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Whole of Life Cost Comparison and Cost Benefit Analysis For Steel Structures Constructed in the Foreshore zone

Final Report

A Report submitted in partial fulfilment of the degree of Bachelor of Civil Engineering with Advanced Studies

Carried Out in Conjunction With:

Griffith University, Industrial Affiliates Program 4001ENG
and
Gold Coast City Council

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Gold Coast City Council

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List of Abbreviations

ASSDA	Australian Stainless Steel Development Association
CBS	Cost Breakdown Structure
CSIRO	Commonwealth Scientific and Industrial Research Organization
DFT	Dry Film Thickness
EA	Equal Angle
GAA	Galvanizers Association of Australia
GCCC	Gold Coast City Council
HDG	Hot Dip Galvanizing
IAP	Industrial Affiliates Program
IRR	Internal Rate of Return
LCC	Life Cycle Cost
RHS	Rectangular Hollow Section
SHS	Square Hollow Section
SSLCC	Structural Steel Life Cycle Costing

Conversions

$1\mu m = 0.001mm = 1x10^{-6}m$

$1g/m^2$ coating mass = 0.14 μm coating thickness

ACKNOWLEDGEMENTS

I would like to acknowledge and thank the following people for the input and benefit they have made towards this project:

Paul Conolly the Industry Supervisor for realising the need in the area and turning it into an IAP project as well as the large amount of time and effort put into helping me with the progression of this project.

Geoff Smart, Andrew Breckenridge, Peter McCabe and Peter Gadd from GCCC for helping in various aspects of the project.

Gary Chai the Academic Advisor for pointing me in the right direction for the requirements of the program.

Richard Matheson, Graham Sussex and Alex Colls of ASSDA for sharing their time, knowledge and literature.

Emmanuel Pimentel of GAA for sharing his knowledge of the workings of HDG steel.

Bill Sherwood of Jotun Coatings for supplying information and prices for paint systems

Bidgeman Stainless Solutions for supplying information on the cost elements of the LCC for stainless steel and demonstrating stainless steel fabrication techniques.

Pryde Fabrication, Midway Metals, Atlas Specialty Metals, ELG Recycling, Sims Metal, Industrial Galvanizers Brisbane and Turner and Townsend Pty. Ltd for all supplying individual cost elements for the life cycle cost analysis.

My parents for always encouraging me with everything and making sure that there was enough food left over from dinner every night to take for lunch the next day.

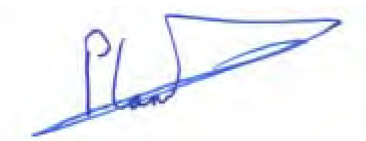
Steph for taking my mind off the project and helping me relax, but still listening to me explain to her why corrosion was occurring whenever I noticed it anywhere.

STATEMENT OF ORIGINALITY

The material presented in this report contains all my own work, and contains no material previously published or written by another person except where due acknowledgement is made in the report itself

Jordan Cocks
IAP Student

Date: 11/06/09



Paul Conolly
Industry Supervisor

Date: 12/06/09

EXECUTIVE SUMMARY

- Hot Dip Galvanized steel is currently used by Gold Coast City Council to construct structures in the foreshore zone. However it is proving to be inadequate.
- As Gold Coast City Council is a local government authority what they construct must be safe, durable and cost effective, in whole of life terms.
- The report examines hot dip galvanizing, paint systems, duplex systems and stainless steel as corrosion protection methods in the foreshore zone.
- Stainless steel is commonly discounted as an acceptable material based on the high initial costs associated with the material.
- This project produced a design guide, life cycle cost analysis and life cycle costing spreadsheet for structures in the foreshore zone.
- The results illustrate that stainless steel is a viable option based on cost alone.

1 INTRODUCTION

1.1 Company Background

Gold Coast City Council (GCCC) is the local government authority for the city of the Gold Coast. The positioning statement of GCCC is "*working for our future – today". *This project was undertaken in the Technical Services branch of GCCC. "*Technical Services provides a multi-disciplinary, professional municipal planning, design and procurement service, ensuring a whole of city approach, across all disciplines, asset classes and works program boundaries"* (GCCC, 2009).

1.2 Project Overview

This project aims to provide GCCC with a Life Cycle Cost (LCC) analysis for steel structures constructed in the foreshore zone using different methods of corrosion protection. The methods of corrosion protection being used for the LCC analysis are:

- Hot Dip Galvanized (HDG) Steel

  HDG Steel is mild steel which has been dipped in molten zinc to form a zinc/steel alloy over the surface of the steel. This coating provides sacrificial protection to the steel.

- Paint Systems

  Paint systems protect the steel by forming an impermeable membrane over the steel to protect from corrosive elements.

- Duplex Systems

  Duplex systems are a combination of HDG and paint systems. The steel is first HDG then painted to form a dual protection system.

- Stainless Steel

  Unlike the other forms of corrosion protection stainless steel has the ability to form a natural coating to protect from corrosive elements. This coating is naturally formed due to the chromium in the steel. The coating will rapidly repair itself in the event of damage.

In addition to the LCC analysis the project has delivered a *Corrosion Protection for Steel in the Foreshore Zone Design Guide*, this guide will outline to GCCC Engineers and Architects how to optimise structures for corrosion resistance.

A Structural Steel Life Cycle Costing Spreadsheet has also been delivered allowing GCCC to estimate the LCC of steel structures using any of the corrosion protection methods described above.

1.3 Project Justification and Aim.

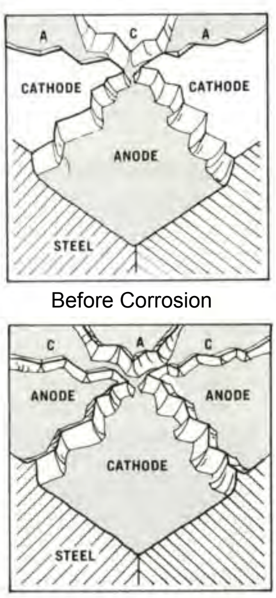
A study carried out by the CSIRO in 2008 found that the total cost of corrosion in Australia totalled $13 Billion. (CSIRO, 2008) Due to the position of the Gold Coast it is inevitable that works will be required in the corrosive foreshore zone. Materials currently used in this zone are not performing as desired by GCCC. This project aims to provide GCCC with knowledge on improving how materials are used and to provide evidence to justify using other materials, such as stainless steel, from a perspective of life cycle cost.

1.4 Project Benefits

The project will provide a benefit to GCCC by giving advice on the materials that should be used, and the best practice methods of using the material, for a structure constructed in the foreshore zone. The deliverables such as the *Design Guide* and the SSLCC Spreadsheet are tools that will enable GCCC to design optimised structures and to perform an LCC analysis.

2 LITERATURE REVIEW

In the natural state iron exists as iron ore. From this ore pure iron is extratcted. The process of corrosion is the iron in the steel reverting back to its natural state. (Eade, 1993). Corrosion is a chemical reaction and requires the presence of an anode, a cathode and an electrolyte solution (Eade, 1993). All these elements are available in most environments. Steel can act as both an anode and cathode due to variations in composition, impurities, uneven internal stresses and a non-uniform environment. (Eade, 1993).There can be many of these anode and cathode sections in a microscopic area. Refer Figure 2.1 which illustrates this. The electrolyte solution is present through humidity in the atmosphere, surface moisture or the metal being immersed in liquid. (Eade, 1993). When all elements for the corrosion reaction are available electrons will flow from the anode to the cathode. This loss of electrons at the anode results in positively charged iron ions being released. These iron ions react with hydroxyl ions in the electrolyte to form iron oxide, or as it is more commonly known, rust. Refer Figure 2.2 for a diagram of the corrosion process. As the anode area corrodes the properties of the steel change resulting in new anodes and cathodes being formed which allows a continual corrosion cycle. Refer Figure 2.1 for a diagram of this change. (Eade, 1993).

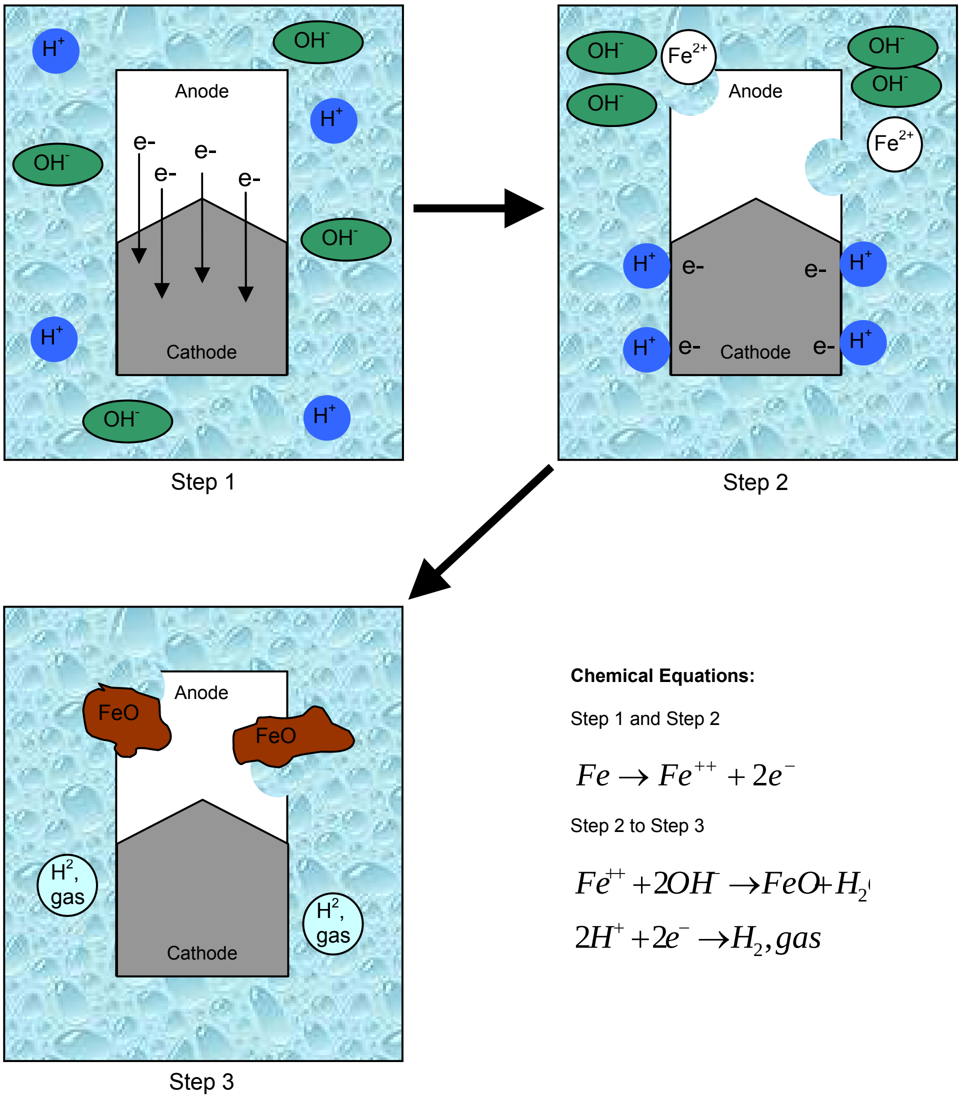


Before Corrosion

A=Anode
C=Cathode

After Corrosion

Figure 2.1 - Anode and cathode areas on steels surface (Eade, 1993)



Chemical Equations:

Step 1 and Step 2

$$Fe \rightarrow Fe^{++} + 2e^{-}$$

Step 2 to Step 3

$$Fe^{++} + 2OH^{-} \rightarrow FeO + H_2$$

$$2H^{+} + 2e^{-} \rightarrow H_2, gas$$

Figure 2.2 – Diagram of corrosion process (based on Eade, 1993)

The foreshore zone is extremely corrosive due to the presence of soluble salts and chlorides, which are the prime drivers of corrosion on metal products and structures. (Robinson, 2007). These soluble salts and chlorides are carried in the air and deposited on structures leading to a build up of corrosive material. Due to this movement of salts, structures up to 18km from the shore can be affected by chloride corrosion. (Housaka, 2001). For the purpose of this report the foreshore zone is classified as up to 400m inland from breaking surf or up to 200m inland from calm water (Blue Scope, 2007).

The addition of sodium chloride (salt) into the chemical equation of corrosion creates a much more aggressive situation. (Robinson, 2007). When chloride ions suspended in the electrolyte become trapped in crevices or pits in the steel a chemical reaction occurs which creates hydrochloric acid. The presence of this acid greatly increases the rate of the formation of iron oxide. (Robinson, 2007)

Due to the destructive nature of corrosion it is a necessity to provide some type of corrosion protection if the structure is to survive an acceptable design life. This report will explore HDG, paint systems, duplex systems and stainless steel as methods to attain structural longevity.

HDG steel gains its protection through the use of a sacrificial coating of zinc. This coating of zinc has a higher electrochemical potential than steel which means it will always be an anode in the presence of steel and corrode in the place of the steel. (Eade, 1993, Robinson 2008). The advantage of using this type of protection is that if the coating is damaged the protection still remains. A study carried out by the Galvanizers Association of Australia removed a range of areas of the HDG coating from a test sample that was placed in a corrosive environment. The results revealed that the sacrificial protection prevented any corrosion occurring within a 3mm diameter circle and minimised corrosion within a 5mm diameter circle. Larger circles also displayed a corrosion free area around the circumference. (Eade, 1993)

HDG steel has its coating applied by completing a rigorous surface preparation procedure, then “dipping” the steel into a bath of molten zinc. The molten zinc chemically reacts with the steel creating a zinc/steel alloy at the surface of the steel out to a pure zinc coating at the new surface. Refer Figure 2.3. (Eade, 1993 and Robinson, 2008). The outer coating of zinc is softer than steel however the alloy layers beneath the pure zinc layer are harder than the steel giving excellent durability to galvanized coatings (GAA, 2008).

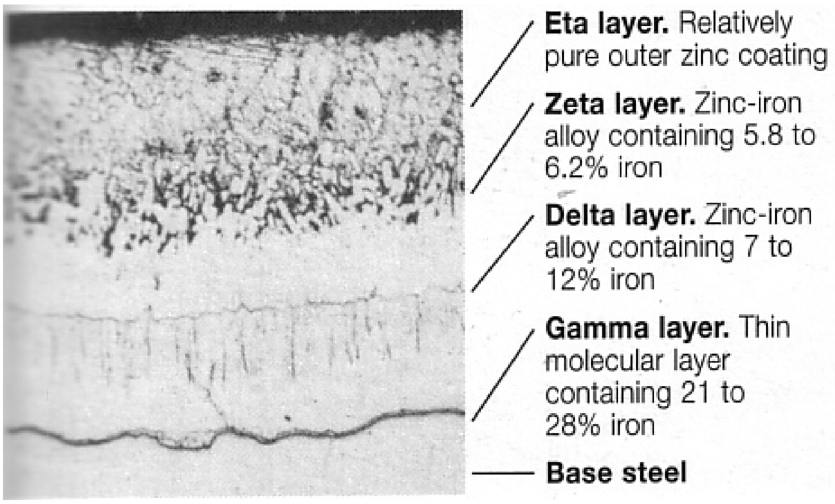


Figure 2.3 – Composition of Zinc Coating (GAA, 2008)

Painted protection of steel works by physically separating the steel from the elements required to allow the corrosion reaction to occur. Paint coatings do not offer any protection if the coating is damaged or applied incorrectly and the steel will begin to rust under the protective coating. (Eade, 1993). To ensure paint systems are applied to their optimum ability the surface must be suitably prepared. The Industrial Galvanizers Association Specifers Manual states that, 95% of all paint failures are caused by inadequate or poor quality surface preparation. (Robinson, 2008)

Stainless steel however does not need any coating to resist corrosion. Stainless Steel is a steel alloy containing a minimum of 10.5% chromium and varying amounts of nickel, molybdenum, titanium, niobium and other elements. There are many different grades of stainless steel and they can be broken up into five major groups: (ASSDA, 2008)

- Austenitic
- Ferritic
- Duplex
- Martensitic
- Precipitation Hardening

The two most common grades of stainless steel are grade 304 which accounts for over 50% of all stainless steel produced, and grade 316 which accounts for approximately 20% of all stainless steel produced (ASSDA, 2008). Grade 316 has higher corrosion resistance than grade 304, and should be used as a minimum specification in foreshore zones. (ASSDA, 2008)

Stainless steel gains its corrosion resistance through the formation of a passive chromium-rich oxide film on the surface. This film is extremely thin and acts like a paint layer, separating the underlying steel from the corrosive environment. However unlike paint systems this naturally occuring layer rapidly repairs itself in the event of damage (ASSDA, 2008). Although stainless steel contains this self healing property it can still be susceptible to corrosion. However, if it is selected, installed and maintained correctly it will not suffer corrosion. (Housaka, 2001)

GCCC currently uses HDG steel for the majority of structural components. However HDG steel is proving to be insufficient for adequate corrosion resistance in the foreshore zone. A study undertaken at Kure Beach, North Carolina has shown the strength of stainless steel's corrosion resistance. A specimen of grade 316 and grade 304 stainless steel were exposed for 15 years and a specimen of HDG steel was exposed for 13 years, all situated 250m from the mean high tide mark. During this time the average corrosion in mm/year was less than 0.000025 for stainless steel and 0.0173 for galvanzied steel. (Housaka, 2001) This makes the stainless steel almost 700 times more resistant to corrosion than HDG steel. HDG steel has two phases of corrosion, initially the corrosion of the zinc coating, which is followed by the corrosion of the steel once the zinc has been removed. Therefore the corrosion reistance of HDG steel is directly proportional to the thickness of the zinc coating. The above experiment does not state the thickness of the coating or the part of the HDG steel which was corroding.

In the past the use of stainless steel has been dominated by kitchen appliances, small fittings and architectural features. (ASSDA, 2008 and Housaka, 2001). There are few examples of stainless steel being used in a structural application. This appears to be due to the lack of standard beams and section sizes available in stainless steel or the higher initial material cost.

Atlas Specialty Metals quoted the price of a grade 316 stainless steel 150x10 strip as $171.78/m and Midway Metals quoted the same product as $110/m. While the price for the same size strip in mild steel was calculated using Cordell Building Cost Guide to be $45/m. As demonstrated the price of stainless steel is notably higher and volatile causing its use to be discounted for many projects.

However ASSDA states:

"*Stainless steel lasts longer and costs less over its lifetime… is relatively cheap to bend and shape (fabricate). Stainless steel is also strong, defending against wear and tear that increases maintenance costs*." (ASSDA, 2008)

Carbon steel requries HDG, painting or both before it can be used. HDG can cost from \$650/tonne up to \$2500/tonne depending on the size and shape of steel being processed and paint will cost an average of \$5.00/m^2 plus labour, depending on the size and shape of the steel components (Robinson, 2008). Prior to the HDG or painting process surface preparation must be undertaken, to ensure a satisfactory finish, at a cost between \$12.00/m^2 and \$45.00/m^2. (Robinson, 2008). These extra costs associated with HDG and painting should bring the initial costs closer to that of stainless steel.

The initial costs of purchasing and constructing are not the only costs incurred during a project, particularly for a structure constructed in the foreshore zone. The foreshore is classified as a 'very high' corrosive environment in accordance with AS2312:2002. Continual maintenance will be required to keep the structure functioning. A life cycle cost analysis in accordance with AS4536 – *Life Cycle Costing – An Application Guide,* takes into consideration all costs involved for a structure throughout its entire life. The results give a dollar value representing the life cycle cost of the structure. (AS4536, 1999) This value can be compared for different materials providing evidence to support the use of particular materials.

Stainless steel performs well in the area of maintenance as the only maintenance required is washing three to four times a year. (Stone, 1994). A maintenance program can easily be established by incorporating it with the window washing or toilet cleaning schedule. No specialised equipment is needed, the stainless steel is simply washed with water and detergent. (Stone, 1994) The salvage value of the stainless steel is much higher than mild steel and as stainless steel is fully recyclable, the LCC is reduced (ASSDA, 2008).

HDG steel performs well in the maintenance area through the sacrificial protection offered by the zinc coating (Eade, 1993). Provided the HDG coating remains intact and providing no cracks or scratches larger than 2mm which reveal "Bare" steel are present, the steel will be protected. (Eade, 1993). However once the HDG coating has been "worn away" the underlying steel will corrode. The coating can last from 3 years in a foreshore environment up to 75 years in a milder environment, depending on the coating thickness. (Robinson, 2008). AS4680:2006 gives the minimum HDG coating mass and thicknesses in Table 1. This table has been reproduced as Table 2.1 in this report. According to GAA in the foreshore zone the HDG coating will be reduced by 4 - 8μm per year. Assuming an average degradation rate of 6μm per year a 600g/m^2 which is equivalent to 85μm will last for 14 years. If the design life of the structure is longer than this a maintenance schedule will be required to allow the structure to survive for the design life. It is recommended by the GAA to maintain galvanzied structures an organic zinc rich primer should be used.

Table 2.1 – Minimum HDG Coating mass and thicknesses in accordance with AS4680:2006

Article Thickness (mm)	Local coating thickness (µm)	Average coating thickness minimum (µm)	Average coating mass minimum (g/m^2)
≤ 1.5	35	45	320
> 1.5 ≤ 3	45	55	390
> 3 ≤ 6	55	70	500
>6	70	85	600

Paint systems may not perform as well in terms of maintenance, as the majority of paints available have a life of approximately 5 years until first maintenance in a marine environment. However using a two pack paint system will allow a time to first maintenance of 10 years (AS2312, 2002). A disadvantage of paints is they do not offer sacrificial protection and therefore once damaged will allow the steel to rust. (Eade, 1993). From the perspective of GCCC this is an important issue as structures are frequently vandalised resulting is small sections of the paint system being removed. This results in the early formation of corrosion.

To control corrosion optimised design methods must also be employed as shown in AS2312 Figure 3.1. A good design will influence the corrosion resistance of a structure significantly. Designing to minimise accumulation of dirt or salt, allowing water to drain from surfaces, minimising crevices and positioning elements of the structure so that they can be washed by rain will improve the corrosion resistance of the structure (AS2312, 2002 and ASSDA, 2008). The *Design Guide – Corrosion Protection for Steel in Foreshore Areas* will detail these, plus other, methods of protection through optimal design.

Consolidated Rutile Limited (CRL) is one of the leading sand mining operations in the world. CRL's Yarraman mine site, located on North Stradbroke Island, employs the use of separate HDG and paint systems to protect their equipment. The site is subject to high chloride levels, frequent sand storms and high rainfall. The mine has been in service for 7 years (as of 2007) and testing of the coating thickness over steel showed that all coatings exceed the minimum thickness requirements specified in AS4680:2006 – Hot dip galvanized (zinc) coatings on fabricated ferrous articles. The mine site runs continually and has a maintenance day scheduled every six weeks, which would definitely contribute to the success of the coatings. (Murphy, 2007)

Corrosion is a problem that can be controlled by appropriate material selection, the application of certain design principles and appropriate maintenance. If due consideration of corrosion is given to a structure it will produce benefits in many areas of the projects.

"*Provision of the appropriate protective coating can bring initial savings plus substantial economies in service, due to reduction or elimination of maintenance and lost service time, and by deferring the replacement date of structures and equipment."* (Eade, 1993)

3 DEVELOPMENT OF THE DESIGN GUIDE

The *Design Guide – Corrosion Protection for Steel in Foreshore Areas* will outline to GCCC, Engineers and Architects the most appropriate way to design buildings for optimum corrosion resistance.

The guide was compiled using information sourced from organizations such as the Australian Standards, Australian Stainless Steel Development Association and Galvanizers Association of Australia. No testing took place to verify the accuracy of corrosion protection methods and the information relies solely on literature research undertaken. The lack of physical testing does not deem the information contained within the *Design Guide* 'unusable' as testing has been carried out by the associations named above. The *Design Guide* is a compilation of research undertaken by others. To validate and enhance the *Design Guide* it was distributed around the GCCC Technical Services office to obtain peer feedback. All feedback has been considered and incorporated into the *Design Guide* where deemed necessary.

It was originally planned that the *Design Guide* would be the first deliverable, however as the project progressed it was determined the *Design Guide* would benefit and be enhanced by being one of the final deliverables. During the design of the optimised structures items were added to the *Design Guide* which would have otherwise been overlooked.

The layout of the *Design Guide* incorporates many diagrams and tables to quickly and accurately relay information to the reader. The aim of the *Design Guide* was to be clear and concise, quickly stating what should or should not be done without the need for a technical explanation. The *Design Guide* does contain references to information sources and appendices allowing readers who would like to further investigate a particular topic ease of access to information.

The majority of the *Design Guide* is self contained through reproducing tables and figures from other information sources. The *Design Guide* is divided into 5 major sections:

- General Design Principles
- Designing for Hot Dip Galvanized Steel
- Designing for Paint Systems
- Designing for Duplex Systems
- Designing for Stainless Steel

Each section covers areas such as size and shape of members, welding, bolting, surface preparation and maintenance, as well as other areas specific to each protection system.

The *Design Guide* has been compiled to be used solely for structures constructed in the foreshore zone. It may be used to design structures in other locations however it would result in structures that are over designed. The guide has assumed that structures are situated in the 'very high' corrosivity category E – M (Marine) in accordance with AS2312:2002.

A new perspective to durability design was highlighted at a seminar held by the Australasian Corrosion Association titled *Building for Durability* in Brisbane on the 2nd of April 2009. It was stated that "designing for corrosion resistance, or durability, is also designing for sustainability". As the issue of sustainable development continues to grow designing for durability will become a much more noticed practice as it allows the objectives of sustainability and corrosion resistance to be fulfilled with one action. The design guide apart from being a beneficial tool for designing durable structures will also align with the GCCC corporate strategies of sustainable development.

Refer Appendix K for a copy of the *Design Guide*.

4 DEVELOPMENT OF THE SSLCC SPREADSHEET

The Structural Steel Life Cycle Costing (SSLCC) Spreadsheet has been developed for GCCC to estimate the LCC of structures. It enables the input of certain variables, such as required steel, coating, maintenance cost, design life and other variable to output a LCC for the structure. The spreadsheet has been developed in two sections, one section for mild steel and the other section for stainless steel. It has been developed with an easy to use interface based around MS Excel functionality. Refer Appendix J for the SSLCC spreadsheet user manual.

The SSLCC spreadsheet was the final deliverable of the project as the development of the spreadhseet required completion of all other project deliverables.

A copy of the spreadsheet was emailed to the IAP inbox on the 4th June 2009.

5 DESIGN OF OPTIMISED STRUCTURES

Integral to the project was the production of optimised designs as the basis on which the life cycle cost analysis could be developed. The designs are based on a toilet building located in Roughton Park, Coolangatta. Refer Figure 5.1 for an aerial photo of the site. The structure is in an aggressive foreshore environment heightening the suseptibility to corrosion. The aim of the design phase was to detail and design the structure in different materials while maintaining optimal corrosion resistance. This was completed using the *Design Guide* as written in conjunction with research being undertaken. As the structures were designed the design guide was also correspondingly enhanced.

Figure 5.1 – Aerial Photo of Site

The initial design of the toilet block to be placed at Roughton Park was supplied by GCCC and included a structural design provided by Cardno (Qld) Pty Ltd. Refer Appendix A. This design formed the basis for the optimised structures in this project. It was assumed the supplied design met the requirements of AS4100:1998 - Steel Structures. Modifications were made to the structure to optimise against corrosion resistance. It was agreed with the industry partner the design would be restricted to the main structural members, as the purpose of the design was to size members for a comparative life cycle cost analysis. The main structural members comprised rafters, columns and primary beams. Purlins, roof sheeting, masonry walls and architectural features were not considered in this design, except for the calculation of loading.

6 DESIGN OF HOT DIP GALVANIZED STRUCTURE

The section and member sizes for the hot dip galvanized structure remained the same as the original plans. Refer Table 6.1 for a summary of member sizes. Refer Appendix B for the member drawings.

Table 6.1 – Hot Dip Galvanized Member Sizes

Member	Section Size
Rafter	150 x 100 x 6 RHS
Column	75 x 6 SHS
Strutting Beam	75 x 4 SHS

6.1 Hot Dip Galvanizing Process Requirements

The major changes to the design were detailing the venting/draining requirements for hot dip galvanizing, as obtained from the Galvanizers Association of Australia publication, *After Fabrication Hot Dip Galvanizing*.

The steel is to be HDG to a coating mass of 600g/m^2 with HDG carried out in accordance with AS4680:2006.

The purlin cleats were checked for strength and it was confirmed the rafter could be lifted using the cleats situated 2.9m from each end of the rafter beam. The columns and strutting beams can be lifted by hooks using the bolt holes in either end as anchorage points. Due to the allocation of lifting points, chains are not required to lift the member and a better overall finish will be obtained.

6.2 Connection Requirements

The structure has been designed in a modular style with the rafters and columns being prefabricated and bolted together on site. This facilitates corrosion resistance as on site welds and consequent repairs will not be required. (GAA, 2008). Refer Appendix A for bolt sizes. Only hot dip galvanized bolts shall be used.

Due to the nature of HDG steel if HDG columns come into contact with the ungalvanized reinforcement in concrete, the HDG coating life may be reduced. In this situation the HDG coating tries to protect the reinforcement as well as the column resulting in the HDG coating quickly diminishing. The problem is overcome by detailing the footing reinforcement so that the immediate vicinity of the column footing bolting assembly is clear of the footing reinforcement. Appendix C contains a case study showing the effects of HDG steel in contact with ungalvanized steel reinforcement.

6.3 Embedded Steel

This section should be read in conjunction with Appendix A.

The HDG steel embedded into the concrete will not require any additional treatment before being placed. (GAA, 2008) However the block work must be core filled with grout when the steel is in place. The interface of the concrete and air must be sealed around the column with a mastic sealant (AS2312, 2002). This is also required at the base of the column if the block work will not be commencing soon after erection of the steel columns. Refer Figure 6.1 for a diagram of the concrete/air interface.

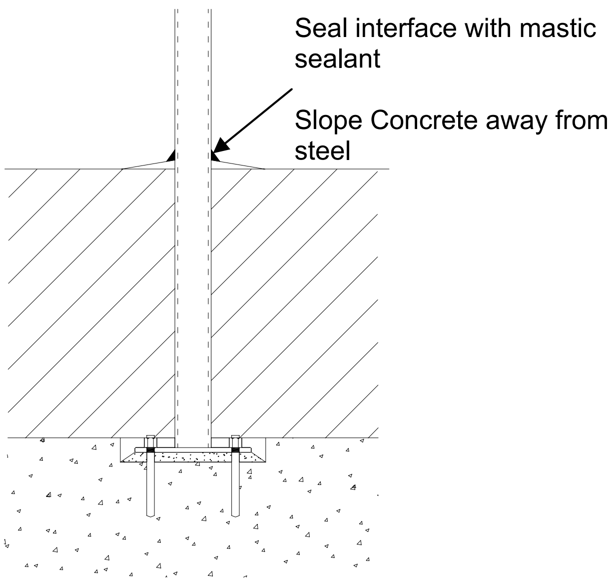


Figure 6.1 – Sealing of the Concrete/Air Interface

7 DESIGN OF PAINTED STRUCTURE

The member sizes for the structure protected by paint systems remained the same as the original plans. Refer Table 7.1 for member sizes. The major change to the detailing of the structure was the rounding of all sharp corners to a minimum radius of 2mm. This allows a uniform paint thickness around the whole structure (AS2312, 2002). Refer Appendix B for drawings of the painted steel members.

Table 7.1 –Painted Member Sizes

Member	Section Size
Rafter	150 x 100 x 6 RHS
Column	75 x 6 SHS
Strutting Beam	75 x 4 SHS

7.1 Application Requirements

The paint system requires application in a shop environment in accordance with AS2312:2002. All edges (including bolt holes) shall be rounded to a minimum of 2mm radius prior to painting. Welds shall be ground smooth or be suitably flat and all weld spatter removed. All contaminants shall be removed and the steel abrasive blast cleaned to AS1627.4:2005 Sa 2 ½ (angular profile of 30 - 50µm is recommended.) Painting shall commence a maximum of 4 hours after cleaning. (Sherwood, 2009)

7.2 Coatings

The coatings applied shall be in accordance with AS2312:2002. The chosen system meets the requirements of system designation 'PUR 5' as outlined in Table 6.3 of AS2312:2002 for long term protection in C4/5 environments which is equivalent to category E-M of AS2312:2002 (Sherwood, 2009).

The coatings for the systems to be applied are as follows:

- 1st Coat – two-pack zinc rich epoxy primer to 75µm Dry Film Thickness (DFT)
- 2nd Coat – two-pack high build epoxy to 200µm DFT
- 3rd Coat – two-pack polyurethane top coat to 75µm DFT
- Total DFT 350µm

7.3 Connections

The structure will be fabricated into modules that are bolted together on site. This facilitates corrosion resistance and allows simple construction on site. Refer Appendix A for bolt sizes. The bolts used must be hot dip galvanized and painted to match the rest of the steel after installation.

7.4 Precautions

- When the structure is being bolted together care must be taken not to damage the coating.
- The members must only be lifted using slings, not chains. Chains will result in damage to the coating.
- After erection of the structure any minor damage to the coating must be repaired in accordance with AS2312:2002 Section 10.
- If any major damage to the coating occurs it must be returned to the shop for repainting.

8 DESIGN OF DUPLEX STRUCTURE

The duplex structure used the existing member sizes from the original plans. The members were then modified by adding venting and draining holes and rounding all edges and corners to a minimum radius of 2mm. Refer Table 8.1 for summary of member sizes.

Table 8.1 – Duplex Member Sizes

Member	Section Size
Rafter	150 x 100 x 6 RHS
Column	75 x 6 SHS
Strutting Beam	75 x 4 SHS

8.1 Hot Dip Galvanizing of Duplex Requirements

After fabrication the members are first to be HDG to AS4680:2006 with a coating mass of 600g/m^2. All venting and draining requirements must be met and the purlin cleats 2.9m from each end can be used as lifting points.

The HDG must not be chromate quenched, to facilitate paint adhesion. (Robinson, 2008)

8.2 Paint Systems Coating of Duplex

Prior to paint application the surface must be cleaned and degreased then brush blasted. Brush blasting shall remove no more than 10 microns from the HDG coating. The specification for brush blasting is (Robinson, 2008):

- Blast Pressure 40 psi maximum
- Abrasive grade 0.2mm – 0.5mm (clean Ilmenite)
- Angle of blasting to surface 45°
- Distance from surface 300 – 400mm
- Nozzle type minimum 10mm venturi type.

The paint system must be applied to the following specification (GAA, 2008):

- 1 coat of inhibitive 2 pack epoxy primer DFT 50μm
- 1 or more coats of high build 2 pack epoxy DFT 200μm/coat
- 2 coats of 2 pack polyurethane DFT 50μm/coat
- Minimum system DFT 400μm

8.3 Connections

The structure will be fabricated into modules to be bolted together on site. This facilitates corrosion resistance and allows simple construction on site. Refer Appendix A for bolt sizes. The bolts used must be hot dip galvanized and painted to match the rest of the steel after installation.

8.4 Precautions

- When structure is being bolted together care must be taken not to damage the coating.
- The members must only be lifted using slings not chains, chains will results in damage to the coating.
- After erection of the structure any minor damage to the coating must be repaired in accordance with AS2312:2002 Section 10.
- If any major damage to the coating occurs it must be returned to the shop for repainting.
- Strict attention is required to ensure correct surface preparation. Failure of the paint sytem will result in decreased service life of the HDG coating.

9 DESIGN OF STAINLESS STEEL STRUCTURE

The stainless steel structure proved to be more difficult and time consuming of all the optimised structures to design. Stainless steel performs differently to mild steel and therefore the existing structure could not be simply modified to allow higher corrosion resistance. Checks of the loading, stresses and deflections in the members were requried to ensure the correct member sizes were chosen for stainless steel members. These checks were performed using manual calculations in association with the computer program STEELbeam Version 5.1 (licensed to GCCC). The critical members of the structure which required analysis were the rafters and the columns supporting the rafters. The analysis of the members sought to determine the governing criteria, either strength or deflection. It was determined that deflection governed the design allowing the structure to be optimised using a deflection basis without a more rigorous structural appraisal. Comparisons with stainless steel sections were undertaken to determine the smallest available section to satisfy the deflection criteria. Refer Table 9.1 for the final stainless steel section sizes chosen. The grade of stainless steel to be used is 316L.

Table 9.1 – Member Sizes

Member	Section Size
Rafter	200 x 100 x 5 RHS
Column	80 x 5 SHS
Strutting Beam	80 x 3 SHS

9.1 Embedded Stainless Steel

This section should be read in conjunction with Appendix A

The stainless steel embedded into the concrete will not require any treatment before being placed. (ASSDA, 2008) However the block work must be core filled with grout when the stainless steel is in place. The interface of the concrete and air must be sealed around the column with a mastic sealant. (Housaka, 2001) This is also required at the base of the columns if the block work will not be commencing soon after erection of the steel columns. Refer Figure 6.1.

9.2 Connections

The stainless steel members shall be prefabricated in modules which are bolted together on site. Prefabrication should be carried out by an ASSDA accredited fabricator. As stated by ASSDA, "*The marvellous properties of stainless steel are able to show themselves only when specialist knowledge and practice are employed*."

All bolts used must be stainless steel and, at least, grade 316. Bolts must be lubricated prior to installation to prevent galling. All welds must be ground smooth and pickled.

9.3 Rafters

The mild steel design employs the use of 150 x 100 x 6 RHS rafters in the structure. The loads taken by the rafters include the roof sheeting, purlins, ceiling sheeting, self weight, live loads and wind loads.

9.3.1 Dead Loads

The dead loading was calculated by taking into account the self weight of all members bearing onto the rafters and the rafters themselves.

Refer Table 9.2 for summary of dead loads.

9.3.2 Live Loads

Using AS1170.1:2002 Clause 3.5.1 the roof structure was classified as an "R2 Other Roofs" designation, meaning that it will not be frequently accessed. The live load was calculated to be 0.25kPa from Table 3.2 of AS1170.1:2002

9.3.3 Wind Loading

The wind loading on the structure was calculated using AS1170.2:2002. The ultimate limit state wind speed was found to be 52m/s and the serviceability limit state wind speed was calculated as 50m/s. Refer Table 9.3 for the individual values used to determine these values.

Table 9.2 – Dead Loading on Rafters

SHEETING		
Type	**BMT**	**kg/m^2**
Colorbond	0.48	4.93
PURLINS		
Type	**Thickness**	**kg/m**
Z15012	1.2mm	2.89
RAFTERS		
Type	**Spacing**	**kg/m**
150 x 100 x 6 RHS	4.9m	21.4
CEILING SHEETING		
Type	**Thickness**	**kN/m^2**
Portland Cement Plaster	13mm	0.29
Purlin Spacing	1.2	m
Rafter Spacing	4.9	m
DEAD LOADING ONTO RAFTERS		
Sheeting	0.2367386	kN/m
Purlins	0.115648167	kN/m
Rafter Self Weight	0.20972	kN/m
Ceiling Sheeting	1.421	kN/m
Total Dead Load	**1.98**	kN/m

Table 9.3 – Wind Loading Values

Value	Ultimate Limit State	Serviceability Limit State	Reference
Region	B	B	AS1170.2 Figure 3.1
Terrain Category	2	1	AS1170.2 4.2.1
Terrain/Height Multiplier	0.91	1.05	AS1170.2 Table 4.1(A)
BCA Importance Level	2	2	BCA 2008 Table B1.2a
Annual Probability of Exceedance	1:500	1:100	2008 BCA Table B1.2b
Regional Wind Speed	57m/s	48m/s	AS1170.2 Table 3.1
Design Wind Speed	52m/s	50m/s	AS1170.2 Equation 2.2

The roof was classified as a monoslope free roof with a pitch of 5°, Appendix D, Table D4(A) of AS1170.2:2002 deals exclusively with monoslope free roofs and was used to calculate the pressure factors on the roof. The three different combinations of the pressure factors were defined for both ultimate and serviceability limit state wind speeds. These were designated as:

- Ultimate Wind Load 1
- Ultimate Wind Load 2
- Ultimate Wind Load 3
- Serviciability Wind Load 1
- Serviciability Wind Load 2
- Serviciability Wind Load 3

These load combinations were based on the $C_{p,n}$ values given from Table D4(A). Values were taken from the 'blocked under' column and the worst case scenario of either a 0° or 15° degree pitch was taken. This conservative approach was adopted as AS1170.2:2002 does not state whether linear interpolation is allowed. Factors for both wind directions were considered. Refer Figure 9.1 for diagrams of the pressure envelopes. These pressure values as well as the wind speeds were then entered into equation 2.4(1) of AS1170.2:2002 to determine actual uplift and downdrag forces applied to the roof in the six wind load combinations. Refer Appendix D for wind load calculations.

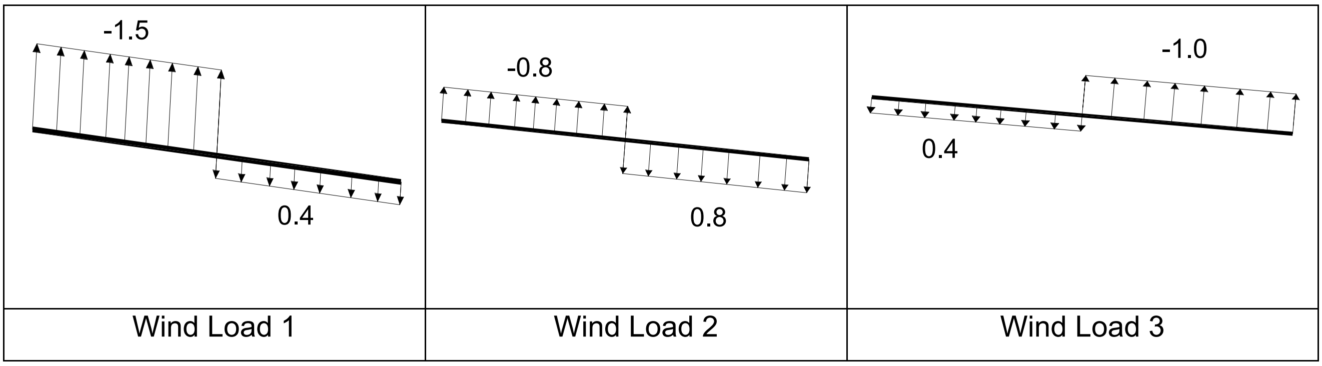


Figure 9.1 – Roof Pressure Envelopes

9.4 Load Combinations

A total of eight load combinations on the structure were used to determine the governing criteria. These load combinations were obtained from AS1170.0:2002 Section 4. Refer Table 9.4 for a summary of the load cases.

Table 9.4 – Load Combinations

Load Case	Equation
A	1.2G + 1.5Q
B Ult Wind Load 1	$1.2G + W_u + \psi_c Q$
B Ult Wind Load 2	$1.2G + W_u + \psi_c Q$
B Ult Wind Load 3	$1.2G + W_u + \psi_c Q$
C Serv Wind Load 1	$G + W_s$
C Serv Wind Load 2	$G + W_s$
C Serv Wind Load 3	$G + W_s$
D	G + Q

Load case A arranged the dead load over the entire rafter and the live load only over particular sections to create the worst case scenario.

For load cases B Ult Wind Load 1 to B Ult Wind Load 3, ψ_c equals 0. This value was obtained from Table 4.1 AS1170.0:2002 and results in the live load not being taken into account.

Load case D positioned the live load so as to create a worst case scenario.

Refer Appendix D for diagrams of wind load combinations

9.5 Limits

To determine the governing limits, the limits themselves must be defined. These limits are discussed in section 9.5.1 and 9.5.2 of this report.

9.5.1 Strength Limit in Bending

The strength limit is determined by two factors:

1. The Section Capacity in Bending
This was calculated using AS4100 Section 5, it is based on the geometrical shape of the member. The section capacity of a 150 x 100 x 6 RHS in bending is 46.9kNm

2. The Member Capacity in Bending

This was calculated using AISC Design Capacity Tables and takes into account the length of the member as well as the geometric properties. The member capacity of a 150 x 100 x 6 RHS 4.6m long in bending is 42.3kNm

The lowest value for strength of this beam is 42.3kNm from the member capacity in bending. This value will govern the strength limit.

9.5.2 Deflection Limit

AS4100 Appendix C contains suggested deflection limits for beams, this was used to determine the deflection limits for the structure. Refer Table 9.5 for deflection limits.

Table 9.5 – Deflection Limits

Section of Rafter	Deflection Limit
4.6m span (largest span)	18.4mm
1.3m cantilever	10.4mm

9.6 Governing Limit Results

The variables input to STEELbeam were beam length, location of supports, beam section size (150 x 100 x 6 RHS Grade 350) and loading. The eight different load cases were input into the software as eight separate load cases. Refer Appendix E for a summary of results and STEELbeam reports.

The maximum bending moment induced in the beam was 24.88kNm which is well below the limit of 42.3kNm. However the maximum deflection from a serviceability load case was 17.13mm under load case C Serv Wind Load 1, which also produced a deflection of 11.14mm at the cantilever. These results indicated the structure was governed by deflection. The fact that the deflection of the cantilever exceeded the limit is not an issue as the deflection criteria are only recommendations for this structure and it would not be economical to increase the member size to achieve a reduction in deflection of 0.74mm. No sheeting or structural damage would result from the deflection criterion being exceeded.

9.7 Stainless Steel Conversion

To determine the deflection in a stainless steel section the *Design Manual for Structural Stainless Steel* was used. To determine the deflection in stainless steel, the stress in the member is required. This was done by substituting the Young's Modulus value in STEELbeam from 200GPa for mild steel to 190GPa for 316L Stainless Steel. The stress was calculated by the software. The actual stress in the beam was divided by the 0.2% proof stress of 316L Stainless Steel to give a stress ratio. This ratio was then used to determine the secant modulus of the Stainless Steel using Table A.1 from the *Design Manual for Structural Stainless Steel.* The secant modulus was then entered into STEELbeam as the Young's Modulus and the maximum deflection was found.

Using the January 2009 edition of the ASSDA Stock Guide, The 150 x 100 x 6 RHS was not available in stainless steel therefore a 150 x 100 x 5 RHS was employed. This resulted in a reduced dead load. This section failed in bending as the factored (0.8) 0.2% proof stress of the stainless steel was reached. Therefore the next size up in the stainless sections was used. This section was a 200 x 100 x 5 RHS section and the above procedure was repeated resulting in an acceptable deflection of 10.68mm. The final stainless steel section chosen for the rafter was a 200 x 100 x 5 RHS Grade 316L. Refer Appendix E for calculations.

9.8 Columns

9.8.1 Loading

The loading on the columns was calculated using the reports from STEELbeam. The reaction forces were taken as the loads being transferred to the column. The largest axial load on the column is 19.87kN under Load Case B Ult Wind load 3. The column under the load is also the longest column and will therefore have the lowest member capacity.

9.8.2 Member Capacity

To determine the capacity of the columns to carry the load the AISC Design Capacity Tables were used. The length of the column is 3.55m and an effective length factor (k_e) of 1.2 was used to increase the member's effective length to 4.3m. Using the design tables the member capacity of a 75 x 6 SHS with an effective length of 4.3m is 100kN. This is much larger than the actual loading of 19.87kN.

9.8.3 Stainless Steel Conversion

It was concluded that the columns had been chosen simply on a nominal size. The columns will not be subject to any lateral loading as the columns supporting the middle rafter are embedded in concrete block work. This central core will make the structure rigid, ensuring that the columns will be loaded in axial compression only. Due to the pitch of the roof being only 5°, the component forces were not taken into account as they will only impose negligible eccentric forces into the column. Due to this nominal sizing of the column the stainless section size was based on the closest possible available size. According to Atlas Metals the closest available size is an 80 x 5 SHS, which was adopted for the columns.

10 SUMMARY OF STRUCTURAL DESIGN

All mild steel members were able to keep the same sections sizes as the design by Cardno. However as stainless steel performs differently to mild steel, the sections were required to be resized. Some changes to the initial design have been made such as venting holes and rounding edges for paint systems. It was interesting to note that considering the original design was intended to be HDG, no provision for venting/draining was visible in the details. Changes to the members such as the addition of venting/draining holes may conflict with the requirements of the Architect.

The designs obtained from this phase of the project allowed the life cycle cost analysis to be completed and a comparison obtained between different methods of corrosion protection.

11 LIFE CYCLE COST ANALYSIS

The life cycle cost (LCC) analysis and cost/benefit analysis were a major part of this project, as they ultimately determined the economic validity of the different methods of corrosion protection.

The LCC analysis was carried out in accordance with *AS/NZS 4536:1999 – Life cycle costing – An application guide*. This standard gives processes to obtain a dollar value representing the life cycle cost of a product (AS/NZS 4536, 1999).

The purpose of the LCC analysis was to compare and contrast the different methods of corrosion protection. It obtained results that can be used to determine the most economically valid corrosion protection method in the foreshore zone.

12 LCC ANALYSIS PLAN

The objective of the life cycle cost analysis was to evaluate the differences in cost of a structure situated in the foreshore zone using four different methods of corrosion protection. The results will determine the economic validity of each particular corrosion protection method. The structure is a public toilet building and is therefore required to be both durable and aesthetically pleasing. The different methods of corrosion protection are:

- HDG Steel
- Painted Steel
- Duplex Coated Steel
- Stainless Steel

The design of the structures is explained in Section 5 to Section 10 of this report. Refer Appendix A and Appendix B for the drawings of the structures.

13 LCC MODEL DEVELOPMENT

13.1 Cost Breakdown Structure (CBS)

It was identified that the structures had three major life cycle phases, which were broken down into smaller sub categories. The categories were broken down until a level was reached where the cost could be readily estimated.

2. Initial Construction
   - Supply of Materials
   - Fabrication
   - Application of Coating

3. Service Life and Maintenance
   - Cleaning
   - Maintenance of coatings

4. Decommisioning and demolition
   - Salvage Value

As the purpose of the LCC analysis was to determine a comparative cost between the alternative methods of corrosion protection, a complete LCC was not required and therefore elements of the CBS which were constant between the different methods of corrosion protection were not included. The elements omitted from the CBS of the structure were:

- Erection of Structure on-site
- Demolition
- Roofing
- Slab and footings
- Masonry Blockwork
- Internal and external architectural work
- Repairing of Vandalism

The focus of the LCC was the major steel structural components, namely the columns, rafters and strut beams.

13.2 Method for Estimating Costs

Two methods have been used to estimate the costs. The first being *Cordell Commercial and Industrial Building Cost Guide, Queensland February 2009* and the second being contacting suppliers, fabricators and manufacturers to obtain quotes for a specific cost element. Further costs have also been attained by finding an average value. The elements determined from each source are shown below:

- Cordell Cost Guide
    - Supply and fabrication of mild steel
    - Fasteners
    - Painting Labour
    - Painting Maintenance
- Contacting Suppliers, Fabricators and Manufacturers
    - Stainless Steel Supply – Atlas Metals and Midway Metals
    - Stainless Steel Fabrication – Bridgeman Stainless Solutions, Pryde Fabrication.
    - Initial Paint Coating Supply – Jotun Coatings
    - Hot Dip Galvanizing – Industrial Galvanizers
    - Salvage Value

As mild steel and stainless steel are both subject to fluctuations in price, the prices shown in this report may be subject to change. All values used are in the form of Present Value. The internal rate of return (IRR) used to calculate these values was 6.34%, obtained through GCCC Corporate Finance.

14 LCC MODEL ANALYSIS

14.1 Galvanized Steel Structure

The prices for the mild steel were obtained from *Cordell Building Cost Guide* under Structural Steel. A price is given for each type of cross-section in $/tonne. The mass per metre of the sections were obtained from the OneSteel cold formed steel sections charts. Refer Table 14.1 for the schedule of the mild steel supply.

Table 14.1 – Supply Costs of Mild Steel

Member	Section	No. of Parts	length	kg/m	kg	$/t	$
Rafter Type 1	150x100x6 RHS	3	10.54	21.4	676.668	3885	2628.85518
Rafter Type 2	150x100x6 RHS	2	4.9	21.4	209.72	3885	814.7622
Column SC1A	75x6 SHS	5	2.83	12	169.8	3759	638.2782
Column SC1B	75x6 SHS	5	3.13	12	187.8	3759	705.9402
Column SC1C	75x6 SHS	3	3.39	12	122.04	3759	458.74836
Column SC1D	75x6 SHS	3	3.55	12	127.8	3759	480.4002
Column SC1E	75x6 SHS	2	2.86	12	68.64	3759	258.01776
Column SC1F	75x6 SHS	2	2.66	12	63.84	3759	239.97456
Strut Beam	75x4 SHS	4	4.8	8.49	163.008	3759	612.747072
Purlin Cleat on Rafters	75x8 strip	35	0.145	4.71	23.9032 5	5700.51	136.260716
Strut Cleat on Rafters	180x10 strip	6	0.145	14.13	12.2931	5700.51	70.0769395
Column Footing	90x10 strip	20	0.24	7.07	33.936	5700.51	193.452507
Column to Rafter Connection	100x12 strip	14	0.175	9.42	23.079	5700.51	131.56207
Column to Rafter top plate	100x12 strip	14	0.175	9.42	23.079	5700.51	131.56207
Column to Strut Connection	90x10 strip	4	0.255	7.07	7.2114	5700.51	41.1086578
Rafter to Facia Purlin	110x8 strip	10	0.12	6.91	8.292	6642.19	55.0770395
Rafter to Facia Purlin	65x5 EA	10	0.388	4.52	17.5376	5700.51	99.9732642
Cleat on strut end to rafter	90x10 strip	8	0.11	7.07	6.2216	5700.51	35.466293
Cleat on strut middle to column	90x10 strip	8	0.09	7.07	5.0904	5700.51	29.0178761
Rafter end plate	100x6 strip	10	0.15	4.71	7.065	5700.51	40.2741032
Strut end plate	75x6 strip	8	0.075	3.54	2.124	5700.51	12.1078832
							$7,813.66

The fabrication costs were obtained by the help of Bridgeman Stainless Solutions who supplied the number of hours it would take to fabricate the structure and an average fabrication rate for mild steel fabricators. Refer Table 14.2 for the total fabrication costs

Table 14.2 – Fabrication Costs

Fabrication Hours	Fabrication Rate ($/hr)	Fabrication Costs for Mild Steel
82	60	$4920

The HDG costs were obtained from Industrial Galvanizers (Brisbane). Refer Appendix F for a copy of the quote received. Refer Table 14.3 for the cost of HDG.

Table 14.3 – Cost of HDG

Total Weight of Mild Steel (t)	Cost of HDG ($/t)	Cost ($)
1.96	1131	**2215.80**

All fasteners used for the HDG structure are to be HDG. Refer Table 14.4. for the prices of the fasteners used. All prices were obtained from Cordell Building Cost Guide.

Table 14.4 – HDG Fasteners

Fasteners	Section Used	Quantity	Price Per Unit	Price ($)
Galv Chemset 130 embedment	Column footings	40	36.32	1452.8
M16 200mm long	Rafter to Column	26	3.1	80.6
M16 50mm long	Strut to Column	8	2.35	18.8
M16 50mm long	Strut to Rafter	16	2.35	37.6
			Total	**$1859**

The HDG structure will require washing approximately every six months to slow the attack on the HDG coating (GAA, 2008). Refer Table 14.5 for the costs of the cleaning. In the 'very high' corrosion category, in accordance with AS2312:2002, the HDG coating will be reduced by 4-8μm per year (GAA, 2003). The structure is HDG with a coating mass of 600g/m^2 which equates to 84μm thickness. Using an average coating reduction of 6μm per year this coating will last 14 years. To repair the coating an inorganic zinc silicate, water-borne paint will be used in accordance with IZS2 of Table 6.3 AS2312:2002. This system has a minimum time to first maintenance of 5 years. This paint system will be applied before the entire HDG coating has diminished therefore a maintenance coating will be first applied during the structures eleventh year of service. The eleventh year is the optimum time to begin maintenance as beginning the maintenance any later will result in increased maintenance costs which can be shown by linear regression. Over the life of the structure the labour costs for maintenance will increase by 5% each maintenance cycle. This increasing cost takes into account the extra preparation required such as removal of previous paint coatings and increased surface preparation that may be required due to rust break through occurring. The future maintenance costs have also had a discount rate of 6.34% applied which is the percentage used by GCCC to account for inflation. The paint used for the LCC is manufactured by Jotun Coatings, who also supplied the cost of the paint. Refer Table 14.6 and Table 14.7 for the cost of the initial maintenance cycle.

Table 14.5 – Cleaning costs

Labour Rate	Charge-out rate	Hours	Cost of Cleaning	Recurrence of Cleaning	Annual Cost
$16.30/hr	$47.20	2	$79.80	2 times per year	$159.60

Table 14.6 – Repair of HDG Coating

Product	Spreading Rate (m2/L)	Required Area (m2)	Required Volume (L)	Cost per L ($/L)	Cost ($)
Resist 5 WF, Grey	4.2	47.42	11.3	36	406.8

Table 14.7 – Labour Costs for Painting the HDG Coating

Labour rate for painting	Required Area	Initial Cost of Labour*
$17.25/m^2	47.42m^2	$818.00

*Note: The initial cost of labour will increase by 5% each cycle

The salvage value of the structure was obtained from ELG Recycling Processors and Sims Metal, both companies supplied a value of $100 per tonne for steel. Refer Table 14.8 for the costs recovered from salvage. The salvage value of mild steel is minimal and will have a negligible effect on the LCC of the structure.

Table 14.8 – Salvage value for Mild Steel

Salvage Rate	Weight of Steel	Salvage Value
$100/t	1.96t	$196

14.2 Painted Structure

The prices for supply and fabrication of the steel, supply of fasteners and washing for the painted structure will be the same as the HDG structure. Refer Table 14.1, Table 14.2, Table 14.4 and Table 14.5 for the costs. The initial painting will be completed in shop conditions to produce a quality surface finish. The surface area to be painted was calculated using the OneSteel tables for the sections and simply calculating the exposed surface area for the flats. Refer Table 14.9 for the calculations.

The paints used for the LCC are manufactured by Jotun Coatings. There are many manufacturers who have similar products which can also be used. Jotun Coatings supplied integrated paint specifications, data sheets and costs of the paint systems.

The price of paint was supplied in a $/L value. To determine the required volume of paint the spreading rate was calculated. The spreading rate takes into account the volume of solids in the paint (%), the required dry film thickness, the percentage of thinner added to the paint, and a loss factor for overspray (Wattyl, 2008) Refer Table 14.10 for the calculations of the spreading rate. Refer Table 14.11 for initial paint costs. Refer Table 14.11 to Table 14.13 for associated costs or calculations for paint systems application.

Table 14.9 – Area to be Painted

Part	Section	No. of Parts	length	m^2/m	Area
Rafter Type 1	150x100x6 RHS	3	10.54	0.474	14.99
Rafter Type 2	150x100x6 RHS	2	4.9	0.474	4.65
Column SC1A	75x6 SHS	5	2.83	0.274	3.88
Column SC1B	75x6 SHS	5	3.13	0.274	4.29
Column SC1C	75x6 SHS	3	3.39	0.274	2.79
Column SC1D	75x6 SHS	3	3.55	0.274	2.92
Column SC1E	75x6 SHS	2	2.86	0.274	1.57
Column SC1F	75x6 SHS	2	2.66	0.274	1.46
Strut Beam	75x4 SHS	4	4.8	0.283	5.43
Purlin Cleat on Rafters	75x8 strip	35	0.145	0.166	0.84
Strut Cleat on Rafters	180x10 strip	6	0.145	0.38	0.33
Column Footing	90x10 strip	20	0.24	0.2	0.96
Column to Rafter Connection	100x12 strip	14	0.175	0.224	0.55
Column to Rafter top plate	100x12 strip	14	0.175	0.224	0.55
Column to Strut Connection	90x10 strip	4	0.255	0.2	0.20
Rafter to Facia Purlin	110x8 strip	10	0.12	0.236	0.28
Rafter to Facia Purlin	65x5 EA	10	0.388	0.26	1.01
Cleat on strut end to rafter	90x10 strip	8	0.11	0.2	0.18
Cleat on strut middle to column	90x10 strip	8	0.09	0.2	0.14
Rafter end plate	100x6 strip	10	0.15	0.212	0.32
Strut end plate	75x6 strip	8	0.075	0.162	0.10
				Total Area (m^2)	**47.42**

Table 14.10 – Paint Systems Spreading Rate

Paint Type	Vol. Solids (%)	DFT	Thinner (%)	Loss Factor (%)	Spreading Rate (m^2/L)
Barrier, Grey	53	75	5	50	3.37
Jotacote Universal, Grey	72	200	5	50	1.71
Hardtop Ultra	52	75	5	50	3.30

Table 14.11 – Paint Costs

Product	Spreading Rate (m2/L)	Required Area (m2)	Required Volume (L)	Cost per L ($/L)	Cost ($)
Barrier, Grey	3.37	47.42	14.09	24	338.23
Jotacote Univeral, Grey	1.71	47.42	27.66	18	497.95
Hardtop Ultra	3.30	47.42	14.36	25	359.10
Thinners			2.81	8	22.45
					$1,217.72

Table 14.12 – Labour for Painting

Labour rate for painting	Required Area	Cost of Labour
$17.25/m^2	47.42m^2	$818.00

Table 14.13 – Surface Preparation for Painting

Surface Preparation Class	Surface Preparation Rate	Weight of Steel	Cost of Surface Preparation
Class 2 ½	$400/t	1.96t	$784

According to AS2312:2002 Table 6.3 the paint system will have a time to first maintenance of 10 – 15 years. This LCC has assumed that the time to first maintenance will be 10 years in an aggressive environment. GCCC maintenance have advised that steel structures in the foreshore zone are repainted every two years once maintenance has begun. The paint used to repaint the structures is an acrylic paint. The cost for this was determined using Cordell building cost guide. The maintenance costs for labour will be increased by 2% each maintenance cycle. This increase willl account for the extra surface preparation and paint removal required as the structure ages. Acrylic paint is used because it is easy to apply and dries quickly resulting in the building being out of use for shorter periods of time. Structures are also subject to frequent vandalism, such as graffiti. The chemicals used to clean the graffitit also reduce the life of the paint system. Refer Table 14.14 for the initial maintenance costs, these costs include labour. The future maintenance costs have also had a discount rate of 6.34% applied to account for inflation, this value converts the maintenance costs back to present worth.

Table 14.14 – Painting Maintenance

Maintenance Painting Cost	Area required to Paint	Cost of Maintenance Cycle
$23.34/m^2	47.42m^2	$1106.86

14.3 Duplex Structure

The duplex structure employs the use of both HDG and paint systems. The supply, fabrication, hot dip galvanizing, supply of fasteners and the washing cost will be the same as for the HDG structure. Refer Table 14.1 to Table 14.5. The initial paint system uses the same paints as the painted structure however thicker DFT are required. (GAA, 2008) Increasing the DFT will result in a reduced spreading rate. Refer Table 14.15 for the duplex coatings spreading rates. The duplex system paint costs will be higher as the spreading rate is lower and the polyurethane top coat (Hardtop Ultra) requires two coats at 50µm DFT. The labour rate for painting the duplex systems will be the same as the painted structure. Refer Table 14.16 and Table 14.17.

Table 14.15 – Duplex Coating Paint Systems Spreading Rate

Paint Type	Vol. Solids (%)	DFT	Thinner (%)	Loss Factor (%)	Spreading Rate (m^2/L)
Barrier, Grey	53	50	5	50	5.05
Jotacote Universal, Grey	72	200	5	50	1.71
Hardtop Ultra	52	50	5	50	4.95

Table 14.16 – Duplex Coating Paint System Cost

Product	Spreading Rate (m2/L)	Required Area (m2)	Required Volume (L)	Cost per L ($/L)	Cost ($)
Barrier, Grey	5.05	47.42	9.40	24	225.48
Jotacote Universal, Grey	1.71	47.42	27.66	18	497.95
Hardtop Ultra	4.95	94.84	19.15	25	478.79
Thinners			2.81	8	22.48
				Cost	**$1224.71**

Table 14.17 – Labour Rate for Painting the Duplex System

Labour rate for painting	Required Area	Cost of Labour
$17.25/m^2	47.42m^2	$818.00

The surface preparation for the paint system to be applied to the HDG steel should be Sa 2 to AS1627.4:2005 (GAA, 2008). The rate for surface preparation was obtained from Cordell Building Cost Guide. Refer Table 14.18.

Table 14.18 – Surface Preparation for Duplex System

Surface Preparation Class	Surface Preparation Rate	Weight of Steel	Cost of Surface Preparation
Class 2	$325/t	1.96t	$637

The duplex system uses an acrylic paint for maintenance of the structure. As with the painted structure the original paint system has a time to first maintenance of ten years and therefore maintenance of the duplex structure will begin after ten years. After this time the structure will be repainted every two years with a 2% increase on the maintenance labour for each cycle. This increase will account for the extra surface preparation and paint removal costs as the structure ages. Refer Table 14.14 for the cost of the initial maintenance cycle. The discount rate of 6.34% will also be applied to account for inflation.

14.4 Stainless Steel Structure

The stainless steel structure has been designed to be constructed from 316L stainless steel. The costs for the supply stainless steel for the structure was supplied by Bridgeman Stainless Solutions. Refer Appendix G. The supply cost is as illustrated in Table 14.19.

Table 14.19 – Stainless Steel Costs

Supply and fabrication costs of stainless steel structure	$17625.00

The stainless steel structure will use stainless steel fasteners for all connections. Refer Table 14.20 for the schedule of fasteners used.

Table 14.20 – Stainless Steel Fasteners

Fasteners	Section Used	Quantity	Price Per Unit	Price
SS Chemset 130 embedment	column footings	40	43.05	1722
SS M16 200mm long	Rafter to Column	26	13.9	361.4
SS M16 50mm long	Strut to Column	8	10.67	85.36
SS M16 50mm long	Strut to Rafter	16	10.67	170.72
		Total Cost of Fasteners		$2339.48

Stainless steel fabrication costs were supplied by Bridgeman Stainless Solutions. The cost includes grinding smooth and pickling of all welds. The surface finish is a milled finish and has not been polished. Refer Table 14.21 for the fabrication cost. Refer Appendix G for a copy of the quote.

Table 14.21 – Stainless Steel Fabrication Costs

Stainless Steel Fabrication Costs
$6250

The only required maintenance on the stainless steel structure will be cleaning of the structure. The cleaning should be carried out three times a year (Stone, 1994) and does not require any specialised cleaning methods. Using Cordell Building Cost Guide a cleaner is designated as a Group 4 labourer. It is estimated that it will take approximately 2 hours to clean the structure. Refer Table 14.22 for the associated cleaning costs. The future maintenance costs will be converted back to present worth using a discount rate of 6.34%, which is the current rate used by GCCC.

Table 14.22 – Cleaning of Stainless Steel

Labour Rate	Charge-out rate	Hours	Cost of Cleaning	Annual Cost
$16.30/hr	$47.20	2	$79.80	$239.40

The salvage value for 316L stainless steel for this project is being used as $2000/t. This value was sourced with the help of ASSDA, ELG Recycling Processors and Sims Metal

Table 14.23 – Salvage Value of Stainless Steel

Salvage Value of 316L	Weight of Stainless Steel	Salvage Cost of Stainless Steel
$2000/t	2.2t	$4400

15 LIFE CYCLE COST OF STRUCTURES

Using the values defined above the LCC of each structure was determined. Refer Appendix J and Figure 14.1 for the breakdown of values, defined in the 'Lower Bound' column and Table 15.1 for the LCC of the structures. This LCC illustrates that HDG steel is the cheapest form of corrosion protection over a 50 year design life, however a HDG coating will only last 14 years in the aggressive foreshore zone and therefore the line on the graph should only extend until 14 years. This project has assumed that the structure will be regularly painted after this time, however the effectiveness of this maintenance cannot be validated. Due to this failure of the coating after such a short time a HDG coating without a subsequent paint system should not be used in the foreshore zone.

The LCC comparison shows that stainless steel is more expensive than any other material over a 50 year design life. However the results obtained from this analysis assume an 'ideal world' situation where maintenance is carried out perfectly and on time. To accommodate for the realistic scenario that maintenance will not be carried out perfectly and events such as vandalism will occur a benefit analysis has been carried out.

Table 15.1 – LCC Analysis

Corrosion Protection Method	Life Cycle Cost
Hot Dip Galvanizing	$21272.25
Paint System	$24014.87
Duplex System	$26237.66
Stainless Steel	$25415.84

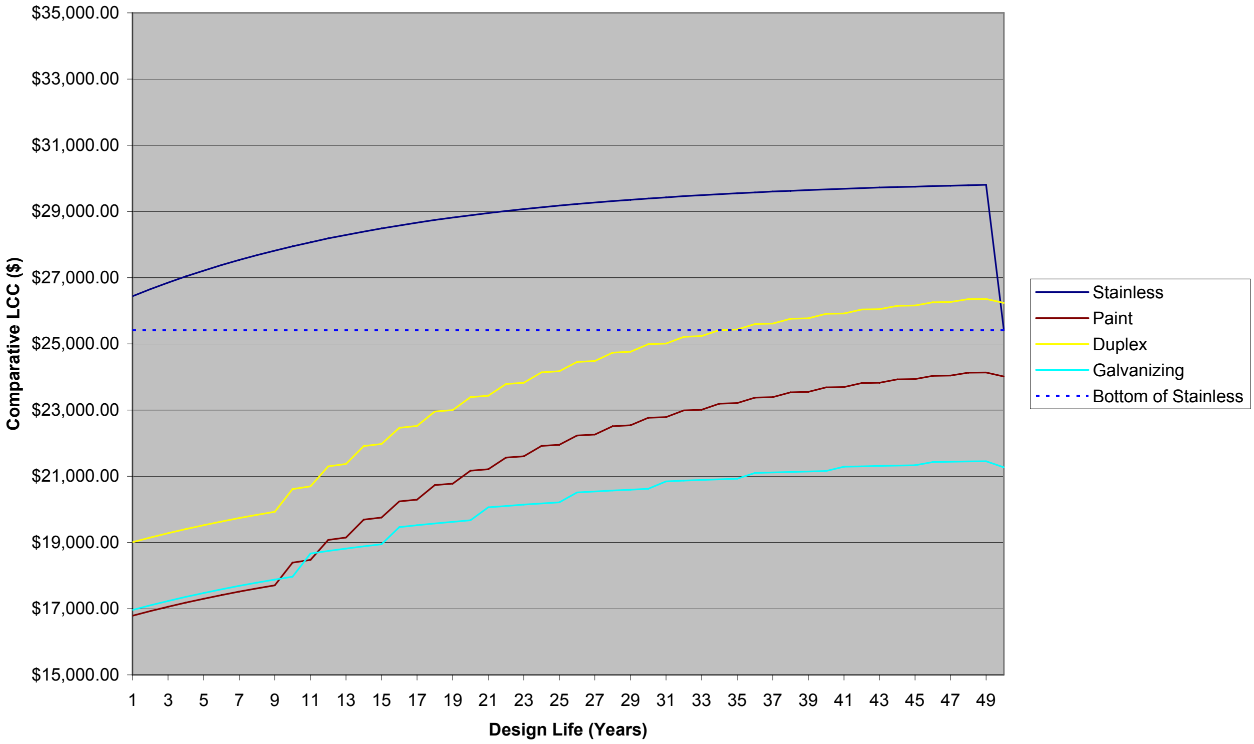


Figure 15.1 – LCC of Structures

16 COST/BENEFIT ANALYSIS

The figures presented above estimate the costs incurred over the life cycle of a structure assuming ideal conditions. However in ‘real world’ applications the actual conditions must be considered. To include these ‘real world’ factors the *risk of system failure* will be introduced and the implications that will occur if maintenance is not properly carried out. This section applies a monetary value to the risk associated with failure of the structure due to the use of mild steel.

All materials lose a predetermined thickness each year due to general wear and corrosion. Refer Figure 16.1 for the degradation rates of the materials examined in this project. HDG coatings will “cease to exist” after 14 years (GAA, 2008) and Painted Coatings will “cease to exist” after 10 years (AS2312, 2002), however stainless steel will last well in excess of either of these with a loss of 1mm every 40000 years (Housaka, 2001). Refer Table 16.1 for the degradation rates of the different coating types.

Table 16.1 – Average Degradation Rates

Coating	Average Degradation Rate (μm/year)
Hot Dip Galvanized	6
PUR 5 Paint System in Accordance with AS2312:2002	35
Grade 316 Stainless Steel	0.025

Assuming a linear risk relationship the risk of failure of the coating can be estimated by Equation 14.1.

$$\frac{T}{C_f} = R_c$$

Equation 16.1

Where:

T = The time the structure has been in service

C_f = Time until coating ceases to exist or fails.

R_c = Risk that the coating will fail

This equation demonstrates that after 14 years if no maintenance is undertaken the risk of the HDG coating failing is 100%. It is then assumed that the structure will fail completely within 2 years due to the presence of extensive rust. This allows the creation of another equation to estimate the risk of infrastructure failure. Refer Equation 14.2.

$$\frac{T}{I_f} = R_I$$

Equation 16.2

Where:

T = The time the structure has been in service

I_f = Time until the infrastructure will fail.

R_I = Risk that the infrastructure will fail.

Refer Table 16.2 for the variables of each corrosion protection method.

Table 16.2 – Corrosion Protection Method Variables

	C_f	I_f
Galvanized Coating (GAA, 2008)	14 years	16 years
Painted Coating (AS2312, 2002)	10 years	12 years
Duplex Coating (AS2312, 2002, GAA, 2008)	24 years	26 years
Stainless Steel (Housaka, 2001)	40000 years	40000 years

Note: The time to infrastructure failure for stainless steel is based on loosing 1mm of metal.

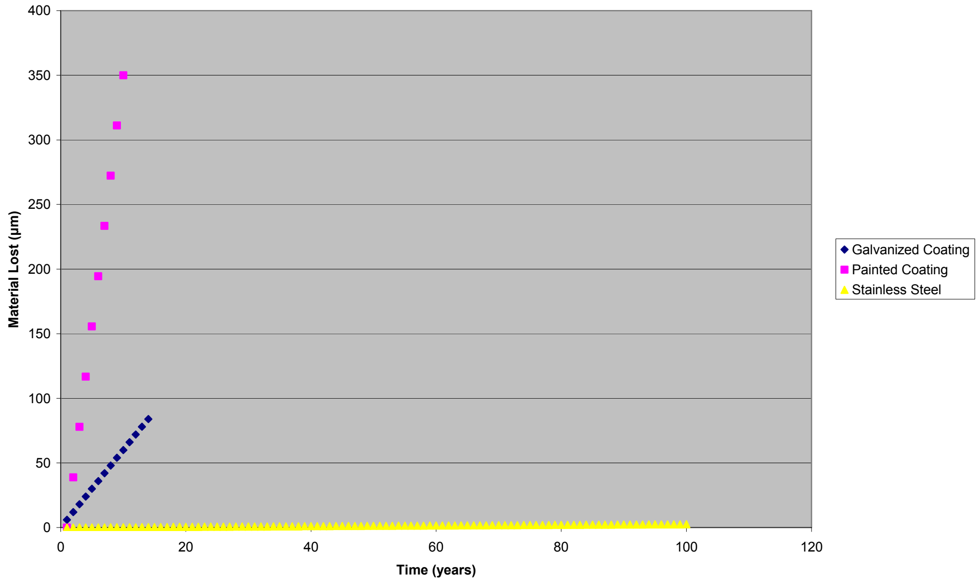


Figure 16.1 – Degradation Rates of Materials

The implications of this introduced risk for the mild steel structures is that once the risk of infrastructure failure reaches 100% the structure will fail due to corrosion and need to be completely replaced. For the HDG, painted and duplex structure a second LCC has been calculated which incorporates this failure of the steel. This has been denoted as the upper bound, while the LCC which does not incorporate the risk has been denoted as the lower bound. The combination of these upper and lower bounds results in the formation of an LCC envelope. A second LCC for stainless steel has not been calculated as the envelope would be extremely small.

17 RESULTS OF LIFE CYCLE COST/BENEFIT ANALYSIS

Refer to Appendix J for the cost breakdown of the LCC analysis.

The cost/benefit analysis gives a realistic model of the LCC of the structures. It takes into account the risk that structres coating will not be maintained properly and may be vandalised or damage

Based on the cost/benefit analysis, stainless steel is a viable option for structures with a design life over 16 years for HDG steel, 11 years for painted steel and 23 years for duplex coated steel. Refer Table 17.1 and Figure 17.1 for the results of the cost/benefit analysis.

Table 17.1 – LCC Comparison

Corrosion Protection Method	Life Cycle Cost
Hot Dip Galvanizing (Lower Bound)	$21272.25
Hot Dip Galvanizing (Upper Bound)	$58180.82
Paint System (Lower Bound)	$24014.87
Paint System (Upper Bound)	$91098.28
Duplex System (Lower Bound)	$26237.66
Duplex System (Upper Bound)	$64323.33
Stainless Steel	$25415.84

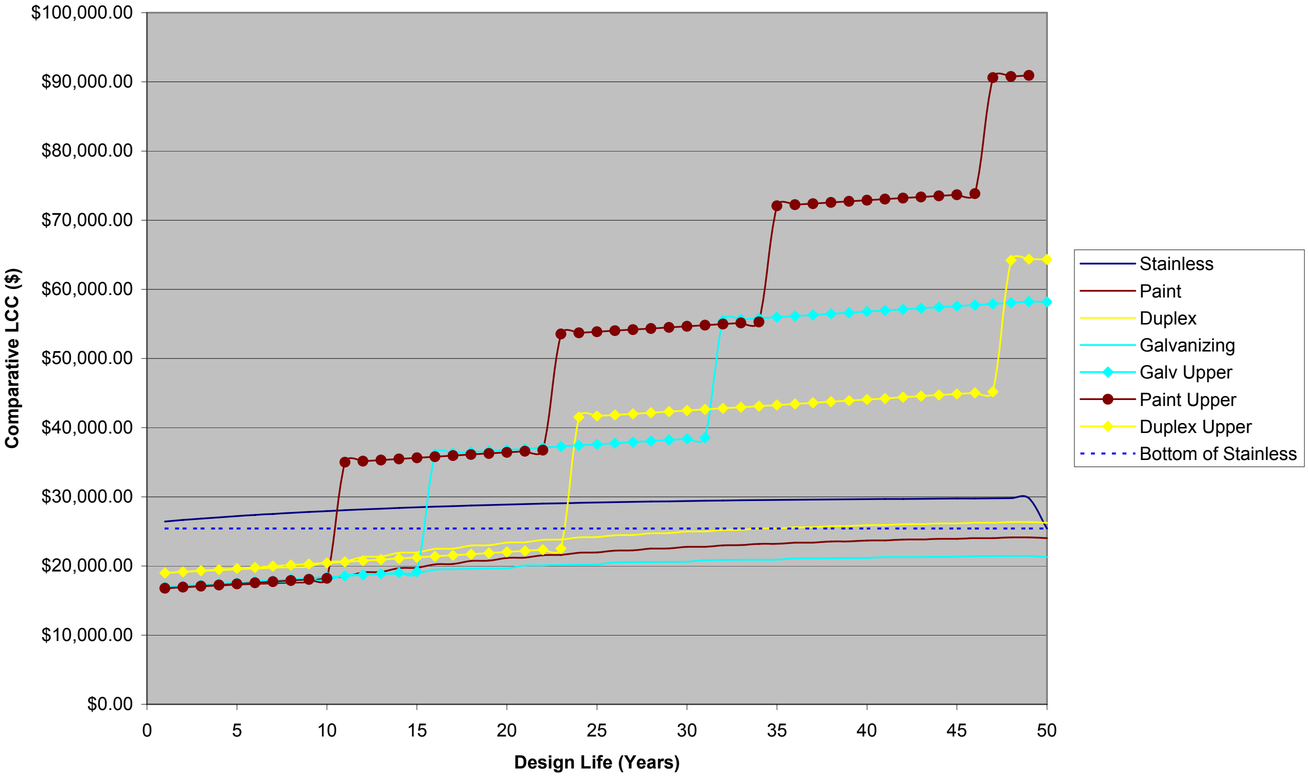


Figure 17.1 – Cost/Benefit Analysis

18 VALIDATION

Two similar case studies were found regarding a comparison of stainless steel and mild steel. These studies only examined the use of stainless steel and carbon steel with a hot dip galvanzied coating. The studies both showed similar results with the initial supply of stainless steel being much higher than mild steel, similar fabrication costs and lower maintenance costs for stainless steel. The results from the case studies are not directly comparable to this project as one of the studies was for buses and the other was for street furniture.

The case study for the buses can be found at the following URL:
http://www.euro-inox.org/LCC/flash.html

The case study for the street furniture can be found in Appendix H.

A graph obtained from the South African Stainless Steel Development Association (SASSDA), after the LCC Analysis was completed, verifies that the results obtained from this project are acceptable. The general shape of the graphs obtained from the project are the same as the graph obtained from the SASSDA. Refer Figure 18.1 for this graph.

Figure 18.1 – LCC Example (SASSDA)

19 WIDER PROFESSIONAL ISSUES

19.1 Financial Control

As GCCC is a government body and the project was funded by public revenue, the costs incurred during the project should have only been for items that will develop the project. The costs incurred over the course of the project were minimal. The major expenditures were liaising with GCCC employees, which was a necessary part of the project.

19.2 Marketing

As the nature of this project is testing materials it had the potential to become a marketing exercise for the associations involved. This has been overcome by carrying out the LCC analysis in accordance with AS4536:1999 and using all information as supplied. The report has been written from a neutral position to obtain an accurate outcome. Information has been sourced from a variety of sources, resulting in a well rounded outcome.

19.3 Sustainability

The vision the GCCC has planned for the city of the Gold Coast is:
Naturally, the world's best place to be... because we will create a city that is recognised internationally for the quality, diversity and sustainability of its lifestyle, economy and environment. The Gold Coast's future will be secure as Australia's most desirable place to live and favourite place to visit. (GCCC, 2009)

A sustainable lifestyle requires the use of sustainable materials. Of the materials examined in this project stainless steel is the most sustainable material. The other materials examined require the use of an artificial coating to protect from corrosion. This coating breaks down over time and requires replacement. The naturally occurring film on stainless steel will regenerate itself when damaged (ASSDA, 2008). The life of stainless steel is also much longer than mild steel. Refer Table 16.2.

Steel is completely recyclable with stainless steel today being made up of approximately 60% recycled content. (ASSDA, 2005) and mild steel being made up of approximately 20% recycled content. (Blue Scope Steel, 2009).

19.4 Risk to the Public

The focus of this project is the validity of different materials based on the life cycle cost. An issue that has not been a focus of this project is the risk to the public of using different materials. Stainless steel has become a very popular material for the construction of balustrades and handrails. An example of this is the Kirra Foreshore on the Gold Coast. A stainless steel handrail was installed into this aggressive environment in 1999 and has functioned will with minimal to no maintenance. It is a maintenance "free" structure providing ongoing structural integrity. Refer Figure 19.1.

Figure 19.1 – Kirra Stainless Steel Handrail (ASSDA)

If a HDG, painted or duplex handrail had been installed it would require regular maintenance and safety checks. As mild steel will corrode to failure a situation as illustrated in Figure 19.2 may have occurred.

Figure 19.2 – Corroded Steel Handrail (ASSDA)

As illustrated above, stainless steel will provide a low risk option for public structures in the foreshore zone.

19.5 Aesthetic Benefits

As seen in GCCC vision statement the aesthetic look of the Gold Coast is an important factor. The materials examined in this project can all be used for aesthetic reasons, however some may be better suited that others. Paint and Duplex systems are best suited for aesthetic applications based on the ability to choose from a range of colours and have a high gloss finish. Stainless steel is also well suited to aesthetic applications with many architectural features being designed from stainless steel and the ability to be finished in a variety of styles. However stainless steel has the potential to “tea stain” if left unmaintained. HDG steel has the lowest aesthetic benefits as it has a dull uneven finish. HDG steel also has a tendency to build up ‘white rust’ which is a bulky unattractive deposit. Refer Figure 19.3 for an example of ‘white rust’.

Figure 19.3 – Example of White Rust

20 DISCUSSION

The values reached in this LCC analysis will be subject to change with time as steel prices will fluctuate. However when calculated they were as accurate as possible.

The results obtained from this LCC analysis do not definitively point to one material being more suitable than everything else. However it provides justification to GCCC that stainless steel is a viable option and should not be overlooked when constructing in the foreshore zone.

According to this LCC analysis the HDG, painted and duplex structure all have similar initial costs and stainless steel has a higher initial cost. The HDG coating is comparable to the price of a painted coating. Using the data supplied by GAA it was estimated that the HDG coating will last for 14 years. Therefore a HDG structure in the foreshore zone should have a maximum design life of 14 years. This can be validated from existing HDG GCCC toilet buildings which have isolated rust appearing after only eighteen months. To maintain a HDG structure after the theoretical life of 14 years an inorganic zinc rich paint must be applied to protect against corrosion. Therefore the structure effectively is no longer a HDG structure but a duplex structure. If the HDG is left unmaintained the risk of infrastructure failure will be 100% after 16 years.

The painted structure provides aesthetic benefits over HDG, however the cost is higher over the life cycle of the structure. Apart from the aesthetic benefits paint systems perform comparably to HDG with a one year difference in time to first maintenance. However maintenance costs for paint systems are much higher than the maintenance costs associated with HDG. As the life of the structure increases the LCC for the painted structure will increase at a greater rate than the LCC for the HDG structure. Refer Figure 17.1 for an illustration of this increase.

The duplex structure is very similar in cost to that of the painted structure. The only difference being the HDG coating. The time to first maintenance and maintenance intervals for the duplex are the same as the painted structure. The fact that the steel is HDG does not allow the structure to be maintained less often, as a failure in the paint system will increase the rate of corrosion in the HDG coating. From GCCC perspective the HDG coating may not be required if the structure is properly maintained, however there is a chance that maintenance will not be correctly completed. Due to the frequent vandalism occuring on public structures the presence of the HDG will still allow the steel to be protected should the painted coating be removed or damaged. This property of the duplex system makes it a sound choice for GCCC.

As illustrated by the LCC analysis the initial cost for the stainless steel structure is much larger than any of the other structures. The cost driver for stainless steel is the supply and fabrication where as maintenance is the cost driver for the other structures. The maintenance costs for a stainless steel structure are notably less than a painted, duplex or HDG structure. A contributing factor to the large supply cost of stainless steel is the lack of available section sizes as compared to mild steel. The stainless steel rafter beam used (200x100x5) is oversized, however it was the smallest available section that would not yield. The benefit of stainless steel is that the maintenance costs will not increase with the life of the structure, maintaining a linear progression. As the other structures age the maintenance costs increase. Refer Figure 17.1 which illustrates this relationship.

During the LCC analysis a range of different costs were obtained and used. Any change in the values associated with the LCC resulted in large fluctuations in the LCC model. This has shown that the model is very volatile and sensitive to changes in values. This volatility has led to the LCC analysis not definitively proving that one material is superior to the others. However the LCC analysis has provided evidence and justification to undertake further study in this area, possibly in the form of another IAP project.

The project required the development of a *Design Guide*, SSLCC Spreadsheert and a LCC analysis of structures constructed in the foreshore zone. All deliverables of this project have been completed and are ready to be used by GCCC. The *Design Guide* was validated through peer review, however further works could be undertaken on the Design Guide to physically validate the techniques by testing. The SSLCC spreadsheet has been modelled on the results obtained through the LCC analysis. Parts of the SSLCC spreadsheet that may need further works are the sections which estimate the fabrication costs of the structure.

21 RECOMMENDATIONS

The outcomes of this project do not explicitly point to one material that should be used over the others. However it does give evidence to GCCC that stainless steel is a viable option for use in the foreshore zone. The major outcomes of the LCC analysis are:

- The LCC of stainless steel structures are comparable or less than mild steel structures
- A HDG coating will cease to exist after 14 years.
- Paint systems do not provide protection if the coating is damaged.
- The only maintenance required for stainless steel is washing.
- Stainless steel structures have an extremely long design life.

This project has also given evidence that HDG structures should not be used if the design life is to be longer than 14 years. HDG should only be used in the foreshore zone in the form of a duplex system.

The above factors give evidence that stainless steel can be economically used as a material in the foreshore zone. The results are not definitive, however this project has given justification to undertake further study into the use of stainless steel as a structural material in the foreshore zone.

22 PROJECT MANAGEMENT

One of the learning curves encountered during the IAP was undertaking the role of project manager. Over the course of the project many tasks ran to schedule while others ran over schedule. This section of the report analyses how the student managed the project of the course of the program

22.1 Program Schedule

The project was initially schedule to progress in the following order:

- Literature Review
- Design guide
- Design of Structures
- LCC Analysis
- SSLCC Spreadsheet.

The majority of the project progressed in accordance with this initial schedule, with the only major change being the *Design Guide* was completed after the Design of the Structures. A major problem in the schedule was the time allocated for the LCC Analysis. It was initially allowed to be completed within 2 weeks. However that time was significantly extended until the end of the program. It has been identified that there were two main reasons as to why the LCC analysis took much longer than initially planned

1. It was difficult to find quotes as the job was not a ‘real’ job that would supply fabricators and suppliers with work.
2. There was an initial misunderstanding of what was required between the student and the Industry Supervisor.

All parts of the project before the LCC Analysis were completed in the allotted time frame and delivered by the required dates. However the LCC Analysis and the SSLCC Spreadsheet were delivered after the delivery dates.

23 CONCLUSION

The aim of this project was to provide GCCC with information to enhance the durability of structures constructed in the foreshore zone. This aim has been achieved by supplying GCCC with the following:

- Design Guide – This guide is a tool that can be used by GCCC to optimise structures against corrosion in the foreshore zone.
- SSLCC Spreadhseet – This is a tool that can be used by GCCC to estimate the life cycle cost of steel structures, allowing GCCC to compare material types for different design lifes.
- Life Cycle Cost/Benefit Analysis – This analysis has given evidence to GCCC that other materials, such as stainless steel, are economocally viable to be used for structures constructed in the foreshore zone.

This report indicates that for a structure being placed in the foreshore zone stainless steel and duplex systems are viable options based on the life cycle cost of the structure as well as the design life. Hot dip galvanized structures and structures protected by a paint system will not provide adequate protection to the structure over the design life. On the basis of cost alone the report does not explicitly identify a material that should always be used, however this report has supplied evidence to justify undertaking further research into the LCC of structures constructed in the foreshore zone.

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APPENDIX A - STRUCTURAL PLANS

Begins on the following page.

ROUGHTON PARK
MUSGRAVE STREET, COOLANGATTA
PUBLIC TOILET FACILITIES

GENERAL NOTES

1. THESE DRAWINGS AND NOTES ARE TO BE READ IN CONJUNCTION WITH ARCHITECTURAL AND OTHER WORKING DRAWINGS, SPECIFICATIONS, AND WITH SUCH FURTHER DETAILS, AND INSTRUCTIONS WHICH MAY BE ISSUED. REFER ALL DISCREPANCIES TO THE ENGINEER BEFORE PROCEEDING WITH WORK.
2. CONSTRUCTION OF ALL STRUCTURAL AND CIVIL WORK SHALL COMPLY WITH CURRENT EDITIONS OF RELEVANT SAA CODES.
3. DIMENSIONS SHALL BE VERIFIED BEFORE COMMENCING CONSTRUCTION. DO NOT SCALE DRAWINGS TO OBTAIN DIMENSIONS.
4. THROUGHOUT CONSTRUCTION THE STRUCTURE SHALL BE MAINTAINED IN A STABLE CONDITION AND NO PART SHALL BE OVER STRESSED.

DESIGN CRITERIA

1. THE STRUCTURAL ELEMENTS SHOWN ON THESE DRAWINGS HAVE BEEN DESIGNED FOR SUPERIMPOSED DEAD AND LIVE LOADS AS NOMINATED ON THE RELEVANT DRAWINGS AND THE FOLLOWING
   WIND LOADS TO AS 1170.2
   REGION - B
   TERRAIN CATEGORY - 2.0
   BCA STRUCTURE IMPORTANCE LEVEL - 2
   Vdes,θ - 51.90m/s
2. CONCRETE ELEMENTS HAVE BEEN DESIGNED FOR THE FOLLOWING DURABILITY EXPOSURE TO AS 3600 (B1 EXPOSURE U.N.O.)
   EXTERNAL B2
   INTERNAL A1
   FOOTINGS A1

AND TESTING IS TO
CONSULTANT IN ACCORDANCE WITH AS3798 AND BORDERTECH'S REPORT. THE CONTRACTOR SHALL PROVIDE DETAILS OF ALL TESTING TO THE GEOTECHNICAL ENGINEER PROGRESSIVELY THROUGHOUT THE WORKS AND NOTIFY THE STRUCTURAL ENGINEER OF ANY NON CONFORMANCES, ALL NON CONFORMING WORK IS TO BE RECTIFIED AT THE CONTRACTORS EXPENSE.
PRIOR TO COMMENCEMENT OF WORKS THE CONTRACTOR IS TO IDENTIFY AND BE SATISFIED OF THE CORRECT LOCATIONS OF ALL EXISTING SERVICES WHETHER INDICATED OR NOT ON THE PLANS. ANY DAMAGE TO EXISTING SERVICES IS TO BE RECTIFIED AS SOON AS POSSIBLE AT THE CONTRACTORS EXPENSE.
REMOVE ALL VEGETATION, ORGANIC TOPSOIL, AND OTHER DELETERIOUS MATERIAL AND DISPOSE OF ALL SUCH MATERIAL OFF SITE. EXCAVATE AND TRIM THE BUILDING OR PAVEMENT PLATFORMS AS REQUIRED.
5. PROOF ROLL THE EXPOSED SUBGRADE. ANY SOFT SPOTS MUST BE INSPECTED BY THE APPROVED GEOTECHNICAL ENGINEER TO ASSESS EXTENT.
6. SOFT SPOTS SHALL BE EXCAVATED AND REPLACED WITH SELECT GRANULAR BACKFILL COMPACTED IN LAYERS NOT EXCEEDING 150mm COMPACTED THICKNESS TO COMPACTION AS NOTED.
7. FILL MATERIAL SHALL BE EITHER IMPORTED SELECT MATERIAL OR EXISTING EXCAVATED SOILS (IF APPROVED BY THE GEOTECHNICAL ENGINEER & FREE OF ORGANIC MATERIAL). IMPORTED FILL MATERIAL SHALL BE LOW PLASTICITY, GRANULAR FILL HAVING THE FOLLOWING CHARACTERISTICS:-
   MINIMUM CBR 15%
   PLASTICITY INDEX <15%
   % PASSING 0.075mm SIEVE <25%
8. FILL MATERIAL SHALL BE COMPACTED IN MAXIMUM 150mm THICK LAYERS (COMPACTED THICKNESS) TO 100% STANDARD DRY DENSITY RATIO IN ACCORDANCE WITH AS1298 U.N.O.

EARTHWORKS CONT.

9. SUB-BASE FILL MATERIAL SHALL HAVE MINIMUM CBR 15% AND MAX PLASTICITY INDEX OF 15% AND IS TO BE PLACED TO FINAL THICKNESS AS DOCUMENTED COMPACTED TO 100% STANDARD MAXIMUM DRY DENSITY IN ACCORDANCE WITH AS1289 U.N.O.
10. FILL SHALL BE COMPACTED AND MAINTAINED AT MOISTURE CONTENTS AT PLACEMENT WITHIN THE RANGE OF PLUS 2% TO MINUS 2% OF STANDARD OPTIMUM MOISTURE CONTENT.
11. THE MINIMUM FREQUENCY OF TESTING FILL COMPACTION SHALL BE IN ACCORDANCE WITH TABLE 8.1 OF AS3798 FOR TYPE 2 EARTHWORKS.
12. ALL EXCAVATED BATTERS AND FILL EMBANKMENTS ARE TO BE INSPECTED AND APPROVED BY THE GEOTECHNICAL ENGINEER.
13. REFER TO STRUCTURAL DRAWINGS FOR DETAILED EXCAVATION.
14. REFER ALSO ARCHITECTS, LANDSCAPE ARCHITECTS AND HYDRAULICS ENGINEER FOR ADDITIONAL WORKS AND REQUIREMENTS.
15. PRIOR TO COMMENCEMENT OF WORK CONFIRM ALL BULK EXCAVATION LEVELS WITH THE ARCHITECT.
16. IT IS THE CONTRACTORS RESPONSIBILITY TO PROTECT THE SITE AND SURROUNDING AREAS FROM DAMAGE RESULTING FROM STORMWATER RUNOFF. TEMPORARY DIVERSION DRAINS AND OR OTHER DRAINAGE CONTROL DEVICES ARE TO BE IMPLEMENTED BY THE CONTRACTOR DURING CONSTRUCTION TO MINIMISE THE EFFECTS OF WEATHER.

FOOTING NOTES

1. AN ALLOWABLE END BEARING PRESSURE FOR HIGH LEVEL FOOTINGS OF 100kPa HAS BEEN ASSUMED IN THE DESIGN OF THE FOOTINGS
2. THE FOUNDATION SYSTEM HAS BEEN DESIGNED FOR A CLASS 'H' SITE CLASSIFICATION AS SPECIFIED IN THE SOILS REPORT
3. WHERE EXCAVATION WORK IS TO BE CARRIED OUT ADJACENT TO EXISTING FOOTINGS THE EXACT LEVEL OF THE UNDERSIDE OF THE FOOTINGS SHALL BE DETERMINED BY TEST PITS PRIOR TO EXCAVATION. UNDERPINNING SHALL BE CARRIED OUT AS DETAILED OR REQUIRED BY THE STRUCTURAL ENGINEER
4. ALL FOOTING EXCAVATIONS SHALL BE FORMED AS NECESSARY WHEN EXCAVATED FACE IS NOT STABLE, DEWATERED AND CLEANED OF LOOSE AND SOFT MATERIAL PRIOR TO PLACING CONCRETE.
5. ALL WALLS AND COLUMNS SHALL BE CONCENTRIC WITH SUPPORTING FOOTINGS UNLESS NOTED OTHERWISE ON THE DRAWINGS.

CONCRETE

1. ALL MATERIALS AND WORKMANSHIP SHALL CONFORM WITH CURRENT EDITIONS OF AS 1379, AS 3600 AND AS3610 EXCEPT WHERE VARIED BY THE CONTRACT DOCUMENTS. REFER ALSO TO INSITU CONCRETE, FORMWORK AND REINFORCEMENT SECTION OF THE SPECIFICATIONS.
2. CONCRETE STRENGTH GRADE FOR PARTICULAR ELEMENTS SHALL BE AS NOTED ON THE DRAWINGS.
3. PROJECT ASSESSMENT OF STRENGTH IN ACCORDANCE WITH AS 1379 SHALL BE ADOPTED FOR SAMPLING AND TESTING. REFER TO SPECIFICATION FOR FREQUENCY OF TESTS.
4. SIZE OF ELEMENTS IS EXCLUSIVE OF APPLIED FINISHES. BEAMS DEPTHS INCLUDE SLAB THICKNESS AND ARE THE FIRST DIMENSION SPECIFIED, FOLLOWED BY WIDTH. UNLESS NOTED OTHERWISE ALL FORMED EDGES AND CORNERS OF CONCRETE MEMBERS SHALL HAVE 20mm CHAMFERS.
5. CONSTRUCTION JOINTS SHALL BE MADE ONLY AT APPROVED LOCATIONS, AND, IN BEAMS AND SLABS SHALL BE CONSTRUCTED WITH A SHEAR KEY TO ENGINEER'S DETAIL U.N.O. SURFACES OF CONCRETE AT ALL JOINTS SHALL BE THOROUGHLY MECHANICALLY SCABBLED, FULLY EXPOSING THE AGGREGATE MIX, UNLESS OTHERWISE NOTED.
6. ALL REINFORCEMENT SHALL BE TO AS 4671 AND REINFORCEMENT GRADE IS DESIGNATED AS FOLLOWS:-
   R: PLAIN ROUND BAR, GRADE 250
   N: DEFORMED BAR, GRADE 500
   SL/RL: WIRE REINFORCING FABRIC GRADE 500

CONCRETE CONT.

7. REINFORCEMENT SHALL BE BENT COLD IN ACCORDANCE WITH AS3600 EXCEPT WHERE APPROVED BY THE STRUCTURAL ENGINEER. NO REBENDING SHALL BE PERMITTED.
8. DO NOT CUT REINFORCEMENT ON SITE TO CLEAR PENETRATIONS. DISPLACE REINFORCEMENT SLIGHTLY AS NECESSARY TO CLEAR BLOCKOUTS.
9. CONCRETE COVER AND LAPS TO REINFORCEMENT SHALL BE AS NOTED ON THE DRAWINGS.
10. SLABS AND BEAMS SHALL BEAR ON ONLY LOAD BEARING ELEMENTS SHOWN ON THE PLANS. ALL OTHER NON LOAD BEARING ELEMENTS INCLUDING WINDOW MULLIONS, NON LOAD BEARING WALLS ETC. SHALL BE KEPT 20mm CLEAR FROM SOFFIT OF STRUCTURE.
11. MASONRY WALLS SHALL NOT BE ERECTED ON SUSPENDED SLABS AND BEAMS UNTIL ALL PROPPING HAS BEEN REMOVED U.N.O.
12. APPLY EVAPORATION RETARDER AND CURE ALL CONCRETE IN ACCORDANCE WITH THE CONCRETE SPECIFICATIONS
13. FORMWORK SHALL REMAIN UNDISTURBED FOR THE MINIMUM STRIPPING TIMES SPECIFIED IN AS3610, UNLESS OTHERWISE APPROVED

REINFORCED CONCRETE MASONRY

1. ALL MATERIALS AND WORKMANSHIP SHALL CONFORM WITH THE CURRENT EDITION OF AS3700 EXCEPT WHERE VARIED BY THE CONTRACT DOCUMENTS. REFER ALSO TO THE STRUCTURAL BLOCKWORK SECTION OF THE SPECIFICATION.
2. CONCRETE MASONRY UNITS SHALL HAVE A MINIMUM CHARACTERISTIC UNCONFINED COMPRESSIVE STRENGTH OF 15 MPa IN ACCORDANCE WITH THE REQUIREMENTS OF AS 2733.
3. PROVIDE ADEQUATE TEMPORARY PROPPING TO WALLS DURING CONSTRUCTION IN ACCORDANCE WITH AS 4455 AND AS 4456.
4. PROVIDE VERTICAL CONTROL JOINTS IN WALLS AT MAXIMUM 8 METRE CENTRES OR WHERE INDICATED ON DRAWINGS.
5. ALL WALLS SHALL BE FULLY BONDED OR TIED AT THEIR INTERSECTIONS UNLESS DETAILED OTHERWISE.
6. ALL NON-LOADBEARING MASONRY WALLS SHALL BE KEPT CLEAR OF SLAB/BEAM SOFFITS BY 20mm U.N.O. AND THE VOID FILLED WITH AN APPROVED COMPRESSIBLE FILLER AND FIRE RATED AS REQUIRED.
7. NO MASONRY WALLS TO BE ERECTED ON SUSPENDED SLABS UNTIL ALL PROPPING HAS BEEN REMOVED.
8. MORTAR SHALL BE MECHANICALLY MIXED AND TYPE M3 U.N.O. CONSISTING OF 1 PART CEMENT, 1 PART HYDRATED LIME AND 6 PARTS OF WELLGRADED SAND, AND SHALL COMPLY WITH THE REQUIREMENTS OF AS 3700. MORTAR SHALL BE SAMPLED AND ...TED, IN ACCORDANCE WITH THE SPECIFICATION.
9. CORES OF ALL BLOCKS SHALL BE CLEAN AND FREE FROM PROJECTING MORTAR. PROVIDE CLEAN OUT OPENINGS AT BASE OF EACH LIFT.
10. CORE FILLING CONCRETE SHALL BE MIXED USING MAX 10mm AGGREGATE, SHALL HAVE F'C 20 MPa AND MAXIMUM SLUMP OF 230mm. CONCRETE SHALL BE PLACED TO COMPLETELY FILL CORES WITHOUT SEGREGATION OR VOIDS. COMPACT BY INTERNAL VIBRATION OR RODDING.
11. FILL CORES TO MAXIMUM 2.4 METRE HIGH FREE DROP IN ANY ONE POUR.
12. PROVIDE WATERPROOF MEMBRANE & D.P.C. AS REQUIRED BY THE ARCHITECTURAL SPECIFICATION.
13. REINFORCEMENT SHALL BE LAPPED AS FOLLOWS:

BAR SIZE	LAP (mm)
N12	500
N16	600
N20	800
N24	1200

ANCHOR TESTING

1. THE CONTRACTOR SHALL ALLOW FOR ALL COSTS ASSOCIATED WITH TESTING CHEMICAL AND MECHANICAL ANCHORS TO THE REQUIREMENTS AS FOLLOWS :
2. TENSILE LOAD TESTS TO BE 150% OF THE SAFE WORKING LOAD IN TENSION AS NOMINATED BY THE ANCHOR MANUFACTURER.
3. TESTS ARE TO BE CARRIED OUT BY A N.A.T.A. REGISTERED LABORATORY AND TEST CERTIFICATES ARE TO BE FORWARDED TO THE ENGINEER FOR REVIEW.
4. TEST PROCEDURE FOR ANCHORS
   a THE ENGINEER MAY ORDER A MINIMUM OF 10% OF THE TOTAL NUMBER OR 5 (WHICHEVER IS GREATER) FOR BOTH CHEMICAL AND MECHANICALANCHORS MAY BE REQUESTED TO BE TESTED.
   b SHOULD AN ANCHOR FAIL THEN A FURTHER 10% ARE TO BE TESTED.
   c SHOULD A FURTHER ANCHOR FAIL ALL ANCHORS ARE TO BE TESTED.
   d ALL ADDITIONAL TESTING AT CONTRACTORS EXPENCE.
   e ALL FAILED ANCHORS TO BE REMOVED AND REINSTALLED IN ACCORDANCE WITH THE MANUFACTURERS SPECIFICATION. ALL REINSTALLED ANCHORS TO BE TESTED.

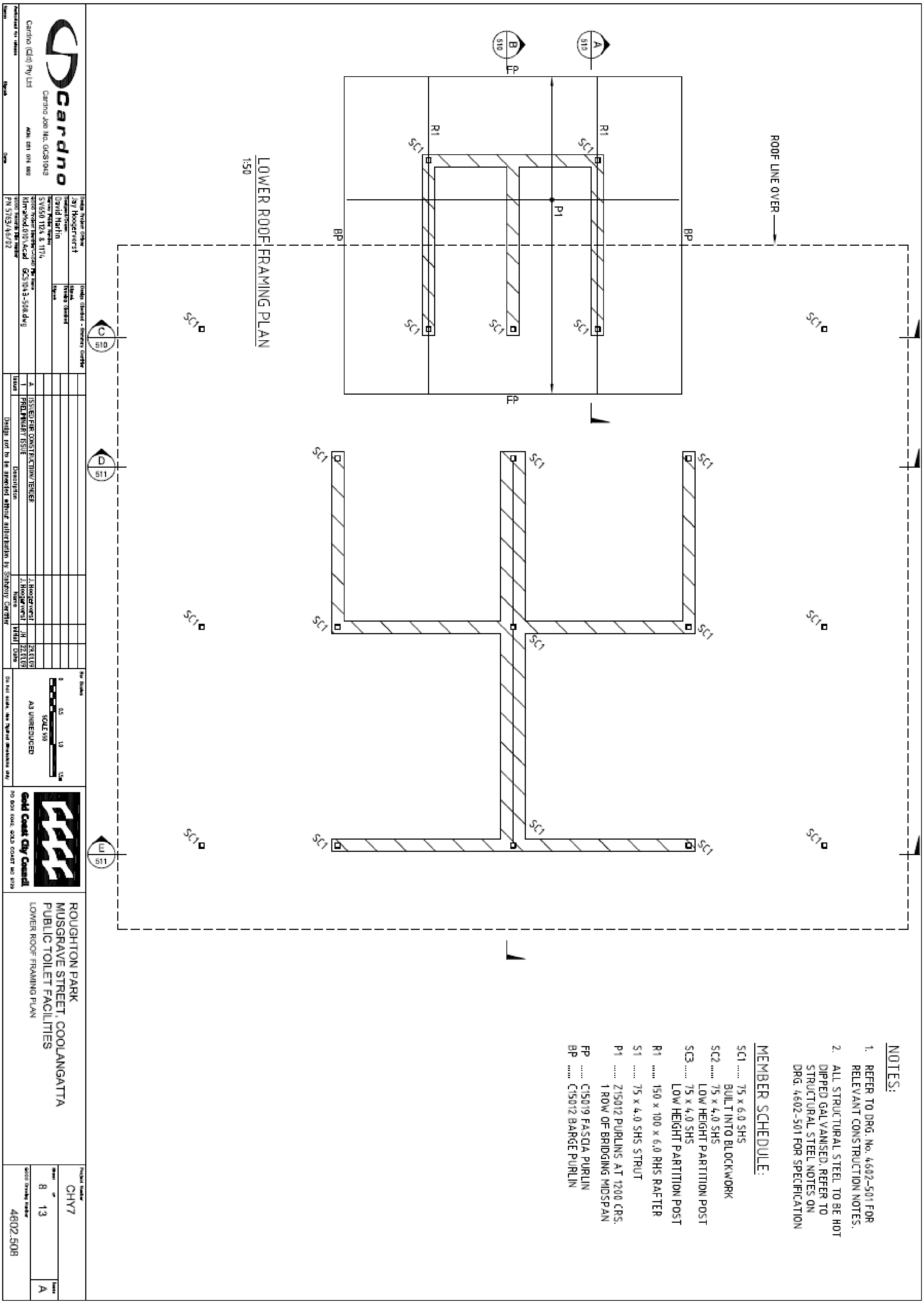
STRUCTURAL STEEL

1. ALL MATERIALS AND WORKMANSHIP SHALL CONFORM WITH CURRENT EDITIONS OF AS4100, AS1554 – 1 AND 2 AND AS4600 EXCEPT WHERE VARIED BY THE CONTRACT DOCUMENTS. REFER ALSO TO THE STRUCTURAL STEELWORK SECTION OF THE SPECIFICATIONS
2. ALL STEEL SHALL COMPLY WITH THE FOLLOWING U.N.O. :-
   WELDED SECTION – GRADE 300 TO AS 3679.2
   ROLLED SECTION – GRADE 300 TO AS 3679.1
   SHS AND RHS – GRADE 350/GRADE 450 TO AS 1163
   CHS – GRADE 250/GRADE 350 TO AS 1163
   FLAT PLATE – GRADE 300 TO AS 3679.1
   STANDARD PLATE – GRADE 250 TO AS 3678
3. REFER TO ARCHITECT FOR FIRE RATING REQUIREMENTS.
4. THE CONTRACTOR SHALL UNLESS SPECIFIED ELSEWHERE:
   (A) PROVIDE AND EMPLOY ANY ADDITIONAL TEMPORARY BRACING ETC. NECESSARY TO ADEQUATELY HOLD STEELWORK IN POSITION DURING CONSTRUCTION.
   (B) PROVIDE ALL PACKS, CLEATS, BOLTS (INCL. H.D. BOLTS) ETC. REQUIRED FOR TEMPORARY AND PERMANENT ERECTION OF STEELWORK AND FOR ATTACHMENT OF TIMBER AND MISCELLANEOUS FRAMING.
   (C) SUBMIT TWO (2) COPIES OF WORKSHOP DRAWINGS TO THE ENGINEER FOR PERUSAL. FABRICATION SHALL NOT COMMENCE WITHOUT A WRITTEN RESPONSE.
5. THE MINIMUM TREATMENT FOR ALL STRUCTURAL STEEL SHALL BE AS FOLLOWS U.N.O. :- ALL STEELWORK HOT DIP GALVANISED TO AS4680 WITH A COATING MASS OF 600g/m^2 (HDG600)
6. ALL STRUCTURAL STEELWORK BELOW GROUND AND EMBEDDED INTO BLOCKWORK LEVEL TO BE PAINTED WITH 2 COATS OF HIGH QUALITY APPROVED BITUMEN PAINT AND ENCASED BY CONCRETE ALL ROUND U.N.O.
7. PROPRIETARY ITEMS (E.G. PURLINS, ROOF/WALL SHEETING, BOLTS ETC.) SHALL BE INSTALLED IN ACCORDANCE WITH THE MANUFACTURER'S SPECIFICATION. FOR LAPPED PURLINS/GIRTS USE M12 4.6/S PURLIN BOLTS AND FOR UNLAPPED PURLINS/ GIRTS USE M12 4.6/S SHOULDERED PURLIN BOLTS. SHOULDERED PURLIN BOLT HEAD TO BE AGAINST COLD FORMED SECTION. ALL PURLIN/GIRT BOLTS SHALL HAVE INTEGRAL WASHERS.

STRUCTURAL STEEL CONT.

8. MINIMUM WELDING REQUIREMENTS IF NOT OTHERWISE SPECIFIED SHALL BE AS FOLLOWS:
   ALL WELDS CATEGORY S.P 6mm CONTINUOUS FILLET WELDS, OR WHERE NOTED, COMPLETE PENETRATION BUTT WELDS (C.P.B.W.) USING E48XX ELECTRODES WITH CATEGORY S.P. INSPECTION WITH NOTED OTHERWISE. ALL WELDING SHALL BE PERFORMED BY A ALL WELDS 100% VISUALLY SCANNED, ALL TO AS1554.1 UNLESS QUALIFIED WELDER IN ACCORDANCE WITH AS1554.1.
9. SITE WELDS WHERE NOTED IN THE DOCUMENTATION SHALL BE THOROUGHLY WIRE BRUSHED CLEANED AND PAINTED IN ACCORDANCE WITH THE SPECIFICATION.
10. THE ARCHITECT OR ENGINEER MAY ORDER NON-DESTRUCTIVE TESTING OF SELECTED WELDS. WELDS PROVED TO BE BELOW THE SPECIFIED QUALITY SHALL BE CUT OUT, REWELDED AND RE-TESTED AT CONTRACTOR'S EXPENSE.
11. ALL BOLTS, NUTS AND WASHERS, INCLUDING HOLD DOWN BOLTS, CAST-IN FERRULES, CAST-IN PLATES AND MASONRY ANCHORS ARE TO BE HOT DIP GALVANISED U.N.O.
12. BOLTS, NUTS AND WASHERS TO ALL EXTERNAL CONNECTIONS (I.E. EXPOSED TO CLIMATE) SHALL BE STAINLESS STEEL INCORPORATING NEOPRENE ISOLATION WASHERS AS DIRECTED BY G.C.C.C.
13. ALL GALVANISED COMPONENTS TO BE CAST INOT CONCRETE MUST BE PASSIVATED.
14. BOLT TYPES SHALL BE AS FOLLOWS:-
   × 4.6/S – COMMERCIAL BOLTS TO AS 1111, SNUG TIGHTENED
   × 8.8/S – HIGH STRENGTH STRUCTURAL BOLTS TO AS 1252, SNUG TIGHTENED ONLY.
   × 8.8/TF & 8.8/TB – HIGH STRENGTH STRUCTURAL BOLTS TO AS 1252, FULLY TENSIONED
15. ALL STRUCTURAL STEEL FIXING DETAILS ARE TO BE BASED ON AISC STANDARDIZED STRUCTURAL CONNECTIONS U.N.O
16. ALL PLATES TO BE FROM STANDARD SQUARE EDGE FLATS U.N.O
17. THE CONTACT SURFACES FOR HIGH STRENGTH FULLY TENSIONED BOLTED CONNECTIONS SHALL BE CLEAN "AS ROLLED" AND NOT PAINTED. FULLY TENSION BOLTS BY THE "PART TURN METHOD OF TIGHTENING", OR BY LOAD INDICATING WASHERS.
18. ALL PURLINS, GIRTS AND BRIDGING SHALL BE EITHER LYSAGHT OR STRAMIT. PURLINS GIRTS AND BRIDGING BY OTHER MANUFACTURERS SHALL BE SUBMITTED FOR APPROVAL SUPPORTED BY SUBMISSION OF SECTION PROPERTIES, PURLIN CAPACITY CALCULATIONS AND BRIDGING CAPACITY CALCULATIONS. ALL HANGERS FOR SUPPORT OF SERVICES AND CEILINGS TO BE ATTACHED TO WEB OF PURLIN, ALL SECTIONS SHALL BE PRODUCED FROM GALVANISED STEEL TO AS1397 AND DESIGNED IN ACCORDANCE WITH AS4600. ALL SECTIONS SHOULD BE INSTALLED IN ACCORDANCE WITH THE MANUFACTURER'S INSTRUCTIONS, WITH PARTICULAR REGARD TO BOLT LOCATION. ALL WORK SHALL BE COMPLETED IN A WORKMANLIKE MANNER PRIOR TO TO INSTALLATION OF THE CLADDING MATERIAL.
19. EDGES OF ROOF SHEETING THAT ARE REQUIRED TO BE CUT TO SUIT CHANGES IN DIRECTION OF THE ROOF SHALL BE SUPPORTED BY TRIMMER PURLINS OF SAME TYPE AND SIZE AS THE MAIN ROOF PURLINS AND FIXED WITH 6 PLATE BRACKETS AND 2M12 4.6/s EACH LEG TYPICAL U.N.O. SIMILAR IS REQUIRED AT ALL ROOF PENETRATIONS TYPICAL UNO

Cardno	Design Project Officer: Jay Hoogervorst	Design Checked – Statutory Certifier	Issue	Description	Name	Initial	Date	For Scales	Gold Coast City Council	ROUGHTON PARK MUSGRAVE STREET, COOLANGATTA PUBLIC TOILET FACILITIES	Project Number: CHY7
Cardno Job No. GCS1043	Designed/Drawn: David Martin	Drawing Checked	A	ISSUED FOR CONSTRUCTION/TENDER	J. Hoogervorst		29.01.09	N.T.S.	PO BOX 5042, GOLD COAST MC 9729	CONSTRUCTION NOTES	Sheet 1 of 13, Issue A
Cardno (Qld) Pty Ltd ABN 051 074 992	Survey Folder Number: SV650 1124 & 1174		1	PRELIMINARY ISSUE	J. Hoogervorst	JH	22.01.09	Do not scale, use figured dimensions only			GCCC Drawing Number: 4602.501
Authorised for release: Name / Signed / Date	GCCC Project Identifier–ACAD File Name: KlrraMod.010\Acad GCS1043-501.dwg; GCCC Records File Number: PN 5763/46/02			Design not to be amended without authorisation by Statutory Certifier							


LOWER ROOF FRAMING PLAN
1:50
ROOF LINE OVER
NOTES:
1. REFER TO DRG. No. 4602-501 FOR RELEVANT CONSTRUCTION NOTES.
2. ALL STRUCTURAL STEEL TO BE HOT DIPPED GALVANISED. REFER TO STRUCTURAL STEEL NOTES ON DRG. 4602-501 FOR SPECIFICATION
MEMBER SCHEDULE:
SC1 ..... 75 x 6.0 SHS BUILT INTO BLOCKWORK
SC2 ..... 75 x 4.0 SHS LOW HEIGHT PARTITION POST
SC3 ..... 75 x 4.0 SHS LOW HEIGHT PARTITION POST
R1 ..... 150 x 100 x 6.0 RHS RAFTER
S1 ..... 75 x 4.0 SHS STRUT
P1 ..... Z15012 PURLINS AT 1200 CRS. 1 ROW OF BRIDGING MIDSPAN
FP ..... C15019 FASCIA PURLIN
BP ..... C15012 BARGE PURLIN
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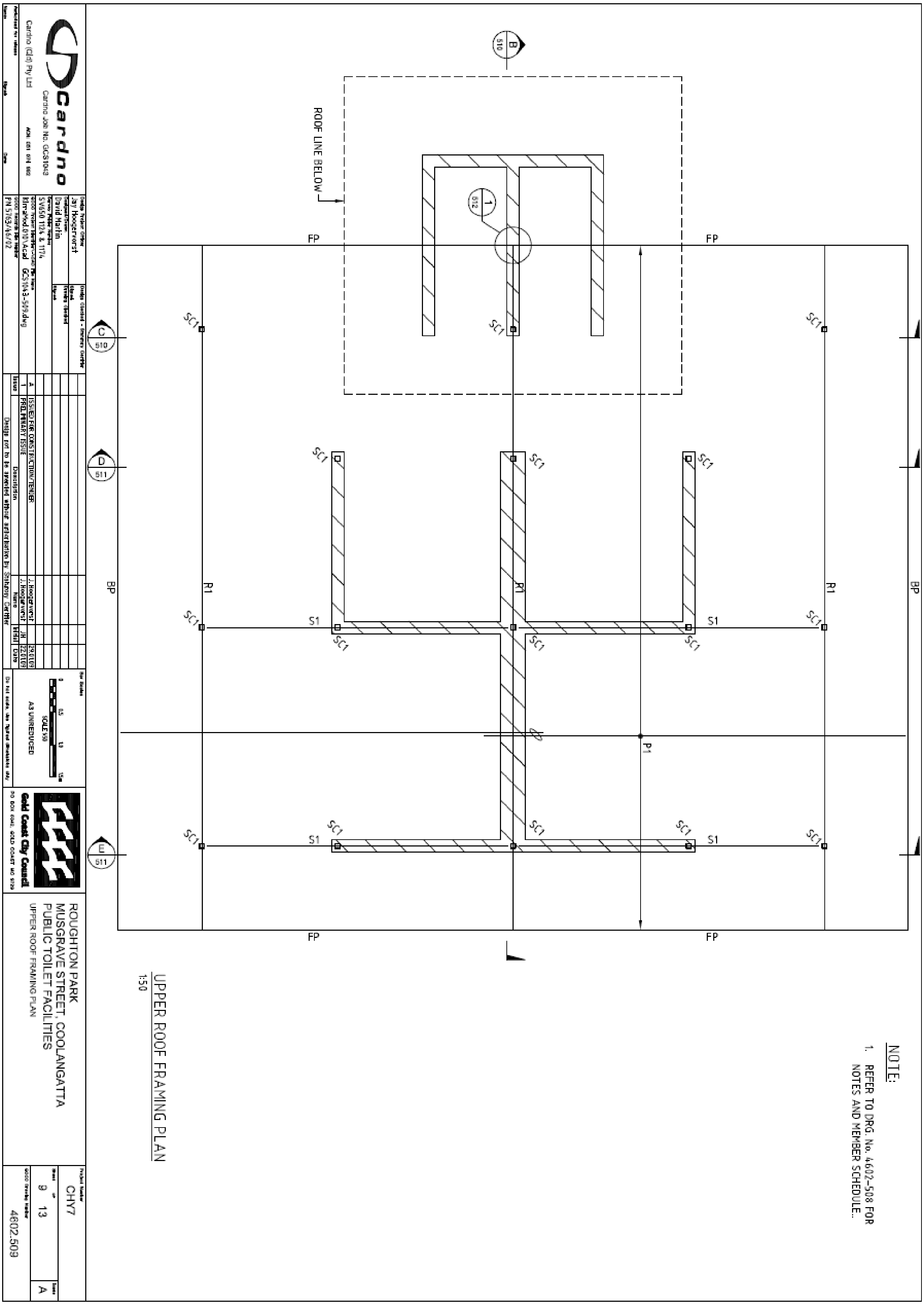
Cardno Job No. GCS1043
A ISSUED FOR CONSTRUCTION/TENDER
1 PRELIMINARY ISSUE
A3 UNREDUCED
Gold Coast City Council
ROUGHTON PARK
MUSGRAVE STREET, COOLANGATTA
PUBLIC TOILET FACILITIES
LOWER ROOF FRAMING PLAN
CHY7
8 13
4602.508
A


ROOF LINE BELOW
FP
BP
SC1
S1
R1
P1
UPPER ROOF FRAMING PLAN
1:50
NOTE:
1. REFER TO DRG. No. 4602-508 FOR NOTES AND MEMBER SCHEDULE..
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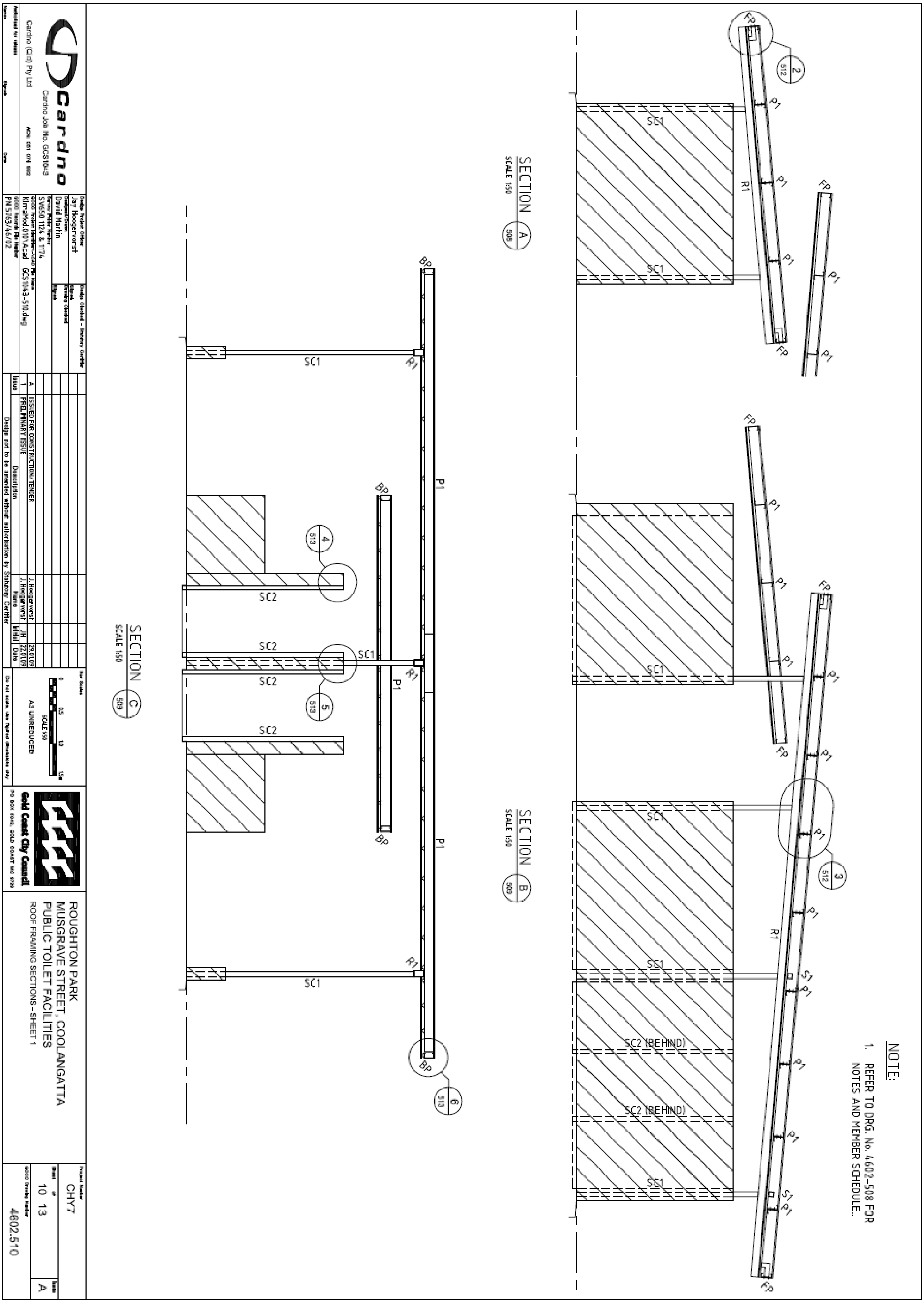
Gold Coast City Council
ROUGHTON PARK
MUSGRAVE STREET, COOLANGATTA
PUBLIC TOILET FACILITIES
UPPER ROOF FRAMING PLAN
CHY7
9 13
A
4602.509


SECTION A
SCALE 1:50
SECTION B
SCALE 1:50
SECTION C
SCALE 1:50
NOTE:
1. REFER TO DRG. No. 4602-508 FOR NOTES AND MEMBER SCHEDULE.
SC1
SC2
SC2 (BEHIND)
P1
R1
S1
FP
BP
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A3 UNREDUCED
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MUSGRAVE STREET, COOLANGATTA
PUBLIC TOILET FACILITIES
ROOF FRAMING SECTIONS - SHEET 1
CHY7
10 13
4602.510
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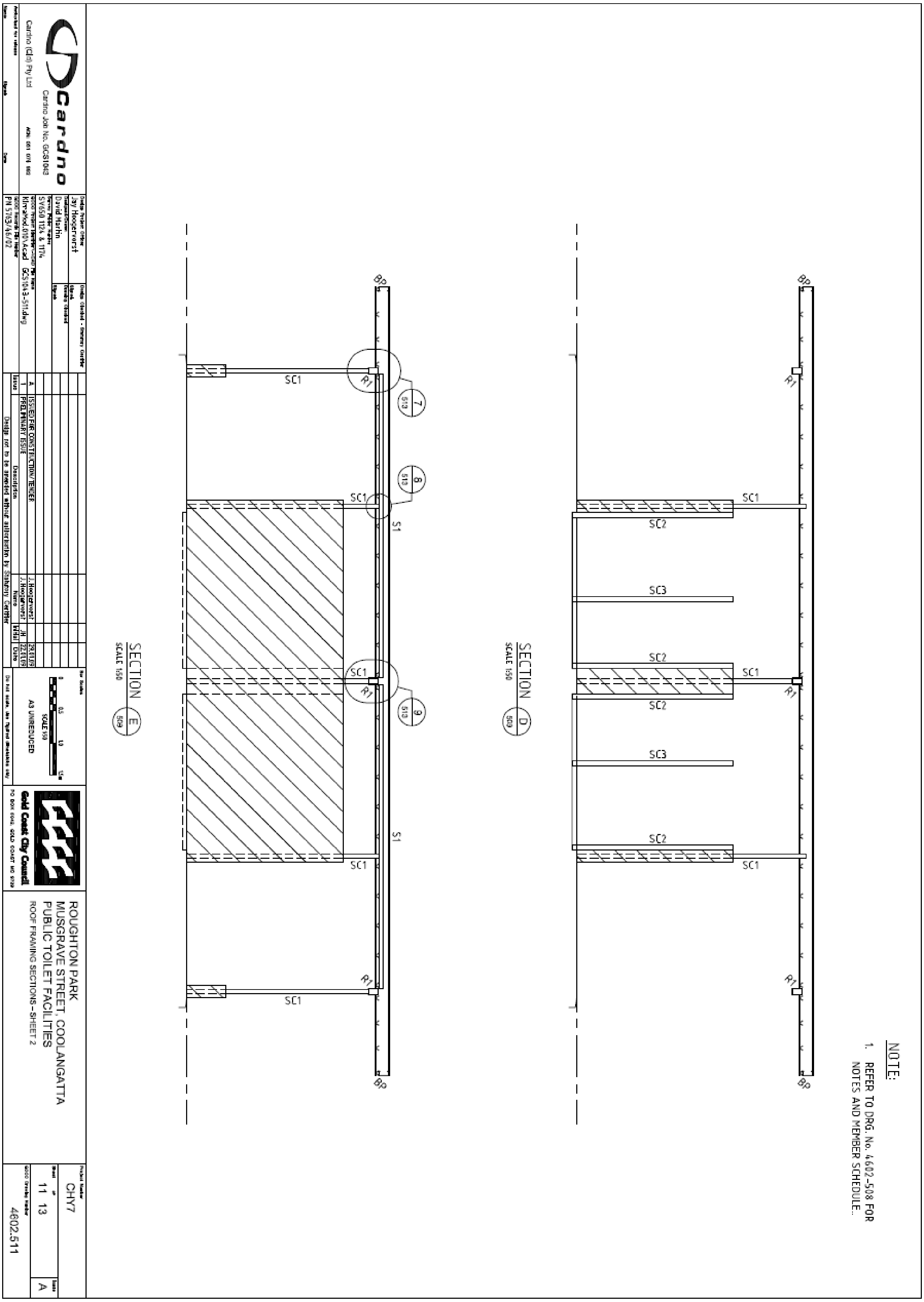
NOTE:
1. REFER TO DRG. No. 4602-508 FOR NOTES AND MEMBER SCHEDULE.
SECTION E
SECTION D
SCALE 1:50
SC1
SC2
SC3
S1
R1
BP
Cardno
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MUSGRAVE STREET, COOLANGATTA
PUBLIC TOILET FACILITIES
ROOF FRAMING SECTIONS - SHEET 2
A3 UNREDUCED
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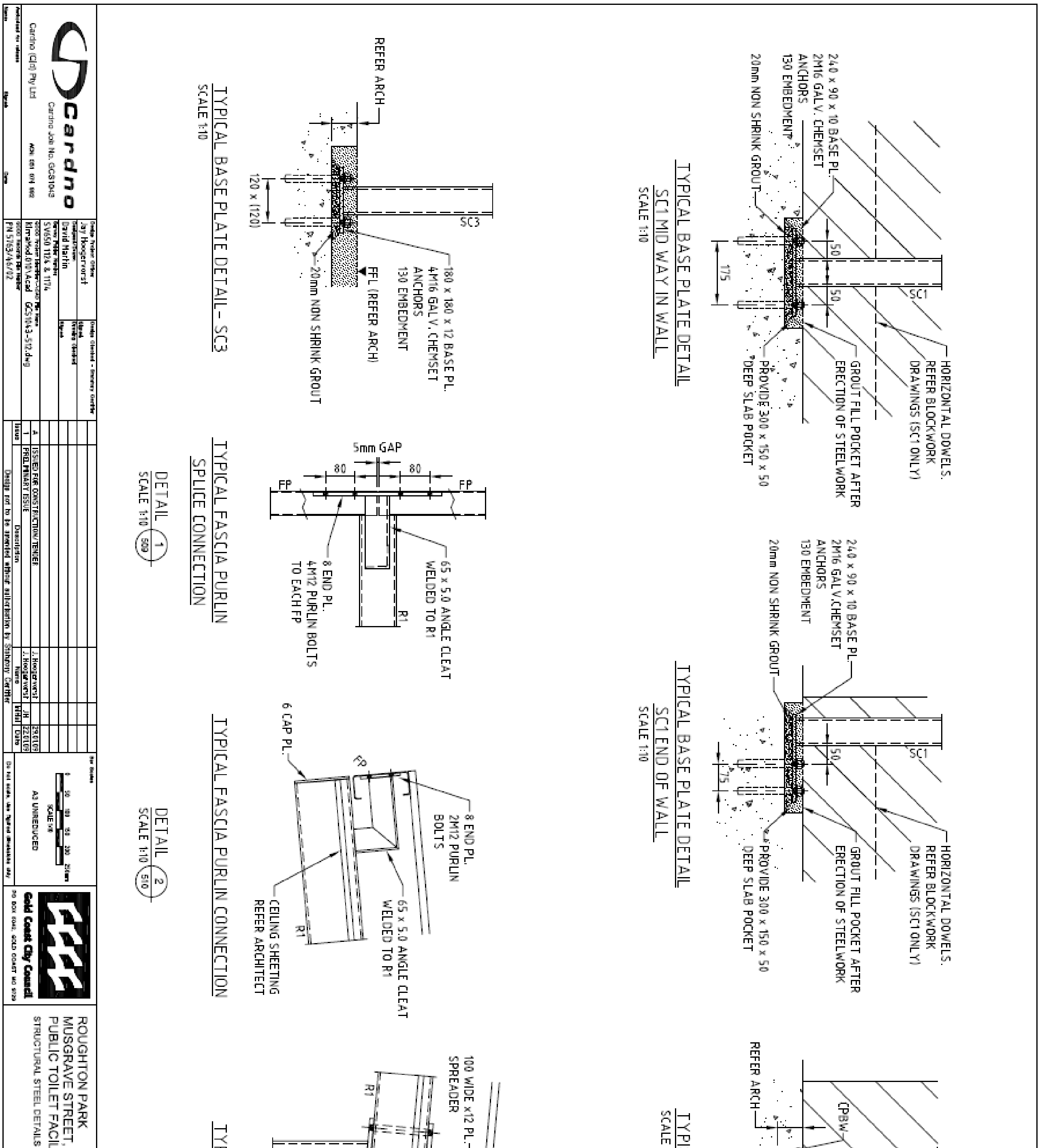
TYPICAL BASE PLATE DETAIL
SC1 MID WAY IN WALL
SCALE 1:10
240 x 90 x 10 BASE PL.
2M16 GALV. CHEMSET
ANCHORS
130 EMBEDMENT
20mm NON SHRINK GROUT
HORIZONTAL DOWELS.
REFER BLOCKWORK
DRAWINGS (SC1 ONLY)
GROUT FILL POCKET AFTER
ERECTION OF STEELWORK
PROVIDE 300 x 150 x 50
DEEP SLAB POCKET
SC1
50
175
TYPICAL BASE PLATE DETAIL
SC1 END OF WALL
SCALE 1:10
75
TYPICAL BASE PLATE DETAIL - SC2
SCALE 1:10
REFER ARCH
CPBW
SC2
240 x 90 x 10 BASE PL.
2M16 GALV. CHEMSET
ANCHORS
80 EMBEDMENT
FFL (REFER ARCH)
NOTE:
1. REFER TO DRG. No. 4602-508 FOR NOTES AND MEMBER SCHEDULE.
TYPICAL BASE PLATE DETAIL - SC3
SCALE 1:10
SC3
120 x (120)
180 x 180 x 12 BASE PL.
4M16 GALV. CHEMSET
ANCHORS
130 EMBEDMENT
TYPICAL FASCIA PURLIN
SPLICE CONNECTION
DETAIL 1
SCALE 1:10
5mm GAP
80
FP
65 x 5.0 ANGLE CLEAT
WELDED TO R1
8 END PL.
4M12 PURLIN BOLTS
TO EACH FP
R1
TYPICAL FASCIA PURLIN CONNECTION
DETAIL 2
6 CAP PL.
2M12 PURLIN
BOLTS
CEILING SHEETING
REFER ARCHITECT
TYPICAL SC1 TO R1 CONNECTION
DETAIL 3
100 WIDE x 12 PL.
SPREADER
8 PL. CLEAT
2M12 PURLIN
BOLTS - TYPICAL
12 END PL.
2M16 THRU BOLTS
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PUBLIC TOILET FACILITIES
STRUCTURAL STEEL DETAILS - SHEET 1
CHY7
12 13
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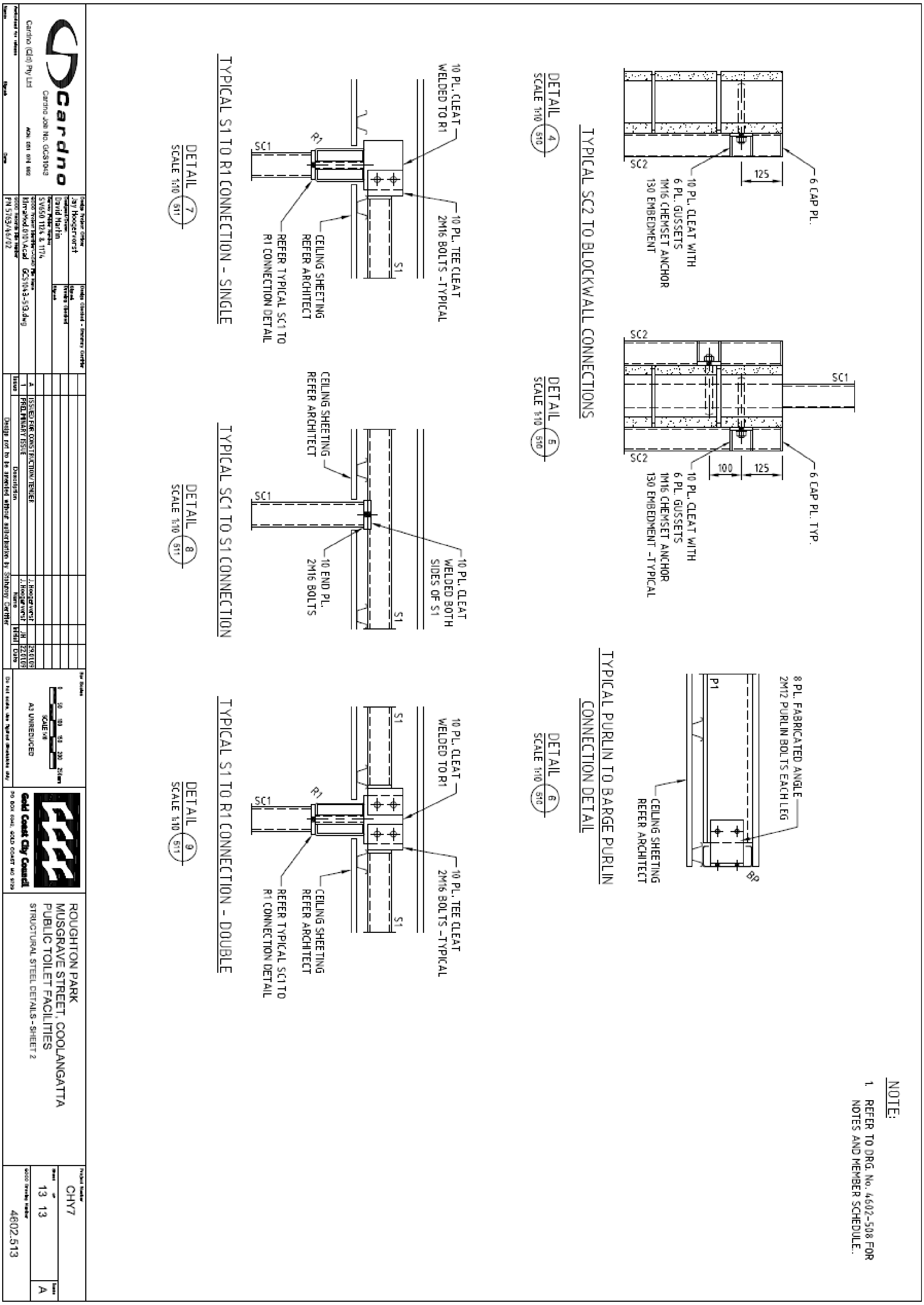
TYPICAL SC2 TO BLOCKWALL CONNECTIONS
DETAIL 4 SCALE 1:10
DETAIL 5 SCALE 1:10
6 CAP PL.
6 CAP PL. TYP.
10 PL. CLEAT WITH
6 PL. GUSSETS
1M16 CHEMSET ANCHOR
130 EMBEDMENT
130 EMBEDMENT - TYPICAL
SC1
SC2
100
125
TYPICAL PURLIN TO BARGE PURLIN CONNECTION DETAIL
DETAIL 6 SCALE 1:10
8 PL. FABRICATED ANGLE
2M12 PURLIN BOLTS EACH LEG
CEILING SHEETING
REFER ARCHITECT
P1
BP
TYPICAL S1 TO R1 CONNECTION - SINGLE
DETAIL 7 SCALE 1:10
10 PL. CLEAT WELDED TO R1
10 PL. TEE CLEAT
2M16 BOLTS - TYPICAL
REFER TYPICAL SC1 TO R1 CONNECTION DETAIL
R1
S1
TYPICAL SC1 TO S1 CONNECTION
DETAIL 8 SCALE 1:10
10 PL. CLEAT WELDED BOTH SIDES OF S1
10 END PL.
2M16 BOLTS
TYPICAL S1 TO R1 CONNECTION - DOUBLE
DETAIL 9 SCALE 1:10
NOTE:
1. REFER TO DRG. No. 4602-508 FOR NOTES AND MEMBER SCHEDULE.
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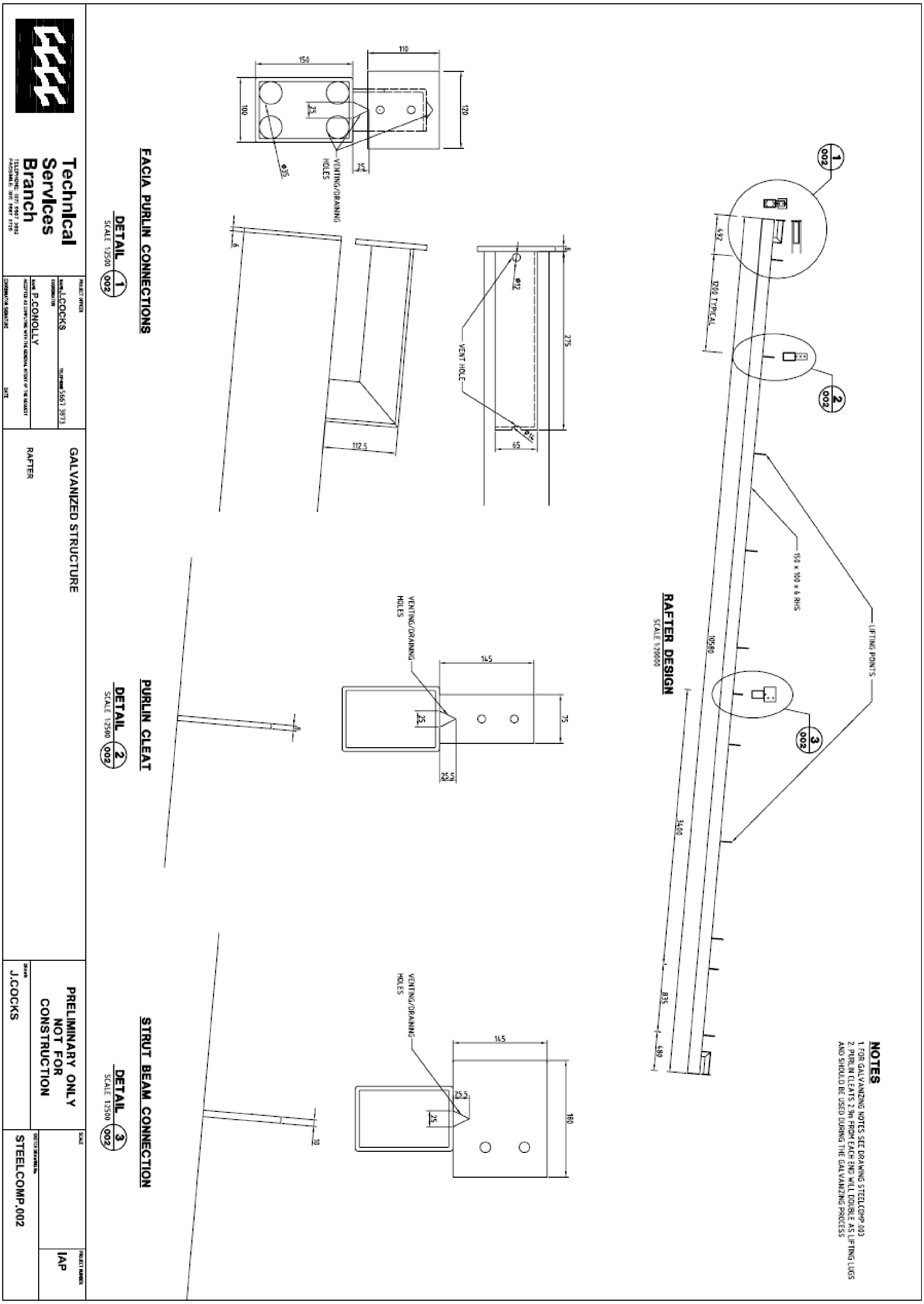
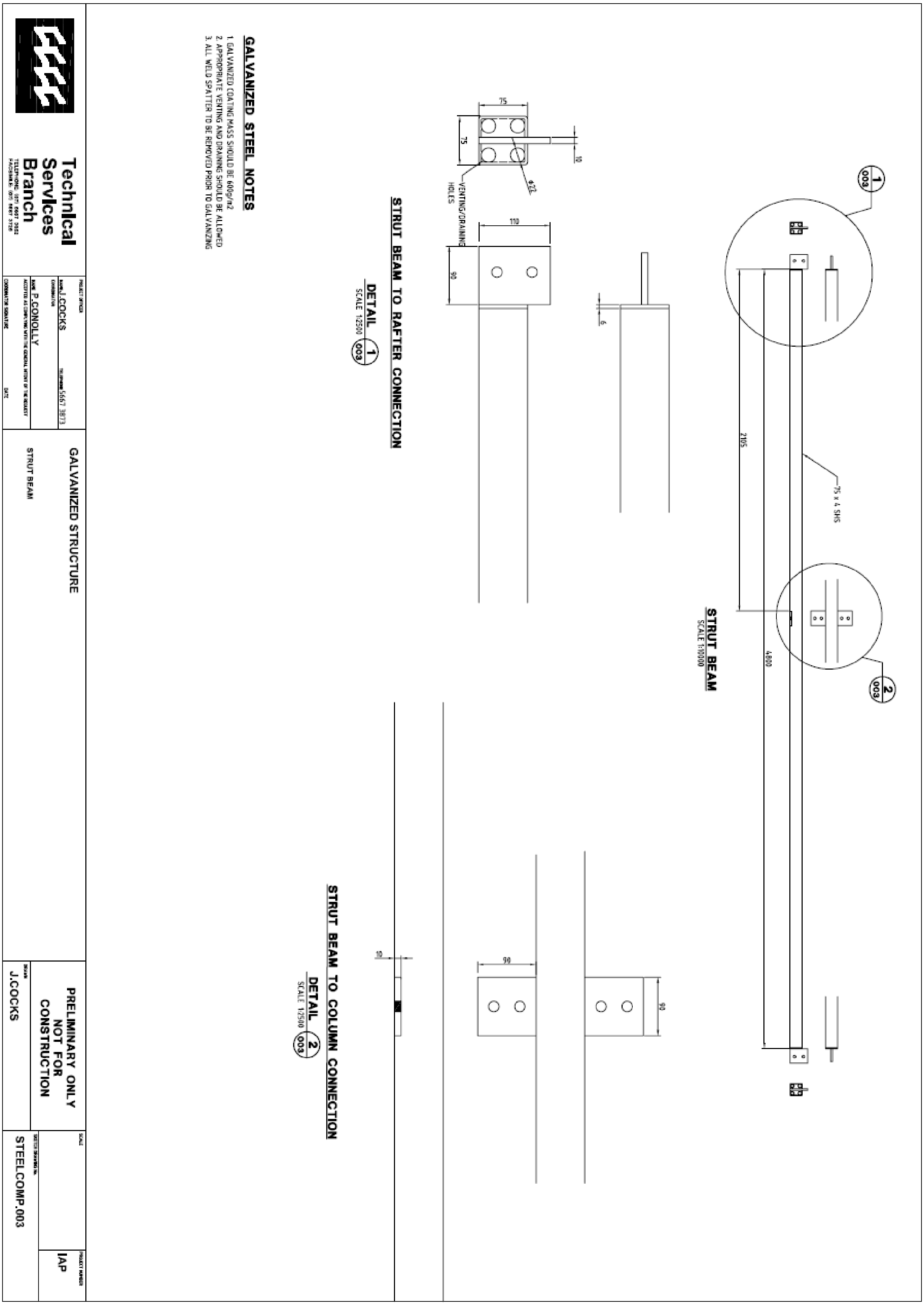
MUSGRAVE STREET, COOLANGATTA
PUBLIC TOILET FACILITIES
STRUCTURAL STEEL DETAILS - SHEET 2
CHY7
13 13
A
4602.513

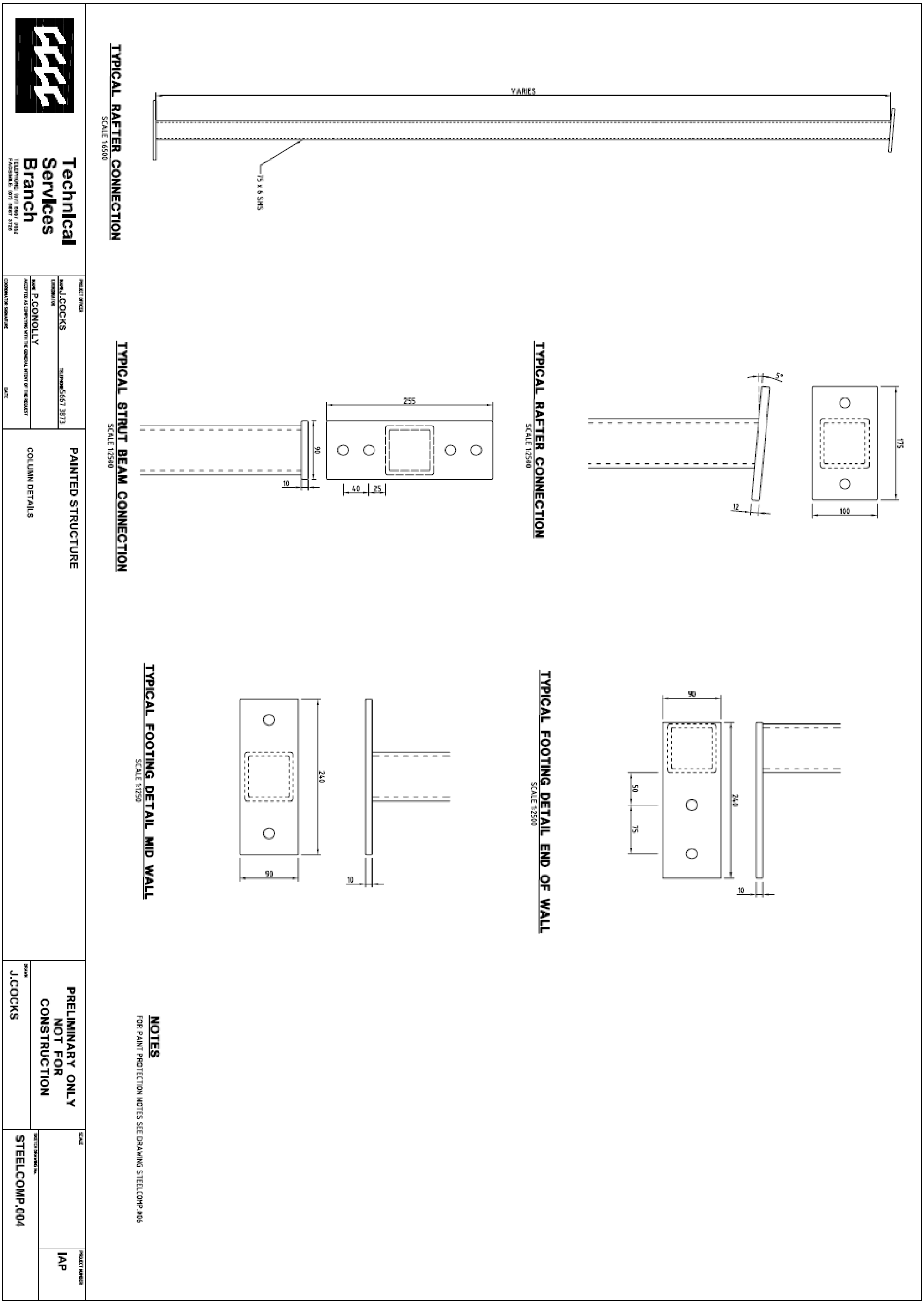
APPENDIX B – DESIGN OF STRUCTURAL MEMBERS

Begins on the following page

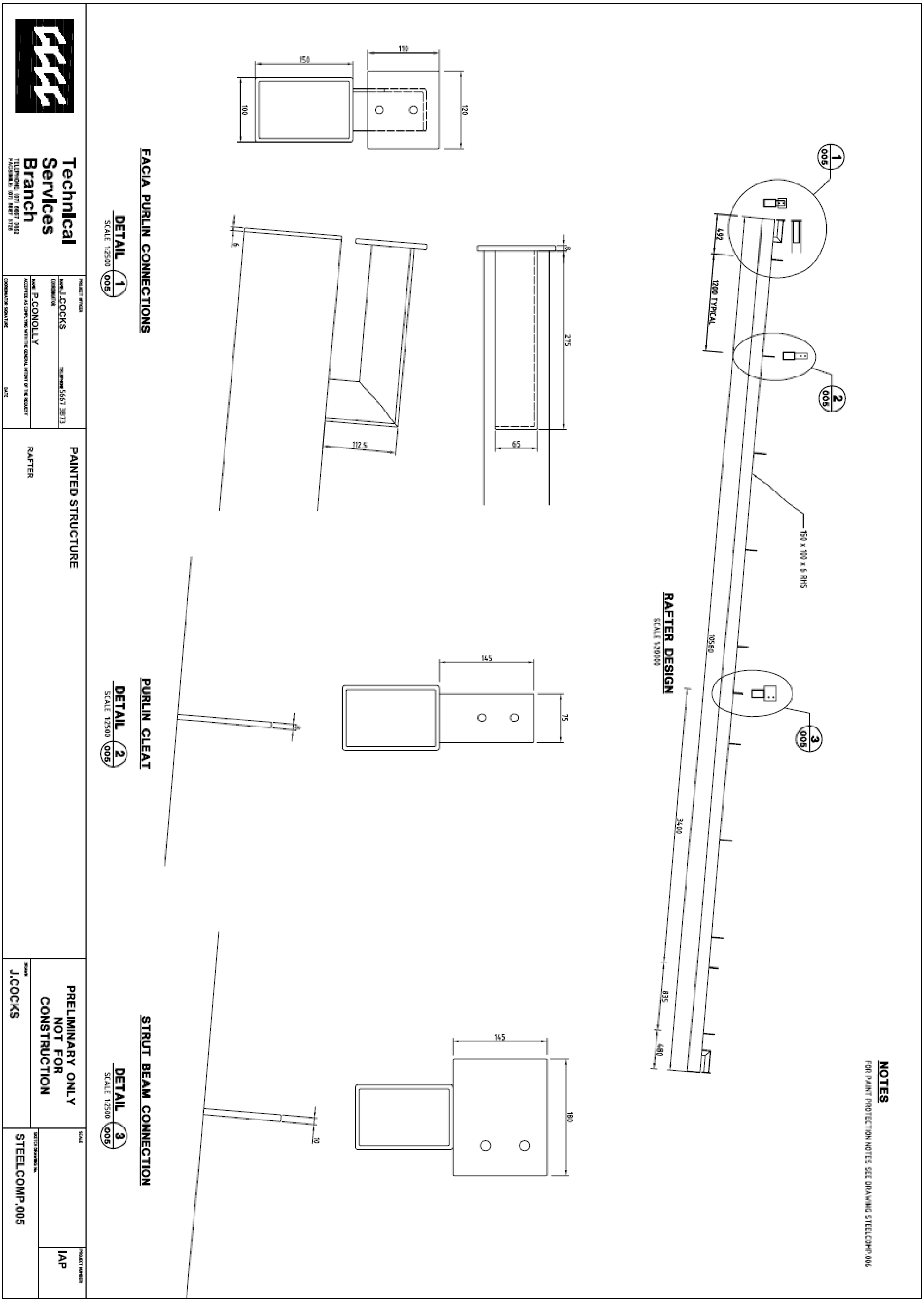


Technical Services Branch
J.COCKS
P.CONOLLY
GALVANIZED STRUCTURE
RAFTER
PRELIMINARY ONLY NOT FOR CONSTRUCTION
STEELCOMP.002
IAP
FACIA PURLIN CONNECTIONS
DETAIL 1
SCALE 1:2500
PURLIN CLEAT
DETAIL 2
STRUT BEAM CONNECTION
DETAIL 3
RAFTER DESIGN
SCALE 1:20000
VENTING/DRAINING HOLES
VENT HOLE
LIFTING POINTS
150 x 100 x 6 RHS
1200 TYPICAL
10580
NOTES
1. FOR GALVANIZING NOTES SEE DRAWING STEELCOMP.003
2. PURLIN CLEATS 2.9m FROM EACH END WILL DOUBLE AS LIFTING LUGS AND SHOULD BE USED DURING THE GALVANIZING PROCESS

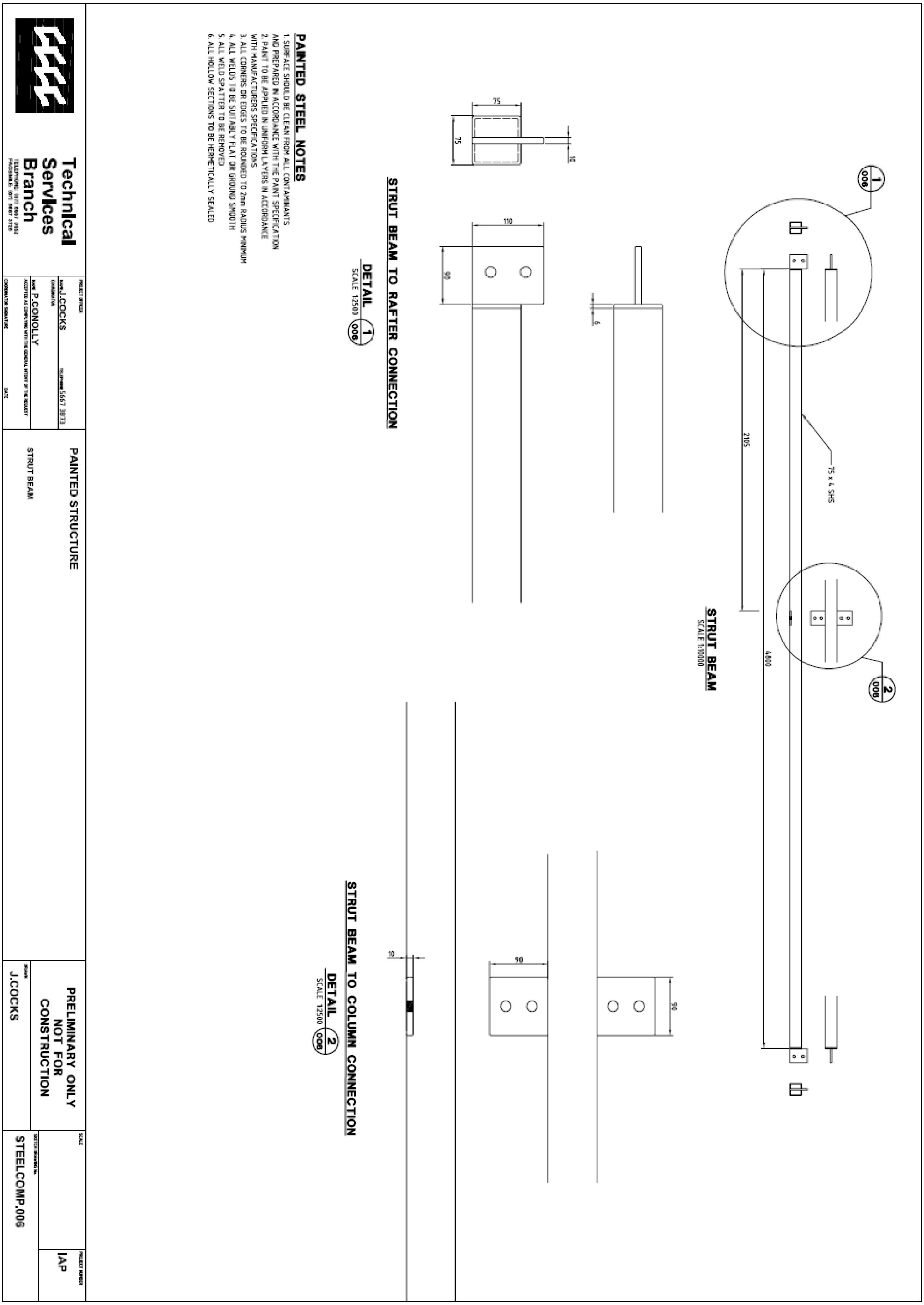

Technical Services Branch
J.COCKS
P.CONOLLY
GALVANIZED STRUCTURE
STRUT BEAM
PRELIMINARY ONLY NOT FOR CONSTRUCTION
STEELCOMP.003
IAP
GALVANIZED STEEL NOTES
1. GALVANIZED COATING MASS SHOULD BE 600g/m2
2. APPROPRIATE VENTING AND DRAINING SHOULD BE ALLOWED
3. ALL WELD SPATTER TO BE REMOVED PRIOR TO GALVANIZING
STRUT BEAM TO RAFTER CONNECTION
DETAIL
SCALE 1:2500
VENTING/DRAINING HOLES
75 x 4 SHS
STRUT BEAM
SCALE 1:10000
2105
4800
STRUT BEAM TO COLUMN CONNECTION
DETAIL
SCALE 1:2500

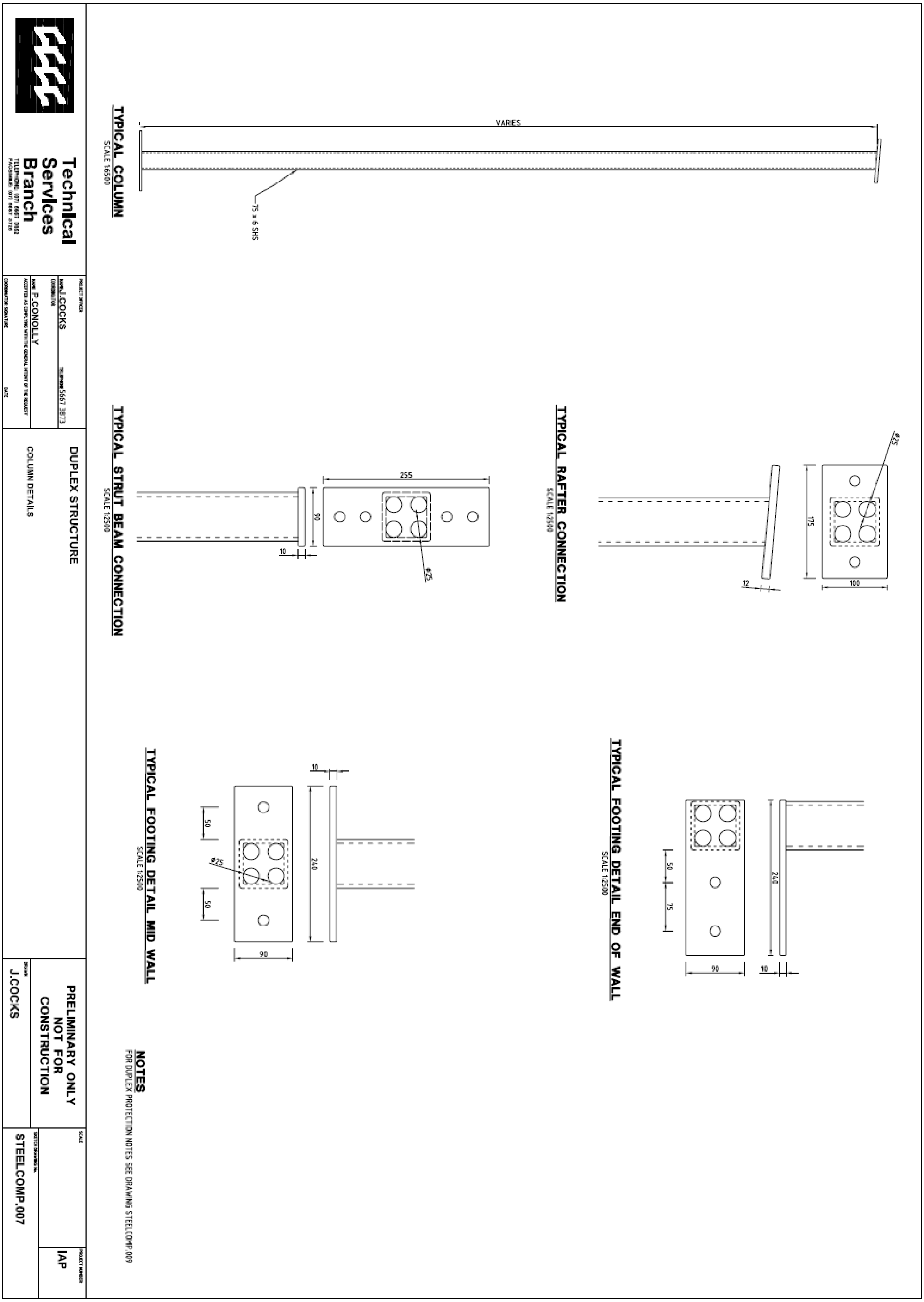


TYPICAL RAFTER CONNECTION
SCALE 1:6500
VARIES
75 x 6 SHS
TYPICAL STRUT BEAM CONNECTION
SCALE 1:2500
255
90
10
40
25
TYPICAL RAFTER CONNECTION
SCALE 1:2500
5°
175
12
100
TYPICAL FOOTING DETAIL MID WALL
SCALE 1:1250
240
90
10
TYPICAL FOOTING DETAIL END OF WALL
SCALE 1:2500
90
50
75
240
10
NOTES
FOR PAINT PROTECTION NOTES SEE DRAWING STEELCOMP.006
Technical Services Branch
P.CONOLLY
J.COCKS
PAINTED STRUCTURE
COLUMN DETAILS
PRELIMINARY ONLY NOT FOR CONSTRUCTION
J.COCKS
STEELCOMP.004
IAP

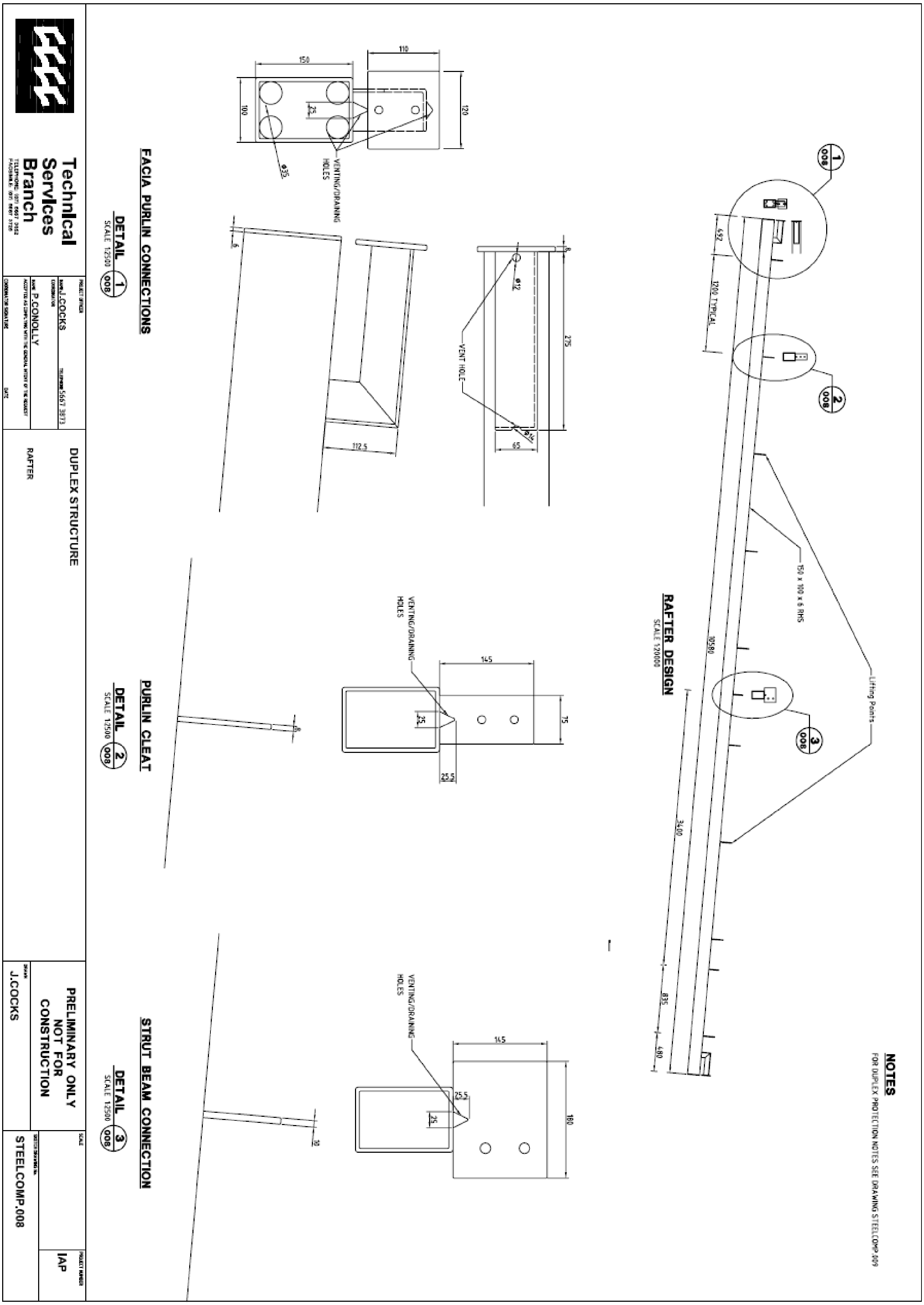


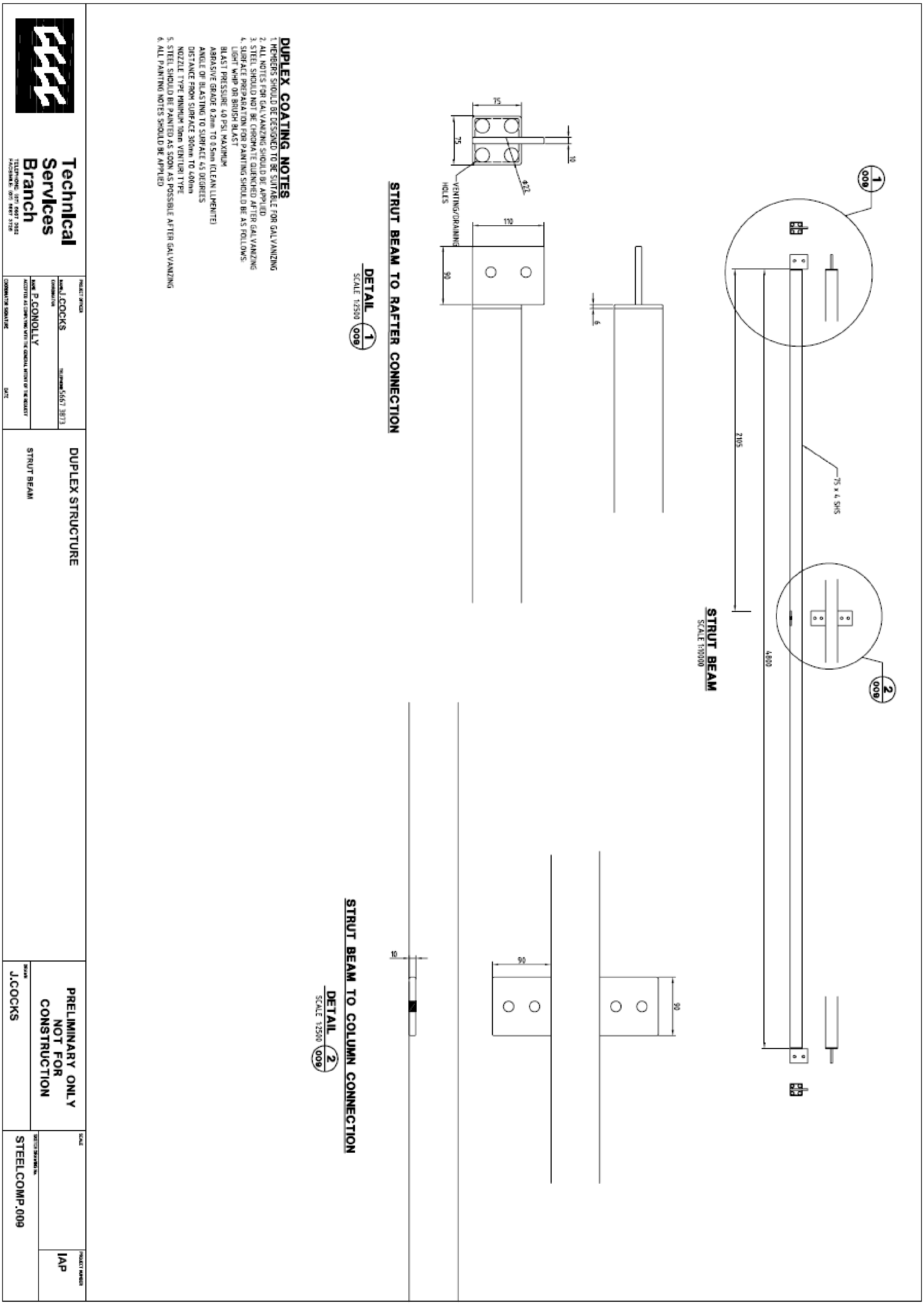
Technical Services Branch
J.COCKS
P.CONOLLY
PAINTED STRUCTURE
RAFTER
PRELIMINARY ONLY NOT FOR CONSTRUCTION
J.COCKS
STEELCOMP.005
IAP
FACIA PURLIN CONNECTIONS
DETAIL 1 005
SCALE 1:2500
PURLIN CLEAT
DETAIL 2 005
SCALE 1:2500
STRUT BEAM CONNECTION
DETAIL 3 005
SCALE 1:2500
RAFTER DESIGN
SCALE 1:20000
150 x 100 x 6 RHS
1200 TYPICAL
10580
3400
NOTES
FOR PAINT PROTECTION NOTES SEE DRAWING STEELCOMP.006

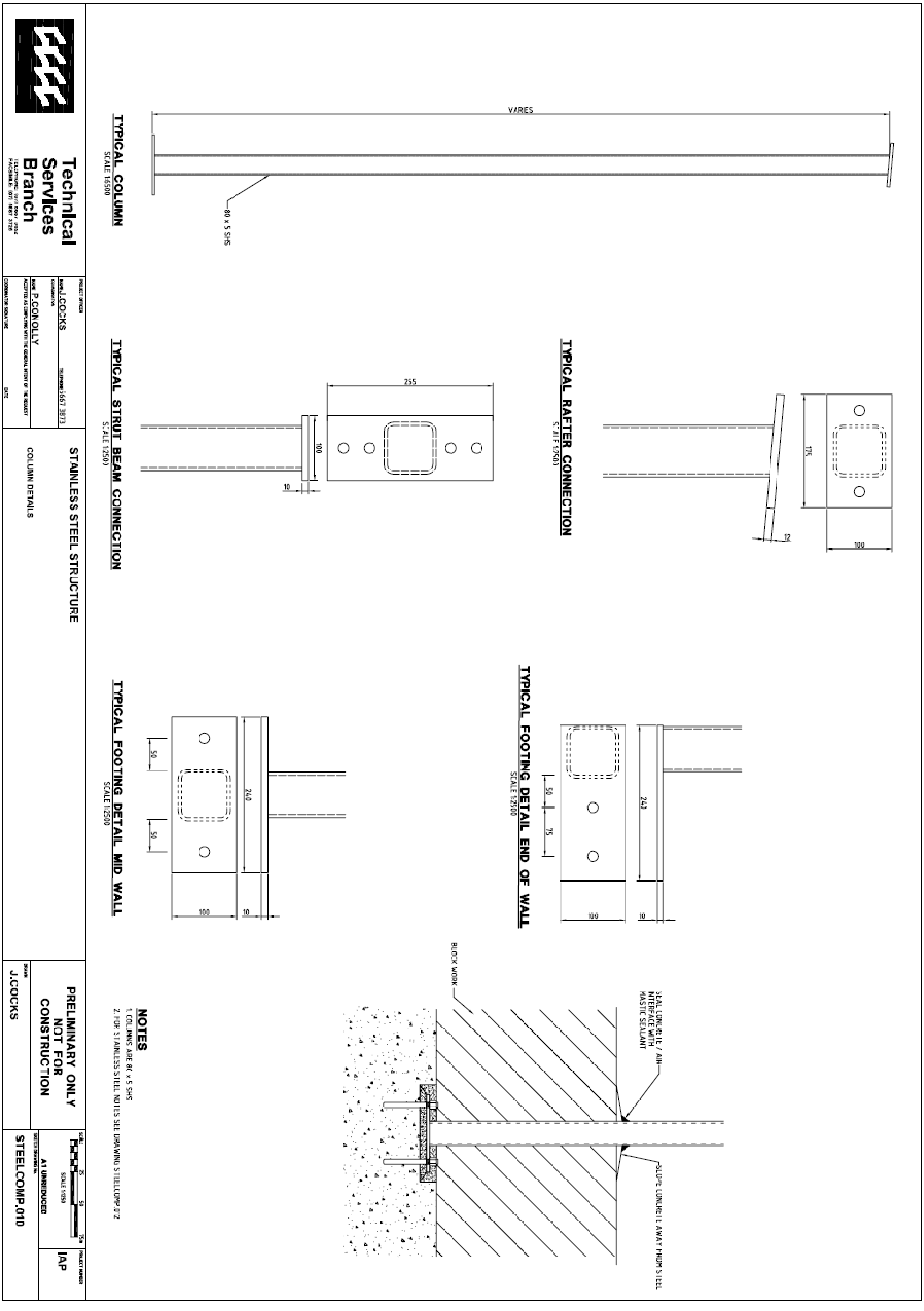

75 x 4 SHS
4800
2105
STRUT BEAM
SCALE 1:10000
STRUT BEAM TO RAFTER CONNECTION
DETAIL 1 006
SCALE 1:2500
STRUT BEAM TO COLUMN CONNECTION
DETAIL 2 006
SCALE 1:2500
PAINTED STEEL NOTES
1. SURFACE SHOULD BE CLEAN FROM ALL CONTAMINANTS AND PREPARED IN ACCORDANCE WITH THE PAINT SPECIFICATION
2. PAINT TO BE APPLIED IN UNIFORM LAYERS IN ACCORDANCE WITH MANUFACTURERS SPECIFICATIONS
3. ALL CORNERS OR EDGES TO BE ROUNDED TO 2nn RADIUS MINIMUM
4. ALL WELDS TO BE SUITABLY FLAT OR GROUND SMOOTH
5. ALL WELD SPATTER TO BE REMOVED
6. ALL HOLLOW SECTIONS TO BE HERMETICALLY SEALED
Technical Services Branch
J.COCKS 5667 3873
P.CONOLLY
PAINTED STRUCTURE
STRUT BEAM
PRELIMINARY ONLY NOT FOR CONSTRUCTION
J.COCKS
IAP
STEELCOMP.006

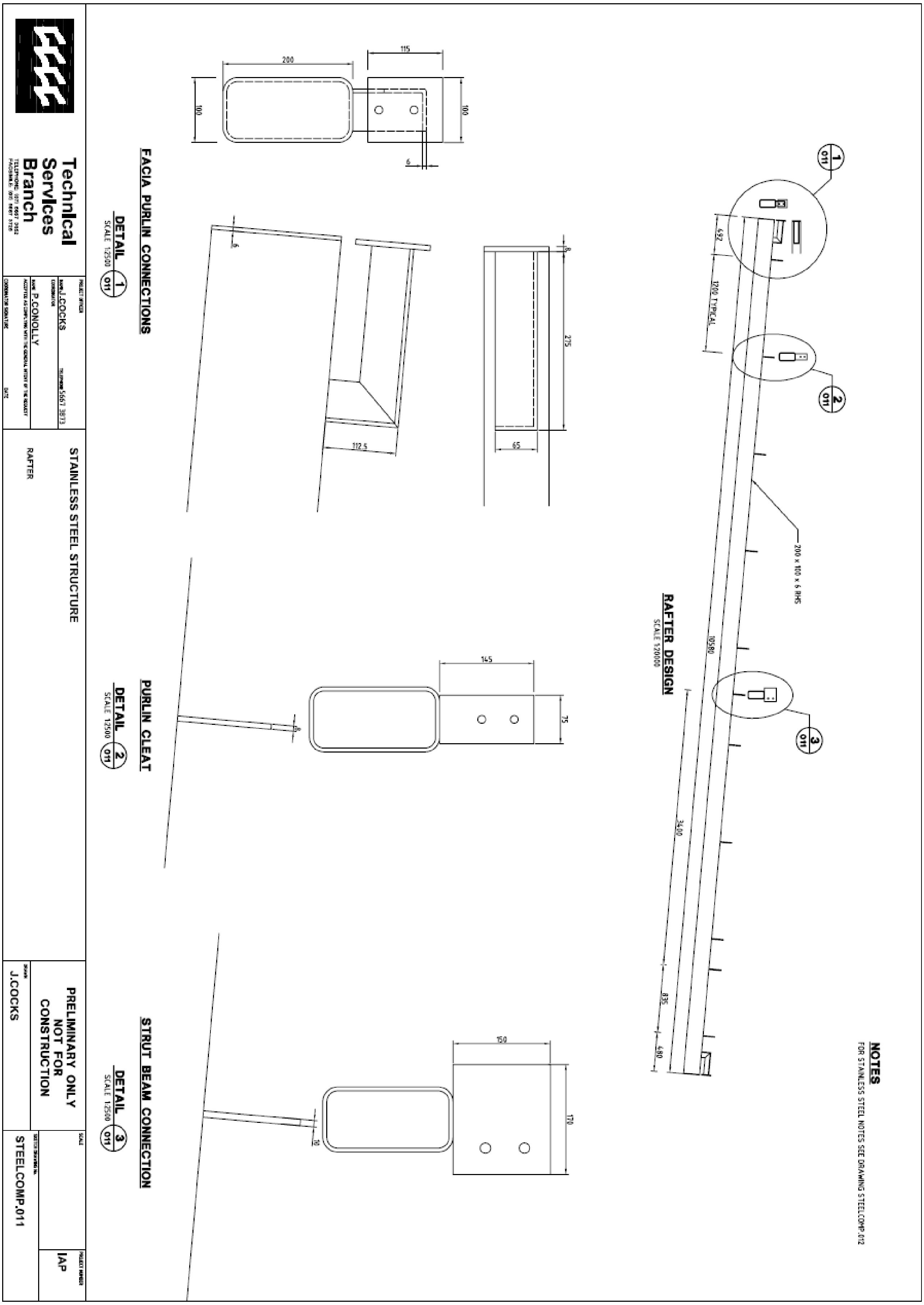


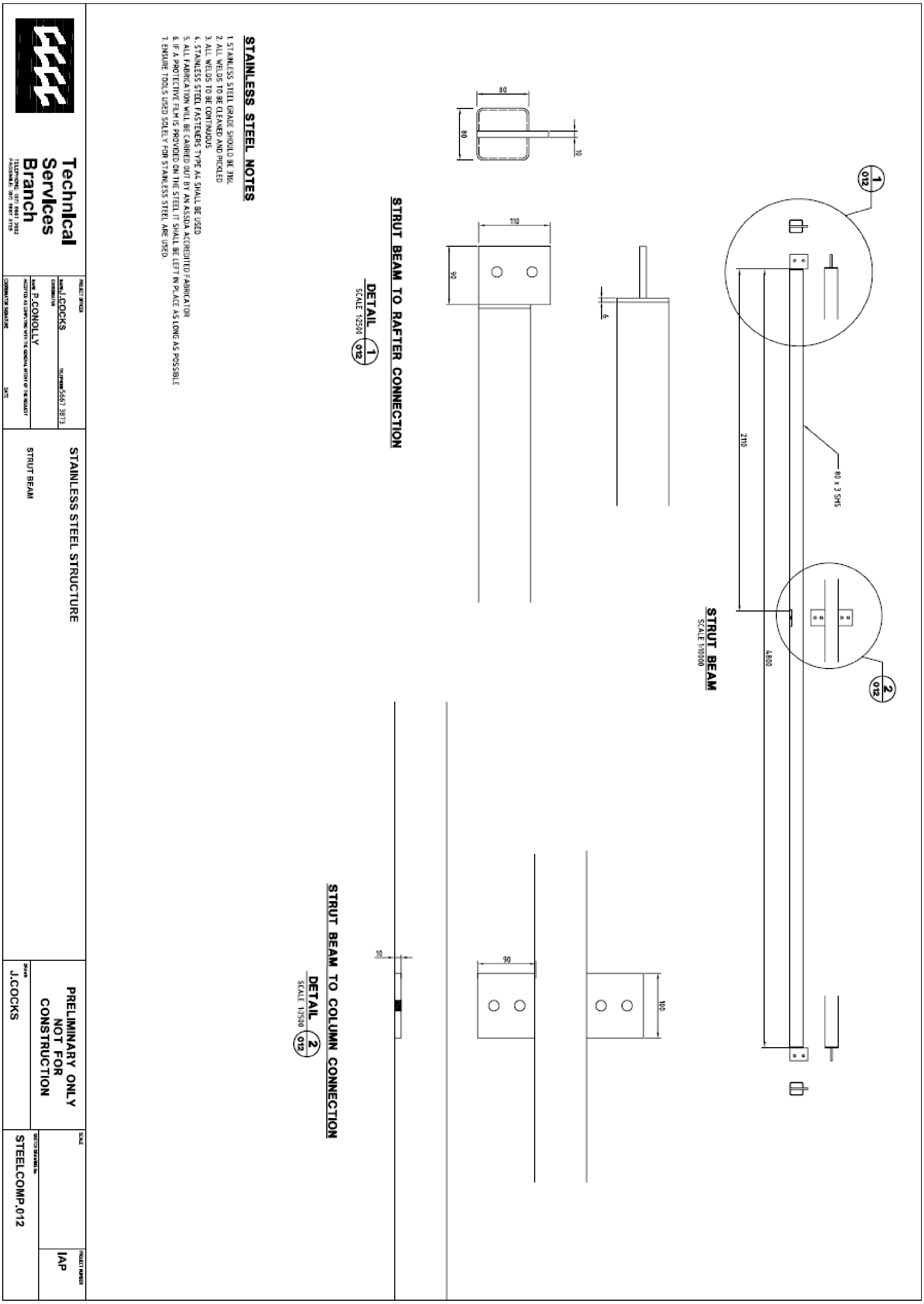
Technical Services Branch
PROJECT OFFICER J.COCKS
P.CONOLLY
DUPLEX STRUCTURE
COLUMN DETAILS
PRELIMINARY ONLY NOT FOR CONSTRUCTION
J.COCKS
STEELCOMP.007
IAP
TYPICAL COLUMN
SCALE 1:6500
VARIES
75 x 6 SHS
TYPICAL STRUT BEAM CONNECTION
SCALE 1:2500
255
90
10
Ø25
TYPICAL RAFTER CONNECTION
SCALE 1:2500
175
100
12
Ø25
TYPICAL FOOTING DETAIL MID WALL
SCALE 1:2500
10
50
240
Ø25
50
90
TYPICAL FOOTING DETAIL END OF WALL
SCALE 1:2500
50
75
240
90
10
NOTES
FOR DUPLEX PROTECTION NOTES SEE DRAWING STEELCOMP.009


Technical Services Branch
J.COCKS
P.CONOLLY
DUPLEX STRUCTURE
RAFTER
PRELIMINARY ONLY NOT FOR CONSTRUCTION
J.COCKS
STEELCOMP.008
IAP
FACIA PURLIN CONNECTIONS
DETAIL 1
PURLIN CLEAT
DETAIL 2
STRUT BEAM CONNECTION
DETAIL 3
RAFTER DESIGN
VENTING/DRAINING HOLES
VENT HOLE
150 x 100 x 6 RHS
Lifting Points
1200 TYPICAL
10580
3400
NOTES
FOR DUPLEX PROTECTION NOTES SEE DRAWING STEELCOMP.009


DUPLEX COATING NOTES
1. MEMBERS SHOULD BE DESIGNED TO BE SUITABLE FOR GALVANIZING
2. ALL NOTES FOR GALVANIZING SHOULD BE APPLIED
3. STEEL SHOULD NOT BE CHROMATE QUENCHED AFTER GALVANIZING
4. SURFACE PREPARATION FOR PAINTING SHOULD BE AS FOLLOWS:
LIGHT WHIP OR BRUSH BLAST
BLAST PRESSURE 40 PSI MAXIMUM
ABRASIVE GRADE 0.2mm TO 0.5mm (CLEAN LLMENITE)
ANGLE OF BLASTING TO SURFACE 45 DEGREES
DISTANCE FROM SURFACE 300mm TO 400mm
NOZZLE TYPE MINIMUM 10mm VENTURI TYPE
5. STEEL SHOULD BE PAINTED AS SOON AS POSSIBLE AFTER GALVANIZING
6. ALL PAINTING NOTES SHOULD BE APPLIED
STRUT BEAM TO RAFTER CONNECTION
DETAIL 1 009
STRUT BEAM TO COLUMN CONNECTION
DETAIL 2 009
STRUT BEAM
75 x 4 SHS
VENTING/DRAINING HOLES
2105
4800
Technical Services Branch
J.COCKS
P.CONOLLY
DUPLEX STRUCTURE
STRUT BEAM
PRELIMINARY ONLY NOT FOR CONSTRUCTION
J.COCKS
STEELCOMP.009
IAP


Technical Services Branch
J.COCKS
P.CONOLLY
STAINLESS STEEL STRUCTURE
COLUMN DETAILS
PRELIMINARY ONLY NOT FOR CONSTRUCTION
J.COCKS
A1 UNREDUCED
STEELCOMP.010
IAP
TYPICAL COLUMN
SCALE 1:6500
VARIES
80 x 5 SHS
TYPICAL STRUT BEAM CONNECTION
SCALE 1:2500
255
100
10
TYPICAL RAFTER CONNECTION
SCALE 1:2500
175
12
100
TYPICAL FOOTING DETAIL MID WALL
SCALE 1:2500
50
240
100
10
TYPICAL FOOTING DETAIL END OF WALL
SCALE 1:2500
50
75
240
100
10
NOTES
1. COLUMNS ARE 80 x 5 SHS
2. FOR STAINLESS STEEL NOTES SEE DRAWING STEELCOMP.012
BLOCK WORK
SEAL CONCRETE / AIR INTERFACE WITH MASTIC SEALANT
SLOPE CONCRETE AWAY FROM STEEL


Technical Services Branch
J.COCKS
P.CONOLLY
STAINLESS STEEL STRUCTURE
RAFTER
PRELIMINARY ONLY NOT FOR CONSTRUCTION
J.COCKS
STEELCOMP.011
IAP
FACIA PURLIN CONNECTIONS
DETAIL 1
PURLIN CLEAT
DETAIL 2
STRUT BEAM CONNECTION
DETAIL 3
RAFTER DESIGN
200 x 100 x 6 RHS
1200 TYPICAL
10580
3400
NOTES
FOR STAINLESS STEEL NOTES SEE DRAWING STEELCOMP.012


1
012
2
012
80 x 3 SHS
4800
2110
STRUT BEAM
SCALE 1:10000
6
10
80
80
110
90
STRUT BEAM TO RAFTER CONNECTION
DETAIL 1
SCALE 1:2500 012
100
90
10
STRUT BEAM TO COLUMN CONNECTION
DETAIL 2
SCALE 1:2500 012
STAINLESS STEEL NOTES
1. STAINLESS STEEL GRADE SHOULD BE 316L
2. ALL WELDS TO BE CLEANED AND PICKLED
3. ALL WELDS TO BE CONTINUOUS
4. STAINLESS STEEL FASTENERS TYPE A4 SHALL BE USED
5. ALL FABRICATION WILL BE CARRIED OUT BY AN ASSDA ACCREDITED FABRICATOR
6. IF A PROTECTIVE FILM IS PROVIDED ON THE STEEL IT SHALL BE LEFT IN PLACE AS LONG AS POSSIBLE
7. ENSURE TOOLS USED SOLELY FOR STAINLESS STEEL ARE USED.
Technical Services Branch
TELEPHONE: (07) 5667 3852
FACSIMILE: (07) 5667 3720
PROJECT OFFICER
NAME J.COCKS
TELEPHONE 5667 3873
COORDINATOR
NAME P.CONOLLY
ACCEPTED AS COMPLYING WITH THE GENERAL INTENT OF THE REQUEST
COORDINATOR SIGNATURE
DATE
STAINLESS STEEL STRUCTURE
STRUT BEAM
PRELIMINARY ONLY
NOT FOR
CONSTRUCTION
DRAWN
J.COCKS
SCALE
PROJECT NUMBER
IAP
SKETCH DRAWING No.
STEELCOMP,012

APPENDIX C - CASE STUDY FROM THE AUSTRALASIAN CORROSION ASSOCIATION

Presented by Arthur Austin at the *Building For Durability Seminar* held by the Australasian Corrosion Association in Brisbane on 2nd April 2009.

Australasian Corrosion Association, Queensland Branch
Building for Durability – Focus on Durability in National Standards

PearlStreet

A Concrete Potable Water Tank with Galvanized Steel Roof-Support Columns

- Tank Commissioned 1999 – 1st red rust noticed in 12 months.

- Photos (2003) show galvanized steel posts, bolted to the concrete floor & to the steel ceiling.
- Galvanized steel ladder bolted to wall & steel ceiling.
- Zinc gone - extensive red rusting evident in immersion zone.

Australasian Corrosion Association, Queensland Branch
Building for Durability – Focus on Durability in National Standards

PearlStreet

A Concrete Potable Water Tank with Galvanized Steel Roof-Support Columns

General Corrosion Average Penetration in mm [1]

	1st year	8th year	16th year	Final Steady Rate (mm/yr)
Zinc	0.01	0.08	0.11	0.0055
Carbon Steel	0.2	0.56	0.66	0.018

The galvanising thickness on the columns (114 x 4.8 CHS) would have averaged about 0.7mm [2] and therefore should have remained intact and protecting the underlying steel for much more than a decade.

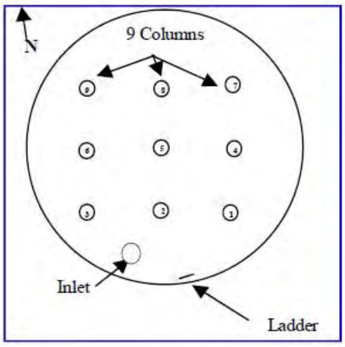
[1] *Corrosion in Tropical Environments – Final Report of 16 year exposures – Fresh lake water results; Southwell, Bultman & Alexander; Materials Performance, July 1997)*

[2] *AS/NZS 4680:1999 Hot-dip galvanised (zinc) coatings on fabricated ferrous articles; Table 1*

Australasian Corrosion Association, Queensland Branch
Building for Durability – Focus on Durability in National Standards

PearlStreet

A Concrete Potable Water Tank with Galvanized Steel Roof-Support Columns



- Corrosion potential testing (relative to $Cu/CuSO_{4(sat.)}$ of each of the 9 columns found that they all resided at about -0.26V, the potential of steel in concrete.
- This confirmed that the columns were connected into the concrete reinforcing.

Australasian Corrosion Association, Queensland Branch
Building for Durability – Focus on Durability in National Standards

PearlStreet

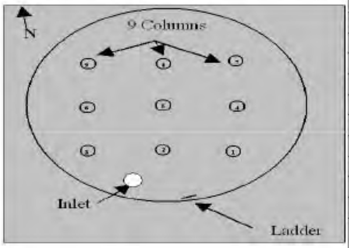
A Concrete Potable Water Tank with Galvanized Steel Roof-Support Columns

- The roof support columns and ladder were replaced with Type 316 Stainless Steel items and care taken to electrically isolate each of the columns and ladder from the concrete reinforcing.
- Electrical isolation was tested for using an applied current interrupt method involving:
  - Connection of the negative terminal of an automatic interrupt 33V DC source to reinforcing in the tank wall.
  - Connection of the positive terminal of a 33V DC source to an anode, consisting of a nominal one metre square piece of galvanised mesh, placed on the tank floor with about 300mm of water was left in the tank, completing the electrolytic circuit.
  - Operating the temporary anode on for 2 seconds, off for 6 seconds.
  - Measurement of the electrical potential of each column, ladder, roof and concrete steel reinforcing between 'on' and 'off' relative to a $Cu/CuSO_{4(sat.)}$ standard half cell electrode.

Australasian Corrosion Association, Queensland Branch
Building for Durability – Focus on Durability in National Standards

PearlStreet

A Concrete Potable Water Tank with Galvanized Steel Roof-Support Columns



Item	Potential (V) rel. Cu/$CuSO_{4(sat)}$ Anode Current Off	Potential (V) rel. Cu/$CuSO_{4(sat)}$ Anode Current On	Voltage Shift (V)	Is ITEM Electrically Isolated
Column 1	+0.060	+0.055	0.015	YES
Column 2	+0.197	+0.204	0.008	YES
Column 3	+0.110	+0.127	0.016	YES
Column 4	+0.013	+0.220	0.207	YES
Column 5	+0.045	+0.120	0.075	YES
Column 6	+0.190	+0.182	0.008	YES
Column 7	+0.213	+0.216	0.003	YES
Column 8	+0.58	+0.67	0.09	YES
Column 9	+0.1	+0.106	0.006	YES
Ladder	-0.5	-2.2	1.7	No
Reinforcing (in wall & Floor)	-0.6	-2.3	1.7	No
Steel Roof	-0.6	-2.3	1.7	No

- The isolation tests found all columns isolated with the ladder still electrically connected. Further works were done and retest confirmed that full electrical isolation of the ladder and all of the columns was attained.
- A long life is now expected.

15

APPENDIX D – WIND LOADING CALCULATIONS

Table A.1 – Wind Loading Calculations

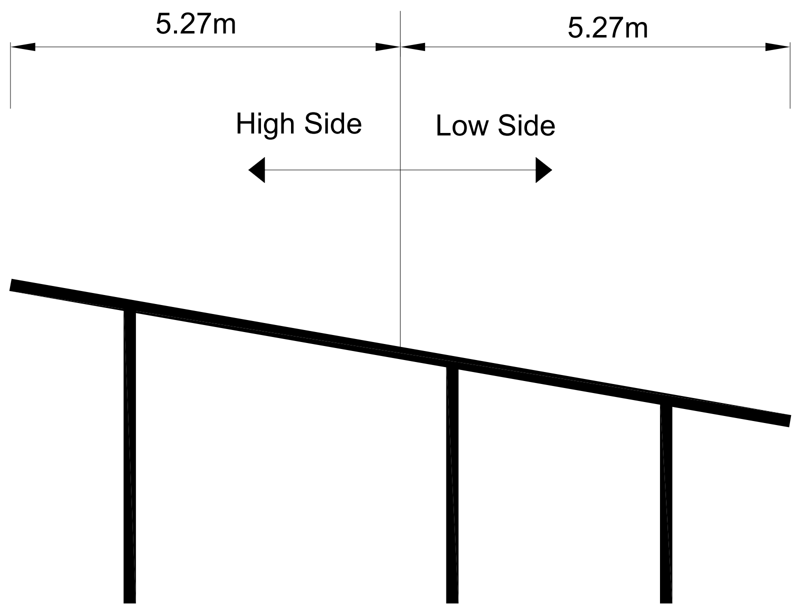
Load Case	$V_{des,\theta}$ (m/s)	$C_{p,H}$	$C_{p,L}$	p_H (kPa)	p_L (kPa)	$Load_H$	$Load_L$
B Ult Wind load 1	52	-1.5	0.4	-2.43	0.65	-11.92	3.18
B Ult Wind load 2	52	-0.8	0.8	-1.30	1.30	-6.36	6.36
B Ult Wind load 3	52	0.4	-1	0.65	-1.62	3.18	-7.95
C Serv Wind Load 1	50	-1.5	0.4	-2.25	0.60	-11.03	2.94
C Serv Wind Load 2	50	-0.8	0.8	-1.20	1.20	-5.88	5.88
C Serv Wind Load 3	50	0.4	-1	0.60	-1.50	2.94	-7.35

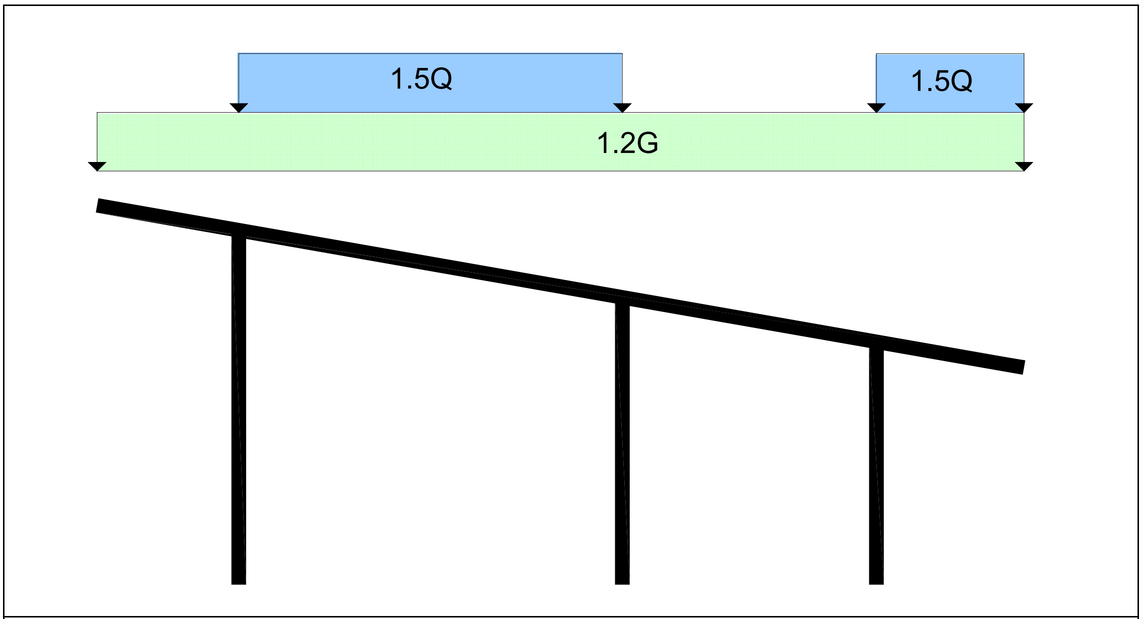
$V_{des,\theta}$ was calculated in accordance with AS1170.2

$C_{p,H}$ and $C_{p,L}$ refer to the pressure coefficients for the High and Low sides of the roof respectively. These values were obtained from Table D4(A) AS1170.2 assuming “Blocked Under” the value which would results in the worst case scenario from roof pitches 0° and 15° were used as it was not stated that linear interpolation could be used.

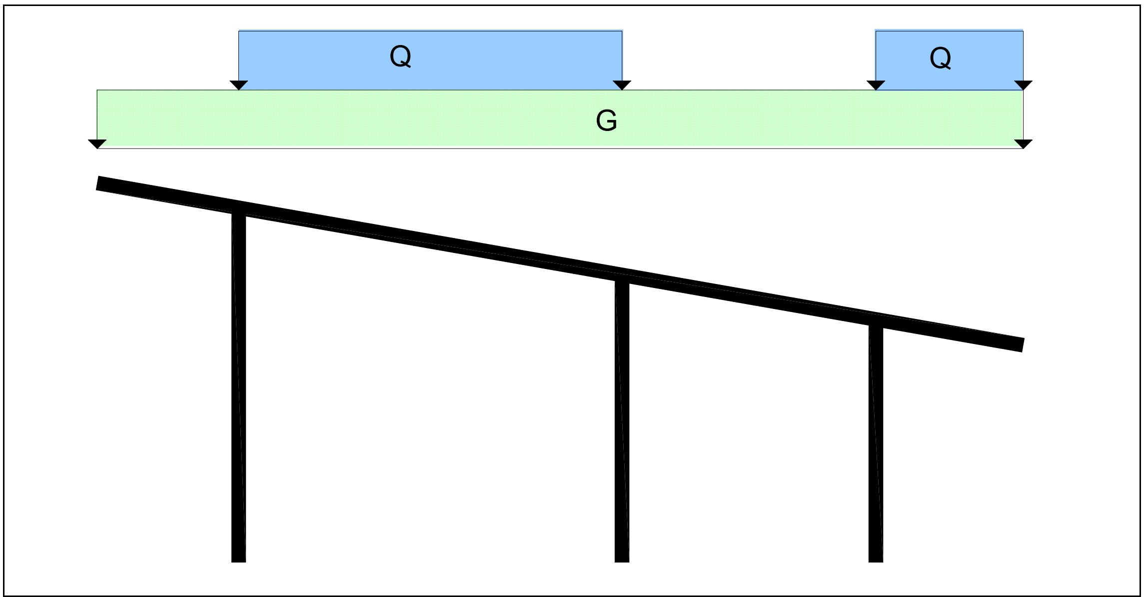
p_H and p_L refer to the uplift or downdrag pressure developed on the roof high and low side. Negative values signify uplift and positive values indicate downdrag. Equation 2.4(1) of AS1170.2 was used to calculate these values.

$Load_H$ and $Load_L$ refer to the load carried by the rafter on the high and low side of the roof respectively. These values are the product of the uplift or downdrag and the rafter spacing (4.9m).





Load Case A



Load Case D

Load cases B and C are simply the dead load (G) with the 3 different wind loading envelopes applied individually.

APPENDIX E – STAINLESS STEEL CONVERSION RESULTS

Analysis of Structure to Determine Governing Limits

Load Case	Equation	Maximum Deflection (mm)	Maximum Bending Moment M* (kNm)	Maximum Bending Stress (MPa)		Percentage of Deflection Limit	Percentage of Allowable Moment
A	1.2G + 1.5Q	-8.21	7.03	64.52		44.62	16.62
B Ult Wind load 1	$1.2G + W_u + \psi_c Q$	N/A	-24.88	-228.24	ψ_c = 0	N/A	58.82
B Ult Wind load 2	$1.2G + W_u + \psi_c Q$	N/A	13.4	122.89	ψ_c = 0	N/A	31.68
B Ult Wind load 3	$1.2G + W_u + \psi_c Q$	N/A	12.49	114.57	ψ_c = 0	N/A	29.53
C Serv Wind Load 1	$G + W_s$	17.13	-14.56	-133.57		93.10	34.42
C Serv Wind Load 2	$G + W_s$	8.84	8.26	75.77		48.04	19.53
C Serv Wind Load 3	$G + W_s$	-10.07	8.39	76.97		54.73	19.83
D	G + Q	-6.07	5.24	48.09		32.99	12.39

-ve = downwards

Deflection Limit of Span	L/250=		18.4	mm
Deflection Limit on Cantilever	L/125=		10.4	mm

Deflection Limits obtained from AS4100 Table B1

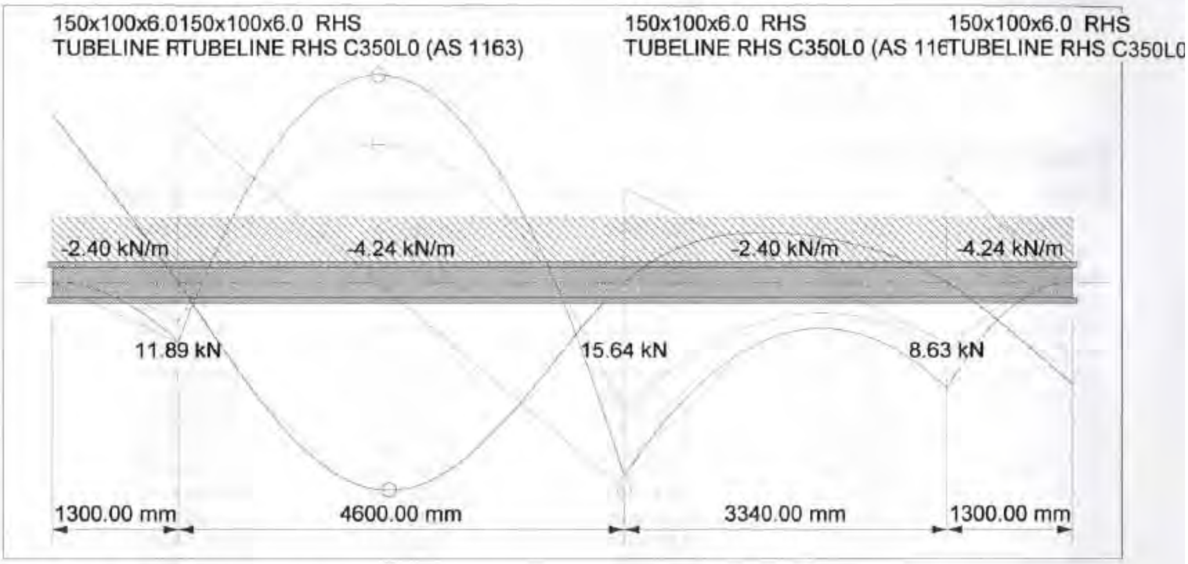
Allowable moment = ΦM_b	From Table 4.1 - 1(1) from AISC: Design Capacity Tables For Structural Steel Hollow Sections	42.3	kNm

STEELbeam Report

Friday, 17 April 2009 08:10:48

Project Name: Roughton Park Rafters Load Case A
Project ID: IAP Rafter
Client Name:
Client ID:

Author: Jordan Cocks
Company: Gold Coast City Council



Total beam length 10540.00 mm
Number of segments: 4

Gravity 0.00 m/s^2

Segment 1 (Constant):
Segment length 1300.00 mm
Mass per length 21.43 kg/m
Moment of inertia (Ixx) 8.17 x 10^6mm^4
Section area 2730.00 mm^2
Young's modulus 200000.00 MPa

Segment 2 (Constant):
Segment length 4600.00 mm
Mass per length 21.43 kg/m
Moment of inertia (Ixx) 8.17 x 10^6mm^4
Section area 2730.00 mm^2
Young's modulus 200000.00 MPa

Segment 3 (Constant):
Segment length 3340.00 mm
Mass per length 21.43 kg/m
Moment of inertia (Ixx) 8.17 x 10^6mm^4
Section area 2730.00 mm^2
Young's modulus 200000.00 MPa

Segment 4 (Constant):
Segment length 1300.00 mm
Mass per length 21.43 kg/m
Moment of inertia (Ixx) 8.17 x 10^6mm^4
Section area 2730.00 mm^2
Young's modulus 200000.00 MPa

Maximum Values

	Position	Value
Maximum shear force	5900.00 mm	-10.74 kN
Maximum bending moment	3367.43 mm	7.03 kNm
Maximum displacement	3475.25 mm	-8.21 mm
Maximum bending stress	3367.43 mm	64.52 MPa

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Page 1/2

STEELbeam Report

Friday, 17 April 2009 08:10:48

Supports and Loads

Support	Position	Type
1	1300.00 mm	Pinned
2	5900.00 mm	Pinned
3	9240.00 mm	Pinned

Uniform Load	Start	End	Load
1	1300.00 mm	5900.00 mm	-4.24 kN/m
2	9240.00 mm	10540.00 mm	-4.24 kN/m
3	0.00 mm	1300.00 mm	-2.40 kN/m
4	5900.00 mm	9240.00 mm	-2.40 kN/m

Results across Beam

Position	Shear Force	Bending Moment	Displacement	Bending Stress
0.00 mm	0.00 kN	0.00 kNm	6.68 mm	0.00 MPa
500.00 mm	-1.20 kN	-0.30 kNm	4.17 mm	-2.75 MPa
1000.00 mm	-2.40 kN	-1.20 kNm	1.61 mm	-11.01 MPa
1500.00 mm	7.92 kN	-0.36 kNm	-1.13 mm	-3.30 MPa
2000.00 mm	5.80 kN	3.07 kNm	-3.90 mm	28.16 MPa
2500.00 mm	3.68 kN	5.44 kNm	-6.22 mm	49.89 MPa
3000.00 mm	1.56 kN	6.75 kNm	-7.72 mm	61.90 MPa
3500.00 mm	-0.56 kN	7.00 kNm	-8.21 mm	64.18 MPa
4000.00 mm	-2.68 kN	6.19 kNm	-7.63 mm	56.74 MPa
4500.00 mm	-4.80 kN	4.31 kNm	-6.12 mm	39.58 MPa
5000.00 mm	-6.92 kN	1.38 kNm	-3.97 mm	12.69 MPa
5500.00 mm	-9.04 kN	-2.61 kNm	-1.62 mm	-23.93 MPa
6000.00 mm	4.66 kN	-6.09 kNm	0.32 mm	-55.83 MPa
6500.00 mm	3.46 kN	-4.06 kNm	1.42 mm	-37.21 MPa
7000.00 mm	2.26 kN	-2.63 kNm	1.90 mm	-24.08 MPa
7500.00 mm	1.06 kN	-1.80 kNm	1.96 mm	-16.47 MPa
8000.00 mm	-0.14 kN	-1.56 kNm	1.75 mm	-14.36 MPa
8500.00 mm	-1.34 kN	-1.93 kNm	1.28 mm	-17.75 MPa
9000.00 mm	-2.54 kN	-2.90 kNm	0.52 mm	-26.64 MPa
9500.00 mm	4.41 kN	-2.29 kNm	-0.69 mm	-21.04 MPa
10000.00 mm	2.29 kN	-0.62 kNm	-2.24 mm	-5.67 MPa
10500.00 mm	0.17 kN	0.00 kNm	-3.91 mm	-0.03 MPa
10540.00 mm	0.00 kN	0.00 kNm	-4.04 mm	0.00 MPa

Results at Supports and Loads

Position	Shear Force	Moment	Displacement	Bending Stress
1300.00 mm	-3.12 kN 8.77 kN	-2.03 kNm	0.00 mm	-18.60 MPa
5900.00 mm	-10.74 kN 4.90 kN	-6.56 kNm	0.00 mm	-60.22 MPa
9240.00 mm	-3.12 kN 5.51 kN	-3.58 kNm	0.00 mm	-32.87 MPa

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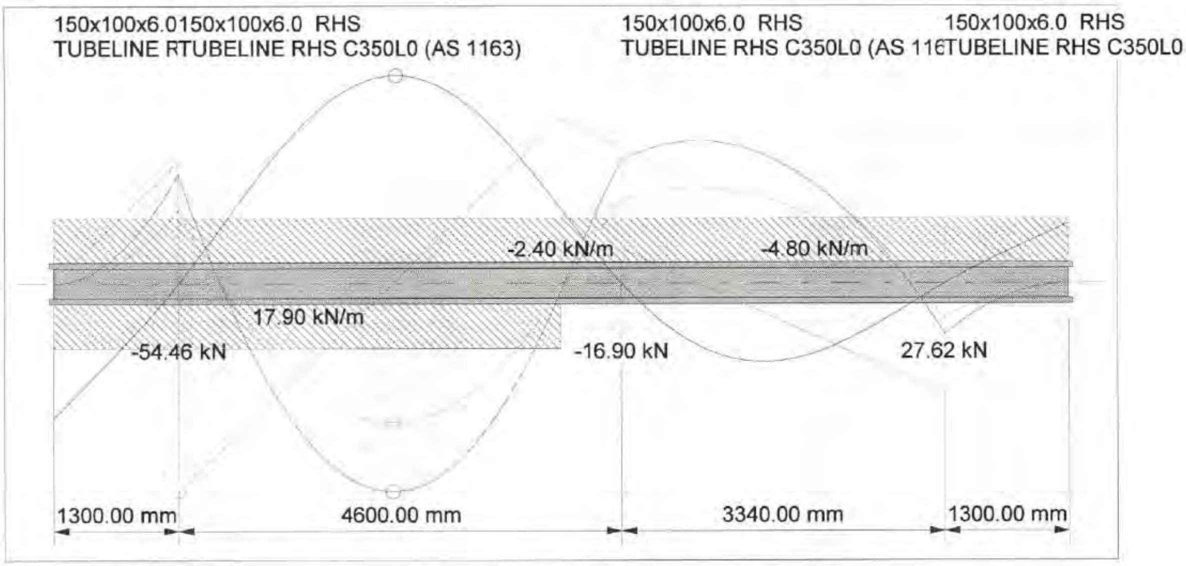
Page 2/2

STEELbeam Report

Thursday, 23 April 2009 11:11:40

Project Name: Load Case B with Ultimate Wind Load 1
Project ID: IAP Rafter
Client Name:
Client ID:

Author: Jordan Cocks
Company: Gold Coast City Council



Total beam length 10540.00 mm
Number of segments: 4

Gravity -9.81 m/s^2

Segment 1 (Constant):

Segment length	1300.00 mm	Young's modulus 200000.00 MPa
Mass per length	21.43 kg/m	
Moment of inertia (Ixx)	8.17 x 10^6mm^4	
Section area	2730.00 mm^2	

Segment 2 (Constant):

Segment length	4600.00 mm	Young's modulus 200000.00 MPa
Mass per length	21.43 kg/m	
Moment of inertia (Ixx)	8.17 x 10^6mm^4	
Section area	2730.00 mm^2	

Segment 3 (Constant):

Segment length	3340.00 mm	Young's modulus 200000.00 MPa
Mass per length	21.43 kg/m	
Moment of inertia (Ixx)	8.17 x 10^6mm^4	
Section area	2730.00 mm^2	

Segment 4 (Constant):

Segment length	1300.00 mm	Young's modulus 200000.00 MPa
Mass per length	21.43 kg/m	
Moment of inertia (Ixx)	8.17 x 10^6mm^4	
Section area	2730.00 mm^2	

Maximum Values

	Position	Value
Maximum shear force	1300.00 mm	-34.31 kN
Maximum bending moment	3513.65 mm	-24.88 kNm
Maximum displacement	3553.81 mm	29.18 mm
Maximum bending stress	3513.65 mm	-228.24 MPa

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Page 1/2

STEELbeam Report

Thursday, 23 April 2009 11:11:40

Supports and Loads

Support	Position	Type
1	1300.00 mm	Pinned
2	5900.00 mm	Pinned
3	9240.00 mm	Pinned

Uniform Load	Start	End	Load
1	0.00 mm	10540.00 mm	-2.40 kN/m
2	0.00 mm	5270.00 mm	17.90 kN/m
3	5270.00 mm	10540.00 mm	-4.80 kN/m

Results across Beam

Position	Shear Force	Bending Moment	Displacement	Bending Stress
0.00 mm	0.00 kN	0.00 kNm	-18.93 mm	0.00 MPa
500.00 mm	7.75 kN	1.94 kNm	-12.06 mm	17.77 MPa
1000.00 mm	15.50 kN	7.75 kNm	-4.84 mm	71.10 MPa
1500.00 mm	-31.21 kN	6.55 kNm	3.57 mm	60.04 MPa
2000.00 mm	-23.46 kN	-7.12 kNm	12.88 mm	-65.35 MPa
2500.00 mm	-15.71 kN	-16.92 kNm	21.14 mm	-155.19 MPa
3000.00 mm	-7.96 kN	-22.83 kNm	26.87 mm	-209.48 MPa
3500.00 mm	-0.21 kN	-24.88 kNm	29.16 mm	-228.23 MPa
4000.00 mm	7.54 kN	-23.05 kNm	27.69 mm	-211.42 MPa
4500.00 mm	15.29 kN	-17.34 kNm	22.74 mm	-159.07 MPa
5000.00 mm	23.04 kN	-7.76 kNm	15.19 mm	-71.17 MPa
5500.00 mm	25.57 kN	5.10 kNm	6.50 mm	46.77 MPa
6000.00 mm	5.07 kN	15.29 kNm	-1.44 mm	140.29 MPa
6500.00 mm	1.47 kN	16.93 kNm	-7.16 mm	155.27 MPa
7000.00 mm	-2.13 kN	16.76 kNm	-10.32 mm	153.74 MPa
7500.00 mm	-5.73 kN	14.79 kNm	-10.94 mm	135.70 MPa
8000.00 mm	-9.33 kN	11.02 kNm	-9.32 mm	101.14 MPa
8500.00 mm	-12.93 kN	5.46 kNm	-6.03 mm	50.07 MPa
9000.00 mm	-16.53 kN	-1.91 kNm	-1.93 mm	-17.51 MPa
9500.00 mm	7.49 kN	-3.89 kNm	1.90 mm	-35.72 MPa
10000.00 mm	3.89 kN	-1.05 kNm	5.15 mm	-9.63 MPa
10500.00 mm	0.29 kN	-0.01 kNm	8.22 mm	-0.05 MPa
10540.00 mm	0.00 kN	0.00 kNm	8.46 mm	0.00 MPa

Results at Supports and Loads

Position	Shear Force	Moment	Displacement	Bending Stress
1300.00 mm	20.15 kN -34.31 kN	13.10 kNm	0.00 mm	120.15 MPa
5900.00 mm	22.69 kN 5.79 kN	14.75 kNm	0.00 mm	135.31 MPa
9240.00 mm	-18.26 kN 9.36 kN	-6.08 kNm	0.00 mm	-55.81 MPa

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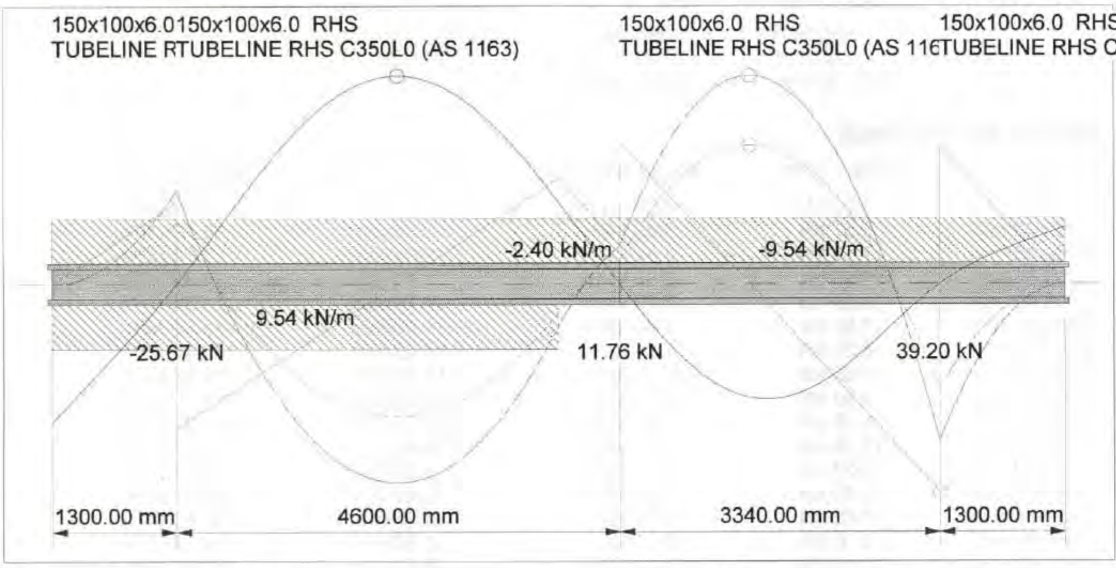
STEELbeam Report

Thursday, 23 April 2009 11:11:45

Project Name: Load Case B with Ultimate Wind Load 2
Project ID: IAP Rafter
Client Name:
Client ID:

Author: Jordan Cocks
Company: Gold Coast City Council



Total beam length 10540.00 mm
Number of segments: 4

Gravity -9.81 m/s^2

Segment 1 (Constant):

Segment length	1300.00 mm
Mass per length	21.43 kg/m
Moment of inertia (Ixx)	8.17 x 10^6mm^4
Section area	2730.00 mm^2

Young's modulus 200000.00 MPa

Segment 2 (Constant):

Segment length	4600.00 mm
Mass per length	21.43 kg/m
Moment of inertia (Ixx)	8.17 x 10^6mm^4
Section area	2730.00 mm^2

Young's modulus 200000.00 MPa

Segment 3 (Constant):

Segment length	3340.00 mm
Mass per length	21.43 kg/m
Moment of inertia (Ixx)	8.17 x 10^6mm^4
Section area	2730.00 mm^2

Young's modulus 200000.00 MPa

Segment 4 (Constant):

Segment length	1300.00 mm
Mass per length	21.43 kg/m
Moment of inertia (Ixx)	8.17 x 10^6mm^4
Section area	2730.00 mm^2

Young's modulus 200000.00 MPa

Maximum Values

	Position	Value
Maximum shear force	9240.00 mm	-23.68 kN
Maximum bending moment	7256.62 mm	13.40 kNm
Maximum displacement	3599.71 mm	15.62 mm
Maximum bending stress	7256.62 mm	122.89 MPa

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STEELbeam Report

Thursday, 23 April 2009 11:11:45

Supports and Loads

Support	Position	Type
1	1300.00 mm	Pinned
2	5900.00 mm	Pinned
3	9240.00 mm	Pinned

Uniform Load	Start	End	Load
1	0.00 mm	10540.00 mm	-2.40 kN/m
2	0.00 mm	5270.00 mm	9.54 kN/m
3	5270.00 mm	10540.00 mm	-9.54 kN/m

Results across Beam

Position	Shear Force	Bending Moment	Displacement	Bending Stress
0.00 mm	0.00 kN	0.00 kNm	-10.36 mm	0.00 MPa
500.00 mm	3.57 kN	0.89 kNm	-6.56 mm	8.19 MPa
1000.00 mm	7.14 kN	3.57 kNm	-2.61 mm	32.75 MPa
1500.00 mm	-14.96 kN	2.90 kNm	1.89 mm	26.59 MPa
2000.00 mm	-11.39 kN	-3.69 kNm	6.79 mm	-33.84 MPa
2500.00 mm	-7.82 kN	-8.49 kNm	11.15 mm	-77.89 MPa
3000.00 mm	-4.25 kN	-11.51 kNm	14.23 mm	-105.56 MPa
3500.00 mm	-0.68 kN	-12.74 kNm	15.58 mm	-116.87 MPa
4000.00 mm	2.89 kN	-12.19 kNm	15.00 mm	-111.79 MPa
4500.00 mm	6.46 kN	-9.85 kNm	12.57 mm	-90.34 MPa
5000.00 mm	10.03 kN	-5.73 kNm	8.66 mm	-52.52 MPa
5500.00 mm	9.21 kN	-0.32 kNm	3.90 mm	-2.95 MPa
6000.00 mm	15.00 kN	3.97 kNm	-0.95 mm	36.40 MPa
6500.00 mm	9.03 kN	9.98 kNm	-5.15 mm	91.53 MPa
7000.00 mm	3.06 kN	13.00 kNm	-7.86 mm	119.28 MPa
7500.00 mm	-2.91 kN	13.04 kNm	-8.62 mm	119.64 MPa
8000.00 mm	-8.88 kN	10.10 kNm	-7.42 mm	92.62 MPa
8500.00 mm	-14.85 kN	4.17 kNm	-4.72 mm	38.22 MPa
9000.00 mm	-20.82 kN	-4.75 kNm	-1.42 mm	-43.57 MPa
9500.00 mm	12.42 kN	-6.46 kNm	1.19 mm	-59.24 MPa
10000.00 mm	6.45 kN	-1.74 kNm	2.83 mm	-15.97 MPa
10500.00 mm	0.48 kN	-0.01 kNm	4.16 mm	-0.09 MPa
10540.00 mm	0.00 kN	0.00 kNm	4.27 mm	0.00 MPa

Results at Supports and Loads

Position	Shear Force	Moment	Displacement	Bending Stress
1300.00 mm	9.28 kN -16.39 kN	6.03 kNm	0.00 mm	55.35 MPa
5900.00 mm	4.44 kN 16.20 kN	2.41 kNm	0.00 mm	22.09 MPa
9240.00 mm	-23.68 kN 15.52 kN	-10.09 kNm	0.00 mm	-92.56 MPa

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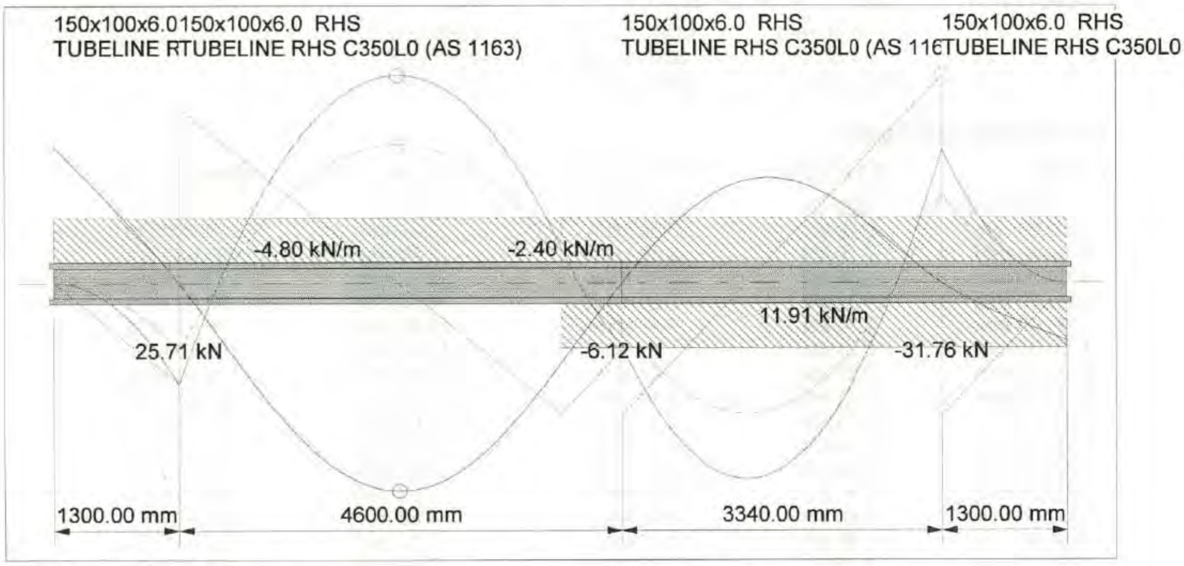
STEELbeam Report

Thursday, 23 April 2009 11:11:50

Project Name: Load Case B with Ultimate Wind Load 3
Project ID: IAP Rafter
Client Name:
Client ID:

Author: Jordan Cocks
Company: Gold Coast City Council



Total beam length 10540.00 mm
Number of segments: 4

Gravity -9.81 m/s^2

Segment 1 (Constant):
Segment length 1300.00 mm
Mass per length 21.43 kg/m
Moment of inertia (Ixx) 8.17 x 10^6mm^4
Section area 2730.00 mm^2
Young's modulus 200000.00 MPa

Segment 2 (Constant):
Segment length 4600.00 mm
Mass per length 21.43 kg/m
Moment of inertia (Ixx) 8.17 x 10^6mm^4
Section area 2730.00 mm^2
Young's modulus 200000.00 MPa

Segment 3 (Constant):
Segment length 3340.00 mm
Mass per length 21.43 kg/m
Moment of inertia (Ixx) 8.17 x 10^6mm^4
Section area 2730.00 mm^2
Young's modulus 200000.00 MPa

Segment 4 (Constant):
Segment length 1300.00 mm
Mass per length 21.43 kg/m
Moment of inertia (Ixx) 8.17 x 10^6mm^4
Section area 2730.00 mm^2
Young's modulus 200000.00 MPa

Maximum Values

	Position	Value
Maximum shear force	9240.00 mm	19.40 kN
Maximum bending moment	3571.39 mm	12.49 kNm
Maximum displacement	3587.37 mm	-15.11 mm
Maximum bending stress	3571.39 mm	114.57 MPa

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STEELbeam Report

Thursday, 23 April 2009 11:11:50

Supports and Loads

Support	Position	Type
1	1300.00 mm	Pinned
2	5900.00 mm	Pinned
3	9240.00 mm	Pinned

Uniform Load	Start	End	Load
1	0.00 mm	10540.00 mm	-2.40 kN/m
2	0.00 mm	5270.00 mm	-4.80 kN/m
3	5270.00 mm	10540.00 mm	11.91 kN/m

Results across Beam

Position	Shear Force	Bending Moment	Displacement	Bending Stress
0.00 mm	0.00 kN	0.00 kNm	9.97 mm	0.00 MPa
500.00 mm	-3.60 kN	-0.90 kNm	6.32 mm	-8.26 MPa
1000.00 mm	-7.20 kN	-3.60 kNm	2.52 mm	-33.03 MPa
1500.00 mm	14.91 kN	-2.96 kNm	-1.84 mm	-27.13 MPa
2000.00 mm	11.31 kN	3.60 kNm	-6.60 mm	33.02 MPa
2500.00 mm	7.71 kN	8.36 kNm	-10.83 mm	76.66 MPa
3000.00 mm	4.11 kN	11.31 kNm	-13.81 mm	103.79 MPa
3500.00 mm	0.51 kN	12.47 kNm	-15.08 mm	114.41 MPa
4000.00 mm	-3.09 kN	11.83 kNm	-14.46 mm	108.51 MPa
4500.00 mm	-6.69 kN	9.38 kNm	-12.06 mm	86.09 MPa
5000.00 mm	-10.29 kN	5.14 kNm	-8.25 mm	47.17 MPa
5500.00 mm	-10.04 kN	-0.46 kNm	-3.67 mm	-4.21 MPa
6000.00 mm	-11.41 kN	-4.90 kNm	0.87 mm	-44.99 MPa
6500.00 mm	-6.66 kN	-9.42 kNm	4.65 mm	-86.43 MPa
7000.00 mm	-1.90 kN	-11.56 kNm	7.01 mm	-106.06 MPa
7500.00 mm	2.85 kN	-11.32 kNm	7.64 mm	-103.88 MPa
8000.00 mm	7.61 kN	-8.71 kNm	6.57 mm	-79.89 MPa
8500.00 mm	12.36 kN	-3.72 kNm	4.19 mm	-34.09 MPa
9000.00 mm	17.12 kN	3.65 kNm	1.27 mm	33.52 MPa
9500.00 mm	-9.89 kN	5.14 kNm	-1.11 mm	47.18 MPa
10000.00 mm	-5.14 kN	1.39 kNm	-2.72 mm	12.72 MPa
10500.00 mm	-0.38 kN	0.01 kNm	-4.09 mm	0.07 MPa
10540.00 mm	0.00 kN	0.00 kNm	-4.20 mm	0.00 MPa

Results at Supports and Loads

Position	Shear Force	Moment	Displacement	Bending Stress
1300.00 mm	-9.36 kN 16.35 kN	-6.08 kNm	0.00 mm	-55.81 MPa
5900.00 mm	-6.24 kN -12.36 kN	-3.72 kNm	0.00 mm	-34.08 MPa
9240.00 mm	19.40 kN -12.36 kN	8.04 kNm	0.00 mm	73.72 MPa

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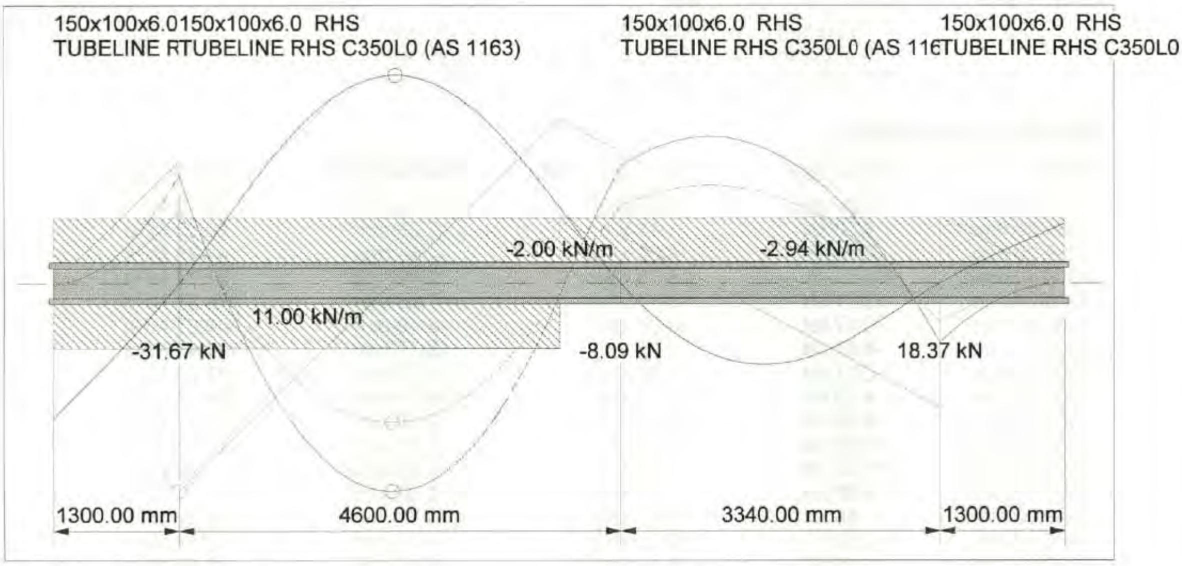
STEELbeam Report

Thursday, 23 April 2009 11:11:55

Project Name: Load Case C with Serviciability Wind Load 1
Project ID: IAP Rafter
Client Name:
Client ID:

Author: Jordan Cocks
Company: Gold Coast City Council



Total beam length 10540.00 mm
Number of segments: 4

Gravity -9.81 m/s^2

Segment 1 (Constant):
Segment length 1300.00 mm
Mass per length 21.43 kg/m
Moment of inertia (Ixx) 8.17 x 10^6mm^4
Section area 2730.00 mm^2

Young's modulus 200000.00 MPa

Segment 2 (Constant):
Segment length 4600.00 mm
Mass per length 21.43 kg/m
Moment of inertia (Ixx) 8.17 x 10^6mm^4
Section area 2730.00 mm^2

Young's modulus 200000.00 MPa

Segment 3 (Constant):
Segment length 3340.00 mm
Mass per length 21.43 kg/m
Moment of inertia (Ixx) 8.17 x 10^6mm^4
Section area 2730.00 mm^2

Young's modulus 200000.00 MPa

Segment 4 (Constant):
Segment length 1300.00 mm
Mass per length 21.43 kg/m
Moment of inertia (Ixx) 8.17 x 10^6mm^4
Section area 2730.00 mm^2

Young's modulus 200000.00 MPa

Maximum Values

	Position	Value
Maximum shear force	1300.00 mm	-19.97 kN
Maximum bending moment	3519.34 mm	-14.56 kNm
Maximum displacement	3557.36 mm	17.13 mm
Maximum bending stress	3519.34 mm	-133.57 MPa

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STEELbeam Report

Thursday, 23 April 2009 11:11:55

Supports and Loads

Support	Position	Type
1	1300.00 mm	Pinned
2	5900.00 mm	Pinned
3	9240.00 mm	Pinned

Uniform Load	Start	End	Load
1	0.00 mm	10540.00 mm	-2.00 kN/m
2	0.00 mm	5270.00 mm	11.00 kN/m
3	5270.00 mm	10540.00 mm	-2.94 kN/m

Results across Beam

Position	Shear Force	Bending Moment	Displacement	Bending Stress
0.00 mm	0.00 kN	0.00 kNm	-11.14 mm	0.00 MPa
500.00 mm	4.50 kN	1.13 kNm	-7.09 mm	10.32 MPa
1000.00 mm	9.00 kN	4.50 kNm	-2.84 mm	41.28 MPa
1500.00 mm	-18.17 kN	3.79 kNm	2.09 mm	34.77 MPa
2000.00 mm	-13.67 kN	-4.17 kNm	7.55 mm	-38.27 MPa
2500.00 mm	-9.17 kN	-9.88 kNm	12.40 mm	-90.67 MPa
3000.00 mm	-4.67 kN	-13.35 kNm	15.77 mm	-122.43 MPa
3500.00 mm	-0.17 kN	-14.56 kNm	17.12 mm	-133.55 MPa
4000.00 mm	4.33 kN	-13.52 kNm	16.27 mm	-124.03 MPa
4500.00 mm	8.83 kN	-10.23 kNm	13.39 mm	-93.87 MPa
5000.00 mm	13.33 kN	-4.69 kNm	8.97 mm	-43.06 MPa
5500.00 mm	14.62 kN	2.73 kNm	3.85 mm	25.00 MPa
6000.00 mm	4.06 kN	8.61 kNm	-0.86 mm	78.97 MPa
6500.00 mm	1.59 kN	10.02 kNm	-4.32 mm	91.92 MPa
7000.00 mm	-0.88 kN	10.20 kNm	-6.27 mm	93.54 MPa
7500.00 mm	-3.35 kN	9.14 kNm	-6.67 mm	83.82 MPa
8000.00 mm	-5.82 kN	6.84 kNm	-5.69 mm	62.78 MPa
8500.00 mm	-8.29 kN	3.31 kNm	-3.67 mm	30.41 MPa
9000.00 mm	-10.76 kN	-1.45 kNm	-1.17 mm	-13.29 MPa
9500.00 mm	5.14 kN	-2.67 kNm	1.13 mm	-24.51 MPa
10000.00 mm	2.67 kN	-0.72 kNm	3.03 mm	-6.61 MPa
10500.00 mm	0.20 kN	0.00 kNm	4.81 mm	-0.04 MPa
10540.00 mm	0.00 kN	0.00 kNm	4.95 mm	0.00 MPa

Results at Supports and Loads

Position	Shear Force	Moment	Displacement	Bending Stress
1300.00 mm	11.70 kN -19.97 kN	7.61 kNm	0.00 mm	69.77 MPa
5900.00 mm	12.64 kN 4.55 kN	8.18 kNm	0.00 mm	75.02 MPa
9240.00 mm	-11.95 kN 6.42 kN	-4.17 kNm	0.00 mm	-38.29 MPa

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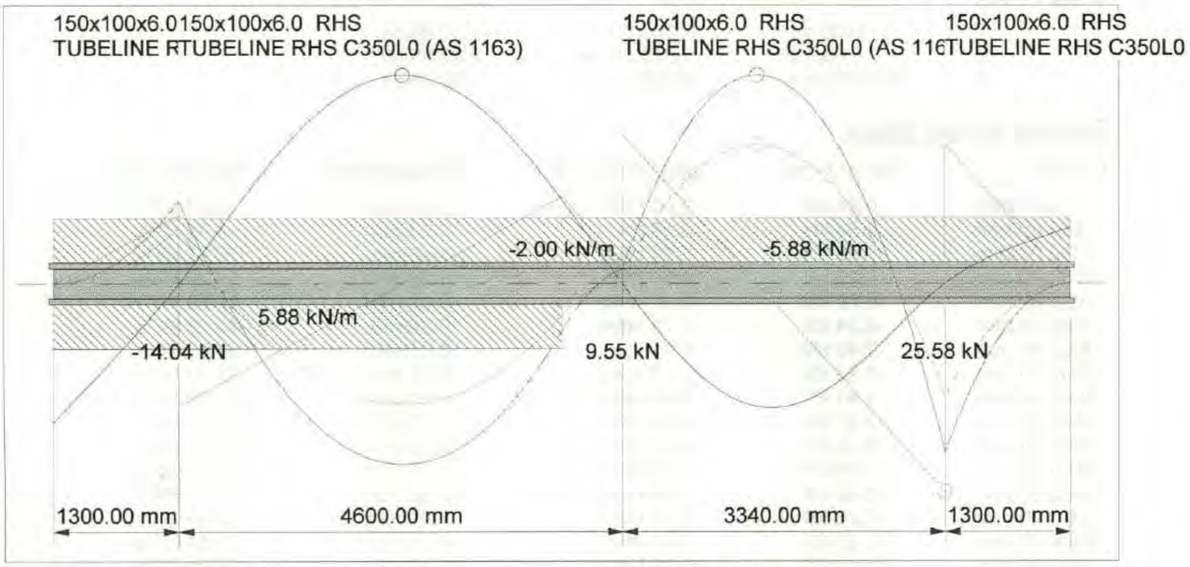
STEELbeam Report

Thursday, 23 April 2009 11:12:00

Project Name: Load Case C with Serviciability Wind Load 2
Project ID: IAP Rafter
Client Name:
Client ID:

Author: Jordan Cocks
Company: Gold Coast City Council



Total beam length 10540.00 mm
Number of segments: 4

Gravity -9.81 m/s^2

Segment 1 (Constant):
Segment length 1300.00 mm
Mass per length 21.43 kg/m
Moment of inertia (Ixx) 8.17 x 10^6mm^4
Section area 2730.00 mm^2
Young's modulus 200000.00 MPa

Segment 2 (Constant):
Segment length 4600.00 mm
Mass per length 21.43 kg/m
Moment of inertia (Ixx) 8.17 x 10^6mm^4
Section area 2730.00 mm^2
Young's modulus 200000.00 MPa

Segment 3 (Constant):
Segment length 3340.00 mm
Mass per length 21.43 kg/m
Moment of inertia (Ixx) 8.17 x 10^6mm^4
Section area 2730.00 mm^2
Young's modulus 200000.00 MPa

Segment 4 (Constant):
Segment length 1300.00 mm
Mass per length 21.43 kg/m
Moment of inertia (Ixx) 8.17 x 10^6mm^4
Section area 2730.00 mm^2
Young's modulus 200000.00 MPa

Maximum Values

	Position	Value
Maximum shear force	9240.00 mm	-15.33 kN
Maximum bending moment	7294.18 mm	8.26 kNm
Maximum displacement	3611.56 mm	8.84 mm
Maximum bending stress	7294.18 mm	75.77 MPa

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STEELbeam Report

Thursday, 23 April 2009 11:12:00

Supports and Loads

Support	Position	Type
1	1300.00 mm	Pinned
2	5900.00 mm	Pinned
3	9240.00 mm	Pinned

Uniform Load	Start	End	Load
1	0.00 mm	10540.00 mm	-2.00 kN/m
2	0.00 mm	5270.00 mm	5.88 kN/m
3	5270.00 mm	10540.00 mm	-5.88 kN/m

Results across Beam

Position	Shear Force	Bending Moment	Displacement	Bending Stress
0.00 mm	0.00 kN	0.00 kNm	-5.90 mm	0.00 MPa
500.00 mm	1.94 kN	0.48 kNm	-3.73 mm	4.45 MPa
1000.00 mm	3.88 kN	1.94 kNm	-1.48 mm	17.80 MPa
1500.00 mm	-8.22 kN	1.56 kNm	1.07 mm	14.28 MPa
2000.00 mm	-6.28 kN	-2.07 kNm	3.83 mm	-18.99 MPa
2500.00 mm	-4.34 kN	-4.73 kNm	6.29 mm	-43.36 MPa
3000.00 mm	-2.40 kN	-6.41 kNm	8.03 mm	-58.83 MPa
3500.00 mm	-0.46 kN	-7.13 kNm	8.81 mm	-65.40 MPa
4000.00 mm	1.48 kN	-6.88 kNm	8.51 mm	-63.07 MPa
4500.00 mm	3.42 kN	-5.65 kNm	7.17 mm	-51.85 MPa
5000.00 mm	5.36 kN	-3.46 kNm	4.98 mm	-31.73 MPa
5500.00 mm	4.59 kN	-0.61 kNm	2.27 mm	-5.56 MPa
6000.00 mm	10.20 kN	1.66 kNm	-0.56 mm	15.23 MPa
6500.00 mm	6.26 kN	5.77 kNm	-3.09 mm	52.97 MPa
7000.00 mm	2.32 kN	7.92 kNm	-4.77 mm	72.64 MPa
7500.00 mm	-1.62 kN	8.09 kNm	-5.26 mm	74.24 MPa
8000.00 mm	-5.56 kN	6.30 kNm	-4.54 mm	57.76 MPa
8500.00 mm	-9.50 kN	2.53 kNm	-2.88 mm	23.21 MPa
9000.00 mm	-13.44 kN	-3.21 kNm	-0.85 mm	-29.41 MPa
9500.00 mm	8.20 kN	-4.26 kNm	0.70 mm	-39.09 MPa
10000.00 mm	4.26 kN	-1.15 kNm	1.61 mm	-10.54 MPa
10500.00 mm	0.32 kN	-0.01 kNm	2.32 mm	-0.06 MPa
10540.00 mm	0.00 kN	0.00 kNm	2.38 mm	0.00 MPa

Results at Supports and Loads

Position	Shear Force	Moment	Displacement	Bending Stress
1300.00 mm	5.04 kN -9.00 kN	3.28 kNm	0.00 mm	30.08 MPa
5900.00 mm	1.44 kN 10.99 kN	0.60 kNm	0.00 mm	5.51 MPa
9240.00 mm	-15.33 kN 10.24 kN	-6.66 kNm	0.00 mm	-61.08 MPa

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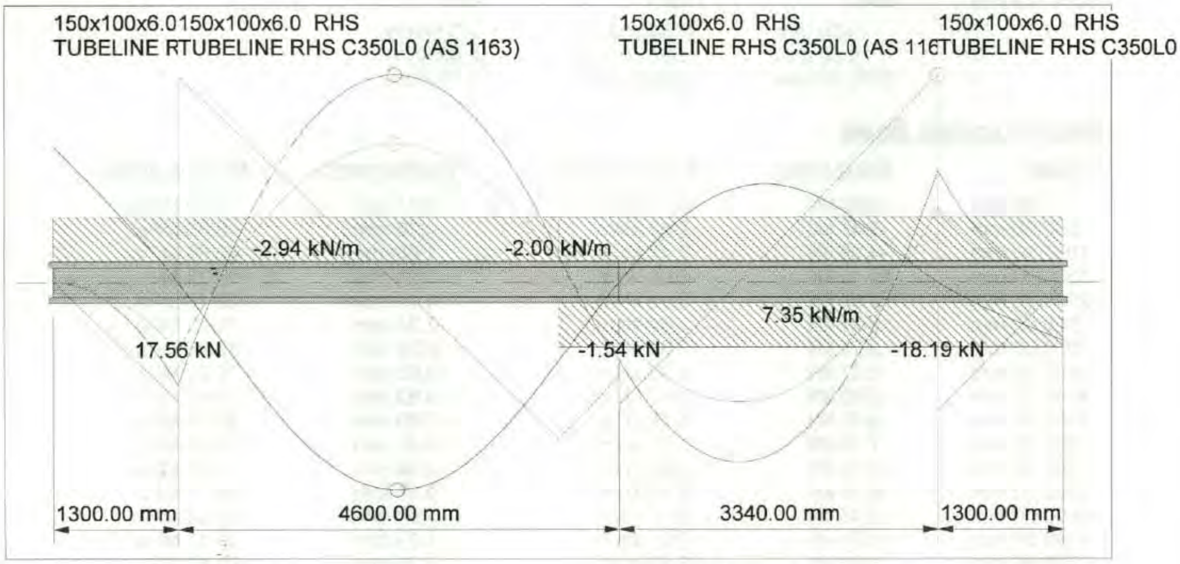
STEELbeam Report

Thursday, 23 April 2009 11:11:28

Project Name: Load Case C with Serviciability Wind Load 3
Project ID: IAP Rafter
Client Name:
Client ID:

Author: Jordan Cocks
Company: Gold Coast City Council



Total beam length 10540.00 mm
Number of segments: 4

Gravity -9.81 m/s^2

Segment 1 (Constant):
Segment length 1300.00 mm
Mass per length 21.43 kg/m
Moment of inertia (Ixx) 8.17 x 10^6mm^4
Section area 2730.00 mm^2

Young's modulus 200000.00 MPa

Segment 2 (Constant):
Segment length 4600.00 mm
Mass per length 21.43 kg/m
Moment of inertia (Ixx) 8.17 x 10^6mm^4
Section area 2730.00 mm^2

Young's modulus 200000.00 MPa

Segment 3 (Constant):
Segment length 3340.00 mm
Mass per length 21.43 kg/m
Moment of inertia (Ixx) 8.17 x 10^6mm^4
Section area 2730.00 mm^2

Young's modulus 200000.00 MPa

Segment 4 (Constant):
Segment length 1300.00 mm
Mass per length 21.43 kg/m
Moment of inertia (Ixx) 8.17 x 10^6mm^4
Section area 2730.00 mm^2

Young's modulus 200000.00 MPa

Maximum Values

	Position	Value
Maximum shear force	9240.00 mm	11.23 kN
Maximum bending moment	3555.35 mm	8.39 kNm
Maximum displacement	3578.57 mm	-10.07 mm
Maximum bending stress	3555.35 mm	76.97 MPa

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STEELbeam Report

Thursday, 23 April 2009 11:11:28

Supports and Loads

Support	Position	Type
1	1300.00 mm	Pinned
2	5900.00 mm	Pinned
3	9240.00 mm	Pinned

Uniform Load	Start	End	Load
1	0.00 mm	10540.00 mm	-2.00 kN/m
2	0.00 mm	5270.00 mm	-2.94 kN/m
3	5270.00 mm	10540.00 mm	7.35 kN/m

Results across Beam

Position	Shear Force	Bending Moment	Displacement	Bending Stress
0.00 mm	0.00 kN	0.00 kNm	6.61 mm	0.00 MPa
500.00 mm	-2.47 kN	-0.62 kNm	4.20 mm	-5.66 MPa
1000.00 mm	-4.94 kN	-2.47 kNm	1.68 mm	-22.66 MPa
1500.00 mm	10.15 kN	-2.04 kNm	-1.23 mm	-18.76 MPa
2000.00 mm	7.68 kN	2.41 kNm	-4.41 mm	22.15 MPa
2500.00 mm	5.21 kN	5.64 kNm	-7.24 mm	51.73 MPa
3000.00 mm	2.74 kN	7.63 kNm	-9.22 mm	69.98 MPa
3500.00 mm	0.27 kN	8.38 kNm	-10.05 mm	76.90 MPa
4000.00 mm	-2.20 kN	7.90 kNm	-9.62 mm	72.49 MPa
4500.00 mm	-4.67 kN	6.19 kNm	-7.99 mm	56.75 MPa
5000.00 mm	-7.14 kN	3.23 kNm	-5.43 mm	29.68 MPa
5500.00 mm	-7.24 kN	-0.68 kNm	-2.39 mm	-6.23 MPa
6000.00 mm	-6.10 kN	-3.78 kNm	0.56 mm	-34.71 MPa
6500.00 mm	-3.43 kN	-6.17 kNm	2.94 mm	-56.58 MPa
7000.00 mm	-0.75 kN	-7.21 kNm	4.39 mm	-66.17 MPa
7500.00 mm	1.92 kN	-6.92 kNm	4.75 mm	-63.49 MPa
8000.00 mm	4.60 kN	-5.29 kNm	4.08 mm	-48.54 MPa
8500.00 mm	7.27 kN	-2.32 kNm	2.61 mm	-21.33 MPa
9000.00 mm	9.95 kN	1.98 kNm	0.80 mm	18.16 MPa
9500.00 mm	-5.56 kN	2.89 kNm	-0.72 mm	26.54 MPa
10000.00 mm	-2.89 kN	0.78 kNm	-1.80 mm	7.16 MPa
10500.00 mm	-0.21 kN	0.00 kNm	-2.75 mm	0.04 MPa
10540.00 mm	0.00 kN	0.00 kNm	-2.83 mm	0.00 MPa

Results at Supports and Loads

Position	Shear Force	Moment	Displacement	Bending Stress
1300.00 mm	-6.42 kN 11.14 kN	-4.17 kNm	0.00 mm	-38.29 MPa
5900.00 mm	-5.10 kN -6.64 kN	-3.15 kNm	0.00 mm	-28.87 MPa
9240.00 mm	11.23 kN -6.95 kN	4.52 kNm	0.00 mm	41.47 MPa

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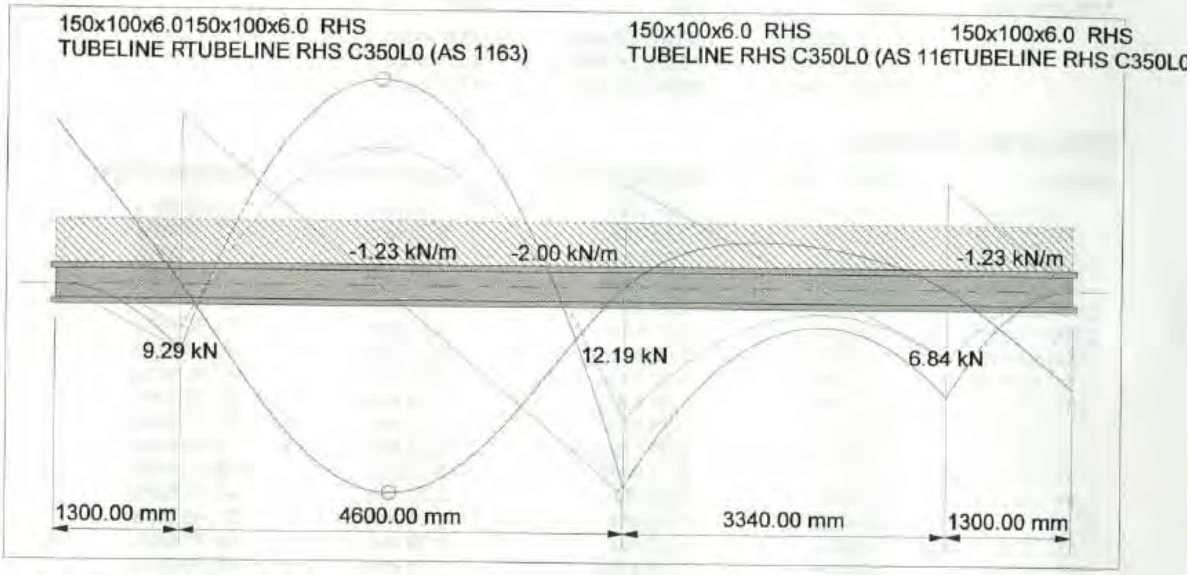
STEELbeam Report

Friday, 17 April 2009 08:30:38

Project Name: Load Case D
Project ID: IAP Rafter
Client Name:
Client ID:

Author: Jordan Cocks
Company: Gold Coast City Council



Total beam length 10540.00 mm
Number of segments: 4

Gravity -9.81 m/s^2

Segment 1 (Constant):

Segment length	1300.00 mm
Mass per length	21.43 kg/m
Moment of inertia (Ixx)	8.17 x 10^6mm^4
Section area	2730.00 mm^2

Young's modulus 200000.00 MPa

Segment 2 (Constant):

Segment length	4600.00 mm
Mass per length	21.43 kg/m
Moment of inertia (Ixx)	8.17 x 10^6mm^4
Section area	2730.00 mm^2

Young's modulus 200000.00 MPa

Segment 3 (Constant):

Segment length	3340.00 mm
Mass per length	21.43 kg/m
Moment of inertia (Ixx)	8.17 x 10^6mm^4
Section area	2730.00 mm^2

Young's modulus 200000.00 MPa

Segment 4 (Constant):

Segment length	1300.00 mm
Mass per length	21.43 kg/m
Moment of inertia (Ixx)	8.17 x 10^6mm^4
Section area	2730.00 mm^2

Young's modulus 200000.00 MPa

Maximum Values

	Position	Value
Maximum shear force	5900.00 mm	-8.15 kN
Maximum bending moment	3373.35 mm	5.24 kNm
Maximum displacement	3475.97 mm	-6.07 mm
Maximum bending stress	3373.35 mm	48.09 MPa

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STEELbeam Report

Friday, 17 April 2009 08:30:38

Supports and Loads

Support	Position	Type
1	1300.00 mm	Pinned
2	5900.00 mm	Pinned
3	9240.00 mm	Pinned

Uniform Load	Start	End	Load
1	0.00 mm	10540.00 mm	-2.00 kN/m
2	1300.00 mm	5900.00 mm	-1.23 kN/m
3	9240.00 mm	10540.00 mm	-1.23 kN/m

Results across Beam

Position	Shear Force	Bending Moment	Displacement	Bending Stress
0.00 mm	0.00 kN	0.00 kNm	4.83 mm	0.00 MPa
500.00 mm	-1.00 kN	-0.25 kNm	3.02 mm	-2.29 MPa
1000.00 mm	-2.00 kN	-1.00 kNm	1.17 mm	-9.17 MPa
1500.00 mm	6.04 kN	-0.42 kNm	-0.82 mm	-3.83 MPa
2000.00 mm	4.43 kN	2.20 kNm	-2.87 mm	20.19 MPa
2500.00 mm	2.82 kN	4.01 kNm	-4.59 mm	36.80 MPa
3000.00 mm	1.20 kN	5.02 kNm	-5.71 mm	46.03 MPa
3500.00 mm	-0.41 kN	5.22 kNm	-6.07 mm	47.85 MPa
4000.00 mm	-2.02 kN	4.61 kNm	-5.65 mm	42.28 MPa
4500.00 mm	-3.63 kN	3.19 kNm	-4.52 mm	29.31 MPa
5000.00 mm	-5.25 kN	0.98 kNm	-2.92 mm	8.95 MPa
5500.00 mm	-6.86 kN	-2.05 kNm	-1.18 mm	-18.82 MPa
6000.00 mm	3.84 kN	-4.66 kNm	0.23 mm	-42.74 MPa
6500.00 mm	2.84 kN	-2.99 kNm	1.01 mm	-27.43 MPa
7000.00 mm	1.84 kN	-1.82 kNm	1.32 mm	-16.71 MPa
7500.00 mm	0.84 kN	-1.15 kNm	1.35 mm	-10.58 MPa
8000.00 mm	-0.16 kN	-0.99 kNm	1.19 mm	-9.04 MPa
8500.00 mm	-1.16 kN	-1.32 kNm	0.88 mm	-12.08 MPa
9000.00 mm	-2.16 kN	-2.15 kNm	0.36 mm	-19.71 MPa
9500.00 mm	3.35 kN	-1.74 kNm	-0.49 mm	-16.00 MPa
10000.00 mm	1.74 kN	-0.47 kNm	-1.60 mm	-4.31 MPa
10500.00 mm	0.13 kN	0.00 kNm	-2.79 mm	-0.02 MPa
10540.00 mm	0.00 kN	0.00 kNm	-2.89 mm	0.00 MPa

Results at Supports and Loads

Position	Shear Force	Moment	Displacement	Bending Stress
1300.00 mm	-2.60 kN 6.69 kN	-1.69 kNm	0.00 mm	-15.50 MPa
5900.00 mm	-8.15 kN 4.04 kN	-5.05 kNm	0.00 mm	-46.35 MPa
9240.00 mm	-2.64 kN 4.19 kN	-2.73 kNm	0.00 mm	-25.00 MPa

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Values used for the Stainless Steel Conversion

Variable	Material	Value		Reference
E	mild steel	200	GPa	
E	316L	190	GPa	Table 3.9 Design Manual for Structural Stainless Steel
f_y	316L	190	MPa	Table 3.1 Design Manual for Structural Stainless Steel
Φf_y	316L	152	MPa	Allowable Stress with a factor of 0.8
f_1	316L	154.39	MPa	STEELbeam Report for 150 x 100 x 5 RHS
f_1/f_y	316L	Failed		
E_s	316L	Failed	GPa	Table A.1 Design Manual for Structural Stainless Steel
Deflection	316L	Failed	mm	STEELbeam Report for 150 x 100 x 5 RHS
f_2	316L	101.11	MPa	STEELbeam Report for 200 x 100 x 5 RHS
f_2/f_y	316L	0.53		
E_s	316L	182	GPa	Table A.1 Design Manual for Structural Stainless Steel
Deflection	316L	10.68mm	mm	STEELbeam Report for 200 x 100 x 5 RHS

key:

E = Young's Modulus

f_y = 0.2% Proof Stress of 316L Stainless Steel

f_1 = Maximum stress developed in 150 x 100 x 6 RHS beam

f_2 = Maximum stress developed in 200 x 100 x 5 RHS beam

f_1/f_y = Stress Ratio required to determine the secant modulus

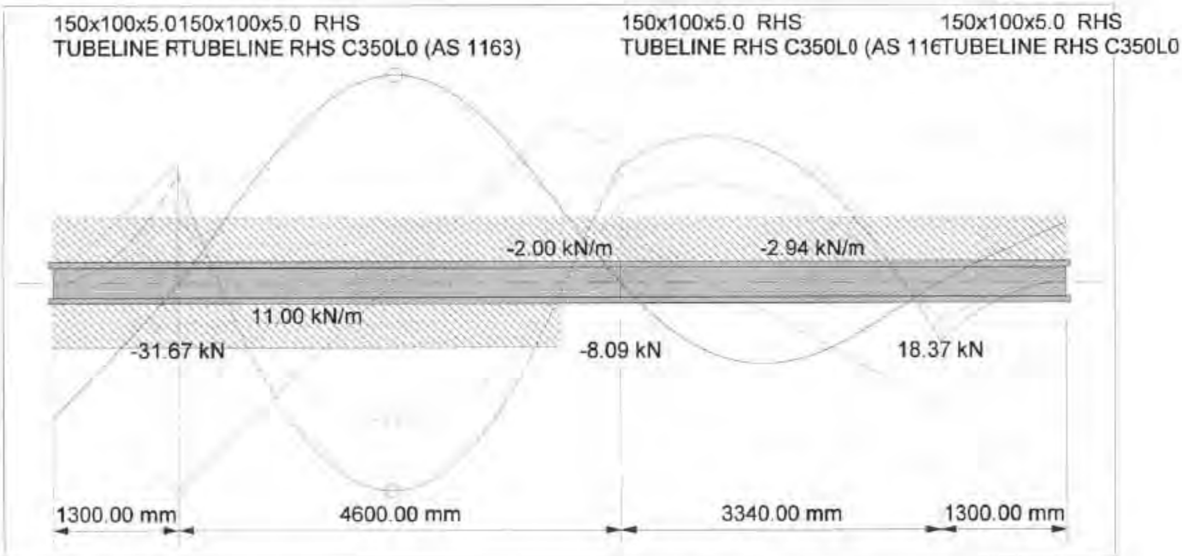
E_s = Secant Modulus for 316L Stainless Steel at corresponding stress ratios

STEELbeam Report

Thursday, 23 April 2009 11:23:25

Project Name: Load Case C with Serviciability Wind Load 1 Stainless Steel
Project ID: IAP Rafter
Client Name:
Client ID:

Author: Jordan Cocks
Company: Gold Coast City Council



Total beam length 10540.00 mm
Number of segments: 4

Gravity -9.81 m/s^2

Segment 1 (Constant):

Segment length	1300.00 mm	Young's modulus 190000.00 MPa
Mass per length	18.13 kg/m	
Moment of inertia (Ixx)	7.07 x 10^6mm^4	
Section area	2310.00 mm^2	

Segment 2 (Constant):

Segment length	4600.00 mm	Young's modulus 190000.00 MPa
Mass per length	18.13 kg/m	
Moment of inertia (Ixx)	7.07 x 10^6mm^4	
Section area	2310.00 mm^2	

Segment 3 (Constant):

Segment length	3340.00 mm	Young's modulus 190000.00 MPa
Mass per length	18.13 kg/m	
Moment of inertia (Ixx)	7.07 x 10^6mm^4	
Section area	2310.00 mm^2	

Segment 4 (Constant):

Segment length	1300.00 mm	Young's modulus 190000.00 MPa
Mass per length	18.13 kg/m	
Moment of inertia (Ixx)	7.07 x 10^6mm^4	
Section area	2310.00 mm^2	

Maximum Values

	Position	Value
Maximum shear force	1300.00 mm	-19.97 kN
Maximum bending moment	3519.34 mm	-14.56 kNm
Maximum displacement	3557.36 mm	20.84 mm
Maximum bending stress	3519.34 mm	-154.39 MPa

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STEELbeam Report

Thursday, 23 April 2009 11:23:25

Supports and Loads

Support	Position	Type
1	1300.00 mm	Pinned
2	5900.00 mm	Pinned
3	9240.00 mm	Pinned

Uniform Load	Start	End	Load
1	0.00 mm	10540.00 mm	-2.00 kN/m
2	0.00 mm	5270.00 mm	11.00 kN/m
3	5270.00 mm	10540.00 mm	-2.94 kN/m

Results across Beam

Position	Shear Force	Bending Moment	Displacement	Bending Stress
0.00 mm	0.00 kN	0.00 kNm	-13.55 mm	0.00 MPa
500.00 mm	4.50 kN	1.13 kNm	-8.63 mm	11.93 MPa
1000.00 mm	9.00 kN	4.50 kNm	-3.46 mm	47.72 MPa
1500.00 mm	-18.17 kN	3.79 kNm	2.55 mm	40.19 MPa
2000.00 mm	-13.67 kN	-4.17 kNm	9.19 mm	-44.24 MPa
2500.00 mm	-9.17 kN	-9.88 kNm	15.09 mm	-104.81 MPa
3000.00 mm	-4.67 kN	-13.35 kNm	19.18 mm	-141.52 MPa
3500.00 mm	-0.17 kN	-14.56 kNm	20.82 mm	-154.37 MPa
4000.00 mm	4.33 kN	-13.52 kNm	19.80 mm	-143.37 MPa
4500.00 mm	8.83 kN	-10.23 kNm	16.29 mm	-108.50 MPa
5000.00 mm	13.33 kN	-4.69 kNm	10.91 mm	-49.78 MPa
5500.00 mm	14.62 kN	2.73 kNm	4.69 mm	28.90 MPa
6000.00 mm	4.06 kN	8.61 kNm	-1.04 mm	91.28 MPa
6500.00 mm	1.59 kN	10.02 kNm	-5.26 mm	106.25 MPa
7000.00 mm	-0.88 kN	10.20 kNm	-7.62 mm	108.12 MPa
7500.00 mm	-3.35 kN	9.14 kNm	-8.11 mm	96.89 MPa
8000.00 mm	-5.82 kN	6.84 kNm	-6.92 mm	72.57 MPa
8500.00 mm	-8.29 kN	3.31 kNm	-4.47 mm	35.15 MPa
9000.00 mm	-10.76 kN	-1.45 kNm	-1.42 mm	-15.37 MPa
9500.00 mm	5.14 kN	-2.67 kNm	1.37 mm	-28.33 MPa
10000.00 mm	2.67 kN	-0.72 kNm	3.69 mm	-7.64 MPa
10500.00 mm	0.20 kN	0.00 kNm	5.85 mm	-0.04 MPa
10540.00 mm	0.00 kN	0.00 kNm	6.02 mm	0.00 MPa

Results at Supports and Loads

Position	Shear Force	Moment	Displacement	Bending Stress
1300.00 mm	11.70 kN -19.97 kN	7.61 kNm	0.00 mm	80.64 MPa
5900.00 mm	12.64 kN 4.55 kN	8.18 kNm	0.00 mm	86.72 MPa
9240.00 mm	-11.95 kN 6.42 kN	-4.17 kNm	0.00 mm	-44.26 MPa

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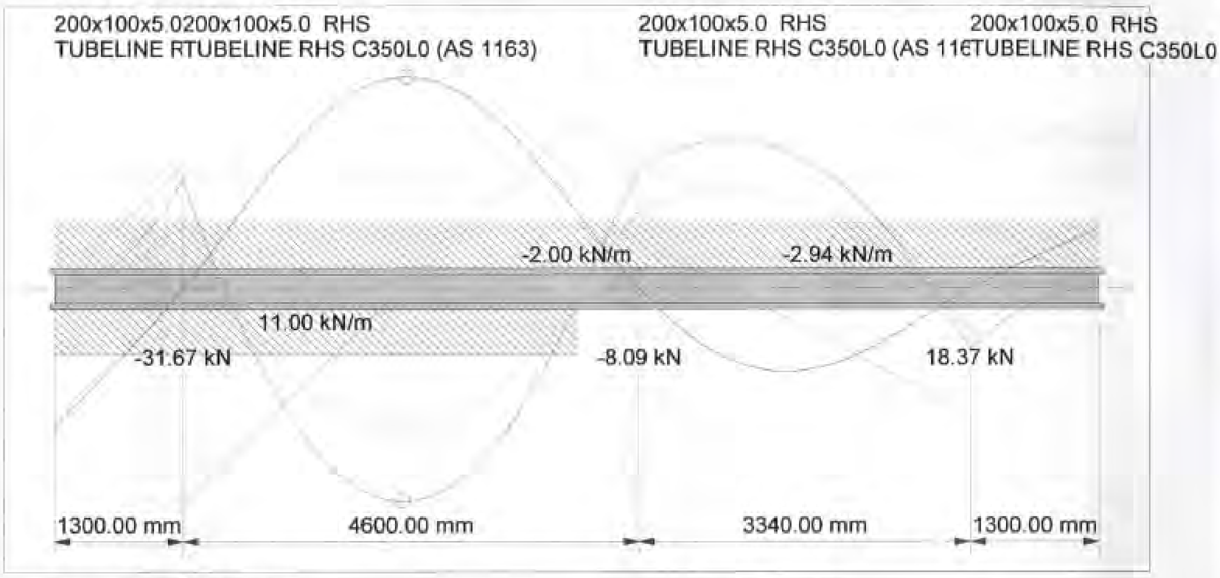
STEELbeam Report

Thursday, 28 May 2009 14:20:00

Project Name: Load Case C with Serviciability Wind Load 1 Stainless Steel Sized Up
Project ID: IAP Rafter
Client Name:
Client ID:

Author: Jordan Cocks
Company: Gold Coast City Council



Total beam length 10540.00 mm | Gravity -9.81 m/s^2
Number of segments: 4

Segment 1 (Constant):
Segment length 1300.00 mm | Young's modulus 190000.00 MPa
Mass per length 22.06 kg/m
Moment of inertia (Ixx) 14.40 x 10^6mm^4
Section area 2810.00 mm^2

Segment 2 (Constant):
Segment length 4600.00 mm | Young's modulus 190000.00 MPa
Mass per length 22.06 kg/m
Moment of inertia (Ixx) 14.40 x 10^6mm^4
Section area 2810.00 mm^2

Segment 3 (Constant):
Segment length 3340.00 mm | Young's modulus 190000.00 MPa
Mass per length 22.06 kg/m
Moment of inertia (Ixx) 14.40 x 10^6mm^4
Section area 2810.00 mm^2

Segment 4 (Constant):
Segment length 1300.00 mm | Young's modulus 190000.00 MPa
Mass per length 22.06 kg/m
Moment of inertia (Ixx) 14.40 x 10^6mm^4
Section area 2810.00 mm^2

Maximum Values

	Position	Value
Maximum shear force	1300.00 mm	-19.97 kN
Maximum bending moment	3519.34 mm	-14.56 kNm
Maximum displacement	3557.36 mm	10.23 mm
Maximum bending stress	3519.34 mm	-101.11 MPa

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STEELbeam Report

Thursday, 28 May 2009 14:20:00

Supports and Loads

Support	Position	Type
1	1300.00 mm	Pinned
2	5900.00 mm	Pinned
3	9240.00 mm	Pinned

Uniform Load	Start	End	Load
1	0.00 mm	10540.00 mm	-2.00 kN/m
2	0.00 mm	5270.00 mm	11.00 kN/m
3	5270.00 mm	10540.00 mm	-2.94 kN/m

Results across Beam

Position	Shear Force	Bending Moment	Displacement	Bending Stress
0.00 mm	0.00 kN	0.00 kNm	-6.65 mm	0.00 MPa
500.00 mm	4.50 kN	1.13 kNm	-4.23 mm	7.81 MPa
1000.00 mm	9.00 kN	4.50 kNm	-1.70 mm	31.25 MPa
1500.00 mm	-18.17 kN	3.79 kNm	1.25 mm	26.32 MPa
2000.00 mm	-13.67 kN	-4.17 kNm	4.51 mm	-28.97 MPa
2500.00 mm	-9.17 kN	-9.88 kNm	7.41 mm	-68.64 MPa
3000.00 mm	-4.67 kN	-13.35 kNm	9.42 mm	-92.68 MPa
3500.00 mm	-0.17 kN	-14.56 kNm	10.22 mm	-101.10 MPa
4000.00 mm	4.33 kN	-13.52 kNm	9.72 mm	-93.89 MPa
4500.00 mm	8.83 kN	-10.23 kNm	8.00 mm	-71.06 MPa
5000.00 mm	13.33 kN	-4.69 kNm	5.35 mm	-32.60 MPa
5500.00 mm	14.62 kN	2.73 kNm	2.30 mm	18.92 MPa
6000.00 mm	4.06 kN	8.61 kNm	-0.51 mm	59.78 MPa
6500.00 mm	1.59 kN	10.02 kNm	-2.58 mm	69.58 MPa
7000.00 mm	-0.88 kN	10.20 kNm	-3.74 mm	70.80 MPa
7500.00 mm	-3.35 kN	9.14 kNm	-3.98 mm	63.45 MPa
8000.00 mm	-5.82 kN	6.84 kNm	-3.40 mm	47.52 MPa
8500.00 mm	-8.29 kN	3.31 kNm	-2.19 mm	23.02 MPa
9000.00 mm	-10.76 kN	-1.45 kNm	-0.70 mm	-10.06 MPa
9500.00 mm	5.14 kN	-2.67 kNm	0.67 mm	-18.55 MPa
10000.00 mm	2.67 kN	-0.72 kNm	1.81 mm	-5.00 MPa
10500.00 mm	0.20 kN	0.00 kNm	2.87 mm	-0.03 MPa
10540.00 mm	0.00 kN	0.00 kNm	2.95 mm	0.00 MPa

Results at Supports and Loads

Position	Shear Force	Moment	Displacement	Bending Stress
1300.00 mm	11.70 kN -19.97 kN	7.61 kNm	0.00 mm	52.81 MPa
5900.00 mm	12.64 kN 4.55 kN	8.18 kNm	0.00 mm	56.79 MPa
9240.00 mm	-11.95 kN 6.42 kN	-4.17 kNm	0.00 mm	-28.99 MPa

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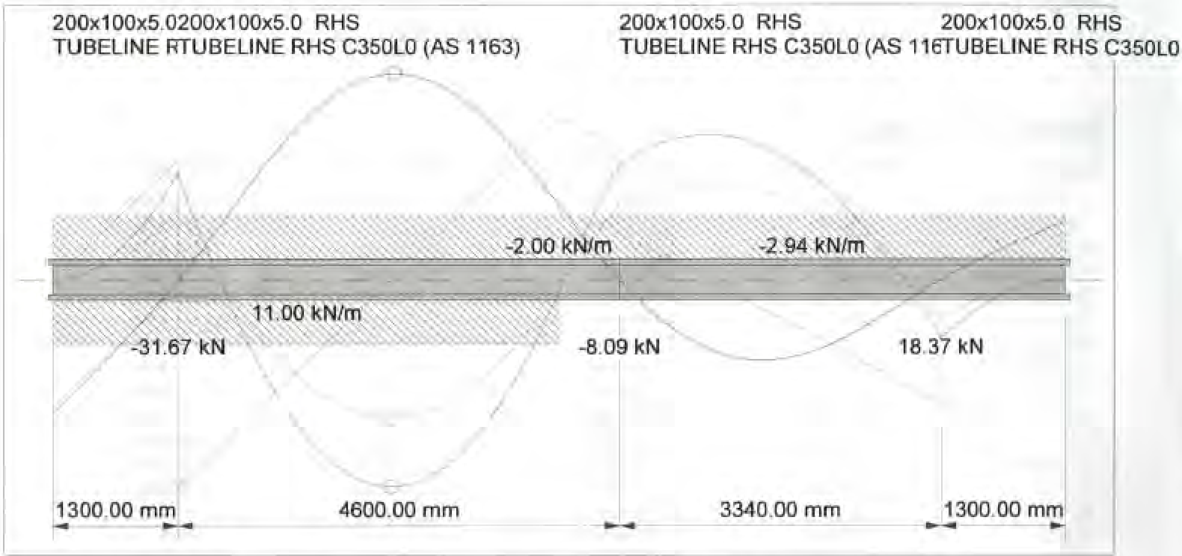
STEELbeam Report

Thursday, 28 May 2009 14:21:55

Project Name: Load Case C with Serviciability Wind Load 1 Stainless Steel Sized Up for Deflection
Project ID: IAP Rafter
Client Name:
Client ID:

Author: Jordan Cocks
Company: Gold Coast City Council



Total beam length 10540.00 mm
Number of segments: 4

Gravity -9.81 m/s^2

Segment 1 (Constant):
Segment length 1300.00 mm
Mass per length 22.06 kg/m
Moment of inertia (Ixx) 14.40 x 10^6mm^4
Section area 2810.00 mm^2
Young's modulus 182000.00 MPa

Segment 2 (Constant):
Segment length 4600.00 mm
Mass per length 22.06 kg/m
Moment of inertia (Ixx) 14.40 x 10^6mm^4
Section area 2810.00 mm^2
Young's modulus 182000.00 MPa

Segment 3 (Constant):
Segment length 3340.00 mm
Mass per length 22.06 kg/m
Moment of inertia (Ixx) 14.40 x 10^6mm^4
Section area 2810.00 mm^2
Young's modulus 182000.00 MPa

Segment 4 (Constant):
Segment length 1300.00 mm
Mass per length 22.06 kg/m
Moment of inertia (Ixx) 14.40 x 10^6mm^4
Section area 2810.00 mm^2
Young's modulus 182000.00 MPa

Maximum Values

	Position	Value
Maximum shear force	1300.00 mm	-19.97 kN
Maximum bending moment	3519.34 mm	-14.56 kNm
Maximum displacement	3557.36 mm	10.68 mm
Maximum bending stress	3519.34 mm	-101.11 MPa

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STEELbeam Report

Thursday, 28 May 2009 14:21:55

Supports and Loads

Support	Position	Type
1	1300.00 mm	Pinned
2	5900.00 mm	Pinned
3	9240.00 mm	Pinned

Uniform Load	Start	End	Load
1	0.00 mm	10540.00 mm	-2.00 kN/m
2	0.00 mm	5270.00 mm	11.00 kN/m
3	5270.00 mm	10540.00 mm	-2.94 kN/m

Results across Beam

Position	Shear Force	Bending Moment	Displacement	Bending Stress
0.00 mm	0.00 kN	0.00 kNm	-6.94 mm	0.00 MPa
500.00 mm	4.50 kN	1.13 kNm	-4.42 mm	7.81 MPa
1000.00 mm	9.00 kN	4.50 kNm	-1.77 mm	31.25 MPa
1500.00 mm	-18.17 kN	3.79 kNm	1.30 mm	26.32 MPa
2000.00 mm	-13.67 kN	-4.17 kNm	4.71 mm	-28.97 MPa
2500.00 mm	-9.17 kN	-9.88 kNm	7.73 mm	-68.64 MPa
3000.00 mm	-4.67 kN	-13.35 kNm	9.83 mm	-92.68 MPa
3500.00 mm	-0.17 kN	-14.56 kNm	10.67 mm	-101.10 MPa
4000.00 mm	4.33 kN	-13.52 kNm	10.15 mm	-93.89 MPa
4500.00 mm	8.83 kN	-10.23 kNm	8.35 mm	-71.06 MPa
5000.00 mm	13.33 kN	-4.69 kNm	5.59 mm	-32.60 MPa
5500.00 mm	14.62 kN	2.73 kNm	2.40 mm	18.92 MPa
6000.00 mm	4.06 kN	8.61 kNm	-0.54 mm	59.78 MPa
6500.00 mm	1.59 kN	10.02 kNm	-2.69 mm	69.58 MPa
7000.00 mm	-0.88 kN	10.20 kNm	-3.91 mm	70.80 MPa
7500.00 mm	-3.35 kN	9.14 kNm	-4.16 mm	63.45 MPa
8000.00 mm	-5.82 kN	6.84 kNm	-3.55 mm	47.52 MPa
8500.00 mm	-8.29 kN	3.31 kNm	-2.29 mm	23.02 MPa
9000.00 mm	-10.76 kN	-1.45 kNm	-0.73 mm	-10.06 MPa
9500.00 mm	5.14 kN	-2.67 kNm	0.70 mm	-18.55 MPa
10000.00 mm	2.67 kN	-0.72 kNm	1.89 mm	-5.00 MPa
10500.00 mm	0.20 kN	0.00 kNm	3.00 mm	-0.03 MPa
10540.00 mm	0.00 kN	0.00 kNm	3.08 mm	0.00 MPa

Results at Supports and Loads

Position	Shear Force	Moment	Displacement	Bending Stress
1300.00 mm	11.70 kN -19.97 kN	7.61 kNm	0.00 mm	52.81 MPa
5900.00 mm	12.64 kN 4.55 kN	8.18 kNm	0.00 mm	56.79 MPa
9240.00 mm	-11.95 kN 6.42 kN	-4.17 kNm	0.00 mm	-28.99 MPa

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APPENDIX F – GALVANIZING QUOTE

INDUSTRIAL GALVANIZERS (BRIS.)

You're better off with...

A division of Industrial Galvanizers Corporation Pty. Ltd. ACN 000 545 415 ABN 40 000 545 415 010

Cnr. Boundary & Cobalt Streets, Carole Park. Queensland

Cnr Holt St & Curtin Ave,
Pinkenba, Queensland

Telephone: (07) 3632 7700 Facsimile: (07) 3632 7797

Telephone: (07) 3632 7700
Facsimile: (07) 3632 7797

Receiving/Despatch Office Facsimile: (07) 3718 2598

Receiving/Despatch Office
Facsimile: (07) 3632 7795

P O Box 1131

P O Box 1131

Eagle Farm Qld 4009

Eagle Farm Qld 4009

QUOTATION NO. SQBN-009279 **QUOTED ON CAROLE PARK PLANT**

5/05/2009

To: Cash Carole Park Fax No: jcocks@ goldcoast.qld.gov.au

Attention: **John Cocks**

Industrial Galvanizers (Brisbane) thank you for the opportunity to quote and wish to confirm the details of our **Quote No** SQBN-009279**.** This quote is based upon Industrial Galvanizers (Brisbane) being your sole supplier of galvanizing services for the quantities of work mix shown below. If the actual work varies significantly from that which has been described, Industrial Galvanizers (Brisbane) reserve the right to charge normal galvanizing rates for that work.

PLEASE ENSURE THE ABOVE QUOTE NUMBER APPEARS ON RELEVANT PAPERWORK ACCOMPANYING GOODS. **SHOULD A CREDIT REQUEST BE SENT AS A CONSEQUENCE OF FAILURE TO INDICATE QUOTATION NUMBERS ON YOUR PAPERWORK WITH GOODS, A $40.00 + GST PROCESSING CHARGE WILL APPLY.**

Project: Project Exercise - Foreshore Toilet.

Quantities: 2.247 Tonnes

Work Description: 5 Off 150x100x6RHS 4.9M to 10.6M,20 Off 75x6SHS 2.7M to 3.5M and 4 Off 75x4SHS @ 4.8M.

THIS IS NOT A REAL QUOTE!

Special Requirements:

Pricing: **SINGLE DIP** **$1,131/Tonne**

Venting & Draining: Our quotation is conditional to suitable venting & draining design to suit the galvanizing process. If necessary, please contact our sales/marketing department for advice before fabrication should our quote be acceptable.

Freight Description: Freight...is not included in this quote

Validity: This quote is valid to 03 August, 2008.

Extra Charges: An additional charge of $472/Tonne will apply if the removal of any previous galvanizing or Zinc coatings is required. If Galstick is specified for reinstatement an additional charge will apply. Any double dip items will incur an additional charge.

Silver Bullet Priority Services must be approved by our Production Staff prior to placement of order and will be charged out at an additional extra cost.

Turn–around: The turn-around time for galvanizing is approximately 5 working days. Please advise Industrial Galvanizers (Brisbane) prior to delivering steelwork.

Standard: Industrial Galvanizers (Brisbane) is Q.A. accredited to ISO9001-2000. All galvanizing and dressing will be in accordance with AS/NZS 4680:2006. Any renovation of uncoated areas will be treated with a Zinc rich paint unless otherwise agreed to.

Specific additions: Special requirements such as surface finish, packing, storage, re-packaging, etc, have not been allowed for in this quotation (unless specifically stated in writing) and may incur an additional charge should the need arise.

Bath Capacity Size: Carole Park: 12.2 metres long, 2.4 metres deep, 1.8 metres wide.
Pinkenba: 10.2 metres long, 2.4 metres deep, 1.7 metres wide.
Consult our sales/marketing department on clarification of individual items.

Crane Capacity Limit: Carole Park: 6.0 Tonne
Pinkenba: 6.0 Tonne
Occupational Health & Safety regulations are a priority Industrial Galvanizers (Brisbane) policy and any heavier fabrications will be a matter for consultation with Operations Managers before consideration to process work occurs.

Design: All steelwork must be correctly fabricated for galvanizing. Please contact Industrial Galvanizers (Brisbane) if design or venting information is required. The fabricator, prior to delivery to Industrial Galvanizers (Brisbane) must sandblast steelwork with other than standard surface conditions that cannot be cleaned using our normal pre-treatment processes.

Storage: Quotation is conditional to work being despatched/collected within 5 working days of notice on completion. Industrial Galvanizers (Brisbane) reserves the

right to charge an additional storage fee of $200.00 per working day for any goods that remain on site after that period.

Terms:	Please note that unless otherwise stated in writing, Industrial Galvanizers Corporation Pty Ltd Standard terms and Conditions of Sale apply. If a credit account has not previously been applied for and granted, all goods must be paid for at the time of collection. All prices are charged on the galvanized weight. Ingal HSQ and Ingal Plus additional terms: this quotation is conditional to all criteria of Industrial Galvanizer's Ingal HSQ and Ingal Plus specification being strictly adhered to, by all parties involved.
GST Conditions:	ALL rates/prices included in this quotation are subject to GST in accordance with GST Act of 1999.
Other Information:	Our receiving hours are from 7:00am to 4:30pm Monday to Friday. Your order number and the quote number shown above must be clearly marked on the paperwork accompanying your steelwork.

For and on behalf of
INDUSTRIAL GALVANIZERS (BRISBANE)

Martin Powell
Sales Manager

APPENDIX G – STAINLESS STEEL QUOTES

Bridgeman Agencies Pty Ltd t/as

Bridgeman Stainless Solutions

QBSA: 1071891

ABN: 29077601962

Gold Coast City Council

11th June 2009

Attention: Jordon Cocks

QUOTATION: LW9813

We have pleasure in submitting our quotation for the manufacture and supply of the following items for the **Roughton Park, Coolangatta Toilet Block.**

The materials requested are available but only in 304 grade stainless. However, you can purchase 80 x 80 x 3 316 RHS as an option.

3 x Type 1 Rafters
2 x Type 2 Rafters

5 x 2.83m Columns
5 x 3.13m Columns
3 x 3.39m Columns
3 x 3.55m Columns
2 x 2.86m Columns
2 x 2.66m Columns

4 x Strut Beams

Total Cost Ex Works $23,875.00 + Gst

As requested we have provided a quote based on labour only to manufacture items from material supplied.

Total Cost $6,250.00 + Gst

We thank you for the opportunity to quote on the above work.

Regards,

Len Webb
Director

Terms: **Orders are subject to our standard trading terms provided a current account is held with Bridgeman Stainless Solutions. All other orders are strictly COD with a 30% deposit payable prior to work commencing. Any payment by credit card will incur a 1.5% bank charge.**
Delivery: **TBA**
Freight: **TBA**
Validity: **This quote is valid for 30 days from the above date**

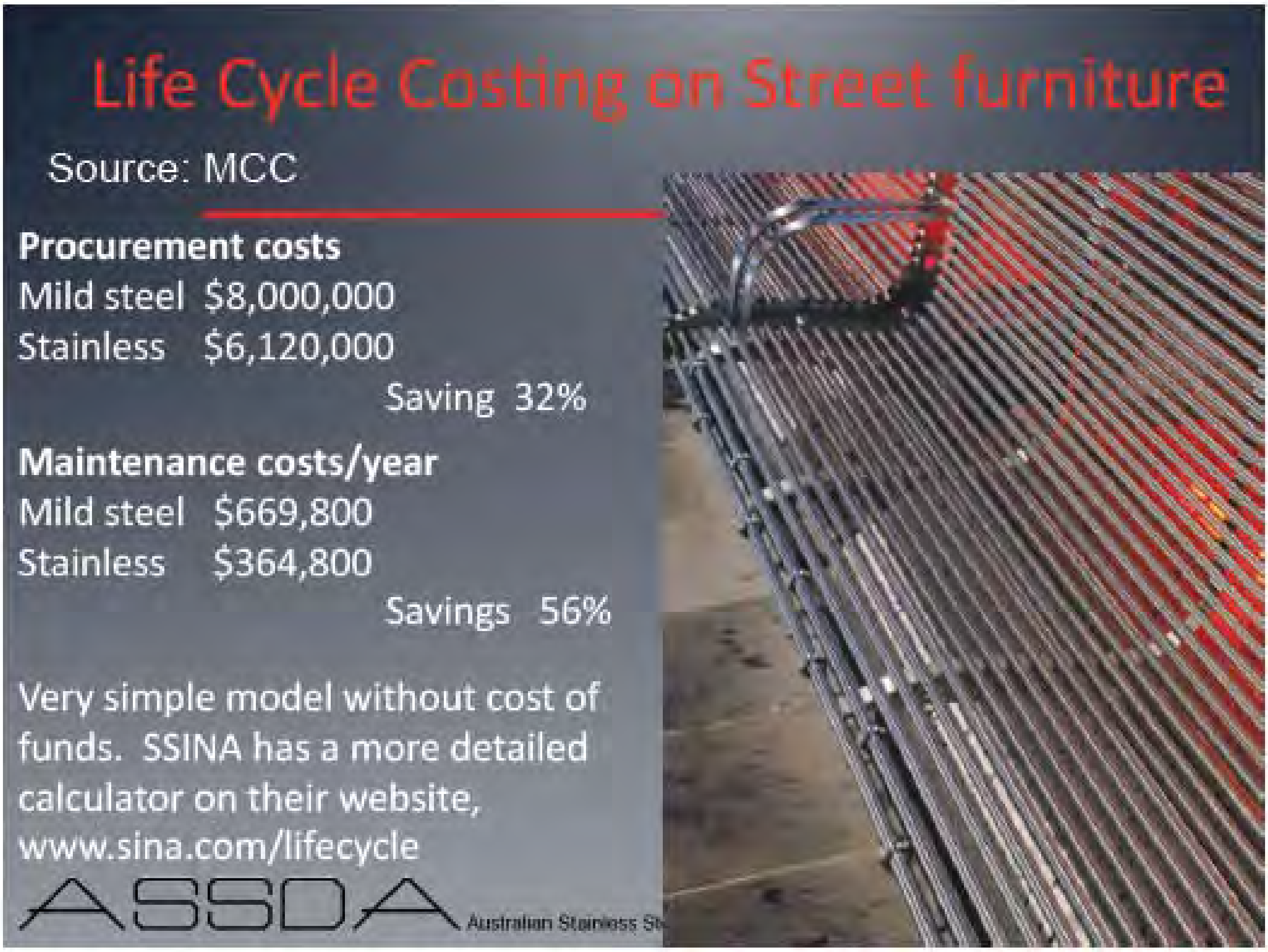
ASSDA ACCREDITED

1/15 Combarton Street
PO Box 5620
Brendale Qld 4500
Phone: 07 3205 9466
Fax: 07 3205 9477
www.bridgeman.com.au
sales@bridgeman.com.au

APPENDIX H – LCC CASE STUDY

This LCC case study is supplied by ASSDA and the Melbourne City Council

Note: There is a mistake in the procurement costs. Mild Steel should be $6,120,000 and Stainless should be $8,000,000. This was clarified by Richard Matheson at the ASSDA Seminar “Stainless Steel in the Built Environment” held on the 29th May 2009 in Brisbane.



APPENDIX I – LCC BREAKDOWN

Table I1 – LCC of Galvanized Structure

	Supply of Materials	Fabrication	Coating	Maintenance	Salvage	Annual Totals	
						Lower Bound	Upper Bound
Year 1	9,672.66	4,920.00	2,215.80	150.08		$16,958.54	$16,958.54
Year 2				141.14		$17,099.68	$17,118.14
Year 3				132.72		$17,232.40	$17,277.74
Year 4				124.81		$17,357.21	$17,437.34
Year 5				117.37		$17,474.58	$17,596.94
Year 6				110.37		$17,584.95	$17,756.54
Year 7				103.79		$17,688.74	$17,916.14
Year 8				97.60		$17,786.34	$18,075.74
Year 9				91.78		$17,878.12	$18,235.34
Year 10				86.31		$17,964.43	$18,394.94
Year 11				704.04		$18,668.48	$18,554.54
Year 12				76.33		$18,744.80	$18,714.14
Year 13				71.78		$18,816.58	$18,873.74
Year 14				67.50		$18,884.07	$19,033.34
Year 15				63.47		$18,947.55	$19,192.94
Year 16				517.74		$19,465.29	$36,151.48
Year 17				56.13		$19,521.42	$36,311.08
Year 18				52.78		$19,574.20	$36,470.68
Year 19				49.64		$19,623.84	$36,630.28
Year 20				46.68		$19,670.51	$36,789.88
Year 21				391.99		$20,062.51	$36,949.48
Year 22				41.28		$20,103.78	$37,109.08
Year 23				38.82		$20,142.60	$37,268.68
Year 24				36.50		$20,179.10	$37,428.28
Year 25				34.33		$20,213.43	$37,587.88
Year 26				296.95		$20,510.38	$37,747.48
Year 27				30.35		$20,540.73	$37,907.08
Year 28				28.54		$20,569.28	$38,066.68
Year 29				26.84		$20,596.12	$38,226.28
Year 30				25.24		$20,621.36	$38,385.88
Year 31				225.08		$20,846.44	$38,545.48
Year 32				22.32		$20,868.77	$55,504.02
Year 33				20.99		$20,889.76	$55,663.62
Year 34				19.74		$20,909.50	$55,823.22
Year 35				18.56		$20,928.06	$55,982.82
Year 36				170.70		$21,098.76	$56,142.42
Year 37				16.42		$21,115.18	$56,302.02
Year 38				15.44		$21,130.61	$56,461.62
Year 39				14.52		$21,145.13	$56,621.22
Year 40				13.65		$21,158.78	$56,780.82
Year 41				129.53		$21,288.31	$56,940.42
Year 42				12.07		$21,300.38	$57,100.02
Year 43				11.35		$21,311.74	$57,259.62
Year 44				10.68		$21,322.41	$57,419.22
Year 45				10.04		$21,332.45	$57,578.82
Year 46				98.34		$21,430.79	$57,738.42
Year 47				8.88		$21,439.67	$57,898.02
Year 48				8.35		$21,448.02	$58,057.62
Year 49				7.85		$21,455.87	$58,217.22
Year 50				7.38	196	$21,267.25	$58,180.82
Totals	**$9,672.66**	**$4,920.00**	**$2,215.80**	**$4,654.79**	**$196.00**		

Table I2 – LCC of Painted Structure

						Annual Totals	
	Supply of Materials	Fabrication	Coating	Maintenance	Salvage	Lower Bound	Upper Bound
Year 1	9672.66	4920.00	2040.51	150.08		$16,783.26	$16,783.26
Year 2				141.14		$16,924.39	$16,942.86
Year 3				132.72		$17,057.11	$17,102.46
Year 4				124.81		$17,181.92	$17,262.06
Year 5				117.37		$17,299.29	$17,421.66
Year 6				110.37		$17,409.66	$17,581.26
Year 7				103.79		$17,513.45	$17,740.86
Year 8				97.60		$17,611.05	$17,900.46
Year 9				91.78		$17,702.84	$18,060.06
Year 10				684.83		$18,387.67	$18,219.66
Year 11				81.17		$18,468.83	$35,002.91
Year 12				605.61		$19,074.44	$35,162.51
Year 13				71.78		$19,146.22	$35,322.11
Year 14				542.51		$19,688.72	$35,481.71
Year 15				63.47		$19,752.19	$35,641.31
Year 16				486.02		$20,238.22	$35,800.91
Year 17				56.13		$20,294.35	$35,960.51
Year 18				435.46		$20,729.80	$36,120.11
Year 19				49.64		$20,779.44	$36,279.71
Year 20				390.19		$21,169.63	$36,439.31
Year 21				43.89		$21,213.52	$36,598.91
Year 22				349.66		$21,563.18	$36,758.51
Year 23				38.82		$21,601.99	$53,541.77
Year 24				313.36		$21,915.35	$53,701.37
Year 25				34.33		$21,949.68	$53,860.97
Year 26				280.86		$22,230.54	$54,020.57
Year 27				30.35		$22,260.89	$54,180.17
Year 28				251.75		$22,512.64	$54,339.77
Year 29				26.84		$22,539.48	$54,499.37
Year 30				225.67		$22,765.15	$54,658.97
Year 31				23.74		$22,788.89	$54,818.57
Year 32				202.32		$22,991.21	$54,978.17
Year 33				20.99		$23,012.20	$55,137.77
Year 34				181.39		$23,193.59	$55,297.37
Year 35				18.56		$23,212.15	$72,080.62
Year 36				162.65		$23,374.80	$72,240.22
Year 37				16.42		$23,391.22	$72,399.82
Year 38				145.85		$23,537.06	$72,559.42
Year 39				14.52		$23,551.58	$72,719.02
Year 40				130.80		$23,682.38	$72,878.62
Year 41				12.84		$23,695.21	$73,038.22
Year 42				117.31		$23,812.52	$73,197.82
Year 43				11.35		$23,823.87	$73,357.42
Year 44				105.22		$23,929.09	$73,517.02
Year 45				10.04		$23,939.13	$73,676.62
Year 46				94.38		$24,033.51	$73,836.22
Year 47				8.88		$24,042.39	$90,619.48
Year 48				84.67		$24,127.06	$90,779.08
Year 49				7.85		$24,134.91	$90,938.68
Year 50				75.96	196	$24,014.87	$91,098.28
Totals	**$9,672.66**	**$4,920.00**	**$2,040.51**	**$7,577.70**	**$196.00**		

Table I3 – LCC of Duplex Structure

						Annual Totals	
	Supply of Materials	**Fabrication**	**Coating**	**Maintenance**	**Salvage**	**Lower Bound**	**Upper Bound**
Year 1	9,672.66	4,920.00	4,263.30	150.08		$19,006.04	$19,006.04
Year 2				141.14		$19,147.18	$19,165.64
Year 3				132.72		$19,279.90	$19,325.24
Year 4				124.81		$19,404.71	$19,484.84
Year 5				117.37		$19,522.08	$19,644.44
Year 6				110.37		$19,632.45	$19,804.04
Year 7				103.79		$19,736.24	$19,963.64
Year 8				97.60		$19,833.84	$20,123.24
Year 9				91.78		$19,925.63	$20,282.84
Year 10				684.83		$20,610.46	$20,442.44
Year 11				81.17		$20,691.62	$20,602.04
Year 12				605.61		$21,297.23	$20,761.64
Year 13				71.78		$21,369.01	$20,921.24
Year 14				542.51		$21,911.51	$21,080.84
Year 15				63.47		$21,974.98	$21,240.44
Year 16				486.02		$22,461.00	$21,400.04
Year 17				56.13		$22,517.13	$21,559.64
Year 18				435.46		$22,952.59	$21,719.24
Year 19				49.64		$23,002.23	$21,878.84
Year 20				390.19		$23,392.42	$22,038.44
Year 21				43.89		$23,436.31	$22,198.04
Year 22				349.66		$23,785.97	$22,357.64
Year 23				38.82		$23,824.78	$22,517.24
Year 24				313.36		$24,138.14	$41,523.29
Year 25				34.33		$24,172.47	$41,682.89
Year 26				280.86		$24,453.33	$41,842.49
Year 27				30.35		$24,483.68	$42,002.09
Year 28				251.75		$24,735.43	$42,161.69
Year 29				26.84		$24,762.27	$42,321.29
Year 30				225.67		$24,987.94	$42,480.89
Year 31				23.74		$25,011.68	$42,640.49
Year 32				202.32		$25,214.00	$42,800.09
Year 33				20.99		$25,234.99	$42,959.69
Year 34				181.39		$25,416.38	$43,119.29
Year 35				18.56		$25,434.94	$43,278.89
Year 36				162.65		$25,597.59	$43,438.49
Year 37				16.42		$25,614.00	$43,598.09
Year 38				145.85		$25,759.85	$43,757.69
Year 39				14.52		$25,774.37	$43,917.29
Year 40				130.80		$25,905.16	$44,076.89
Year 41				12.84		$25,918.00	$44,236.49
Year 42				117.31		$26,035.31	$44,396.09
Year 43				11.35		$26,046.66	$44,555.69
Year 44				105.22		$26,151.88	$44,715.29
Year 45				10.04		$26,161.92	$44,874.89
Year 46				94.38		$26,256.30	$45,034.49
Year 47				8.88		$26,265.18	$45,194.09
Year 48				84.67		$26,349.84	$64,200.13
Year 49				7.85		$26,357.70	$64,359.73
Year 50				75.96	196	$26,237.66	$64,323.33
Totals	**$9,672.66**	**$4,920.00**	**$4,263.30**	**$7,577.70**	**$196.00**		

Table I4 – LCC of Stainless Steel Structure

	Supply of Materials	Fabrication	Coating	Maintenance	Salvage	Annual Total
1	19,964.48	6,250.00	0.00	225.13		$26,439.61
2				211.70		$26,651.31
3				199.08		$26,850.39
4				187.21		$27,037.61
5				176.05		$27,213.66
6				165.56		$27,379.22
7				155.69		$27,534.90
8				146.40		$27,681.30
9				137.67		$27,818.98
10				129.47		$27,948.45
11				121.75		$28,070.19
12				114.49		$28,184.68
13				107.66		$28,292.35
14				101.24		$28,393.59
15				95.21		$28,488.80
16				89.53		$28,578.33
17				84.19		$28,662.52
18				79.17		$28,741.70
19				74.45		$28,816.15
20				70.01		$28,886.17
21				65.84		$28,952.01
22				61.92		$29,013.92
23				58.22		$29,072.15
24				54.75		$29,126.90
25				51.49		$29,178.39
26				48.42		$29,226.81
27				45.53		$29,272.34
28				42.82		$29,315.16
29				40.26		$29,355.42
30				37.86		$29,393.28
31				35.61		$29,428.89
32				33.48		$29,462.37
33				31.49		$29,493.86
34				29.61		$29,523.47
35				27.84		$29,551.32
36				26.18		$29,577.50
37				24.62		$29,602.12
38				23.16		$29,625.28
39				21.77		$29,647.05
40				20.48		$29,667.53
41				19.26		$29,686.79
42				18.11		$29,704.89
43				17.03		$29,721.92
44				16.01		$29,737.94
45				15.06		$29,752.99
46				14.16		$29,767.15
47				13.32		$29,780.47
48				12.52		$29,792.99
49				11.78		$29,804.77
50				11.07	4400	$25,415.84
Totals	**$19,964.48**	**$6,250.00**	**$0.00**	**$3,601.36**	**$4,400.00**	

APPENDIX J – USER MANUAL

Begins Next Page

Working for our future – today

User Manual

Structural Steel Life Cycle Costing Spreadsheet

Gold Coast City Council

TABLE OF CONTENTS

1 INTRODUCTION

Determining the life cycle cost (LCC) of a structure gives an accurate value of how much the structure will cost over its complete life. The development of the Structural Steel Life Cycle Costing (SSLCC) Spreadsheet will allow the LCC to be easily calculated and organised into a standard form.

2 OVERVIEW OF THE SPREADSHEET

The spreadsheet can be used for calculating the LCC of structures constructued from mild steel with a hot dip galvanized, painted or duplex coating and stainless steel structures. Using a spreadsheet allows the data to be stored in an organised way which can be easily modified. The use of the spreadsheet will set a standard for the level of LCC requried. This will result in comparable results for different projects.

Currently the spreadsheet can only be used for estimating the cost of the steel elements of a structure.

Generally all parts that require data to be input or can be changed will be coloured light blue.

3 GETTING STARTED – NAVIGATION PAGE

Upon opening the spreadsheet the navigation page will be displayed. The navigation page allows the user to select which page to show. Clicking on a link will take the user to that particular page. An explanation of each page is supplied next to the link.

This page can be accessed by clicking on any of the '*Navigation Page*' buttons

To begin calculating the LCC of a structure one of the links titled Selecting Main Structural Elements or Select Steel Required should be selected, depending on which type of steel is being used, either mild steel or stainless steel.

4 SELECTING MAIN STRUCTURAL ELEMENTS – MILD STEEL

This page displays a set of text boxes and buttons. Text should be entered into the text boxes. When all the text boxes contain data, clicking the '*Add*' button will enter the data into the spreadsheet. Refer Figure 4.1. Only the size of the main structural members should be added. Cleats and other connection items will be added in the Fabrication stage. Refer Table 4.1 for an explanation of what should be entered into each text box.

Table 4.1 – Mild steel text box titles

Identification	The name or identifying reference that has been given to the member eg: Rafter1
Section Type	The cross section of the steel used. The available options can be chosen from the drop down menu.
Section Size	The dimension of the cross section
Length	The length of the member
No. of Parts	The number of identical members to be used.
kg/m	The mass per metre of the steel cross section used

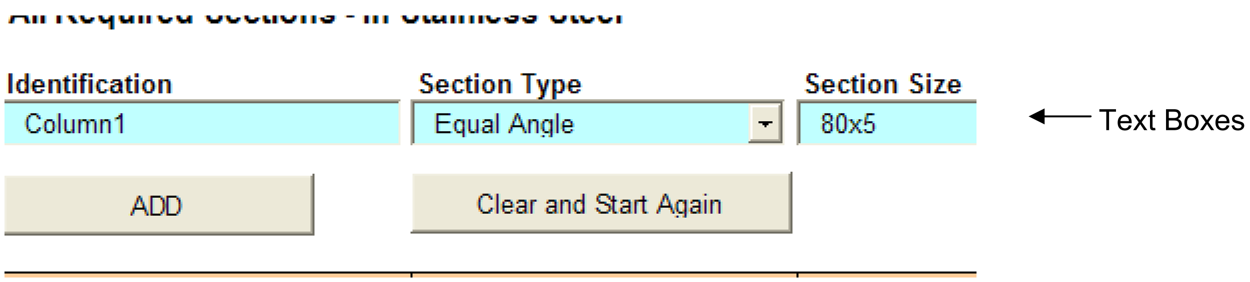


Figure 4.1 - Text Boxes

Once all member have been entered click '*Continue to Next Stage*' button.

All other values will be automatically calculated.

5 SELECTING STEEL REQUIRED – STAINLESS STEEL

This page can be accessed by clicking Select Steel Required under Stainless Steel on the Navigation Page.

This page displays a set of text boxes and buttons. Text should be entered into the text boxes and then the '*Add'* button should be clicked to enter the data. Refer Figure 4.1. In this stage all steel being used should be entered, including cleats and connection items. Refer Table 5.1 for an explanation of what should be entered into each text box.

Table 5.1 – Stainless steel text box titles

Identification	The name or identifying reference that has been given to the member eg: Rafter1
Section Type	The cross section of the steel used. The available options can be chosen from the drop down menu.
Section Size	The dimension of the cross section
Length	The length of the member
No. of Parts	The number of identical members to be used.
kg/m	The mass per metre of the steel cross section used
$/m	The price per metre of the cross section used. This can be obtained from a stainless steel manufacturer, such as Midway Metals or Atlas Specialty Metals.

Once all steel has been entered click ‘*Continue to Next Stage’* button.

6 FABRICATION – MILD STEEL

This page can be accessed by clicking Fabrication under mild steel on the Navigation Page.

This page works in the same way as the *Selecting Main Structural Elements* page. Data should be entered into the text boxes and it is then entered by clicking the ‘*Add’* button. The elements added should be parts such as cleats and other connection elements. The titles of the text boxes are basically the same as the *Selecting Main Structural Elements* page.

On this page fabrication elements such as cleats and connectors should be added. The fabrication costs are calculated using a general estimation rate.

7 FABRICATION – STAINLESS STEEL

This page can be accessed by clicking Fabrication under stainless steel on the Navigation Page.

This page calculates the fabrication costs for stainless steel as either a percentage of the supply costs for the steel or a price obtained by a quote from a stainless steel fabricator. To choose what fabrication cost is used, select the appropriate option button to the left of the tables. Refer Figure 7.1 where the option buttons are shown on the far left.

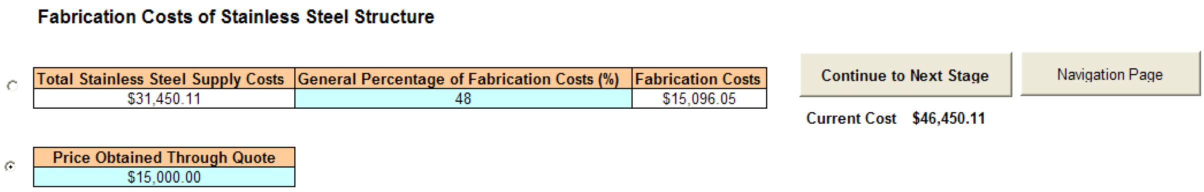


Figure 7.1 – Stainless Steel Fabrication Costs

8 SELECTION OF COATINGS

Note: This section does not apply to stainless steel

This page can be found by clicking Coatings on the Navigation Page.

Using the check boxes select which type of coating shall be applied. (For Duplex coatings select both check boxes). Refer Figure 8.1.

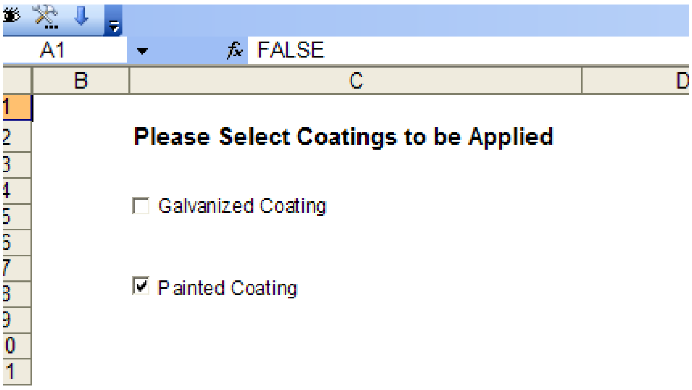


Figure 8.1 – Check Boxes for Coatings

8.1 Painted Coatings

For painted coatings the m^2/m of the members is required to be entered into the blue cells. This will calculate the area that is required to be painted. Refer Figure 8.2. If an area is not required to be painted enter the m^2/m value as 0.

Painted Coating

Identification	Section Type	Section Size	Length	No. Parts	m^2/m	m^2
Column	Channel	150x100x6	5	3	5	105
Column	Channel	150x100x6	5	3	2	15
Column	Channel	150x100x6	5	3	1	75
Column	Channel	150x100x6	5	3	2	90
Column	Channel	150x100x6	5	3	3	90
Column	Channel	150x100x6	5	3	9	135
Cleats	Square edge flat	75x8	5	3	1	15
Cleats	Square edge flat	75x8	5	3	2	30
Cleats	Square edge flat	75x8	5	3	3	45
Cleats	Square edge flat	75x8	5	3	7	105
				Total area to be Painted		510 m^2

Figure 8.2 – Table that calculates the area to be painted

To specify the paint specification to be used data can be entered into the text boxes followed by clicking the '*Add*' button. This process should be repeated for all paint layers to be applied. If a standard paint system is all that is required the '*Use Standard Paint Specification*' button can be clicked. This will display a standard paint specification and all associated data. Refer Figure 8.3.

Paint Specification

Paint Type	Specified DFT (μm)	Volume of Solids (%)	Theoretical Coverage Rate (m^2/L)	Thinner (%)	Loss Factor (%)	Practical Spreading Rate (m^2/L)	Cost ($/L)

Add | Use Standard Paint Specification | Clear

Paint Type	Specified DFT (μm)	Volume of Solids (%)	Coverage Rate (m^2/L)	Thinner (%)	Loss Factor (%)	Spreading Rate (m^2/L)	Cost ($/L)	Cost ($/$m^2$)
Polyurethane Gloss	75	52	6.93	5	50	3.30	25	7.57
High Build Epoxy	200	72	3.60	5	50	1.71	18	10.50
Zinc Rich Primer	75	53	7.07	5	50	3.37	24	7.13
						Total Cost for Paint Supply		$12,854.14

Figure 8.3 – Paint specification section

The paint labour costs and surface preparation costs are obtained from Cordell Commercial and Industrial Building Cost Guide, Queensland, February 2009. The blue cells are able to be modified. The labour costs can be changed to any desired value, the level of surface preparation can also be changed. Surface preparation levels and definitions can be found in AS1627.4:2005.

8.2 Hot Dip Galvanized Coatings

The cost for the HDG coating is calculated by using a $/t value. The weight of the structure is determined from the values entered into the '*Selecting Main Structural Elements*' and '*Fabrication*' pages. The blue cell containing the $/t value of the galvanizing can be changed to another value. The original value used was $1131/t quoted by Industrial Galvanizers on 5/5/09.

9 MAINTENANCE – MILD STEEL

This page can be reached by selecting Maintenance on the Navigation Page.

To calculate the maintenance costs select the type of coating to be applied and click the '*Calculate Maintenance Costs*' button.

Note: After clicking the '*Calculate Maintenance Costs*' button it may take a few moments for the spreadsheet to refresh the page.

For a HDG coating the m^2/m of the members will need to be entered into the blue cells. However for a painted or duplex coating these values will be copied from the coatings page. The design life of the structure can also be changed.

The maintenance is converted into a present value cost using an internal rate of return. The internal rate of return can be changed using the text box on the LCC page.

10 MAINTENANCE – STAINLESS STEEL

This page can be reached by selecting Maintenance in the stainless steel section on the Navigation Page.

For stainless steel the only maintenance requried is cleaning of the steel. For foreshore structures it is recommended that structures are cleaned 3 to 4 times a year.
To calculate the cleaning costs of the structure enter the estimated time required to clean the structure, the labour rate (Group 4 labourer, Cordell Commercial and Industrial Building Cost Guide) and the number of times to be cleaned per year. The annual cleaning cost will be auotmatically calculated.

The maintenance is converted into a present value cost using an internal rate of return. The internal rate of return can be changed using the text box on the Stainless Steel LCC page.

11 SALVAGE VALUE

This page can be reached by selecting Salvage under either Mild Steel or Stainless Steel on the Navigation Page.

In the blue cell on the left choose either Mild Steel or Stainless Steel from the drop down box. The salvage value will then be calculated at the rate shown in the other cells.

Before clicking the '*Next Page*' button ensure that the required type of steel is selected in the drop down box as this determines which LCC page will be navigated to.

12 LCC – MILD STEEL

This page can be reached by selecting LCC under Mild Steel on the Navigation Page.

Once all the other sections of the spreadsheet have been completed, clicking the '*Calculate LCC*' button on the LCC page will compile the information into a table showing the costs for each year of the structures life and the total LCC cost. There are a range of buttons on the right hand side to navigate to other areas of the spreadsheet to change variables.

The *Percentage Increase on Labour Per Maintenance Cycle* is the amount that labour is increased each maintenance cycle due to extra surface preparation and paint removal. For HDG systems the value used is 5% and for Paint and Duplex Systems the value is 2%. However these values can be changed as necessary.

The *Time to Infrastructure Failure* is the time for the Risk of Infrastructure failure to reach 100%. Refer Table 12.1 for these values.

Table 12.1 – Time to Infrastructure Failure

Galvanized Steel	16 years
Painted Steel	12 years
Duplex System	24 years

The '*Add Results to Graph*' button is explained in Section 14 of this manual.

13 LCC – STAINLESS STEEL

This page can be reached by selecting LCC under Stainless Steel on the Navigation Page.

As with the mild steel LCC page clicking the '*Calculate LCC*' button will compile all information entered into the other pages and calculate a total LCC. On the Stainless Steel LCC page the design life of the structure can be modified without navigating away from the page.

The '*Add Results to Graph*' button is explained in Section 14 of this manual.

14 LCC COMPARISON GRAPH

This page can be reached by selecting LCC Comparison Graph on the navigation page.

On the mild steel LCC page clicking the '*Copy Results to Graph*' button will bring up a message box asking what type of coating the current LCC is for. Choose the coating type from the drop down box. Then click continue.
The results from the LCC will then be added to the graph.

From the Stainless Steel LCC page the '*Add Results to Graph*' button will add the results to the graph.

The design life shown on the graph is determined by the mild steel design life.

The '*Clear Graph*' button will clear all the lines from the graph. This should be done before beginning any graphing.

The checkboxes under the graph allow the user to choose which lines will be displayed on the graph.

15 PRINTING

The LCC Page can be printed as is and the whole design life will be printed.

The graph can also be printed and only the graph will be shown on the page.

16 EDITING AUTOMATIC VALUES

Throughout the spreadsheet many values are entered by 'looking up' the values in other tables. To change the values in the lookup tables use the change data link of the navigation page.

This sheet provides all the lookup tables with the data that can be changed.

APPENDIX K – DESIGN GUIDE

Begins on the Next Page.

Working for our future – today

Corrosion Protection for Steel in Foreshore Areas

Design Guide

Gold Coast City Council

TABLE OF CONTENTS

List of Tables

List of Figures

List of Abbreviations

ASSDA	Australian Stainless Steel Development Association
DFT	Dry Film Thickness
GAA	Galvanizers Association of Australia
GCCC	Gold Coast City Council
HDG	Hot Dip Galvanized

For a list of Australian Standards and other standards used see Section 9 – References.

1 PURPOSE OF THE GUIDE

This guide is to be used by GCCC when designing and constructing steel structures within the foreshore zone. It will ensure that best practice is followed resulting in an optimised design for the structure. It is not an exhaustive reference of corrosion protection methods and should not be viewed as something that must be adhered to, but rather as guidance towards optimal corrosion protection.

2 INTRODUCTION

Corrosion in steel is not only unappealing it can ultimately threaten the structural stability of a structure. Corrosion is a parameter in using steel. It can be avoided over the design life of the structure through good design and appropriate corrosion protection.

This guide identifies the current best practice methods of design for steel structures to resist corrosion. The guide is focused on corrosion protection for:

- Hot Dip Galvanizing
- Paint Systems
- Duplex Systems
- Stainless Steel

3 GENERAL CORROSION RESISTANCE DESIGN METHODS

Corrosion is an electrochemical reaction that occurs in metal by passing electrons through an electrolyte. This flow results in the parent metal being 'eaten' away. The process of corrosion protection endeavours to separate the steel from the elements that produce corrosion, most commonly water and chloride ions, such as salt spray in foreshore zones. (Robinson, 2007)

3.1 Exposure Environment

The foreshore zone is designated as a very high exposure category in AS2312:2002 – *Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings,* which classifies it as Category E – M which is:

3.1.1 Category E: Very High (E-I: Industrial E-M: Marine)

This category is common offshore and on the beachfront in regions of rough seas and surf beaches. The region can extend inland for several hundred metres. (In some areas of Newcastle, for example, it extends more than half a kilometre from the coast.) This category may also be found in aggressive industrial areas, where the environment may be acidic with a pH of less than 5. For this reason, Category E is divided into Marine and Industrial for purposes of coating selection. Some of the damp and/or contaminated interior environments in Category D may occasionally extend into this category. (AS2312:2002)

For the purpose of this guide the foreshore zone shall be classified as up to 400m from breaking surf. (Blue Scope, 2007)

3.2 Construction Materials

This guide examines the use of mild steel and stainless steel. Mild steel requires a coating system, and stainless steel does not require any coating system. The selection of material should be decided upon taking into account:

- Cost
- Corrosion resistance
- Coatings required
- Fabricability
- Availability
- Aesthetics
- Maintenance requirements
- Salvage value
- Durability against general wear and vandalism
- Structural Capacity
-

3.3 Coating Systems

This guide addresses the design of hot dip galvanized coatings and paint systems. These two systems can be combined into a duplex system by painting galvanized steel. Stainless steel does not require coating systems. The coating system should be chosen by taking into account:

- Cost
- Corrosion Resistance
- Environmental impact
- Application process
- Durability
- Availability
- Aesthetics
- Maintenance requirements

Each coating type will degrade at a certain rate. Refer Table 3.1 for the average degradation rates of coatings in the foreshore zone.

Table 3.1 – Average Degradation Rates

Coating	Average Degradation Rate (μm/year)
Hot Dip Galvanized (GAA, 2003)	6
PUR 5 Paint System in Accordance with AS2312:2002	35
Grade 316 Stainless Steel (Housaka, 2001)	0.025

3.4 Design Methods

Corrosion protection must be considered early in the design, as the way a structure is designed will have a large impact on its corrosion resistance. Figures 3.1 to 3.12 illustrate good design principles suitable for all materials and coatings to resist against corrosion. (AS2312, 2002)

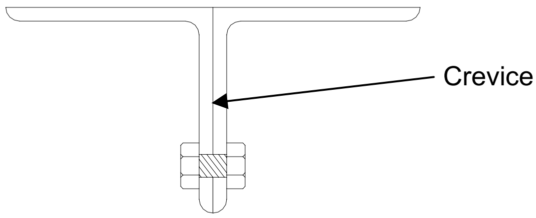
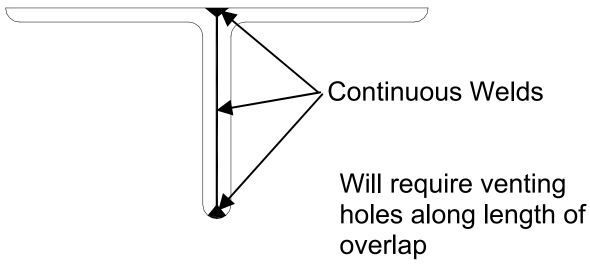
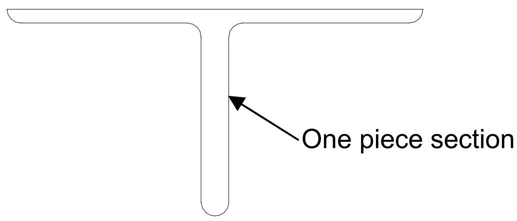
Bad Design	
Better Design	
Good Design	

Figure 3.1 - Design for Crevices (AS2312, 2002, Housaka, 2001)

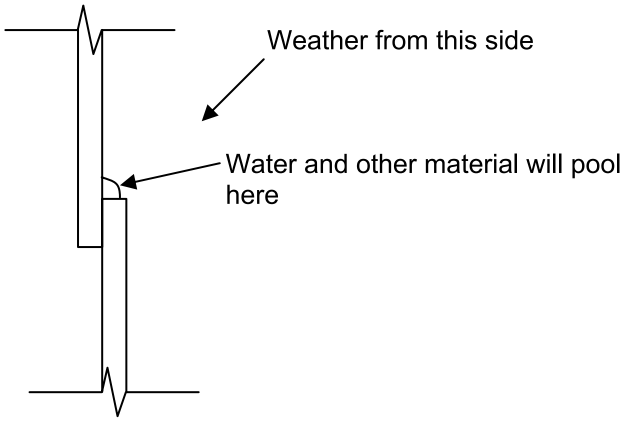
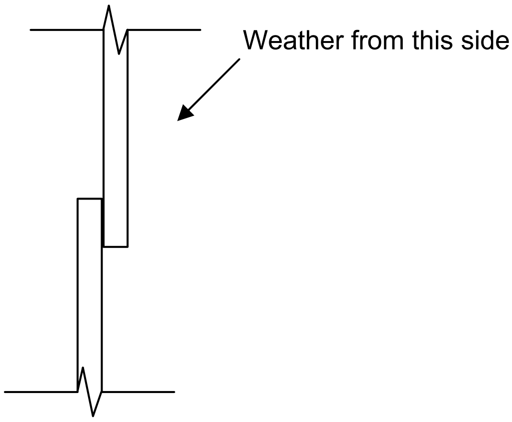
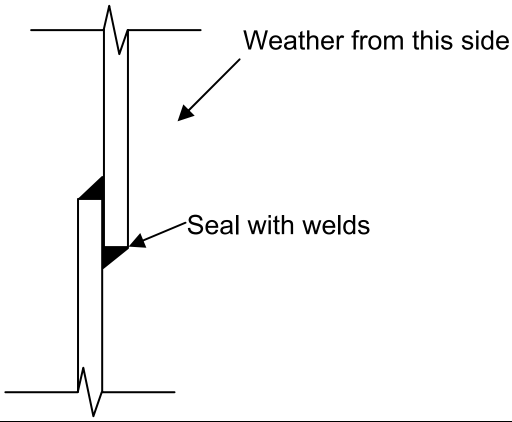
Bad Design	
Better Design	
Good Design	

Figure 3.2 - Design for Ledges (AS2312, 2002, Housaka, 2001)

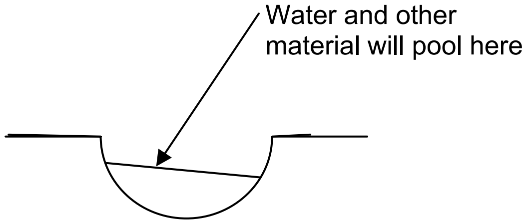
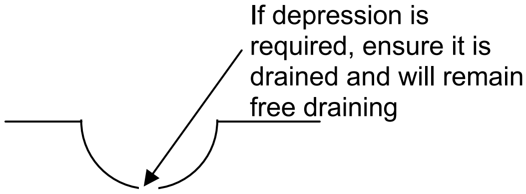
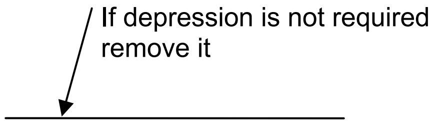
Bad Design	
Better Design	
Good Design	

Figure 3.3 – Design for Depressions

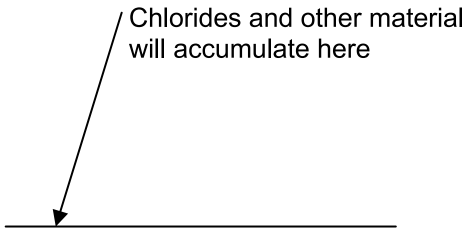
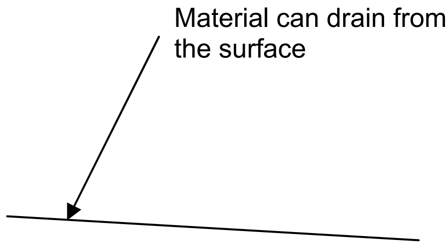
Bad Design	
Good Design	

Figure 3.4 – Design for Flat Surfaces

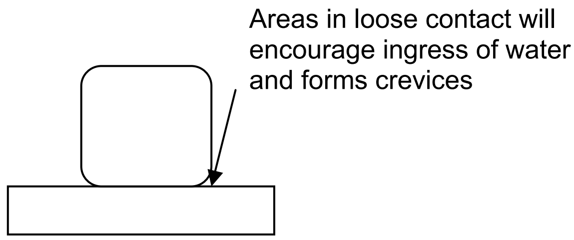
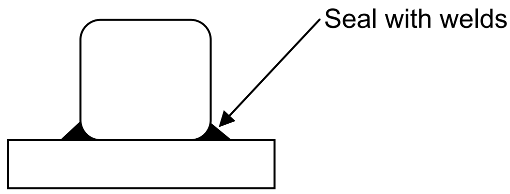
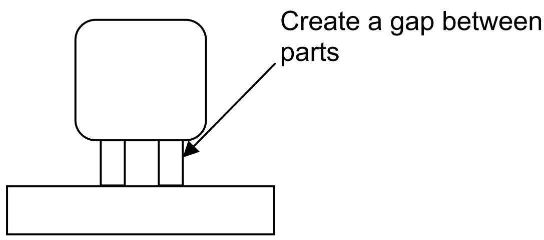
Bad Design	
Better Design	
Good Design	

Figure 3.5 – Areas in Loose Contact (AS2312, 2002)

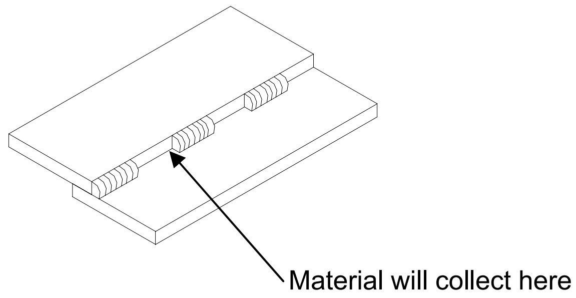
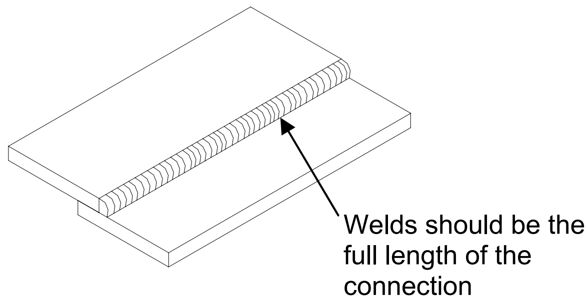
Bad Design	
Good Design	

Figure 3.6 – Intermittent Welds

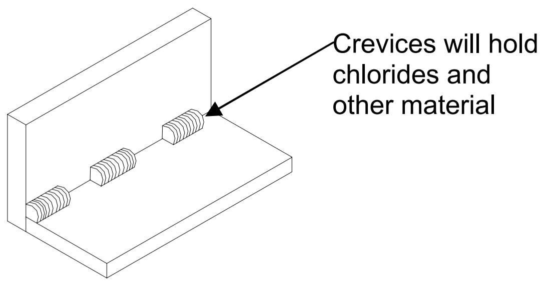
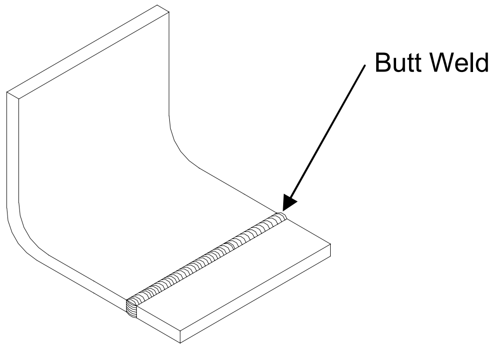
Bad Design	
Good Design	

Figure 3.7 – Corners (AS2312, 2002, Housaka, 2001)

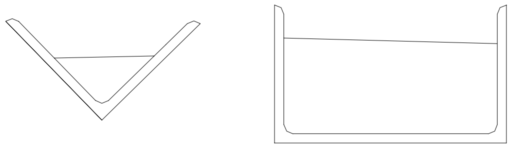
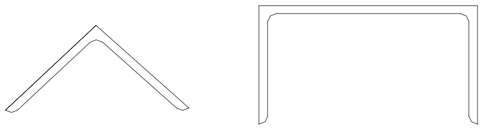
Bad Design	
Good Design	

Figure 3.8 – Drainage of Sections (AS2312, 2002, Housaka, 2001)

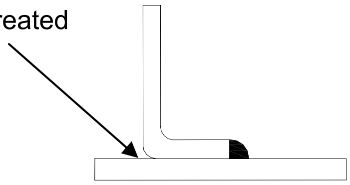
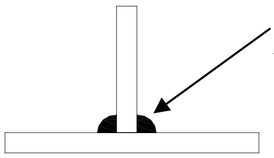
Bad Design	
Good Design	

Figure 3.9 – Crevices at the edge of sections (Housaka, 2001)

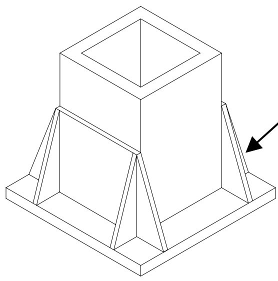
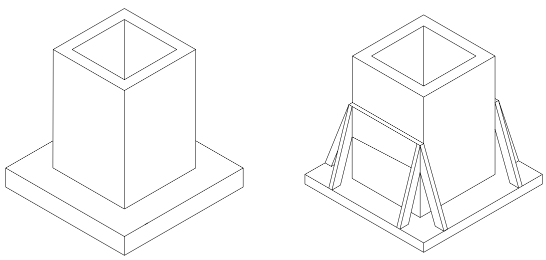
Bad Design	
Good Design Remove gussets or allow drainage	

Figure 3.10 – Gussets (AS2312, 2002, Housaka, 2001)

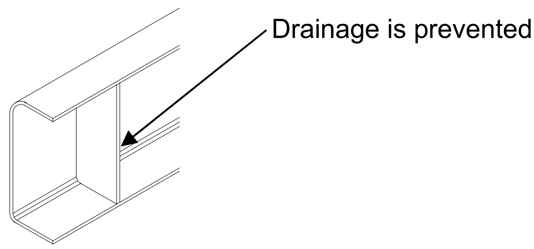
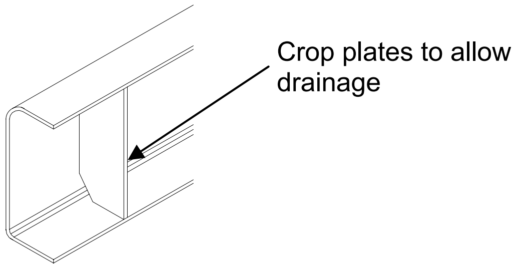
Bad Design	
Good Design	

Figure 3.11 – Cropping for Drainage (AS2312, 2002, Housaka, 2001)

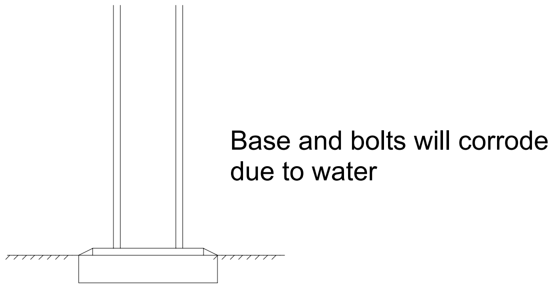
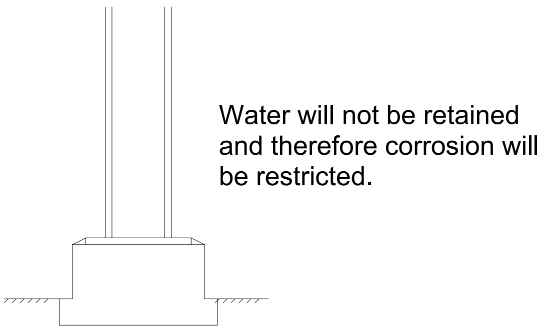
Bad Design	
Good Design	

Figure 3.12 – Raising Base Plates (Housaka, 2001)

3.5 Good Design Principles

- Use butt welds in preference to lap welds
- Where lap welds are used face joints downwards to avoid collection of moisture and sediment
- Avoid use of horizontal boxed sections, ledges, seams and flat undrained areas.
- Use rounded internal corners rather than squared corners in vessels and containers to avoid build up of sediment
- Design to eliminate crevices and unnecessary openings
- Avoid contact of galvanized surfaces with brass or copper
- Provide ventilation where possible in condesation areas
- Under conditions of extreme humidity use an inhibitive jointing compound between contacting galvanized surfaces such as roof overlaps
- Provide maintenance access where anticipated service life of certain components is less than that of the complete structure.

4 DESIGNING FOR HOT DIP GALVANIZED STEEL

4.1 Introduction

Hot Dip Galvanized steel is mild steel which has been rigorously cleaned and placed in a bath of molten zinc for a period of time. In the bath the zinc and iron react to create a protective coating around the steel member. The steel is protected through the sacrificial protection of the zinc coating, the zinc is corroded instead of the steel. This has the major advantage of still protecting the steel if scratches or wear reveal the steel (GAA, 2008).There are many publications which outline good design of prefabricated members to be galvanized. This section combines information from these other publications.

4.2 Size of Parts

To be HDG steel needs to be dipped into a molten zinc bath. Best galvanizing results are obtained when the part can be dipped once. However if the part is too large to fit in the bath, in one dimension only, it can be dipped twice, this is called 'double end dipping' (GAA, 2008). Refer Figure 4.1. The maximum size of a member to be galvanized is governed by whether it can fit in the bath. Refer Table 4.1 for the size of the galvanizing baths in fairly close proximity to the Gold Coast. Refer Table 4.1.

Table 4.1 Galvanizing Plants

Plant Name	Location	Bath Size (m)	Maximum Member Length
Industrial Galvanizers Pty Ltd	Carole Park	12.2 x 1.8 x 2.4	17m
Industrial Galvanizers Pty Ltd	Pinkenba	10.2 x 1.7 x 2.4	18m
National Galvanizing Industries	Richlands	10.5 x 1.6 x 2.6	18m
Galvanizing Services Pty Ltd	Coffs Harbour	8.1 x 1.38 x 1.7	

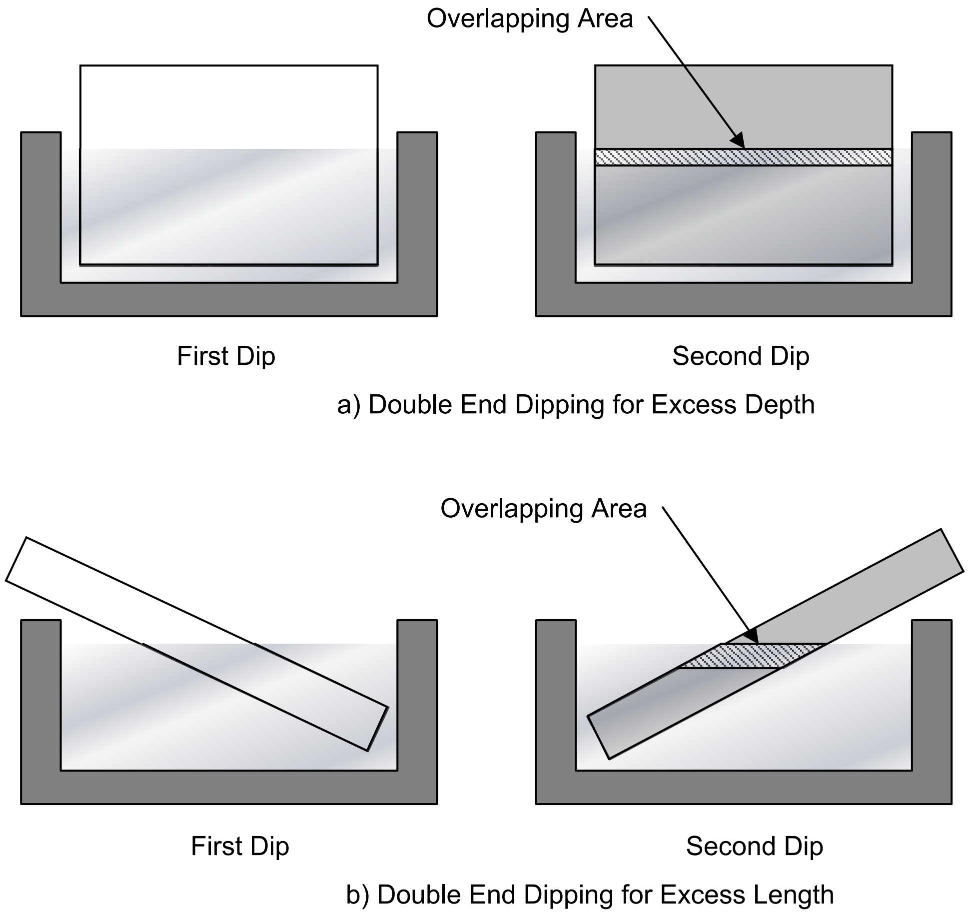


Figure 4.1 - Double End Dipping Techniques

4.3 Venting and Draining

Attachment A graphically illustrates the venting and draining guidelines and also contains drawings of good design examples.

It is critical that the molten zinc be in contact with the steel for a sufficient protective coating to be formed. To allow internal surfaces to be coated holes or openings must be manufactured into the steel members allowing the zinc to flow through and air to escape. Venting must be allowed as the temperature of the molten zinc is 450°C - 455°C and any air trapped within the steel will greatly expand potentially resulting in an explosion (GAA, 2008)

The location of the holes should be as follows (GAA, 2008):

- The venting holes and drainage holes should be diagonally opposite each other. This allows one end to fill with molten zinc while the air can escape through the opposite end.
- Flanges should not stop drainage from occurring, drainage holes must be located on the edge or flush with the drainage path of the molten zinc. Refer external vent and drain guidelines Attachment A.
- Any section that can create an air pocket <u>or</u> cause zinc pooling should be drained or vented in some way. Cropping gusset plates or fabricating holes are common preventative measures.
- Vent holes should be located so no air is trapped during immersion.

Refer Figure 4.2 for an example of a good design.

Galvanizers Association of Australia rules for venting and drainage are (GAA,2008):

- No vent hole should be less than 10mm
- Preferred minimum vent hole size is 12mm
- Vent holes should not be located in the centre of end plates and connections
- Vents holes should be located at the edges of hollow sections oriented in the same plane as the fabrication
- Large hollow vessels require 1250mm^2 of vent hole area for each cubic metre of enclosed volume. This is equivalent to a 40mm diameter hole for every cubic metre of volume.
- Hollow sections ideally require vent holes equivalent to 25% of the sections cross section, made up of single or multiple vent holes. The preferred design option is to leave the ends of hollow sections completely open
- Hollow sections that are connected require external vent holes as close to the connection as possible. If internal vent holes are used, they should be a total of at least 50% of the internal diameter of the connecting section.
- Large seal welded overlapping surfaces will require venting if the enclosed area may contain condensation or allow process chemicals to enter the overlap during the galvanizing process. Overlaps between 10,000mm^2 and 40,000mm^2 should be vented with a 10mm vent hole. Overlaps under 10,000mm^2 generally do not require venting. Intermediate sized overlaps should be judged on the basis of weld integrity and residual welding heat in the joint to ensure total dryness at time of sealing. Longer or larger overlapping areas require spaced holes for progressive venting. Very large overlapping areas should be avoided as they are an undesirable design for galvanizing or corrosion protection in general.
- Vent and drain holes must be located as close to the high and low points of the hollow section as possible to prevent air locks, entrapment of pre-treatment chemicals and zinc puddling.
- No drain holes should be less than 10mm
- Preferred minimum drain hole size is 25mm particularly for items with a large internal volume
- Large hollow sections require a 10,000mm^2 drain hole area for each cubic metre of enclosed volume
- Drain holes should be at the edges of hollow sections
- Hollow sections such as tube, RHS and SHS require minimum drain holes diameter equivalent to 25% of the section diagonal cross section. The preferred design option is to leave the ends of tube, RHS and SHS open.

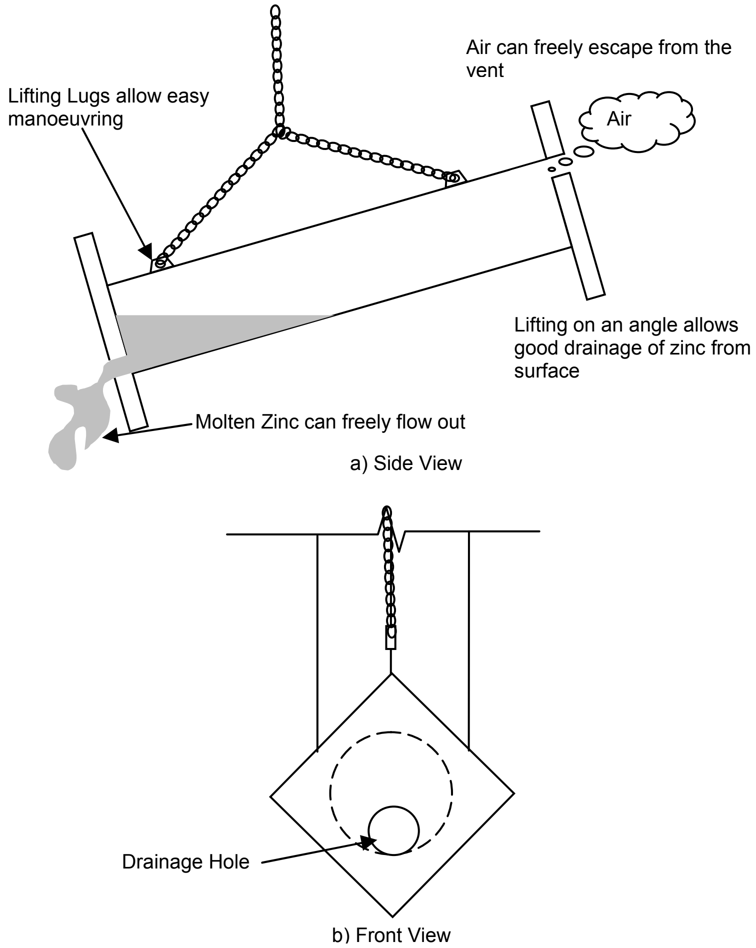


Figure 4.2 - Drainage and Venting Design Example

4.4 Lifting and Moving

The HDG process requires parts to be lifted and relocated. A good design should incorporate lifting lugs or utilise existing elements to allow the part to be easily suspended. If lifting lugs aren't supplied, chains must be wrapped around the part and this will result in chain marks in the coating and an uneven finish. Smaller items can be hung by wire or hooks (GAA, 2008).

4.5 Galvanized Steel in Concrete

Galvanized steel is commonly used in concrete and performs well. At the air and concrete interface, some form of sealant must be provided. Refer Figure 7.2.

Galvanized steel **must not** be in contact with any ungalvanized steel reinforcement in the concrete. Refer Attachment C for a case study illustrating why galvanized steel should not be in contact with ungalvanized concrete reinforcement.

4.6 Clearances

All gaps must be larger than 3mm.

Due to the surface tension in molten zinc there must be no gaps smaller than 2mm present. The zinc will not flow through gaps smaller than 2mm and will therefore not coat the steel (GAA, 2008)

4.7 Distortion

During HDG the yield stress of the steel is halved due to the heat. If the steel is heated unevenly or large residual stresses are present it will result in distortion of the steel. This can be overcome by designing to the following guidelines (GAA, 2008):

- Use uniform thickness material if possible
- Use a symmetrical design
- Avoid double dipping if the part contains a lot of thin sheeting.

4.8 Coating Thickness

Galvanized coatings shall conform to AS4680:2006 – *Hot dip galvanized (zinc) coatings on fabricated ferrous articles,* Table 1. This table has been reproduced as Table 4.2 in this guide.

Table 4.2 – Galvanized Coating Thicknesses

Article Thickness (mm)	Local coating thickness (µm)	Average coating thickness minimum (µm)	Average coating mass minimum (g/m^2)
≤ 1.5	35	45	320
> 1.5 ≤ 3	45	55	390
> 3 ≤ 6	55	70	500
>6	70	85	600

The thickness of the coating is dependent upon the mass of the steel, generally: thicker steel = thicker coating.

Coating thickness cannot be increased by completing multiple dips.

4.9 Transport and Storage of Galvanized Steel

Galvanized steel should be completely dry and allowed adequate ventilation during transport and storage. If galvanized steel is stored incorrectly ‘white rust’ will form, which is only superficial, however it creates a very aesthetically unpleasing surface on the steel (GAA, 2008)

Galvanized steel should never be stored in contact with cardboard, paper, cinders, clinkers, unseasoned or treated timber or harmful chemicals, mud or clay as surface staining may occur or in extreme cases premature corrosion could occur. (GAA, 2008).

4.10 Bolting Galvanized Steel

Due to the galvanizing process the zinc coating is typically 35 – 55% thicker on structural steel than on bolts, therefore the bolts will always be the first parts to show signs of corrosion. To avoid corrosion by dissimilar metals, **only galvanized bolts should be used with galvanized steel** (Robinson, 2008).

Bolting galvanized structures will give higher corrosion resistance than on site welding, as repairs to the coating are not required.

4.10.1 High Strength Friction Grip Connections

These connections gain their strength from the frictional forces gained by forcing the plates together through tensioning the bolts. The strength of the connection therefore relies on the slip factor of the steel and the strength of the bolts, therefore only high strength bolts should be used for these connections. The GAA states that the slip factor for galvanized steel lies in a range from 0.14 to 0.19, as compared to 0.35 for clean as-rolled steel (GAA, 2008). The slip factor of galvanized steel can be improved by wire brushing or “brush off” grit blasting. When these methods are used the slip factor must be verified in accordance with AS4100:1998 Appendix J (GAA, 2008).

AS4100:1998 provides more information on these type of connections.

4.10.2 Bolt Relaxation

Due to the malleable nature of zinc the coating on galvanized steel will be ‘squashed’ under the force of the bolted connections. This results in lower tension in the bolts. The Galvanizers association of Australia states that there is a *loss of bolt load of 6.5% for galvanized plates and bolts, as against 2.5% for uncoated bolts and members. This loss of bolt load occurred in 5 days and little further loss is recorded. This loss can be allowed for in design and is readily accommodated.*(GAA, 2008)

4.10.3 Nut Stripping Strength

Due to the galvanized coating on bolt threads, the nut must be tapped oversize to accommodate. This reduces the stripping strength of the nut and therefore galvanized high strength nuts must have a higher specified hardness (GAA, 2008)

4.10.4 Torque/Induced Tension

Galvanized high strength structural bolts have increased friction between the nut and bolt during tightening increasing the risk of bolt fracture during tightening. To reduce this risk a lubricant must be provided in accordance with AS1252:1996. GAA state that lubricant should be pre-applied by the manufacturer (GAA, 2008).

4.10.5 Bolt Hole Allowances

To allow for build up of the zinc coating in bolts holes the dimension from Table 4.3 should be added to the radius of the hole (GAA, 2008):

Table 4.3 – Bolt Hole Allowances

Nominal Bolt Diameter	Typical Hole Diameter	Radial Allowance	HDG Hole Diameter
Up to M22	Up to 24mm	0.40mm	Up to 24.8mm
M24	26mm	0.45mm	26.9mm
M27	29mm	0.50mm	30mm
M30	32mm	0.55mm	33.1mm
M36	38mm	0.60mm	39.2mm
M36-M48	38mm-50mm	0.80mm	39.6mm-51.6mm
M48-M64	50mm-66mm	1.00mm	52mm-68mm

4.11 Welding Galvanized Steel

Galvanized steel can be welded using all common welding techniques. However welding conditions must be more closely monitored than uncoated steel. The following addresses the suitability of different types of welding, recommendations for each type of welding and the reconditioning of the galvanized coating after welding (Robinson, 2008).

4.11.1 Gas Metal Arc (GMA) Welding

- Use of a splatter release compound must be used if using a CO_2 gas shield
- A 92%Ar/5%CO_2/3%O_2 mix provides excellent results on sheets up to 3.0mm thick
- Welding speed should be decreased by about 10 to 20 percent, to allow the galvanized coating to be burnt off at the front of the weld pool.
- For fillet welds where the protective coating is quite thick increasing the current by 10 amps may help the welding process.
- *Penetration of the weld in galvanized steel is less that for uncoated steel so that slightly wider gaps must be provided for butt welds. A slight side-to-side movement of the welding torch helps to achieve consistent penetration when making welds in the flat position.*(Robinson, 2008)
- *To achieve complete penetration in the overhead position on galvanized steel with 600 g/m_2 coatings, weld current should be increased by 10 amps, and voltage by 1 volt. Welds in the vertical downwards and overhead positions may require a speed reduction of 25 to 30 per cent by comparison with uncoated steel, depending on joint type and coating thickness, to prevent rising zinc vapour from interfering with arc stability. Butt welds in the horizontal-vertical positions require less reduction in speed because the zinc vaporises away from the weld area.* (Robinson, 2008)

4.11.2 Gas Metal Arc Braze Welding

- Very similar to GMA welding as described above. Braze welding is performed at a lower temperature than the melting point of the base metal.
- The lower temperature means that damage to the coating on the underside of the material is minimised.
- The lower temperature also minimises distortion on sheet metal.

4.11.3 Manual Metal Arc Welding

- Only recommended for galvanized steel over 1.6mm thick.
- Should be applied more slowly than for plain steel. A whipping action should be used, moving the electrode forward and backward.
- Use a short arc length
- Butt joint gaps should be wider than usual, up to 2.5mm
- The galvanized coating can be ground off before welding
- Galvanized coating should be repaired.
- *Electrodes to Australian Standard 1553.1 classifications E4112 and E4113 are recommended as suitable for all positions. In butt and tee-joint welds in the flat and horizontal-vertical positions the E4818 basic coated electrode is highly suitable, giving fast, easy welding, improved bead shape, and easier slag removal.* (Robinson, 2008)

4.11.4 Gas Tungsten Arc Brazing

- *Hold the weld torch at a 70° angle rather than the 80° angle normally used for uncoated steel* (Robinson, 2008)
- *Increase shielding gas flow from 6 to 12 L/min to flush zinc oxide fume from the electrode area.* (Robinson, 2008)

4.11.5 Reconditioning Welded Areas

The most convenient method of repairing galvanized coatings that have been damaged during welding is the use of an organic zinc rich paint. The paint should contain a minimum of 92% zinc. AS4680:2006 Clause 8.3 states that a minimum dry film thickness of 100µm should be applied, but not less than 30 µm thicker than the surrounding galvanized coating. The paint should be applied in two coats. AS/NZS3750.9:2009 outlines the requirements for the paint. If colour matching is required the zinc rich paint can be coated with an aluminium vinyl paint. (Robinson, 2008)

Before applying the zinc rich paint the surface must be appropriately prepared by removing all weld slag and rigorous wire brushing as advised by Galvanizers Association of Australia.

In certain cases zinc spraying may be used to repair the coating around welds. The coating should be sprayed to the same thickness as the surrounding zinc coating and coated with an aluminium paint.

Reconditioning a welded area cannot reinstate the level of corrosion protection that is initially provided by a galvanized coating. Wherever possible welds should be completed before HDG is commenced. (GAA, 2008)

4.12 Galvanic Corrosion

Dissimilar metals should not be in electrical contact with each other. If dissimilar metals are close to each other they should be electrically isolated to stop galvanic corrosion occurring. Galvanized steel is especially susceptible to galvanic corrosion through contact with copper and brass. Contact with large areas of stainless steel will also cause galvanized steel to corrode (GAA, 2008).

The galvanic series can be used to determine whether metals will be susceptible to galvanic attack. Refer Attachment B for a galvanic series. The metals higher in the series will be corroded by the metals lower in the series. If water will be flowing over both types of metal, it should be routed to flow from the metal higher in the series to the metal lower in the series to protect from galvanic corrosion.

5 DESIGNING FOR PAINT SYSTEMS

5.1 Introduction

Paint systems protect the steel from corrosion by physically separating it from the corrosive environment. As paint systems provide minimal galvanic or chemical protection to the steel, they rely solely on the bond to the steel and the coatings ability to keep out water and other corrosive materials.

All paint systems must comply with AS2312:2002 –*Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings*.

All coatings shall be applied off site in a controlled environment to ensure appropriate surface preparation and paint application processes are adhered to.

5.2 Paint Film Thickness

Figures 3.1 to 3.12 show general design principles that should be followed when designing for corrosion protection. Figures 5.1 and 5.2 show principles specifically for designing paint systems. For the paint to effectively protect against corrosion the paint film thickness must be uniform over the entire structure (AS2312, 2002). Refer section 5.3 of this guide for the required Dry Film Thicknesses (DFT).

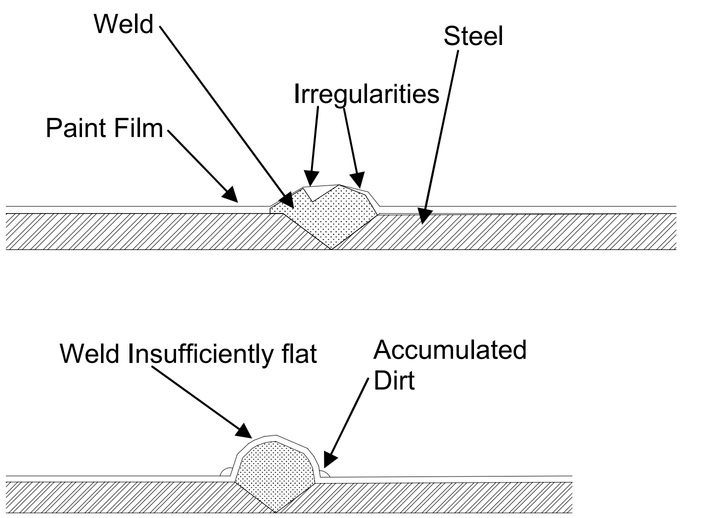
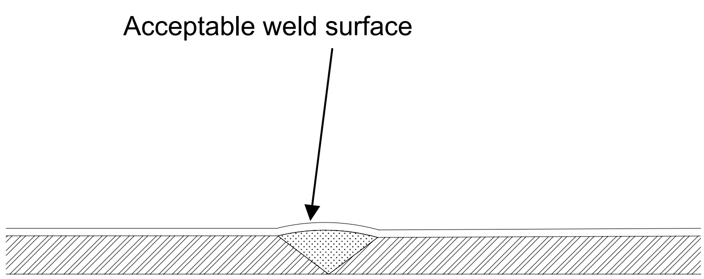
Bad Design	
Good Design	

Figure 5.1 – Weld Quality for Paint Systems (AS2312, 2002)

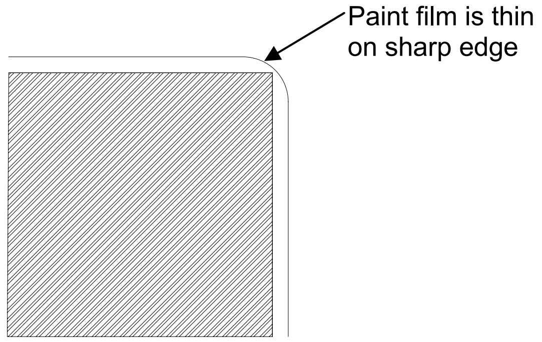
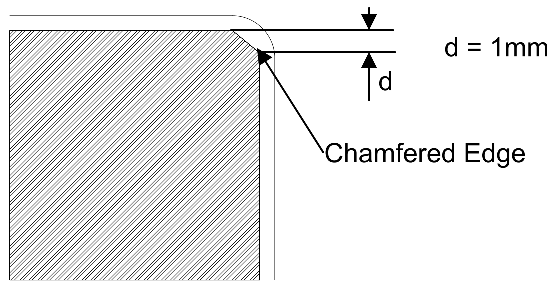
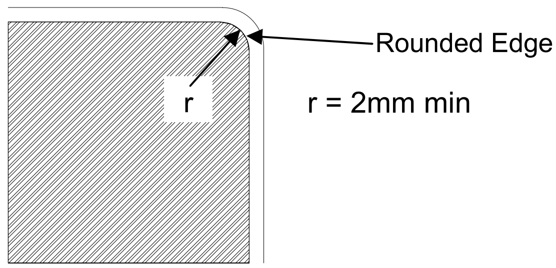
Bad Design	
Better Design	
Good Design	

Figure 5.2 – Edge design for Paint Systems (AS2312, 2002)

5.3 Paint Selection

Table 6.1 of AS2312:2002 provides a table of types of paint and their properties. The paint to be used should be chosen from this table. All paint should be from the same manufacturer.

For foreshore areas the paint system to be applied shall be a PUR 5 classification from AS2312:2002 Table 6.3. Refer below for the paint types to be used:

- 1st Coat – Zinc Rich Primer to 75μm DFT
- 2nd Coat – High Build Epoxy to 200μm DFT
- 3rd Coat – Polyurethane Gloss to 75μm DFT

5.4 Surface Preparation

INGAL Specifiers Manual states that 95% of all paint failures are caused by inadequate or poor quality surface preparation (Robinson, 2008)

For the paint system specified in section 5.3 the surface shall be prepared by abrasive blast cleaning to Sa 2 ½ in accordance with AS1627.4:2005 with a recommended angular profile of 30 – 50μm. The painting shall commence no longer than 4 hours after cleaning. (Sherwood, 2009)

5.5 Welding Painted Steel

Welding of steel protected by paint systems should preferably be completed before painting commences. Welds should optimally be ground to a smooth surface, however where this does not take place sharp crests of welds should be ground to a minimum radius of 1.5mm.
Weld spatter, slag fumes and flux residues shall also be removed (AS2312, 2002)

If on site welding is required the painting completed in the shop must leave an uncoated margin of 75mm for the first coat and an additional 50mm margin for each subsequent coat. The remainder of the coatings should then be applied after the weld area has cooled and been cleaned (AS2312, 2002)

5.6 Bolting Paint Systems

5.6.1 Friction grip bolted connections

Where friction grip connections are used the mating surface shall be coated as follows, irrespective of other painted coatings on the steel (RTA, 1997):

- Abrasive blast cleaned to AS1627.4 Class 3
- Surface Profile 25 to 65 Microns
- Application of 1 coat of inorganic zinc primer conforming to AS2105 Type 4 and GPC-C-29/8A with minimum dry film thickness of 75 microns.

5.7 Hollow Sections

Hollow sections should be hermetically sealed as the inner surface will not receive any coating. Inside surfaces shall be dry at the time of sealing.

5.8 Galvanic Corrosion

Dissimilar metals should not be in electrical contact with each other. When dissimilar metals are close to each other they should be electrically isolated to stop galvanic corrosion occurring. Paint systems <u>cannot</u> be classified as electrical isolation.

The galvanic series can be used to determine whether metals will be susceptible to galvanic attack. Refer Attachment B for a galvanic series. The metals higher in the series will be corroded by the metals lower in the series. If water will be flowing over both types of metal, it should be routed to flow from the metal higher in the series to the metal lower in the series to protect from galvanic corrosion.

5.9 Maintenance

Paint systems will require maintenance over the design life. Therefore when designing painted structures acceptable access space must be allowed for all areas to be repainted. AS2312:2002 Clause 3.3.4.6 provides guidance on designing structures to be accessible for later maintenance. Any part that will restrict maintenance access must be easily removable.

5.10 Transport and Storage

Members should be tied down and lifted using only slings, not chains. Chains will damage the coatings surface resulting in low corrosion resistance.

6 DESIGNING FOR DUPLEX SYSTEMS

6.1 Introduction

A duplex system consists of a steel member that has been galvanized and is then painted. Duplex systems can increase the design life of a structure quite dramatically when compared to either galvanized steel or paint systems alone (Robinson, 2008).

The structure should be designed utilising both galvanized and painted structures methods. Therefore all draining and venting requirements must be met. Sealing hollow sections will not apply, as the inside of hollow sections will be protected by the galvanized coating.

6.2 Galvanizing Requirements

A member being duplex coated should meet all required venting/draining requirements. The coating mass should be 600g/m^2 in accordance with AS4680:2006. The galvanizing should not be chromate quenched.

6.3 Paint Selection

GAA recommend the following paint specification for a duplex system be used:

- 1 coat of inhibitive 2 pack epoxy primer DFT 50µm
- 1 or more coats of high build 2 pack epoxy DFT 200µm/coat
- 2 coats of 2 pack polyurethane DFT 50µm/coat
- Minimum system DFT 400µm

6.4 Surface Preparation

As with plain paint systems the quality of the surface preparation is directly proportional to the success of the coating. The surface to be painted should be clean from all grease, oil, dirt and other contaminants. After cleaning the area should be thoroughly dried.

When possible the paint should be applied to newly galvanized steel as weathered galvanizing reduces the coating bond. Galvanized steel should be specified as not to be chromate quenched.

A light whip or brush blasting will prepare the surface to be painted, however no more than 10 microns of the galvanized coating should be removed by this process. The INGAL Specifiers Manual gives the following guidelines:

- Blast Pressure 40psi maximum
- Abrasive Grade 0.2 – 0.5mm (clean Ilmenite)
- Angle of blasting to surface 45°
- Distance from surface 300 – 400mm
- Nozzle type minimum 10mm venturi type

AS2312:2002 Section 4 also outlines the standards for surface preparation.

A failure in the paint system will result in the galvanized coating corroding faster due to water entering beneath the paint system resulting in localised corrosion cells.

6.5 Maintenance

Duplex systems will require repainting over the design life of the structure and therefore allowances for access must be made in the design. These design considerations are the same as a standard paint application and all design methods associated with both hot dip galvanized steel and paint applications must be incorporated into the design.

6.6 Bolting Duplex Systems

Bolted connections are preferred for duplex coatings as both the galvanized coating and the paint system will not be damaged by welding.

6.6.1 Friction grip connections

Depending on the mating surface used (either the galvanized coating or the painted coating). The surface should be prepared in accordance with the friction grip connection details for that coating type.

6.6.2 Bolt Relaxation

Bolt relaxation will occur due to the galvanized coating being “squashed”. Refer section 4.7.2 of this guide.

6.7 Welding Duplex Systems

Preferably all welds should be completed before galvanizing and painting. However if this is not possible the guidelines for welding galvanized steel and painted steel, section 4.8 and section 5.5 of this guide respectively, must be followed. Welding a duplex system on site will result in lower corrosion resistance.

6.8 Galvanic Corrosion

Metals of different type should not be in contact with each other. If two different types of metal are close to each other they should be electrically isolated to stop galvanic corrosion occurring. Steel with painted coatings are still susceptible to galvanic corrosion and the painted layer cannot be classified as electrical isolation (GAA, 2008).

The galvanic series can be used to determine whether metals will be susceptible to galvanic attack. Refer Attachment B for a galvanic series. Metals higher in the series will be corroded by metals lower in the series. If water will be flowing over both types of metal, if possible it should be routed to flow from the metal higher in the series to the metal lower in the series to protect from galvanic corrosion.

6.9 Paint Film Thickness

The paint film thickness should be a uniform thickness over the entire structure. Refer Figure 5.1 and Figure 5.2 for details of good design to ensure a uniform paint film thickness. Refer section 6.3 for required DFT’s of the paint system.

6.10 Transport

Duplex systems should only be handled using slings. The use of chains will damage the coating resulting in reduced corrosion resistance.

7 DESIGNING FOR STAINLESS STEEL

7.1 Introduction

Stainless steel is not immune to corrosion however good design will ensure that the product survives and may exceed the design life. An advantage of stainless steel is that corrosion will rarely compromise the structural stability of a structure. In the majority of cases, corrosion on stainless steel is merely a visual problem affecting only the aesthetics of the material, this is called 'tea staining' (ASSDA, 2008)

7.2 Grade Selection

The grade of stainless steel selected is critical to the success of the material. Selecting the correct grade can be a procedure requiring expert advice (ASSDA, 2008). However the International Molybdenum Association have created a useful tool to help in specifying the correct grade, which can be found at:

http://www.imoa.info/_files/pdf/folder_which_stainless_steel_06.pdf

For the foreshore zone, grade 316 should be used as a minimum.

7.3 Surface Finishes

The type of surface finish will affect the look of the structure and the corrosion resistance. Surface finishes are most readily classified by the surface roughness which is designated as the 'Ra' value. The more highly polished a surface becomes the higher the corrosion resistance. As surfaces become more highly polished the price also increases (ASSDA, 2008). Refer Table 7.1 for the most frequently used surface finishes and their properties

Table 7.1 Surface Finishes

Finish Type	Ra, microns	Description (ASSDA, pg59)
2D	0.13 – 1.0	A matt non reflective finish produced by cold rolling followed by annealing and descaling.
2B	0.06 – 0.51	A Bright, moderately reflective cold rolled finish. Can be used as is and is the most common finish used.
BA	0.01 – 0.1	A bright annealed finish approaching a mirror like appearance Used in architectural applications where a mirror like finish is required..
No. 4	0.18 – 0.64	This is a general purpose polished finish widely in the food industry.
No. 8	0.019 – 0.1	A mirror like finish. Is commonly used for architectural parts, small mirrors and reflectors.

7.4 Crevices and Drainage

A crevice can basically be defined as an abrupt transition in the surface profile, such as two pieces being lapped over each other. Crevices should be avoided as much as possible as they have a much greater potential to corrode (ASSDA, 2008). Refer Figure 7.1 for an example of how crevice corrosion has affected the overlapping area. This could have been avoided by continuing the weld around the perimeter of the overlap. Drainage should always be allowed from a surface otherwise material will collect on the surface. Refer Figures 3.1 to 3.12 for examples of removing crevices and allowing drainage. Refer Figure 7.2 for another example of how to eliminate crevice corrosion.

Figure 7.1 – Crevice Corrosion

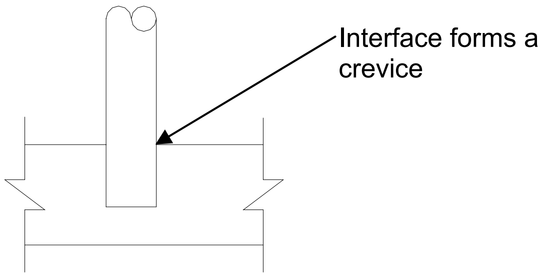
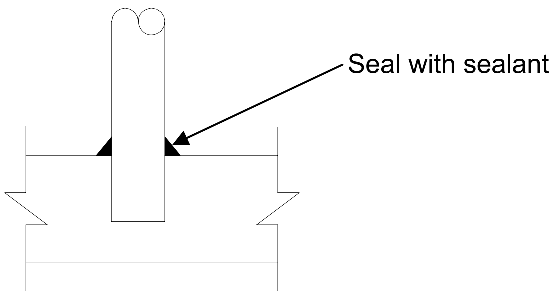
Bad Design	
Good Design	

Figure 7.2 – Crevice Corrosion where stainless steel enters concrete

7.5 Position of Members

Ideally members should be positioned where they will be washed by the rain. Allowing members to be washed will remove chlorides and other corrosive materials. Sheltered members will require manual washing to ensure corrosion is prevented. Where the surface finish of the steel has a directional grain this should optimally be positioned in a vertical orientation to allow material to be flushed out of the grain (ASSDA, 2008).

7.6 Galvanic Corrosion

Dissimilar metals must not be in electrical contact with each other. If dissimilar metals are close to each other they should be electrically isolated to stop galvanic corrosion occurring. Stainless steel is a noble metal and will usually corrode other metals that come into contact with it. Therefore it should be ensured that stainless steel is isolated from other metals in the structure (ASSDA, 2008).

The galvanic series can be used to determine whether metals will be susceptible to galvanic attack. Refer Attachment B for a galvanic series. The metals higher in the series will be corroded by the metals lower in the series. If water will be flowing over both types of metal, if possible it should be routed to flow from the metal higher in the series to the metal lower in the series to protect from galvanic corrosion.

7.7 Maintenance Program

The build up of surface contaminants on stainless steel such as salt and dust will hinder the corrosion resistance and lead to tea staining. However basic washing of the stainless steel will greatly increase the corrosion resistance. As a general rule of thumb, if the windows need washing, then the stainless steel will also need washing. (ASSDA, 2008). Depending on the environment, stainless steel should be washed at least once a year and up to four times a year in harsh coastal or marine environments. The Nickel Development Institute recommends the following procedure for cleaning:

1. Rinse with water to remove loose dirt
2. Wash with water containing soap, detergent or 5% ammonia, using a soft, long – fibre brush if necessary.
3. Rinse with water
4. If required, remove the water with a squeegee, using overlapping strokes, working from top to bottom.

The structure should be designed to accommodate the washing process. This can take the form of aligning the grain of the steel in a vertical direction and designing simple connections.

7.8 Bolting Stainless Steel

7.8.1 High Strength Friction Grip Connections

Stainless steel is not suitable for friction grip connections (Euro Inox, 1994)

7.8.2 Bearing Connections

Stainless steel is suitable for bolted connections provided washers are supplied under both the nut and bolt. To allow adequate corrosion resistance the fasteners must be stainless steel of an equal or higher corrosion resistance level. Design of bolted connections must be in accordance with AS/NZS 4673:2001 Section 5.3.

7.8.3 Galling

Stainless steel fasteners are susceptible to seizing when over tightened. This can be avoided by using a bolt with rolled threads or a torque wrench to tension bolts. The use of a lubricant containing molybdenum disulphide or nickel powder are effective in preventing galling.

7.9 Welding Stainless Steel

7.9.1 Welding Process

All work shall be in accordance with AS1554.6:1994 *Structural Steel Welding – Welding Stainless Steel for Structural Purposes.* Welding should be limited to thin gauges for ferritic stainless steel grades. Austenitic and Duplex grades are good for welding. Butt welds are preferred for corrosion resistance (ASSDA, 2008).

7.9.2 Post Weld Treatment

To ensure corrosion resistance remains, all welds should be finished to Grade II (a) in accordance with AS1554.6:1994. This finish requires acid pickling to remove heat tint, oxides and underlying chromium depleted layer. Pre pickling abrasion permitted. Post pickling passivation by nitric acid is permitted and recommended by ASSDA for severe environments.

7.10 Use of Tools on Stainless Steel

Any tools used to cut, grind, polish or clean should be solely dedicated to use on stainless steel. If tools are mixed between stainless steel and mild steel, iron from the tool will become embedded into the stainless steel causing rust stains and could lead to pitting corrosion. Steel wool should not be used to clean stainless steel for the same reason. Any cuts made to stainless steel should be given a passivation treatment to remove any embedded iron (ASSDA, 2008).

7.11 Protective Film

If provided the protective film on stainless steel should be left on as long as possible It should only be removed before the completion of construction if it hinders the progress of other stages or will not be able to be removed at a later stage (Housaka, 2001).

8 CONCLUSION

Although steel is suseptible to corrosion, the corrosion can be controlled if appropriate methods are taken. Designing the structure to prohibit corrosion is equally as important as specifying the correct corrosion protection method. Appropriate design for corrosion resistance should be considered from the beginning of the design.

9 REFERENCES

AS1252:1996 – High strength steel bolts with associated nuts and washers for structural engineering.

AS1554.6:1994 – Structural steel welding – Welding stainless steel for structural purposes.

AS1627.4:2005 – Metal finishing – Preparation and pretreatment of surfaces – Abrasive blast cleaning of steel

AS2312:2002 – Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings

AS/NZS3750.9:2009 – Paints for steel structures – Organic zinc-rich primer

AS4100:1998 – Steel Structures

AS/NZS4673:2001 – Cold formed stainless steel structures

AS4680:2006 – Hot dip galvanized (zinc) coatings on fabricated ferrous articles

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ATTACHMENT A

Safety in Venting for Galvanizing

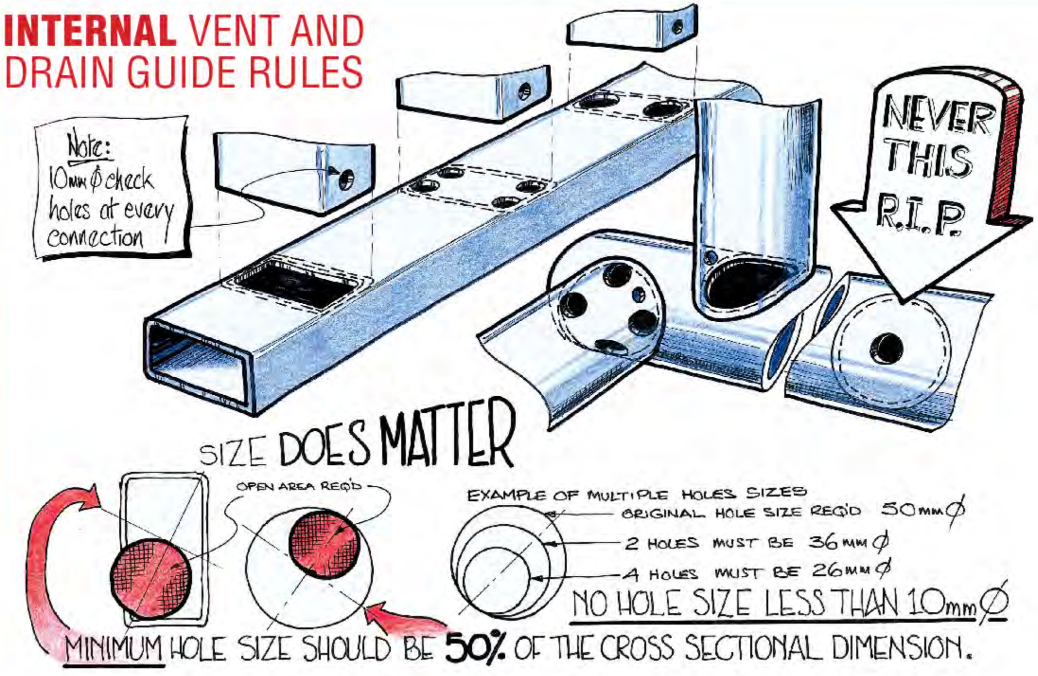
Galvanizers Association of Australia

SAFETY
IN VENTING FOR GALVANIZING

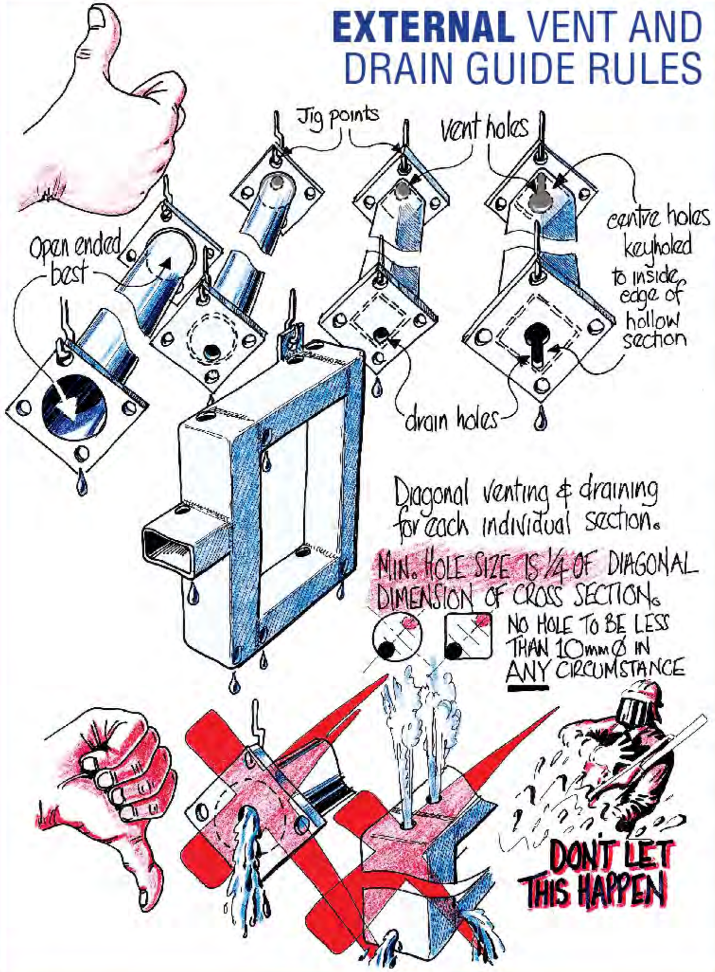
Certain rules must be followed when designing components for galvanizing and adoption of the following design practices will ensure the safety of galvanizing personnel and produce optimum quality galvanizing.

IF IN DOUBT CONCERNING PREFERRED DESIGN DETAILS, CONSULT WITH YOUR GALVANIZER.

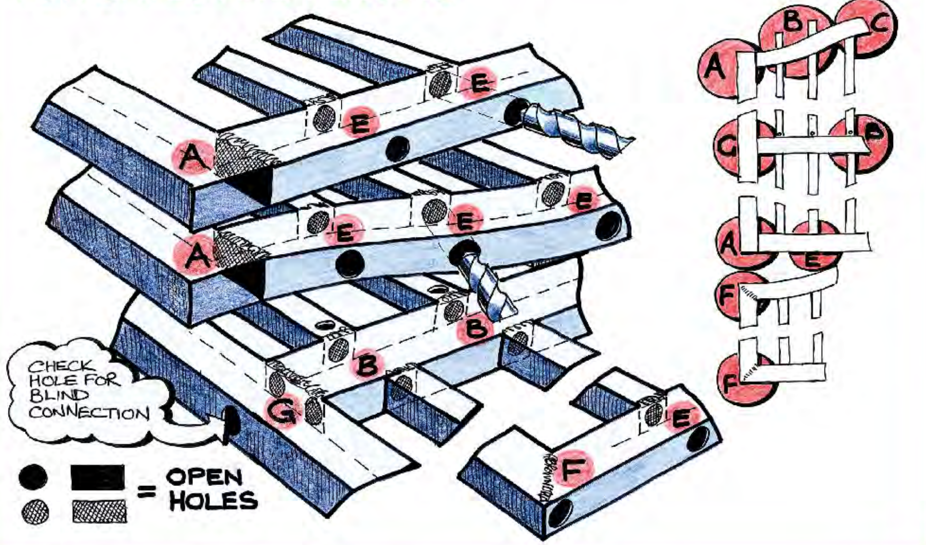
INTERNAL VENT AND DRAIN GUIDE RULES



EXTERNAL VENT AND DRAIN GUIDE RULES



VENT AND DRAIN REQUIREMENTS FOR GATES AND FENCING

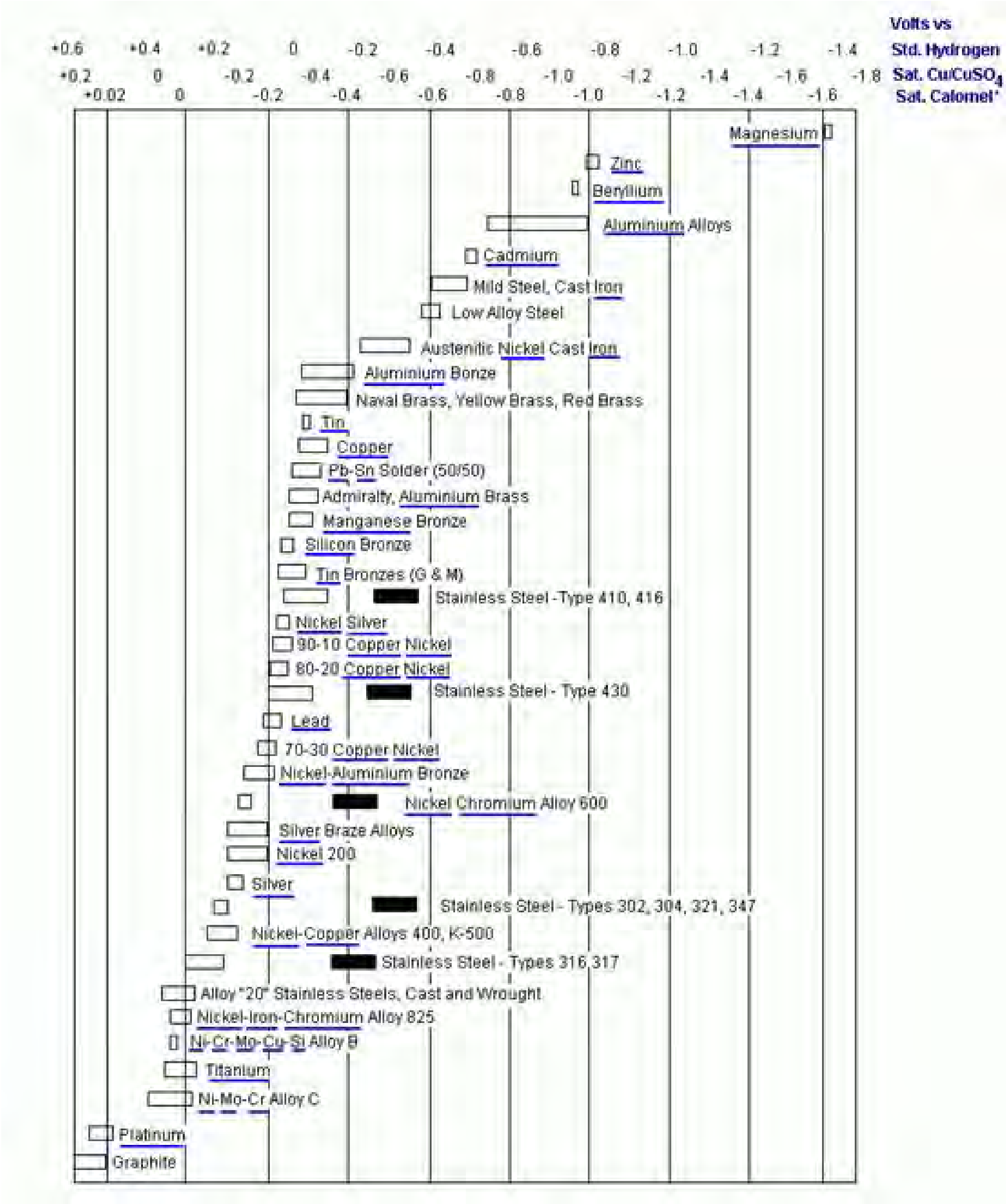


Vessels and hollow sections, including those in small diameter tubular fabrications, MUST be vented to atmosphere for the safety of galvanizing personnel and to prevent possible damage to the article. At galvanizing temperatures, moisture trapped in closed sections is converted rapidly to superheated steam, generating explosive forces unless vented.

galvanizers
ASSOCIATION OF AUSTRALIA
www.gaa.com.au

ATTACHMENT B

Galvanic Series (Robinson, 2008)



ATTACHMENT C

Case Study from the Australasian Corrosion Association

Presented by Arthur Austin at the *Building For Durability Seminar* held by the Australasian Corrosion Association in Brisbane on 2nd April 2009.

Australasian Corrosion Association, Queensland Branch
Building for Durability – Focus on Durability in National Standards

PearlStreet

A Concrete Potable Water Tank with Galvanized Steel Roof-Support Columns

- Tank Commissioned 1999 – 1st red rust noticed in 12 months.

- Photos (2003) show galvanized steel posts, bolted to the concrete floor & to the steel ceiling.
- Galvanized steel ladder bolted to wall & steel ceiling.
- Zinc gone - extensive red rusting evident in immersion zone.

Australasian Corrosion Association, Queensland Branch
Building for Durability – Focus on Durability in National Standards

PearlStreet

A Concrete Potable Water Tank with Galvanized Steel Roof-Support Columns

General Corrosion Average Penetration in mm [1]

	1st year	8th year	16th year	Final Steady Rate (mm/yr)
Zinc	0.01	0.08	0.11	0.0055
Carbon Steel	0.2	0.56	0.66	0.018

The galvanising thickness on the columns (114 x 4.8 CHS) would have averaged about 0.7mm [2] and therefore should have remained intact and protecting the underlying steel for much more than a decade.

[1] *Corrosion in Tropical Environments – Final Report of 16 year exposures – Fresh lake water results; Southwell, Bultman & Alexander; Materials Performance, July 1997)*

[2] *AS/NZS 4680:1999 Hot-dip galvanised (zinc) coatings on fabricated ferrous articles; Table 1*

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PearlStreet

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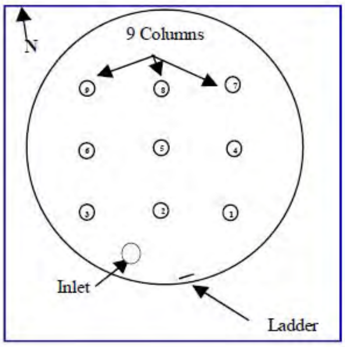


- Corrosion potential testing (relative to $Cu/CuSO_{4(sat.)}$ of each of the 9 columns found that they all resided at about -0.26V, the potential of steel in concrete.
- This confirmed that the columns were connected into the concrete reinforcing.

Australasian Corrosion Association, Queensland Branch
Building for Durability – Focus on Durability in National Standards
PearlStreet

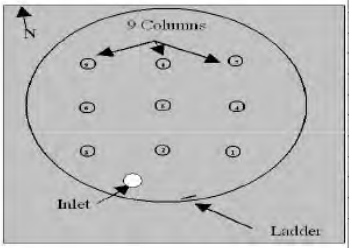
A Concrete Potable Water Tank with Galvanized Steel Roof-Support Columns

- The roof support columns and ladder were replaced with Type 316 Stainless Steel items and care taken to electrically isolate each of the columns and ladder from the concrete reinforcing.
- Electrical isolation was tested for using an applied current interrupt method involving:
  - Connection of the negative terminal of an automatic interrupt 33V DC source to reinforcing in the tank wall.
  - Connection of the positive terminal of a 33V DC source to an anode, consisting of a nominal one metre square piece of galvanised mesh, placed on the tank floor with about 300mm of water was left in the tank, completing the electrolytic circuit.
  - Operating the temporary anode on for 2 seconds, off for 6 seconds.
  - Measurement of the electrical potential of each column, ladder, roof and concrete steel reinforcing between 'on' and 'off' relative to a $Cu/CuSO_{4(sat.)}$ standard half cell electrode.

Australasian Corrosion Association, Queensland Branch
Building for Durability – Focus on Durability in National Standards

PearlStreet

A Concrete Potable Water Tank with Galvanized Steel Roof-Support Columns



Item	Potential (V) rel. $Cu/CuSO_{4(sat)}$ Anode Current Off	Potential (V) rel. $Cu/CuSO_{4(sat)}$ Anode Current On	Voltage Shift (V)	Is iTEM Electrically Isolated
Column 1	+0.060	+0.055	0.015	YES
Column 2	+0.197	+0.204	0.008	YES
Column 3	+0.110	+0.127	0.016	YES
Column 4	+0.013	+0.220	0.207	YES
Column 5	+0.045	+0.120	0.075	YES
Column 6	+0.190	+0.182	0.008	YES
Column 7	+0.213	+0.216	0.003	YES
Column 8	+0.58	+0.67	0.09	YES
Column 9	+0.1	+0.106	0.006	YES
Ladder	-0.5	-2.2	1.7	No
Reinforcing (in wall & Floor)	-0.6	-2.3	1.7	No
Steel Roof	-0.6	-2.3	1.7	No

- The isolation tests found all columns isolated with the ladder still electrically connected. Further works were done and retest confirmed that full electrical isolation of the ladder and all of the columns was attained.
- A long life is now expected.

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