Institute’s technical activities expand
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Dalrymple Bay Coal Terminal expansion
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The Lorne Pier, at Lorne, about 65km southwest of Geelong, Victoria, was first constructed in 1878 as a safe place for ships to dock. A couple of years ago McConnell Dowell was selected to construct a new 196m concrete and timber pier to replace the existing 1960s concrete structure and appointed Hollow Core Concrete to prepare shop drawings and produce the precast concrete components. Once construction of the new pier was complete the team demolished the old concrete structure. The new pier was opened in March 2007.

Consultants to the project were ADAW Australia, Maunsell Australia and The Department of Sustainability and Environment. The project was a winning entry in the Engineering Projects category of the 2005-2007 Excellence in Concrete Awards.
A solid start to a new year

2008 is already shaping up to be a bumper year for Concrete Institute of Australia activity. By now, each Branch has conducted the first of their technical events for the year and a series of joint seminars with other specialist technical organisations is already underway. The Concrete Masonry Association of Australia, National Precast Concrete Association Australia, Australian Corrosion Association, Concrete Pipe Association of Australasia and Post-Tensioning Institute of Australia are all working closely with the Institute to offer members and the wider industry a solid bank of seminars, workshops and higher level educational opportunities.

With the appointment of the Institute’s own in-house technical staff towards the end of last year, we are now well placed to continue the development of our technical education program. Ben Cosson is working with a number of the Institute’s members to develop full day workshops which focus on providing much needed information on specialist technical areas.

Here in Western Australia the industry continues to experience record levels of activity and just about everyone is at the limits of their capacity dealing with new projects, satisfying demand and dealing with staff shortages. Other states are experiencing similar levels of activity. While we are all so busy, it is important that we remember the networking opportunities which the Institute provides through its regular meetings. The opportunities to meet with our colleagues, peers and industry contacts at Institute events are essential. While other organisations may be reducing their face-to-face contact, the Institute continues to expand this important membership benefit.

During 2008 the Institute will be announcing several major initiatives which are all designed to increase membership benefits. A number have been in the planning stage for some time and our increased staff resources are enabling the organisation to start delivering on these important developments.

If you have suggestions on how the Institute can better meet the needs of its members please contact me direct at the email address below. The Institute’s success reflects the input from our members and suggestions are always welcome.

Tony Kinlay
President, Concrete Institute of Australia
president@concreteinstitute.com.au
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Is the standards development model broken?

The Concrete Institute of Australia has a number of representatives on significant standards development committees. These committees, through a process under the management of Standards Australia, are responsible for the development of Australian Standards.

Recent activities across a range of committees have demonstrated that the model used to develop standards is not perfect.

In one instance, it has been reported to the Institute that the relationship between a number of committee members is such that there is little or no hope of outstanding issues being resolved while the protagonists are part of the committee.

In another case, a major standard development process was shelved after more than seven years because the committee members could not agree on part of the standard. Together with other associations in the industry, the Institute made representations to Standards Australia which have resulted in at least the agreed material being issued as part 1 of the standard, avoiding the wasting of seven years of work.

From time to time the Institute has been criticised for a perceived lack of consultation with the broader membership when developing responses to standards development issues. While there may be some validity in these criticisms, members need to be aware that the standards development process is dynamic in nature and as such presents challenges which the Institute and its nominated representatives are often forced to face without the opportunity for wider consultation. In addition, Standards Australia has a policy of “committee – in confidence” which, when taken at face value, is extremely limiting in what nominated representatives can and cannot openly discuss.

In response to the need to better respond to members in this important area, the Institute’s Council has adopted a policy which, when implemented, will see the Institute’s nominated representatives to various standards committees supported by reference groups comprised of interested members who are qualified and prepared to contribute to the standards development process. This policy is being implemented to ensure the Institute’s position on any standard is based on the general views of members.

We hope you are able to consider the contribution you are able to make so that the Institute’s position on any standards development issue is appropriate, representative and valid.

Ian Booth
Chief Executive Officer
Concrete Institute of Australia
admin@concreteinstitute.com.au
Practice note on non-destructive testing

The Concrete Institute is in the final stages of preparations for publishing a Current Practice Note on Non Destructive Testing of Concrete. This publication is the result of a review and update of the Concrete Institute’s Current Practice Note 22 – 1987, Insitu Testing of Concrete – a review by Samia Guirguis.

Stephen Evans from Hanson Construction Materials and Rueben Barnes from Papworths have compiled the details for the revision.

Much of the work and text presented by Dr Guirguis in the previous publication CPN22 –1987 has been adopted in the revision as most of the test methods and principles of the tests remain the same. In several cases, testing equipment has been developed and improved in some manner and the text and images have been updated accordingly.

Several new tests have been included (on ground penetrating radar) as have several other tests that are now commonly used to provide concrete durability performance information in Australia today (namely sorptivity and chloride penetrability).

It is not the intention of this publication to provide full details and interpretation instructions for all available non-destructive concrete test methods, but rather to present the tests that are commonly used within the Australian construction industry that have been found to be relatively easy to perform, and provide quick, meaningful and accurate information.

This publication generally provides: the scope of the test, a brief description of the methods and procedures used, and the major advantages, disadvantages, difficulties, reliability, variability and precision.

Copies of the review document are available by contacting the Institute’s national office on (02) 9736 2955 or by email to technical@concreteinstitute.com.au.

New Zealand conference – call for papers

The New Zealand Concrete Industry Conference 2008 will be held in Rotorua from 2-4 October 2008.

A call for papers is being made for the conference, jointly organised by the Cement & Concrete Association of NZ, NZ Concrete Masonry Association, NZ Concrete Society, NZ Ready Mixed Concrete Association and Precast New Zealand Inc.

The call for papers is open until 4 April 2008. Authors are asked to submit the following to the Conference Secretary:

• A 300 word synopsis of their proposed paper.
• A short career history and a written commitment to personally attend and present the paper at the conference, if the paper is accepted.

A six to ten page paper is required from authors of accepted papers. Papers will be published in the conference proceedings.

The deadlines are:

• Receipt of synopsis 4 April 2008
• Preliminary acceptance of papers 15 April 2008
• Receipt and final acceptance of papers 7 July 2008

All aspects of the concrete construction and associated technologies will be covered. Papers are being sought on research, design trends, marketing opportunities, recent developments, construction, materials, methodologies and new issues for cement and concrete.

All papers accepted for the 2008 Concrete Industry Conference will be eligible for the Sandy Cormack Award. The author judged to have presented the best paper at the Conference will receive a certificate and a cheque for NZ$1000.

Please address all enquiries to:
The NZ Concrete Industry Conference
PO Box 12, Beachlands,
Auckland, New Zealand
Phone: (09) 536 5410
Fax: (09) 536 5442

Green concrete sculpture

Alan Clark is an artist and landscaper from WA and has recently completed this gecko sculpture with a TecEco Tec-Cement formulation. Clark used a Tec cement mix of 3:1 sand and Portland cement, with 15% magnesia, 10% Boral fly ash and 5% clinoptilolite, a natural zeolite. Chopped glass and steel fibre were also added to the wet mix. The gecko weighs about 700kg. It is acid stained and coated with an anti-graffiti coating.
NEWS

Briefing notes for decorative floors and paths

A range of techniques for creating unique decorative finishes on concrete floors and paths is covered in two new briefing notes from Cement Concrete & Aggregates Australia (CCAA).

Colouring, stencilling and stamping concrete flatwork and Exposed aggregate finishes for flatwork each provide an excellent overview of the technical and construction considerations involved in achieving beautiful finishes.

Both briefing notes can be downloaded for free at www.concrete.net.au.

Colouring, stencilling and stamping concrete flatwork looks at the various ways colour can be introduced into concrete flatwork finishes, including the use of integrated colour mixes and

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more efficient delivery

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dryshake toppings, chemical stains, dyes and tints and applied coatings. The briefing note covers technical and construction considerations, including some advice on what to do or not do.

The procedures involved in stencilling and stamping concrete flatwork, as well as applying spray-on toppings, is also explained in some detail.

Exposed aggregate finishes for flatwork discusses the various techniques for exposing aggregate in floors and pavements. It looks at various factors that can influence the finish of these applications, such as aggregate colour, size and grading, the use of special aggregates such as glass, marble and granite. It also discusses durability issues.

The briefing note provides a thorough explanation of the construction issues involved in achieving exposed aggregate finishes, as well as finishing techniques such as abrasive blasting, honing and polishing, and acid etching.

A first for strand supplier

OneSteel is the first Australian strand supplier to be compliant to the newly published standard for AS/NZS4672 and become certified by the Australian Certification Authority for Reinforcing Steel (ACRS.)

The accreditation was reached after an audit of the OneSteel quality management system, wiredrawing, stranding and mechanical testing processes.

“We have successfully supplied the precast and post-tensioning market with strand for most of Australia’s major road infrastructure projects for the past 40 years,” said OneSteel sales manager for strand and LR wire, Andrew Milliss.

“OneSteel has been the leader in the Australian strand industry, with the highest technical input and consistent quality. “We see this accreditation as a reflection of our commitment to our product,” he said.

“OneSteel Wire’s rigorous testing includes compliance testing of every unit of manufacture, 1000 hour relaxation tests and statistical assessment of long-term quality parameters as specified in AS/NZS 4672,” said OneSteel quality assurance and testing manager, Chris Wlodarczyk.

“We see this accreditation as confirmation that OneSteel has a demonstrated a consistent quality product to supply the market, and, therefore our customers can be confident they will receive superior strand,” he said.

adding value in changing climates

Key Dates

March 2008 Release of sponsorship and exhibition prospectus
July 2008 Awards entries open
September 2008 Call for abstracts
December 2008 Acceptance of abstracts
March 2009 Papers due
May 2009 Papers accepted
September 2009 Concrete 09
ASEC 2008 Australasian Structural Engineering conference

by Greg Schofield

ASEC 2008 – Engaging with structural engineering, will be held at The Sebel Albert Park on Queens Road Melbourne on Thursday 26 and Friday 27 June.

This conference will provide the opportunity for structural engineers to:
- examine how theory is put into practice
- discuss the practice of structural engineering
- hear about innovations in structural engineering
- find out about lessons from structural failures
- evaluate new concepts in sustainable structural engineering.

ASEC 2008 is a biennial conference specifically directed at practicing structural engineers. ASEC 2008 will provide a time out for structural engineers to meet, share ideas, learn about new technologies and broaden their technical skills.

IStructE, IABSE, Australian Steel Institute, Concrete Institute of Australia and the Galvanizer’s Association of Australia are supporting the conference. IStructE members from Hong Kong and SESOC members from New Zealand are also expected to attend.

A summary of the submitted abstracts can be found at www.asec2008.com.

The Thursday morning keynote address, sponsored by the Institution of Structural Engineers (the IStructE is celebrating its centenary year), will be presented by Professor Werner Sobek from Stuttgart, Germany. Sobek is renowned for his work on lightweight structures. Sobek’s recent Kenneth Kemp lecture in London, was described as “absolutely brilliant”.

The conference dinner on Thursday evening will be held at the Melbourne Aquarium. The conference organisers are delighted that Emeritus Professor Peter Darvall, a structural engineer and past Vice Chancellor of Monash University, has agreed to speak at the function.

The Friday keynote address is sponsored by IABSE (International Association of Bridge and Structural Engineering). Dr Donald Charrett, a past director at Hardcastle & Richards and now a barrister, will deliver what promises to be a most interesting presentation on structural disputes.

ASEC 2008 is an opportunity for engineering service providers and allied structural engineering companies to present their goods to a receptive audience (refer conference web site).


Greg Schofield is Chairman of the ASEC 2008 organising committee.
Sulfate-resisting concrete guide

Cement Concrete & Aggregates Australia (CCAA) has recently released Technical Note 68 which reports on Sulfate-resisting Concrete.

The technical note discusses the mechanisms of external sulfate attack and the physio-chemical effects on concrete. It reports the outcome of a research project conducted by CCAA in which the performance of 10 Australian concrete mixes, proportioned using five sulfate-resisting cements (Type SR) complying with AS3972 Portland and blended cements were evaluated in both neutral and acidic sulfate conditions.

The results were examined in relation to the long-term concrete exposure data from the US Portland Cement Association and the 40-year non-accelerated exposure program at the US Bureau of Reclamation.

Current specifications for sulfate-resisting concrete in relevant Australian Standards and some road authorities’ specifications are reviewed in the context of CCAA research findings which are applicable to concrete structures in sulfate or acid sulfate soil conditions.

The technical note may be downloaded from the CCAA website at www.concrete.net.au.

NPCAA relocates to Adelaide

The National Precast Concrete Association Australia has relocated its office to Adelaide, South Australia.

The contact details for the new location and executive officer Sarah Moore are:

- Post: 6/186 Main Road, Blackwood SA 5051
- Phone: (08) 8178-0155
- Fax: (08) 8178-0355
- Email: s.moore@npcaa.com.au

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Locating post-tensioning down the track

I refer to the article on post-tensioned slabs in the December edition of Concrete in Australia, in particular to the section referring to locating post-tensioning conduits (PTCs) in existing slabs. I was amazed to find that many in the industry still promote antiquated methods when searching for PTCs.

The methods described in the article are only of use when diligence has been observed by the contractors and the PTC locations marked promptly after stripping. The practice of following the staples on the underside of the slab is certainly one way of finding PTCs. However, many slabs with exposed undersides are often “dressed” for visual improvement. This removes any trace of the staples.

In commercial buildings it can often be difficult to find the staples due to the presence of ceilings and more often than not, the amount of clutter from services located inside the ceiling cavity, makes it impossible to accurately trace the line of the PTC. Even when the PTCs can be identified from underneath, there still remains the task of transferring these locations accurately to the top of the slab as, in most instances, penetrating the slab is done from the top down. This therefore means that there must be an existing penetration or service or some form of reference point available above and below the slab in order to accurately transfer the PTC positions to the top of the slab.

In turn, this would mean that any services that are offset in the slab or columns and walls that are not cast accurately over the ones on the floor below would be cause for incorrect repositioning of these marks on top of the floor. Another method commonly used in the past to locate PTCs, would be to drill 3-4 small holes around the perimeter of the proposed core hole with a percussion/hammer drill. Not only is this a tedious and a time consuming method but has consistently proven to be a confusing and unreliable practice. Firstly, it is difficult to determine the difference between PTCs or conventional reinforcing. Secondly, determining the extremities of the PT duct can only be done by drilling a series of holes. Finally, personal experience has shown that gaps can exist between individual cables in a duct. If the percussion drill bit has a diameter smaller that that of the gap between the cables, there is an opportunity for the drill to pass between the cables allowing the PTCs to go undetected. Some would suggest that the duct itself would have provided some resistance to the drill, however it can be argued that the ducts themselves are of very thin construction and the difference in drilling between the metal duct and high MPa concrete is minimal. PT ducts are rarely laid in a completely straight line or are completely true to grid and as mentioned in the article, the height of the PTC can vary dramatically according to the design of the slab. This means that PTCs can be under threat of damage even from minor holes drilled for fixing formwork or services.

A solution is now at hand that allows for accurate location of, not only PTCs but almost all services, regardless of their material composition.

Ground Penetrating Radar or GPR as it is more commonly known is a fast, effective and accurate way of locating reinforcing and services encased in concrete. It works by transmitting radar waves into the concrete and recording the resultant reflections. Unlike magnetic impulse machines such as cover meters that require a ferrous material in which to generate a magnetic field, GPR works by detecting the changes in the dielectric resistivity or the way in which a radar wave reacts to differing materials. This gives the system the ability to detect non-ferrous and non-metallic targets, including water and air filled voids.

The size and complexity of surveys have a direct influence on the availability and speed of results. Depending on the client’s requirements, simple searches for PTCs can in most cases deliver almost instantaneous on-site results allowing contractors to complete their work with minimal disruption.

The portability and self contained construction of GPR systems allow for surveys to be conducted in most areas.

GPR has on occasions been confused with X-Ray, possibly because the images are somewhat similar. However the difference is like chalk and cheese. Whereas an X-Ray emits harmful radiation and requires a substantial clear area around and underneath the machine, GPR emits radio waves at outputs lower than that of most mobile phones, allowing work to continue with minimal disruption.

Although GPR has had it place in geology and mining for the past 40-50 years, the transition into the construction industry has only been in the past 10 years. Possibly one of the most documented surveys in Australia and one that provided the proving ground for the application of GPR in construction was the Cattle Creek project in Northern Queensland. This project was undertaken by Georadar Research in an attempt to identify defective precast bridge beams. The foam void formers had floated during the pouring of concrete allowing pockets of air to become entrapped under the foam. Surveying the beams using GPR allowed not only the identification of defective beams but also allowed for the most appropriate method of remedial action to be undertaken on particular beams. At the completion of the project it was deemed that GPR had saved considerable time and resources for the precast contractor. Had it not been for GPR, the contractor would have been responsible for removal, disposal and replacement of all the beams.

With the ever increasing use of PTCs in construction, it is important that reliable methods are used to locate the tendons at a later stage, particularly during tenancy fitouts. Many PTCs have been severed during fitouts either because of lack of information or inadequate location techniques. Most of these will have gone undocumented. As slabs become thinner, distances between columns longer and reliance on PTCs greater, the greater the structural impact and cost of repair if damaged. There is no longer any reason for accidental damage to occur.

Harald Hauschild
SoftScan
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OneSteel is proudly the first Australian Strand supplier to be compliant with the new standard for AS/NZS 4672 and become certified by the Australian Certification Authority for Reinforcing Steel (ACRS).

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Part of Australia’s largest container and general cargo port facility, Swanson Dock in the Port of Melbourne is currently undergoing a major upgrade and redevelopment.

The multi-million dollar program of works, which forms part of the Port of Melbourne Corporation’s 30-year strategic vision for the port, incorporates major refurbishments to all berths and supporting structures throughout both Swanson Dock East and West, including structural repairs, removal and replacement/repair of deteriorated concrete components, and the installation of a cathodic protection system.

The Swanson Dock refurbishment offers a number of other significant challenges, including minimising disruption across the port.

Contractors working on the Swanson Dock refurbishment have specified a number of specialist repair mortars and grouts from BASF Construction Chemicals, including Shotpatch 22S spray-applied repair mortar, Masterflow 880 ultra-high-strength precision grout, Barra Mortar HL lightweight polymer modified repair mortar and Emaco CP 15 specialist cathodic protection mortar.

Stage One of the redevelopment, which was carried out about 18 months ago, incorporated repairs to Berth 1 on Swanson Dock East and Swanson Dock West, which after years of exposure to the harsh marine environment were both showing significant signs of deterioration along the supporting structure, beams and crossheads. On these berths, the works involved cleaning and removal of the deteriorated areas and installing a cathodic protection (CP) system, prior to repprofiling with Shotpatch 22S, a cementitious, spray-applied shrinkage compensated repair mortar which has been specifically formulated for use in CP overlay applications.

Stage Two of the Swanson Dock redevelopment, incorporates repair and protection works to Berths 2-5 along both Swanson Dock East and Swanson Dock West, together with upgrade works to the docks’ crane rail system. As with the Stage One works, the Stage Two repair and protection works involve the removal of damaged and degraded concrete along the support structures, followed by the installation of a CP system to minimise future damage.

The Swanson Dock East works incorporate the installation of anodes along the underside of the beams, which are subsequently covered with Emaco CP 15, a specialist grout for CP anode installations from BASF Construction Chemicals. The CP system along the Swanson Dock West wharves incorporates specially designed ribbon anodes which are covered using BASF’s Barra Mortar HL.

The rails for the new deck crane system are being supported on Masterflow 880 cementitious, ultra high-strength grout, also from BASF Construction Chemicals.

This article was contributed by BASF Construction Chemicals.
The fascinating evolution of bridge design

by Rob Wheen

The design of concrete bridges and their continuing evolution since my youth has always held a great fascination for me. I decided on Civil Engineering as a result of an early discovery of bridges at school and my delight with them has persisted.

My first contact with a real bridge was during the construction of the Mann River bridge at Jackadgery in northern NSW in 1958. I was a student and it was the first time I ever saw prestressing. I was hooked.

It was not the first prestressed concrete bridge in Australia, but it was certainly an early one. I also had the good fortune to live, as a student, near the Gladesville Bridge during its construction and haunted the site at weekends watching progress.

One of the highlights of my student days was to be present on the first rib of the arch as it was jacked clear of the falsework. It was only with the perspective of time that I truly realised what had been undertaken “under my very eyes”. A world record 1000 foot (305m) concrete arch span and a highly innovative method of construction all made possible with the use of flatjacks.

The then NSW Department of Main Roads’ other achievements were also impressive. I think of Albert Fried’s unique Rip Bridge, a cantilever truss bridge of 183m main span at the entrance to Brisbane Water near Gosford. It was assembled from precast concrete elements and stitched together with BBR prestressing tendons to leap across the tiderace known as The Rip.

The balanced cantilever bridges at Pheasant’s Nest and Moonee Moonee creek and the mighty Gateway Bridge in Brisbane are all outstanding examples of a construction method which would have been inconceivable without prestressing.

I recall with pleasure hearing the visiting German Professor Fritz Leonhardt speak at the DMR about the development of his incrementally launched prestressed concrete bridges. He spoke of the idea as having been in his mind for some years but not achieved until 1958. The sentence I took from his lectures was his assertion that he read in the Reader’s Digest about this new material Teflon with its 1% to 2% friction coefficient and knew immediately that he could successfully launch bridges. There have been some notable examples, though not a large number, of incrementally launched bridges in locations around the country.

Leonhardt also spoke about cable stayed concrete bridges, and the past 20 years have seen some remarkable structures. Sydney’s 345m span Anzac Bridge is a fine example and one that RTA and Baulderstone Hornibrook can be justifiably proud of. Some years ago I had the good fortune to visit and admire Virlogeux’s 856m span Normandie Bridge across the Seine in France, but one has to concede that he did use steel for the central 624m of the main span.

One form of prestressed concrete construction that appealed to me when I discovered it in 1965 was Finsterwalder’s concrete stress-ribbon structure. Modest spans have been built around the world but so far as I’m aware none has been built in Australia. Perhaps we will see one here some day.

I see an interesting future in the now mature prestressing field as a result of the development of high-strength and high-modulus synthetic materials. Aramid fibres (eg Kevlar) and carbon fibres have strengths perhaps 50% greater than high tensile steel and have elastic moduli as high as 50% of that of high tensile steel. Their properties are ideal for prestressing and they don’t corrode. The challenge is to find simple practical ways of anchoring tendons made from these materials.

Now that we have moved to 500MPa steels, we could be moving to an era where flexural cracking under service loads, hitherto relatively unimportant, may start to cause problems if not carefully considered. I worry too, that we have yet to see some of the consequences of the reduced ductility that we seem so willing to accept. I well recall the durability problems that we created with our move from prescriptive mixes to purely strength specifications for concrete. In some case these have taken decades to manifest themselves.

It may not seem too significant but I believe that the development of concrete pumping technology, along with the advent of superplasticisers, has revolutionised the field of concrete construction. We can now produce high performance concretes, and strengths readily achieved have at least doubled in the past 15 years (yet we still remain vulnerable to “the bloke who places the grey stuff”).

Just when we think that we have the whole game under control new possibilities open up. I have no doubt that the years to come will see developments at present only glimpsed and some not yet imagined.

Rob Wheen is an honorary associate professor and former head of the School of Civil Engineering at the University of Sydney.
The importance of conferences

by Malcolm Boyd

It was an honour to be asked to chair the organising committee for the biennial national concrete conference in 2009 (Concrete 09). For me it is an exciting challenge to work with a team of committed “concrete people” to deliver a successful conference – technically, commercially, socially and financially. But what makes a successful conference and, more particularly, why do we have conferences?

The primary reason for having the biennial concrete conference is to assist the Concrete Institute in achieving its mission to promote and develop excellence in concrete technology, application, design and construction throughout Australia. But, do we still need to have conferences to achieve this? Are such conferences the best use of resources in this electronic age?

There is no doubt that the internet has revolutionised the sharing of information. Up-to-date technical information, case studies and research can be placed on the web almost immediately and on-line discussion can open up wide discourse. Technical conferences on the other hand have traditionally had long lead-times and the presentation and discussion of the papers often has been given limited exposure and time.

It seems that I am presenting conferences as dinosaurs – likely for extinction!

That is not necessarily the case. I believe that conferences can be more important than ever – provided that they embrace the new technologies and become more responsive to the needs of a changing world.

The key benefit of conferences over journal publications is interaction – at a social, commercial and professional level. The establishment of personal contact is as important now as it was in the days of post and telephone communications, despite the power of the internet and the ability to see and speak with people all over the world in real time. It will be the personalisation of connections with colleagues that will be increasingly valued to reinforce the electronic connections, which more and more tie people to their computers with the attraction of ever increasing output and “productivity”.

Another key benefit of conferences is that people have the opportunity to see a presentation and join in the discussion. If properly facilitated, such discussions can be incredibly valuable in attracting alternative or complementary views, which can open up new directions. How can this be better achieved?

Perhaps one way is to actually shorten presentation time in order to focus on the scope of work presented and its key elements and outcomes with the objective of making the audience want to seek out the detail in the paper rather than be fully educated on the spot. Too many presenters waste the valuable time they have with unnecessary background or detail. Providing a short time for presentation (maximum 10 minutes, say) and increasing the discussion period might seem to be more valuable, particularly if each session chair was required to review each paper in their session beforehand and then stimulate and facilitate the discussion. Food for thought!

Already we have seen the power of the Internet in managing the selection, reviewing and publication of papers. This is allowing us to shorten lead times and make the paper content even more timely when it is delivered. However, this should not compromise quality by limiting effective peer review.

Of course, conferences could adopt a “Wikipedia” approach to paper submission and then use the conference forum itself as the means of peer review. That would allow the latest information to be presented but would impose a totally different approach to management of the conference and its outputs. In some ways this is already occurring as presenters and interlocutors alike use the conference itself to present updated or sometimes-different information to that which has been reviewed and accepted. Is this fair, or is it simply a response to a need?

In looking at Concrete 09, the organising committee will build on the experiences of past conferences. We will need to recognise the solid basis and hard work, which has made past conferences successful while seeking to respond to new challenges. Our approach will be evolutionary, rather than revolutionary.

Our challenge is to better attract people to the Sydney conference and to get them to participate fully in its activities. We need to have a full mix of people from the academic community as well as the practising community.

Malcolm Boyd is a former managing director of Reinforced Earth, a long standing member of the Concrete Institute of Australia, and has been appointed as Chairman of the Organising Committee for the Institute’s biennial conference to be conducted in Sydney in September 2009.
Focus on education, publications, technical and standards activities

by Ben Cosson

Education

The educational activities of the Institute aim to satisfy one of the Institute’s key goals, to work to a framework that maximises benefits to its members. As well as disseminating the most relevant industry technical material, it is just as important to encourage members to identify and develop this material.

For the maximum member input to occur it is imperative for the Education Committee to have direct links with other Institute initiatives. Such initiatives currently underway and with increased member participation will be further developed.

Consultation processes currently underway include:
• the National Technical Survey that was recently distributed to members. Among other subjects the survey seeks to identify members’ wishes for technical education programs
• the Research Forum, whereby invited members will be able to identify research projects with high importance and high impact to the industry.

Another key source for identifying topics of interest to the concrete and construction industry is through building upon current strong ties with allied groups of concrete-related organisations. Through mutual objectives and common member interests, working closely with associated organisations on seminars allows for better use of available technical resources. This also makes way for greater sharing of technical information among all those involved within the concrete industry; limiting overlap from occurring, while still maintaining autonomy.

Establishing such initiatives, whereby member input from the industry as a whole is taken into account, can help deliver more extensive educational programs. The initial programs for dissemination of information will take the form of one and two day educational products that can be delivered across the nation. National workshop programs have been established and implemented and further work is underway on others that will travel to the various states throughout the year. Below is a brief summary of the programs that are currently underway.

The programs include:
• Precast concrete in buildings for structural engineers (held in conjunction with NPCAA). The workshop has already been held in Sydney, with positive feedback forthcoming. This one-day seminar, focusing on the use of precast in buildings, covers topics such as: materials and tolerances; precast building design; manufacture, transport and erection; design of elements; contractual issues; connections, fixings and joints.
• National water sensitive urban design (held in conjunction with CMAA). This is a one-day seminar featuring an overview of options for water sensitive urban pavement design and an in depth tutorial of the design software CMAA has been developed called PermPave and Lockpave.
• Concrete Pipe Association of Australasia half day workshop, focusing on four key areas of manufacture, design, installation and asset management.
• Prestressed Concrete Refresher Program in conjunction with Dr Peter Dux.
• Australian Corrosion Association and Australian Concrete Repair Association focusing on the Corrosion and Protection of Reinforced Concrete Certificate Program.

With the successful implementation of national workshop products, the Institute can then build upon the educational framework and develop even broader programs. National workshop products developed will serve as a means of supplementing the existing Branch level technical programs with the Branch Committee structure continuing to be the direct communication method among members.

In addition to supplementing the state-based programs with national workshops, it is important to explore the wider resources that may be available in developing and presenting Branch level seminars. These resources can come from considering the Institute’s membership base and seeking input from members who have the time, expertise and experience on different topics. Such willingness from those members would provide a beneficial service to the Institute by attracting potential younger members to the organisation.

Publications

The Institute’s publications serve as beneficial
Continued support from members and the application of their high level of expertise has enabled the regular review of existing Institute publications with the most up-to-date and relevant information.

A journal format. This will provide members with current research findings and hopefully, along with other Institute initiatives, encourage Australian research within the concrete industry. The first edition of Concrete forum has just been published.

- Web-based technical notes which will serve members with straightforward practical information on common issues surrounding concrete practice.
- Concrete in sustainable development – is a short commentary guide with Australian case studies, featuring concrete in sustainable development with the three focal areas of economic, social and environmental factors taken into account.

Such initiatives demonstrate how broader member consultation and feedback will necessitate creating other sub-committees and working groups to bring the full array of publications to fruition.

Review teams established nationally and within Branches assist with the promptness of delivery of these reviewed publications.

The current status of reviewed and recently printed publications is:

- CPN17 The Use of Galvanised Reinforcement in Concrete: Currently under review with an anticipated publishing date in August 2008.
- CPN29 Prestressed Concrete Anchorage Zones: Queensland Branch currently undertaking review.
- CPN22 In situ Testing of Concrete: Review completed by Queensland Branch and peer review underway.
- Z48 Precast Concrete Handbook: Review underway and anticipated publishing date in the second half of the year.
- Z15 Cracking in Concrete Structures: Queensland Branch currently undertaking review.
- Z05 Shotcrete Guide: Review complete and in the final steps of preparation for publishing by April 2008.
- Z39 Render: Review complete and to be published in March 2008.

The review process for existing publications will continue throughout 2008 and beyond.

Technical

The flow of technical information to members is at the core of the Institute’s mission. The information attainable through the various technical seminars and workshops, publications and conferences needs to be supported by a well resourced Technical Committee. The Technical Committee keeps abreast of the latest technical material within academia and industry and endeavours to channel this information to members via the most appropriate means within the scope of the Institute’s portfolios.

The Institute is unique among similar organisations due to the diversity of its membership base. Members cover the wide array of individuals involved within the concrete industry from students and academics to all those within the various industry sectors – from materials, designers or those from within the construction sector. With each member comes a specific interest in the technical information that may be appropriate, sought after, and relevant to their roles within the industry. With the full breadth of technical information taken into consideration, the establishment of sub-committees will maximise the benefits to all member groups.

While there are explicit technical preferences and requirements of members, there are also many technical topics that are of common interest to the entire industry and researchers alike. These topics often present issues that are likely to have an overall effect on the concrete industry and pose questions that from a collaborative framework can be addressed by the Institute. Institute activities, such as the programmed Research Forum, along with the facilitation of meetings with allied partners to share identified common technical matters, are the first steps to developing outcomes that will be of benefit to the entire industry.

A goal of the Technical Committee is to ensure the Institute is on the front foot when it comes to common industry issues. Sustainability is one issue that will increase in significance to the industry in coming years. For this reason
it is important for the Institute to seek consultation from its membership base to initially provide commentary as to the role concrete can play within sustainable development and the opportunities that may exist. As time progresses and more detail becomes available as to the regulatory requirements that will be in place within Australia, it is intended the Institute will have at hand readily dispensable information that can be of assistance to its members.

Standards

Standards within the industry aid in providing benefits to the public in regards to safety, while ensuring that the materials and methods used meet minimum quality and reliability criteria. The Institute enjoys representation rights on many of the Australian Standard committees involved within the industry. The Institute’s consultation process in support of Standards activities aims to provide for the widest degree of member awareness.

Members are made aware of the opportunity to express an interest in becoming an Institute representative on a standard committee via electronic newsletter whenever an opening arises. This allows for the maximum numbers of members to be informed in the most timely manner. Through the responses attained, a representative, who possesses the required knowledge, understanding and expertise, is nominated by Council. Once selected, it is important that the Institute’s representative is supported by a wider reference group with the acumen required to provide appropriate comment. For the most judicious delivery of Institute views on Standards committees work, effective communication between the reference group and Standard’s representative is important.

The activities of Standards Australia committee work will continue to be broadcast to the wider membership via electronic newsletter. Each member of the Institute will have the opportunity to express a view on the activities of the Standards Australia committee. This is a cooperative process whereby information obtained from an Institute representative will be disseminated to members. The resulting broader membership feedback can then provide assistance to the collaborative workings of the corresponding Institute representative and reference group.

Issue 7 of last year’s President’s electronic newsletter called for an expression of interest for members wishing to serve as representatives on the following Standards Australia committees:

- ME-072 Technical Drawing
- BD-043 Formwork.

Expressions of interest in the above two committees are also sought from members who are prepared to serve on the reference groups.

Other recent actions in the Institute’s Standards activities have included the expansion of the reference group for BD-002 Concrete Structures (AS3600). This will lead to a broader consideration of unresolved issues currently under review by that committee.

It is anticipated that all representatives to Standards Committees will be supported by reference groups by the end of April this year.

Ben Cosson, the Institute’s Project Manager Technical Services, provides a commentary on developments in four key portfolios areas of the Institute’s activities. Members wishing to actively participate in any of the activities under discussion are invited to contact Ben Cosson at the Institute’s national office on (02) 9736 2955 or by email to technical@concreteinstitute.com.au.

Membership of the Concrete Institute of Australia provides a range of benefits at affordable prices. Whether it’s discounts on registrations for seminars, technical events and conferences or the right to participate in the most dynamic network of industry professionals and technical experts in the industry in Australia, the Institute has something to offer you.

Concrete in Australia magazine, an interactive web site, technical publications and Concrete Forum, a fully reviewed academic and applied technology journal are just some of the tools the Institute provides to place you at the leading edge of concrete technology, application, design and construction throughout Australia.

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Different types of membership have been designed to meet the needs of individuals, students, companies, organisations and academic institutions.

To find out more about the advantages of Institute membership, download an information package from our web site or contact the Institute’s membership co-ordinator through the national office.

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DON’T RISK IT!

• Did you know that not all steel bar, mesh and strand sold in Australia meets Australian Standards? The dangers from the use of rebar & mesh that don’t comply with Australian Standards are real, possibly life threatening and could involve you in serious legal action.

• Are you regularly checking your materials supply for compliance with Australian Standards? So, why not use the easy way to check your materials comply with Australian Standards.

• If your reinforcing materials supplier has an ACRS certificate it means their materials:
  • Are independently assessed
  • Are monitored throughout the year
  • Can be verified through ACRS and;
  • Meet the Standard

• Ask your reinforcing steel supplier for proof that the sources of both manufacture and processing have been independently certified by ACRS. Anything else just isn’t worth the risk.

For further information on ACRS & ACRS Certificated Suppliers of Steel Reinforcing, please visit www.acrs.net.au
ACRS, PO Box 1369, Crows Nest NSW 1585 Australia.
Tel: (02) 9965 7216 Fax: (02) 9965 7219
Email: info@acrs.net.au  ABN 40 096 692 545
Concrete pipes and structures are an integral part of all sewerage systems. They are however susceptible to corrosion which, if not addressed, can ultimately lead to a failure of the system and costly replacement.

Concrete access and inspection chambers are some of the assets where corrosion can occur. However, it has also been observed within concrete pipes, sewerage pumping stations and sewerage treatment plants. These assets represent considerable financial investment by those in the water industry and need to be well maintained to obtain maximum operational life.

Protection against destructive microbes requires specialised coatings and knowledge of how microbiologically induced corrosion occurs.

Xypex, a corporate member of the Australian Concrete Repair Association (ACRA), has been involved in the repair and rehabilitation of numerous access holes (manholes) affected by hydrogen sulphides and sulphuric acid.

It is well understood that sulphate attack on concrete results from a chemical reaction between sulphate ions and hydrated calcium hydroxide and/or the calcium aluminate components of hardened cement paste, in the presence of water. The products resulting from these reactions are calcium sulphate hydrate, known better as gypsum and calcium sulphaaluminate hydrate, commonly referred to as ettringite. These solids have a very much higher volume than the solid reactants and, as a consequence of their formation, stresses are produced within the concrete matrix that result in the cracking of the paste and ultimately, in the reduction of concrete's integrity.

Importantly, water is not only a necessary reactant in sulphate attack on concrete but, as it readily enters concrete through capillary action, it is also the medium for the transport of the sulphate ions into the matrix of the concrete, resulting in the formation of expansive by-products at depth.

Concrete is a highly alkaline material and generally not resistant to the effects of strong acids or other compounds which may convert to acids. The most vulnerable component in hardened concrete is calcium hydroxide which is readily dissolved and neutralised when attacked by certain acids. The most common manifestation of this attack is the obvious surface erosion which under conditions of lengthy exposures to acidic conditions may continue unabated.

There are many kinds of acid attack on construction materials. The attack can be from water containing free carbon dioxide or acid rain (which may contain dissolved gases such as carbon dioxide, sulphur dioxide and/or nitrous oxide), pure water from desalination plants or melting ice, sewage and food acids and those generated from organic wastes.

There are also high levels of naturally occurring sulphates in soils in many regions throughout the world which give rise to concerns for the durability of concretes placed in these environments. In sewerage facilities, including tunnels, pits and access holes in particular, sulphate-producing anaerobic bacteria produce hydrogen sulphide (H₂S) which volatises in the sewer atmosphere. The H₂S dissolves in the moisture condensing on the concrete surface and is further oxidised by bacteria forming sulphuric acid. The resulting high levels of sulphuric acid give rise to a quite aggressive attack on the cement paste, resulting in accelerated deterioration of the concrete.

The process of remediation involves relining the cementitious substrate to reinstate the loss of cover with a high performance repair material.

As the environment described earlier is extremely acidic, an internal coating to protect the alkaline concrete repair mortar will also be required.

Several high performance resins and epoxies have been used successfully in combination with the Xypex system for repair and rehabilitation of access holes, all of which are designed to protect concrete in chemically aggressive environments.

The specialised nature of the repair process and the use of ACRA members, who have the trained technical and corporate resources, will successfully ensure the long-term repair of these important assets.

This article was supplied by Xypex Australia.
Concrete Pipe Association of Australasia

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The Concrete Pipe Association of Australasia is excited to introduce the new web site for the Association, providing users with more information that is up to date and easier to find.

Some of the new features found at www.concpipe.asn.au include:

- the “Concrete Pipe Bulletin Board” on the front page of the web site with updates and news in the world of concrete pipe
- a page titled “About Concrete Pipe” which is devoted to informing the user of everything there is to know on concrete pipe

The popular CPAA design software for concrete pipe, PipeClass, is still available for all designers and specifiers, and can be downloaded quickly and easily. The software has been updated to reflect the updates made in the standards AS/NZS4058 “Precast Concrete Pipes” and AS/NZS3725 “Design for installation of buried concrete pipes” in 2007.

The CPAA was recently accepted as a member of Standards Australia at their annual general meeting in Melbourne. The Association is an active participant with Standards providing assistance and representatives on a number of committees. Most recently the CPAA was involved on the WS8 committee that completed the revisions of AS/NZS4058 “Precast concrete pipe” and AS/NZS3725 “Design for installation of buried concrete pipe”, and is active on the CE26 committee that is working towards the completion of AS1597.1 “Precast reinforced concrete box culverts – small” and the review of AS1597.2 “Precast reinforced concrete box culverts – large”.

An important revision has also been made to the Technical Information page. The technical resource section is now set out by category, rather than publication type, which means you can find information about reinforced concrete pipe with respect to a specific subject quickly and easily.

We hope you enjoy the new web site. If there are any suggestions on content or format, please contact CPAA Executive Director, David Millar, at dpmillar@concpipe.asn.au

CPAA ACCEPTED AS STANDARDS AUSTRALIA MEMBER

CPAA Executive Director, David Millar, with Standards Australia CEO, John Tucker
The Gold Coast Desalination Project Tunnels

Thirty metres below the seafloor and 50 metres below sea-level, two 150-tonne Tunnel Boring Machines (TBMs) have been working day and night to create the intake and outlet tunnels which will link the largest desalination plant on the Eastern Seaboard to the ocean.

Once complete in February 2008, the 2.2 kilometre intake tunnel and 2 kilometre outlet tunnel will be lined with almost 21,000 precast, reinforced concrete segments, constructed by Queensland precaster Precast Concrete Products Pty Ltd.

These two tunnels are a vital part of the Gold Coast Desalination Project – a $1.2 billion joint initiative between the Queensland State Government and Gold Coast City Council - which will provide 125 ML/day of clean, fresh water for South-East Queensland.

The project is currently under construction near the Gold Coast Airport in Tugun, and will begin producing water at the end of November 2008. It will operate at full capacity by January 2009.

The nature of the project and the strict time frames for its construction required the employment of leaders in this field nationally and globally. At the helm of the project’s tunnelling operations is Tony Bermingham, who has worked on a number of iconic tunnels throughout the world, including the Channel Tunnel linking the UK to France. Mr Bermingham said the tunnel design and construction provided numerous challenges, which his expert team has eagerly met.

“We chose two purpose-built TBMs because they have minimal impact on both the environment and the community compared with other tunnelling methods,” he said.

“We also needed to ensure the tunnel lining was durable enough to cope with the constant flow of saltwater, seventy metres underground for the design period of 100 years.”

To this end, the concrete segments, of which six link together to form a ring inside the tunnels, had to be created from a special concrete mix. The mix was formulated following a testing process undertaken over many months prior to the start of tunnel construction.

The tunnel lining specifications included:
- A compressive strength of 50 MPa;
- A first crack flexural strength of 4.6MPa; and

Story continued over the page...

A Precast Concrete Lifeline to the Ocean

Presidents Column

Relatively few construction projects are truly successful delivering an end result to the full satisfaction of all interested parties. It is worthwhile considering the factors that influence this outcome.

Certainly the degree of complexity need not be an issue.

Some important considerations are:
- Competent contributors are assembled as a team. (Consultants, head contractor & sub-contractors)
- Clear communications are made in an environment where timely input from all is encouraged.
- Clarity is achieved on the obligations of each participant.
- Contractual arrangements are put in place which are fair and reasonable.

For a number of reasons the corporate members of the National Precast Concrete Association punch above their weight and feature in more ‘successful’ projects than their turnover would suggest.

Why? Because they are competent and will generally only work with competent clients. Because they fully appreciate the need for close coordination and are used to working in a team environment. Because they deliver what they promise.

Continual improvement in the level of service is always possible but this is primarily a function of the input from the team rather than the individual sub-contractor. The worst case scenario is a late decision of who is required to do what by when coupled with contractual conditions which are unreasonable or are unreasonably interpreted.

Significant construction time can be saved by prefabricating off-site but adequate planning is a pre-requisite. The sooner an input from a precast supplier is sought and the sooner a precast solution is confirmed, the more value can be added. Too often only part of the precast advantage is realised which could have been fully optimised by an earlier involvement and an earlier decision.

Alan Morrison
President
Forty-eight machine moulds were designed and fabricated by the precaster and were required to form the segments. Trapezoidal vertical joints were incorporated in the design to ensure the structural integrity of each tunnel and to allow rapid installation.

To ensure durability and strength and to minimise any porosity, the concrete mix included silica fume and fly ash. In addition, a high-range water reducer was used to provide a low water/cement ratio to enhance durability, and steel fibres (35 kilograms per cubic metre of concrete) were included to increase corrosion resistance and ductility of the segmental lining.

“QA is always at the top of our minds on this project, so all elements and aspects of the segment fabrication process were required to be tested, including the raw materials from the quarry,” Mr Bermingham said.

“Our tunnel design and construction is the result of considerable research to ensure the best possible product for the South-East Queensland community – tunnels that will be able to help provide drinking water for the region for at least 100 years.”

Dimensional, material and concrete tests were conducted on each segment fabrication shift. The moulds were also required to undergo significant testing in order to meet tight dimensional tolerances for approximately 500 casts.

Colin Ginger, of Precast Concrete Products, said the amount of testing undertaken for this project was the highest recorded since the company was established 40 years ago.

In order to meet the strict time frames required for the project, the company operated two shifts throughout the manufacturing process, with 48 segments cast twice a day (early morning and evening), six-days-a-week.

This allowed for approximately ten truck loads of segments to be delivered daily to the project site at Tugun. Once delivered, the segments were carefully lowered into the tunnel shaft, 70 metres below ground, and taken – by locomotive – to the TBMs for installation.

Each TBM has a round, rotating cutter head which is covered in disk cutters (like giant teeth). As the head spins, the teeth cut into the rock. The rock is crushed and mixed with a naturally occurring lubricant – bentonite clay – to form a slurry. It is then pumped, via pipelines inside the tunnel, to the surface at the plant site.

After the TBMs cut through 1.2 metres of rock, they stop and the lining is erected from the back of the machines. Six segments are linked together to form a ring, which is grouted into place.

Using hydraulic rams, the TBMs then thrust off the completed ring and begin the cutting process once again.

These rams are capable of pushing about 1200 tonnes on the edge of the segments – a critical issue that also needed to be considered in the design and fabrication of the segments. Failure to do so would have resulted in local pressure points which would cause cracks and possible failure of the segments.

The segment geometry is also complex, as all of the longitudinal joints are offset 10 degrees to the axis of the tunnel, resulting in trapezoidal shaped segments. In the circumferential joints the nominal 1200mm long ring tapers from 1193mm to 1207mm allowing the tunnel to navigate around large radius bends.

“We used 3D computer software to model the mould components in a language that could be directly downloaded to the machine shops that milled the parts, and then assembled all of the fabricated components in our mould workshop,” Mr Ginger said.

“A special curing regime was also used with variable amounts of steam piped to each mould. The temperature of the concrete and rate of temperature rise were tightly controlled to allow for stripping of the moulds only six hours after casting. This enabled us to undertake the daily double castings.

“Concave and convex vacuum lifters were custom made for us in Melbourne. These were used to lift the segments out of the mould and move them to storage. In addition, a customised rotating device was built and attached to a forklift, allowing the segments to be rotated 180 degrees prior to delivery to Tugun.”

The Gold Coast Desalination Project is being constructed by the GCD Alliance, comprising John Holland Constructions, Veolia Water Australia, Sinclair Knight Merz and Cardno. The Alliance will also operate the project for 10 years.
What is thermal efficiency?

Thermal efficiency is part of energy efficiency and energy efficiency is one part of sustainability. Sustainability includes not only energy but also considerations of water, materials, food, waste and air quality, to name but a few. Thermal efficiency in a building is achieved when minimal energy is consumed, so as to maintain thermal comfort.

How a building or building element such as a wall, floor or roof performs thermally has a significant impact on its energy consumption. Energy consumption in Australia normally means greenhouse gas emissions, as most energy used in buildings is coal-fired electricity.

Section J of the BCA

Edition 46 of National Precaster (November 2007) outlines the new Section J of the Building Code of Australia (BCA), specifically written to establish energy efficiency measures.

Section J covers most of the elements of a building that contribute to its energy consumption:
- Building fabric
- External glazing
- Building sealing
- Air movement
- Air conditioning and ventilation systems
- Artificial lighting and power
- Hot water supply
- Access for maintenance.

For the precast industry, the relevant part of Section J is that of Building Fabric (p.439, BCA Volume 1). This section must be read with the identified class of building (Part A3) and climate zone (see Climate Zone Map in Part A1 – Interpretation [the definitions]). In particular:

J1.2 – Thermal construction general
Covers insulation and refers to the thermal properties of materials listed in Specification J1.2

J1.3 – Roof and ceiling construction
Specifies requirements for insulation values – see Specification J1.3

J1.5 – Walls
Specifies requirements for insulation values with options from tables J1.5a or J1.5b and Specification J1.5

J1.6 – Floors
Specifies requirements for insulation values with options from table J1.6 and Specification J1.6.

Thermally efficient buildings rely on three key factors: climate, physics and design.

Three key factors: climate, physics and design

Climate
Every building site comes with a piece of climate, for free!

Climate is a non-steady state which creates periodic heat flow. Diurnal variations (i.e. variations within the course of a single day) create repetitive cycles of temperature: peaks during the day and troughs during the night.

Physics
Concrete is the perfect material to satisfy the requirements for human thermal comfort. The physics of heat flow in buildings is the reason why.

Physics tells us that energy flows by conduction, convection and radiation. In building envelopes, the conductivity of a material is central. The reciprocal of a material’s conductivity is its resistivity (refer to Section J Specifications above). While concrete is a good conductor (in other words it has low resistivity), it has a high density and a high volumetric heat capacity.

This gives concrete a very high thermal mass (the capacity to store energy). Concrete also has two other characteristics which make it an ideal material for use inside a building envelope: the time lag for heat to travel through the material and the decrement factor (the reduction in amplitude of the indoor building temperature). These combine to create the thermal lag or thermal fly-wheel effect which allows concrete to flatten out the temperature peaks and troughs inside a building: it takes a long time to heat up and a long time to cool down (see diagram).
Concrete Time lag Decrement

<table>
<thead>
<tr>
<th>Concrete</th>
<th>Time lag</th>
<th>Decrement</th>
</tr>
</thead>
<tbody>
<tr>
<td>100mm</td>
<td>3 hours</td>
<td>0.45 (55% reduction)</td>
</tr>
<tr>
<td>200mm</td>
<td>6 hours</td>
<td>0.20 (80% reduction)</td>
</tr>
<tr>
<td>300mm</td>
<td>9 hours</td>
<td>0.10 (90% reduction)</td>
</tr>
</tbody>
</table>

For concrete to be an appropriate material for thermal design and energy efficiency in a building, it needs to be fully insulated from the outside climate. Section J of the BCA focuses on insulation and the conductivity of materials, as these reduce energy consumption and increase thermal comfort by increasing the mean radiant surface temperatures of the building envelope. As a result, less energy is consumed and therefore there are fewer greenhouse gas emissions contributing to climate change.

Insulation on the outside of the building envelope also reduces the incidence of condensation. Any material with warmth on one side and ‘coolth’ on the other can have condensation occur on the warm side if the dew point is reached. Insulation and/or a vapour barrier will prevent condensation.

For thermal mass to be effective, it should also be exposed to the interior and its occupants, not covered up with cosmetic finishes such as plasterboard.

Design factors affecting the thermal design of buildings are:
- Shape
- Fabric
- Fenestration
- Ventilation.

Precast solutions for thermal performance

It is widely accepted now that thermal bridging – conduction paths between the inside and the outside – has a significant detrimental effect on building performance. As well, the combination of thermal mass on the inside and insulation on the outside of a building envelope significantly increases comfort and also reduces energy consumption.

Knowing this, the precast industry has developed a new way of detailing, to eliminate thermal bridging and to develop heavyweight, mass interiors that are insulated from the exterior: precast sandwich panels.

Precast sandwich panels consist of two layers of concrete that are factory-made with a central layer of uninterrupted rigid insulation. They typically have a narrow (say 50 - 75mm) outer precast skin which is attached through the insulation to a wider (say 100 - 200mm) load bearing inner precast section, using non-conductive ties (connectors). Precast sandwich panels achieve the ideal thermal solution as they combine high internal mass insulated from the outside in a form of construction that has no thermal bridging.
New dimensions in grey wall panels

In 2006 new technology for colouring concrete was introduced to the precast industry. When combined with one of Reckli’s 300 standard formliners or custom-made moulds, the application of Nawkaw’s coloured emulsions and stains results in design possibilities which are now only limited by the imagination.

Nawkaw’s specialty is in matching the colour requirements of any project by custom-blending and hand-applying their products to the surface of the moulded, cured precast. The result can mimic traditional brickwork, blockwork, stone work, slate, sandstone, or timber, and the penetrating colour finish is guaranteed for 25 years.

The industry is starting to take notice of the significant benefits realised when using the stained formliner combination. Builders are enjoying the more than fifty percent cost savings as well as increased turnaround time, whereby panels can be supplied three times faster than the traditional alternatives. And the architects prefer the increased flexibility and more vivid colours which can be achieved.

Melbourne’s Mt Martha bridge was specified with a ‘cream splitface architectural CMU blockwork finish’. Precaster Humes realised that there were significant time and cost savings in casting the bridge sections with a blockwork relief formliner in grey concrete, then staining the moulded surface. The result is one that is indistinguishable from the traditional blockwork that was specified.

Precast does it for the $100M IKEA Perth superstore

Construction work on the new $100M IKEA Perth store commenced in October 2006 and has a target completion date at the end of February 2008. The development comprises a combined 5,100m² showroom and 7,000m² warehouse, a 400-seat family restaurant and an IKEA style children’s playground, and undercover parking for over 1,000 cars. It will be the largest single tenant retail store in Western Australia with floor space of approximately 26,500m².

The entire floor for the store is suspended to provide undercover car parking and is designed to take a heavy live load for access for deliveries and storage racks. Design consideration needed to take into account the enormity of the project, foundation conditions, site access and an extremely tight construction program. In addition the number of car bays needed to be maximised.

Precaster Delta Corporation Ltd, consulting engineers Worley Parsons and head contractor Multiplex Constructions, worked together to develop a precast concrete solution. Early award of the $5M precast supply-only contract allowed for off-site precast manufacture and storage, well ahead of site requirements. It comprises Deltacore hollowcore floor panels with precast beam shells as the main deck supported on insitu concrete columns. Post tensioning cables are incorporated in an insitu structural concrete topping bonded to the hollowcore. The beam shells are propped until post tensioning is completed.

In all some 1,618 precast elements are used in the key sections of the project, broken down as follows:
- Deltacore floor planks (up to 400mm thickness) 1,260 No
- Beam shells 312 No
- Retaining wall units 46 No

The Deltacore totalled 20,750m², in thicknesses of 400mm, 250mm, and 200mm. There were 2,445 lineal metres of beam shells delivered to site.
New Precast Seminars in 2008

Precast for Architects

Shape, Colour & Texture: Your vision into reality with precast concrete Thursday 10th April 2008 at Form & Function, Sydney

Building with Precast: A panel of professionals Friday 11th April 2008 at Form & Function, Sydney

Section J & Precast Concrete Saturday 12th April 2008 at Form & Function, Sydney

Refer to the Form & Function website for times and locations at Form & Function 2008 www.formandfunctionexpo.com.au.

Precast for Structural Engineers

One Day Seminars – Presented by John Woodside (winner of the John Connell Gold Medal) together with local NPCAA precasters and engineers.

<table>
<thead>
<tr>
<th>City</th>
<th>Date</th>
<th>Venue</th>
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<tbody>
<tr>
<td>Hobart</td>
<td>Thursday 28th February 2008</td>
<td>The Old Woolstore</td>
</tr>
<tr>
<td>Adelaide</td>
<td>Wednesday 12th March 2008</td>
<td>Housing Industry Association</td>
</tr>
<tr>
<td>Brisbane</td>
<td>Tuesday 13th May 2008</td>
<td>Hotel Grand Chancellor</td>
</tr>
<tr>
<td>Melbourne</td>
<td>Tuesday 17th June 2008</td>
<td>Designbuild</td>
</tr>
<tr>
<td>Canberra</td>
<td>Tuesday 8th July 2008</td>
<td>Master Builders Association</td>
</tr>
<tr>
<td>Perth</td>
<td>Friday 17th October 2008</td>
<td>Designbuild</td>
</tr>
</tbody>
</table>

This seminar is for recent structural engineering graduates, those who wish to freshen up on the latest precast trends around Australia, and those who are new to precast construction.

The seminar will cover: Materials & Tolerances, Precast Building Design, Manufacture, Transport & Erection, Design of Elements, Contractual Issues, Connections, Fixings & Joints. Opportunities to discuss your own precast challenge with industry representatives will be available at different times throughout the day. Handouts include The Precast Concrete Handbook on disk, worth $180.

For more information call Nicole at the Concrete Institute on (02) 9736 2955, email admin@concreteinstitute.com.au or go to the Seminars & Workshops tab of www.nationalprecast.com.au.

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www.nationalprecast.com.au
SKILLS TRAINING UNDERWAY

The Skills Training courses commenced in November 2007 with thirty leading hands and team leaders completing modules 1-4, and fifteen new and existing PT employees completing modules 1 and 2. Courses recommence in February as shown on the back page of this newsletter. Look for the “Skills Ticket” holders on your building projects.

A progressive New Year

Happy New Year to all members and friends.

The PTIA Board, elected at our inaugural Annual General Meeting on 19 November, 2007 remains largely unchanged with myself as President, Ian Stuart (VSL Australia) as Vice President and Max Schweiger (Structural Systems) as Secretary/Treasurer. Continuing directors are Michael O’Neill (Australia Prestressing Services) and Ed Cross (Austrial Freyssinet). I particularly welcome David Carolan (Taylor Thomson Whitting) as a new director and look forward to his contribution from a consulting engineer’s perspective.

Your Board has a strong and ambitious programme for 2008, key items of which are:

• completion of Skills Training courses in New South Wales, then extending these to Queensland and Victoria
• conduct of six Prestressed Concrete Design workshops for consulting engineers
• a new seminar series to be held in Sydney, Brisbane and Melbourne jointly with the Concrete Institute
• development of new Technical documents which will be highlighted in these newsletters and posted to our web site
• expansion of our interaction with other groups including CCAA, ASA, ACRS, Engineers Australia, ACSE and Natspec.

I am also delighted to welcome our new members who are listed on the last page of this newsletter.

PTIA has planned a significant series of courses and seminars which are detailed on the last page. We are presenting these in accordance with our mission to promote high standards in design, construction and materials for post-tensioning.

The 2008 seminar series builds on the 2007 seminars and will present details on a range of post-tensioning applications, D&C requirements and technical topics. These should be of particular value to design engineers, builders and contractors.

We are also pleased to sponsor the Prestressed Concrete Design workshops presented by Cement and Concrete Services, and to be able to offer our consulting engineering Associate members substantial subsidies on the fees for these workshops.

Our Skills Training courses commence again in February following on from a successful start late in 2007. All employees completing these courses are issued with a “Skills Ticket” card and will be required to be reassessed at annual intervals.

I encourage people in the PT industry to feel free to visit the PTIA web site or to contact the PTIA for any queries which they may have about post-tensioned concrete construction.

DAVID PASH
President
Construction is nearing completion on the Chatswood Transport Interchange (CTI), which is being developed in a Public Private Partnership between the Transport Infrastructure Development Corporation (TIDC) and CRI. The CTI, which in addition to the new Chatswood Railway Station and bus interchange includes a 10,000m² retail complex and a residential development of 500 units in three towers, has an estimated value on completion in excess of $360 million. The project is scheduled to finish in line with the commencement of rail services on the Epping to Chatswood Rail Line in 2008.

Laing O’Rourke, the D+C Contractor engaged Taylor Thomson Whitting (TTW) as the structural design engineers and Australian Prestressing Services (APS) as the post-tensioning contractor. The project is an unusual mix of rail, building and civil engineering works. Post-tensioned banded slabs and flat plates have been used for the basement carpark floors and the retail slabs. There are approximately 350m of suspended track structure which is typically a post-tensioned flat plate. New rail bridges have also been constructed at each end of the project over Help St and Albert Ave. These are single span structures using precast pretensioned girders.

Chatswood is currently the ninth busiest station on the City Rail network and is used by some 35,000 rail commuters daily. Except for the occasional track closures during possessions, two tracks were required to remain operational through 30 months of construction. Initially a temporary platform was constructed to provide an area sufficient to commence construction of the permanent works. The western half of the project was constructed first. Following its completion, train services were relocated to the newly constructed western platform and concourse area. The temporary platform was then demolished and construction commenced on the eastern half.

The north track slab consists of a 1m thick post-tensioned slab, 120m in length. The western half was constructed top-down and the pair of tracks became operational prior to excavating beside and beneath this slab. Finite element models were prepared for all construction stages and these models were used to check stresses resulting from concrete shrinkage and the restraint from the supporting bored piers.

The central area of the project consists of three basement carparks, the rail concourse level, track level, retail podium and roof slab. Temporary columns were required to support the post-tensioned band beams at the podium and roof levels along the line of the construction joint between the two construction stages. These temporary columns were also located adjacent to an active rail line. Instead of designing these columns for rail collision loads, the podium and roof band beams were designed to be able to cantilever and support construction loads should a collision occur. The podium slab located above track level was also required to be designed for a collision impact load in its final configuration.

The project brief included limits on the transfer of structure borne noise from the rail level to nearby apartment floors. This was achieved by the use of a floating track slab (FST) which consists of precast planks and rubber bearing pads supporting the rail.
ACHIEVING WATERTIGHT CONCRETE SLABS

“Watertight” concrete is a controversial issue and is often confused with the term “waterproof” concrete.

Concrete is a mixture of materials bound by a cement paste, which is porous. Passage of water is able to pass through the concrete via a capillary tract system, which links these pores. By adopting best practices, this small amount of water does not affect the end service condition and hence enables the designer to refer to this particular element as watertight. Due to its porous nature we do not refer to any concrete element as “waterproof”.

Definition of a Watertight Slab
The Concrete Institute of Australia defines watertightness by the concrete element as: “being impermeable to water except when under hydrostatic pressure sufficient to produce structural discontinuity by rupture”.

In many international standards reference to watertight concrete is only made in specific instances relating to liquid retaining structures or structures exposed to severe conditions. AS 3600 is also silent with regard to the watertightness of concrete slabs, however the inference can be drawn from sections of the standard that define degrees of crack control. By limiting the possibility of cracking and crack widths, the designer is able to achieve a watertight slab.

How do we achieve a watertight slab?
There are many factors which may influence the ability of a concrete element to be considered watertight. Factors which need consideration are:
- Structural design
- Detailing for restraining members
- Concrete mix
- Concrete placement, compaction and finishing
- Environmental conditions (rain, wind, hot weather etc)
- Concrete curing

Design: Utilising post-tensioned techniques it is possible to achieve a design that in the primary direction provides almost no tensile stresses in flexure hence leading to uncracked conditions under service loads. In terms of the secondary direction, watertightness can be achieved by combining appropriate levels of prestress and reinforcement for the control of cracking. AS3600 (clause 9.4.3) provides minimum requirements based on exposure classifications and restraint conditions for this to be satisfied. It is generally accepted that residual compression (P/A) levels between 1.8-2.0MPa plus the inclusion of mesh reinforcement satisfy these requirements.

Detailing: To successfully achieve a watertight element it is imperative that restraint conditions are closely examined. Large pours and vertical elements such as columns and walls can create significant restraining actions which may cause cracks to develop. In such instances attention to detail and appropriate isolation of the member is required to relieve the resultant stresses and alleviate the risk of cracking. A typical example of such a detail is shown below in the case of a concrete wall supporting a slab.

Concrete Mix: The choice of mix design is equally important. Typically for watertight elements shrinkage strains within the concrete should be limited. Similarly the mix should be proportioned to prevent early thermal cracking in the plastic state and sufficient in strength gain to apply a nominal 25% stress level at 24 hours (9MPa).

Concrete placement/Environmental Effects/Curing: Factors affecting the final result of the concrete element is largely determined by the on site placement of the concrete on the formwork. It is essential that best practices in terms of adequate compaction of the concrete occur and finishing of the concrete is commenced and completed at the correct time. Early finishing of the concrete may be detrimental resulting in excessive bleeding of the mix and hence excessive evaporation of water. Hot weather and high wind can also cause rapid evaporation of the mix leading to quick drying resulting in increased tensile stresses on the top surface which can develop into cracks. In these instances fast and efficient curing of the concrete should be undertaken which prevent and reduce the rate of evaporation of water from the concrete in the plastic state. The use of aliphatic alcohol can prevent the rapid evaporation of bleed water prior to the application of the final curing method.

Conclusion
With adequate attention to design, detailing and concrete placement methods a watertight post-tensioned structure may be achieved for a large variety of projects such as roof slabs, walls, retention basins, reservoirs, containment vessels and the like. For further information on the achievement of watertight structures feel free to contact one of the PTIA members for assistance.
PRESTRESSED CONCRETE DESIGN WORKSHOPS – 2008

PTIA is sponsoring a series of Prestressed Concrete Design workshops to be presented by Cement and Concrete Services (CCS). For consulting engineering firms who are Associate Members of the PTIA, there are significant subsidies on the fees for these courses – details are available from CCS at www.cementandconcrete.com. Registrations for workshops are to be made through CCS.

These two day workshops are developed for engineers who are familiar with reinforced concrete but who have little experience with prestressed concrete and who wish to gain an understanding of the principles of analysing and designing statically determinate prestressed beams. An optional third day workshop on computer aided design for prestressed concrete is also available.

<table>
<thead>
<tr>
<th>City</th>
<th>Venue</th>
<th>Dates 2008</th>
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<tbody>
<tr>
<td>Brisbane</td>
<td>Mercure Hotel</td>
<td>5 &amp; 6 March</td>
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<td>Melbourne</td>
<td>Hotel Grand Chanceller</td>
<td>16 &amp; 17 April</td>
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<tr>
<td>Sydney</td>
<td>Stamford Grand Hotel, North Ryde</td>
<td>7 &amp; 8 May</td>
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<td>Melbourne</td>
<td>Hotel Grand Chanceller</td>
<td>17 &amp; 18 Sept</td>
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<tr>
<td>Sydney</td>
<td>Stamford Grand Hotel, North Ryde</td>
<td>15 &amp; 16 Oct</td>
</tr>
<tr>
<td>Brisbane</td>
<td>Mercure Hotel</td>
<td>12 &amp; 13 Nov</td>
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SEMINARS AND OTHER EVENTS SCHEDULE - 2008

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<thead>
<tr>
<th>Location</th>
<th>Event</th>
<th>Dates 2008</th>
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<tbody>
<tr>
<td>Newcastle</td>
<td>Latest developments in post-tensioned concrete structures. Jointly with CIA &amp; Eng Aust</td>
<td>Feb/ March (tentative)</td>
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<tr>
<td>Sydney</td>
<td>Seminar with CIA</td>
<td>9 April</td>
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<tr>
<td>Sydney</td>
<td>Seminar with Eng Aust</td>
<td>27 May</td>
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<tr>
<td>Brisbane</td>
<td>Seminar with CIA</td>
<td>27 Aug</td>
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<td>Melbourne</td>
<td>Seminar with CIA</td>
<td>Nov (tentative)</td>
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PTIA SKILLS TRAINING COURSES SCHEDULE - 2008

All courses will be conducted at Manns Road, Gosford.

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<tr>
<th>Course Modules</th>
<th>Attendees</th>
<th>Dates 2008</th>
</tr>
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<tbody>
<tr>
<td>Module 3</td>
<td>Stressing and grouting operators</td>
<td>20 Feb</td>
</tr>
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<td>Modules 1 &amp; 2</td>
<td>New and existing PT employees</td>
<td>5 March</td>
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<tr>
<td>Module 3</td>
<td>Stressing and grouting operators</td>
<td>19 March</td>
</tr>
<tr>
<td>Modules 1 &amp; 2</td>
<td>New and existing PT employees</td>
<td>2 April</td>
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<tr>
<td>Module 3</td>
<td>Stressing and grouting operators</td>
<td>16 April</td>
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<td>Modules 1 &amp; 2</td>
<td>New and existing PT employees</td>
<td>30 April</td>
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<tr>
<td>Module 3</td>
<td>Stressing and grouting operators</td>
<td>14 May</td>
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<tr>
<td>Modules 1 &amp; 2</td>
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<td>28 May</td>
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<tr>
<td>Module 3</td>
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<td>11 June</td>
</tr>
<tr>
<td>Modules 1 &amp; 2</td>
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<td>25 June</td>
</tr>
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*PTIA welcomes its new members*
- Paul Davis (Paul Davis Rajalingam Consulting Engineers, Sydney) as an Individual member
- Robert Alexander (Parsons Brinkerhoff, Brisbane) as an Individual member

*Member Companies*

**Corporate Members**
- Australian Prestressing Services Pty Ltd (founding member)
- Austress Freyssinet Pty Ltd (founding member)
- Structural Systems Group (founding member)
- VSL Australia Pty Ltd (founding member)

**Associate Members – suppliers**
- Ajax Foundry Pty Ltd
- CMC (Australia) Pty Ltd
- Haggie Reid Pty Ltd
- OneSteel Wire Pty Ltd

**Associate Members – consulting engineers**
- Hyder Consulting Pty Ltd
- Taylor Thomson Whitting

*Post-Tensioning Institute of Australia Limited*
ABN 86 121 218 228
PO Box 861, Five Dock NSW 2046
Phone 02 8765 6199
Fax 02 9743 4013
Email info@ptia.org.au

Please visit the PTIA web site www.ptia.org.au for details about membership, membership benefits and membership application forms. If you have questions about membership, please contact PTIA through this web site and our office will contact you to discuss your questions.

“ensuring excellence and accreditation for the post-tensioning industry”
The bond and anchorage properties of bars and mesh are not detrimentally affected by a light coating of rust which has formed on the steel surface after normal exposure to the atmosphere.

Normal Conditions

Hot-rolled bars, as delivered from the mill, have a layer of tightly-adhering mill-scale on the surface. If stored under cover this mill-scale will help to preserve the steel. However, with handling and storage of the rods and bars, the mill-scale can be loosened and, if stored in the weather, rusting can occur and the mill-scale can become detached and “loose”. Research has shown that the sorting and normal handling and placing of bars removes the loose scale and the remaining rust and bonded scale is not detrimental to the bar bond.

Under some climatic conditions, where the atmosphere is hot and humid, “black” rust may form on bundled bars. When unbundled and exposed to dry conditions, the corrosion products will dry and convert to red rust which is powdery and will tend to readily fall off the bar.

Potential Problems

The major potential problem with rust on reinforcement is caused by rain washing particles onto the formwork and this can subsequently cause staining of the concrete surface on floor soffits and external facades. This problem can be avoided by ensuring that all loose and extraneous material is removed from the formwork prior to placing concrete. In some critical situations, galvanised reinforcement could be used to eliminate potential staining problems.

Where reinforcing steel is exposed to salt water, more significant problems may occur. Corrosion of reinforcement in concrete is promoted by the presence of chloride ions which are present in salt water[3]. Reinforcing steel which has been subjected to salt water exposure and has been severely rusted should not be placed in concrete without some prior treatment such as high-pressure washing to remove the loose corrosion and salt[4]. Severely corroded and pitted steel should not be used unless the material has been checked for strength and cross-sectional area limitations.

AS 3600, Clause 19.2.4 Surface condition

AS 3600, Clause 19.2.4 states:

“At the time concrete is placed, the surface condition of reinforcement shall be such as not to impair its bond to the concrete or its performance in the member. The presence of millscale or surface rust shall not be cause for rejection of reinforcement under this Clause.”

AS 3600 Commentary on Clause 19.2.4 states:

“Rust and millscale has little effect on bond[1,2]. Moderate rusting has been shown to improve bond[3].”

References


This information and other Technical Notes are available for free download from the web site: www.sria.com.au

For further information on steel reinforcement or any other associated matters, contact SRIA on: (02) 9410 3224
Adhesive anchor failure under tensile load – analysis of Boston Tunnel accident

The sudden collapse of about 26t of concrete panels on a tunnel roof in Boston, US in mid 2006 carries a warning to all engineers using adhesive anchors in concrete under sustained tensile loads. The findings of an inquiry into the accident also re-emphasise the risks of specifying and building with insufficient expertise (1).

“Boston: A woman was killed and a man injured Monday night when several 3-ton ceiling panels in a Big Dig connector tunnel collapsed onto their car, crushing it,” Massachusetts Turnpike Authority officials said (2).

The above news story relates to a section of the suspended concrete ceiling of the Interstate 90 (I-90) connector tunnel in Boston, Massachusetts; part of the so-called “Big Dig”, the largest transport infrastructure project in US history. On July 10, 2006, about 26t of concrete panels and associated suspension hardware became detached from the tunnel roof, crushing the right side of a vehicle roof; fatally injuring the driver’s wife (3).

The Big Dig partial collapse of some tunnel lining begs the safety question, as to what measures could have been taken to prevent the occurrence of the accident and the needless loss of a life.

An independent US Federal Government agency, the National Transportation Safety Board (NTSB), has the responsibility of determining the probable cause of transportation accidents and promoting transportation safety (1). A report prepared by the NTSB after its investigation of the ceiling collapse highlighted the probable cause to be the use of an epoxy anchor adhesive with poor creep resistance, that was not capable of sustaining long-term loads (3). Several failings identified by the NTSB, emphasised how the subsequent collapse was not a result of a product being outside of its own specification (which in this case it wasn’t); but moreover a product that was specified and used in an application that it wasn’t suited for. These failings also underline how a holistic approach needs to be applied to projects and all involved have responsibility and accountability to ensure public safety prevails. The six key failings identified by the NTSB (3) leading to the probable cause and resulting tunnel collapse were:

• using an inappropriate epoxy formulation due to the failure of management and design consultants to identify potential creep in the anchor adhesive as a critical long-term failure mode
• a general lack of understanding and knowledge in the construction community about creep in adhesive anchoring systems
• the epoxy supplier failing to provide sufficient, accurate and detailed information about the suitability of the company’s fast set epoxy for sustaining long-term tensile loads
• the failure of the epoxy supplier to determine previous noted anchor displacement was a result of anchor creep caused by the epoxy, known by the company to have poor long-term load characteristics

• the management consultant and construction contractor failing to continually monitor anchor performance subsequent to prior anchor displacement and to dispel uncertainty as to the likely cause
• failure by the project owners in implementing a timely tunnel inspection program that could have identified ongoing anchor creep in adequate time to correct and rectify it.

Safety issues identified through the NTSB investigation, demonstrate the importance of correct overall engineering practices in the way of testing, specifying, installation, inspection and monitoring for the appropriate and effective use of engineered products. The four key safety issues presented in the NTSB report are (3):

• insufficient understanding among designers and builders of the nature of adhesive anchoring systems
• lack of standards for the testing of adhesive anchors in sustained tensile-load applications
• inadequate regulatory requirements for tunnel inspections
• lack of national standards for the design of tunnel finishes.

The following discussion presents the main points for the key safety issues as set out in the NTSB report (3).

Insufficient industry understanding

An important finding from the investigation was that no one involved with the project appeared to have the knowledge that under sustained tensile load, there was potential for the epoxy to gradually deform. A major failing was the oversight by project managers and overseers to recognise the weakness in the epoxy adhesive, following evidence displaying anchor creep.

The I-90 tunnels were a rare, if not the first application where adhesive anchors had been used in the numbers and in such a challenging environment as they were. Use of adhesive anchors in civil projects typically involve short-term or shear load applications. While the susceptibility of the adhesive to creep is still apparent in such applications, the displacement will likely never reveal itself. This then leads to a lack of awareness of the potential for creep, from those responsible for specifying, approving, installing and testing the anchors. Following the lack of awareness of the nature of epoxy anchors, comes a knowledge gap whereby these anchors could be specified and used in applications such as tunnels where the susceptibility to creep could be a threat to public safety.

As adhesive anchors are also used in commercial construction, it is important for all to realise the possible risks associated with using such anchors in concrete under sustained tensile-load applications. If these anchors are to be used in applications involving sustained tensile loading then it is imperative to properly assess the creep characteristics of the adhesive anchors.

Lack of standards

The partial ceiling collapse clearly highlights the inadequacy of the installation and test procedures used for the adhesive
anchors in the I-90 tunnels. Information on the long-term strength of the adhesive anchors under sustained load could not be attained by the proof-test procedure used on the anchors. Furthermore, the overhead installation of the adhesive anchors appeared to have induced voids due to poor installation technique, reducing the anchor load capacity irrespective of the creep resistance of the epoxy.

The project managers and owners had failed to perform independent testing to verify load capacities provided by the epoxy supplier, or that the anchors would perform similarly in the application used. This neglected a recommendation by the American Association of State Highway and Transportation Officials (AASHTO) in its 2002 Standard Specifications for Highway Bridges, 17th Edition, that embedment anchors be subject to sacrificial tests at the job site to document the anchors’ capability to achieve the full tension value as shown in the manufacturer’s literature.

Given the safety-critical nature of the system used it would have been prudent to test a sample of the anchors to their ultimate loads. The management and design consultants should have insisted on the requirement that ultimate load tests be conducted on the adhesive anchors prior to installation, due to the potential catastrophic effects of a failure.

The property of the epoxy that eventually led to the accident would not have been revealed by ultimate load tests alone. This then highlights the need for more refined and specific testing of any adhesive anchor system that is being considered for use in a sustained tensile-load application. Standards and protocols for the testing of adhesive anchors in such applications will provide designers and builders with methods designed specifically to accurately assess the long-term safety of those anchors.

Site-specific ultimate strength values as well as the creep characteristics of the adhesive over the structure’s expected life should be considered in any standard and protocol developed.

Although a lack of sustained tensile testing standards for adhesive anchors in the USA is cited, a distinction needs to be made between testing required in the product development and rating phase and that which might be employed on site to prove already installed anchors. Product rating tests (acceptance criteria) for creep performance of adhesive anchors are already in use in the USA. At the time of the Boston project the appropriate code was AC58, published by ICC-ES (International Code Council Evaluation Service). This is referred to in the NTSB report. Indeed, products which satisfy this standard are referred to, as are ones which don’t, which includes the failed adhesive in question. Unfortunately in Boston some confusion was present about exactly which type had been installed – tragically the wrong type – another contributing factor. Although there appears to be no codified sustained-load test specifically for on-site proving, it also appears that nobody involved even thought to suggest creep effects in the face of instantaneous site testing which didn’t explain the observed displacements.

That we have neither of these types of testing standards in Australia is not necessarily a problem. In fact, there are no Australian Standards relating at all to the design or installation of post-installed anchor systems, mechanical or otherwise. However, Australia does not seem to suffer from unacceptable levels of adverse incidents. Australia has a largely self-regulated sector of the structural concrete industry where the major anchor systems suppliers opt for a high standard of applied engineering and refer as they can to AS3600 and other research and testing findings. Whether for marketing advantage or for industry safety (possibly both) we all benefit and, given that this approach is serving the industry, it would seem preferable to initiating external regulation unnecessarily.

**Inadequate regulatory requirements for tunnel inspections**

From the time the I-90 eastbound connector tunnel was first opened to traffic on January 18, 2003 until the day of collapse, inspections to determine the physical and functional condition of the ceiling system had not been performed. A comprehensive and detailed inspection manual had been provided to the owners by the management consultants. However, this manual was not used.

A large number of anchors had become displaced from the tunnel roof above the suspended ceilings, which was revealed by a post accident inspection. The displacement of the hanger plates had been obvious enough that the threatened structural integrity of the ceiling system would have been shown by even a cursory inspection of the area before the accident. The anchor creep would have likely been identified and preventative rectification action taken, had the owners conducted inspections of the area above the suspended ceilings at regular intervals.

Identification of problems with some of the anchors in the tunnel occurred within weeks or months of their installation, which indicates that recently built structures are not necessarily exempt from defects. This could lead to the need for government bodies to develop and implement tunnel inspection programs to identify critical inspection elements and specify an appropriate inspection frequency.

**Lack of national standards for the design of tunnel finishes**

The outcomes of a US national survey showed adhesive...
Anchorages in concrete in Australia

Bruce Ireland

The 2001 edition of AS3600 Concrete Structures makes no specific acknowledgement of post-installed connections (neither mechanical nor adhesive) and is relatively vague even about cast-in-place connection devices. However, by default, the provisions of Section 14.3 Requirements for Fixings could be interpreted broadly as applying to both cast-in-place and post-installed anchors.

A review of technical literature and technical information from a number of leading Australian post-installed anchor system manufacturers and suppliers shows the design procedures recommended for their particular products or systems are generally based on the Concrete Capacity method prescribed in Appendix D of the 2002 and 2005 editions of ACI 318 Building Code Requirements for Structural Concrete and Commentary.

The methodology of ACI 318 Appendix D has been developed by ACI Committee 355 Anchorage to Concrete. This same group developed a method of evaluating test data for post-installed mechanical anchors. ACI 355.2 Qualification of Post-Installed Mechanical Anchors in Concrete and Commentary, has been working on a similar document for adhesive anchors, Qualification of Post Installed Adhesive Anchors in Concrete for release later in 2008, and has started work on a qualification procedure for screw anchors.

These qualification documents are in turn used as the basis for acceptance criteria necessary for organisations in the US which approve the performance of specific products and systems. While this may appear to be somewhat cumbersome, it does work, and it provides designers and the users of anchorage systems in the US construction industry a reasonably high degree of confidence that the products promoted by the manufacturers perform as claimed.

A benefit that may not be apparent to designers and users of the same products and systems in Australia is that the leading suppliers here are part of the multi-national companies operating in the US and the data that is used in the US marketplace can be applied here also with a similar degree of confidence, noting, however, that the manufacturers have changed the published information to reflect the requirements of sections of Australian Standards that apply.

At least one other Australian manufacturer/distributor of adhesive anchoring systems has based its technical information on British design methodology, which, like the US method, has been developed over a period of time, and has high degree of acceptance by specifiers and users in the UK.

Bruce Ireland has been an active member of ACI Committee 355 since 1992 as well as participating in the activities of three other ACI Committees. He is Product Development Manager for Danley Construction Products and is a member of the Queensland Branch Committee of the Concrete Institute.

Fixings could be interpreted broadly as applying to both cast-in-place and post-installed anchors. The 2001 edition of AS3600 has high degree of acceptance by specifiers and users in the US which approve the performance of specific products and systems. While this may appear to be somewhat cumbersome, it does work, and it provides designers and the users of anchorage systems in the US construction industry a reasonably high degree of confidence that the products promoted by the manufacturers perform as claimed.

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At least one other Australian manufacturer/distributor of adhesive anchoring systems has based its technical information on British design methodology, which, like the US method, has been developed over a period of time, and has high degree of acceptance by specifiers and users in the UK.
Behaviour of one-way continuous reinforced concrete slabs – constructed with grade 500 Class L mesh steel, under support settlement

U Siddique, H Goldsworthy and R J Gravina

U Siddique and H Goldsworthy are from the Department of Civil and Environmental Engineering at the University of Melbourne, Victoria.

R J Gravina is from the School of Civil, Environmental & Chemical Engineering at RMIT University, Victoria.

The impact of constantly changing properties of construction materials on the behaviour of the structures and the relevant code provisions needs to be reassessed on a regular basis. The introduction of higher strength steel, Grade 500MPa, in Australia has led research to study the behaviour of concrete structures constructed with the new steel. A number of analytical and some limited experimental studies have been carried out and have shown concerns about its ductility and/or the related provisions of AS3600-2001. In particular, the ductility of class L mesh has surfaced as a controversial issue. Some studies have concluded that the use of class L mesh in suspended slabs is undesirable, in particular under accidental loadings like relative support settlements. However, AS3600-2001 [1] permits the use of class L steel with certain restrictions. Further detail about these issues is available in another publication [2] of the authors. The present study consists of full-scale experimental testing of one-way continuous slabs under imposed settlement and aims to examine their ductility, moment redistribution, moment-rotation relation and crack pattern. This paper is intended to provide some results and details of the second experiment conducted, while the results from the first experiment are available in [3].

The experimental program

Two full-scale continuous one-way slabs were constructed and tested. The design was carried out following the provisions of AS3600-2001, incorporating Amendment No1. The simplified method for continuous one-way slabs (clause 7.2) was followed for the design purposes without considering foundation movement (clause 7.6.8.1). This approach was adopted to consider an adverse scenario where a structure, designed without considering such effects, undergoes support settlement. This experimental program has been devised to study the behaviour of suspended slabs constructed with class L mesh under such an eventuality. In the first test slab, settlement was imposed in the upward direction while the second test slab was settled downward (see Figure 1). However, only details of the second experiment are given in this paper. The material properties and loads considered for the design of the slab for the second experiment are as follows:

- dead load (G) = 1kPa (excluding self weight)
- live load (Q) = 3 kPa
- load combination = 1.2 G + 1.5 Q
- concrete $f'_c$ = 32MPa
- steel $f_{sy}$ = 500MPa (class L type mesh).

Test slab set up and instrumentation

The test slab was cast in position and tested after 28 days. All the supports were pin-ended to allow free rotation of the test slab and built by an assembly of steel plates and a roller. A special arrangement was made at the intermediate support to impose the support settlement. Two hydraulic jacks were used to lower the support by a pre-determined amount and the support reaction was recorded using a load cell at each jack. Also, various other instruments and techniques were used to observe/record the experimental data consisting of conventional instruments like strain gauges and transducers, and modern techniques like digital photogrammetry surveying. During the test, the slab was loaded until failure occurred. The following loading sequence included:

- self-weight
- intermediate support settled by a predetermined amount
- dead and live loads on each span.

After the support settlement, dead and live loads were imposed by using concrete blocks of various weights at four points on each span. The four-point loads were used since the
even number of point loads better simulate the distributed load [5]. Near the ultimate load, the concrete blocks were, of necessity, spread out over the whole span rather than only at four points. During the testing, the data was recorded from strain gauges, transducers, load cells, photogrammetric survey and observations were made to determine the crack widths and pattern at various stages of the loading. Later, this data was used to calculate the moment redistribution and to plot the moment rotation and load deflection curves for the critical sections of the test slab.

Material properties
The average compressive strength from five standard concrete cylinder tests was found to be 32MPa. The mechanical properties of the steel reinforcement used in both test slabs, as tested and provided by Smorgon Steel Reinforcing, are provided in Table 1. More details of the test results are available in [2].

Experimental results

Load deflection curve
A curve for total applied load on each span (excluding self-weight) versus the average mid-span deflection is shown in Figure 3. The deflection is measured with reference to the position of the slab after it had been displaced by the support settlement. It is noticeable that the curve near the maximum load does not reach a plateau, indicating that the full plastic collapse mechanism is unable to form before localised failure occurs. The failure itself was very sudden and brittle resulting from the abrupt snapping of the top steel reinforcement close to the mid-span support. A deflection of Span/97 was recorded at the penultimate load, indicating that the large reduction in stiffness after cracking led to the development of significant deflections.

<table>
<thead>
<tr>
<th>Mesh</th>
<th>$R_u$ (MPa)</th>
<th>$R_s$ (MPa)</th>
<th>$R_u/R_s$</th>
<th>$A_{gt}$ (%)</th>
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<td>RL918</td>
<td>612.56</td>
<td>646.53</td>
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<td>618.42</td>
<td>645.81</td>
<td>1.044</td>
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</table>

Figure 3. Load versus average mid-span deflection curve.

Slab behaviour under loading and crack pattern
The test slab developed a crack over the intermediate support due to the self-weight moment reaching the cracking moment of the slab section. At the start of the test, the slab settled downward by an amount of 17mm at the intermediate support. A downward support reaction of 3.65kN was recorded at the intermediate support. This support settlement closed the initial crack developed over the intermediate support due to self-weight.

Applying the four-point loads caused cracking within the spans initially. Due to this cracking, significant moment redistribution occurred from the mid-span regions to the intermediate support. After the serviceability load of 8kN was reached, cracks also appeared over the intermediate support. The slab exhibited well distributed cracking when the load reached the ultimate design load (1.2x Dead Load + 1.5 x Live Load). It was able to withstand this load despite the initial application of the support settlement. In fact, failure occurred at a much higher load as shown in Figure 3. The application of further loading after the ultimate design load of 14kN had been reached caused major cracking of the span regions with further cracks over the intermediate support region. At the failure load, both spans had developed widespread cracks and the cracks over the intermediate support had also widened considerably.

The slab resisted a moment of 15.72kNm just before failure, compared to a design moment of 8.35kNm. The main reason for this was the higher actual strength of the materials, in particular, the steel having an ultimate tensile strength of...
651MPa compared to a design yield value of 500MPa. The section capacity at the support was calculated to be 15.18kNm when taking into account the actual concrete strength and ultimate steel strength of 651MPa, less than a 5% difference from that recorded. The failure mode observed in the test slab was very similar to the first test slab. The failure occurred at the face of the intermediate support with sudden failure of the top reinforcement. Also there was no sign of the concrete crushing anywhere in the slab. Figures 4a and 4b show the load at failure and the failure section at the intermediate support respectively.

A deflection curve of the test slab at selected load stages is shown in Figure 5. The displaced shapes are shown with reference to the displaced position after the settlement was imposed. The curve shows that the slab was able to deflect significantly at mid span before failure. The span to deflection ratio just before the failure was 97 (average).

**Moment redistribution**

From the measured support reaction over the intermediate support and known imposed loads, it was possible to calculate the moment in the spans as well as at the face of the central support occurring during the experiment for different load cases. With the recorded value of the central support reaction, experimental end support reactions were determined by assuming symmetry. The symmetry of the imposed loading was also confirmed from the comparable deflection values for both spans obtained by the photogrammetry survey. The degree of moment redistribution is defined according to the CEB Task Group 2.2 [6] as:

\[ \beta = (1-\delta) \times 100 \] (1)

where

\[ \delta = \frac{M_{\text{expt}}}{M_{\text{elas}}} \] (2)

The elastic hogging moment at the central support, \( M_{\text{elas}} \), was calculated using elastic theory and also taking into account the moment due to the support settlement. The experimental hogging moment also includes the effects of support settlement and is found using the end reaction and the known values and positions of the applied loads. Table 2 shows the values of \( \beta \) for various load conditions. It is important to note that this moment redistribution can mainly be attributed to cracking, since yielding of the reinforcement at the critical section did not occur until the applied load had reached approximately 24kN.

**Moment vs rotation curve**

The moment rotation curve was determined for the plastic hinge region close to the central support. The rotation was determined over the plastic hinge length, taken as equal to the depth of the slab, and based on the transducer data for different load cases. However, in the test slab 2 due to the malfunctioning of a few transducers, it was not possible to determine the rotation over the whole plastic hinge length assumed. Therefore the moment and rotation values (see Table 3) have been calculated based on consideration of only half of the plastic hinge length (ie: over 60mm adjacent to the intermediate support face). Figure 6 shows the relation between the experimental moment and rotation. The moments and rotations are those occurring after the support settlement has been imposed.
Conclusions
The overall test program has included two full-scale tests using mesh steel from one manufacturer and with relative support settlements of a fixed amount. Nevertheless, these results will be very useful in calibrating theoretical models developed to study the behaviour of slabs subjected to imposed support settlements.

Once these models have been calibrated, it is anticipated that further experimental work considering larger amounts of relative support settlement, and possibly using steel from different manufacturers, will be needed to allow further refinement of the theoretical models.

Acknowledgments
Financial assistance from Cement, Concrete and Aggregates Australia and donation of materials from Smorgon Steel and ReadyMix Concrete are greatly acknowledged, without which this study could not have been possible.

References

Table 3. Experimental moment and rotation.

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<thead>
<tr>
<th>M_{EXPT} (kNm)</th>
<th>Θ_{EXPT} (rad)</th>
<th>Comments</th>
</tr>
</thead>
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<td>7.06</td>
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<td>Support Settlement Load</td>
</tr>
<tr>
<td>4.37</td>
<td>-0.00354</td>
<td></td>
</tr>
<tr>
<td>0.66</td>
<td>-0.00126</td>
<td>Serviceability Load</td>
</tr>
<tr>
<td>-3.58</td>
<td>0.002536</td>
<td></td>
</tr>
<tr>
<td>-5.24</td>
<td>0.004439</td>
<td></td>
</tr>
<tr>
<td>-7.45</td>
<td>0.005504</td>
<td></td>
</tr>
<tr>
<td>-12.19</td>
<td>0.010125</td>
<td>Penultimate Load</td>
</tr>
</tbody>
</table>

Notation
- $f_c'$ = Characteristic compressive strength of concrete (MPa)
- $f_y$ = Yield strength of reinforcing steel (MPa)
- $R_y$ = Yield strength determined from tensile tests (MPa)
- $R_m$ = Ultimate tensile strength determined from tensile tests (MPa)
- $A_p$ = Uniform elongation strain at $R_m$ determined from tensile tests (%)
- $\beta$ = Degree of moment redistribution
- $\delta$ = Ratio of moment recorded during the experiment to the elastic moment
- $M_{\text{elas}}$ = Moment calculated using elastic theory (kNm)
- $M_{\text{exp}}$ = Moment determined by the support reactions measured during the experiment (kNm)

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Dalrymple Bay Coal Terminal – DBCT 7X project

Dr Andrew Whiting
Senior Associate, Connell Wagner

This paper, which describes a project currently under construction, was presented at Concrete 07 on 18-20 October 2007.

Dalrymple Bay Coal Terminal (DBCT) is a port facility located south of Mackay in Queensland, Australia, which exports metallurgical and thermal coal mined in the Bowen Basin region of Queensland. DBCT is a multi-user facility servicing 15 mines and is capable of exporting up to 55 different coal blends.

Already one of the largest coal terminals in the world, DBCT’s capacity is being expanded from 59 million tonnes a year (Mt/a) to 85Mt/a to meet ongoing customer demand, primarily overseas. The DBCT 7X Project involves substantial modifications and enhancements to all major elements of the terminal: inloading, stockyard and outloading. The expansion scope was developed to minimise disruption to terminal operations during implementation.

The terminal owner, Babcock & Brown Infrastructure (BBI), engaged Connell Hatch as Engineering Procurement and Construction Management (EPCM) contractor for the project. An EPCM delivery method was selected as it provided the most appropriate blend of owner control/influence for a brownfield environment and balanced risk allocation through award of competitively bid lump sum contracts for execution of the work.

The following sections describe three aspects of the project which involved significant quantities of concrete:

- Rail receival pit RRP3
- Bunds 4A and 5A in the stockyard
- Offshore works.

Rail receival pit RRP3

Description of works

Rail Receival Pit RRP3 was built as part of the third inloading system and operates at a rate of up to 8100t/hr. Coal is brought from various mines in central Queensland to the terminal in trains up to 2km in length and containing 10,000t of product. The coal is bottom-dumped into a hopper which provides surge control before being transferred via a belt feeder onto an overland conveyor (S11) which transports the coal to the stockyard.

RRP3 is a reinforced concrete structure approximately 45m long x 13m wide and up to 20m deep where the coal transfers onto the overland conveyor (refer Figure 1). The pit is bounded on three sides by existing structures: Rail Receival Pit RRP1 to the west and concrete tunnels for Conveyors S1 and S2 to the north and south, respectively. The proximity of these adjacent structures required careful consideration during the design phase and subsequent implementation phase to ensure that existing terminal operations were not unduly affected.

Design issues

The rail receival pit was designed to AS3600 and AS5100 as it is effectively a bridge structure supporting rail wagons and locomotives. Three of the main design issues are discussed below.

Design loads

The primary loads affecting design of the pit walls and base slab were earth pressure and hydrostatic pressure resulting from groundwater. In combination, these loads required walls and slab thicknesses up to 1m thick and extensive shear reinforcement in some areas. 66 post-tensioned ground anchors were used to resist hydrostatic uplift. Anchors were CT stress bars fully encapsulated in corrugated polyethylene tube with an average length of 12m and a design life of 100 years. For design purposes, the water table was assumed at ground level – a likely situation considering the sustained rainfall experienced in Mackay during the wet season. The resistance to uplift conservatively ignored friction on the external pit walls.

The design of the track slab, internal beams and walls was dictated by maximum hopper loads (hopper full of coal), train

Figure 1. Long section through rail receival pit RRP3.

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load (wagons fully laden with coal) and wagon derailment. The latter occurs occasionally on the existing pits due to the use of bottom dump wagons. Accumulation of coal on top of the rail beams causes the wagons to ride up mounds of coal resulting in loss of contact between wheel flange and rail head. Measures were implemented to minimise the potential for derailment in Rail Receival Pit RRP3 by promoting coal flow.

Construction sequence
The construction sequence assumed by the designer was critical to the design itself. For example, it was assumed that the perimeter walls at the deepest section of the pit would be constructed in two lifts. The lower lift could be backfilled while the wall was acting as a cantilever, however, the upper section of wall required the completion of the track slab to provide propping action prior to backfilling operations. It was therefore imperative that the assumed construction sequence be documented on the design drawings. The designer subsequently worked with the contractor to accommodate adjustments in construction sequence, primarily related to the location of construction joints.

Temporary ground retention system
Due to the critical nature and proximity of adjacent infrastructure and time constraints on the overall project, design of the temporary ground retention system was undertaken by Connell Hatch rather than by the contractor as would traditionally be the case for temporary works.

The temporary ground retention system comprised 900mm diameter bored piles at 2m centres on three sides of the excavation. Piles were anchored top and bottom with temporary ground anchors to enable subsequent excavation below the pile toe level. Infill panels between piles and the exposed rock face beneath the piles were covered with sprayed concrete. Although a geotechnical investigation was conducted prior to the commencement of works on site, an intensive monitoring regime was implemented during construction which included the use of survey controls and inclinometers to verify the geotechnical parameters assumed in design. Field observations confirmed that assumptions were conservative and no design changes were required. In order to accommodate for geotechnical uncertainty, the number and length of piles, ground anchors, rock nails and shotcrete were priced on a schedule of rates basis with the remainder of works being a lump sum contract.

Construction issues
Rail Receival Pit RRP3, the first major construction package on the project, was awarded to Golding Contractors. The temporary ground retention system and rail receival pit were constructed throughout 2006, including the wet season, and completed in 2007. The main issues were:

Temporary ground retention system
Flowing groundwater proved to be an issue during construction with the grout in some ground anchors being washed out and needing to be done again. There was also concern expressed by the contractor that the temporary ground retention system had not been designed for a full head of water (the design assumed dewatering of the pit area...
by means of a network of deep wells around the perimeter of the excavation as well as a grid of drainage points at 1.5m x 1.5m centres in the sprayed concrete between the bored piles). Ultimately, it was agreed that discharge of water from the drains in the bored pile wall would be monitored to provide an indication of the water pressure in the ground behind. In the event that water was found to be jetting from two or more drains in a vertical line (indicating a head of more than 3m behind the wall), the pit would be evacuated. Although the pit was periodically evacuated due to inundation during torrential rain, monitoring of discharge from wall drains did not indicate excessive hydrostatic pressure behind the wall at any stage of construction.

The presence of existing conveyor tunnels and other structures in the vicinity of the pit meant that there were a number of constraints imposed on the installation of ground anchors. Limitations of the drilling rig resulted in the need to adjust the level and orientation of some of the ground anchors for the bored pile wall. This generally required additional prestressing strands to maintain equivalent anchorage at steeper angles of inclination.

During excavation for the pit, two of the bored piles were found to have voids extending through the full cross-section of the pile and for a height of approximately 0.5m. The cause of these defects was attributed to the rate of withdrawal of the temporary pile liner. The photograph above shows a general view of the ground retention system under construction including repairs to one of the defective piles (at centre of photo).

### Dump station and tunnel

The dump station and tunnel involved more than 4000m³ of cast-in-situ concrete. Due to the size of some concrete pours, and in an effort to expedite the schedule, several concrete pours were carried out at night.

During the course of the works, a number of changes were made to construction joint locations documented on the design drawings to suit the contractor’s formwork and falsework system. In each case, the design implications were assessed promptly and reinforcement detailing revised where required.

### The stockyard bunds

#### Description of works

Development of the stockyard includes construction of new bunds and the provision of additional stockpiles to increase the yard capacity and improve stockpile efficiency by increasing the independence of stacking and reclaiming operations. Three new bunds are being constructed, each 1.3 km long: Bund 4A to support the new Stacker ST4, Bund 5A to support the new Stacker ST4 and Bund 6 to support relocated yard machines Stacker-Reclaimer SR6 (formerly SR3 from Bund 4) and Reclaimer RL2 (formerly SR4 from Bund 5).

Bunds 4A and 5A are being constructed in the middle of existing stockpile rows. In order to maximise storage capacity, vertical retaining walls will be provided in areas where coal is to be stockpiled and conventional earth bunds with 1V:1.3H batters will be provided in other areas. In addition to a new stacker, each bund supports a conveyor and a roadway.

The cross sections for Bunds 4A and 5A are virtually identical and comprise two opposing 6.1m high precast concrete retaining walls supported on a 1.5m high earth embankment. The retaining walls extend approximately 2.4m above road level to provide a physical barrier between personnel on the bund and the bucketwheels of adjacent stacker-reclaimers. A 45˚ return is provided on top of the wall to reduce coal falling onto the bund surface.

It is intended that coal be stockpiled no higher than 3.5m below the top surface of the bund to provide some immunity against overtopping of the wall if the stockpile slumped. This figure was determined by considering the likelihood and consequences of slumping which depends on coal type, seasonal effects and other factors.

The sides of the embankment are covered with steel fibre-reinforced sprayed concrete and provide a chamfer to the bucketwheel of the stacker-reclaimers on adjacent bunds to maximise recovery of coal.

A total of 1100 precast concrete panels were required per bund, each panel being 2.25m long, representing a combined length of 2.5km (1.25 km along each side) and a total concrete volume of 6200m³.

Opposing precast concrete wall panels are tied together with passive anchors at the base (one 32mm-diameter Reidbar) and at mid height (two 36mm-diameter stress bars). As the ties were installed progressively during backfill operations, subsequent backfill and compaction resulted in partial prestress of the transverse ties. The tied-cantilever configuration was adopted to prevent sliding of the base and to reduce bending in the stem during construction and in service.

The bunds have an overall longitudinal fall of 1:700 from one end of the stockyard to the other. Drainage of the top surface is achieved by provision of 3% cross fall and 1.5% longitudinal fall to gully pits at 36m centres, which in turn discharge...
beneath the eastern rail beam into the adjacent stockyard row.

The yard machines on each bund are supported by two 1.3km-long concrete rail beams with cross ties at 36m centres. Each rail beam is 1500mm wide x 500mm deep resulting in a total volume of cast insitu concrete of 2000m³ per bund. Long travel buffers are provided at the ends of the rail beams to prevent the machine from running off the end of the rails in the event of combined operator error and electrical/control system failures.

Design issues

Structural concepts

Both precast and cast insitu wall options were considered, however, it was determined early in the design phase that the precast solution was preferred as construction time was a critical factor in delivering the project within the required timeframe. A number of structural arrangements were considered including:

- reinforced soil wall
- cantilever retaining wall
- tilt-up wall panels with anchor ties
- buttress wall (or counterfort) with direct support for rail beam
- cantilever retaining wall with anchor ties.

Reinforced soil wall

The main issues for discounting a reinforced soil wall were potential durability problems with reinforcing straps (sulphate content of the coal and chloride content of the air due to proximity to the ocean), susceptibility to vertical and lateral movement (resulting in potential problems with stacker rail alignment) and robustness (potential impact damage of relatively thin facing panels from dozer clean-up operations alongside the wall).

Cantilever wall

For the wall height required and high lateral loads, a cantilever wall system was found to be uneconomical. Heavy precast concrete panel segments would also have necessitated the use of additional trucks for transportation and larger cranes for handling.

Tilt-up wall

This structural system was discounted on the basis that the props would either disrupt coal stockpile operations (if supporting panels from the outside) or complicate backfill and compaction of the fill material (if supporting panels from the inside).

Buttress wall

This structural system comprises four separate components – a cast insitu base slab, 1325mm deep x 350mm wide precast counterforts, 4.5m long x 225mm thick precast wall panels and upper and lower ties (required to resist sliding and overturning moments due to high lateral pressures from a heavy vibrating roller). The rail beam spans between counterforts so that the stacker load is transferred directly to the ground rather than by bending of the retaining wall. Grouted reinforcement couplers are required to maintain continuity of reinforcement between the wall/counterfort panels and the base slab. Similarly, the joint between precast wall panels and counterfort panels needs to be stitch-poured to ensure composite action between the individual components. Ultimately, this arrangement was not selected because of the delays associated with curing time for base jointing, concrete stitch joints and grouted bar couplers and the slow compaction of fill between counterforts due to the use of a small manoeuvrable roller.

Tied cantilever wall system

This structural system involves a conventional retaining wall with two upper ties and one lower tie. Advantages of this structural arrangement include simple construction method (minimal use of cast insitu concrete and other time consuming site-based activities) and good access for backfill and compaction.

Ultimately, the tied cantilever wall system was selected as the best compromise between desirable structural attributes and speed of construction, and resulted in a robust and practical retaining wall system for an industrial environment.

Design loads

Two of the dominant load cases for design of the bund were compaction pressures during construction and stacker wheel loads in service.

The stacker wheels exerted an equivalent uniformly distributed load of 300kN/m along each rail for the normal operating load case. Load combinations were assessed in accordance with AS4324 Mobile equipment for continuous handling of bulk materials.

Horizontal pressures on the wall due to vibrating rollers were calculated in accordance with the method described in Appendix J of AS 4678 Earth-retaining structures, together with a spreadsheet calculation method to derive the pressure in the case when the roller is a certain distance away from the wall.

The following construction load cases were considered in the

Figure 2. Typical section though Bund 5A.
Projects

Design of the Retaining Wall:
Case A: 16t roller up to the back face of the wall
Case B: 16t roller to within 1.5m of the wall and then a 5t roller up to the back face of the wall

For the tied cantilever wall system, the following results were obtained:

<table>
<thead>
<tr>
<th>Wall thickness</th>
<th>Base thickness</th>
<th>Panel weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case A: 350mm</td>
<td>350mm 13.9t</td>
<td></td>
</tr>
<tr>
<td>Case B: 300mm</td>
<td>300mm 12.2t</td>
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</table>

The cost savings in materials and transport and handling were deemed to offset the increased costs associated with the use of two rollers during backfilling operations and therefore final design was based on Case B.

Embankment Design

The presence of high bearing pressures beneath the base of the retaining wall and the proximity of wall to the edge of the embankment (approximately 500mm) meant that the design of the embankment required special attention. Two arrangements were designed and documented: a geogrid reinforced embankment and a cement stabilised embankment.

The geogrid embankment design involved passive synthetic reinforcement which improves stability by providing a resistive tensile force across the shear zone. Material specification requirements for the reinforcing elements took into account the potential for highly aggressive groundwater, the tropical environment with high ambient temperature and humidity, and the requirement for long-term creep performance. A trial embankment was specified so that the design partial factors used by the reinforcement supplier (including the amount of damage caused by backfill and compaction) could be verified for the locally obtained fill material (which was potentially harder and more granular than those materials for which partial factors are available).

A trial embankment was also specified for the cement stabilised embankment option (with cement contents ranging from 2% to 6%) to verify the cement content required to achieve the required geotechnical properties.

Ultimately, the embankment was constructed from cement stabilised rock fill based on construction program and cost.

Construction Issues

Following a formal tender process, BMD Group was awarded the contract for construction of Bund 5A. As a result of their competitive tender and performance on Bund 5A, BMD Group was subsequently invited to construct Bund 4A on a negotiated sole source basis.

Construction of the bund was constrained to some degree by the operations of the coal terminal and by the presence of other contractors on site at the same time resulting in limited lay down areas.

The contract for Bund 5A involved two separable portions: the first 200m of bund was to be completed early to enable erection of the stacker under a separate contract; and the remainder of the bund including rail beams and conveyor.

Precast concrete wall panels were cast off site in Rockhampton on their side and then transported to site where they were stockpiled on the ground (also on their side to avoid being tipped over in high winds).

The bottom photo opposite shows Bund 5A under construction with the embankment complete and precast wall panels in the foreground erected but not yet backfilled. Wall panels closest to camera were terminated at the top of bund level as these are located in an area where no coal is to be stockpiled.

Offshore Works

Description

The offshore works involve construction of a third outloading conveyor system including a 3.6km-long jetty parallel to the existing jetty, a fourth berth 420m-long capable of accommodating cape size vessels and approximately 12,500m² of reclamation to provide for onshore expansion works.

The new jetty comprises driven steel tubular piles and steel headstocks supporting a roadway and conveyor with 24m long spans between jetty bents. The roadway has an overall width of 4.3m and consists of seven precast prestressed concrete deck units, each 596mm wide, transversely post-tensioned. Passing bays are provided at regular intervals although it is intended to operate a one-way traffic flow in combination with the roadway on the existing jetty.

Berth 4 is of similar construction to the jetty with a steel skeletal support structure and precast concrete deck. Construction works for Berth 4 also include extension of the existing wharf conveyor and relocation of the existing L17 drive tower. The deck roadway width varies from 4.3m to 16.0m.

The offshore works involve significant quantities of concrete, both precast and cast in situ. In total, about 1640 deck units are required for the jetty, L17 drive platform and Berth 4 with a combined length in excess of 32km. The statistics for precast concrete deck units are summarised in the table on the next page. Cast in situ concrete is used for suspended floors in the transfer tower and drive towers.

Design Issues

Deck Units

One of the key considerations in design of the deck units was durability, particularly considering the project design life (50 years) and exposure in a tropical marine environment. In order to provide a durable concrete product, the material specification included limits on drying shrinkage of the aggregate and alkali content of all constituents, and a requirement for a minimum of 20% fine grade fly ash. In addition, regular drainage holes were provided in the deck to prevent water ponding (thereby limiting water ingress and the deleterious reactions that can result, especially due to the presence of sulphur in coal slurry).

Reclamation

Three-dimensional physical modelling was undertaken by the Water Research Laboratory at the University of NSW to investigate and optimise the design of the reclamation, more specifically the density and positioning of armour rock and concrete Hanbars. The study was conducted using a 1:42 scale model with various breakwater configurations subjected to a variety of wave climates (water levels and incident wave directions) with a 100 year average recurrence interval (ARI).
Summary of deck unit statistics.

<table>
<thead>
<tr>
<th>Location</th>
<th>No of deck units</th>
<th>Depth (mm)</th>
<th>Lineal metres (m)</th>
<th>Weight (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jetty</td>
<td>1073</td>
<td>800</td>
<td>25,278</td>
<td>23,700</td>
</tr>
<tr>
<td>L15 drive platform</td>
<td>171</td>
<td>450</td>
<td>2052</td>
<td>1100</td>
</tr>
<tr>
<td>Berth 4</td>
<td>396</td>
<td>500</td>
<td>5138</td>
<td>3000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1640</strong></td>
<td><strong>32,468</strong></td>
<td></td>
<td><strong>27,800</strong></td>
</tr>
</tbody>
</table>

Existing seawall prior to reclamation works.

The effects of different wave conditions occurring at different parts of the site were considered, allowing the Hanbar size and density to be reviewed for different locations.

The results of the physical modelling demonstrated that, in comparison with the existing seawall, the new seawall could be constructed with a reduced placement density of 5t and 11.5t Hanbars and still achieve the required immunity.

Even though the length of seawall was slightly increased, it was possible to reuse the majority of existing rock armour and Hanbars with only a minimal number of new units required.

Construction issues

The contract for OL3 Offshore was awarded to John Holland, which is constructing the wharf and jetty using traditional over-the-top construction techniques.

The reclamation work was awarded as a separate contract to BMD Group. This involved the relocation of 358 No. 5t Hanbars and 1246 No. 11.5t Hanbars and the manufacture and placement of 524 No. new 11.5t Hanbars. All rock armour was reused and fill material for the reclamation was sourced locally on site.

The reclamation works were completed in April 2007, with much of the work being undertaken during the wet season. As the works involved the removal of rock armour and Hanbars from the existing seawall, there was a period of time during which the existing facilities were potentially exposed. Project risk mitigation strategies included a rapid construction program and partial construction of the new seawall in front of the existing seawall to provide some degree of protection prior to removal and relocation of the existing armouring.

Concluding remarks

The DBCT 7X Project is not only a major project involving interfaces and interaction between multiple contractors but also has the complexities associated with brownfield work resulting in challenges to the designer and contractors alike. The project is ongoing with construction scheduled for completion late this year.

Acknowledgements

The design of the concrete structures presented in this paper result from the combined efforts of a team of structural engineers and drafters from Connell Hatch with input from the terminal owner (BBI) and terminal operator (DBCT Pty Ltd).

The author gratefully acknowledges the roles of all parties and the permission of BBI to publish this paper.
Use of fault tree analysis in risk assessment of reinforced concrete bridges exposed to aggressive environments

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RMIT University, Melbourne, Victoria, Australia

This paper was presented at ISEC-4, the 4th International Structural Engineering and Construction Conference (organised by RMIT) in Melbourne, 26-28 September 2007.

Deterioration of reinforced concrete bridges when exposed to aggressive environments

Strengthening and rehabilitation of distressed reinforced concrete bridges costs millions of dollars in Australia. Deterioration of reinforced concrete bridges can often be related to deficiencies in durability of the concrete, resulting from the composition of the concrete, poor quality control and the aggressive environments which they are exposed to (VicRoads 1995). Evaluation of the risk of failure of these bridges is of importance in decision making in relation to different rehabilitation options for managing aging bridges.

A reinforced concrete bridge can deteriorate in service if its quality does not match the environment to which it is exposed. The environment mentioned in this research generally includes some combination of the following (Guirguis 1980):
• cycles and gradients in temperature and humidity
• gases in the atmosphere such as CO₂
• chemical in solution such as chloride ions in seawater.

Risk assessment using fault tree analysis

Risk is measured in terms of a combination of the consequences of an event and its likelihood (AS/NZS 4360 2004). Likelihood is a general description of probability describing the uncertainty of an event. Consequence is the outcome or impact of an event. Considering an activity with only one event with potential consequences C, the risk R equals to the probability that this event will occur P multiplied by the consequences – ie:

\[ R = P \cdot C \]  

A fault tree is a model that logically and graphically models various combinations of cause-effect relationships involved in causing the undesired event by using logic gates and fault events. The symbolic notations of fault tree in common use are illustrated in Table 1.

Fault tree analysis is the process to convert this graphical model into a mathematical model to compute failure probabilities and system importance measures (Ericson 2005). The equation for an AND gate is

\[ P = \prod_{i=1}^{n} p_i \]  

and the equation for an OR gate is

\[ P = 1 - \prod_{i=1}^{n} (1 - p_i) \]  

where n is the number of input events to the gate, \( p_i \) are the probabilities of failure of the input events and it is assumed that the input events are independent (Faber 2006). Fault tree analysis can be used for risk assessment based on the likelihood and consequence ratings of various events of fault tree (Williams et al 2001). Likelihood estimates are assigned to basic events of the fault tree while consequence ratings are assigned to each failure mode (Creagh 2006, Vick 2002). In the fault tree, the likelihood of each failure mode can be estimated by converting the AND/OR Gates into mathematical equations as mentioned above. Therefore risk can be assessed using the equation 1.

Using fault tree analysis for bridges

Sianipar (1997) has pointed out that fault tree analysis can be used to represent and quantify the interaction phenomena in a bridge system. A research of fault tree analysis on bridges is completed by Johnson (1999) in analysis of bridge failure due to scour and channel instability. As scour at bridges is a very complex process, Johnson used fault tree analysis to examine possible interactions of scour processes and their effect on bridge piers and abutments. The probabilities of basic
events in the fault tree were evaluated by simulation of scour equations presented in other researches. He also stated that it is possible to examine a more complex fault tree that would lead to a bridge failure. Another fault tree model of bridge deterioration has been developed to calculate the probability of bridge deterioration by LeBeau and Wadia-Fascetti (2000). The probabilities of basic events were obtained by assigning questionnaires to seven bridge engineers and inspectors. A comparison between the efficiency of different rehabilitation alternatives also has been evaluated. However, the probability of deterioration is obtained under a number of assumptions on bridge structures and exposure environment is not considered in this model.

Proposed method

Development of the complete fault tree for a bridge

A reinforced concrete bridge is comprised of superstructure and substructure which can also be further divided into several components, as shown in Figure 1. The top event of this fault tree is defined as bridge failure due to poor durability. Each of the components of failure A-E can be decomposed further. This is an overall frame of the fault tree model. After fully examining each component of failure, the overall failure risk of a bridge can be assessed.

The fault tree method concerns all the possible conditions that could lead to the occurrence of major distress mechanisms, the output risk ratings can be regarded as a prediction of the performance of the bridge or bridge components during service life.

The model also can be used to rank the risk of failure of a number of bridges based on sufficient construction and inspection data.

Parameters needed to establish a risk ranking of bridges

To analyse the failure risk of a bridge or a selected bridge component, information on the elements being assessed is needed. This will require information on:

- major failure modes;
- the likelihood of the factors that contribute to each of the major failure modes;
- the consequences of each of the failure modes.

Following sections will describe the method to acquire these parameters respectively.

Considering major sub-tree of the entire fault tree

At this stage, the research mainly focuses on the sub-tree related to pier deterioration for several reasons. Piers are crucial components in a reinforced concrete structure. They are usually located in the tidal, splash or submerged zone which is directly exposed to an aggressive environment. Thus the problem of pier deterioration is considered as a major issue. By examining the pier branches, the analysis of pier conditions can be accomplished which might reflect the durability of the bridge at a certain extent. Other components failure can follow the same path to composition and analysis to get an overall risk of an entire bridge. Figure 2 shows the sub-tree of piers mentioned in this research.

Application of the proposed method

Fault tree for failure of piers

Based on literature review and case studies, the following distress mechanisms were identified:

- chloride induced corrosion
- alkali-Silica reaction
- carbonation
- stress corrosion of reinforcement
- plastic shrinkage.

These major distress mechanisms were selected as key failure modes because they obviously indicate deficiencies in material durability of reinforced concrete bridges. They can often lead to cracking, spalling, honeycombing of concrete and significant reduction of structural safety (Venkatesan et al 2006). Figure 3 presents the fault tree for piles deterioration.
Analysis of major failure modes

The occurrence of major failure modes is related to complex interaction of various factors. These variables can be grouped into (Ropke 1982; Rendell et al 2002):

- applied loads
- material variables, such as concrete strength, compaction, permeability
- design variables, such as size of aggregate, depth of concrete cover
- exposed environment, such as climatic condition, aggressive sources and element position
- construction and curing.

Table 2. Events table of fault tree for ASR on piles.

<table>
<thead>
<tr>
<th>Events</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASR</td>
<td>Alkali-silica reaction</td>
</tr>
<tr>
<td>A1</td>
<td>Reactive aggregate</td>
</tr>
<tr>
<td>A2</td>
<td>Excessive moisture</td>
</tr>
<tr>
<td>A3</td>
<td>Poor material</td>
</tr>
<tr>
<td>A4</td>
<td>Improper admixture</td>
</tr>
<tr>
<td>A5</td>
<td>Permeable concrete</td>
</tr>
<tr>
<td>A6</td>
<td>Crazing due to plastic shrinkage</td>
</tr>
<tr>
<td>A7</td>
<td>Improper water cement raction design</td>
</tr>
<tr>
<td>A8</td>
<td>Improper construction and curing</td>
</tr>
<tr>
<td>PS</td>
<td>Plastic Shrinkage</td>
</tr>
<tr>
<td>PS1</td>
<td>Arid environment</td>
</tr>
<tr>
<td>PS2</td>
<td>Improper curing</td>
</tr>
<tr>
<td>PS3</td>
<td>High wind speed</td>
</tr>
<tr>
<td>PS4</td>
<td>Low relative humidity</td>
</tr>
</tbody>
</table>

Fault tree construction

As mentioned above, chloride induced corrosion, ASR, carbonation, stress corrosion and plastic shrinkage were identified as major failure modes for the sub-tree of pier elements condition. In this paper, ASR on piles provides an example for the construction and analysis of the fault tree model. Other failure modes were analysed using the same approach and the outcome is shown in Figure 7.

Table 3. Likelihood Ratings.

<table>
<thead>
<tr>
<th>Likelihood Rating</th>
<th>Description</th>
<th>Log Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Low</td>
<td>Low likelihood of occurrence</td>
<td>0.001</td>
</tr>
<tr>
<td>2-Medium</td>
<td>Moderate likelihood of occurrence</td>
<td>0.01</td>
</tr>
<tr>
<td>3-High</td>
<td>High likelihood of occurrence</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Table 4. List of likelihood of A3 according to exposure classification.

<table>
<thead>
<tr>
<th>No</th>
<th>Exposure classification</th>
<th>Likelihood of A3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Below low water level (submerged)</td>
<td>High</td>
</tr>
<tr>
<td>2</td>
<td>In tidal zone (also wetting and drying zone)</td>
<td>Medium</td>
</tr>
<tr>
<td>3</td>
<td>In Splash Zone</td>
<td>Medium</td>
</tr>
<tr>
<td>4</td>
<td>In Splash - Spray zone (also wetting and drying zone)</td>
<td>Medium</td>
</tr>
<tr>
<td>5</td>
<td>In splash-tidal zone</td>
<td>Medium</td>
</tr>
<tr>
<td>6</td>
<td>Above Splash zone</td>
<td>Low</td>
</tr>
<tr>
<td>7</td>
<td>Well above splash zone (nearly top deck)</td>
<td>Low</td>
</tr>
<tr>
<td>8</td>
<td>Benign Environment</td>
<td>Low</td>
</tr>
</tbody>
</table>

Using fault tree analysis to calculate the overall likelihood of each failure mode

As it is not a very complex fault tree, the overall likelihood of failure modes can be calculated using equation 2 and 3. The approach starts with the basic events and goes through the fault tree to the top event. The probability of occurrence of the top event in Figure 4 can be evaluated by the following steps:
Semi-quantitative inputs of consequence ratings

Consequence ratings of failure modes are required to be assigned by experts, considering the effects on load capacity, the severity of expenditure of retrofitting or rehabilitation, and so on, as shown in Table 5.

The model converts these ratings into numerical ratings based on the same logarithmic, three point scale as likelihood ratings. Table 6 shows the opinion of a CRC research team on the consequence ratings for the failure modes of piles malfunction. The value of consequence can also be determined by assigning questionnaires to a group of experts and bridge inspectors, using weight factors to achieve a more reasonable result.

Risk ratings

Given the all the likelihoods and consequences available, risk is calculated using equation 1. In the output, the numerical risk is converted back into risk ratings on a scale from 0.0 (very low risk) to 3.0 (highest risk), shown in Table 7.

In order to exclude the difference resulting from disparate fault tree structures and to achieve more comparable results, the risk ratings for each failure mode have been normalised by assigning 3.0 to the one with the highest inputs and apportioning other results relative to this highest value.

Model outputs

Calibration using a case study

The model was applied on the piers of a case study bridge to calibrate model results against experimental data. Cracking defects of the piles and pilecaps of the case study bridge were
observed. It was concluded in a report of condition review that the pier pilecaps were suffering from chloride induced corrosion while the primary reason for cracks on piles was ASR (from personal communication with Dr John Fenwick of the Queensland Department of Main Roads).

The report provided most data for inputs of the risk assessment model. The remainder unspecified likelihoods were assumed to be “medium”. Headstocks and columns were not assessed because the report does not mention any details for them. In this case study, the risk of stress corrosion is assumed to be “low” by reason of insufficient data about the properties of the steel. To avoid overlooking the high risks of individual failure modes, both individual risk ratings and total scaled risk ratings are required when comparing between projects or bridge components. As presented in Figure 7, the primary failure mode of piles is ASR with a “high” risk and other failure modes all have acceptable risks. For pilecaps; chloride induced corrosion is the major problem, followed by ASR, with questionable risk. The result of total scaled ratings indicates that pilecaps have a higher risk of failure than piles.

![Figure 7. Risk ratings of case study bridge piers.](image)

**Sensitivity analysis**

Sensitivity analysis of likelihoods and consequences mainly focuses on their contribution to total risk rating. Consequence ratings for each failure mode are the most sensitive factors. Changing the consequence rating will result in a notable difference in total risk rating. In the likelihoods of various basic events, the ones in the material properties group are the most influential contributors. The use of poor material will produce a significant risk of poor performance and durability. The risk will be more severe if the bridge element is exposed to an aggressive environment.

**Conclusions**

The paper has demonstrated a structured method of ranking the performance risks of distressed reinforced concrete bridges. Fault tree analysis has been used to model the likelihood of occurrence of major distress mechanisms. This model can be used to identify the important risks for particular bridge components and their relative severity and to rank the performance trends of bridges. At this stage, this model has many limitations as it examines only several major distress mechanisms and neglects many others. It requires highly detailed information to estimate the likelihood of various basic events of different components of bridges. The result of the risk analysis is very sensitive to the consequence ratings. The accuracy of the model could be substantially enhanced by using five point scales in the assignment of likelihoods and consequences, as well as establishing more specific and authoritative guidelines for the assignment.

**Acknowledgement**

Dr John Fenwick, of the Queensland Department of Main Roads, is kindly acknowledged for provision of data for this work.

**References**

1. AS/NZS 4360, 2004 Risk management, Standards Australia.
9. Personal communication, Dr. John Fenwick, Queensland Dept. of Main Roads.
Saw cutting of green concrete pavements

by John Crocker

How concrete is treated in the first 24 hours of its life often determines future sustainability. Under normal climatic conditions, and when left to its own devices, concrete will crack randomly at about 4m centres within 24 hours of casting. This is a result of drying and shrinkage. To control random cracking, engineers usually specify the installation of a saw cut to a depth greater than that of the deepest preexisting crack or defect and at an appropriate time (usually 6 to 10 hours after casting).

Depth of saw cuts

Cracking commences at the top of the slab and works its way down to the substrate. By installing a saw cut very early, the crack will commence at the base of the saw cut and thence to the substrate.

Most engineers prefer slabs to be cut to a depth which is 25% of the total slab thickness (ie D4) and deeper than the maximum aggregate size. The maximum aggregate size is strongly linked to the depth of pre-existing cracks or defects. For example, on a 200mm-thick industrial slab, if the depth of drying is 30mm and a 20mm aggregate has being used, then the saw cut should be 50mm deep (D4).

Saw cut grid or plan

Concrete left alone will crack randomly at about 4m centres. Therefore many engineers design to a 4m grid plan. If due care is taken during the casting and finishing processes and saw cuts are installed at the appropriate time, grid plans can be extended to 6m, but no further.

Due care is taken to include:
• adequate pre-placement preparation of substrate, formwork, reinforcing, etc
• monitoring of a bleed sample
• the constant use of aliphatic alcohol

• adequate vibration procedures
• good surface compaction with either screed or power trowel.

Timing of saw cuts

Timing of saw cuts is critical. The earlier a saw cut is installed the shallower the cut needs to be. The later a saw cut is installed the deeper the saw cut needs to be. Pre-existing cracks deepen with the depth of drying (see Figure 1). The following aspects of timing are critical.
• Design engineers usually allow for a “cutting window” (sometimes referred to as “the green zone”) of between three and five hours (see Figure 2)
• If the cutting is too early, coarse aggregate particles are dislodged causing raveling and/or spalling
• If cutting is too late, unplanned and/or random cracks will occur
• The correct time to install saw cuts varies from day to day,
depending upon prevailing weather conditions
- The type of concrete saw being used will also have an effect on timing—for example the dry cutting Soff-Cut saws (with patented skid plates) are usually able to finish several hours before conventional wet cut saws can commence.

**Cutting procedure**
- Appropriate personal protection equipment must be worn at all times.
- The saw cut grid should be pre-marked with a chalk line.
- Choose the appropriate blade type for the concrete being cut (ie aggregate hardness).
- Saw cutting should commence in the area of the slab where concrete was first placed and then follow the placement sequence.
- Sacrificial joint protectors should be inserted at cross cuts to prevent the forming of weak triangular shaped corners.
- Damp concrete residue (Soff-Cut saws) or wet concrete slurry (conventional wet cutting saws) should be collected and disposed of in accordance with the EPA requirements for each particular site.

**Curing**
- An approved curing compound should be applied to the concrete as soon as possible.
- Where Soff-Cut saws are being used the saw is basically following the power trowel "up the slab" (see Figure 2). Therefore, it is acceptable, in these circumstances only, that the curing compound be applied after the Soff-Cut saw has completed its task.

On sites where conventional wet cutting saws are being used curing compounds should be applied immediately the surface compaction (ie power trowel) process has been completed.

John Crocker is product manager of Soff-Cut Systems – Asia Pacific for Husqvarna Construction Products Australia.

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This Handbook is the first on the market specifically devoted to all aspects of Australian precast concrete construction including design, specification, manufacture and installation. It reflects current industry best practice featuring the latest innovative applications of precast concrete ranging from simple structural elements to industrial and skeletal frame buildings, to decoratively finished complex-shaped architectural facade panels and sophisticated bridge girders. It provides guidelines in the form of graphs, charts and worked examples to assist in the design of precast concrete structures in accordance with AS 3600-2001. The Handbook is intended for architects, engineers, quantity surveyors and students as well as those involved in the building, infrastructure and construction industry.
The study sets forth an experimental analysis aimed at evaluating the use of by-products of industrial processes, in particular two types of sands coming from cast-iron processing (called foundry or mould sands and sandblast sands), to partly replace the stone aggregates used to mix concretes going to build reinforced or prestressed-concrete structures. The purpose is to reduce the amounts of material thrown away and raw materials used. The economic advantages include diminishing the cost of waste disposal and of procuring natural aggregates.

**FIRE RESISTANCE; SPALLING**

The fire resistance of reinforced concrete structures

Plank R

Accession Number: 013978

Concrete 07: Adelaide SA, 18-20 October 2007, pp 731-739

Reinforced concrete building structures have traditionally been designed for fire resistance using very simple approaches. However, there is a growing recognition that these methods may be oversimplified and that more sophisticated approaches could offer advantages by providing a more complete picture of likely behaviour. This paper reports on recent research into the performance of reinforced concrete structures in fire, illustrating the effects of two important phenomena – spalling and diaphragm action – not accounted for in the current simple approaches. These have been modelled using a highly non-linear finite element analysis developed specifically for structural fire engineering.
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Georgiou Group

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QR Concrete
Robert Bird Group
Rocla
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The Rix Group
Thiess
The Reinforced Earth Company
Thomson White Australia
VicRoads
Wood & Grieve Engineers
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Platinum Members

Gold Members

Silver Members
Permeable concrete segmental paving was first applied in Europe almost 20 years ago. Research into permeable paving began in Australia in the early 1990s and was directed both to adapting permeable paving to suit Australian climates and rainfalls and to providing fundamental information for the design of permeable pavements to carry traffic. This work, taken in conjunction with overseas investigations, means that there is now a substantial body of information that can be used in the design and application of permeable concrete segmental pavements under Australian conditions.

The seminar begins by exploring the options for water sensitive urban pavement design. Permeable pavement systems provide sustainable options for stormwater management – flood control, water quality and water harvesting. Design criteria for these options are included in the PERMPAVE ® software.

PERMPAVE ® software has been developed by CMAA and the University of South Australia to provide the hydrological design inputs and requirements for concrete segmental permeable pavements incorporating storm data from “Australian Rainfall and Runoff” publication.

LOCKPAVE ® software – structural design for concrete segmental pavements, is discussed. This software has recently been upgraded by Dr Brian Shackel to incorporate design procedures, methodology and material specifications for PCSPs.

NOTE: Each registrant will receive the PERMPAVE/LOCKPAVE package included in the registration fee. (RRP $100)
WATER SENSITIVE URBAN DESIGN
Permeable Concrete Segmental Pavements
Introducing Hydraulic and Structural Pavement Software

SPEAKERS

- **Alan Pearson**
  BE MBA FIEAust CPEng
  Executive Director, Concrete Masonry Association of Australia.
  A Fellow of the Institution of Engineers of Australia, Alan is a graduate in Civil Engineering from the University of New South Wales.

- **David Pezzaniti**
  BEng MIEAust
  Technical Manager, Centre for Water Services and Systems, University of South Australia.
  Senior Research Engineer specialising in water conservation and reuse. His research interests include: harvesting, treatment and reuse at all catchment scales; Integrated Institutional Frameworks; infiltration systems; irrigation systems and continuous simulation modelling for reuse. His expertise also extends to grey water reuse, hydrology and runoff pollution control.

- **David Smith**
  Technical Director, ICPI - USA
  Having helped launch the Interlocking Concrete Pavement Institute (ICPI) in 1993, David Smith's experience with segmental concrete pavements reaches back to 1977. He has authored many technical papers, publications, books and manuals, including one on permeable pavements. Permeable pavements are one of the fastest growing sustainable pavements in the US and Canada.

- **Dr Brian Shackel**
  Visiting Professor Civil and Environmental Engineering UNSW - BEng(Civil), MEngSc in Highway Engineering, PhD. He has lectured on pavement engineering in some 23 countries worldwide and is author of many learned technical papers. His book on Concrete Block Pavements has been republished in both Japanese and German editions. Dr Shackel also developed the LOCKPAVE® concrete segmental pavement design software, now used and licensed in Australia, Europe, USA, Africa, Japan and Asia.

Continuing Professional Development (CPD)

Attendance may be credited towards Engineers Australia and other organisations' CPD requirements. (Engineers Australia members are required to undertake a minimum 150 hours of equivalent CPD every three years.)

REGISTRATION (Please return 7 days prior to the event to Concrete Institute of Australia)

I wish to attend the seminar and/or workshop on:

- Friday 7 March 2008 Sydney
- Tuesday 11 March 2008 Melbourne
- Thursday 13 March 2008 Brisbane
- Monday 17 March 2008 Cairns

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Registration fees must be paid prior to the event or at the event. Cancellations less than a week before the event will not be subject to a refund. All fees are GST inclusive – tax invoices provided on request.

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