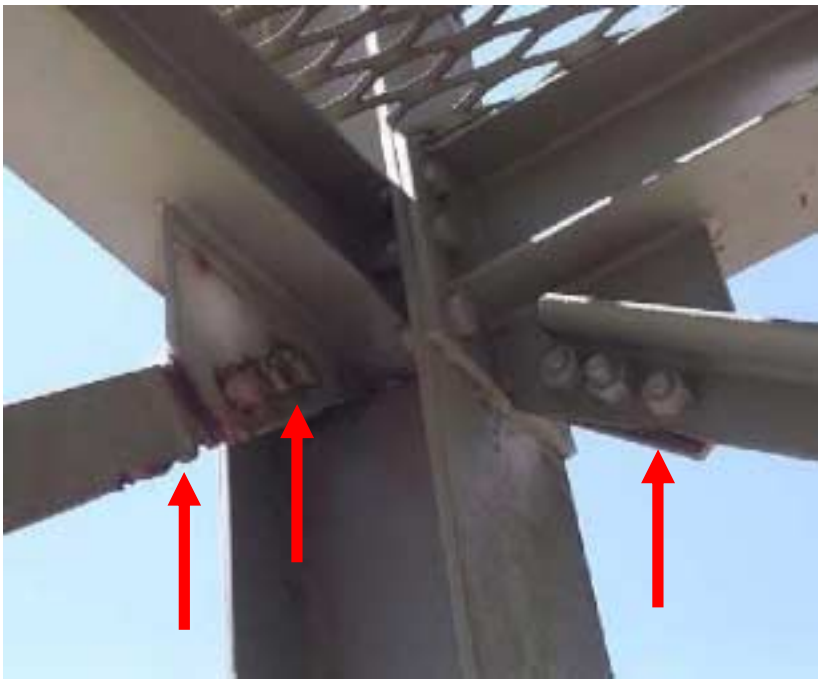
Industrial Maintenance Roundtable NSW
Common Interest Workgroup (CIWG) Report
from Meeting on Maintenance 7th May 2008

Maintenance and Reliability of Structures CIWG



This document is compiled from discussions during the NSW IMRt Common Interest Workgroup (CIWG) on 7th May 2008.

Document Compiled by Peter Todd - NSW IMRt Facilitator

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Maintenance and Reliability of Structures

Attendee List

Attendee	Organisation
Rod Byne	Blue Circle Minerals
Garry Bell	Blue Circle Minerals
Mark Dobbins	Bluescope Steel
John Read	Bluescope Steel
Hans Zandbergen	Boral Quarries
John Benson	Boral Quarries
Craig Blackburn	Delta Electricity
Noel Fitzgerald	Eraring Energy
Paul Soldas	Grain Corp
Glenn Bigland	Grain Corp
Jan Van Heerden	Illawarra Coal
Paul Spencer	OneSteel
Troy Page	Orica/ WorleyParsons
Mark Brennan	PWCS
Elliot Burns	PWCS
Bart Cupitt	Qenos
Duncan Romoser	Qenos
Peter Todd	SIRF Roundtables
Michelle Todd	SIRF Roundtables
Ed Rueda	Sydney Water

Introduction

The NSW Industrial Maintenance Roundtable (IMRt) held a Common Interest Work Group (CIWG) meeting on Maintenance and Reliability of Structures focusing on how best to maintain the condition of structural steel and concrete assets. This meeting was held on the 7th May 2008 at the Asquith Leagues Club near Hornsby. The meeting was attended by 20 people from 13 different organisations. The information and ideas included in the document came directly from the discussions that took place at the meeting. The NSW IMRt has not held a CIWG meeting on this topic previously).

The meeting started at 8.00am with discussions on steel structures and their maintenance and repair. This moved onto concrete structures after morning tea, with a few other structural issues were covered after lunch, finishing before 2.00pm.

The IMRt is a maintenance networking organisation coordinated by SIRF Roundtables (SIRF Rt) www.sirfrt.com.au . This report gives feedback to meeting attendees and other interested parties. The meeting included the development of a comparison matrix, which is shown on the following page. This matrix was filled out by attendee organisations to enable comparisons to be made between organisations on the issues discussed.

Structures Comparison Matrix

Structures Comparison Matrix	Eraring Energy	Qenos	PWCS	Blue Circle - Minerals	West Cliff Colliery	Boral Quarries	Bluescope Steel	Grain Corp	Sydney Water
What steel structures/ components cause the most problem and what types of problems do they have?	- Exposed purlins & girts - Corrosion - Steel Sheeting - Corrosion - Dissimilar metals	- Columns Supporting Silos - corrosion of bolting - Corrosion @ feet/ pedestals (water, ash, debris buildup) - Structural corrosion under fibreglass lagging - Internal corrosion of handrails	- Transfer houses/ Conveyors/ Machines - Corrosion - Reliability - Maintenance/ Inspection Strategies	- Buildup around Base of Columns - Corrosive Materials - Dust buildup behind Cladding	- Conveyor Gantry and platforms - Coal Bins	- Corrosion - Particularly in wet plants - Impact damage from loaders and trucks	- Column bases - Corrosion on steel facing ocean side of plant. - Overload or impact damage - Conveyor structures	- Silos (Paint) - Shiploaders - Paint, Corrosion/ coastal - Cladding - corrosion - Chutes/ elevators/ gantries - corrosion	- Pipelines & aqueducts - Corrosion - Access - Vandalism/ Graffiti
What Concrete structures/ components cause the most problem and what types of problems do they have?	-Suspended Slabs - Chloride attach - tropical type misted salts in the air	- Wall openings - forklift damage - Concrete roofs - Exploding reo - Penetrations - Exposed reo corrosions	- Reinforced conc. Tunnels/ Foundations - Cracking - Water ingress - Rio deterioration - Maint/ Inspection: Develop strategy & integrate with Maint Management Systems	- Water under footings causing subbase failure	- Winder headgear - Concrete Cancer - Shaft concrete lining	- Damage around base plates from loader doing cleanup work	- Underside of channels, ducts, cellars etc with bottom cover separating reo expansion - Pile cap/ column base cracking	- Silos - corrosion - W/B foundations (Qld) - poor design - Falling concrete	- Sewer wet wells - concreter corrosion - chemical attack - Above ground pipelines, aqueducts & supports - Cracks - Spalling - corroded reo bars
Who inspects your structures and who does the technical assessment of problems found?	- Clerk of Works (internal) - Specialist material consultants	- Kellogs Brown & Root (KBR) Structural Engineers - In-house engineers - Tradespeople (ad hoc)	- Anyfab (Technical Inspections) - In-house engineering evaluation - External Consultants (Inspect and Assess)	- In-house inspections - PM's - Group Engineering	- Engineers - Consultants (Hatch Canada)	- External structural engineer	- Wide range from trades & employee engineers, ext contractors including PEA,Hatch, Forbes Rigby. - In-house engineering, then external for solutions	- Shiploaders - NDT consultant (10 years) - Tradesmen - Engineers by exception only	- Level 1 civil inspection - yearly program by trained graduate engineers - Review by structural specialist (internal) & external consultants as required
What system is used to store, analyse and trend structural problems?	- Database on server	- Spreadsheet of Alet work drives and hard copy files - Gradually moving to storage within CMMS	- Maint Management System (Maximo) - PWCS Asset Management Strategy	- Maximo	- SAP - Reports (hard Copy) - Photo's - Spreadsheets - Network Drives	- We don't have a documented system. Just rely on regular inspection - MEX and eAM CMMS to store data	- Local databases, SAMS, FAARMS, SAP. Moving towards 1 system (SAP) (mainframe based)	- Records are stored - PM system for tradesmen - Not enough data to trend	Inspection and condition assessment records stored & managed using MS Access database
How do you specify the severity and risk from structural problems?	Condition Assessment System 1 - Bad -3 to +3 Good System 2 - 5 steps from Low to High - Low priority = 3 to 5 year review and High Priority = Urgent Business Function Priority P1 Safety P2 Environment P3 Business Continuity	- Analogy & Comparisons - Time within which repair/ remediation is required - Subjective prioritisation	- Risk Assessment - Formal Structural Reviews	- Maximo Risk Ranking	- Use BHPB risk rating system - Probability x Exposure x Severity Severity: Safety, Environment, Cost $	- Structural inspection report provides risk ranking and time frame for rectification work.	- BSL Division policy with 5x5 matrix: Consequence x Likelihood = Risk - Considers Safety, Environment, Business, Outrage - Risks managed with 'Harminie" database.	- Current Risk assessment matrix	- Condition grades 1 to 5 - 1 Excellent - 5 Worst condition - Consequence Impact of Failure - Low, Medium & High - Risk score = Grade x Consequence

Steel Structures

Quantifying Asset Structural Condition and Justifying Maintenance

Troy Page talked about some work Orica is currently doing to help decide how to determine how bad a structure is and what its remaining life is. The question is, what data do you need to answer the question of "When will the deterioration have reached the stage that it is critical and 'must' be repaired". Historically Orica did regular structural inspections that had conservative recommendation specifying repairs that were required. The problem was, when they were not acted on, nothing negative occurred. This engendered a management attitude of not trusting structural recommendations. Orica is now trying to determine how to make structural recommendations that can be trusted. The recommendations should give the current asset condition, the expected condition in 2 years time and what needs to be done. The analyses involves collecting data on section loss, corrosion rate and actual loads on the structure. The most difficult information to determine is corrosion rate data, as the published standards do not cover the range of option found in a plant like Orica's. The structural standard that is available is only a starting point. On-site corrosion mapping, testing, trending and review of local history is required to confirm actual site corrosion rates. Just because a structure has deteriorated, does not mean it will fail.

On the question of who and how structural inspections should be done, Mark from PWCS suggested that to manage an asset properly, as well as operators and local plant people finding problems, there should be a system of planned structural inspections. The outputs from these inspections should be what repairs are required, the required timing of the repairs and when you need to reinspect. The inspection system should be a part of an overall asset management strategy. The inspections should quantify the current condition of the steel structure and then, using models using section loss rates etc, as discussed by Troy, future condition should be estimated and prioritised repairs be proposed based on the overall strategy. If long term condition of the structure is important then repairs are best carried out while blasting and painting will control deterioration and before more major repairs are necessary. Having boiler maker cutting, over-plating or replacing items becomes hugely more costly compared to the option of doing cleaning and painting early. Once you have established your asset condition, set an overall strategy and estimated the future structural condition, you can produce a 5 year budget to minimise risk and future liability. With this type of information you can say, if you don't spend this amount of money soon, then you will generate a specified amount of future financial liability. People understand the "a stich in time saves nine" effect. It is all about managing risk and liability.

It was suggested by Mark Dobbins from Bluescope Steel that the problem with structures is that the deterioration occurs so slowly and to management, there always seems more important things to spend the available money on. When a section of plant has problems with their production equipment, then they readily take money from the structural budget. Bluescope has many old structures that are subject to corrosive environments and mobile equipment damage and there have been close calls with structural problems in the past. One issue they have is that the priority of structural problems vary across their plant and does not always match the local budget available to get the problem under control. They are working on a model that takes into account the risk of structural failure, the severity of the fault, the importance of the structure and what sort of remedial options that are available. The model is in its infancy but at least it can generate a prioritised list of problems and to make sure the available money goes to address the tip 10 or top 15. If the 16th priority problems has a

structural failure, then at least you have done your best at trying to avoid disasters. Bluescope do a lot of work on risk assessment focusing on Safety, Environment and Business but there is also lots of work done on the remediation options available. The Structural Strategy for an area is also important. If a structure will only be required for another 5 years then it changes the requirement significantly.

Bluescope use Hatch to do their structural inspections and they use a risk rating from 1 to 10 where 8 is something that you need to get to fairly quickly. They had a structural failure on their F33 conveyor which had been only rated as a 6 and so should have been safe for quiet a while. What had occurred was that there was buildup of spillage on the structure and so the inspection was not able to identify its condition effectively. This was identified as a common problem for a number of the meeting attendees. One technique was to use water blasting to clean a structure so that it can be inspected effectively and where necessary to form a scope of work for repair. The comment was made was that it would be nice to do some painting after the water blasting but often there is not the budget to do both. A number of horror stories were mentioned such as where cleaning had unearthed beams with no webs left or where columns were in the state of collapse. The suggestion was made that if cleaning is to be carried out where corrosion damage is likely, to include an allowance/contingency for urgent painting or repair.

As well as the Hatch 1 to 10 structural condition rating system mentioned above, there was mention of simpler 3 level condition assessment systems or the Boral Structural Inspection standard in Appendix 1 is an example of a 5 level system.

Inspection of Steel Structures

Paul from Grain Corp raised the question of who is used to do inspections on steel structures. The 4 levels of inspection options discussed are:

- Local tradesmen (eg.$60/hr) utilising the CMMS or other PM system to specify the inspection. Need to be trained if not already experienced.
- Structural Associates. Specialist inspection personnel/ structural auditors (usually external). Does not need to be an engineer but must have extensive experience in structural inspection. Will find problems, quantify the condition of structures and recommend when to be reinspected (will usually not recommend repair/ remediation methods or prioritise actions)
- Structural engineer to do the inspection (eg.$120/hr). The advantage of using engineers is they can estimate remaining strength in structures, cost repair/ remediation options and prioritise repair/ remediation actions.
- Specialist Structural Consultant. Used for difficult or high cost problems or where an independent opinion is of value. Can be used to help setup Structural Asset Management strategies and to audit effectiveness of implementation.

Unless a local tradesman is trained and has an assessment standard then it was suggested that structural engineers are probably better value as they can as well as assess condition, they can assess the business risk of further deterioration, propose repairs/ remediation options and produce cost estimates for the options.

An number of attendee organisations such as PWCS, Sydney Water and Boral used local trades personnel to do the first level inspections, which has the advantage that they find where the more serious problems are to focus further assessment. It was suggested that there

should higher levels of structural engineering assessment for structural problems where repair costs are significant. An advantage of using an external assessment is that an external assessment often holds more weight with management and is more likely to get approval.

There is structural awareness courses run at TAFFE that are useful. Appendix 2 shows some structural training material used by Sydney Water. Ed from Sydney Water discussed how their strategy is based on a 5 year plan. Their program uses Level 1 structural inspectors making assessment of structures and grading the condition from 1 to 5 with level 5 being an issues that needs to be addressed immediately. Level 3 or 4 issues get referred to their internal structural engineers and if required would be referred to a structural consultant for investigation. Structural problems that need repairing/ remediation are put together as a package of work to be contracted out.

Baseline Surveys

It was suggested that if there are not reports available that effectively documents your structural assets condition, then a Baseline Condition Survey should be carried out. This should include a Structural Engineering review and should be used to trend all future structural condition changes from this baseline. Troy from Orica suggested the baseline survey report should specify the criticality of specific structures and how often they need to be inspected. Where the consequence of unexpected failure is low, then very infrequent or no inspection is required. For structures where the risk is higher then inspection frequency can be set from expected deterioration rate. Orica use a one page flow chart for this assessment process.

PWCS, Bluescope and Eraring also spoke about their use of a Baseline of Structural condition. All used it as a global look at structural risk, structural condition, current action priorities and a strategy to move forward. Once information has been brought together in the baseline, it can become part of a longer term system of maintaining continuity and traceability for your structural asset strategy. Eraring are using a standalone database to track the condition of there structural assets & buildings and it stores asset criticality information and what repair work has been carried out. Bluescope use Hatch to do structural auditing and they have a database systems called FAARMS that is used to collect structural condition data to help generate structural reports but it is not used as a history system. It can attach pictures and display rating but it does not store history for trending. The Bluescope Coke Ovens area have there own system called SAMS to help collect and report on their structural problems (see Appendix 3) and is designed similar to the Eraring system to track history. If a problem with a beam is identified then the system tracks the deterioration and repairs carried out. Storing a history of photos can dramatically helps this, as the assessment of condition deterioration can be judged against previous photos rather than from memory or previous text description. One comment was that storing lots of pictures over time require significant disk storage capacity.

Mark from PWCS was involved with setting up a Structural Database system at OneSteel Rod and Bar Mill that used an SQL database. The system included data on risk assessment, area of plant, sub area, grid prosition, level and structural member, photos and links to reports and drawings. Maintenance had access to complete repair information and had a good search function. This system was very useful.

Protecting Steel with Coatings

Mark from PWCS suggested that there are some sophisticated coating available including iron oxide, zinc or epoxy based systems and their use, where specified well, is an excellent way to protect steelwork. He indicated that Port Waratah are constantly blasting and painting steelwork. Glenn from Grain Corp made the point that one problem with paint coatings is that it only takes one point where the coating has not been applied effectively such as a pin hole in an epoxy coating to cause corrosion to start. Mark indicated the trick is to have someone there to do QA while painting is carried out, such as to ensure the thickness of primers. The details have to be done right. It was suggested that where you often have the problems is in the difficult to access nooks and crannies. Shot blasters and painters often think they are there to get the big stuff done and are happy to ignore the fiddley bits, which are often the most critical for corrosion protection. The comment was also made that often the nooks and crannies are not necessary in the first place and can be eliminated by attention to detail in the original design (see section on Design).

Qenos have open air structures that were painted 25 years ago with zinc rich coating and they are still in as new condition today. Appendix 5 is the protective coating specifications used at Qenos and is intended as an example only. The supplier is Dulux who would likely supply similar information to others or potentially carry out site surveys to assess your applications. Another large supplier of industrial coatings in Australia is PPG (SIRF Member). A link to their industrial coating web page is http://www.ppgpmc.com.au/default.asp?id=171 .

Wet Environments

Ed from Sydney Water asked a question about how best to protect steel reservoirs from corrosions. The two options discussed were using a protective lining or high quality painting of the internal water wetted surfaces or to use Cathodic Protection. The problem with using a lining/ paint to protect the steel is that it only requires one very small fault to cause a failure. Cathodic protection does not have this problem but required more monitoring and maintenance.

Port Waratah have currently a Cathodic Protection system on the 20 year old steel piles that support the wharf at Carrington and Kooragang terminals. Another initiative being used for the wharf piles is the **Sea Shell** protection system where the Steel piles have been Denso tape (Grease impregnated cloth tape) wraped and then a heavy duty plastic liner is strapped over the top of the Denso tape. It is a good protection system for salt-water splash zones. Buildup on the piles are removed before application. The tape is applied from a meter below the tide line and up to the bottom of the wharf. This system has proven to be very successful compared to blasting and paining and even though it is expensive, PWCS plan to use it on other of their wharfs. Denso wrapping of steel structures has also been used successfully at Orica where there are very aggressive corrosion causing chemicals. The reason for its success is that the tape stops all oxygen from access to the steel surface.

Qenos have a problem with corrosion of their boiler plant where they have fibre glass lagged and clad systems exposed to rain. The fibre glass insulation can absorb moisture in some location even though it is clad. Inspection to locate problem areas requires removal of the cladding, which is difficult. Only areas where moisture buildup is thought likely is cladding removed. This corrosion is not thought to be such a problem where zinc rich paint coatings have been applied to the equipment.

There was a question asked about potential problems with corrosion and deterioration of steel piles. Mark from PWCS had the experience of excavating down around a pile in a muddy tidal zone and found no deterioration. The suggestion was that underground is usually a low oxygen environment and so piles will not deteriorate significantly from corrosion. Only one of the attendees knew of an installation under a cooling tower system where cathodic protection was used on the piles and this was considered unusual.

Connectors and Fasteners

Hans from Boral Quarries spoke about a problem they had with a modification to a hopper cone section. The modification required the use of high strength structural bolts and the ones supplied were not of the correct quality and with some high operating loads, caused a failure of the bolts. Others had heard of similar stories and so the suggestion was that you need to have confidence in the source and QA on high strength bolts.

Bluescope Steel are using a thick plastic spray on coating to go over bolts and flanges for corrosion protection. They have not any long term experience of its effectiveness and were interested in feedback from others. It dries hard and is resistant to some level of damage.

Another bolting issue mentioned wase use of stainless steel bolts around nitric acid plants. You get embrittlement of the stainless. At Orica they had to go back to normal steel bolts.

Noel from Eraring spoke about a problem they have with aluminium sheeting on Galvanised structures with stainless steel screws. There was a separation tape used between the dissimilar metals but with age and wind movements etc, the tape falls out. This causes a problem with corrosion of the sheeting around the stainless steel bolts. Where dissimilar metals have to be used, the quality and longevity of any separation materials should be investigated. One suggestion was use of insulation batts material (see section below).

There was some discussion of inspection of bolts. They can be checked for looseness without removal but for elongation checks, the requirement is to remove them one at a time. If bolts have significant corrosion it was agreed that the best approach is to replace bolts one at a time. If there is no information on the specification of the bolts to be replaced, a check that can be performed on bolts in service is a hardness check to give some indication of the grade of material for high strength bolts.

Bluescope steel had a case where some large 1½“ bolts were failing under short duration operational loads. Their solution was to use Belleville Washers rated at the bolt tension so that they give sightly under overload conditions.

Walkways, Platforms, Stairways, Ladders and Cladding

Problems with walkways were discussed. Buildup of debris on walkways was suggested to be a significant problem, as the debris will likely encourage corrosion as well as hide the damage. Platforms that are regularly used rarely become a risk as problems are identified early but platforms that are rarely visited can be a serious issue. Sometimes platforms may only be visited during structural inspections and so these risks should be considered when doing the structural inspection Job Safety Analysis. Sydney Water have a similar issue with inspections inside steel water reservoirs as the steel ladder that has to be used for entry can often have suffered deterioration.

A question was asked about FRP walkways used outdoors and the deterioration due to ultraviolet light in applications like cooling towers. The suggestion was that this product has not been around long enough to confirm it is resistant and so should be checked.

Cladding materials were discussed. Craig from Delta indicated that they have had good experience with Colour Bond Ultra in their environment. The suggestion was made that these type of sheetings degrade from cut ends where the corrosion protection is not complete. Very good performance can be achieved from Marine Grade Aluminium sheeting but is very expensive. Again, care should be taken with dissimilar metals. One suggestion for a separation material for sheeting that should have better performance than normal separation tapes is thermal insulation batts (eg Pink Batts).

Design-out Solutions

One problem area discussed was corrosion and damage at the bottom of columns and the associated steel base. This was a problem area for a number of attendees. One design-out solution to this problem was to raise the concrete base up 600mm off the floor and this get the steel work out of the most severe damage and corrosion area. Another option to this problem is to use Denso wrapping or something similar to protect this same area and putting on shedder plates to protect it from damage. It was mentioned that at the Newcastle Incitec plant, the bottom of the columns were boxed in and oil was used to fill up the box and although unusual, it was successful. Another comment was that building are often designed for areas that are intended for heavy mobile equipment use and there is no thought to damage that will inevitably occur.

The comment was made that there is a requirement for input by experienced plant people into structural design to eliminate obvious future corrosion problems. Often at no additional cost locations for moisture and debris buildup can be eliminated by more sensible selection and positioning of sections. Troy from Orica suggested that as there are no standards that specify this level of detail in structures, structural design consultants often get very lazy with getting this detail right. Maintenance people suffer for this many years later. Unless experienced people review the details of a design then these problems are rarely picked up. A simple example of this was given of using round section handrails in areas where corrosion is expected. As there is no way to protect the inside of the pipe they tend to rust out from the inside and becomes a safety problem. Use of a 50x50 angle section eliminates this problem.

Concrete Structures

Concrete Failure Modes

One of the main concrete failure modes is concrete Spalling. This is corrosion of the steel reinforcement bars (reo) and this corrosion causes substantial growth of the steel bars, which produces cracking and spalling and eventual removal of the concrete cover. This can be a significant issue in salt water and other corrosive environments. It can also can be a major safety issue if overhead.

The root causes of this concrete spalling failure mode was discussed. A typical reason for the reo corrosion is chloride attack and this chloride can be from external sources and occasionally from materials within the concrete. It is common to see these issues in salt water or costal environments. Carbon dioxide can also cause corrosion by its reaction with the

concrete. Carbon dioxide is more likely to effect concrete in indoor areas of buildings and tunnels where CO_2 can build up. Entry of salts or carbon dioxide effects can be measured by core drilling to check how close the permeation is to the reo.

One design cause is not putting enough concrete cover over the reo. Another suggestion was that in the 70's it was a common practice to use salt water in the curing process for the concrete and this now producing this type of failure. Mark from PWCS suggested that concrete available now has a finer microstructure and may not be as subject to this problem as much as it was in the past.

Concrete Inspection and diagnostic Methods

The main concrete inspection method is visual. The next approach is to tap with a hammer to determine the integrity of the cover over the reo bars and is called a rebound survey. It is easy to tell the different sound drumming or ringing concrete when there is internal cracking of the concrete caused by expansion of corroding reinforcement bars. These tests can be carried out by anyone. This technique is particularly important for testing around areas of existing spalling to determine the extent of the problem. Once a significant problem is found, it is typical to involve a concrete material consultant to carry out more extensive tests to confirm the failure mechanism and the extent of the problem. The point was made that there is a difference between concrete material specialists and cathodic protection specialists.

Concrete should only increase in strength with age but there can be entry of carbon dioxide or wind-borne or other salts that penetrate into its pores. There can also be design or installation problems such as with the layout of the reo or Alkali reactions from within the concrete. Concrete diagnostic tests can confirm its strength is OK. One comment was that 40 years ago the grinding of the cement was not as fine as it is now and so it was suggested that recent concrete structures are likely to have longer life than the older concrete that are causing problems today.

A non-destructive test that can be carried out to roughly assess the compressive strength of concrete is the Schmit Hammer test. Other core drilling tests can confirm the degree of Cloride attack on the concrete by how far chlorides have impregnated into the concrete. Another test they can do is to drill to the reo to check the half-cell electrical potential survey of the reo. The level of current measured gives an indication of the level of corrosion activity. Another important measure is the thickness of cover over the reo, which can be measured with a cover meter.

PWCS have a number of concrete tunnels and have situations where there is water coming through cracks and there is the need to do testing to more fully understand the reo and concrete condition before making a repair decision. They have decided to grout the cracks up with a special NBT product. Mark from PWCS gave a recommendation for concrete testing services, which was Martin from BCRC http://www.bcrc.com.au/ .
Cracks in concrete structures were discussed. It was suggested that cracks in concrete structures are often not overly critical. Some cracks are just shrinkage cracks that will not effect structural strength. If cracks are of a concern, an analysis is carried out by a structural engineer to see if the cracks are in a location that matches the loading on the structure. Otherwise they can usually be ignored.

There was discussions on how difficult it is to get access to inspect some structural assets due to outages being required and or the difficulty of getting physical access. Mark from PWCS mentioned a low cost video inspection system they use for chutes and the underside of floors etc, which has been very successful. The system involves a $200 camera on a long aluminium rod. Noel from Eraring spoke about their successful use of video technology for issues like finding water leaks in inaccessible areas around their boilers.

Concrete Repair Methods

Craig from Delta showed some picture of cracking of the concrete at the Vales Point salt water entry channel. This crack has allowed salt water to directly contact the concrete reinforcement and so there will need to a major repair of this area. This type of fault has been repaired by delta in the past by scabling the concrete away, cutting out the damaged reo, welding in new galvanized reo and applying a layer of a special concrete cover specified for this task. With a 40 yr old power station there are a number of instances of this type of deterioration.

Elliot from PWCS suggested that in many situations this type of failure is not worth repairing back to original. If carbonation or chloride attack has reached the reo, then the area of spalling is only the first symptom of the failure mode and either side or other areas of concrete will start spalling in the future. One solution they use is to just water blast the reo and spraycreted over the reo and then implement cathodic protection to the concrete structure.

Mark from Bluescope suggested that just because you have some spalling in the concrete top cover does not mean you need to do a repair. If the reo is still mostly in tact and bonded to the concrete, most of the strength is probably still remaining and it just needs a structural engineering confirmation of the remaining strength in relation to loads. Bluescope have whole lengths of cable ducts where the concrete cover on the roof has spalled. As the concrete strength is still OK, all they have done is cleanup the spalling, and sprayed an anti corrosion product over the reo and left it that way. There is a whole range of anti-corrosion coating products available. There was discussion around the value of these sorts of products as the application method of the products for a specific situation can be very critical. One issue is the quality of the bond system between the product and the concrete. There had been some experience in the group about problem with the installation of special coatings. Moisture can be a problem with some applications needing a breathable coating. The outside cover of concrete is only to protect the reo and does not have significant strength in it. Another advantage of this approach is that you can still see the reo, as compared to other solutions like spraycreting where further deterioration of the reo can’t be detected easily.

There was some discussion on the benefits of replacing the concrete cover over the reo and the potential problems with coatings. One problem discussed is where moisture is coming through the concrete and an impervious anti-corrosive coating will trap the moisture at the reo.

It was stressed that it is important to get a structural engineering assessment of the reo deterioration and any strength loss with cover/ reo deterioration. It was suggested that in some situations there is significant over design/ high factor of safety in concrete structures and sometimes reo and cover is only there to reduce surface cracking. In other situation as with the picture of spalling on the concrete beam then some repair such as adding more reinforcement steel may be required. For beams and roofs which have strength deterioration, adding additional steel columns or other methods to reduce structural stresses may be the

easiest repair method. Other repair methods involve putting bands or plating around beams or columns to add strength and retain material.

Troy from Orica indicated that they have recently used an SECA product that is sprayed onto the outside of the concrete and it is supposed to stop Cloride and Carbon Dioxide ingress. It will take a while before the success of the Orica application will be successful. It was suggested that the field of coating concrete seems to be relatively new and even the experts are still learning and it is easy to fix one problem and cause another. A conservative approach

A number of the attendees had success with shotcreting as a successful method of rebuilding up concrete. Can be applied in layers up to 200mm think. The technique requires good operator skill especially on roofs. Nylon or other fibers are often introduced into the shotcreting mix but is usually only to help hold the concrete together and not to add strength.

Elliot from PWCS asked a question about what people do when an access hole has to be cut/drill through concrete, such as for a pipe run. If the reo is exposed then this is a new location to initiate corrosion. The suggestion was that it was necessary to jack-pick extra concrete away, cut out the protruding reo and recast the concrete around the hole with the required cover over the reo. The only other option is to use one of the range of coating options as discussed above. The suggestion was that the Hatch Concrete Remediation group at Port Kembla have experience in specifying coating (Sav Dell'Aquala SdellAquila@hatch.com.au). Hatch Structural Asset Newsletters http://www.hatch.ca/Engineering/Structural_%20Assets/newsletters.htm .

Steel Fiber Concrete

Troy from Orica raised the issue of durability of concrete wearing surfaces. Bluescope had some experience with using stainless steel fibers in concrete rail crossing. They have loads from very heavy mobile equipment and use of this material definitely gave longer life then standard concrete. Noel from Eraring also had a positive feedback for there use of mild steel fibers for concrete in heavy vehicle applications.

Concrete Plinth and Hold-down Bolt Repairs

Paul from Grain Corp asked about repair of corroded hold-down bolts in concrete plinths. Duncan from Qenos showed some photos of corroded hold down bolts from there plant, which were discussed by the group. Craig from delta indicated that they had jack-picked out in individual studs and welded a new one into the reo and then re-grouted around the plinth. Bluescope have also done similar repairs with up to 2 ½" bolts at the base of columns of outside crane run ways. Smaller bolts where the concrete is in good condition there is an option the drill new holes in the steel base and the concrete and chemset new studs into the concrete. If there are concerns with the strength of the chemset studs suppliers, Ramset and Hilti can do pullout tests. If extra strength is required, then longer than standard studs can be used. Attendees had successfully used chemset bolts up to 32mm.

Another approach is available where the bottom of the column is badly corroded as well as bolts needing to replacement. The column is propped up, the damaged section is chopped off, and a new column section is installed with the base plate on at a different angle. This gives access to drill new chemset bolts or if necessary to recast the whole plinth.

The key issue to ensure these type of problems do not occur in the first place is to have good housekeeping and not to allow buildup of debris on bases and to protect them from mobile

equipment and other sources of damage. This often requires a culture change and the building of a feeling of plant ownership by the operators in order for them to maintain the required level of cleanliness of the plant and structures.

Cathodic Protection

Cathodic protection is a vital technology to reduce the corrosion rate in structures where the reinforcing steel is or is likely to suffer corrosion. Eliot from PWCS stressed that Cathodic Protection (CP) is a complex field and told of their experience of having to get a second CP consultants opinion on a problem before they understood the full picture, as the original consultant missed critical issues.

Below are some useful links and the Australian Standard for Cathodic protection.
http://www.deir.qld.gov.au/electricalsafety/business/manufacturers/cathodic/index.htm
http://www.corrosion.com.au/Home/index.aspx

- AS 2832.1-2004 - Cathodic protection of metals - Pipes and cables
- AS 2832.2-2003 - Cathodic protection of metals - Compact buried structures
- AS 2832.3-2005 - Cathodic protection of metals - Fixed immersed structures
- AS 2832.4-2006 - Cathodic protection of metals - Internal surfaces
- AS 2832.5-2002 - Cathodic protection of metals - Steel in concrete structures
- RUL ML.1-2008 - Rulings to metal Standards - Cathodic protection interference levels (Ruling to AS 2832.1-2004)

Craig from Delta is looking to try a type of Sacrificial Cathodic Protection that does not need an external power supply and thus much easier to maintain. See Appendix 4 for details.

Justification of Money for Structural Repairs

One of the approaches recommended for convincing management to invest in structural repairs is to get respected external advice on failure risk, deterioration rates and future liabilities. Graphic photos of the deterioration problem and examples of actual failures in similar cases can be a large help. The factors that are important to a business may vary but common factors should include safety, environment and business losses. The problem when you have significant structural problems is that repair/ remediation costs are sometimes large and can't be covered in existing maintenance budgets. Also there are many lower cost remediation options for structural problem that may not be ideal but they still work. These should be followed up, especially if finances are tight in your business,

One problem is that submission documentation for additional money may not make it to the actual financial decision makers. It is important to understand what is important to the financial decision maker so the problem can be put in the most meaningful terms. Most structural problems are long term so if management are only worried about short term issues, it is important to only to be trying to implementing solutions for the highest priority issues. In the budget process, not every item is likely to get through, so it is important to ensure the items are prioritized so the most important issues get through. Many structural issues can be delayed so it is important to make use of money when it is available and accept that structural budget may be spent on other issues when there are other high priority issues.

Other Structures

Pipeline repairs

Delta Electricity used a Berolina Liner very successfully about 6 years ago on concrete lined pipe in a demineralised water application. The approach gave a significant cost savings to other solutions, as a part of the pipework was underground. The application included heat expansions of the ¼" liner to the inside of the old pipe. It was supplied and installed by a company called Veoliaes (Then Collex Nodig).
http://www.veoliaes.com.au/industrial-services/pipeline-services/pipeline-rehabilitation.asp
Another other supplier recommended was CLM Trenchless (CLMT)
http://www.infolink.com.au/c/Collex-No-Dig/Trenchless-pioneer-plots-course-n765368
There is a range of these type of liner solutions for a range of pressure and non-pressure applications so was recommended to be worth checking out this technology if you have difficult pipework repair applications.

Ed from Sydney Water spoke about some of the work they have been doing on their very large concrete lined pipes with use of epoxy paints on top of the concrete lining to stop the attach of the concrete from corrosive material in the sewerage and waist water.

Maintenance of Roads and Bridges

A question was asked about problems with maintenance of roads. The importance of good subgrades was stressed with the need to keep moisture out to stop damaging pumping effects. One issue is that often repairs are done to the damage you can see on the surface but if you have a recurring problem, the issue is usually down in the subgrades. The subgrade is the compacted original base material and with levels of different road material added on top. If the subgrade gets soaked, then it can easily deteriorate. The problems are usually with low areas where moisture can be trapped.

Grain Corp have some problems with the roads into grain silos. Mark from PWCS indicated that one problem area is at the change from a road support to a concrete foundations such as the entry for a bridge of a weighbridge. It is very difficult to stop a step developing between the two and requires regular servicing. It was suggested that the RTA when they build a bridge always come back in 12 months time to fix any step that has developed. A possible design solution is to have an apron slab under the road at the interface to help support the load in the abutment transition area.

A question was asked by Noel from Eraring about bridges and how often bearing checks are made. The suggestion was that inspection 6 monthly was appropriate by a bridge inspector. The comment was made that the best documentation on bridge inspection comes from the Queensland Mainroads (see link below).
http://www.mainroads.qld.gov.au/web/partnersCR.nsf/DOCINDEX/Technical+Reference+Centre?OpenDocument

One difficult area is under bridge inspection. The comment was made that there are special cherry picker type machines available and smaller trailer based units to assist with this. These units sit on the road and access under the bridge from over the side for detailed inspection. The typical problems for bridges are drainage, corrosion, cracks, abutments, bearings and

expansion joints. The RTA put out a regime for bridge inspection. For public roads, formal 3 yearly inspection has to be done by an accredited person.

Mark from Bluescope mentioned a major cracking problems in 50’ crane girders that they have recently spent $7M in the slab yard repairing. The girders had 45 degree cracks propagating in them. Most of these cracks started from very small weld defects. He indicated that these defects grew from original bracing welds at the top flange and would typically not have been treated as an issue during manufacture but 40 or 50 years on they have been the initiation point for fatigue cracks. It shows that older highly loaded steel structures need to have detailed inspections carried out.

Explosion Protection

Craig from Delta raise an issue they have with the risk of explosions from high voltage transformers and a problem they have at Munmorah Power Station. In this case they have very little access to install heavier blast protection from an explosion. This was discussed and Mark from Bluescope suggestion in they use steel square mesh successfully in front of crane window to stop larger shrapnel. This could be combined with sheeting 150mm behind to stop smaller shrapnel, heat and fire.

Brickwork Deterioration

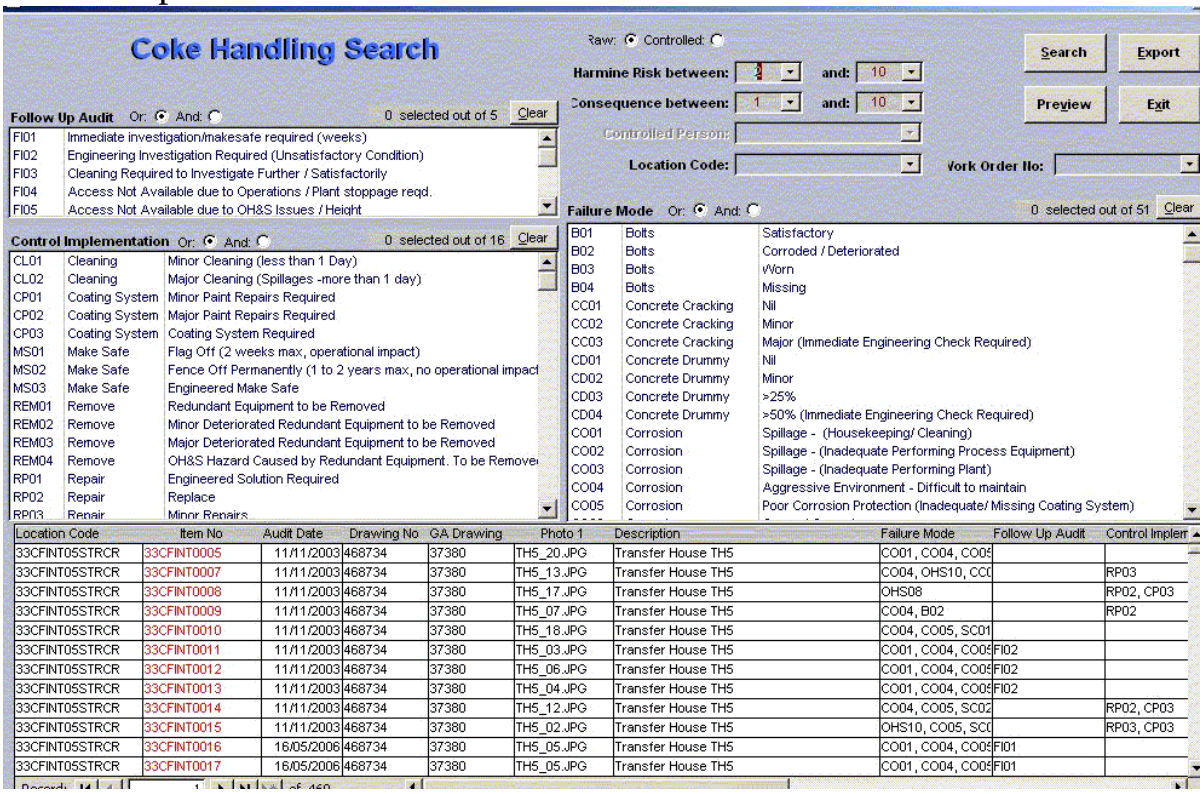
Craig from Delta asked about management of a Brick deterioration problem he has (see photo below). Mark from Bluescope suggested he had seen similar problems electrical substation building brick walls at his site. The issue only occurs on the lower courses of brickwork and appears to be salt buildup related. Some possible causes were discussed but the consensus was to involve brick specialist from brick suppliers or the Brick and Paver Institute.

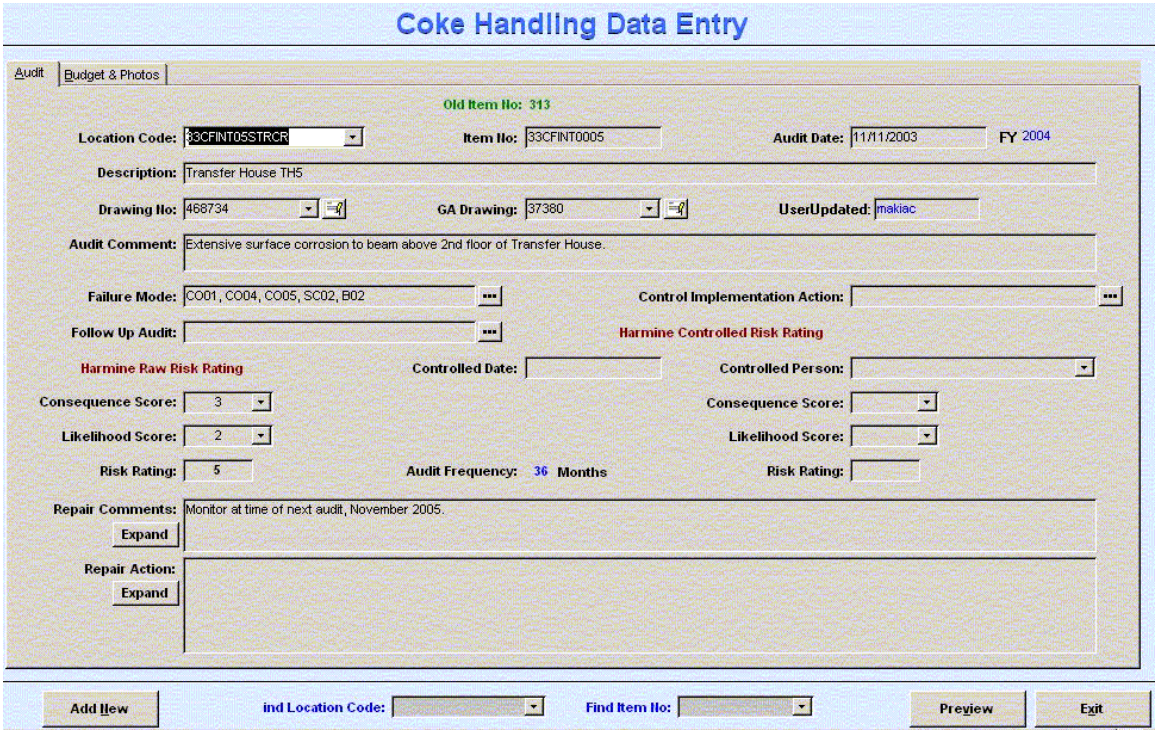
Appendix 1 - Boral – Protocol for Inspection of Plant Structures

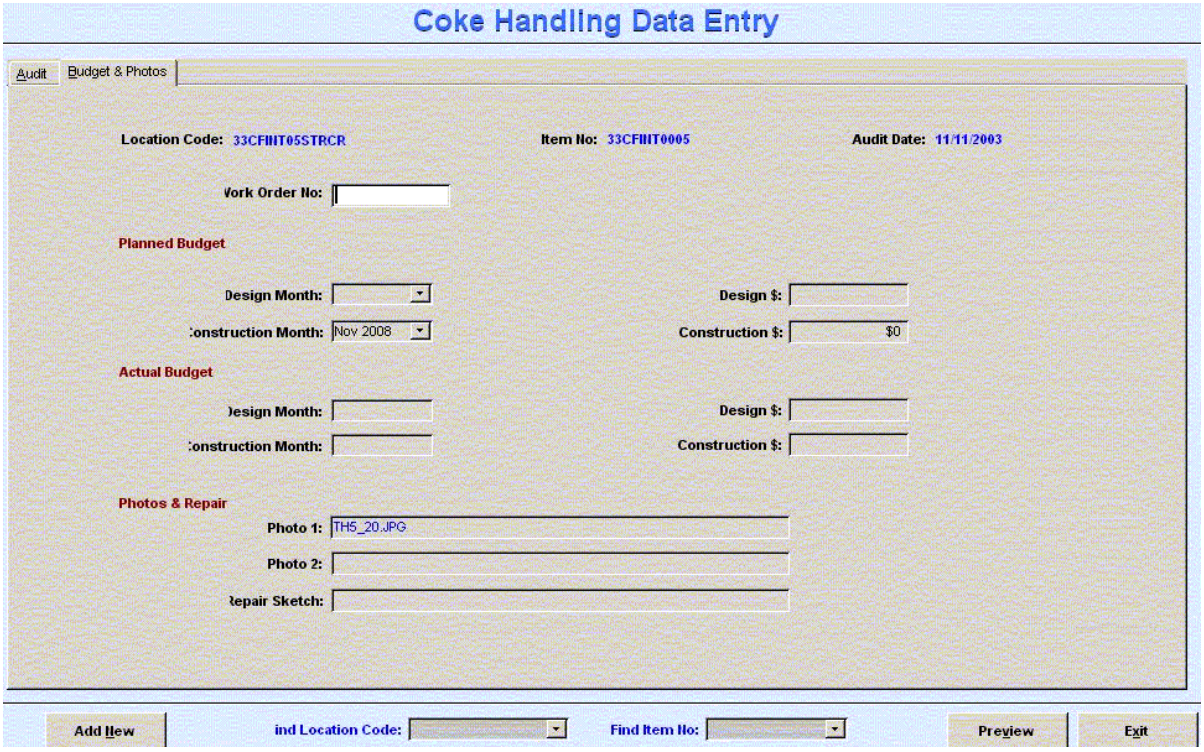
Appendix 2 – Sydney Water – Protocol for Inspection of Plant Structures

Appendix 3 - Bluescope Steel CokeMaking - SAMS Access Database

Screen captures below






Coke Handling Data Entry
Audit
Budget & Photos
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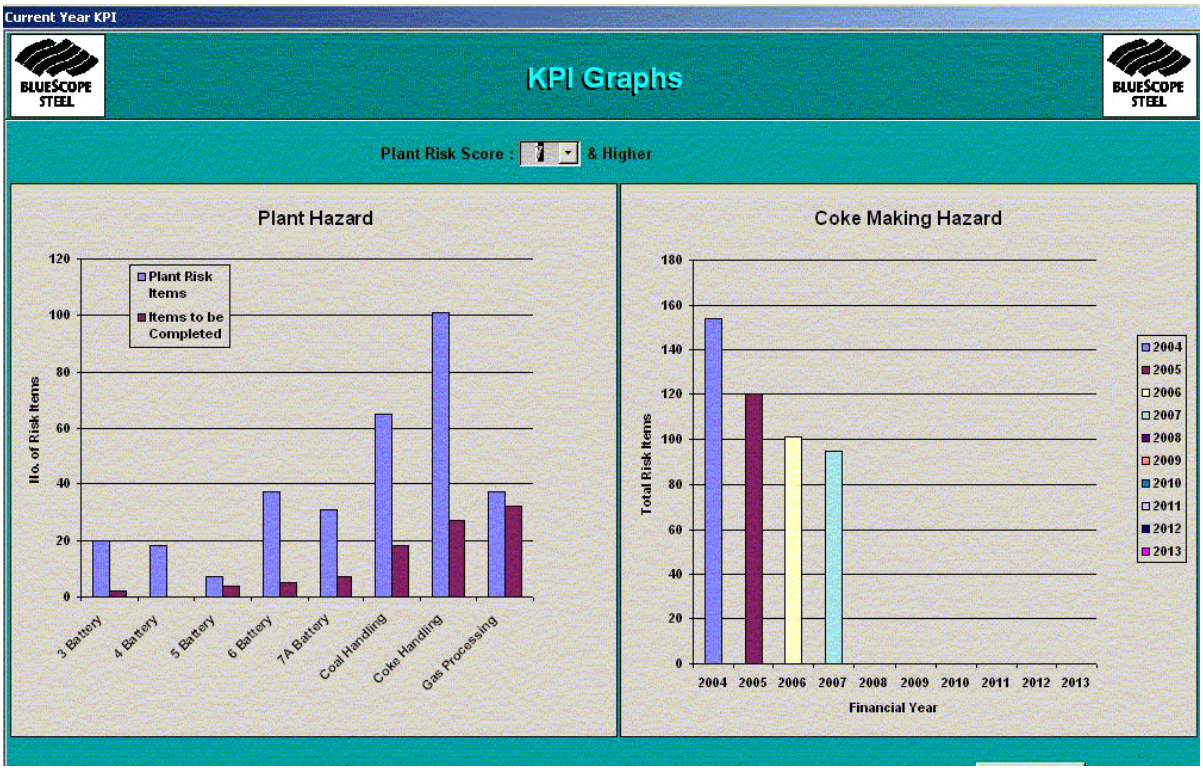
Item No: 33CFINT0005
Audit Date: 11/11/2003
Work Order No:
Planned Budget
Design Month:
Design $:
Construction Month: Nov 2008
Construction $: $0
Actual Budget
Design Month:
Design $:
Construction Month:
Construction $:
Photos & Repair
Photo 1: TH5_20.JPG
Photo 2:
Repair Sketch:
Add New
Find Location Code:
Find Item No:
Preview
Exit


Current Year KPI
BLUESCOPE STEEL
KPI Graphs
BLUESCOPE STEEL
Plant Risk Score : 7 & Higher
Plant Hazard
Plant Risk Items
Items to be Completed
No. of Risk Items
120
100
80
60
40
20
0
3 Battery
4 Battery
5 Battery
6 Battery
7A Battery
Coal Handling
Coke Handling
Gas Processing
Coke Making Hazard
Total Risk Items
180
160
140
120
100
80
60
40
20
0
2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
Financial Year
2004
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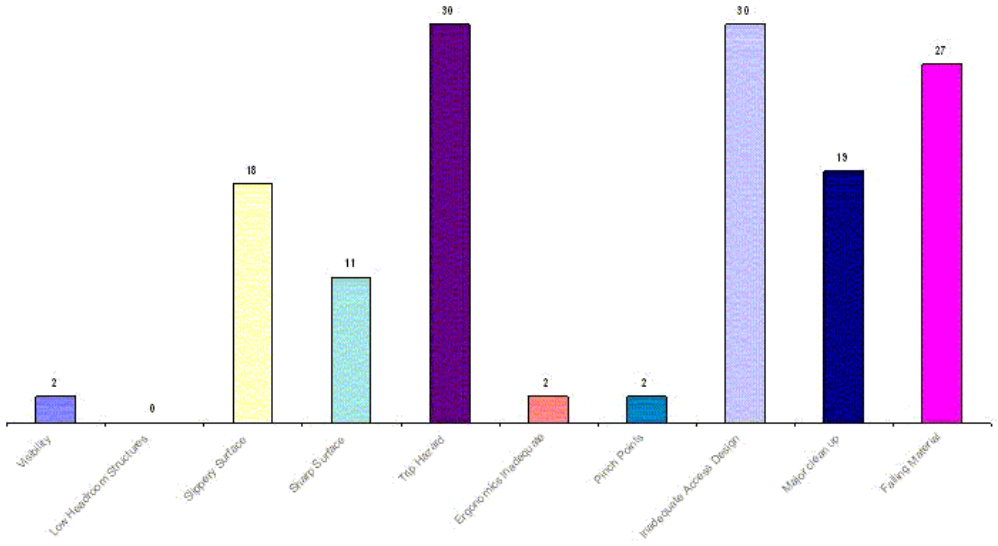
2006
2007
2008
2009
2010
2011
2012
2013

BlueScope Steel

Coke Handling / Safety

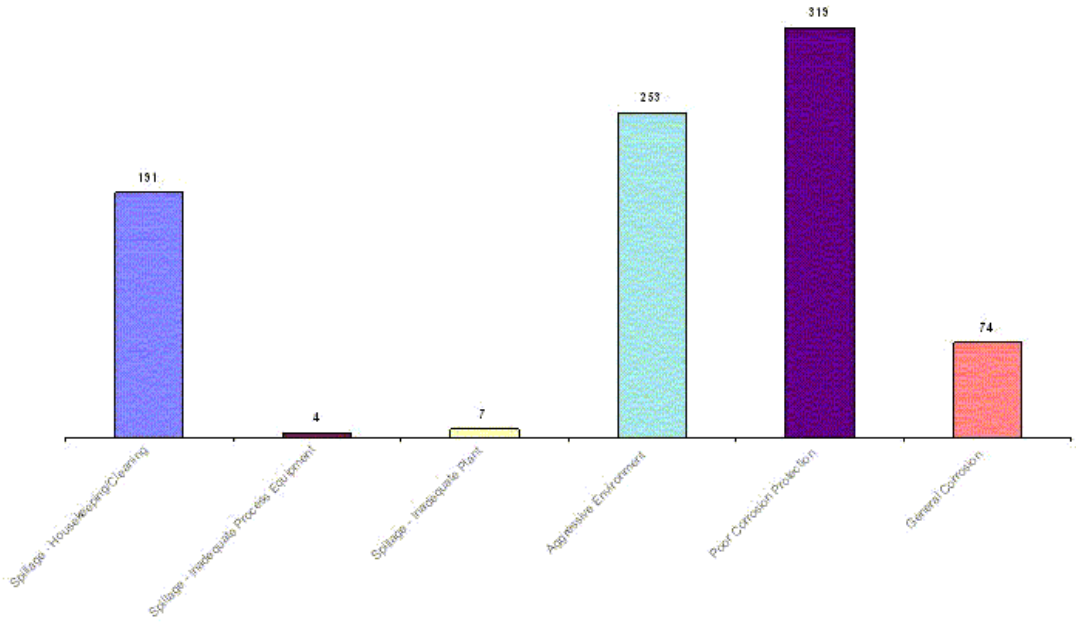


Printed on : 6/05/2008

Page 1

BlueScope Steel

Coke Handling / Corrosion



Appendix 4 – A new type of Cathodic Protection System – Sacrificial

Finished Condominium Column with Galvashield CC's Installed.

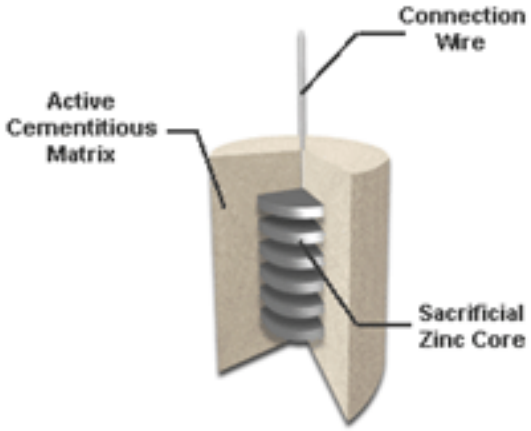
Vector Galvashield® CC

Embedded Galvanic Anode for Corrosion Control

Vector Galvashield CC embedded galvanic anodes are used to control on-going corrosion and to prevent the initiation of new corrosion activity in concrete structures. Galvashield CC anodes consist of a sacrificial zinc core that is activated by the surrounding specially formulated precast cementitious mortar. The cylindrical anode, available in a variety of standard sizes, is quickly and easily installed into concrete that is mechanically sound but has on-going corrosion activity. Once installed, the zinc core corrodes preferentially to the surrounding rebar, thereby providing galvanic corrosion control to the adjacent reinforcing steel. Custom size anodes are available for specifi c project needs.

Applications:

- Balconies
- Columns and beams
- Bridge decks
- Parking garages
- Piers and wharfs
- Prestressed concrete
- Post-tensioning anchors



Features and Benefits

- **Proven Technology** - supported by independent test program.
- **Focused protection** - discrete anodes can be installed to provide corrosion protection in areas with high corrosion potentials or active corrosion.
- **Economical** - save money by only protecting the remaining chloride-contaminated (unrepaired) areas.
- **Versatile** - effective in chloride-contaminated and carbonated concrete. Can be used for both conventionally reinforced and prestressed or post-tensioned concrete.
- **User friendly** - installation is quick and easy.
- **Low maintenance** - requires no external power source or system monitoring.
- **Measurable** - anode performance can be easily monitored if required.
- **Long lasting** - 10 to 20 year service life reduces the need for future repairs.

Appendix 5 – Qenos – Example of a Painting Specification

Appendix 6 – PWCS – Example of a Painting Specification

Appendix 7 – Supplied by Boral Quarries High Strength Bolt Assemblies – Certification to AS/NZS 1252-1996… Reject of Accept?

Appendix 8 – PWCS Warf Protection – Denso Sea Shield

Sea more details on http://www.densoaustralia.com.au/products.html#marine

APPLICATION INSTRUCTIONS

SEASHIELD SERIES 100

CYLINDRICAL STEEL PILE PROTECTION

CONSTRUCTION:

A HIGH DENSITY POLYETHELYNE OUTERCOVER FASTENED WITH SMARTBAND STRAPPING AND BUCKLES

USES:

FOR SPLASH ZONE PROTECTION OF STEEL CYLINDRICAL PILING IN RELATIVELY SHELTERED ENVIRONMENTS

MARKET SEGMENTS:

YACHT CLUBS - MARINAS, MOORING BERTHS

ROAD AUTHORITIES - BRIDGES, JETTIES

LOCAL COUNCIL - BRIDGES, JETTIES, PIERS

REFINERIES / PROCESS - LOADING WHARFS, JETTIES

PORT AUTHORITIES - LOADING WHARFS, DOLPHINS, JETTIES, PIERS, BEACONS

SHIPYARDS - LOADING WHARFS

APPLICATION INSTRUCTIONS

SEASHIELD SERIES 100

CYLINDRICAL STEEL PILE PROTECTION

STEP 1. - TOOLS REQUIRED

Hand tools such as a scraper, hammer, wire brush, cold chisel, etc. and/or appropriate water blasting equipment.

STEP 2. - SURFACE PREPARATION

Remove all loose rust, original coating, marine growth, etc., by scraping, chipping, water blast cleaning, or ships hull scrubber.

STEP 3. - INSPECTION

When all growth, rust, etc., has been removed, a close examination must be made of the surface area that has been prepared, to ensure a thoroughly clean surface without growth, sharp or protruding areas is obtained.

STEP 4. - PRIMING

After approving the surface preparation and inspection is satisfactory, Denso Seashield Primer is applied to the surface area with hand, cloth or roller, at a spreading rate of 1.0kg/m².

Denso Seashield Primer is applied in a circular motion obtaining an even film, while all voids, concaves, and holes should be filled.

Denso Seashield Primer can be applied above and below the water surface.

STEP 5. - INSPECTION

The primed area must be thoroughly inspected to ensure that all the surface area has been properly coated with the primer, including voids, concaves and holes.

STEP 6. - TAPE WRAPPING

Starting from the bottom of the pile surface area, apply Denso Seashield Tape with a double thickness and then in an upward direction, spirally apply Denso Seashield Tape with an overlap of 55%. This will ensure a double thickness. Commence each new roll of tape 150mm below the end of the previous roll of tape.

IMPORTANT: As wrapping proceeds, smooth by hand to exclude water, air bubbles and wrinkles, and to aid sealing of overlaps.

APPLICATION INSTRUCTIONS

SEASHIELD SERIES 100

CYLINDRICAL STEEL PILE PROTECTION

STEP 7. - INSPECTION

It is important to thoroughly inspect the pile surface area, ensuring it has been wrapped with the specified 55% overlap, all water, air bubbles and wrinkles have been excluded, and overlaps sealed.

STEP 8. - FIXING OF OUTERCOVER

(a) Wrap Denso Seashield Series 100 Outer cover around the pile at the nominated level, ensuring the vertical edge of the P.V.C. Stiffening Strip is to the outside.

(b)

(c) Locate Denso Smartband strapping and buckle 50mm from the top and bottom of the jacket then 250mm vertically apart, while ensuring the buckles are all approximately in the same vertical position (as close as possible to the P.V.C. Strip).

STEP 9. - INSPECTION

Check all strapping for correct tension and ensuring none is loose.

Check the outer cover is securely fixed to the pile and not able to be moved in any direction.

APPLICATION INSTRUCTIONS

SEASHIELD SERIES 100

CYLINDRICAL STEEL PILE PROTECTION