C is actually a threshold for chemically-induced changes in a cementitious system exposed to elevated temperatures at an early age. The chemical changes occur once the temperature range is exceeded. These chemical changes may later, under moist conditions result in a disruptive onset of expansion in hardened cementitious systems due to delayed ettringite formation (DEF). It now appears that at the threshold temperature range, there could be a link between the chemical disruption and the physical properties of concrete as used in earlier studies to underpin the threshold temperatures for heat curing practice but this relationship has not been clearly understood.

Another underlying problem is that even non-heat treated concretes may easily attain temperatures far in

excess of the 60 to 70°C threshold. This is potentially an important issue in tropical countries when large concrete sections are cast under hot weather conditions. Research has shown that concrete temperatures can rise to levels in excess of 80°C even without external application of artificial heat (Hobbs, 1997; Johansen and Thaulow, 1997). In this regard, it is clear that both heat-treated and non-heat treated concretes can be vulnerable to elevated temperatures.

### 2.3 Durability of heat-treated concrete

The rate of hydration of cementitious systems increases with an increase in curing temperature. As a result, there is insufficient time for the rapidly-formed hydration products to diffuse away from the surface of the hydrating cement grains. The hydration products are then deposited within the vicinity of the hydrating cement particles. Further hydration leads to accumulation of the hydration products at the grain surface, which in turn block water penetration towards the partially hydrated cement grain. The effects are that hydration of the cement grain slows down and may soon stop, while a smaller volume of hydrates form than would otherwise develop under normal moist curing conditions (Roy and Parker, 1983; Detwiler et al., 1991; Kjellsen et al., 1991). The resulting pore structure is made of open and loosely packed hydrates, which are also non-uniformly distributed throughout the cement matrix. Such is a generally coarse pore structure. Fig. 4 shows greater hydration of cement grains in the concrete that was moist cured under normal conditions as compared to the grains in the heat cured concrete given in Fig. 5. The implications of a coarse pore structure are largely detrimental including reduced late strength, ultimately reduced durability characteristics due to increase in permeability and other transport properties (Goto and Roy, 1981; Detwiler et al., 1991), allowing enhanced ingress of deleterious ions into concrete and reducing its service life.

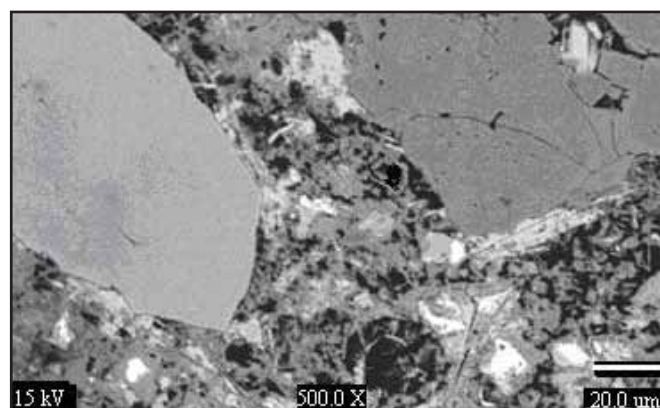


Fig. 4 The bright alite (cement) grains are seen to be partially consumed during hydration (Ekolu, 2004)



## Technical Paper (cont.) - Heat curing practice in Concrete Precasting Technology

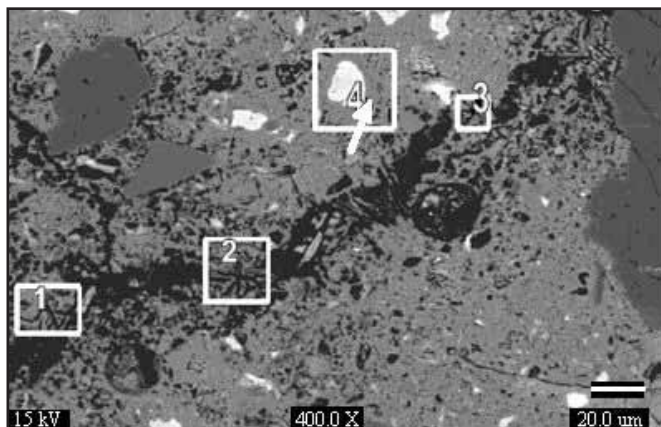


Fig. 5. 4 – Dense, packed C-S-H layers formed at the surface of the cement particle prevents further hydration of the grain due to lack access to water. Note that the grain has not been significantly consumed since hydration likely stopped; 1, 2, 3 – ettringite formed inside a crack (Ekolu, 2004)

### 2.4 Delayed ettringite formation

DEF is a deterioration phenomenon in concrete that only came to the limelight recently. It has been reported in several countries including South Africa. It is rare and not yet fully understood. DEF is a form of internal sulphate attack, so far considered to occur only in concretes exposed to high curing temperatures in excess of 70°C (Famy, 1999; Ekolu, 2004; See Fig. 6). But DEF has also been reported in field concretes that were not heat treated (Lawrence et al., 1997; Thomas, 1998). When fresh concrete is subjected to high temperatures, the ettringite that normally forms during hydration is destroyed releasing sulphate and aluminate ions, which then get adsorbed on calcium silicate hydrate (C-S-H). In the presence of moisture, the sulphate ions are released from the C-S-H, they react with monosulphate found within the cement paste re-forming ettringite and causing disruption in the hardened concrete (Famy, 1999).

DEF is considered to occur only with certain portland cements while the influence of aggregates varies depending on aggregate type. Rapid hardening portland cements are particularly susceptible to DEF. Often, the cements used in heat cured concretes to achieve high early strength also contain high levels of sulphates and they generate substantial heat evolution that can raise concrete temperatures to higher levels. Ironically, these factors in combination with other chemical influences set up conditions suitable for DEF.

Studies have shown that DEF co-exists and interacts with other deterioration mechanisms that occur in concrete especially alkali-silica reaction (Pettifer and

Nixon, 1980; Diamond and Ong, 1994; Brown and Bothe, 1993; Shayan and Ivanusec, 1996; Oberholster et al., 1992), chloride attack (Ekolu et al., 2006), and frost action (Ekolu, 2004). The influences between these processes and DEF are not fully understood, and are sometimes controversial.

### 3. Inadequacy of current Counter Measures

#### 3.1 Standardization of heat treatment

Standardization of the heat treatment cycle can be seen as a recognition of the potential adverse effects associated with elevated temperature curing. Typically the heat curing cycle consists of 3 to 5 hours pre-cure period followed by heating at a rate of 20 K/hour to a maximum temperature of 60 to 70°C. The maximum temperature is maintained for a specific time period before cooling at about 20 K/hour. In reality, the setting time of concrete depends on the mix design and the ingredients used. Use of plasticizing chemical admixtures can extend setting time. Unless the setting time is monitored and properly allowed for during heat curing, there is a potential risk of microcracking during heat treatment as a result of extended setting times. Also, high performance concretes might be capable of withstanding high temperatures above 70°C without exhibiting unusual adverse effects. It cannot therefore be considered that applying the standard heat curing cycle is optimal for executing heat treatment of concretes.

#### 3.2 Use of cement extenders in heat-cured cementitious systems

The use of extenders is of double benefit for concretes subjected to heat treatment. Firstly, cementitious systems incorporating extenders give proportionally higher early strength gain upon heat treatment compared to systems with portland cement alone. Secondly, the use of extenders are an important counter measure to durability-related detrimental effects of heat treatment.

The extenders fly ash, silica fume, slag, and natural pozzolans, when incorporated in concretes, have the distinct ability to promote a more refined and tortuous pore structure. Through this influence, extenders reduce the pore coarsening effect of heat treatment and as such minimize the related adverse effects of heat treatment on concrete durability (Detwiler, 1991; Roy and Parker, 1983; Fapohunda, 1992; Campbell and Detwiler, 1993; Titherington, 1998). However, the use of extenders neither stops retrogression in late strength due to heat treatment nor prevents coarsening of the pore structure.



## Technical Paper (cont.) - Heat curing practice in Concrete Precasting Technology

### 4. What is required

Future trends could involve attempts to develop heat cured concrete mixtures that are free of adverse effects due to heat treatment and that could possess properties superior to moist cured concretes. To this end, the need for smart materials and different approaches in material science might be essential. The complex but key requirement involves control of heat evolution while promoting cement hydration to obtain ideally robust cement paste matrix. Attempting to replace heat treatment with use of high performance concretes of low water-cement ratios does not resolve temperature related problems since even non-heat cured concretes can experience heat exposure levels similar to those of heat cured concretes.

### 5. Summary

The foregone discussion identifies issues associated with the use of heat treatment and advances that the use of the standard heat treatment cycle as currently practiced is only a secondary means of minimizing significant adverse effects from occurring. Presently, there are no known methods of avoiding adverse effects due to heat curing. The use of extenders only improves performance but cannot prevent the detrimental causes involving late strength retrogression and coarsening of the pore structure. Despite some extensive research, there are still many unknown issues regarding the recent and controversial DEF phenomenon including the need for appropriate test methods, cement susceptibility, prevention and control measures, and DEF interaction with other deterioration processes in concrete.

Future advancements in promoting heat curing practice could involve rigorous efforts towards development of heat-cured concretes that will be free of the adverse effects of heat curing and could exhibit superior behaviour to their non-heat cured counterparts. That way, heat curing practice can be a contribution to the improvement of concrete technology rather than simply an essential practice.

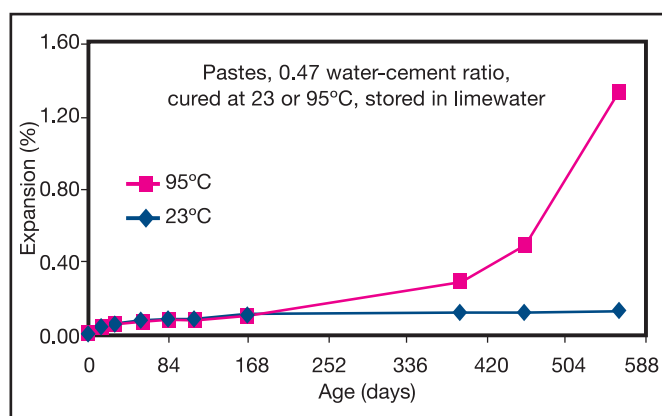


Fig. 6 Expansion of heat-cured cement pastes due to delayed ettringite formation (Ekolu, 2004)

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Project Name	Submitted By	Civil Engineering	Building	Unique Design	Construction Technique	Aesthetic Appeal	Special
Toyota Paint Plant, Durban	BKS (Pty) Ltd						
Cathodic Protection of Historic Rail Bridge over the Silvermine River	BKS (Pty) Ltd						
Pezula Private Estate, Knysna	Engineering Advice & Services, cc						
Harbour Tunnel, Durban	Goba (Pty) Ltd			X	X		
Water Tower, Walvis Bay	H Contracting (Pty) Ltd	X					
Exposed Concrete Roads, L'Omarins Estate, Franschoek	Melt Wahl Concrete Services Cape						
Effluent Plant, Richards Bay	Grinaker-LTA Civil Engineering						
Concrete House, Melville, Johannesburg	I N K						
Walter Sisulu Square of Dedication, Soweto	Grinaker-LTA Building Inland						
Maguga Hydropower/Irrigation Project, Pigg's Peak, Swaziland	Group Five/Ninham Shand - Joint Venture			X	X		
Michelangelo Towers, Sandton	Group Five		X			X	
Berg River Dam, Franschoek	Group Five	X					
Waterval Water Treatment Works, Kliprivier	Group Five	X					
Ocean View Luxury Apartments, Strand	Group Five		X	X		X	
Concrete Road, Senekal	Group Five Civil Engineering				X		
Tarka Bridge, Cradock	Group Five Civil Engineering	X					
New Head Office, Dept of Science & Technology, CSIR, Pretoria	BVI Consulting Engineers		X			X	
Five Compartment Cement Storage Silo, Port Shepstone	Kantey & Templar						
The Quality Street/M4 Interchange Upgrade, Durban	Vela VKE Consulting Engineers						
Fairlands Office Project, Johannesburg	WBHO/ Grinaker-LTA - Joint Venture		X				
Impala Platinum's Shaft, Rustenburg	Chryso Southern Africa (Pty) Ltd						
Universal Infrabolt Sleeper System, National	David Beer Communications						X
The Red Location Museum of the Peoples' Struggle, Nelson Mandela Bay	Noero Wolff Architects/De Villiers & Hulme Consulting, jv		X			X	
Bosmansdam Road Footbridge, Cape Town	Jeffares & Green (Pty) Ltd						
Mkomas River Footbridge, KZN	Jeffares & Green (Pty) Ltd						
Marquard Reservoir, Ficksburg, Free State	Kwezi V3 Engineers						
Freedom Towers, Johannesburg	Lafarge South Africa						
ACSA Parkade MSP1, Cape Town International Airport	Murray & Roberts Construction		X	X	X	X	
Fynbos House, Betty's Bay, Western Cape	Sarah Calburn Architects						
Little Cliff House, Johannesburg	Sarah Calburn Architects						
House Duyver, Morningside	Barrow Construction						
Desalination of 40-year old Interchange Bridge Deck, Port Elizabeth	HHO Africa/Africoast - Joint Venture			X			
Sishen Expansion Project, Sishen	Grinaker-LTA Civil Engineering						
New Paint Shop for Volkswagen South Africa, Uitenhage	Grinaker-LTA Civil Engineering						
University of Johannesburg Pedestrian Bridge	Themba Consultants (Pty) Ltd	X				X	
Athlone Stadium, Athlone, Cape Town	Lafarge SA/Vusela Construction jv	X					
House Millar, Nelspruit, Mpumalanga	Mathews & Assoc. Architects cc						
Repair of Hermanus Harbour, Hermanus	Ninham Shand (Pty) Ltd	X					
Bridge over Orange River, Riemvasmaak, N. Cape	Ninham Shand (Pty) Ltd	X					





# DYNAMIC EVALUATION OF THE SOLAR CHIMNEY

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This paper was reviewed specifically for the 3rd Young Engineers, Practitioners & Technologists Conference and the Society has decided to publish it, since it was judged as a worthwhile paper.

**Abstract:** *Previous studies on the solar chimney, a reinforced concrete tower of 1500m high, internal diameter 160m, have shown that its structural integrity might be compromised by the occurrence of resonance. The wind gust spectrum peaks near the solar chimney's fundamental resonance frequency. This phenomenon poses a reliability threat, not only to the solar chimney, but also to all high-rise, slender structures. The dynamic equation of motion incorporates four terms that bind the factors responsible for resonance: accelerated mass energy, dissipated energy (damping), stiffness energy and input energy (loading). The study scrutinises each of these terms individually in the context of the solar chimney as designed to date. A dynamic analysis is undertaken with all the above-mentioned parameters as defined and estimated by the study. The results from the analysis show amplifications of approximately three times the static displacements. In load cases where the wind direction inverts along the height, higher eigen-modes are amplified. However, the most severe dynamic amplification occurs at the fundamental eigen-mode. In the context of solar chimney research, this study brings valuable new insights regarding the dynamic behaviour of the chimney structure to the fore.*

## INTRODUCTION AND BACKGROUND

### Higher and Higher

The time of super structures is upon us. No more fictional star wars like high-rise skyscrapers, fiction is turning into reality. With the assistance of computer power today, engineers are able to design buildings of larger proportions than before. There is no need for over-simplification anymore. Today it is possible to simulate a physical structure, in the finest of detail, on a regular desktop pc. Civil Engineers have acquired the ability to predict structural behaviour with accuracy, based on design and computational modelling. Only in exceptional cases it is required to study behaviour by physical, scale modelling. And it is not surprising that developers have the confidence to go wider, larger, and higher. Is it possible, even with advanced design capabilities and descriptions of nature, to build structures of limitless proportions today, unlike the ancient builders of the tower of Babylon?

### Background to the solar chimney

In the past ten years universities in Germany, Australia and South Africa have been doing research on the feasibility of a Solar Updraft Tower, or solar chimney. The system will produce energy by means of updraft airflow from under a glass collector through a chimney, turning turbines that generate power. One such system can generate at a constant rate of 200MW throughout the day and night. Schlaich Bergermann und Partner is the leading engineering company in promoting the concept to potential energy users (Schlaich et al, 2004).

The challenging component of the system is the tower or chimney. The planned reinforced concrete chimney will be a freestanding structure reaching to a height of 1500m. According to Schlaich Bergermann und Partner "towers 1000m high are a challenge, but they can be built today".

"What is needed for a solar updraft tower is a simple, large diameter hollow cylinder, not particularly slender, and subject to very few demands in comparison with inhabited buildings." (Schlaich et al, 2004). Since the publication of the first concept the height has increased to 1500m, where a higher efficiency will be reached.

The peak power output should be achieved with a chimney of 1500m in height and a collector 7000m in diameter according to Schlaich (1995). With these dimensions the power output is large enough to be compared to the efficiency of small coal-fired power plants and small nuclear plants. The concept was presented to various countries around the world with the hope that someone somewhere would consider funding the construction of a full-scale prototype. It was during this marketing campaign that more questions were raised on the reliability of the project. The fathers of the solar chimney concept gave little attention to the scale of the structure they wanted to build. In their minds it was a fairly simple matter: construct an upright cylinder 1500m tall in a desert. But to a structural design engineer such a request is not as simple as it seems. And with questions such as the construction feasibility, a new generation of research studies was undertaken concerning the structural viability of the solar chimney.



## Technical Paper (cont.) - Dynamic Evaluation of the Solar Chimney

### Researched concerns

Stellenbosch University has participated in the project for numerous years, working closely with their German colleagues searching for solutions regarding the physical feasibility of the system. The departments of Mechanical, Electrical and Civil engineering have all contributed valuable research studies on the subject. In the past 6 years the following research has been done regarding the structural validity of the chimney:

- Structural integrity of a large-scale solar chimney (C. van Dyk, 2002)
- The realization of the solar chimney inlet guide vanes (C. van Dyk, 2004)
- Optimization of wall thickness and steel reinforcing of the solar chimney (M. Lumby, 2003)
- The development of ring stiffener concept for the solar chimney (E. Lourens, 2004)
- Wind effects on the Solar Chimney (L. Alberti, 2004)

These studies placed the complexity of engineering such a structure under the spotlight, but all of these aspects are related to design variables, which are concrete and very possible to define with enough research and detailed design. It has also been shown that the construction of such a large chimney might indeed be possible. However, the conditions regarded in these analyses are ideal, neglecting complex environmental actions. Although the danger of resonance due to wind loads was identified, simplified methods of wind loading were used, probably conservative. Environmental actions should be characterized to refine the prediction of the response of the structure. Thus, the limit of the domain of applicability of engineering models has been reached and must be extended to prove the integrity of the solar chimney tower.

### CHIMNEY AND TOWER DESIGN

The science behind chimney design developed independently of concrete skyscrapers. Modern industrial tower designers have to deal with problems such as thermal variations over the height, chemical reactions with the building material etc. Modern TV towers have a new spectrum of criteria to be met regarding broadcasting equipment. It was not until the development of radio and television technology that the height factor in tower structure design came to the forefront once more. The 1970's saw a boom in the construction of radio and television towers world wide, the one being taller than the other. Most of these types of towers have observation decks or revolving restaurants and are therefore under high constraints with regard to movement. Both towers and chimneys are slender structures. They are the best examples of similar

structures to the solar chimney. It is therefore important to study the design methods of these structures in the light of the solar chimney design, as these structures' main load source is also wind.

### Identifying Resonance Modes

The first important characteristic of a structure that is subject to dynamic loads is its modes of resonance. The mathematical problem used to solve resonance modes (also known as 'fundamental' frequencies) is called the eigen-value problem. In the 1950's Arnoldi, Francis, Givens, Householder, Kublanovskaya, Lanczos, Ostrowski, Rutishauser, Wilkinson, and many others further developed algorithms and analysis for complex eigen-problems (O'Leary, 1995). Although these pioneers furthered the development of eigen-value analysis from a few differential equations to large systems, their work was only implemented in the engineering industry during the late 1970's with the development of desktop PC's. Until then simple hand calculations were used to estimate the vibration modes of structures.

It was not necessary to use complex eigen-solvers during the early years of dynamic computations. Structures such as chimneys and TV towers could be modeled with simplified mathematical models, only incorporating the most important global degrees of freedom, limiting the number of differential equations to a manageable amount. Furthermore, it was widely accepted that only the first fundamental vibration mode was of importance to resonance. As a result simple algorithms were used in chimney design to estimate these vibration frequencies.

### Incorporating Damping

As early as scientists realised that structures can resonate, it was also discovered that other energy losses exists in a system (mostly a combination of aerodynamic damping and structural damping). These energy dissipaters were modelled as one energy term in the dynamic equation in order to simplify the complex damping phenomenon. The result of this is that damping could not be calculated accurately as there are many unknown energy dissipation role players in this one mathematical term. The only way of knowing how large the 'energy extraction' of such dissipaters is, is to measure the decay of a structure's oscillating motion. Such tests serve as a database for future designers to consult in predicting the damping in a new structure.

### Wind loads

Wind effects studied in tower and chimney designs include static wind loads, gusting dynamic wind effects, vortex shedding and ovalisation effects due to



## Technical Paper (cont.) - Dynamic Evaluation of the Solar Chimney

a distribution pressure around the shell. In towers and chimneys vortex shedding is often the most critical. These dynamic phenomena may lead to resonance and failure, despite sufficient resistance to static wind loads. A commonly used static wind load formulation is the power law profile.

Since gusting winds are unpredictable they are usually dealt with in a probabilistic approach. From statistical data reworked from measurements, hand calculation methods have been developed to simplify this complex phenomenon. A.G. Davenport (1967) proposed one such method known as the gust pressure factor approach. The static is wind profile is multiplied by a gusting factor,  $G$ .

Vortex shedding occurs as a result of vortices or eddies that form as air passes by the section profile. From the Strouhal number, the critical airflow velocity for a certain frequency can be determined. If the critical airflow velocity of the first mode's natural frequency is outside the reach of the mean airflow, the structure is safe.

Ovalisation occurs in sections with large diameters and thin walls. This can be the effect of airflow around the section and the resulting cantilever bending moment which warps higher circular sections on the free end of the cantilever. Bending moments form along the circumference of the section in the wall. In reinforced concrete cracks will form and reduce the stiffness. This threatens limit states as defined in building codes.

### Design

Once the stiffness of the structure is determined, deflections can be calculated by applying static loads. The structure may be designed according to this criterion as long as the dynamic loads' frequencies are well out of range of the structures fundamental frequencies. The traditional methods of calculating these frequencies are very simplified. For more accuracy a full scale frequency domain dynamic analysis was performed on the solar chimney model.

### THE FINITE ELEMENT MODEL

Although previous finite element models of the solar chimney exist, it was important to re-assess the effectiveness of the model in the light of a dynamic analysis. Dynamic analyses require more computing power, more time and more variables than just stiffness, displacement and load, as is the case with a static finite element analysis.

### Mesh refinement

The solar chimney model is meshed with CQ40S

quadrilateral isoperimetric curved shells. Each element has eight nodes and each node in turn has five degrees of freedom, three translational and two rotational. The in plane torsion degree of freedom is ignored. Such nodes are known as 'drifting' nodes. The structure has certain limitations regarding meshing, as certain nodes in the height axis and along the parameter is fixed according to the ring stiffeners situated on the inside of the structure. The ring stiffeners are spoke-like wheels placed horizontally at certain heights in the tower to minimize ovalisation. The nodes at these stiffeners are fixed in torsion in the vertical direction to simulate a drifting effect in the ring stiffener plane. In order to get an idea of the effect of different meshes the computed behaviour of the structure will be compared when finer meshed. An optimum mesh was chosen where the model behaves the least stiff.

### The Eigen problem

In order to simplify the analysis, a frequency domain dynamic analysis was chosen to reduce computing time. A structure consists of various Eigen frequencies, or resonance frequencies. For each of these frequencies the structure will oscillate in a certain displacement pattern (Figure 1). This is known as the structure's Eigen modes, to which the various Eigen frequencies correspond. If the structure encounters a vibrating load with frequency components matching any or some of the structure's eigen frequencies, it will resonate to a greater or lesser extent in that particular eigen mode shape.

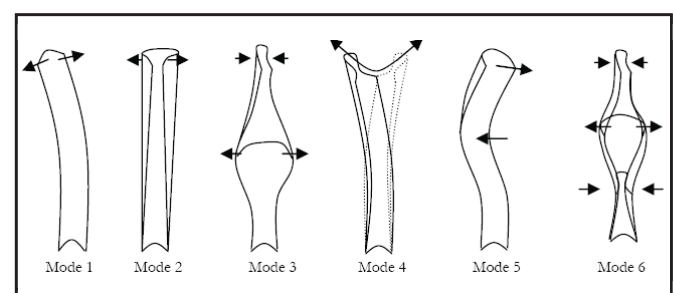


Figure 1: The first five Eigen modes

A mathematical model has as many Eigen frequencies as it has degrees of freedom. Each individual mode response is a vector of the global response. Every Eigen mode-shape carries a certain amount of the total resonating energy. At very high frequencies the displacement response is so small that they can be ignored for all practical purposes. Of the 6000 Eigen modes in the solar chimney only the first 400 was considered in the analysis, of which only 10 were global Eigen modes.

## Technical Paper (cont.) - Dynamic Evaluation of the Solar Chimney

### Proportional damping

Damping is the absorption of energy, based on a structure's material and geometric properties. In order for things to move, to flex, to crack etc. energy is needed. This requires energy to be taken out of the global motion energy of the structure. Hence the energy equilibrium with stiffness energy, momentum energy and damped or dissipated energy is taken from the initial energy put into the system.

The damping matrix is set up to enable the decoupling of the degrees of freedom. The damping matrix will be orthogonal if the orthogonal mass and stiffness matrices are multiplied by coefficients  $\alpha$  and  $\beta$ . The damping is thus assumed to be directly related to stiffness and mass-kinetic energy.

### ESTIMATING DAMPING CHARACTERISTICS

The estimation of damping in an untested structural geometry is a difficult matter. Although a variety of literature is available on the subject of damping, it remains a poorly known aspect of general vibration analysis. Woodhouse (1998) proposed that the reason for this is that a fundamental, universal mathematical model of damping forces does not exist, and needs to be characterized experimentally.

### Understanding damping mechanisms

Various methods of modelling damping and their mechanisms have been proposed in the literature. The most general are Viscous, Coulomb and Hysteretic damping, all resulting from different energy dissipaters and characterised by their unique decay curves. Coulomb and Hysteretic damping is material related, whereas viscous damping results from drag forces from the medium in which movement occurs. The term 'equivalent viscous damping' was coined by engineers who observed the damping in tall concrete structures by means of measuring the decay rate, and concluded that the decay rate curve looks similar to viscous damping. Hence, the mathematical formulation of viscous damping is generally used in tall concrete structure analysis, although it is known that the damping sources are more hysteretic and coulomb related.

### Measuring damping

As mentioned, damping mechanisms are characterised by their rate of decay. In the case of Viscous damping, the rate of decay is a logarithmic function, hence the term characteristic parameter – logdec. The logdec of a structure can be measured by observing the decay in oscillation when the first Eigen mode is activated (either by a instantaneous force or by a initial displacement). In

turn, the measured logdec can be related to the ratio of critical damping (the least amount of damping needed to keep the system from oscillating in that particular mode). Critical damping in turn is a function of stiffness and mass.

For the dynamic analyses of medium height towers or chimneys, the logdec can be determined by comparing measurements of structures with similar fundamental Eigen frequencies and heights. In the case of the solar chimney, no structure of its magnitude exists. Thus, a logdec value had to be estimated by looking at smaller, existing structures with the same type of slenderness ratio, and close to the fundamental frequency of the solar chimney. A database of logdecs of the tallest TV towers and chimneys in the world was plotted against their fundamental frequencies, and a trend line extrapolated to the frequency of the solar chimney (Figure 2). Although the theory states that measured logdec is independent of frequency, measurements from different tower-like structures shows a tendency to higher logdec values with a decrease in the first eigen-mode frequency.

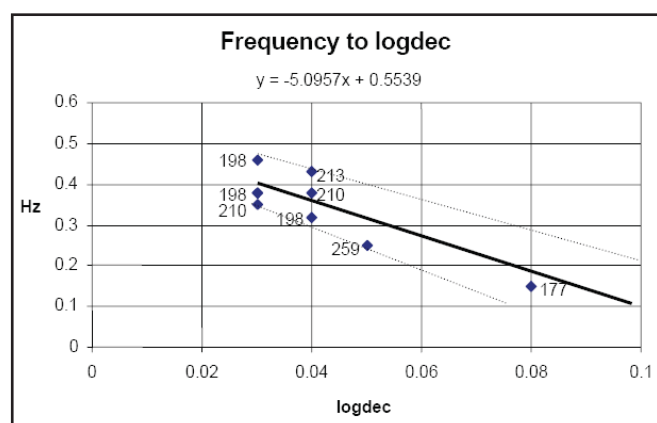


Figure 2: Linear estimation of the logdec at 0.1Hz based on existing tower measurements

From the available data, a logdec value of between 0.09 and 0.12 can be estimated for the fundamental vibration frequency of the solar chimney. This implies 1.43% to 1.91% percent of critical damping. This range agrees with the generally accepted range of damping ratio for concrete structures in the high amplitude range, as presented by Jeary (1986).

### Rayleigh damping

Rayleigh's principle proposes to define damping as an energy loss due to a combination of a mass's movement through a medium and bending of a member or structural component. When a mass moves through a medium (like water or air), energy is lost because of drag. Little energy is lost because of small drag, resulting



## Technical Paper (cont.) - Dynamic Evaluation of the Solar Chimney

from slow movement. At high frequencies, more energy is lost because of higher oscillating velocities, resulting in higher strain and thus greater drag forces. Energy is transformed to heat when a piece of material bends in rapid succession as a result of internal material friction. Faster repetitive bending results in higher energy loss. Thus, mass proportional damping ( $\beta$ ) damps out lower modes, where stiffness proportional damping ( $\alpha$ ) damps out higher modes.

Choosing values for  $\alpha$  and  $\beta$  can be difficult for structures with many degrees of freedom. The choice of  $\alpha$  and  $\beta$  determines the damping proportion of the uncoupled system's critical damping value. Hence mathematicians have developed calibration methods to compute  $\alpha$  and  $\beta$ . One method, described by Chowdhury and Dasgupta (2003) is to calibrate the proportions by means of interpolating the modal damping ratio for each uncoupled equation based on mass participation (the ratios of participating energy in each Eigen mode). The mathematical formulation of Chowdhury and Dasgupta could be applied to compute the  $\alpha$  and  $\beta$  terms of the solar chimney, in order to calculate the damping matrix.

From the author's frequency analysis results presented later it is shown that the second mode's resonance peak is about six times lower than the first mode. Furthermore, there are little signs of high frequency resonance even at 1% of critical damping. The need to damp out higher modes is therefore not critical, and the lower frequency modes are dominated by the first mode. The need for calibrating each modal damping value does not arise yet, but depending on the wind loads (described in the next section) it might become important in some cases.

### CHARACTERISING WIND

The density of air varies in height, resulting in different wind speeds at different altitudes. In most cases, structural dimensions are so small in comparison to the scale of the differences in air movement, that it can be assumed the structure is experiencing a constant pressure load, uniformly distributed over the whole exposed area. However, skyscrapers and high towers experience a variation in wind speeds with height. Building codes prescribe a vertical wind speed profile for tall structures, but this profile is limited to the layer in which air movement is highly effected by ground friction.

#### Static wind profile

As mentioned earlier, the most commonly used wind profile is the power law profile. These types

of formulations are subject to the effects of ground roughness and the boundary layer. This layer is more or less the height at which the effect of ground friction dies out (1km above ground), and the wind patterns are governed by geostrophic or gradient winds. Thus, 3 regions occur: friction influenced, boundary and geostrophic. The difference between geostrophic or gradient winds and wind in the boundary layer is the forces working in on a particle of air. Two characteristic length scales therefore affect the mean velocity curve. The surface friction close to the ground dominates the one and the other is dominated by the free flow at the top of the boundary layer.

The corrected logarithmic profile is a more precise expression for heights above 200m above the ground. Harris and Deaves (1980) developed the formula. This equation is valid up to the height where airflow becomes geostrophic and stabilizes in velocity over height. The wind speed is then a function of the local weather system and isobar gradient. The advantage of the logarithmic profile is that it can characterise wind velocity over two distinct air layers, tying it into the constant geostrophic region. The advantage of the power-law profile is its simplicity, fairly accurate up to 300m. Above this level the profile becomes very unrealistically exaggerated (Figure 3).

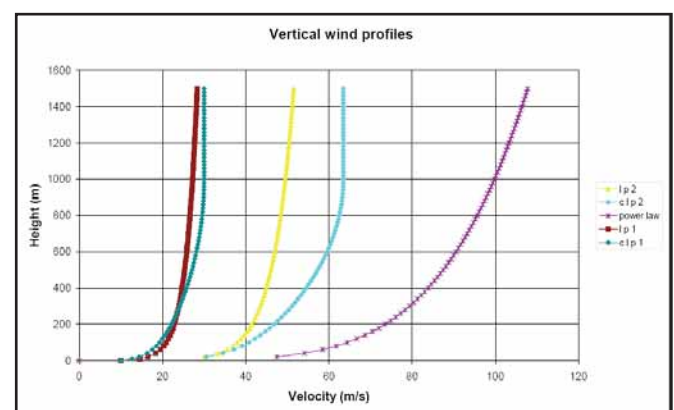


Figure 3: Comparative vertical wind profiles

#### Dynamic wind loading

The turbulence component shown in figure 5-1 is what causes the fluctuating nature of airflow referred to as gust. It is this component that will cause a structure to respond in a dynamic way. To characterise this behaviour is difficult, as gust is a random process. Its characterisation depends on the nature of the instantaneous fluctuations of pressure; hence it cannot be determined by normal averaging accelerometers. The whole process of obtaining data is unique in itself.

For application in the solar chimney analysis, the power

## Technical Paper (cont.) - Dynamic Evaluation of the Solar Chimney

spectral density function proposed by A.G. Davenport (1962) was used to generate an artificial wind gust history. This data was compared to measurements taken with a home-made accelerometer (working with a strange-gauge and being able to take 10 readings per second). As shown by the tests conducted at two gusty locations in South Africa, Davenport's power spectral density for gusting wind is a realistic description and applicable in the relevant frequency range.

### Direction variation in height

From the meteorological knowledge of the Uptington region, it can be shown that wind direction inversions are a frequent phenomenon as a result of temperature inversions. This can affect the response of higher modes in the solar chimney. To test this effect, three direction load-cases was applied at maximum gust speeds to amplify the effect. The first was in one direction only (LC1); the second turned 180 degrees at 750m (LC2); the third changed 180 degrees at 500m and changed back to the first direction at 1000m high (LC3). The third load case may result from airflow inversions due to thunderstorm activity (Figure 4).

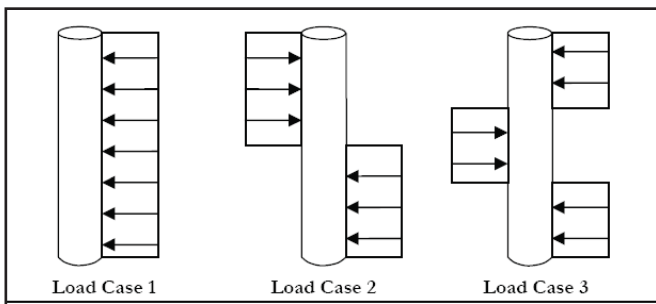


Figure 4: Three load case inversions (direction vectors only)

### DYNAMIC ANALYSIS RESULTS

The maximum dynamic amplitude at 30m/s is 7.92m at 0.1Hz with a static displacement of 2.91m and the root mean square value (calculated from 0.01 Hz to 0.48 Hz) is 8.22m. At 42.5m/s the maximum amplitude is 35.8m at 0.1 Hz with a static displacement of 5.81m and the root mean square value (calculated from 0.01 Hz to 0.48 Hz) is 36.986m.

### Damping Sensitivity

To estimate the effect of damping on the system, the simulation was done with varying damping values, ranging from 1% to 5% in increments of 1% (Figure 5). Although higher damping will occur at higher modes, the same percentage of critical damping was assumed for all modal frequencies, as the effect of the higher modes

was very little even with low damping. Therefore, this approach can be considered as conservative concerning higher resonance modes. Between one and 3 percent of critical damping, the increasing effect of damping has a considerable effect on reducing the resonance amplitude. From 4% to 5% the amplitude decreases with 0.44m as opposed to a 3.58m difference between 1% and 2%. From 5% damping onward, the decreasing amplitude effect becomes small. At 5% damping the dynamic amplification factor is 1.6.

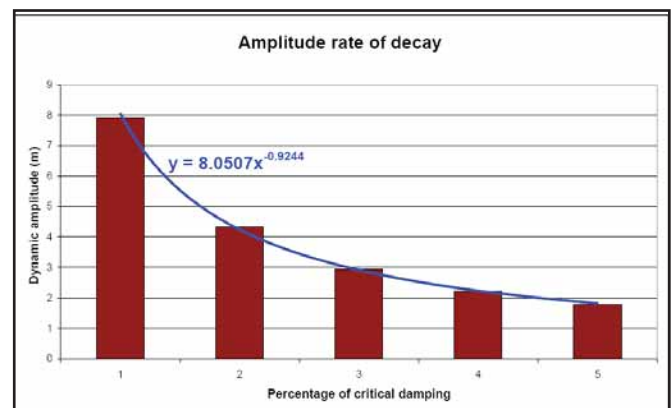


Figure 5: The decay rate of response amplitude

### Inverting load directions

As a result of the change in direction, it is expected that LC2 and LC3 can amplify eigen-modes where the eigen-vectors correspond to the load vectors. LC3 resembles the fifth eigen-mode shape, thus it is not surprising that, even though the static response is less, LC2 and LC3 show much higher amplitudes at 0.33Hz (mode 5) than LC1. At 0.1Hz (mode 1) LC3 shows the smallest amplitude since the height of the top pressure distribution (that activates mode 1) is the smallest. At the static state, however, LC2 shows the smallest deflection as the resulting pressure load on the whole tower is minimal (Figure 6).

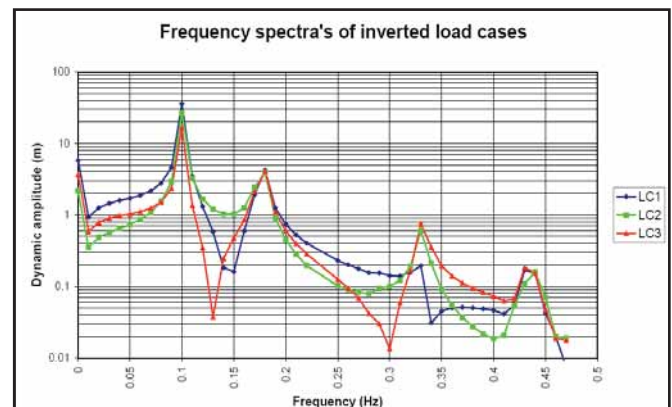


Figure 6: Log plot of LC1 to LC3





## Technical Paper (*cont.*) - Dynamic Evaluation of the Solar Chimney

The amplitude response of LC1 at 0.33Hz is 0.19m. With LC3 it is 0.793, just over 4 times higher. Although these amplitudes seem small in comparison to the amplitude at the first mode (16.7m for LC3) it can still result in significant stress levels as the oscillation period is much less (3 seconds appose to 10 seconds) and the length over which the displacement occurs is much less (i.e. the curvature is larger for a given displacement).

### Ovalisation

As a result of the pressure distribution around the parameter of the solar chimney and 2<sup>nd</sup> order reaction to bending, the circular section shape is warped. This is the same deformation industrial chimneys experience, as mentioned earlier. The difference is, in this case the warping is dynamic. As the wind gusts by the chimney and fluctuates in speed, the pressure distribution fluctuates as well. The resonance effect may be amplified if the frequency of vortex shedding is close to the frequency of the second eigen-mode.

### CONCLUDING REMARKS

The goal of this study is to better characterise the dynamic response of the solar chimney structure, rather than to produce an exact result. Although the contributing factors in the dynamic force-equilibrium equation are not exact, a wide scope of new insight has been gained through this investigation.

From the results it can be concluded that noticeable resonance behaviour will occur at yearly reoccurring gusting speeds (30 m/s). At 50-year (or more) reoccurring speeds (45.2 m/s), as shown by records of the De Aar weather station, the resonance amplitude may exceed static limitations as defined in building codes, based on the slenderness ratio of the structure. Although these amplitudes are subject to the percentage of critical damping in the structure, which exact value is unknown, conservative projections of energy dissipation must be kept in mind when estimating conservative amplitudes, as these above-mentioned results are based upon.

The study highlighted the complexity in understanding, estimating and simulating the factors that contribute to dynamic behaviour. It is clear that noticeable resonance will occur, no matter how conservative these factors are regarded to be. The contribution of this study in the development of the solar chimney project is that it proves that dynamic behaviour will certainly be a consideration factor in the geometric design and the reliability estimation of the chimney structure.

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## Sika Launches New Products

With **SikaQuick-2500** a quick fix is now a durable fix! This system is a single component cementitious patching material for concrete that sets very rapidly and attains high early strength. These features make it ideal for use on highway overlays, structural repairs to concrete roadways, parking structures, bridges, ramps and dams as well as for repairs to industrial floors where downtime is critical.

**Sika Seal Waterproofing Slurry** is a single component, ready to use waterproofing slurry. Specifically developed to prevent moisture ingress to foundations, underground or half-buried walls, this product can be applied to concrete, masonry blocks, retaining walls or breeze-blocks. **Sika Seal Waterproofing Slurry** contains fibres, which is why it is a single component product.

**AnchorFix** is a range of fast curing anchoring adhesives. While **AnchorFix-1** is for general anchoring, **AnchorFix-2** is geared towards the professional. Both are used to anchor all grades of rebars, threaded rods and bolts into concrete, natural stone, hollow or masonry working in conjunction with a plastic sleeve for all hollow block anchoring applications. **AnchorFix-3** is not moisture tolerant & can be used on damp concrete.



**Cape Town:** On 12 October 2006, Sika Western Cape held their product launch for the construction industry. Speaking at a windy Royal Cape Yacht Club, Kevin Kimbrey presented the products SikaQuick 2500, Anchorfix-1, -2, -3 and Sika Seal Waterproofing Slurry to the 150-strong group of contractors and engineering consultants.

**Johannesburg:** Sika Gauteng launched three products to the construction market on Thursday 23 November 2006 at the Johannesburg branch premises.

Shaun Saxby introduced Sika Seal Waterproofing Slurry, Sika Quick 2500 and Anchorfix-2 & -3 to the group and was followed by Carl Hoffend's Concrete Business Unit presentation.

The evening was attended by approximately 100 contractors and engineers who make up some of the most prominent players in South Africa's construction industry.

After the presentation, a lucky draw was held before everyone headed to the braai area for the more relaxed part of the evening.

Both successful evenings granted an opportunity for client / supplier relationships to be reinforced and as always, were thoroughly enjoyed by all present. Well done to Kevin, Shaun and their teams for putting together these functions which are sure to cement Sika in the minds of these decision-makers!

Admixtures

# Concrete Solutions

### SikaPaver®-AE1

Concrete Blocks:  
Anti-Efflorescence  
compaction and  
waterproofing aid

### Sika ViscoCrete®-25MP

Foundation/ Precast  
paving. Multi-purpose  
3rd generation  
superplasticiser

### SikaPaver®-HC1

High compaction aid for semi-dry concrete

### Sika ViscoCrete®-20HE

Concrete Columns:  
High early strength  
superplasticiser for  
pre-cast concrete

### Sikament® V100

Concrete Slab/Floor  
superplasticiser

### Sika ViscoCrete®-10

Cobblestones: 3rd  
generation superplasticiser  
with extended workability



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## Concrete Tips

## AGGREGATES FOR CONCRETE – PART 1

### Introduction and Grading Requirements

#### 1. Introduction

The standard specification for aggregates for concrete is currently SABS 1083: 1994. This standard replaced the previous edition (which also covered aggregates for road construction). The previous edition also contained appendices which contained commentary on the specified aggregate properties. These appendices were not included in the 1994 standard.

The Cement and Concrete Institute published a commentary on SABS 1083 in 1995 to redress this (*Commentary on SABS 1083:1984 - Aggregates from natural sources – aggregates for concrete*).

This Tip, and those to follow, discusses some of the more commonly measured aggregate properties specified in SABS 1083 and refers frequently to the C&CI Commentary.

#### 2. Grading of aggregates

The grading of an aggregate refers to the distribution of particle sizes in that aggregate. It is also called the particle size distribution. It is determined by passing a representative sample of the aggregate through a series of standard sieves. The method is described in SABS Method 829:1994, *Sieve analysis, fines content, and dust content of aggregates*.

Apart from the particle size distribution (continuous, gap-graded or single-sized), a grading analysis gives an indication of the fineness of the aggregate (Fineness Modulus), and the dust content (minus 75 micron fraction).

By definition aggregates larger than 4,75 mm in size are coarse aggregate (commonly called stone) and those smaller are called fine aggregate (sand). Almost all coarse aggregate used in South Africa is derived from crushed rock, whereas sand may be either crusher sand or naturally occurring sands from dunes, rivers or pits.

##### 2.1 Particle size distribution

Aggregates may be either continuously graded (all

particle sizes present), gap graded (one or more particle sizes missing), or single-sized (one size dominates).

##### Coarse aggregate:

As far as coarse aggregate is concerned, the vast majority sold for use in concrete is nominally single-sized, and most of that is 19-mm stone. The grading requirements of the standard are given below:

Stone size	37.5-mm	26.6-mm	19.0-mm	13.2-mm	9,5-mm	6,7-mm
Sieve size	Cumulative percentage passing					
53.0-mm	100					
37.5-mm	85-100	100				
26.5-mm	0-50	85-100	100			
19.0-mm	0-25	0-50	85-100	100		
13.2-mm	0-5	0-25	0-50	85-100	100	
9.5-mm		0-5	0-25	0-55	85-100	100
6.7-mm			0-5	0-25	0-55	85-100
4.75-mm				0-5	0-25	0-55
2,36-mm					0-5	0-25
1,18-mm						0-5

The advantages of single sized gradings are that the grading is easier to control, the aggregate does not segregate in stockpiles and the slump of concrete made with single-sized stone is more sensitive to water content. Concrete made with continuously graded coarse aggregate does however tend to produce more workable concrete if the aggregate particle shape is good; but if the particle shape is poor, particle interference can result in harsh mixes.

As can be seen from the table, a stone of any particular size may contain up to 50% (or 55%) by mass of the material retained on the sieve below, and up to 25% of the material retained two sieves below. It is unusual in practice for a stone to approach these upper limits unless a quarry has an excess of finer material that it wishes to dispose of.

## Concrete Tips (cont.) - Introduction and Grading Requirements

### Fine Aggregate

The grading envelope specified in SABS 1083:1994 for sand is so wide that it can hardly be called an envelope. The requirements are tabulated below, together with preferred limits for sand for use in pumped concrete, sliding formwork and concrete for high quality surface finishes:

Sieve size	Cumulative percentage passing	
	SABS 1083:1994	Preferred limits
4,75-mm	90 - 100	90 – 100
2,36-mm		75 – 100
1,18-mm		60 – 90
600 µm		40 – 60
300 µm		20 – 40
150 µm	5 - 25	10 – 20
75 µm	0-5 (10) <sup>*(1)</sup>	3 – 6 (6 – 15)*

\* Crusher sands

(1) these limits may be exceeded if the methylene blue absorption value is < 0,7 and the clay content is < 2,0%

While natural sands are rarely consistently well graded, it is often possible to produce well-graded sands by blending river or dune sands with crusher sands. Dune sands from a specific source are generally single-sized but fairly consistent in particle size. River sands tend to be less consistent, the particle sizes being dependent on the river conditions at the time of deposition.

*Note that grading is only one indicator of an aggregate's performance in concrete, and compliance with specification requirements is no guarantee of good performance in concrete. Other factors affecting performance are dust content, particle shape and particle surface texture.*

### 2.2 Fineness Modulus (FM)

The fineness modulus of an aggregate is an indicator of the average particle size of the aggregate. It is determined by adding the percentages retained on the standard sieves, down to the 150-micron sieve, and dividing the sum by 100. It is normally applied to sands, but can also be determined for stone and is

sometimes used in concrete masonry manufacture for blends of fine and coarse aggregate.

The fineness modulus does not describe the sand grading in any way. Single sized and well-graded sands can have the same FM. For example Cape Flats dune sands and Malmesbury pit sands have very similar FM's in the 1,8 to 2,2 range, but very different grading characteristics.

SABS 1083:1994 permits a range of FM for sand from 1,2 to 3,5. Sand with an FM of 1,2 is very fine while a value of 3,5 indicates a coarse sand. For high quality concrete the preferred range of FM for sand is 2,0 to 3,0.

### 2.3 Dust content

The dust content is the fraction of the sand finer than 75 microns. This fraction, together with the binders, effectively controls the cohesiveness of the fresh concrete and the bleeding characteristics of the concrete.

Upper limits are placed on the dust content to limit possible clay contamination, and this is why the limit for crusher sands is higher as they are less likely to contain clay.

Too much dust in the concrete will make the concrete sticky and difficult to compact and will also promote plastic shrinkage cracking.

On the other hand, too little dust will tend to promote segregation, settlement and bleeding.

## 3. Summary

In general it is possible to make good quality concrete from aggregates with a wide range of particle size distributions and dust contents. What is more important from a quality control point of view is that the aggregates used on a particular project must be as consistent as possible, even if their gradings do not comply with the requirements of SABS 1083:1994. The grading limits in the standard should be regarded as indicators of, but not reliable predictors of, satisfactory performance in concrete.

Part 2, page 22 will cover other relevant physical properties of aggregates and their effects on the water requirement of concrete and the effects of water requirement on concrete economy and performance.

### Acknowledgement

Compiled for ConQuest by: Steve Crosswell - PPC Cement





## Concrete Tips

### AGGREGATES FOR CONCRETE – PART 2

## The effects of aggregate particle size, shape, surface texture and absorption on the water requirement of concrete

### Introduction

The water requirement of a concrete mix is the amount of water required to produce one cubic metre of concrete of the required workability. The water requirement of a concrete mix is important as it has a direct effect on the economy of the mix (high water requirement = high binder content = high cost), and on the drying shrinkage of the concrete (high water content = high drying shrinkage).

The water requirement of any specific mix is primarily a function of the physical properties of the sand, and is modified to a lesser degree by coarse aggregate properties, binder properties and the use of admixtures.

This Tip discusses the effects of particle size, shape and surface texture on the workability and water requirement of concrete. Reference is made to SABS 1083:1994 and to the Cement & Concrete Institute's Commentary on that standard.

### 2. Fine aggregates

#### 2.1 Particle size, grading and dust content

As a general rule coarse sands have lower water requirements than fine sands, but this is not always true. Well-graded sands tend to have lower water requirements than single-sized sands and increasing dust contents tend to increase the water requirement of sands. There are exceptions, however. For example pit sands from the Klipheuwel, Malmesbury and Saldanha areas tend to be of average fineness modulus and contain excessive amounts of dust, but they have very low water requirements, among the lowest in the country. Many attempts have been made to try and correlate water requirement with particle size distribution and aggregate surface area (logic suggests that a sand with a low surface area would have a low water requirement as there would be less surface to wet), none being particularly successful. Some mix design methods use a modified aggregate surface area method to

determine a first estimate of the water requirement of the aggregate.

#### 2.2 Particle shape

Aggregate particle shape has a significant influence on the workability and water requirement of concrete. It is intuitive that sands with well-rounded particles will be less thirsty and make more workable concrete than sands with flaky, elongated particles. This is one reason (dust content and surface texture being the others) why crusher sands tend to have higher water requirements than natural sands.

#### 2.3 Particle surface texture

In general sands with a rough surface texture will have a higher water requirement than sands with smooth particle surfaces. Again this is intuitive. On the other hand sands with a slightly rough surface texture give slightly higher concrete strengths because of improved bond. In some cases (for example crushed dolerite from De Aar) there may be a significant strength increase.

#### 2.4 Water absorption

All aggregates absorb water to a greater or lesser degree. The higher the water absorption the higher the water requirement will be, but the water absorbed into the aggregate will not affect the effective water: binder ratio or the strength. It will however lead to rapid slump loss if absorption is excessive, say >1% by mass. In general it is preferable to avoid aggregates with water absorptions of more than 1 to 1,5% by mass.

### 3. Coarse aggregates

The same factors affect water requirement as is the case with sands, but the effect is smaller, more predictable and easier to quantify:





## Concrete Tips (cont.) - The effects of aggregate particle size, shape, surface texture and absorption on the water requirement of concrete

### 3.1 Grading

Concrete made with well-graded stone generally has a lower water requirement than that made with single-sized stone. Other factors being equal the difference is of the order of 10 to 15 litres per cubic metre.

The workability of concrete made with single-sized stone is, however, more sensitive to water content than the workability of concrete made with continuously graded stone.

### 3.2 Particle size

The larger the coarse aggregate, the less water is required. Using 19-mm stone as a reference, changing to 26,5-mm stone will require 5 litres less, and to 37,5-mm 15 litres less. Changing to 13,2-mm stone will require about 15 litres more water.

### 3.3 Particle shape and surface texture

The particle shape and surface texture of crushed coarse aggregate affects the water requirement in the same manner as sands, but to a lesser degree. Angular, smooth particles have lower water requirements, but produce concrete with slightly lower flexural strengths. A useful measure of particle shape is the voids content of the aggregate. This is calculated as follows:

Voids (%) =  $100 (1 - \text{Consolidated Bulk Density} / 1000 \times \text{Relative Density})$

The average voids content of South African sands is 35% with a range from 28 to 44%. For stone the respective figures are 46% average, ranging from 34 to 50%.

In general, aggregates with low void contents have low water requirements.

### 4. Example of the effect of water requirement on concrete materials costs

It is common practice when tendering for contracts to phone around for prices for sand and stone, and then to price the concrete accordingly, using the cheapest available sand and stone. Unfortunately the combination of the cheapest available materials does not necessarily produce the most cost-effective combination once the water requirements of the aggregates are taken into account.

Take a mix design for 25 MPa concrete where there is a choice of two sands, sand "A" at R50/m<sup>3</sup> and sand "B" at R75/m<sup>3</sup>. Their water requirements are 210 and 185 litres/m<sup>3</sup> respectively. Cement cost taken at R650/T, stone at R90/T.

The mixes and costs are tabulated below: (*mix proportions by mass are in kg based on dry aggregates. The sand volumes are bulked volumes assuming 25% bulking*).

Material	Sand "A"	Sand "B"	Cost mix "A"	Cost mix "B"
Water	210	185	-	-
Cement	315	280	204.75	182.00
Stone	1150	1150	103.50	103.50
Sand	725 (0,60m <sup>3</sup> )	785 (0,65m <sup>3</sup> )	30.00	48.75
Total			338.25	334.25

In this example, concrete made with the cheap sand actually costs R4 more per cubic metre. This is not always the case but it is essential that concrete mixes are costed on the basis of the total materials cost per cubic metre, not on the basis of the cheapest available materials.

#### Acknowledgement

Compiled for ConQuest by: **Steve Crosswell** - PPC Cement

Following a directive from the Concrete Society of Southern Africa's Executive Council, that the Society's publications should be enhanced to provide greater benefit and broader coverage for our members, readers will start noticing significant changes to the format and content of the publications and will include, but not be limited to the following:

- The combination of ConQuest into the Concrete Beton publications
- The inclusion of more technical papers in each volume of Concrete Beton
- Comprehensive and numerous articles regarding significant projects or pertinent new technologies
- A facility for companies to contribute technical advertorial articles, conditional on them being paid for
- A section dedicated to amendments of relevant SANS codes of practice
- A letters section
- Advertising space
- A "new products" section
- A "new publications" section

Suggestions from members regarding ways in which we can further enhance the publications and add value to our members would be greatly appreciated.

**Francois Bain**  
Chairman of the Editorial Board





## Concrete Tips

## Aggregate contaminants and their effects

## Introduction

From time to time cases arise where aggregate related contaminants cause serious serviceability problems, and these seem to have become more frequent in the past year in the Western and Eastern Cape Provinces. This is possibly due to the depletion of historically sound aggregate sources and the opening of new sand pits and quarries.

Broadly speaking contaminants can be classified as organic or inorganic in origin. Contamination may occur at the sand pit or quarry (i.e. intrinsic contaminants), during transportation, or on site.

## Organic materials

Organic materials, when present, are usually found in the sand or fine aggregate, but from time to time are also found in coarse aggregates. The contaminants can be solid in origin, for example seeds or roots or decomposed vegetable matter; or liquid in origin, for example fertilizer, tree resin, and urine. Examples of contamination by sugar and coal are also on record elsewhere in South Africa. Solid contaminants may be so small as to be almost un-noticeable to a casual visual check. They are also low density materials which tend to float to the surface of the concrete and this has caused serious problems with power floated concrete floors in particular.

Organic contaminants generally cause retardation of set, either generally or localised, as well as discolouration as tabulated below:

Contaminant	Retardation		Discolouration	Softness	Other/Remarks
	Local	General			
Seeds (esp. Port Jackson)	No	No	No	No	Surface popping, time of occurrence unpredictable and not possible to determine when the popping will stop.
Root particles	Yes	No	Local, straw to dark brown	Local	Aesthetics, stain tends to bleed through paint
Vegetable matter	Yes	No	Local, straw to dark brown	Local	Same as root particles
Tree resin	Yes	No	Straw to brown	Local with sticky resin	Aesthetics
Fertilizer	No	Yes	Sometimes	General	Retardation can last for days – in extreme cases concrete will not harden properly and will have to be demolished.
Sugar	No	Yes	Yes - dark grey	General	Same as fertilizer
Urine	No	Yes	Sometimes – dark grey	General	Same as fertilizer



Fig 1: Example of plaster made with contaminated sand – sand contaminated with loosely cemented decomposed vegetable matter

## Inorganic materials

Contamination by inorganic materials is rare and generally occurs on site or at the batch plant, although it is possible for contamination to occur while aggregates are being transported. These materials include pieces of steel or other metals, steel wire, and other aggregates. This type of contamination is almost always the result of poor housekeeping.

The effects of this type of contamination are normally aesthetic, for example rust stains from accidentally embedded steel. There have been cases where contamination by unsound “aggregate” particles has caused severe damage through expansion and resultant spalling of the cover concrete.

## Remedial measures

It is not possible to recommend general remedial measures; each case must be evaluated individually. In extreme cases of general retardation the concrete will have to be demolished and replaced. Local retardation is often repaired by drilling out the soft spot and patching the hole with a proprietary repair material, but the result is unsightly unless the concrete or plaster is then painted.

Prevention is definitely better than cure in these cases and aggregate deliveries and stockpiles should be checked regularly, particularly if changing aggregate source, supplier or transporter.

## Acknowledgement

Compiled for ConQuest by: Steve Crosswell - PPC Cement



## Branch Calendars for 2007

Date	Function	Venue/Co-ordinator
<b>Inland Branch</b>		
Inland Branch Chairman Contact Trevor Sawyer Cell: 082 851 1531		
01 Feb	Branch Committee meeting	C&CI, Waterfall Park, Midrand
12 Feb	Mini-seminar - Grouts and grouting	TBA
01 Mar	Branch Committee meeting	C&CI, Waterfall Park, Midrand
15 Mar	Branch AGM/Technical Meeting	TBA
05 Apr	Branch Committee meeting	C&CI, Waterfall Park, Midrand
03 May	Branch Committee meeting	C&CI, Waterfall Park, Midrand
10 May	Mini-seminar - Self compacting concrete	TBA
07 Jun	Branch Committee meeting	C&CI, Waterfall Park, Midrand
08-10 Jun	<b>Fulton Awards 2007 WEEKEND</b>	<b>Champagne Sports Resort, Drakensberg</b>
05 Jul	Branch Committee meeting	C&CI, Waterfall Park, Midrand
16 Jul	Mini-Seminar - Architectural Concrete	TBA
02 Aug	Branch Committee meeting	C&CI, Waterfall Park, Midrand
23 Aug	Concrete Cube Competition - Casting	Not applicable
30 Aug	Concrete Cube Competition - Crush-in	TBA
06 Sep	Branch Committee meeting	C&CI, Waterfall Park, Midrand
15 Sep	Annual Concrete Boat Race Day	Germiston Lake Club
04 Oct	Branch Committee meeting	C&CI, Waterfall Park, Midrand
15 Oct	Mini-seminar - Durability Index	TBA
01 Nov	Branch Committee meeting	C&CI, Waterfall Park, Midrand
09 Nov	Chairman's Luncheon	TBA
<b>KwaZulu-Natal</b>		
Kwa-Zulu Natal Chairman Contact Ken Brown Tel: 031 205 2707 or Cell 082 554 5460		
15 Feb	AGM & Concrete Achiever Award	Gart Gamble/Rolf Schutte
15 Mar	Site Visit to Steeldale ARC	Ken Brown
19 Apr	Pavement Concrete for Airport Runways & Aprons	Raj Naidoo
17 May	Detailing & Fixing of Reinforcing	Garth Gamble
08-10 Jun	<b>Fulton Awards 2007 WEEKEND</b>	<b>Champagne Sports Resort, Drakensberg</b>
12 Jun	<b>Fulton Awards 2007 Branch Review</b>	<b>TBA</b>
21 Jun	Admixtures - Including Practical Demonstrations	Wayne Smithers
19 Jul	Concrete Testing - The Full Spectrum	Raj Naidoo
27 Jul	Golf Day	TBA
16 Aug	Case Study - Durban Harbour Tunnel Project	TBA
21 Sep	Cements - Specifications and Selection	Rolf Schutte
18 Oct	Site Visit - 2010 Soccer Stadium	Garth Gamble
Oct	Egg Protection Device Competition	Lyn/Rolf
Oct	Strongest Cube Competition	Raj Naidoo
<b>Western Cape</b>		
Western Cape Branch Contact Philip Ronné Tel: 021 950 7500 or Cell 083 775 3677		
30 Jan	Branch Committee Meeting	3rd Floor, Ninham Shand Building
12-13 Feb	FIB course on precast concrete	University of Cape Town
14-16 Feb	International Concrete Conference	Cape Town International Convention Centre
14-15 Feb	Second African Concrete Code Symposium	University of Stellenbosch
15-Feb	Annual General Meeting	Cape Town International Convention Centre
27 Feb	Branch Committee Meeting	3rd Floor, Ninham Shand Building
15 Mar	Golf Day and Branch Dinner	Parow Golf Course
3 Apr	Branch Committee meeting	3rd Floor, Ninham Shand Building
19 Apr	Monthly Technical Meeting/Site visit	TBA
8 May	Branch Committee meeting	3rd Floor, Ninham Shand Building
17 May	Monthly Technical Meeting/Site visit	TBA
5 Jun	Branch Committee meeting	3rd Floor, Ninham Shand Building
08-10 Jun	<b>Fulton Awards 2007 WEEKEND</b>	<b>Champagne Sports Resort, Drakensberg</b>
14 Jun	<b>Fulton Awards 2007 Branch Review</b>	<b>TBA</b>
03 Jul	Branch Committee meeting	3rd Floor, Ninham Shand Building
19 Jul	Monthly Technical Meeting/Site visit	TBA
07 Aug	Branch Committee meeting	3rd Floor, Ninham Shand Building
16 Aug	Monthly Technical Meeting/Site visit	TBA
30 Aug	Concrete Cube Casting date	Not applicable
04 Sep	Branch Committee meeting	3rd Floor, Ninham Shand Building
20 Sep	Monthly Technical Meeting/Site visit	TBA
27 Sep	Concrete Cube Crush-in and Branch Social	TBA
02 Oct	Branch Committee meeting	3rd Floor, Ninham Shand Building
18 Oct	Monthly Technical Meeting/Site visit	TBA
06 Nov	Branch Committee meeting	3rd Floor, Ninham Shand Building
15 Nov	Annual Cocktail party	TBA
04 Dec	Branch Committee meeting	3rd Floor, Ninham Shand Building
<b>Eastern Cape</b>		
Eastern Cape Branch Contact Venance da Silva Tel: 041 505 8000 or Cell 082 777 0083		
Feb	Site Visit to Shukuma Flooring	TBA
Mar	AGM Coupled with Brian Perry Seminar	TBA
May	PPC Visit	TBA
08-10 Jun	<b>Fulton Awards 2007 WEEKEND</b>	<b>Champagne Sports Resort, Drakensberg</b>
13 Jun	<b>Fulton Awards 2007 Branch Review</b>	<b>TBA</b>
Jul	Concrete Admixtures Technical Talk Presented by Craig Handler - Sika	TBA
Aug	Rocla P.E. Site Visit (Precast Concrete Systems)	TBA
Sep	Bort Longyear Technical Talk	TBA
Sep	Golf Day	TBA
Nov	Year End Function	TBA





## Diary of Forthcoming Events

### DIARY 2007

Tbc	Kangwon, Korea	12th International Conference on Polymers in Concrete (ICPIC'07)
14-15 February	Cape Town	International Concrete Conference and Exhibition
14-16 February	Lisbon, Portugal	5th International Conference on Dam Engineering
24-25 May	Yantai, China	3rd International Conference on The Concrete Future
27-29 June	Venice, Italy	4th International Conference on The Conceptual Approach to Structural Design
2-4 July	Venice, Italy	5th International Conference on New Dimensions in Bridges, Flyovers, Overpasses & Elevated Structures
15-17 August	Sandton	The Water, Energy, Earth and Air Exhibition
27-29 August	Singapore	32nd Conference on our World in Concrete & Structures
3-5 September	Ghent, Belgium	5th International RILEM Symposium on Self Compacting Concrete
4-6 September	Dundee, Scotland	7th International Congress on Concrete: Construction's Sustainable Option
10-12 September	Cape Town	3rd International Conference on Structural Engineering, Mechanics and Computation
19-21 September	Maryland, USA	1st International Conference on Recent Advancement in Concrete
10-12 October	Yantai, China	9th International Conference on Steel, Space & Composite Structures
14-15 October	Beijing, China	9th International Conference on Steel, Space & Composite Structures
17-19 October	Beijing, China	7th International Conference on Shock & Impact Loads on Structures
18-20 October	Adelaide, Australia	Concrete 07, Design, Materials & Construction
28-30 November	Changsha, China	2nd International Conference on Geotechnical Engineering
2-5 December	Kingdom of Bahrain	4th Middle East Nondestructive Testing Conference & Exhibition 2007

### DIARY 2008

11-16 August	Washington DC, USA	6th International Conference on Case Histories in Geotechnical Engineering
August	Singapore	33rd Conference on Our World in Concrete & Structures



# Announcement

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

## Concrete/Beton



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

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

- Financial rewards from the Department of Education
- Prestige gained by peer review and industry dissemination
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