After Fabrication
HOT DIP GALVANIZING

A PRACTICAL REFERENCE FOR DESIGNERS, SPECIFIERS, ENGINEERS, CONSULTANTS, MANUFACTURERS AND USERS

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Galvanizing makes sense and saves dollars

www.galvanizing.org.nz

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Prevention of Corrosion

When iron is extracted from its ore, a fundamental tendency of nature is abruptly reversed. Unless protected, iron and steel will corrode in most environments, slowly returning to their natural state.

Corrosion prevention is an essential factor in the economic utilisation of steel. 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.

In suitable applications, galvanizing provides ideal corrosion protection for steel – no other coating matches galvanizing's unique combination of low first cost, ease of inspection for coating quality, durability, predictable performance, low maintenance, and resistance to abrasion and mechanical damage.

This manual is designed to assist designers, specifiers, materials engineers, consultants, and fabricators to protect and improve their steel products. All important aspects of the galvanizing process and the properties and applications of galvanized coatings are covered. Sections detail the design and specification of galvanized products, fabrication methods including bolting and welding, and the painting of galvanized steel surfaces.

Great effort has been made to make this manual accurate and up-to-date, but responsibility is not accepted for any loss, damage or other consequence resulting from its use.

Welcome to GANZ, the Galvanizing Association of New Zealand.

What is GANZ?

The core of the very best galvanizers in New Zealand belong to the association and meet regularly to discuss technology and product improvements to ensure a quality service and finish. We are united in trying to enhance the product and productivity of our industry and the support we can bring to our Building and Engineering industries as a whole.

Our industry body is 23 years young and is based on a technology that is effectively 150 years old. Some have seen us as a market in either maturity or decline, however this could not be further from the truth. Ours is a growing market as people become more aware of the green push for environmental responsibility and have seen the impact of leaky homes.

At GANZ our motto is "Galvanizing makes sense and saves dollars". This play on words is at the heart of the Galvanizing offer – Galvanizing is often cheaper and faster to apply than many coatings, and even if it does cost only a few cents more to apply, the long-term saving in maintenance, replacement or repair, the ease of installation and the lowering of environmental impact ultimately save you many, many dollars down the line.

It makes sense!

Please enjoy the CD and all it has to offer, and don't hesitate to email or call us with any technical question of problem you may encounter - the earlier the better!

Jonathan White
Chairman
Galvanizing Association of New Zealand

GANZ acknowledges GAA for the writing and production of this After Fabrication Hot Dip Galvanizing Manual.

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Galvanizing makes sense and saves dollars

Standard specification for hot dip galvanized coatings

This specification has been prepared by the galvanizing industry through its technical working group, in consultation with industry and a number of consulting engineering groups. It is intended to be used in conjunction with Australian/New Zealand Standard 4680 and is designed for simple insertion into specifiers' overall materials specifications.

Note

1. Prior to commencement of design it is recommended that the designer/fabricator refer to Australian/New Zealand Standard 4680, in particular Appendix C 'Recommended procedures for design and preparation of materials prior to galvanizing', and to the chapter on Design in the CD 'After Fabrication Hot Dip Galvanizing', produced by Galvanizers Association of Australia.
2. The designer is referred to the recommendations contained in Appendix D of AS/NZS 4680 to minimise distortion and reduce the likelihood of other issues occurring.
3. High strength low alloy steels, particularly those containing high silicon can, when galvanized, produce brittle coatings which are thicker and different in colour to normal coatings. The high silicon content in weld deposits made by automatic welding processes may result in thicker coatings being formed on these areas. These coating characteristics are usually beyond the control of the galvanizer.
4. **If the galvanized coating is to be subsequently painted or any other special treatment is required, these requirements should be brought to the attention of the galvanizer at the time of enquiry and order so that they can prepare the product appropriately.**

Scope

This specification covers the galvanized coating applied to general steel articles, structural sections, angles, channels, beams, columns, fabricated steel assemblies, threaded fasteners and other steel components.

This specification does not apply to the galvanized coating on semi-finished products such as wire, tube or sheet galvanized in specialised or automatic plants.

Relevant Standards

AS 1214	Hot dip galvanized coatings on threaded fasteners.
AS 1627.1	Preparation and pre-treatment of surfaces - Removal of oil, grease and related contamination.
AS 1627.4	Preparation and pre-treatment of surfaces - Abrasive blast cleaning of steel.
AS 1627.5	Preparation and pre-treatment of surfaces - Pickling
AS 2309	Durability of galvanized and electrogalvanized zinc coatings for the protection of steel in structural applications – Atmospheric
AS/NZS 2312	Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings
AS 4312	Atmospheric corrosivity zones in Australia
AS/NZS 4680	Hot-dip galvanized (zinc) coatings on fabricated ferrous articles.

General

The galvanized coating on all steel articles on the following drawings and material lists shall conform to the requirements of AS/NZS 4680 and as specified herein.

Drawings: ______________________

____

____

Items: ______________________

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Fabrication

Care shall be taken to avoid fabrication techniques which could cause distortion or embrittlement of the steel.

All welding slag and burrs shall be removed prior to delivery to the galvanizer

Holes and/or lifting lugs to facilitate handling, venting and draining during the galvanizing process shall be provided at positions as agreed between the designer and the galvanizer.

Unsuitable marking paints shall be avoided and consultation by the fabricator with the galvanizer about removal of grease, oil, paint and other deleterious materials shall be undertaken prior to fabrication.

Surface Preparation

Surface contaminants and coatings, which cannot be removed by the normal chemical-cleaning process in the galvanizing operation, shall be removed by abrasive blast cleaning or some other suitable method.

Steelwork shall be pre-cleaned in accordance with the requirements of AS 1627.1 followed by acid pickling, in accordance with the requirements of AS 1627.5. Abrasive blast cleaning to Class 2 finish in accordance with the requirements of AS 1627.4 may be used.

Galvanizing

All articles to be galvanized shall be handled in such a manner as to avoid any mechanical damage and to minimise distortion. (See Note 2 above)

Design features that may lead to difficulties during galvanizing should be pointed out prior to galvanizing.

Galvanizing parameters such as galvanizing temperature, time of immersion, and withdrawal speed shall be employed to suit the requirements of the article.

The composition of the zinc in the galvanizing bath shall comply with AS/NZS 4680.

Coating Requirements

1 Thickness

The thickness of the galvanized coating shall conform with Table 1 in AS/NZS 4680

Table 1. Requirements for coating thickness and mass for articles that are not centrifuged

Steel Thickness mm	Local coating thickness minimum 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

Note: 1 g/m^2 coating mass = 0.14 µm coating thickness.
The thickness of the galvanized coatings on threaded fasteners shall conform with Table 2 in AS 1214:

Table 2. Requirements for coating thickness and mass for articles that are centrifuged

Thickness of articles (all components including castings) mm	Local coating thickness minimum µm	Average coating thickness minimum µm	Average coating mass minimum g/m^2
<8	25	35	250
≥8	40	55	390

Notes: 1. For requirements for threaded fasteners refer to AS 1214.
2. 1g/m^2 coating mass = 0.14 µm coating thickness.

The thickness of the galvanized coating shall first be tested by the purchaser/designer at the galvanizer's works, using an approved magnetic measuring device. In the event of any dispute, an independent test shall be carried out in accordance with AS/NZS 4680, Appendix G.

2 Surface Finish

The galvanized coating shall be continuous, adherent, as smooth and evenly distributed as possible, and free from any defect that is detrimental to the stated end use of the coated article. On silicon killed steels, the coating may be dull grey, which is acceptable provided the coating is sound and continuous (See Note 3). Any reparation is to be carried out as per Clause 8 of AS/NZS 4680.

The integrity of the coating shall be determined by visual inspection and coating thickness measurements. Where slip factors are required to enable high strength friction grip bolting, where shown, these shall be obtained after galvanizing by suitable mechanical treatment of the faying surfaces.

Where a paint finish is to be applied to the galvanized coating, all spikes shall be removed and all edges shall be free from lumps and runs. (See Note 4).

3 Adhesion

The galvanized coating shall be sufficiently adherent to withstand normal handling during transport and erection.

Inspection

Inspection shall be carried out at the galvanizer's works by a designated party, or at some other place as agreed between fabricator and galvanizer.

Certificate

When requested by the purchaser/designer, a certificate shall be provided stating that the galvanizing complies with the requirements of AS/NZS 4680.

Transport And Storage

Galvanized components shall, wherever possible, be transported and stored under dry, well-ventilated conditions to prevent the formation of wet storage staining following the recommendations contained in AS/NZS 4680 Appendix F.

A passivation treatment after galvanizing may be used to minimise the wet storage staining which may occur on articles unable to be stored in dry, well-ventilated conditions.

Any wet storage staining shall be removed by the galvanizer if formed prior to leaving the galvanizer's plant, unless late pick-up or acceptance of delivery has necessitated the material being stored in unfavourable conditions. Provided the coating thickness complies with the requirements of AS/NZS 4680, no further remedial action is required to the stained areas.

Welding

Where galvanized steel is to be welded, adequate ventilation shall be provided. If adequate ventilation is not available, supplementary air circulation shall be provided. In confined spaces a respirator shall be used.

Grinding of edges prior to welding may be permitted to reduce zinc oxide fumes formed during welding and eliminate weld porosity which can sometimes occur.

All uncoated weld areas shall be reinstated – see **Coating Reinstatement** or Clause 8 of AS/NZS 4680.

Coating reinstatement

Areas of significant surface that are uncoated shall, by agreement between the purchaser and the galvanizer, be reinstated by following the recommendations contained in AS/NZS 4680 - Repair after Galvanizing, or by other methods nominated by the galvanizer and approved by the contractor. Similar repair methods shall be used for areas damaged by welding or flame cutting, or during handling, transport and erection.

The size of the area able to be repaired shall be relevant to the size of the object and the conditions of service but shall normally be in accordance with the provisions of AS/NZS 4680 - Repair after Galvanizing.

SWEEP (BRUSH) BLAST CLEANING OF GALVANIZED STEEL PRIOR TO PAINTING

Refer AS/NZS 4680 Appendix I

GENERAL INFORMATION ON FACTORS THAT AFFECT THE CORROSION OF GALVANIZED STEEL

Refer AS/NZS 4680 Appendix H

Galvanized products should be specified in accordance with the appropriate national standards, which have been drawn up to provide minimum standards to ensure optimum performance of galvanized products and to give guidance in selection, application, and design.

AS/NZS 2312 'Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings' is a particularly valuable reference in the selection of the most practical, economic coating in particular applications.

CHAPTER 1

Hot Dip Galvanizing – Process, Applications, Properties

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GALVANIZING ASSOCIATION

Hot Dip Galvanizing
Process, applications, properties

Hot dip galvanizing protects steel from corrosion by providing a thick, tough, metallurgically bonded zinc envelope, which completely covers the steel surface and seals it from the corrosive action of its environment.

The galvanized coating provides outstanding abrasion resistance. Where there is damage or minor discontinuity in the sealing coat of zinc, protection of the steel is maintained by the cathodic action of the surrounding galvanized coating.

Metallic zinc is strongly resistant to the corrosive action of normal environments and hot dip galvanized coatings therefore provide long-term protection for steel. By contrast, most organic paint coatings used on steel need frequent renewal and when coatings are breached, corrosion begins at the exposed area of steel, spreading rapidly beneath the coating film.

The galvanized coating

The galvanizing process produces a durable, abrasion-resistant coating of metallic zinc and zinc-iron alloy layers bonded metallurgically to the steel base and completely covering the work piece. No other coating for steel matches galvanizing's unique combination of properties and advantages:

1. For most classes of steelwork, galvanizing provides the lowest long-term cost. In many cases galvanizing also provides lowest initial cost.
2. The galvanized coating becomes part of the steel surface it protects.
3. The unique metallurgical structure of the galvanized coating provides outstanding toughness and resistance to mechanical damage in transport, erection and service.

4. The galvanized coating is subject to corrosion at a predictably slow rate, between one-seventeenth and one-eightieth that of steel, depending on the environment to which it is exposed.
5. Galvanizing's cathodic protection for steel ensures that small areas of the base steel exposed through severe impacts or abrasion, are protected from corrosion by the surrounding galvanized coating.
6. An inherent advantage of the process is that a standard minimum coating thickness is applied.
7. During galvanizing the work is completely immersed in molten zinc and the entire surface is coated, even recesses and returns which often cannot be coated using other processes. If required, internal surfaces of vessels and containers can be coated simultaneously. See '**Design**'
8. Galvanized coatings are virtually 'self-inspecting' because the reaction between steel and molten zinc in the galvanizing bath does not occur unless the steel surface is chemically clean. Therefore a galvanized coating which appears sound and continuous is sound and continuous. See '**Metallurgy of galvanizing**' and '**Inspection of galvanized products**'.
9. Galvanizing is a highly versatile process. Items ranging from small fasteners and threaded components, up to massive structural members can be coated. See '**Galvanizing**' and '**Design**'.
10. The mechanical properties of commonly galvanized steels are not significantly affected by galvanizing. See '**Mechanical properties of galvanized steels**'.
11. Galvanizing provides outstanding corrosion performance in a wide range of environments. See '**Performance in various environments**'.
12. 'Duplex' coatings of galvanizing-plus-paint are often the most economic solution to the problem of protecting steel in highly corrosive environments. Such systems provide a synergistic effect in which the life of the combined coatings exceeds the total life of the two coatings if they were used alone. See '**Painting galvanized steel**'.

Cathodic protection

Metallic zinc is anodic to steel as indicated by the galvanic series of metals. See '**Galvanic corrosion of galvanized coatings in contact with other metals**'.

In the presence of an electrolyte, the anodic zinc coating on a galvanized article corrodes preferentially to the cathodic steel basis metal, preventing corrosion of small areas which may be exposed through accidental damage to the coating. The cathodic or sacrificial protection continues for as long as some of the galvanized coating remains.

A simple description of the phenomenon of corrosion of steel is given on following pages as background for the explanation of cathodic protection.

The nature of corrosion

Corrosion is basically an electrochemical process. It occurs because of differences in electrical potential which exist between dissimilar metals in contact or between small areas on a metal surface in the presence of an electrolyte.

Differences in potential on a metal surface can be caused by:

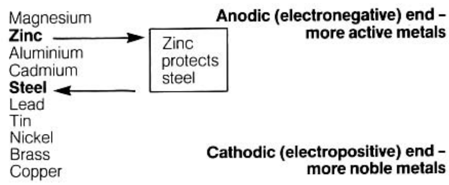
1. Variations in composition
2. Presence of impurities
3. Uneven internal stresses
4. A non-uniform environment

The environment may be a damp atmosphere, surface moisture, or liquid in which the metal is immersed. All serve as electrolytes allowing formation of small electrolytic cells at the metal surface, with resulting corrosion.

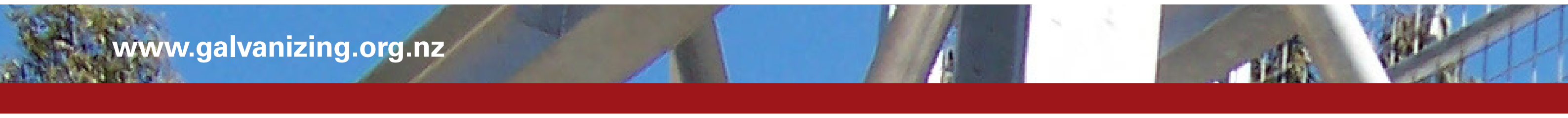
Each cell comprises a positive electron-producing anode and a negative cathode. Negatively charged electrons flow from anode to cathode. The loss of electrons converts some atoms of the anode to positively charged ions which in turn react with negatively charged ions in the electrolyte. This reaction between anode and electrolyte causes disintegration and corrosion of the anode metal. There is no corrosion of the cathode metal.

Galvanic series of metals in a sea water electrolyte

The table below shows a series of metals arranged in order of electrochemical activity in a sea water electrolyte. Metals high in the scale provide cathodic or sacrificial protection to the metals below them. Zinc therefore protects steel.

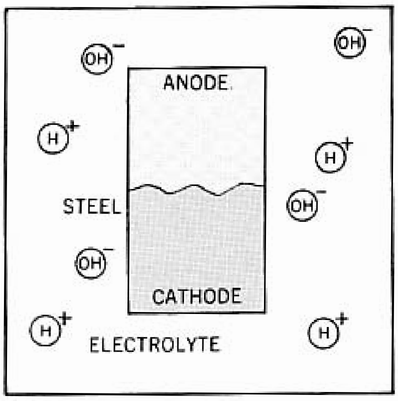


The scale indicates that magnesium, aluminium and cadmium should also protect steel. In most normal applications magnesium is highly reactive and is too rapidly consumed. Aluminium forms a resistant oxide coating and its effectiveness in providing cathodic protection is limited. Cadmium provides the same cathodic protection for steel as zinc but its applications are limited for technical, economic and environmental reasons.

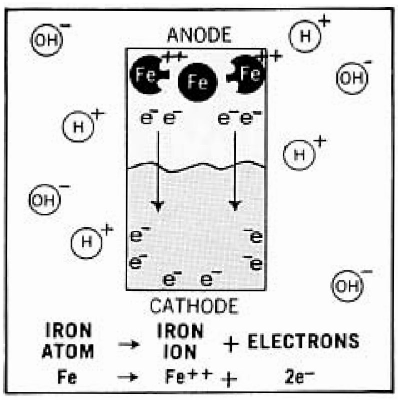


Corrosion of steel

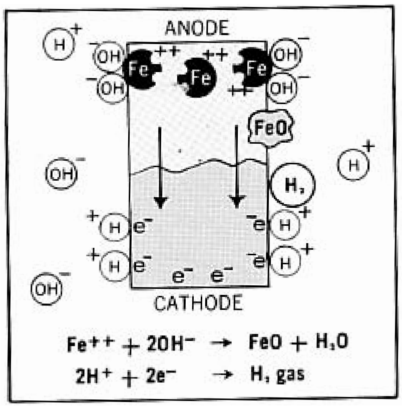
Differences in electrical potential are caused on surface areas of exposed steel by non-uniformity of surface composition, by surface moisture or by the electrolyte in which it is immersed. Small electrolytic cells are formed comprising anodes and cathodes. One such cell is shown diagrammatically.



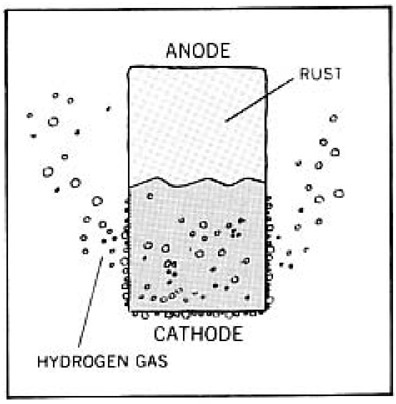
As the result of differences in electrical potential within the cell, negatively charged electrons flow from anode to cathode and iron atoms in the anode area are converted to positively charged ions.



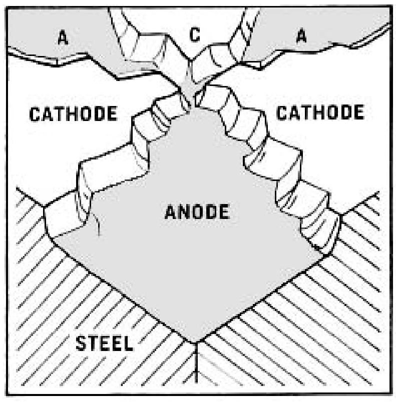
The positively charged iron ions of the anode attract and react with negatively charged hydroxyl ions in the electrolyte to form iron oxide or rust. Negatively charged electrons react at the cathode surface with positively charged hydrogen ions in the electrolyte to form hydrogen gas.



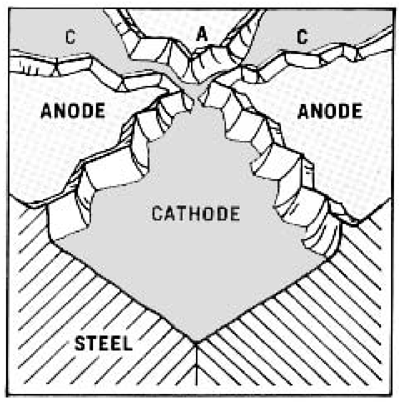
Under suitable conditions corrosion occurs at the rate of billions of complete reactions every second and soon results in a layer of rust appearing over the surface of the anode area.



The anode and cathode areas on a piece of steel are actually microscopic. When greatly magnified the surface might appear as the mosaic of anodes and cathodes visualised here, all electrically connected by the underlying steel. Corrosion occurs in the anode areas.

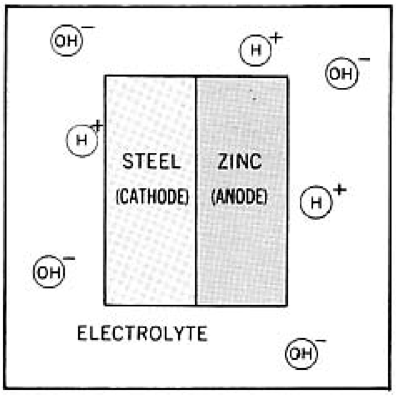


As anode areas corrode new material of different composition and structure is exposed. This results in changes in electrical potentials, causing anodes and cathodes to exchange roles, though not all at once, and areas previously uncorroded are now attacked. These processes may continue until the steel is entirely consumed.

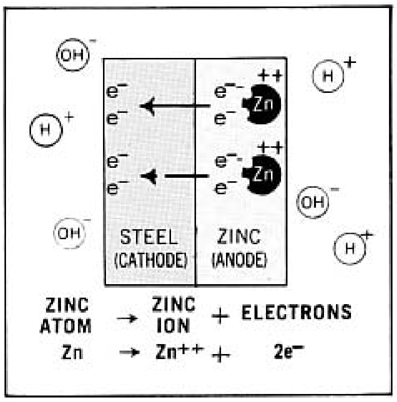


The mechanism of cathodic protection

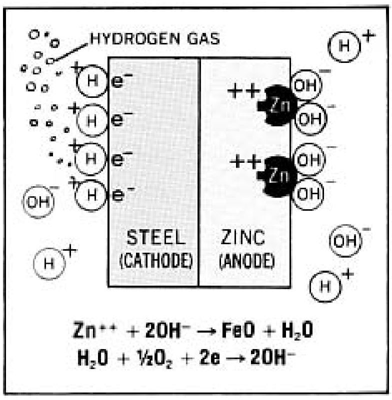
When zinc and steel are in contact in an electrolyte, differences in electrical potential develop and an electrolytic cell is formed. Zinc is more electrochemically active than steel, as shown in the galvanic series on page 9. The zinc therefore becomes the anode for all the steel, preventing the formation of small anodic and cathodic areas on the steel surface.



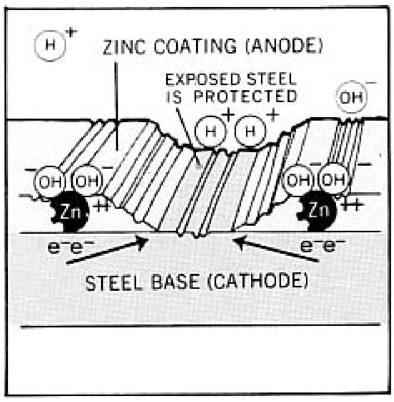
As a result of the differences in electrical potential within the cell, negatively charged electrons flow from the zinc anode to the steel cathode and zinc atoms in the anode are converted to positively charged zinc ions.



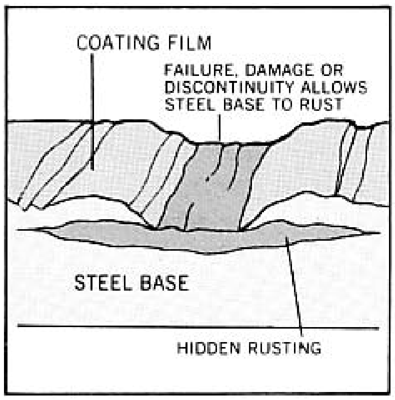
At the cathode surface, negatively charged electrons attract and react with positively charged hydrogen ions from the electrolyte, liberating hydrogen gas. There is no chemical reaction between the steel cathode and the electrolyte. This phenomenon which prevents corrosion of the cathode, is known as cathodic protection. The positively charged zinc ions at the anode surface react with negatively charged hydroxyl ions from the electrolyte and zinc is slowly consumed, providing sacrificial protection for the steel.



When discontinuity or damage in the zinc coating exposes the underlying steel, the cathodic protection which zinc provides for steel comes into action and ensures that the exposed steel does not corrode.



Most organic coatings and paint films depend on their sealing ability and in some cases anti-corrosive inhibitive pigments to protect steel from corrosion. They offer little or no protection to bare steel exposed by failure, damage or discontinuity in the coating film. Corrosion starts and spreads rapidly beneath the coating.



The galvanizing process

Metallic zinc coatings are applied to prepared steel surfaces by galvanizing, electroplating, mechanical plating, sherardising, painting with zinc-rich coatings and zinc spraying or metallising. Of these the galvanizing process is by far the most widely used. Galvanizing is normally carried out to AS/NZS 4680 'Hot dip galvanized (zinc) coatings on fabricated ferrous articles'.

Prepared items are galvanized by immersion in molten zinc. The surface of the work is completely covered, producing a uniform coating of zinc and zinc-iron alloy layers whose thickness is determined principally by the mass of the steel being galvanized. This is an important advantage of the galvanizing process – a standard minimum coating thickness is applied automatically regardless of the operator.

The molten zinc in the galvanizing bath covers corners, seals edges, seams and rivets, and penetrates recesses to give complete protection to areas which are potential corrosion spots with other coating systems. The galvanized coating is slightly thicker at corners and narrow edges, giving greatly increased protection compared to organic coatings which thin out in these critical areas. Complex shapes and open vessels may be galvanized inside and out in one operation.

Articles ranging in size from small fasteners to structures hundreds of metres high may be protected by the use of modular design techniques. Large galvanizing baths, in conjunction with modular design techniques and double-end dipping allow almost any structure to be galvanized, with greatly reduced maintenance costs and extended service life.

Visual inspection of galvanized products show that work is completely protected and gives an excellent guide to overall coating quality.

Preparation of work for galvanizing

Scale, rust, oil, paint and other surface contaminants are carefully removed from the steel by suitable preliminary treatment and subsequent acid cleaning or pickling in sulphuric or hydrochloric acids, followed by rinsing. Iron and steel castings are usually abrasive blast cleaned followed by a brief acid cleaning or they may be cleaned electrolytically to remove foundry sand and surface carbon.

Rolled steel surfaces covered by heavy mill scale may require abrasive blast cleaning prior to acid cleaning.

Fluxing

The acid-cleaned steel article is immersed in a flux solution, usually 30% zinc ammonium chloride with wetting agents, maintained at above 65°C. The flux solution removes the oxide film which forms on the highly reactive steel surface after acid cleaning, and prevents further oxidation before galvanizing. The work is then dried ready for galvanizing.

Galvanizing

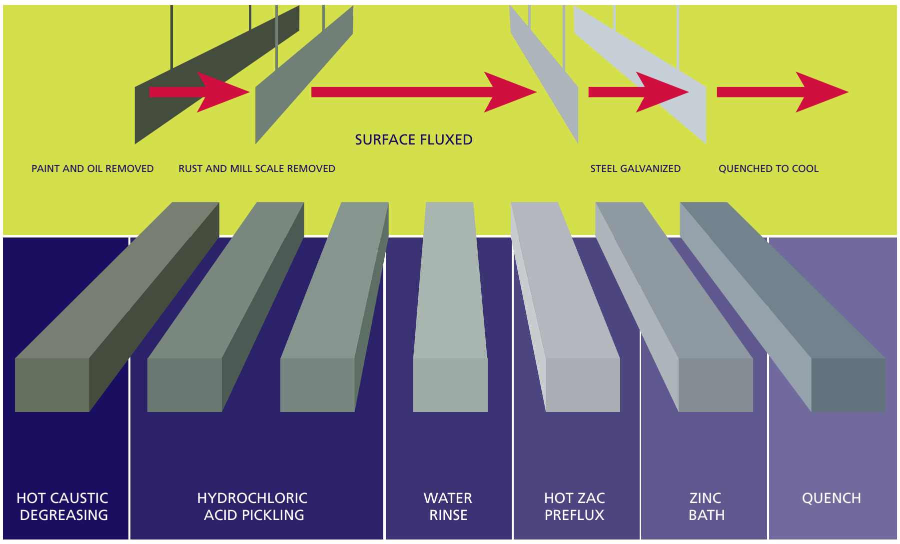
On immersion in the galvanizing bath the steel surface is wetted by the molten zinc and reacts to form a series of zinc-iron alloy layers. To allow formation of the coating the work remains in the bath until its temperature reaches that of the molten zinc, in the range of 445°C to 465°C. The work is then withdrawn at a controlled rate and carries with it an outer layer of molten zinc which solidifies to form the relatively pure outer zinc coating.

The period of immersion in the galvanizing bath varies from a few minutes for relatively light articles, or longer for massive structural members.

Upon extraction from the galvanizing bath the item is then quenched to cool.

The resulting galvanized coating is tough and durable, comprising relatively pure zinc and zinc-iron alloy layers bonded metallurgically to the underlying steel, completely covering the article and providing unmatched resistance to abrasion.

An important advantage to the galvanizing process is that visual inspection shows that work is completely protected and gives an excellent guide to coating quality.



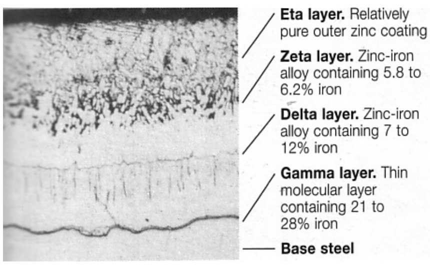
Galvanizing fasteners and small components

Fasteners and small components are loaded into perforated cylindrical steel baskets. After acid pickling and prefluxing, baskets are lowered into the galvanizing bath. On withdrawal from the molten zinc, baskets are raised without delay into a centrifuge or 'spinner' and rotated at high speeds for 15 to 20 seconds. Excess zinc is thrown off, providing a smooth, uniform coating and maintaining the integrity of threaded items.

Metallurgy of galvanizing

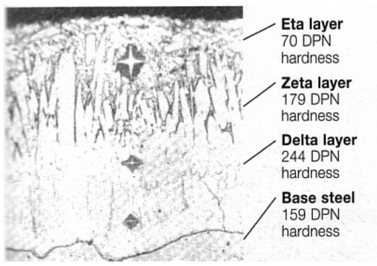
When the cleaned and fluxed steel surface contacts the molten zinc of the galvanizing bath the protective flux layer is removed leaving a clean steel surface which is immediately wetted by the zinc. This results in reaction between zinc and steel with the formation of zinc-iron alloy layers.

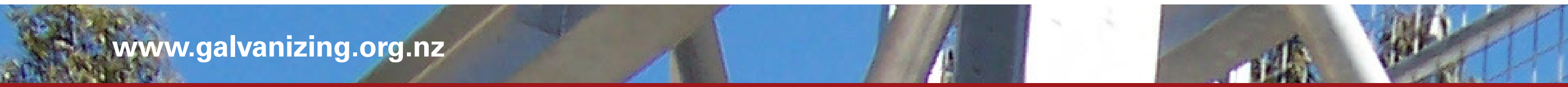
The photomicrograph below shows a section of typical galvanized coating which consists of a progression of zinc-iron alloy layers bonded metallurgically to the base steel, with the relatively pure outer zinc layer.



Abrasion resistance of galvanized coatings

The photomicrograph below shows that the delta and zeta zinc-iron alloy layers are actually harder than the base steel, resulting in galvanizing's outstanding resistance to abrasion and mechanical damage. Abrasive or heavy loading conditions in service may remove the relatively soft eta layer of zinc from a galvanized surface, but the very hard zeta alloy layer is then exposed to resist further abrasion and heavy loading.





Coating thickness

During the first minute of immersion in the galvanizing bath, zinc-iron alloy layers grow rapidly on the surface of the steels which are most commonly galvanized. The rate of alloy layer growth then diminishes and is finally very slow. When the work is withdrawn from the bath an outer layer of relatively pure zinc is also carried out. The total zinc coating mass applied depends mainly on the mass and thickness of the steel being galvanized.

AS/NZS 4680 specifies the following minimum average coating thickness.

Table 1
Requirements for coating thickness and mass for articles that are not centrifuged

Steel Thickness mm	Local coating thickness minimum µm	Average coating thickness minimum µm	Average coating mass minimum g/m²
≤1.5	35	45	320
>1.5 ≤3	45	55	390
>3 ≤6	55	70	500
>6	70	85	600

Note: 1 g/m² coating mass = 0.14 µm coating thickness

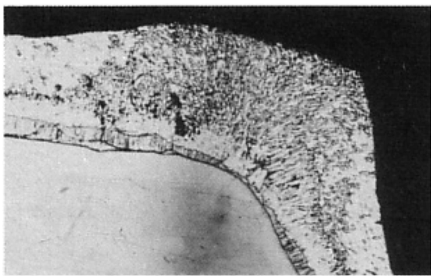
Table 2
Requirements for coating thickness and mass for articles that are centrifuged

Thickness of articles (all components including castings) mm	Local coating thickness minimum µm	Average coating thickness minimum µm	Average coating mass minimum g/m²
<8	25	35	250
≥8	40	55	390

Notes:

1. For requirements for threaded fasteners refer to AS 1214
2. 1 g/m² coating mass = 0.14 µm coating thickness

As indicated the total coating mass on heavier steel sections normally contains a minimum of 600 grams of zinc per square metre of surface area, (g/m²) equivalent to about 85 µm thickness. As illustrated below, coating thickness is slightly greater at corners.



Galvanized coatings are slightly thicker at corners and edges as shown, an important advantage over most organic coatings which thin out in these critical areas.

The structure of the galvanized coating and the relative thickness of its zinc-iron alloy layers have little or no effect on the protective life of the coating. Protective life depends on total coating mass.

On most commonly galvanized steels, the relatively pure outer zinc layer of the galvanized coating solidifies to give the typical bright zinc crystal or 'spangle' finish. Certain steel compositions may cause the zinc-iron alloy layer to grow through to the surface of the galvanized coating producing a matt grey finish sometimes known as 'grey bar', as discussed below under '**Composition of steel**' and under "**Dull grey coating**". There is negligible difference between the protective lives provided by each coating.

Factors influencing coating thickness

The thickness, alloy structure and finish of galvanized coatings are influenced by:

1. Surface condition of the steel
2. Composition of the steel

Increasing the period of immersion in the galvanizing bath will not increase coating thickness except in the case of silicon steels, as discussed on this page.

Surface condition of steel

Grit blasting steel before galvanizing roughens the surface and increases its surface area, resulting in higher reactiveness to molten zinc. Greater zinc-iron alloy growth occurs during galvanizing, producing thicker coatings, though at the expense of rougher surface and poorer appearance.

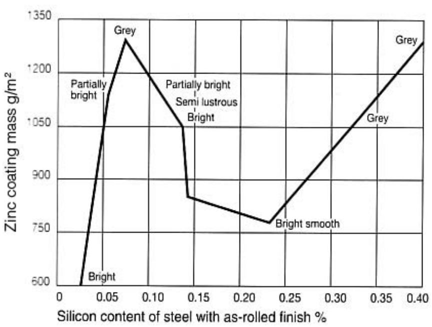
Application of this method of achieving thicker coatings is generally limited by practical and economic considerations. Where increased service life or reduced maintenance is required the use of duplex galvanizing-plus-paint systems is a preferable alternative.

Composition of steel

Both silicon and phosphorous contents can have major effects on the structure, appearance and properties of galvanized coatings. In extreme cases, coatings can be excessively thick, brittle and easily damaged.

Silicon. As shown in the graph below, certain levels of silicon content will result in thicker galvanized coatings. These thicker coatings result from the increased reactivity of the steel with molten zinc, and rapid growth of zinc-iron alloy layers on the steel surface. The graph shows that such growth in coating thickness takes place on steels with silicon contents in the range of 0.04 to 0.14%. Growth rates are less for steels containing between 0.15 and 0.22% silicon, and increase again with increasing silicon levels above 0.22%.

Effect of silicon content of steels on galvanized coating mass and appearance.



Phosphorous. The presence of phosphorous above a threshold level of approximately 0.05% produces a marked increase in reactivity of steel with molten zinc, and subsequent rapid coating growth. When present in combination with silicon, phosphorous can have a disproportionate effect, producing excessively thick galvanized coatings.

Suitability of silicon/phosphorous steels for galvanizing. As a guide to the suitability of silicon and phosphorous containing steels for galvanizing, the following criteria should be applied if aesthetics is the critical consideration:

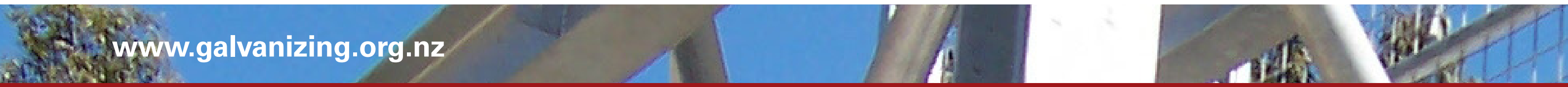
% Si < 0.04%
and
% Si + (2.5 x % P) < 0.09%

Note that steels with very low silicon contents can sometimes produce coatings of a reduced thickness:

Galvanized coatings on silicon steels can be dull grey or patchy grey in colour with a rough finish, and may be brittle if there is excessive growth. Coating service life is proportional to the increased thickness and is unaffected by appearance, provided the coating is sound and continuous. The thickness, adherence and appearance of galvanized coatings on silicon and phosphorous steels are outside the control of the galvanizer. (see also '**Dull grey coatings**').

Double dipping or galvanizing a second time will not increase the thickness of a galvanized coating for reasons discussed under "Coating thickness", and may adversely affect coating appearance.

The terms 'double dipping' and 'double-end dipping' are sometimes confused. Double-end dipping is a method of galvanizing articles too long for the available bath by immersing one end of the work at a time.



Mechanical properties of galvanized steels

The galvanizing process has no effect on the mechanical properties of the structural steels commonly galvanized.

Strength and ductility

The mechanical properties of 19 structural steels from major industrial areas of the world were investigated before and after galvanizing in a major 4-year research project by the BNF Technology Centre, UK, under the sponsorship of International Lead Zinc Research Organization. Included were steels to Australian Standard 1511 grade A specification, and British Standard 4360 series steels.

The published BNF report 'Galvanizing of structural steels and their weldments' ILZRO, 1975, concludes that '… the galvanizing process has no effect on the tensile, bend or impact properties of any of the structural steels investigated when these are galvanized in the "as manufactured" condition. Nor do even the highest strength versions exhibit hydrogen embrittlement following a typical pre-treatment in inhibited HCl or H_2SO_4.

'Changes in mechanical properties attributable to the galvanizing process were detected only when the steel had been cold worked prior to galvanizing, but then only certain properties were affected. Thus the tensile strength, proof strength and tensile elongation of cold rolled steel were unaffected, except that the tensile elongation of 40% cold rolled steel tended to be increased by galvanizing. 1-t bends in many of the steels were embrittled by galvanizing, but galvanized 2-t and 3-t bends in all steels could be completely straightened without cracking.'

Embrittlement

For steel to be in an embrittled condition after galvanizing is rare. The occurrence of embrittlement depends on a combination of factors. Under certain conditions, some steels can lose their ductile properties and become embrittled. Several types of embrittlement may occur but of these only strain-age embrittlement is aggravated by galvanizing and similar processes. The following information is given as guidance in critical applications.

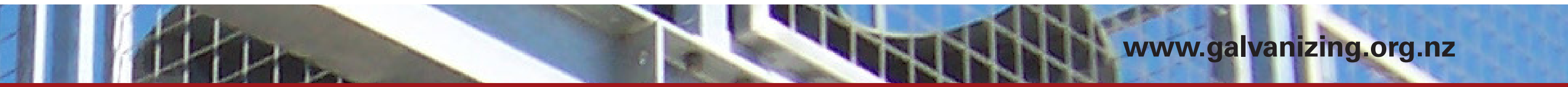
Susceptibility to strain-age embrittlement. Strain-age embrittlement is caused by cold working of certain steels, mainly low carbon, followed by ageing at temperatures less than 600°C, or by warm working steels below 600°C.

All structural steels may become embrittled to some extent. The extent of embrittlement depends on the amount of strain, time at ageing temperature, and steel composition, particularly nitrogen content. Elements that are known to tie up nitrogen in the form of nitrides are useful in limiting the effects of strain ageing. These elements include aluminium, vanadium, titanium, niobium, and boron.

Cold working such as punching of holes, shearing and bending before galvanizing may lead to embrittlement of susceptible steels. Steels in thickness less than 3 mm are unlikely to be significantly affected.

Hydrogen embrittlement. Hydrogen can be absorbed into steel during acid pickling but is expelled rapidly at galvanizing temperatures and is not a problem with components free from internal stresses. Certain steels which have been cold worked and/or stressed, can during pickling be affected by hydrogen embrittlement to the extent that cracking may occur before galvanizing.

The galvanizing process involves immersion in a bath of molten zinc at about 450°C. The heat treatment effect of galvanizing can accelerate the onset of strain-age embrittlement in susceptible steels which have been cold worked.
No other aspect of the galvanizing process is significant.



Recommendations to minimise embrittlement

Where possible, use a steel with low susceptibility to strain age embrittlement. Where cold working is necessary the following limitations must be observed:

1 **Punching**. The limitations specified in AS 4100 and AS/NZS 4680 on the full-size punching of holes in structural members must be observed. Material of any thickness may be punched at least 3 mm undersize and then reamed, or be drilled. Good shop practice in relation to ratios of punched hole diameter to plate thickness, and punch/die diametral clearance to plate thickness should be observed.

For static loading, holes may be punched full size in material up to $\frac{5600}{Fy}$ mm thick where Fy is material yield stress up to 360MPa.

2 **Shearing.** Edges of steel sections greater than 16 mm thick subject to tensile loads should be machined or machine flame cut. Edges of sections up to 16 mm thick may be cut by shearing.

Sheared edges to be bent during fabrication should have stress raising features such as burrs and flame gouges removed to a depth of at least 1.5mm. Before bending, edges should be radiused over the full arc of the bend.

3 **Bending**. Susceptible steels should be bent over a smooth mandrel with a minimum radius 3 times material thickness. Where possible hot work at red heat. Cold bending is unlikely to affect steels less than 3 mm thick.

4 **Critical applications.** It is better to avoid cold work such as punching, shearing and bending of structural steels over 6 mm thick when the item will be galvanized and subsequently subjected to critical tensile stress. If cold working cannot be avoided a practical embrittlement test in accordance with ASTM A143 should be carried out.

Where consequences of failure are severe and cold work cannot be avoided, stress relieve at a minimum of 650°C before galvanizing.

Ideally, in critical applications structural steel should be hot worked above 650°C in accordance with the steelmaker's recommendations.

5 **Edge distances of holes**. In accordance with Australian Standard 4100 'Steel structures', minimum edge distances from the centre of any bolt to the edge of a plate or the flange of a rolled section should be used.

Fatigue strength

Research and practical experience shows that the fatigue strength of the steels most commonly galvanized is not significantly affected by galvanizing. The fatigue strength of certain steels, particularly silicon killed steels may be reduced, but any reduction is small when compared with the reductions which can occur from pitting corrosion attack on ungalvanized steels, and with the effects of welds.

For practical purposes, where design life is based on the fatigue strength of welds, the effects of galvanizing can be ignored.

Fatigue strength is reduced by the presence of notches and weld beads, regardless of the effects of processes involving a heating cycle such as galvanizing. Rapid cooling of hot work may induce microcracking, particularly in weld zones, producing a notch effect with consequent reductions in fatigue strength.

In critical applications, specifications for the galvanizing of welded steel fabrications should call for air cooling rather than water quenching after galvanizing to avoid the possibility of microcracking and reductions in fatigue strength.

Other metallic zinc coatings for steel

Zinc plating should not be confused with after-fabrication galvanizing which applies much heavier coatings providing a correspondingly longer service life. However several grades of plating now exist, ranging up to 100g/m^2 where use in coating systems for automobile and white goods continuous production lines, have become known as electrogalvanizing.

There is in general an economic upper limit to the zinc coating mass which can be applied by electroplating. Zinc plating therefore is normally not recommended for outdoor exposure without supplementary coatings. (refer Table 1 of AS 2309).

Zinc plating is an economic, versatile and effective method of applying a protective coating to small steel components. It is the most widely used method of applying metallic zinc coatings to small fasteners. However, fasteners used with after-fabrication galvanizing should have comparable coating and composition.

Sherardising is a method of zinc coating small, complex steel parts such as fasteners, springs and chain links. The dark grey sherardised coating is hard, abrasion resistant and uniform in thickness over the whole surface of the article.

Mechanical plating or peen plating is an electroless plating method used to deposit coatings of ductile metals onto metal substrates using mechanical energy. It is used to plate zinc onto steel parts, particularly threaded components and close tolerance items.

Zinc spraying or zinc metallising allows coatings of fabricated items which cannot be galvanized because of their size or because coating must be performed on site. Zinc spraying has the advantage that zinc coatings up to 250 μm thick, equivalent to 1500g/m^2 can be applied, by either manual or mechanized methods. The steel surface must be prepared by grit blasting. The resulting zinc coating provides cathodic protection for the underlying steel in the same way as a galvanized coating.

Zinc rich coatings consist of zinc dust in organic or inorganic vehicle/binders. Surface preparation by abrasive blast cleaning is necessary, and coatings may be applied by brush or spray. Zinc rich coatings are barrier coatings which also provide cathodic protection to small exposed areas of steel, provided the steel surface is properly prepared, and the paint conforms to relevant Australian/New Zealand Standards AS/NZS 3750.9 and AS/NZS 3750.15. Suitable zinc rich paint coatings provide a useful repair coating for damaged galvanized coatings.

Preconstruction primers are relatively thin weldable zinc rich coatings used widely for ship building, storage tanks, and similar steel plate constructions, intended for subsequent top coating.

Continuous galvanizing processes. Steel sheet, pipe and wire are continuously galvanized in specially developed galvanizing processes which allow accurate control of coating thickness, ductility and other characteristics of the zinc coating, producing a wide range of products to suit the varying requirements of subsequent manufacturing operations and end usage. Because of the differing process and wide variety of coatings offered, these products should not be confused with after-fabrication galvanizing. In-line products with thinner coatings often require supplementary protection for outdoor exposure.

Zinc coating mass comparisons

The range of zinc coating mass which can be applied efficiently and economically by various zinc coating processes is given below. As the protective life of any zinc coating is proportional to thickness, the figures show that galvanizing has an advantage for many applications in that 600g/m^2 is the normal coating mass on fabricated articles. Heavier coatings can be applied by zinc spraying at greater cost but the coating lacks many of the characteristics of a galvanized coating which is alloyed to the base steel.

Zinc coating mass applied by commercial processes, g/m^2

Zinc plating	Up to 100 g/m^2				
Sheet galvanizing*	40 to 240 g/m^2				
Hot dip galvanizing				300 to 900g/m^2	
Zinc spraying	600 to 1500 g/m^2				
		300	600	900	1200	1500

* Manufacturers of continuous sheet galvanized products quote coating mass as the total coating mass on both sides of the sheet. To provide a valid comparison figures given here are for coating mass on one side only.

Corrosion rates of steel and zinc

Exposure tests by The American Society for Testing and Materials show that panel weight loss – a measure of the rate of corrosion – is much lower for zinc than for steel in a wide range of exposures. Galvanized coatings are consumed at rates between one seventeenth and one eightieth that of steel, so that even in aggressive environments, hot dip galvanizing provides long life.

Corrosion rates, Steel: Zinc

Test panel weight loss in various exposures

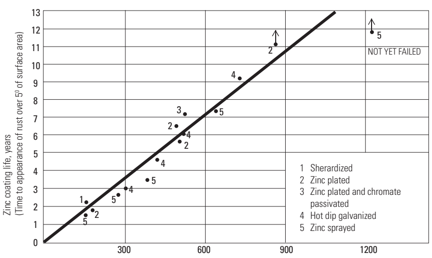
Arid	Pheonix, Arizona	17:1
Rural	State College, Pa	22:1
Light Industrial	Monroeville, Pa	28:1
Industrial	East Chicago, Ill	52:1
Marine	Kure Beach, NC	80:1

Protective life of galvanized coatings

The protective life of a metallic zinc coating on steel is roughly proportional to the mass of zinc per unit of surface area regardless of the method of application. The graph below demonstrates this by the results of tests conducted by British Iron and Steel Research Association at Sheffield Corrosion Testing Station, UK, on different masses of zinc coatings applied by sherardising, zinc plating, galvanizing and zinc spraying.

The graph shows that the period of corrosion protection provided in a given environment is proportional to the mass of zinc in the coating, and that the protective life of a coating is therefore directly determined by the environment to which it is exposed.

Service life test results, various zinc coatings



Note. These test results were obtained in an extremely corrosive environment, and should not be taken as a guide to coating life for applications under normal conditions.

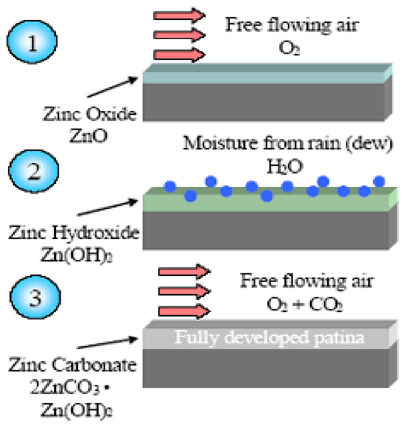
In these severely corrosive conditions galvanized coatings in combination with suitable paint systems provide longer, more economic life than the best alternative systems. Suitable paint systems and applications techniques are described in the section **'Painting galvanized steel'.**

The following notes are offered for general guidance. An indication of the life of a galvanized coating in a particular environment may be given by monitoring the performance of existing galvanized structures; more detailed information on coating life for specific applications is available from your galvanizer.

Barrier Protection

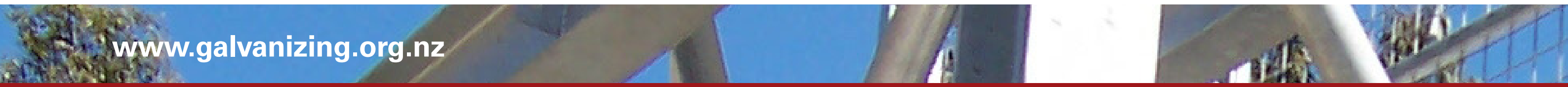
Barrier protection, as its name implies, works by providing an impermeable barrier over the steel item. Galvanizing provides barrier protection in two ways: firstly, the galvanized layer provides a protective physical envelope around the steel; secondly, the galvanized layer also develops a protective **patina** on its surface upon exposure to the environment. This is made up of insoluble zinc oxides, hydroxides, carbonates and basic zinc salts depending on the nature of the environment. Once the patina stabilises, it reduces the exposure of the base galvanized steel to the environment, thus considerably slowing the corrosion process. This patina regenerates itself after damage by very slowly consuming the zinc outer coating.

Once the pure zinc of the outer layer has been consumed, the iron-zinc alloys are exposed to the environment and their corrosion resistance is up to 30% greater, providing even longer life.



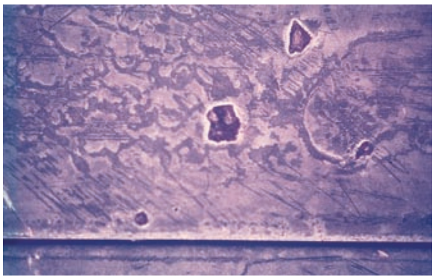
The zinc patina begins its development with exposure to oxygen in the atmosphere. Moisture from rain or humid air reacts with this layer to form zinc hydroxide. This layer then reacts with carbon dioxide present in the atmosphere to form the tightly adherent, insoluble zinc patina.

The barrier protection qualities of galvanized steel are also enhanced by the fact that it is immune to ultraviolet radiation and thus will not degrade on exposure to New Zealand's harsh environment. Most other corrosion protection coatings will degrade on exposure to solar radiation. This is usually one of the key limiting factors to the performance of such coatings.



The problem with conventional barrier protection such as painting is that it will not prevent corrosion if the base steel is exposed due to mechanical impact damage or abrasion. In fact, barrier protection can allow corrosion to proceed undetected. This is known as underfilm corrosion.

In the event of severe mechanical damage and exposure of the base steel to the environment, galvanizing also provides **cathodic protection**. The galvanizing performs in a similar way to other sacrificial protection systems, except in this case the sacrificial anode is distributed over the article to be protected and electrical continuity is assured. The cathodic protection characteristics of galvanizing ensure that mechanical damage does not result in concealed under-film corrosion and potential catastrophic failure prevalent in some other protective coatings. For further information refer to the section on **Cathodic Protection.**



Damaged transmission tower being cathodically protected by its galvanized coating

Performance in various environments

The excellent corrosion resistance of galvanized coatings in the atmosphere and in most natural waters is due to the formation of a protective layer or patina which consists of insoluble zinc oxides, hydroxides, carbonates and basic zinc salts, depending on the environment. When the protective patina has stabilized, reaction between the coating and its environment proceeds at a greatly reduced rate resulting in long coating life.

In the atmosphere

The appraisement of the protective life of a galvanized coating in a particular location must take into account factors such as climatic conditions, the presence in the atmosphere of contaminants introduced by urban or industrial activity, and chlorides in the air due to proximity to the sea. Environments which appear to be generally similar often produce considerable differences in corrosive conditions due to relativity minor variations such as the effects of prevailing winds, proximity to corrosive effluents and general atmospheric conditions.

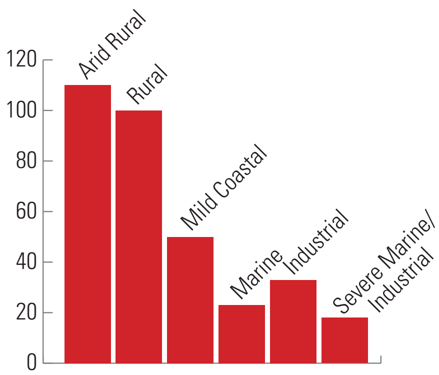
In warm dry atmospheres zinc is very stable. The patina formed during initial exposure remains intact preventing further reaction between the galvanized coating and the air, and protection continues indefinitely.

In the presence of atmospheric moisture the zinc oxide film is quickly converted to zinc hydroxide, and carbon dioxide normally present in the air reacts to form basic zinc carbonates. These stable inert compounds resist further action and ensure long life for the protective galvanized coating.

In rural areas the life of galvanized coatings may be reduced due to the effects of aerial spraying of fertilizers or insecticides. In dry form most fertilizers and insecticides are harmless to zinc coatings but when wetted by rainwater or irrigation spray water, aggressive solutions can be formed which will attack galvanized coatings until washed off by further wetting.

Near the sea coast the rate of corrosion is increased by the presence of soluble chlorides in the atmosphere. The performance of galvanized coatings relative to other protective systems is outstanding however, particularly when used as part of a duplex galvanizing-plus-paint system.

In industrial areas the presence of atmospheric impurities such as sulphurous gases and chemicals results in the formation of soluble zinc salts. These are removed by moisture, exposing more zinc to attack. In light industrial areas galvanized coatings give adequate protection, but in the extremely corrosive conditions of heavy industrial areas it is desirable to reinforce galvanized coatings with a paint system resistant to the prevailing chemical attack.



Anticipated life of 700 g/m^2 (100µm) galvanized coatings in various environments (years)

Galvanized steel test piece has had circular areas of the coating removed before exposure in a severe industrial environment. Sacrificial protection provided by the surrounding zinc coating has prevented corrosion of circles up to 3 mm diameter and minimised corrosion of 5mm circle. Larger circles also exhibit corrosion-free annular areas adjacent to the surrounding coating.

Effect of temperature

Hot dip galvanized coatings will withstand continuous exposure to temperatures of approximately 200ºC and occasional excursions up to 275ºC without any effect on the coating. Above these temperatures there is a tendency for the outer zinc layer to separate, but the alloy-layer, which comprises the majority of the coating, remains. Adequate protection may often, therefore, be provided up to the melting point of the alloy layer (around 650ºC).

Under Water

General. The corrosion rate of zinc under immersed conditions can be high in acidic solutions below pH 6 and alkaline solutions above pH 12.5. Between these limits the rate of corrosion is much lower.

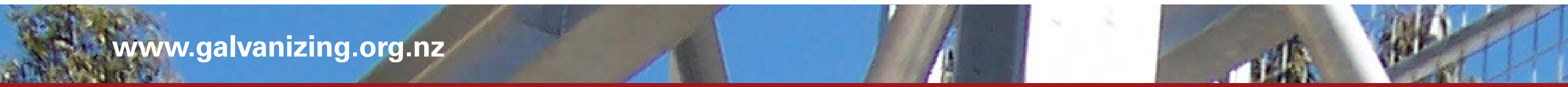
In mains supply water of pH 6 to pH 8, calcium carbonate is normally present and this is precipitated onto the galvanized coating as an adherent calcium carbonate scale, together with zinc corrosion products, forming an impervious layer. When sufficiently dense, this layer virtually stops corrosion of the coating, resulting in very long life in many domestic water systems.

Other factors may interfere with this scale deposition. If the water has a high concentration of uncombined carbon dioxide, the protective scale is not formed and full protection never develops. The characteristics of the water supply should be taken into account in the design of domestic water systems. The presence of even small quantities of dissolved copper of the order of 0.1 parts per million in the water may cause corrosion by rapid pitting as discussed under galvanic corrosion.

In unfavourable waters, galvanized steel may require the added protection of galvanic anodes or suitable paint coatings.

Pure water. When newly galvanized articles are immersed in pure water, such as rainwater, there are no dissolved salts present to form the film of insoluble compounds which normally protects the coating from further action. Where practical this condition can be corrected by the addition to the water of controlled amounts of salts during initial immersion.

Most natural waters contain sufficient dissolved salts to prevent initial attack and galvanized tanks and equipment give excellent service.



Effect of water temperature. In cold water of normal composition galvanized coatings are most effective and the rate of consumption of the coating is very low. This has resulted in almost universal use of galvanized steel for tanks for water storage and transport.

At about 60ºC to 65ºC the rate of corrosion of galvanized coatings increases and continued corrosion resistance depends on early formation of adequate non-flaking scale. Hard water in hot water systems will deposit a scale of calcium and magnesium carbonates on the galvanized surface, nullifying the temperature effect. Soft water may not deposit a protective scale. In such cases galvanized coatings are unsuitable for hot water systems.

Sea water. Galvanized coatings perform relatively well in submerged sea water conditions which are severely corrosive to most protective systems. Dissolved salts present in sea water react with zinc to form a protective layer minimizing corrosive action.

The addition to the galvanized coating of a suitable paint system is recommended in areas of severe sea water exposure, particularly in the splash zone. Such duplex systems provide the best available protective coating for steel in sea water. Suitable paint coating systems are listed in '**Painting galvanized steel**'.

Underground

The corrosion behaviour of buried galvanized steel varies greatly with the type of soil. Knowledge of local conditions is therefore essential in estimating the life of galvanized steel pipes. Generally galvanized steel lasts considerably longer than uncoated or painted steels but performance is best in alkaline and oxidizing soils, where 600g/m^2 galvanized coating will give an additional life of about 10 years to steel pipes. Highly reducing soil is most aggressive and may consume zinc coatings at more than 13 µm per year.

The life of galvanized steel underground is extended by the use of paint coatings, bituminous compounds, tape wraps or concrete encasement.

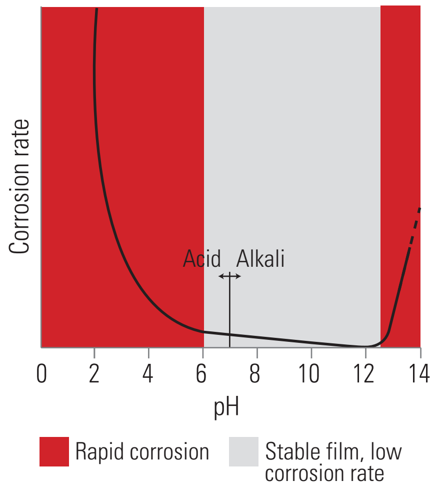
In contact with chemicals

Galvanized coatings are highly resistant to attack over a wide pH range, particularly in moderately alkaline solutions as shown in the diagram below. Unprotected galvanized coatings should not be used with acid solutions below pH 6 or alkaline solutions above pH 12.5.

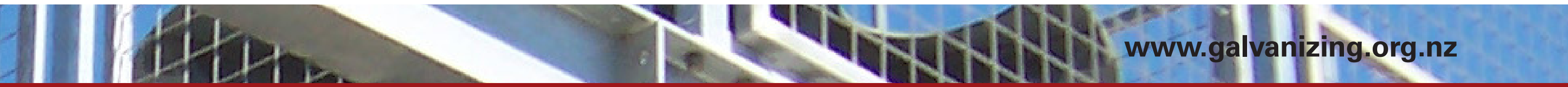
At intermediate values between these limits a protective film is formed on the zinc surface and the coating corrodes very slowly. Since this range covers most types of water and all but the strongest alkalis, galvanized coatings have wide application for storing and conveying liquids.

Most organic liquids, other than those acid, attack zinc only slightly and galvanized coatings are suitable for storage tanks and equipment for handling a wide range of organic chemicals, including motor fuels, creosotes, phenols and esters.

Galvanized coatings are used in refrigeration equipment circulating brine solutions treated with sodium dichromate inhibitor.



In the range pH 6 to pH 12.5 the zinc coating forms a stable protective film and corrosion rate is low.



Compatibility of galvanized coatings with various media

Compatibility of galvanized coatings with various media is summarised in the table below. Further specific information is available from your galvanizer.

Compatibility of galvanized coatings with various media		
Aerosol propellants		excellent
Acid solutions	weak, cold quiescent strong	fair not recommended
Alcohols	anhydrous water mixtures beverages	good not recommended not recommended
Alkaline solutions	up to pH 12.5 strong	fair not recommended
Carbon tetrachloride		excellent
Cleaning solvents	chlorofluorocarbon	excellent
Detergents	inhibited	good
Diesel oil	sulphur free	excellent
Fuel oil	sulphur free	excellent
Gas*	towns, natural, propane, butane	excellent
Glycerine		excellent
Inks	printing aqueous writing	excellent not recommended
Insecticides	dry in solution	excellent not recommended
Lubricants	mineral, acid free organic	excellent not recommended
Paraffin		excellent
Perchlorethylene		excellent
Refrigerants	chlorofluorocarbon	excellent
Sewage		excellent
Soaps		good
Timber preservatives: Copper-chromium-arsenic, After drying is completed Boron	 freshly treated	 poor excellent excellent
Trichlorethylene		excellent

*Chromate passivation is recommended because moisture may be present.

Sewage treatment

Galvanized coatings perform extremely well by comparison with other protective coatings for steel in the severely corrosive conditions prevailing in most sewage treatment operations. As a result galvanized steel is used extensively in sewage treatment plants throughout the world.

Water Reclamation Plant

In contact with building materials

Galvanized coatings give invaluable protection to steel used in all sections of the building industry. The slight etching action upon galvanizing by mortar, concrete and plaster ceases after setting.

When galvanized steel products and fasteners are installed in direct contact with unseasoned timber it may be necessary to protect them by the application of suitable paint.

Care should be taken that galvanized products are stored and transported under dry ventilated conditions as discussed above.

Galvanized lintels

Lake Vasto, WA

In contact with timber preservatives

Timbers freshly treated with acidic preservatives of copper-chromium-arsenic type, such as Celcure, Copas and Tanalith, can be severely corrosive to metallic building materials, including galvanized coatings. Once the timber has dried out the preservatives become fixed, and the performance of galvanized coatings in contact is excellent, even when the timber is again wetted. Galvanized coatings also perform well in contact with boron-treated timbers.

For further information contact GANZ for a copy of "A guide to the service life of galvanizing in the Australian environment".

Transport and storage

New galvanized products should be handled, transported and stored with the normal care given to any other surface-finished building material. New galvanized steel surfaces which have not yet developed the patina of protective insoluble basic zinc carbonates, which normally contributes to the long life of aged coatings, are highly reactive and susceptible to premature corrosion under poor conditions of exposure.

Transport should be under dry, well ventilated conditions. When stored on site, material should be covered where possible and raised clear of the ground on dunnage or spacers. When shelter is not possible material should be stacked to allow drainage of rainwater. Storage in contact with cinders, clinkers, unseasoned timber, mud or clay will lead to surface staining and in severe cases, premature corrosion.

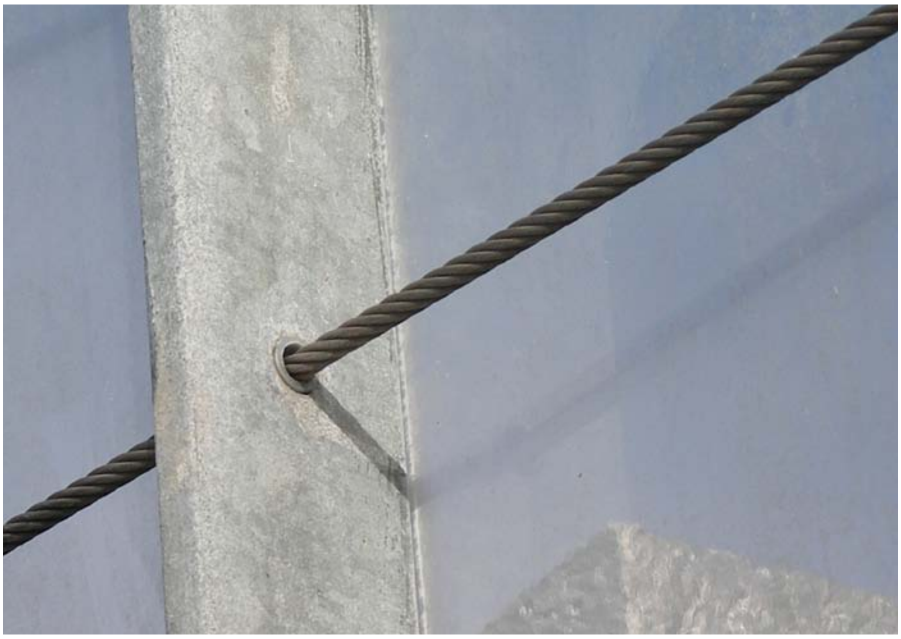
Clearance for ventilation between stacked galvanized products is necessary under damp or humid conditions to avoid the possibility of wet storage stain and the development of bulky white corrosion product. Attack on the galvanized coating producing white corrosion is caused by the retention of condensation or run-off water between the contacting surfaces under conditions of restricted air circulation. The attack is frequently superficial despite the relative bulkiness of the corrosion product but may be objectionable because of appearance. In severe cases corrosion product should be removed to allow the natural formation of protective basic zinc carbonate film.

Where galvanized products are likely to be stored or transported under poor conditions the galvanizer can, on request, apply a simple chromate treatment which will minimise wet storage stain. Under severe conditions chromating should not be relied on and new galvanized products should be packed carefully and protected for shipment and storage.

Continuously galvanized sheet steel products designed for outdoor exposure are normally given a carefully controlled chromate treatment during manufacture. This treatment provides excellent resistance to wet storage staining and against early dulling during initial outdoor exposure. Care should nevertheless be taken to see that sheet and coil is kept dry while awaiting fabrication or erection.

Galvanizing can cope with inappropriate handling.

Bimetallic corrosion



Prevention of bimetallic corrosion in a highly corrosive coastal environment. The stainless steel wire is electrically isolated from the hot dip galvanized balustrade.

Bimetallic or electrolytic corrosion with resulting rapid consumption of the zinc coating is likely if a galvanized article is installed in contact with brass or copper, particularly in a moist environment. Contact between aluminium, cadmium and galvanized surfaces is normally satisfactory.

Bimetallic corrosion occurs for the same electrochemical reasons as those by which zinc provides cathodic protection for steel but the rate of consumption of zinc coatings by galvanic corrosion may be extremely high.

A guide to compatibility of metals and alloys in contact is given in the table on the next page.

Galvanized surfaces in contact

For maximum corrosion resistance under conditions of extreme humidity, overlapping galvanized surfaces should be isolated from each other by the application of an inhibitive jointing compound such as Dulux Foster C1 Mastic or equivalent. Alternatively a suitable paint may be used. Galvanized surfaces in contact with other materials may also require isolation.

Galvanized members in contact with aluminium conductors may require the use of an electrical conductive compound at joint faces to repel moisture and inhibit corrosion. Contact your galvanizer for further information.

Copper and copper alloys

Bimetallic corrosion requires electrical contact in the presence of an electrolyte and cannot occur in the absence of these factors. However, run-off water from copper surfaces frequently contains small quantities of dissolved copper, sufficient to cause attack and rapid deterioration of zinc coatings through chemical deposition of copper.

Where use of copper or brass together with galvanized steel in the presence of an electrolyte cannot be avoided, precautions should be taken to prevent electrical contact between the dissimilar metals. Joint faces should be insulated using non-conducting gaskets or mastics and connections should be made with insulating grommet-type fasteners. The design should be arranged so that water flows from the galvanized surface onto the brass or copper surface and not the reverse.

Galvanic corrosion of galvanized coatings in contact with other metals

Contacting Metal	Environment: Atmospheric exposures: Rural	Industrial/ Urban	Marine	Immersed: Fresh Water	Sea-water
Aluminium and aluminium alloys	0	0 to 1	0 to 1	1	1 to 2
Aluminium bronzes and silicon bronzes	0 to 1	1	1 to 2	1 to 2	2 to 3
Brasses including high tensile (HT) brass (manganese bronze)	0 to 1	1	0 to 2	1 to 2	2 to 3
Cadmium	0	0	0	0	0
Cast irons	0 to 1	1	1 to 2	1 to 2	2 to 3
Cast iron (austenitic)	0 to 1	1	1 to 2	1 to 2	1 to 3
Chromium	0 to 1	1 to 2	1 to 2	1 to 2	2 to 3
Copper	0 to 1	1 to 2	1 to 2	1 to 2	2 to 3
Cupro-nickels	0 to 1	0 to 1	1 to 2	1 to 2	2 to 3
Gold	(0 to 1)	(1 to 2)	(1 to 2)	(1 to 2)	(2 to 3)
Gunmetals, phosphor bronzes and tin bronzes	0 to 1	1	1 to 2	1 to 2	2 to 3
Lead	0	0 to 1	0 to 1	0 to 2	(0 to 2)
Magnesium and magnesium alloys	0	0	0	0	0
Nickel	0 to 1	1	1 to 2	1 to 2	2 to 3
Nickel copper alloys	0 to 1	1	1 to 2	1 to 2	2 to 3
Nickel-chromium-iron alloys	(0 to 1)	(1)	(1 to 2)	(1 to 2)	(1 to 3)
Nickel-chromium-molybdenum alloys	(0 to 1)	(1)	(1 to 2)	(1 to 2)	(1 to 3)
Nickel silvers	0 to 1	1	1 to 2	1 to 2	1 to 3
Platinum	(0 to 1)	(1 to 2)	(1 to 2)	(1 to 2)	(2 to 3)
Rhodium	(0 to 1)	(1 to 2)	(1 to 2)	(1 to 2)	(2 to 3)
Silver	(0 to 1)	(1 to 2)	(1 to 2)	(1 to 2)	(2 to 3)
Solders hard	0 to 1	1	1 to 2	1 to 2	2 to 3
Solders soft	0	0	0	0	0
Stainless steel (austenitic and other grades containing approximately 18% chromium)	0 to 1	0 to 1	0 to 1	0 to 2	1 to 2
Stainless steel (martensitic grades containing approximately 13% chromium)	0 to 1	0 to 1	0 to 1	0 to 2	1 to 2
Steels (carbon and low alloy)	0 to 1	1	1 to 2	1 to 2	1 to 2
Tin	0	0 to 1	1	1	1 to 2
Titanium and titanium alloys	(0 to 1)	(1)	(1 to 2)	(0 to 2)	(1 to 3)

Key

0 Zinc and galvanized steel will suffer either no additional corrosion, or at the most only very slight additional corrosion, usually tolerable in service.

1 Zinc and galvanized steel will suffer slight or moderate additional corrosion which may be tolerable in some circumstances.

2 Zinc and galvanized steel may suffer fairly severe additional corrosion and protective measures will usually be necessary

3 Zinc and galvanized steel may suffer severe additional corrosion and the contact should be avoided.

General notes: Ratings in brackets are based on very limited evidence and hence are less certain than other values shown. The table is in terms of additional corrosion and the symbol 0 should not be taken to imply that the metals in contact need no protection under all conditions of exposure.

Source: British Standards Institution.

Cathodic protection of damaged areas

Where continuity of galvanized coating is broken by cut edges, drilled holes or surface damage, small areas of exposed steel are protected from corrosion cathodically by the surrounding coating. No touch up is necessary, and cathodic or sacrificial protection continues for many years. In service, zinc corrosion product tends to build up in coating discontinuities, slowing the rate at which the surrounding coating is consumed in protecting a damaged area.

Practical examples of this cathodic protection phenomenon include exposed cut edges in galvanized steel roofing and cladding, and the uncoated internal threads of certain fasteners.

In standard building practice cut edges in galvanized sheet are not treated in any way and when failure of the coating finally occurs after long exposure, corrosion normally is relatively uniform across the sheet surface without concentration at edges or fastener holes. Similarly, the uncoated internal threads of large galvanized nuts are protected from corrosion by the zinc coating on mating bolts and studs.

When substantial coating damage has occurred to a galvanized coating during handling, fabrication or erection, coating repairs are necessary.

See '**Reconditioning damaged surfaces in galvanized steel**'.

Comparative properties of coatings*

The following tables provide a useful assessment of the properties and characteristics of various coatings for steel in a range of applications and environments.

	Key	Galvanizing	Paint	Bitumen	Vitreous enamel
Corrosion Protection	(1)	A	B	B	B
Electrochemical protection	(1)	A	D	D	D
Durability in atmosphere	(1)	A	B	C	A
Durability in water	(1)	B	B	A	A
Adhesion	(1)	A	B	B	A
Resistance to damage	(1)	A	C	C	D
Resistance to abrasion	(1)	A	C	C	A
Size limitations	(2)	B	A	A	C
Risk of deformation	(2)	B	A	A	B
Inspection possibilities	(1)	A	B	B	C
Initial costs	(3)	B	B	B	C
Maintenance costs	(3)	A	C	B	A

	Key	Galvanizing	Zinc Spraying	Zinc Plating	Zinc rich paints	Mechanical plating
Alloying with base steel	(1)	A	D	D	D	D
Durability of coating	(1)	A	A	C	C	B
Cathodic protection	(1)	A	A	A	C	B
Resistance to mechanical damage	(1)	A	B	C	C	C
Resistance to abrasion	(1)	A	B	C	C	C
Piece size limitations	(2)	B	A	C	A	C
Risk of deformation	(2)	B	A	A	A	B
Ease of inspection	(1)	A	C	C	C	C
Initial costs	(3)	A	B	C	B	B
Maintenance costs	(3)	A	A	D	B	C
Suitability for painting	(1)	B	B	B	B	B

Key

1 **A** Very good
B Good
C Poor
D Very poor

2 **A** None
B Little
C High
D Very High

3 **A** Very Low
B Low
C High
D Very High

* R. Thomas, 1980 (modified).

Galvanized coatings for buildings and structural steel

A vital factor to be taken into account in the assessment of coating systems for buildings and structural steel is the relative effectiveness of coatings. No protective coating applied to a structure after completion can provide the same protection as a galvanized coating which covers the entire surface of all components, automatically protecting areas to which later access may be difficult or impossible.

When steel members, fascias and other components which are to receive a final decorative or protective coating are galvanized, no surface deterioration will occur during storage, handling, erection or waiting time until completion of the project. Galvanized coatings can save considerable time and cost which might otherwise be necessary for rectification of damaged or corroded surfaces.

Exposed frame structures. Open frame industrial steel structures which are not protected by roofing or cladding are particularly vulnerable to corrosion. Normally they are sited in industrial areas and frequently, maintenance access is difficult.

In these circumstances no other coating system matches the economy/performance of galvanized coatings. Even in the most severe atmospheres a duplex system of galvanizing-plus-paint will usually provide the best practical balance between cost and the longest possible maintenance-free operating period. The galvanized coating provides a stable base for the paint film, ensuring far longer coating life, and film may be damaged through impacts or abrasion in service.

Internal steelwork in industrial buildings. Galvanized coatings are ideal for many structures which house industrial processes; in structures where the humidity of contained air is high, as in breweries, paper manufacture and sewage treatment; and in food processing and other areas where cleanliness is essential. Whether used alone or in combination with paint coatings as discussed above, galvanized steel will provide very low total long term cost, with longer maintenance-free service periods.

Galvanized lintels or arch bars

Once rusting begins in a lintel or arch bar, it cannot be stopped. The exposed surface may be repainted but there is no treatment for concealed areas.

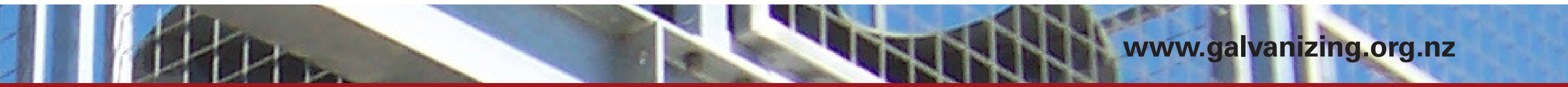
The advance of corrosion may continue until the expansion of steel corrosion products causes cracking of brickwork and ultimately, serious structural damage. In the paper 'Arch bars and angle lintels for brick walls' Australia's Department of Housing and Construction Experimental Building Station points out that:

'Arch bars and angle lintels are vulnerable to corrosion. Cracking of brickwork because of the build-up of rust is very common and is a more serious consequence of corrosion than is the deterioration of the lintel itself. However, hot-dip galvanizing (zinc coating) is so readily available that it could well be adopted as standard practice for all arch bars…'

Galvanizing provides practical, economic protection for lintels in all external applications and is particularly valuable near the sea coast.

Galvanized lintels are widely available in stock lengths and sections coded to user needs.

Galvanized lintels



Reliability of coatings for steel

Protective coatings for steel are normally compared on the basis of coating life, first cost, and total long term cost. The 'reliability factor' of a coating should also be taken into account since it is crucial in determining the extent to which the apparent properties of a coating will be realised in practice, and hence the relative economics of the coating.

The reliability factor of a coating may be defined as the extent to which its optimum complex of physical-chemical and mechanical characteristics can be consistently realised during and after application.

There are numerous paint systems for steel and a wide range of possible specification and application variables. Together these variables can substantially reduce the performance of a given system and therefore its economics. By contrast, the galvanizing process is simple, standardised and virtually self-controlling, governed mainly by the laws of metallurgy. As a result it is inherently reliable and predictable.

The following table summarises factors determining reliability of typical paint systems for steel, and for galvanizing. The reliability factor for galvanizing is shown to be superior, mainly because it is not influenced by most of the variables which can reduce the ultimate performance of typical paint systems.

A more detailed evaluation of these factors is contained in the paper "Reliability of hot dip galvanizing, compared with two paint systems and a duplex system' by Ing JFH van Eijnsbergen, available from GANZ.

Factors determining protective coating system reliability

An analysis of variables which determine the extent to which apparent properties of a coating system will be realised in practice. Draws on data from Australian Standard 2312 'Guide to the protection of iron and steel against exterior atmospheric corrosion'.

Variable	Paint systems - inorganic zinc, organic zinc, chlorinated rubber etc	Galvanizing
Nature of steel	No effect	High silicon steels may increase coating thickness by 2 to 3 times, give rough surface finish, may result in brittle coatings.
Surface preparation	AS 2312 recommends abrasive blast cleaning or acid cleaning, rather than flame cleaning or wire brushing. Inadequate grit blasting can reduce paint durability 60 to 80%. Inadequate degreasing and rinsing can reduce life by a factor of 4. Inspection procedures are critical.	Degreasing, acid cleaning and rinsing are part of the galvanizing process. The steel surface must be properly prepared, otherwise no coating will form.
Process variables	Accurate formulation, careful mixing, continued agitation, correct thinning can be critical.	The minor variations possible in the galvanizing process have minimal effect on coating integrity.
Application	Coating build and uniformity variable with method of application, eg spray, airless spray, brush or roller. Inspection at each stage is critical. Highly reactive blast-cleaned surfaces must be painted within hours.	Formation of coating during immersion is automatic, governed by laws of metallurgy.
Application conditions:		
1. Temperature	Satisfactory results may be difficult to achieve at certain air temperatures.	Process not affected.
2. Humidity	Dew and surface condensation prevent painting. Painting should not proceed when relative humidity exceeds 85%.	Process not affected
3. Air quality	The presence of steam, fumes, exhaust gases, dust and grit are detrimental to good painting.	Process not affected
4. Hot surfaces	High steel surface temperatures (eg painting in the sun) may interfere with paint application and curing.	Not applicable
5. Uniformity of application	Paint film thins out at sharp corners and edges. Bolt holes generally not protected. Paint may not penetrate narrow gaps. Shadowed areas may receive less paint build.	Total coverage obtained by submersion of article in molten zinc. Coating is usually 50% thicker on sharp corners and edges.
Coating Thickness	Critical to coating performance. Variable with number of coats and application method. Inspection and checking necessary at each stage.	Reaction between molten zinc and steel surface guarantees a standard minimum coating thickness. Mass and thickness of steel influences coating thickness (thicker steel = thicker zinc).
Coating adhesion	Depends on surface preparation, paint system type, time from surface preparation to first coat, curing time between coats.	Coating is bonded metallurgically to base steel.
Inspection	Imperative after surface preparation and at every coating stage to ensure quality. Thickness testing required.	Normally visual inspection and magnetic thickness testing after completion.
Curing time	Ranges from hours to days for safe handling, depending on paint system and application conditions, and up to several weeks to full coating hardness.	Coating is completely solidified within seconds of withdrawal from galvanizing bath.
Dimensional stability	Not affected	Process may relieve locked-in stresses if incorrect design, fabrication and welding techniques are used.
Transport and erection damage	Possible damage in handling and transport	Unlikely. Coating is tough and abrasion resistant. Delta alloy layer of coating is harder than base steel.
Welding damage	Extent of damage dependent on coating system. May require full surface preparation	Localised damage may need repair. Restoration with organic zinc rich paint is general practice.

CHAPTER 2

Design, Specification & Inspection Of Galvanized Products

CONTENTS

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OTHER CHAPTERS

GALVANIZING ASSOCIATION

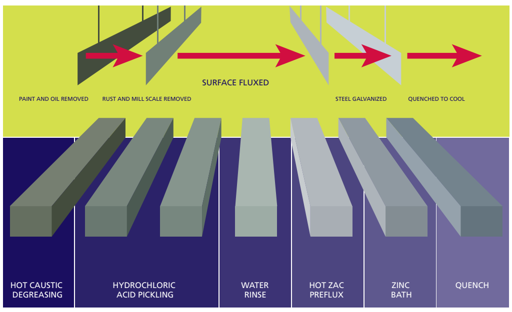
Design, Specification & Inspection of galvanized products

Consistently good galvanized steel products will be produced when the essential requirements listed are incorporated at the design and fabrication stages of production. **Design features should be discussed with the galvanizer. Close liaison between design engineer, materials engineer, specifier, fabricator and galvanizer will ensure high quality galvanized products, minimum cost and faster delivery.**

Galvanizing fundamentals

Hot dip galvanizing is an immersion process where steel sections and fabrications undergo the following operations:

1. **Hot caustic degreasing** (removal of oil, organic materials, selected mill primers and paint)
2. **Hydrochloric acid pickling** (removal of rust and mill scale)
3. **Rinsing** (removal of pickling acid residues)
4. **Prefluxing in zinc ammonium chloride solution** (surface conditioning)
5. **Hot dip galvanizing** (at 450-460°C)
6. **Quenching** (passivation of the zinc surface to prevent early oxidation)
7. **Surface clean up & inspection.** (eg. deburring)



Design considerations

Protection against corrosion begins on the drawing board. No matter what corrosion protection system is used, it must be factored into the design of the product.

Once the decision has been made to use hot dip galvanizing to provide corrosion protection for steel, the design engineer should ensure that the pieces can be suitably fabricated for high quality galvanizing. Adopting the following design practices will ensure the safety of galvanizing personnel, reduce coating cost, and produce optimum quality galvanizing.

It must be remembered that the process involves dipping in molten metal at 450°C and this can have effects on the material being processed or can be extremely hazardous to workers if there is any danger of molten metal being thrown out of the bath. Molten zinc and all processing solutions must be able to enter and drain from fabrications without difficulty and this may require additional holes for venting and draining.

If you have additional questions regarding design requirements, your galvanizer can provide the desired information.

Hot dip galvanizing is a self inspecting process that relies heavily on proper design of the steelwork to achieve a quality result.

- The zinc will not react with the steel to form the galvanized coating unless the surface of the steel is perfectly clean. Good design ensures this will occur.
- The hot dip galvanized coating will not form unless the zinc can intimately contact the steel surface
- The hot dip galvanized coating will not form unless the steel is heated to about 440°C
- Steel items to be processed must fit into the preparation tanks and galvanizing bath. This is not limited to the physical vessel dimensions but that space which results from double end dipping techniques, which normally meet the permissible road transport dimensions

Double end or depth dipping is a term used to describe the process of galvanizing an item which is longer or deeper than available bath dimensions. In this procedure the item is lowered into the bath so that half or more of its length or depth is immersed in the zinc bath. When the zinc coating has been achieved, the item is raised from the bath and adjusted in handling so that the ungalvanized part can be immersed in the bath. It should be noted that in this procedure an overlap of zinc coating will occur and this may have to be addressed in the case of visually obvious structural elements that require an aesthetic finish.

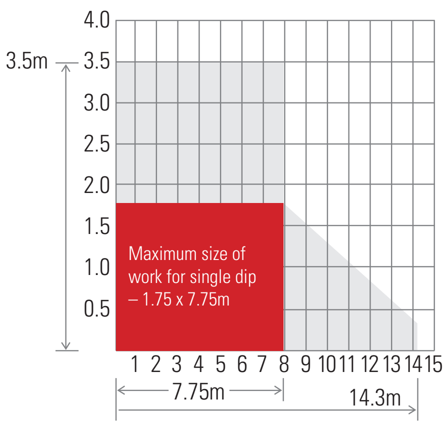
Guidance in these cases should be sought from the galvanizer.

Size and shape

Facilities exist to galvanize components of virtually any size and shape, depending on the handling facilities and layout of the galvanizing plant. Large cylindrical objects can often be galvanized by progressive dipping.

The chart below shows the dimensions of work that could theoretically be galvanized by double-end dipping in (for example) a bath 8m long x 2 m deep, assuming that the width of the work also suits the bath.

Schematic indication of double-end dipping capacity of a galvanizing bath 8 metres long x 2 metres deep



3.5m = Maximum size of work which can be coated by double-end dipping for excess depth: 3.5m x 7.75m

14.3m = Maximum size of work which can be coated by double-end dipping for excess length – up to 14.3m

The chart shows that a bath nominally 8m long x 2m deep could process work 7.75m x 3.5m, or long components of up to about 14m. *Note that the above chart is purely indicative and similar charts can be prepared for baths of different dimensions.* The maximum sizes which a particular galvanizer can process should always be checked at the design stage.

Modular design

Large structures are also galvanized by designing in modules for later assembly by bolting or welding. Modular design techniques often produce economies in manufacture and assembly through simplified handling and transport.

Weld areas in structures assembled by welding after galvanizing must be repaired to give corrosion protection equivalent to the galvanized coating as described under **Reconditioning damaged surfaces in galvanized steel.**

The size and shape of large or unusual structures should always be checked with the galvanizer early in the design process.

Materials suitable for galvanizing

Most ferrous materials can be galvanized. Mild and low alloy steels and iron and steel castings are all regularly and successfully galvanized. Steel fabrications which incorporate stainless steel parts and fittings are also readily galvanized.

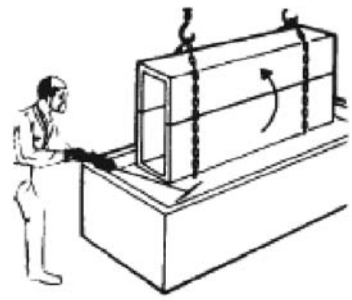
Soft-soldered assemblies or those with aluminium rivets cannot be galvanized. Brazed assemblies may be galvanized, but the galvanizer should be consulted at the design stage.

Castings. The galvanizing of sound stress-free castings with good surface finish will produce high quality galvanized coatings. The following rules should be applied in the design and preparation of castings for galvanizing:

1. Design for uniform section thicknesses wherever possible.
2. Use large radii at junctions with webs, fillets and raised features such as cast-in part and pattern numbers.
3. Avoid deep recesses and sharp corners.
4. Large grey iron castings should be normalised by the fabricator.
5. Castings should be abrasive blast cleaned by the fabricator to remove foundry sand and surface carbon. Alternatively castings may be cleaned electrolytically using the Kolene process.

Combinations of ferrous materials and surfaces. There may be appreciable variation in the pickling times of various ferrous metals and differing surface conditions. Fabricated assemblies containing a mixture of materials and surfaces such as a combination of castings with other steels, or new or machined steel surfaces with rusted or scaled steel surfaces, must be abrasive blast cleaned to minimise differences in pickling time.

Omission of abrasive blast cleaning will result in combined under- and over-pickling of the different surfaces, producing galvanized coatings of inconsistent appearance.



Double-end dipping for excess depth

Double-end dipping for excess length

Heavy mill scale on rolled steel surfaces should be removed by abrasive blast cleaning before galvanizing.

Thicker than normal galvanized coatings are produced when abrasive blast cleaned surfaces are galvanized as discussed in **Factors influencing coating thickness.**

Steel pipe for fabrication of galvanized assemblies should be specified by the fabricator when ordering from the merchant as 'Not oiled or painted'. Manufacturers produce steel pipe with clear varnish or black bituminous coatings which are by design extremely resistant to chemical removal and necessitate expensive manual stripping before pickling to ensure satisfactory galvanizing.

Heavy gauge seamless pipe must also be clearly specified in the unoiled, unpainted condition when ordering.

Weld areas. Due to the silicon content of some welding rods, weld areas may produce localised grey coatings when galvanized. The galvanized coating is likely to be slightly thicker in these areas and will have no detrimental effect on coating life.

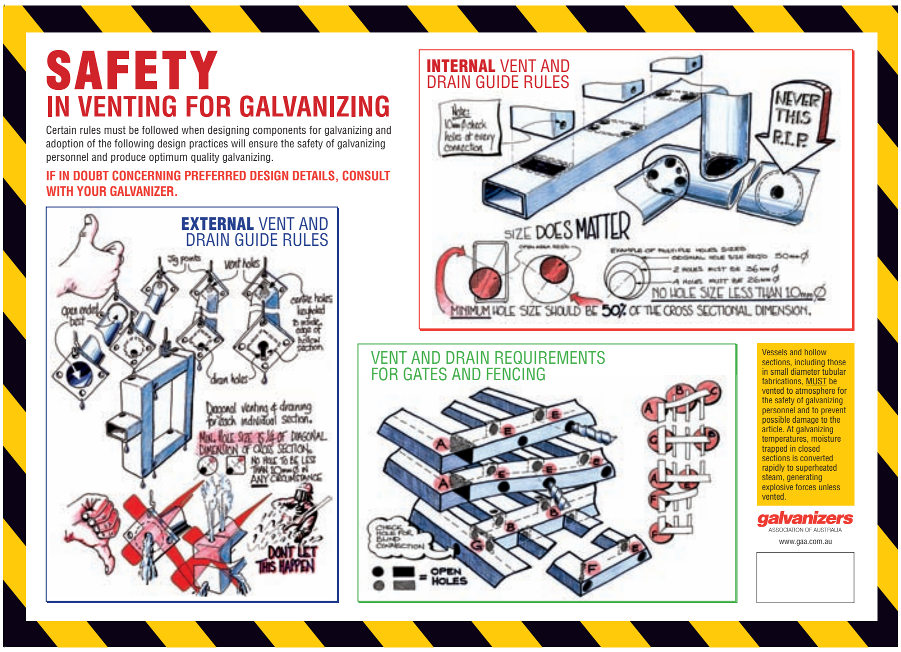
The development of grey coatings due to silicon steels is entirely related to steel composition and cannot be controlled by the galvanizer. Even when these weld areas are ground flush prior to galvanizing, heavier grey coatings may still result. Low silicon welding rods can be used to reduce this effect.

Welding slags. Arc welding slags are chemically inert in acid cleaning solutions and must be mechanically removed before articles are delivered to the galvanizer. The fabricator should remove these by chipping, wire brushing, flame cleaning, grinding or abrasive blast cleaning.

Welding electrode manufacturers supply general purpose electrodes coated with fluxes which produce virtually self-detaching slags and their use is recommended.

Good joint design with adequate access facilitates the welding process to produce sound continuous welds, avoiding locked-in slag, and easing slag removal.

Design and fabrication of components for galvanizing



New Safety in Venting for Galvanizing A1 Poster available from GANZ.

Safety

Vessels or hollow structures which incorporate enclosed sections must have provision for adequate venting during galvanizing. At galvanizing temperatures any moisture present in closed sections is rapidly converted to superheated steam, generating explosive forces unless adequately vented to the atmosphere. **For the safety of galvanizing personnel, equipment and the work being galvanized, it is essential that venting is provided.**

Correct venting ensures that the entire internal surface of work is properly galvanized and fully protected. This also ensures that lighter items will not float in the zinc bath due to trapped air pockets

Closed vessels which are not to be galvanized inside, such as certain types of heat exchanger, must be provided with snorkel-type vent pipes long enough to project above the level of pickling, fluxing and galvanizing baths when the work is fully immersed. The exact venting requirement should be discussed with the galvanizer.

Venting, filling and draining

Basic venting rules

(Note: the bigger the holes the better)

1. No vent hole should be less than **10mm** in diameter unless otherwise agreed with the galvanizer
2. Preferred **minimum** vent hole size is **12mm**
3. Vent holes should not be located in the centre of end plates and connections
4. Vent holes should be located at the edges of hollow sections oriented in the same plane as the fabrication
5. 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
6. Hollow sections (pipe, RHS, and SHS) 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
7. 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
8. 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 an undesirable design for galvanizing or corrosion protection in general
9. 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.

Adequate hole sizes in sealed hollow sections in the correct locations ensure galvanizing quality

Basic draining rules

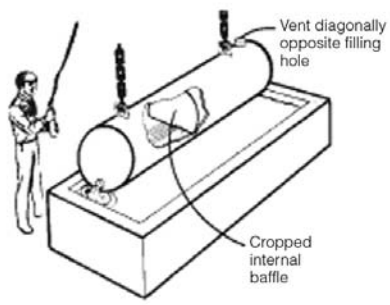
- No drain hole should be less than 10mm
- Preferred minimum drain hole size is 25mm particularly for items with a large internal volume
- Large hollow sections (tanks, pressure vessels) require a 10,000mm^2 diameter of drain hole area for each cubic metre of enclosed volume
- Drain holes should be at the edges of hollow sections
- Hollow sections such as tube, RHS and SHS require minimum drain hole area equivalent to 25% of the section' diagonal cross section. The preferred design option is to leave the ends of tubes, RHS and SHS open

Tanks and closed vessels

As illustrated, design must allow for pickle acids, fluxes and molten zinc to enter, fill and flow upwards through the enclosed space and out through an opening at the highest point so that no air is trapped as the article is immersed. The design must also provide for complete drainage of both interior and exterior details during withdrawal.

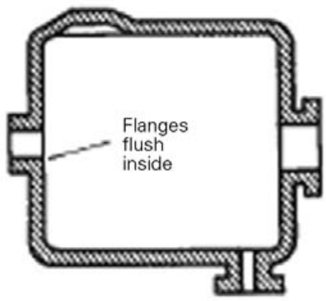
A vent hole of equal dimensions should be provided diagonally opposite the filling hole to allow the escape of enclosed air and to facilitate draining.

Tanks and closed vessels should have at least one filling/draining hole with a vent diagonally opposite.



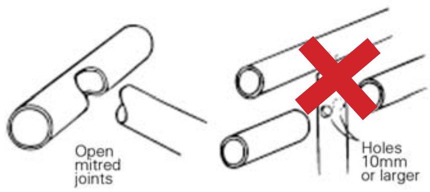
Internal baffles in tanks should be cropped on the bottom and top or provided with suitable drainage holes to permit free flow of molten zinc and air venting. Access ports, bosses and openings should be finished flush inside.

Openings should finish flush inside and should be positioned so that all pickle acid and molten zinc can be drained out during the galvanizing operation.



Hollow structurals and fabricated columns

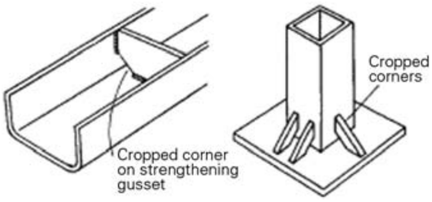
Closed sections must never be included in tubular fabrications. Vent holes at least 50% of internal diameter or diagonal dimension and a minimum of 10 mm diameter should be provided by the fabricator at locations agreed with the galvanizer.



All welded sections in fabricated pipe work should be interconnected with open tee or mitre joints. Alternatively each closed section must be provided with a vent hole of not less than 10 mm diameter with an external viewing hole to confirm the venting is appropriate. Pipe ends or flanges should always be left open, or provided with removable vent plugs.

Closing of unwanted vent holes.
Small vent holes which are necessary for galvanizing but not wanted in the finished job may be closed by hammering in lead plugs after galvanizing and filing off flush with surrounding surfaces, or by the use of threaded plugs. Threads may need re-tapping after galvanizing.

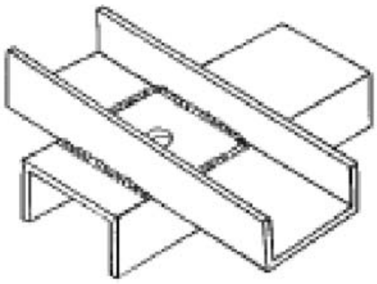
Welded strengthening gussets on fabricated columns and strengthening gussets in members fabricated from channel sections should have corners cropped to allow free flow of zinc during galvanizing as illustrated.

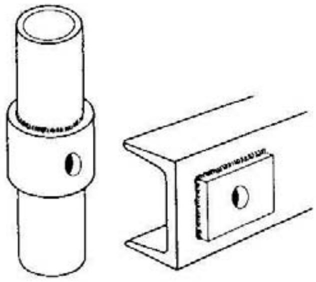


Overlapping surfaces. Narrow gaps between plates and in particular, overlapping surfaces and back-to-back angles and channels should be avoided. As discussed under **Design and fabrication of components for galvanizing - 'Safety'**, any pickle acid or rinse water trapped in narrow gaps between members is rapidly converted to superheated steam at galvanizing temperatures, with the possibility of an explosion.

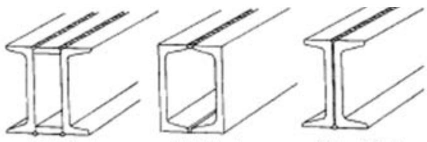
Where small overlapping areas are unavoidable, edges should be sealed after consultation with the galvanizer, by a continuous pore-free weld to prevent penetration of pickle acid. For the safety of galvanizing personnel the sealed area **must** be provided with a vent hole for every 10,000 mm^2 of sealed area according to the following table:

Steel plate thickness	Vent hole size
Up to 6 mm	At least 10 mm diameter
Over 6 mm	Hole diameter to be 10 mm or greater

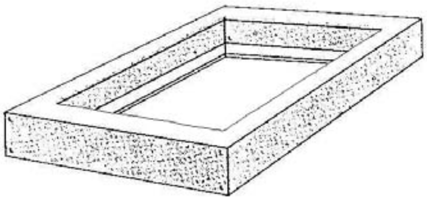




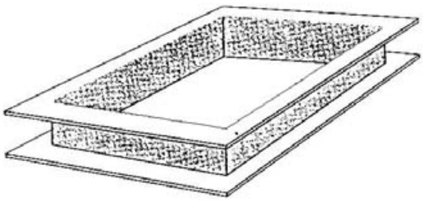
Back-to-back channels should be avoided. C below is potentially dangerous because of the risk of explosion.



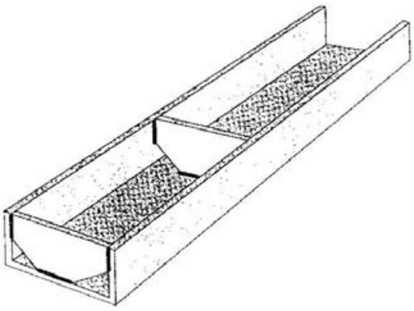
Some basic design and venting recommendations



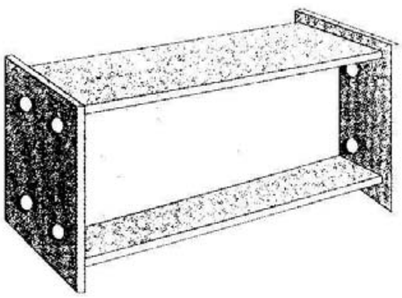
Channel frames require at least four and preferably eight vent/drain holes using conventional design.



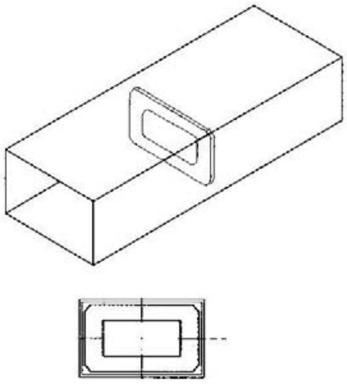
By using outward facing channels, no special venting or draining provisions are required.



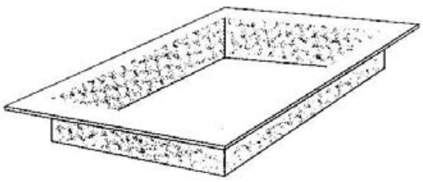
Gussets and stiffeners should be cropped prior to assembly for good drainage.



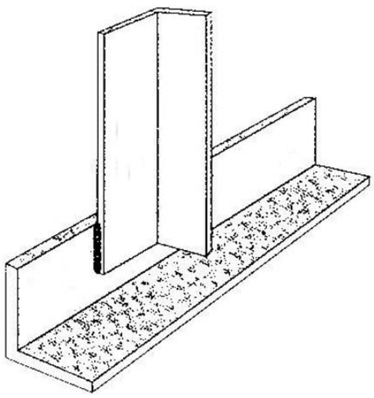
End plates should have vent/drain holes in the corner(s) of the connecting angle, channel or beam.



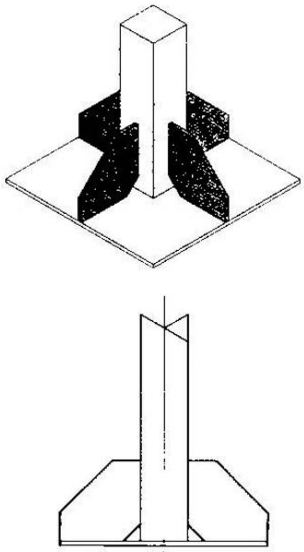
In fabricated box sections, internal diaphragms should be corner cropped and if possible have a central hole.



Outward facing angles and channels in fabricated frames reduce venting and drainage problems.



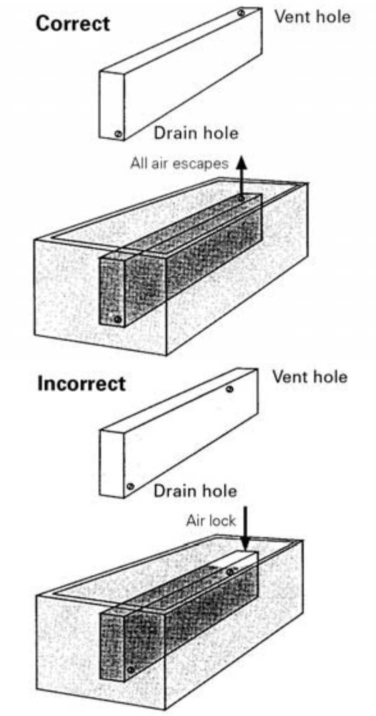
Terminating bracing short of adjacent flanges will allow free flow of zinc through the connection and eliminate pockets in service.



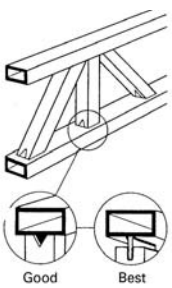
Gussets to base plates should be corner cropped.

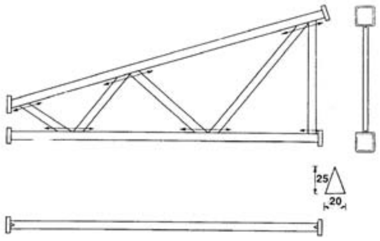
NOTE: Water, process solutions and molten zinc enter hollow sections during fabrication or during the galvanizing process. If the drain holes are not located at the lowest point on both sides in the fabrication:

- Process chemicals will be trapped internally and cause an explosion hazard when immersed in the molten zinc
- Zinc will be trapped internally and will freeze in the undrained area. This may interfere with assembly, it will add to the weight of the item in service and it is a waste of zinc which adds to the cost of galvanizing.

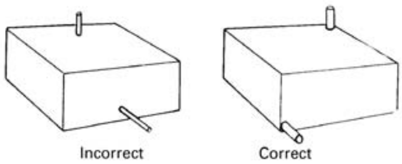


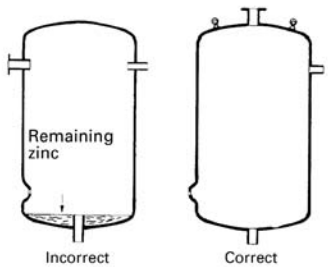
Vent and drain holes must be located as close to the high and low points of the hollow section as possible to prevent air locks, entrapment of pre-treatment chemicals and zinc puddling.





In welded structures venting holes must be inserted at all junctions. The holes must enable the zinc to run in and out freely. Closed tubes incur the risk of explosion!





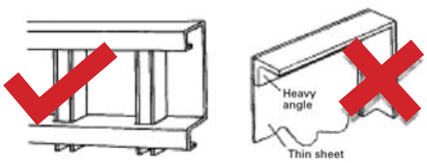
Inwardly projecting pipe connections prevent containers from being completely emptied of zinc and flux. Locate pipe connections near corners and diagonally. It will also be easier for the zinc to run out if the pipe connections are not too small. On large containers lifting eyes should be applied for easier handling.

Dimensional stability

In certain cases, fabricated assemblies may be liable to loss of shape at galvanizing temperatures due to the release of stresses induced during manufacture of the steel and in subsequent fabricating operations. These stresses may be compounded by bad design incorporating unequal thicknesses or non-symmetrical sections. Observance of the following recommendations will improve dimensional stability:

1. Avoid designs which require double-end dipping to fit into the galvanizing bath. It is preferable to build assemblies and sub-assemblies in suitable modules so that they can be immersed quickly and fully in a single dip.
2. Use symmetrical sections in preference to angles or channels.
3. Use sections of near equal thickness at joints.
4. Bend members to the largest acceptable radii.
5. Accurately preform parts to avoid force or restraint during joining.
6. Continuously weld joints if possible using balanced welding techniques to reduce uneven thermal stresses. Balanced, staggered welding is permissible. For staggered welding of material of 3 mm and lighter, weld centres should be closer than 100 mm.
7. Design castings to conform to the rules listed under **Materials suitable for galvanizing – Castings**. Large grey iron castings should always be normalised by the fabricator and then abrasive blast cleaned prior to galvanizing.

Advice on design to minimise distortion is available from the galvanizer.

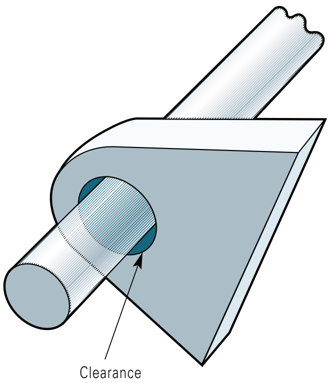


Use of symmetrical sections minimises distortion during galvanizing. Avoid combinations of thick and thin materials. Such designs should preferably have the items galvanized separately and then bolted together.

Clearance for moving parts

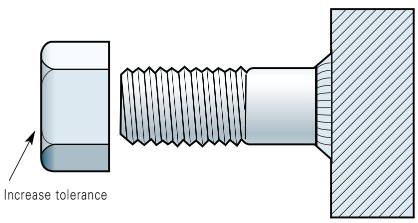
Moving parts such as drop handles, hinges, shackles and shafts must incorporate minimum radial clearances as detailed below:

Shaft or spindle size	Minimum radial clearance
Up to 10 mm diameter	1.0 mm
10 to 30 mm diameter	2.0 mm
Over 30 mm diameter	2.5 mm



Galvanized threads

When assemblies to be galvanized incorporate threaded components, the tolerance normally allowed on internal threads must be increased to provide for the thickness of the galvanized coating on external threads. Standard practice is to tap nuts oversize after galvanizing, according to figures in the table under **Oversize tapping allowances for galvanized nuts** (listed in the Bolting galvanized steel section).



Nuts for galvanized studs must be tapped oversize. The galvanized coating on the stud provides corrosion protection for the internal thread.

Bolted assemblies should be presented for galvanizing in the disassembled condition. Nuts and bolts or studs for galvanizing should also be supplied disassembled.

When internal pre-tapped threads included in components are required not to be galvanized they may be plugged temporarily by means of bolts or studs screwed fully in, after discussion with the galvanizer.

For safety reasons, high strength bolts must not be welded to galvanized structures for use as high strength studs. Galvanized bolts and the bolting of galvanized structures are discussed in detail in the **Bolting galvanized steel** section.

Handling parts for galvanizing

Parts may require suspension holes if there is no convenient point to attach a jig or hook. No special requirements apply if the work can be handled by chains, baskets, tongs or racks. Your galvanizer will advise of necessary provision to suit the handling equipment available.

Large pipe sections, open top tanks and similar structures may require cross stays to maintain the shape of the article during handling and galvanizing.

Marking for identification

For temporary identification, water soluble paints or paint markers can be used. There are a wide variety of pens that can be used in such applications, for example Pentel Paint Marker XMMP20. Oil-based paints should not be used as they must be removed manually before galvanizing.

For permanent identification intended to remain legible after galvanizing, the fabricator should provide heavily punched or embossed figures (indentation depth of 0.8 – 1 mm) either on the work or on steel (not aluminium) tags wired to the work.

Design for maximum corrosion protection

Galvanized coatings provide outstanding corrosion protection for steel. Treatment of design details in accordance with good corrosion design practice as discussed below will further increase the life of galvanized steel fabrications.

Many of the design requirements for good galvanizing detailed earlier, such as the provision of flush-finished internal flanges in tanks and vessels will also ensure good drainage in service and optimum corrosion resistance.

Fabricated assemblies should be designed to eliminate undrained areas which will collect water and sediment in service, producing localised corrosion pockets. The following rules should be followed:

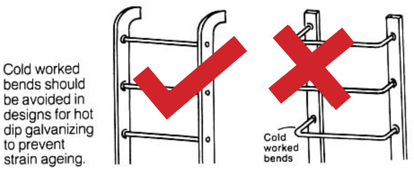
1. Use butt welds in preference to lap welds.
2. Where lap welds are used face joints downwards to avoid collection of moisture and sediment.
3. Avoid use of horizontal boxed sections, ledges, seams and flat undrained areas.
4. Use rounded internal corners rather than squared corners in vessels and containers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

Galvanizing design aids

As an aid to designers and specifiers, the Association publishes and distributes free of charge the colour wall chart 'Design for Galvanizing' and 'Safety in Venting for Galvanizing'. Contact GANZ

Metallurgical aspects of design

The galvanizing process has no effect on the mechanical properties of the structural steels commonly galvanized. In susceptible steels the galvanizing process may accelerate the onset of strain ageing which, with ageing, would occur naturally due to earlier cold working operations.



Strain ageing can be avoided by the use of non-susceptible steels, or when susceptible steels must be used, by adopting the procedures specified in relevant standards, as discussed in more detail under **Mechanical properties of galvanized steels.**

Minimum edge distances for holes in structural members

In bolted connections minimum edge distances from the centre of any bolt to the edge of a plate or the flange of a rolled section should be used as specified in the table below, taken from the Australian Standard 4100 'Steel structures'.

Sheared or hand Flame-cut edge,	Rolled plate, machine flame-cut, sawn or planed edge flat bar or section,	Rolled edge of a rolled flat bar or section
$1.75d_f$	$1.50d_f$	$1.25d_f$

NOTE. Edge distance may also be affected by clause 9.3.2.4, AS 4100

Inspection of work before despatch to the galvanizer

Fabricated assemblies, castings and other components for galvanizing should be inspected before despatch to the galvanizer to ensure that the following points conform to design requirements detailed earlier. This may avoid costly rectification and delays at the galvanizing plant.

Size and shape. Check that work is suitably sized and dimensioned for the handling and galvanizing facilities of the selected galvanizer. It may be too late to make changes to the design, but it is costly to despatch work which the galvanizer cannot process.

Structural steel. Check that bending, punching and shearing have been carried out in conformity with the recommendations under **Embrittlement**.

Satisfactory galvanizing

Observance of the points listed below and described in more detail previously in this section will ensure optimum galvanized product quality and minimise extra costs or delays:

1. Check that closed vessels and hollow structures are vented for safety and satisfactory galvanizing.
2. Check that welding slags have been removed.
3. Check that assemblies comprising castings and steels of widely differing surface conditions have been abrasive blast cleaned to minimise differences in galvanized finish.
4. Check that castings are abrasive blast cleaned before despatch unless otherwise arranged. Check that large grey iron castings have been normalised.
5. Check that appropriate temporary or permanent markings are provided.

Standards for galvanized products

Coating reinstatement

Areas of significant surface that are uncoated shall, by agreement between the purchaser and the galvanizer, be reinstated by following the recommendations contained in AS/NZS 4680 - Repair after Galvanizing, or by other methods nominated by the galvanizer and approved by the contractor. Similar repair methods shall be used for areas damaged by welding or flame cutting, or during handling, transport and erection.

The size of the area able to be repaired shall be relevant to the size of the object and the conditions of service but shall normally be in accordance with the provisions of AS/NZS 4680 - Repair after Galvanizing.

SWEEP (BRUSH) BLAST CLEANING OF GALVANIZED STEEL PRIOR TO PAINTING

Refer AS/NZS 4680 Appendix I

GENERAL INFORMATION ON FACTORS THAT AFFECT THE CORROSION OF GALVANIZED STEEL

Refer AS/NZS 4680 Appendix H

Galvanized products should be specified in accordance with the appropriate national standards, which have been drawn up to provide minimum standards to ensure optimum performance of galvanized products and to give guidance in selection, application, and design.

AS/NZS 2312 'Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings' is a particularly valuable reference in the selection of the most practical, economic coating in particular applications.

Relevant Australian standards

AS/NZS 4680	Hot dip galvanized (zinc) coatings on fabricated ferrous articles.
AS 1214	Hot dip galvanized coatings on threaded fasteners.
AS 2309	Durability of galvanized and electrogalvanized zinc coatings for the protection of steel in structural applications – Atmospheric.
AS/NZS 2312	Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings.
AS 2331.1.3	Methods of test for metallic and related coatings Method 1.3: Local thickness tests – Magnetic method
AS 2331.1.4	Methods of test for metallic and related coatings Method 1.4: Local thickness tests – Magnetic induction and eddy current methods
AS 4312	Atmospheric corrosivity zones in Australia.

New Zealand standards

AS/NZS 4680	Hot dip galvanized (zinc) coatings on fabricated – ferrous articles.

British standards

BS/EN/ISO 1461	Hot-dipped galvanized coatings on fabricated iron and steel articles – Specifications and Test methods.

American (ASTM) standards

A 36	Specification for Structural Steel
A 123 / A A 123 M	Specification for zinc (hot-dip galvanized) coatings on iron and steel products
A 143	Practice for safeguarding against embrittlement of hot-dip galvanized structural steel products and procedure for detecting embrittlement.
A 153 / A 153 / M	Specification for zinc coating (hot-dip) on iron and steel hardware.
A 384	Practice for safeguarding against warpage and distortion during hot-dip galvanizing of steel assemblies.
A 385	Practice for providing high quality zinc coatings (hot dip).
A 767 / A 767 M	Specification for zinc coated (galvanized) steel bars for concrete reinforcement.
D 6386	Practice for preparation of zinc (hot dip galvanized) coated iron and steel products and hardware surfaces for painting
E 376	Practice for measuring coating thickness by magnetic-field or eddy-current (electromagnetic) test method

Inspection of galvanized products

Visual inspection is the simplest and most important means of assessing the quality of galvanized coatings. A useful characteristic of the galvanizing process is that if the coating is continuous and has a satisfactory appearance it will be sound and adherent, with a zinc coating mass of at least 600 g/m^2 on fabricated articles over 6 mm thick, as discussed in more detail under **Coating Thickness.**

Appearance

A galvanized coating is normally smooth, continuous and free from gross surface imperfections and inclusions. While the heavy zinc coating on general galvanized articles should be smooth and continuous it cannot be compared for surface smoothness to continuously galvanized sheet steel or wire since these are produced by processes which permit close control of coating thickness and appearance.

Differences in the lustre and colour of galvanized coatings do not significantly affect corrosion resistance and the presence or absence of spangle has no effect on coating performance. As discussed under 'Dull grey coating' below, uniform or patchy matt grey galvanized coatings give equal or better life than normal bright or spangled coatings.

It is recommended that inspection of galvanized work should be carried out by a designated party at the galvanizer's works in accordance with the following guidelines, and tested when necessary as detailed under **'Non-destructive testing for coating thickness'.**

Variations in appearance and their relationship to coating quality

Variations in appearance of galvanized coatings listed below and their influence on coating quality are discussed on the following pages.

Dull grey coating

General comment: Acceptable.

A dull grey appearance is caused by growth of the zinc-iron alloy layers through to the surface of the galvanized coating. Grey coatings may appear as localized dull patches or lacework patterns on an otherwise normal galvanized coating or may extend over the entire surface.

Dull grey coatings usually occur on steels with relatively high silicon content which are reactive to molten zinc as discussed under **'Composition of steel'**

Welds made with steel filler rods containing silicon may also produce localised grey areas in an otherwise normal galvanized coating, as discussed under **Welding galvanized steel**.

Dull grey coatings are often thicker than the normal bright or spangled coatings and therefore give longer life. It is rarely possible for the galvanizer to minimise or control the development of dull grey coatings which are dependent basically on steel composition.

A dull grey coating can also result where air cooling rather than quenching is requested.

Rust stains

General comment: Acceptable when present as a surface stain.

Rust staining on the surface of galvanized coatings is usually due to contact with or drainage from other corroded steel surfaces. Steel filings or saw-chips produced during erection and fabrication operations should be removed from galvanized surfaces to prevent possible localised rust staining. Rust staining may also be caused by the weeping of pickling acid from seams and joints causing damage to the galvanized coating, and in such cases requires a modification in design as discussed under **'Overlapping surfaces'.**

A thin brown surface staining sometimes occurs in service when the galvanized coating comprises entirely zinc-iron alloys as discussed in **'Dull grey coating'** above. Staining arises from corrosion of the iron content of the zinc-iron alloy coating and is therefore outside the control of the galvanizer. It has no effect on the corrosion resistance of the coating. Long term exposure testing has shown that the corrosion resistance of zinc-iron alloys is similar to that of normal galvanized coatings.

General roughness and thick coatings on welds

General comment: Acceptable, unless otherwise agreed.

Rough galvanized coatings usually result from uneven growth of zinc-iron alloys because of the composition or surface condition of the steel. Where welding electrodes containing silicon have been used, the galvanized coating on the weld area may be thicker than normal and may also be brittle. Rough coatings of this type are usually thicker than normal and therefore provide longer protective life.

In some applications where a smooth finish is aesthetically or functionally required, the steel composition and surface preparation should be closely discussed with the galvanizer at an early stage. It is virtually impossible for the galvanizer to improve the appearance after galvanizing.

Lumpiness and runs

General comment: Acceptable unless otherwise specified.

Australian/New Zealand Standard 4680 'Hot dip galvanized (zinc) coatings on fabricated ferrous articles' demands that a galvanized coating shall be as smooth and evenly distributed as possible but points out that smoothness is a relative term and that coatings on fabricated articles should not be judged by the same standards as those applied to continuously galvanized products such as sheet steel and wire, since these are produced by processes which permit a high degree of control over coating thickness and appearance. Lumps and runs arising from uneven drainage are not detrimental to coating life.

When zinc drainage spikes are present on galvanized articles and their size and position is such that there is a danger they may be knocked off in service removing the coating down to the alloy layers, they should be filed off by the galvanizer and, where necessary, the coating should be repaired as described in **Reconditioning damaged surfaces in galvanized steel.**

For special applications the galvanizer can sometimes achieve a smoother finish than the normal commercial coating, depending on the shape and nature of the product. The steel should be carefully specified and the galvanizer consulted at the design stage and advised when the order is placed. Extra cost may be involved.

Pimples

General comment: May be grounds for rejection depending on size and extent.

Pimples are caused by inclusions of dross in the coating. Dross, which comprises zinc-iron alloy particles, has a similar corrosion rate to the galvanized coating and its presence as finely dispersed pimples is not objectionable. Gross dross inclusions may be grounds for rejection as they tend to embrittle the coating.

Bare spots

General comment: Acceptable if small in area and suitably repaired, depending on the nature of the product.

Small localised flaws up to about 3 mm wide in a galvanized coating are usually self-healing because of the cathodic protection provided by the surrounding coating as discussed under **Cathodic Protection**. They have little effect on the life of the coating.

Australian/New Zealand Standard 4680 – section 8 'Repair after Galvanizing' specifies that "…the sum total of the damaged or uncoated areas shall not exceed 0.5% of the total surface area or 250 cm^2, whichever is the lesser, and no individual damaged or uncoated area shall exceed 40cm^2. Uncoated areas greater than 40cm^2 which have been caused by unavoidable air locks or prior contamination of the steel surface shall be repaired. Repairs shall be carried out in accordance with Clause 8.2".

Bare spots may be caused by under-preparation by the galvanizer and by a number of factors outside his control, and for which he cannot be responsible, including the presence of residual welding slags, rolling defects such as laps, folds and laminations in the steel, and non-metallic impurities rolled into the steel surface.

Wet storage stain or bulky white deposit

General comment: Not the galvanizer's responsibility unless present before first shipment. Acceptable if non-adherent deposit is removed and the coating meets coating mass requirements.

A bulky white or grey deposit, known as wet storage stain may form on the surface of closely stacked freshly galvanized articles which become damp under poorly ventilated conditions during storage or transit. In extreme cases, the protective value of the zinc coating may be seriously impaired but the attack is often very light despite the bulky appearance of the deposit.

Initiation and development of wet storage staining on new galvanized surfaces is readily prevented by attention to conditions of storage and transport and by application of a chromate passivation treatment.

Where the surface staining is light and smooth without growth of the zinc oxide layer as judged by lightly rubbing fingertips across the surface, the staining will gradually disappear in service and blend in with the surrounding zinc surface as a result of normal weathering.

When the affected area will not be fully exposed in service, particularly on the underside of steelwork and in condensation areas, or when it will be subject to a humid environment, wet storage staining must be removed as detailed below, even if it is superficial. Removal is necessary to allow formation of the basic zinc carbonate film, which normally contributes to the corrosion resistance of galvanized coatings.

Medium to heavy build up of white corrosion product must be removed to allow formation of a basic zinc carbonate film in service. Light deposits can be removed by brushing with a stiff bristle brush. Heavier deposits can be removed by brushing with a 5 percent solution of sodium or potassium dichromate with the addition of 0.1% by volume of concentrated sulphuric acid. This is applied with a stiff brush and left for about 30 seconds before thorough rinsing and drying.

A check should be made to ensure that the coating thickness in affected areas is not less that the minimum specified in relevant standards for the various classes of galvanized coatings.

In extreme cases, where heavy white deposit or red rust has been allowed to form as a result of prolonged storage under poor conditions, corrosion products must be removed by thorough wire brushing and the damaged area repaired as detailed under **Reconditioning damaged surfaces in galvanized steel**.

Dark spots

General comments: Acceptable if flux residues have been removed.

Smuts of dirt may be picked up on the surface of the galvanized coating from floors and trucks or from contact with other articles. These smuts are readily washed off to reveal a sound coating and are not harmful.

Blisters

General comment: Small intact blisters acceptable.

Extremely rare. Small blisters in galvanized coatings are due to hydrogen absorbed by the steel during pickling being expelled as a result of the heat of the galvanizing process. Their occurrence is due to the nature of the steel, usually low strength, and is outside the control of the galvanizer. Blisters do not reduce the corrosion resistance of the coating.

Non-destructive testing for coating thickness

Magnetic gauges provide simple non-destructive testing methods for coating thickness, which are reliable and more convenient than the physical tests given under the various national standards listed under **Standards for galvanized products.**

Most gauges described are compact and can be used very quickly. They give coating thickness readings over very small areas and several readings should be taken and averaged. Uniformity as well as actual thickness can thus be easily checked.

These magnetic gauges give reliable thickness readings although some require frequent recalibration against non-magnetic coatings of known thickness and the makers' instructions are followed precisely. Accurate readings cannot be obtained near edges of work and obvious peaks or irregularities in the coating should be avoided. Surface curvature, surface area and steel thickness all affect readings in a predictable manner and allowances must be made.

Guidance on the use of these instruments is given in AS 2331.1.3 "Methods of test for metallic and related coatings Method 1.3: Local thickness tests – Magnetic method", and AS 2331.1.4, "Methods of test for metallic and related coatings, method 1.4: Local thickness tests – Magnetic induction and eddy current methods".

PosiTector 6000

The PosiTector 6000 is an easy-to-use digital readout single-point coating measurement instrument which works on a magnetic field simulation principle. It needs no calibration and gives accurate results unaffected by shock, vibration, or temperature.

Elcometer coating thickness gauge 456

This Elcometer contains a horseshoe magnet with its two poles exposed and works on a magnetic induction principle. When the instrument is placed with both poles touching the surface to be tested, changes of magnetic field brought about by variations in coating thickness move the bar magnet and the pointer. A mean thickness reading is given over the two points of contact.

The Inspector magnetic balance

The magnetic balance is based on the calibration of magnetic attraction to the steel beneath a coating. The same principle is used by pull-off type gauges, but the magnetic balance gives a stable reading and incorporates a counterbalanced magnet, allowing use in any position.

Pull-off type gauges

Simple pull-off magnetic thickness testing gauges such as the Tinsley Pencil Gauge and the Elcometer Pull-off Magnetic Gauge Model 157 are convenient and inexpensive, but require greater operator skill and in general do not provide the accuracy of the gauges described above.

Reconditioning damaged surfaces in galvanized steel

When severe damage to the galvanized coating has occurred during welding or as the result of rough handling in transport or erection, protection must be restored.

Small areas of the basis steel exposed through mechanical damage to galvanized coatings, are protected from corrosion cathodically by the surrounding coating and may not need repair, depending on the nature of the product and the environment to which it is exposed. Small exposed areas normally have little effect on the life of the coating as discussed under **'Bare spots'** and **'Cathodic protection'**.

Repair methods

The coating repair methods detailed below are in accordance with AS/NZS 4680 section 8 – Repair after Galvanizing. They include:

Zinc rich paints. The application of an organic zinc rich paint is the most rapid and convenient method of repair. The paint should conform to AS/NZS 3750.9 'Paints for steel structures – Organic zinc-rich primer' applied in two coats by brush to provide a total film thickness of a minimum of 30 µm more than the local coating thickness requirements in AS/NZS 4680 and for optimum performance should contain not less than 92% zinc in the dried paint film.

Where colour matching is required aluminium paint may be applied over the hardened zinc rich paint.

Zinc metal spraying. In certain circumstances, by prior agreement, zinc metal spraying may be used as a method of coating repair. The damaged area must be grit blasted to Class 3 followed by zinc metal spraying to a coating thickness equivalent to that of the undamaged coating, and seal coated using an aluminium vinyl paint.

CHAPTER 3

Galvanized Steel Reinforcement for Concrete

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GALVANIZING ASSOCIATION

Galvanized steel reinforcement for concrete

Hot dip galvanizing is a viable means of protecting reinforcement, particularly where the durability of concrete cannot be guaranteed. Its use should be considered for harsh exposure conditions, precast construction and prestige facades where long life, freedom from rust staining and low maintenance are important criteria. Rust-stained surfaces and cracking and spalling of concrete in recently completed structures demonstrate the wide need to protect steel reinforcement.

Current Practice Note 17 published by and available from the Concrete Institute of Australia concludes that "Wherever there are serious doubts that (impermeable concrete) will be achieved and maintained for the design life of the structure, then galvanizing should be given serious consideration".

Galvanized coatings provide important advantages for the protection of reinforcement.

Research and practical experience since the 1950s have shown the corrosion resistance of galvanized steel reinforcement to be greatly superior to uncoated steel, while the bond strengths of galvanized and black steel bars to concrete are not significantly different.

The corrosion protection of the galvanized coating ensures that the design strength of concrete is maintained and the possibility of surface rust staining and eventual corrosion of reinforcement and spalling of concrete is removed.

Steel accessories for use in reinforced concrete structures, particularly fittings and inserts which may be partially exposed, are susceptible to the effects of corrosion and should be galvanized.

Where only parts of a reinforced concrete element require the reinforcement to be galvanized, such as the external mesh of a precast panel or the top mat of a slab, and black steel is to be used elsewhere in the element, it is vital that the steel be placed in strict compliance with the design requirements.

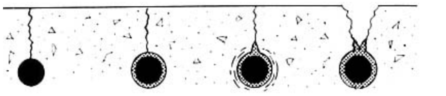
If galvanized bars are placed in contact with black bars in areas prone to corrosion, there is a likelihood that the galvanizing will attempt to sacrificially protect the uncoated bars, resulting in a reduction in the life of the galvanized coating. However, this effect is likely to be observed only in situations where the galvanic couple – the connection between the galvanized and the black steel – is prone to corrosion such as in areas of reduced cover to the reinforcement or poor compaction or cracking (i.e. overall poor quality) of the concrete.

To ensure that this is not a durability concern, it is recommended that where particular parts of RC elements are to utilize galvanizing, all steel in that area should be galvanized including tie wire, inserts and bar chairs. Alternatively, plastic coated ties should be used. Further, any point of connection to uncoated steel should be deeply embedded in the concrete to ensure that both the steel and the galvanized coating are maintained in their respective passive state. Under these conditions, neither the steel nor the galvanizing will be prone to corrosion.

Corrosion of reinforcement

Corrosion of steel reinforcing bars inevitably weakens concrete members, reducing load bearing capacity and safety factors. In extreme cases, failure of reinforced concrete members can occur, partly because of loss of strength due to corrosion of the reinforcement itself, and partly because of the breaking up of the concrete surrounding the reinforcement.

When steel reinforcement corrodes, the corrosion product occupies more than three times the volume of the original steel, exerting great disruptive tensile stress on the surrounding concrete, leading to further cracking, more weather access and further corrosion. In mild cases rust staining occurs. In more serious cases, severe spalling of concrete may occur and ultimately concrete members may fail completely.



Steps in the corrosion of uncoated steel reinforcing bars.

Galvanized rebar is not subject to this effect and retains full bond strength to concrete.

In normal circumstances uncoated steel reinforcing bars give satisfactory service provided the following requirements are maintained:

1. The design provides for adequate concrete cover over the steel reinforcement.
2. Precise placement of reinforcement is maintained.
3. Uniformly high quality concrete is used.
4. Complete compaction of concrete is attained with no voids or pockets.

It is sometimes impractical or impossible to achieve all these requirements and depending on exposure conditions, corrosion of uncoated reinforcement may begin.

The benefits of galvanizing reinforcement include:

- Protection to the steel during storage and construction prior to placing the concrete.
- Diminished effect of variations in concrete quality.
- Safeguards against poor workmanship, especially misplacement of reinforcement, poor compaction, and inadequate curing.
- Delayed initiation of corrosion and the onset of cracking.
- Reduced likelihood of surface staining.
- Increased structural life of concrete, particularly where chloride contamination is likely.

Factors determining the durability of reinforcement

Environment

The external environment of the concrete provides the agents which commonly cause corrosion in reinforcement: oxygen, water, carbon dioxide and chloride ions.

Marine structures and structures close to coastal waters are particularly at risk from corrosion of reinforcement due to the ingress of chloride ions from sea spray and salt-laden air.

Away from the sea coast most corrosion of reinforcement in concrete is due to the process of carbonation, which reduces the alkalinity of the surrounding concrete. This process can occur at any geographic location. The rate of carbonation is at a maximum when the relative humidity is about 50 per cent, and increases with increasing temperature.

Surveys have shown that the corrosion problem in relatively new buildings is worst in coastal areas.

Carbonation resistance. Galvanized reinforcement is better able to resist the effects of carbonation because of the much wider range of pH (to about pH 8) over which the zinc coating remains passivated. Since black steel typically depassivates when the pH of concrete drops below about 11.5, it is apparent that as the carbonation 'front' moves past a galvanized rebar, little or no effect will occur until the concrete adjacent to the reinforcement is almost completely neutralised.

Chloride tolerance. Though zinc can be depassivated and attacked in the presence of chloride ions, the tolerance of galvanized reinforcement to chloride depassivation is substantially higher than that of black steel. In a survey of a number of long-serving marine structures* galvanized bars were shown to have been exposed to chloride contents as high as 2.2% (by approximate weight of cement) over periods of 10-20 years, with less than 10% loss of original coating thickness and no record of failure. This should be compared to chloride levels in the range of 0.2-0.3% by weight of cement leading to severe corrosion of black steel in similar circumstances.

*Tonini, DE and Cook, AR (1978) 'The performance of galvanised reinforcement in high chloride environments – field study reports.' International Corrosion Forum, NACE, Houston.

Quality of concrete

In preventing corrosion of reinforcement, the most critical property of concrete is permeability. The degree of permeability determines the extent and rate of the diffusion of chloride ions and carbon dioxide through the concrete. Permeability is a function of mix design, compaction and curing:

Mix design. To achieve low permeability, concrete must be dense, with a good bond between aggregate and cement paste. These desirable characteristics can be obtained by using good quality materials, with an adequate portland cement content, a low water/cement ratio, and small sized, well graded aggregates.

Compaction. Proper compaction of concrete is of vital importance in minimising permeability. Problems are likely to arise when placing and vibrating techniques are incorrect, slump is too low, reinforcement is congested, or form shapes are not conducive to the necessary flow of concrete during placement.

Curing. Proper curing of concrete is essential to achieve low permeability, as the continued hydration of the cement increases the volume of the gel and hence decreases pore spaces and blocks capillaries. Proper field curing must be provided for.

Depth of Cover

Lack of concrete cover for reinforcement has been identified as a major problem associated with ‘failures’ in high rise buildings.* In a survey of 95 Sydney buildings ranging in height from 5 to 36 storeys and aged between 2 and 17 years, the average depth of concrete cover at sites where spalling occurred was 5.45mm. The maximum depth of cover at any failure point was 18 mm compared with recommended covers to AS 3600 ‘Concrete structures’ in the range 25 – 30 mm, depending on the type of member.

* Marosszeky, M and Sade, D (1986). “Concrete durability – the problem of reinforcement corrosion and improving workmanship”. Building Research Centre, University of NSW.

Cracks in concrete

The type and size of cracks have an important influence on durability of concrete. Cracks caused by shrinkage or thermal stresses may contribute significantly to reinforcement corrosion, particularly when they run parallel to reinforcing bars and are close to the concrete surface.

Crack widths of less than 0.1 mm are generally regarded as not causing significant corrosion risk, provided cover is adequate and the structure is not exposed to highly corrosive environments. Flexural cracks are not generally a problem as they decrease in width from a maximum at the surface and become narrower at the level of the reinforcing steel.

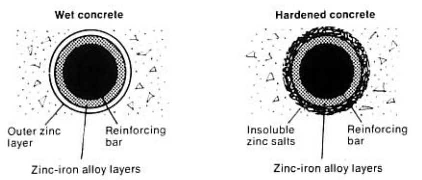
Surface treatment of concrete

In the production of architectural finishes the concrete surface is sometimes washed or treated to expose the aggregate. These practices are not recommended if there is any possibility of aggressive chemicals such as acids or salts being left behind to permeate the concrete.

Etching, washing and mechanical concrete surface finishing may also result in loss of the valuable cement-rich paste which forms the surface layer of the concrete, reducing carbonation resistance and depth of cover.

Reaction between galvanized coatings and concrete

During initial contact of galvanized reinforcement with wet concrete, the outer zinc layers of the galvanized coating react to form stable insoluble zinc salts. Attack ceases as the concrete hardens and the galvanized coating remains intact.



Corrosion protection provided by galvanizing

In areas where the reinforcement may be exposed accidentally due to thin or porous concrete, cracking, or damage to the concrete, the galvanized coating provides extended protection. Since the corrosion product of zinc occupies a smaller volume than the corrosion products of iron, any small degree of corrosion which may occur to the galvanized coating causes little or no disruption to the surrounding concrete mass.

Studies were made at the Structural Engineering Materials Laboratory, University of California, Berkeley California, of the effects of corrosion on reinforced concrete test prisms.

Prisms 300 x 100 x 100 mm were axially – reinforced with 19 mm diameter galvanized or black steel bars. A 12.5 mm deep notch was cut at the mid section of each prism to enforce formation of a crack at the notch should corrosion products exert sufficient disruptive stresses. Prisms were placed in loading frames and the steel reinforcing bars stressed to 140 MPa. Prisms were then subjected to alternate immersion/ drying cycles in a 4% NaCl solution.

Cracks occurred in test prisms reinforced with uncoated steel bars in less than ten months exposure. Large crack areas had developed by about 18 months and were still increasing at 24 months. No cracks were observed in prisms reinforced with galvanized bars until almost 16 months exposure. These crack areas were very small compared to those in prisms reinforced with uncoated steel bars and crack development ceased after a further 2½ months exposure.

Economics of galvanized reinforcement in concrete

When the costs and consequences of corrosion damage to a reinforced concrete building are analysed, the extra cost of galvanizing is small. It can be regarded as an 'insurance premium', but a premium which is low and need be paid once only.

While the cost of galvanizing may be up to 50% of the cost of the steel, the cost of galvanized reinforcement as a percentage of total building cost is much lower than generally realised. It can be as little as 0.5%, depending on the nature of the structure. For most structures, even in the most aggressive environments, the use of galvanized reinforcement can be confined to the exposed surfaces and critical structural elements such as:

- Thin precast cladding elements
- Facades of prestigious buildings
- Surface exposed beams and columns
- Window and door surrounds
- Prefabricated units
- External facades of buildings near the sea coast
- Architectural features.

Determining the likely cost

Recent case histories show that the galvanizing of reinforcement increases reinforced concrete costs in a typical building by about 6 to 10%. Since the cost of the structural frame and skin of a building normally represents only about 25 to 30% of total building costs, multiplying these figures out shows that the additional cost of galvanizing the reinforcement adds between 1.5 and 3.0% to total building cost.

However, in the majority of structures only certain vulnerable or critical elements require protection. If only these critical areas are galvanized the additional cost of galvanizing comes down still lower, to as little as 0.5 to 1.0%.

These percentages relate only to total building costs. When related to total project costs and to final selling prices the added cost of galvanizing becomes very small indeed.

Such costs represent a very small proportion of the cost of repairs should unprotected reinforcement corrode. In recent cases repair costs on major buildings and structures have been as high as 5 – 10% of the original building costs. Frequently such repairs eliminate only the visible damage and cannot be relied upon as a long-term solution.

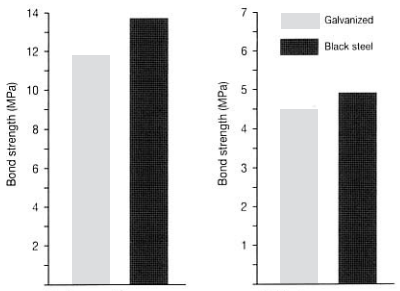
Accordingly, wherever there is concern that premature corrosion of reinforcement might occur, reinforcement should be galvanized. The use of galvanizing however should not be considered an alternative to the provision of an adequate cover of dense, impermeable concrete.

Bond strength of concrete to galvanized reinforcing bars

The results of extensive programs of pull-out testing by a number of researchers reveal no significant difference in the bond strengths of black and galvanized steel deformed (ie, ribbed) reinforcing bars in concrete.

The tests also indicate no significant difference in the bond strengths of black and galvanized plain bars in concrete.

Bond strengths of galvanized unpassivated steel bars and black steel bars to concrete*



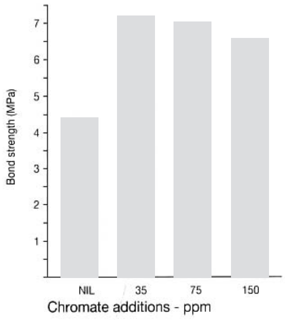
Deformed bars

Pull-out testing showed no significant difference in bond strengths, due to the effect of mechanical interlock. Tests showed no significant effect of chromate additions on the bond strength of deformed galvanized bars.

Plain bars

Pull-out testing showed no significant difference in bond strengths of black plain bars and unpassivated galvanized plain bars.

Bond strengths of galvanized plain bars at various levels of chromate additions to concrete*



Mix water additions of 35-150 ppm chromates by weight of cement increased bond strength of galvanized bars by at least 50%

* Yeomans SR and Ellis DR, 'Further studies of the bond strengths and slip characteristics of galvanized and epoxy coated steel reinforcement in concrete'. ILZRO Project ZE-341, University of New South Wales, Canberra ACT. Progress report No 5, December 1992.

Passivation and additives

The research into bond strengths also shows that there is little or no need for the current practice of chromate passivation of galvanized reinforcement by the galvanizer (other than to minimise the possibility of wet storage staining), or the alternative addition of chromium trioxide to the concrete mix. While the addition of chromates to the concrete mix in the ratio of 35-150 ppm by weight of cement increases the bond strength of galvanized plain bars significantly, there is no measurable improvement in the bond strength of galvanized deformed bars, as the mechanical interlock effect provides almost all of the bond.

Specification and installation of galvanized reinforcement

Reinforcing bar such as that manufactured under the ACRS certification scheme meets the requirements of Australian Standard AS/NZS4671, Grade 500N. These properties are retained after galvanizing and are altered only marginally on bars bent prior to galvanizing.

Properties of galvanized Grade 500N bar

Tensile properties:	No change from ungalvanized condition
Bending properties:	No change from ungalvanized condition
Toughness:	Similar to ungalvanized

Galvanizing pre-bent Grade 500N bar

Grade 500N reinforcing bar bent prior to galvanizing remains ductile, allowing straightening and re-bending. The following minimum diameters (for 90° bends) are recommended in AS3600 if subsequent straightening* of the bar is required.

Up to 16 mm dia:	5d
Greater than 20 mm dia:	8d

*Re-bending from these bend diameters may cause cracking of the galvanized coating.

Grade 500N bar that has been bent, galvanized and straightened in accordance with the above practices retains the full yield and tensile strength of the original bar. Tensile elongation may be slightly reduced, but still easily meets the requirements of AS/NZS 4671

Do not use heat for bending or re-bending

The use of heat for bending or re-bending galvanized Grade 500N or any other reinforcing bar should be avoided due to the possibility of the zinc coating causing liquid metal embrittlement. Similarly, should welding of galvanized bar be required, the galvanized coating should first be removed by pickling, grinding or grit blasting.

Where possible, bend after galvanizing

The galvanizing of straight bars is easier and more economical. Transport costs are lower, and special bend configurations cannot be lost or misplaced during handling and storage.

Bending, re-bending after galvanizing

Although the bendability of galvanized Grade 500N bar is only marginally altered from that of uncoated bar, to minimise cracking of the galvanized coating the following minimum bend diameters (for 90° bends) are recommended in AS 3600.

Up to 16 mm dia:	5d
Greater than 16 mm dia:	8d

Effect of bending on the coating

Some cracking or flaking of the galvanized coating may occur at bends using smaller diameters than those recommended above. Any damage to the galvanized coating should be repaired using a suitable zinc-rich paint in accordance with AS/NZS 4680. Cut ends of galvanized bars should also be repaired.

Specifying galvanized reinforcement

Reinforcing steel should be specified to comply with Australian Standard AS/NZS 4671 "Steel Reinforcing Materials" and galvanized in accordance with AS/NZS 4680 'Hot-dip galvanized (zinc) coatings on fabricated ferrous articles', and GAA's standard specification for hot-dip galvanized steel.

Welding galvanized steel reinforcement

In order to volatilise the zinc coating and so achieve adequate weld penetration, both tack welds and load-bearing welds in galvanized steel reinforcement require greater heat input than similar welds in uncoated steel reinforcement. Manual metal arc, GMA and torch welding processes are all suitable techniques, as detailed in Australian Standard 1554 Part 3. In the case of GMA welding, the use of pure CO_2 shielding gas will help weld penetration.

Comment on welding techniques is given under "**Welding galvanized steel**".

Butt splice welds. In general, welds are made without changes to standard operating parameters other than reduced welding speed to achieve greater heat input. To achieve sound welds, all cracked or damaged areas on bar ends must be removed by sawing or grinding. To provide access for welding at least one bar end must be bevelled.

Lap splice welds. Welds are made satisfactorily using the welding processes listed above. A reduction in welding speed and an increase in heat input will help to volatilise the zinc coating and achieve adequate weld penetration.

For manual metal arc welding, the use of electrodes of a size and type which facilitate volatilisation of the zinc coating will minimise the possibility of weld porosity and liquid metal embrittlement. Cellulose-coated electrodes have given good results. Procedure testing may be helpful.

Alternatively, the galvanized coating may be removed prior to welding by using an oxy-fuel gas flame, or by grit blasting or grinding.

For all welding processes, attention should be given to ventilation or fume extraction to minimise zinc oxide fume in the welder's breathing zone.

Acknowledgement

Edited and updated June 2005 by Building Knowledge.

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CHAPTER 4

Bolting Galvanized Steel

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GALVANIZING ASSOCIATION

Bolting Galvanized Steel

This chapter gives information on the characteristics, advantages and economics of bolted galvanized structures and zinc coated fasteners, and offers comment on bolting procedures when these are influenced by the presence of zinc coatings. All information given is in accordance with current Australian Standards, and with the rationalised approach to the design, detailing and fabrication of structural connections developed by Australian Steel Institute.

Information given is based on work carried out by Ajax Spurway Fasteners, Australian Steel Institute and International Lead Zinc Research Organization.

Bolting steel structures

Bolting has become the most widely used, versatile and reliable method of making field connections in structural steel members. The major advantages of bolting over welding are:

1. Economy, speed and ease of erection
2. Reliability in service
3. Relative simplicity of inspection
4. Fewer and less highly skilled operators required
5. Good performance under fluctuating stresses
6. Ease of making alterations and additions
7. Absence of coating damage
8. No pre-heating of high-strength steels
9. No weld cracking or induced internal stress
10. No lamellar tearing of plates.

Galvanized steel structures

In the construction of galvanized steel structures, bolted connections offer further advantages. Damage to the galvanized coating from local heating during welding is eliminated and with it the need for coating repairs to the affected area.

The high cost of maintenance labour and wide use of steel communications towers, exposed industrial structures, steel bridges and power transmission towers, often in remote areas, have made low maintenance corrosion protection systems an essential aspect of design. As a result, galvanizing has become the accepted standard for exposed steel, placing greater emphasis on bolted joints for structural steelwork and leading to development of specialised bolting techniques.

A wide range of galvanized, sherardised and zinc plated structural bolts and related fittings is available to meet any steel construction need.

Zinc coatings for fasteners

In bolted steel structures, the bolts and nuts are critical items on which the integrity of the entire structure depends.

For exterior use these critical fasteners must be adequately protected from corrosion. Where steel members of the structure are galvanized it is recommended that fasteners employed should also be galvanized or suitably zinc coated to maintain a uniform level of corrosion protection throughout the structure.

Selection of zinc coatings for fasteners

The zinc coating selected is decided primarily by the period of protection desired which should be equivalent to the life of the protective system selected for the structure.

The zinc coating process selected must also produce a relatively uniform coating over small parts of varying shape. With the thicker zinc coatings, allowances in thread dimensions must be made to accommodate the thickness of the coating.

These requirements dictate that in practice one of four types of zinc coating will be suitable:

1. Galvanizing
2. Zinc plating
3. Sherardising
4. Mechanical plating

Galvanizing

The galvanizing of fasteners produces a heavy coating of zinc ideally suitable for long-term outdoor exposure. The coating is applied by the immersion of clean, prepared steel items in molten zinc. The resulting zinc coating is metallurgically bonded to the basis steel, and consists of a succession of zinc-iron alloy layers and an outer zinc layer.

Fasteners are generally centrifuged immediately on withdrawal from the molten zinc of the galvanizing bath to remove excess free zinc and produce a smoother finish and cleaner threads.

Australian/New Zealand Standard 4680 'Hot dip galvanized (zinc) coatings on fabricated ferrous articles' provides for a standard minimum coating thickness regardless of fastener dimensions:

Requirements for coating thickness and mass for articles that are centrifuged

Thickness of articles (all components including castings) mm	Local coating thickness minimum µm	Average coating thickness minimum µm	Average coating mass minimum g/m^2
< 8	25	35	250
≥ 8	40	55	390

Note: 1. For requirements for threaded fasteners refer to AS 1214
2. 1 g/m^2 coating mass = 0.14µm coating thickness

Oversize tapping allowances for galvanized nuts

To accommodate the relatively thick galvanized coating on external threads, it is usual to galvanize bolts of standard thread dimensions, and to tap nuts oversize after galvanizing. AS 1214 'Hot dip galvanized coatings on threaded fasteners' specifies the following oversize tapping allowances on internal threads:

Nominal diameter of internal threads	Allowance, mm
Up to M22	0.40 mm
M24	0.45mm
M27	0.50mm
M30	0.55mm
M36	0.60mm
M36-48	0.80mm
M48-64	1.0mm

To ensure that nut stripping strength is adequate after oversize tapping, galvanized high strength nuts are manufactured from steel with a higher specified hardness than standard high strength nuts, as discussed under '**Galvanized high strength nuts**'.

Galvanized high strength bolts and nuts must be provided with a supplementary lubricant coating for satisfactory bolt tightening. See '**Influence of the galvanized coating on design**'.

Economics of galvanized coatings on bolts

Corrosion protection on bolts should match the rest of the structure and in most circumstances economics favour the use of galvanized bolts rather than painting after erection. The following table* gives indicative cost-in-place relationships for unpainted, painted, and galvanized M20 bolts in structural applications:

Bolt strength grade/ Bolting procedure	Cost-in place		
	Unpainted	Painted	Galvanized
4.6/S	100	190	110
8.8/S	120	210	140
8.8/T	170	260	190

* TJ Hogan and A Firkins, 'Bolting of steel structures' Australian Institute of Steel Construction

Zinc plating

Zinc plating on fasteners produces relatively light, uniform coatings of excellent appearance which are generally unsuitable for outdoor exposure without additional protection.

There is in general an economic upper limit to the coating mass which can be applied by plating, although certain specialised roofing fasteners are provided with zinc plated coatings up to 35 to 40 μm thick. Where heavy coatings are required galvanizing is usually a more economic alternative.

Zinc plated bolts having a tensile strength above 1000 MPa must be baked for the relief of hydrogen embrittlement.

Zinc plated high strength bolts and nuts must be also provided with a supplementary lubricant coating to provide for satisfactory bolt tightening. See '**Torque/induced tension relation in tightening**'.

Australian standards for zinc plating require that one of a range of chromate conversion coatings be applied in accordance with Australian Standards 1791 'Chromate conversion coating on zinc and cadmium electrodeposits'. Clear, bleached, iridescent or opaque films may be produced, depending on the level of resistance to wet storage staining required.

Australian Standard 1897 'Electroplated coatings on threaded components (metric coarse series)' specifies plating thicknesses which can be accommodated on external threads to required tolerances.

Sherardising

Sherardising produces a matt grey zinc-iron alloy coating. The process impregnates steel surfaces with zinc by rumbling small components and zinc powder in drums heated to a temperature of about 370°C. The least known of the various processes for zinc coating steel, sherardising is not used in Australia. The process is characterised by its ability to produce a very uniform coating on small articles.

The thickness of sherardised coatings is generally of the order of 15μm but can vary depending on cycle time from 7.5 to 30μm. Sherardised coatings therefore fall between zinc plated and galvanized coatings in thickness and life.

Although sherardising is an impregnation process there is some build up in dimensions. British Standard 729 'Zinc coatings on iron and steel articles, Part 2: Sherardised coatings' recommends an oversize tapping allowance of 0.25mm on nuts to ensure easy assembly with sherardised bolts.

Mechanical (peen) plating

Mechanical or peen plating offers advantages in the zinc coating of fasteners. Coatings are uniform, and because the process is electroless there is no possibility of hydrogen embrittlement. High strength fasteners not susceptible to embrittlement need not be baked after coating. Lubricant coatings must be applied to ensure satisfactory tightening.

Influence of the galvanized coating on design

The presence of either galvanized coatings or zinc plating on high strength bolts, and galvanized coatings on structural members may need to be taken into account in design. The following factors should be considered:

1. Slip factors of mating surfaces
2. Fatigue behaviour of bolted galvanized joints
3. Bolt relaxation
4. Effect of galvanized coating on nut stripping strength
5. Torque/induced tension relation in bolt tightening

1. Slip factors affecting mating surfaces

In a friction type bolted joint all loads in the plane of the joint are transferred by the friction developed between the mating surfaces. The load which can be transmitted by a friction type joint is dependant on the clamping force applied by the bolts and the slip factor of the mating surfaces.

Australian Standard 4100 'Steel structures' assumes a slip factor of 0.35 for clean as-rolled steel surfaces with tight mill scale free from oil, paint, marking inks and other applied finishes. AS 4100 permits the use of applied finishes such as galvanizing in friction type joints, but requires that the slip factor used in design calculations be based on test evidence in accordance with the procedures specified in Appendix J of the standard. Tests on at least three specimens are required, but five is preferred as the practical minimum.

Bearing type joints are not affected by the presence of applied coatings on the joint faces, so galvanizing may be used without affecting design strength considerations.

Slip factors of galvanized coatings

Research conducted in Australia and overseas shows mean slip factors for conventional galvanized coatings over a large number of tests to be in the range 0.14 to 0.19, as compared to 0.35 for clean as-rolled steel.

Design values take these lower slip factors into account, and galvanized steel is used widely in high strength friction type joints.

Work by Professor WH Munse* for International Lead Zinc Research Organization, and others, shows that the slip factors of galvanized surfaces can be substantially improved by treatments such as wire brushing, light 'brush off' grit blasting, and disc abrading. In each case the treatment must be controlled to provide the requisite scoring or roughening to expose the alloy layers of the coating. Care must be taken to ensure that excessive coating thickness is not removed.

The following table shows the results of slip factor testing various galvanized surfaces in four-bolt joints.

It is important to recognise more recent developments in galvanizing technology which produce harder final layers of zinc. Testing has been undertaken to establish higher slip factors for structural steel produced in the modern galvanizing facilities. Designers should check with the galvanizer before assuming a slip factor for slip critical joints in a structure.

Fully alloyed 'grey' galvanized coatings which can result from the galvanizing of silicon steels have also been shown to develop higher slip factors.

Slip factors given here are indicative only, and designs must be based on proven slip factors established by testing in accordance with the requirements of AS4100, Appendix J.

Surface Treatment	No. of tests	Average	Min	Max
As received	15	0.14	0.11	0.18
Weathered	3	0.20	0.15	0.26
Wire brushed	4	0.31	0.27	0.33
Grit blasted	2	0.31	0.28	0.34

* WH Munse 'High strength bolting of galvanized connections' presented to the symposium 'Bolting galvanized connections and new steel design specifications', Australian Institute of Steel Construction and Australian Zinc Development Association, 1968

2. Fatigue behaviour of bolted galvanized joints

While the galvanized coating behaves initially as a lubricant it has been shown in fatigue tests carried out by Munse that after the first few cycles galvanized mating surfaces tend to 'lock up' and further slip under alternating stress is negligible. The figure below taken from work by Munse illustrates this effect. Note the rapidly decreasing amplitude of slip from first to second and then to fifth stress cycle.

Further indications of 'lock up' behaviour became apparent when joints were disassembled, galling of the galvanized coating being observed in regions where there had been high contact pressure. Where no initial slip can be tolerated a reduced slip factor must be used in design. The slip factor of the galvanized coating may be improved by wire brushing or 'brush off' grit blasting as discussed above, but slip factors for galvanized surfaces post treated in this way must be verified in accordance with Appendix J of AS 4100.

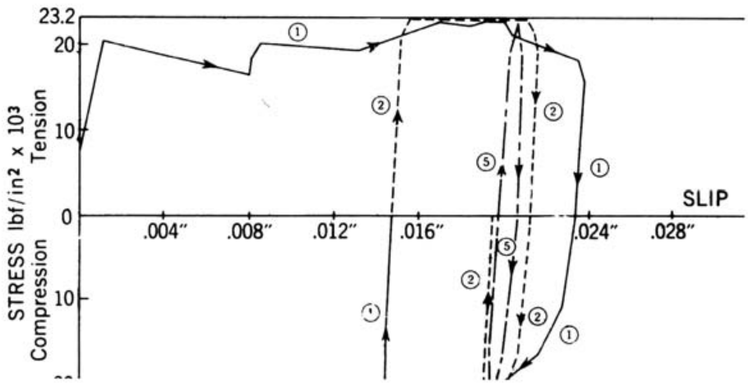
3. Bolt relaxation

The possible effect of bolt relaxation caused by the relatively soft outer zinc layer of the galvanized coating on the member must also be considered. If the zinc coating flowed under the high clamping pressure it could allow loss of bolt extension and hence tension. This factor was also studied by Munse. He found a loss of bolt load of 6.5 percent for galvanized plates and bolts due to relaxation, as against 2.5 percent 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.

4. Effect of galvanized coatings on nut stripping strength

Galvanizing affects bolt-nut assembly strength primarily because the nut must be tapped oversize to accommodate the thickness of the zinc coating on the bolt thread. The oversize tapped thread reduces the stripping strength of the nut when tested on a standard size threaded mandrel.

In high strength bolting correct tightening is essential and Australian Standard 1252 'High strength steel bolts with associated nuts and washers' makes no exceptions for oversized tapped galvanized nuts and specifies that all high strength nuts must meet the full stripping load when tested on a standard-size hardened mandrel. To meet this requirement galvanized high strength nuts must have a higher specified hardness in accordance with AS 1252. For this reason normal high strength nuts must not be galvanized and tapped oversize for use in high strength bolted joints.



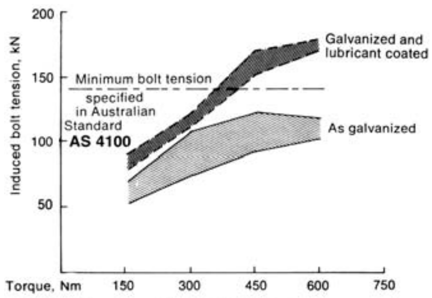
Stress versus slip for fatigue specimen subjected to alternating stress of 23.2 kips/in^2 Galvanized members and bolts. First, second and fifth stress cycles. WH Munse "Structural Behaviour of hot galvanized bolted connections'. Proceedings 6th International Conference on Hot Dip Galvanizing 1968.

5. Torque/induced tension relation in tightening

The relationship between torque and induced tension in tightening is dependent on bolt and nut thread surface finish, thread surface coatings, and conditions of lubrication.

Galvanized coatings and zinc plated coatings on threads both increase friction between the bolt and nut threads, and make the torque/induced tension relation much more variable.

The effect of lubricants on galvanized or zinc plated threads is significant. The torque/tension relationship shows much reduced variability, and it becomes possible to tighten in excess of the minimum tension without danger of bolt fracture.



Torque/induced tension-relation for M20 high strength structural bolts, galvanized and lubricant coated, and as-galvanized.

The diagram shows the torque/induced tension relation for as-galvanized, and lubricant coated galvanized M20 high strength structural bolts. With the as-galvanized assemblies there is a wide scatter in induced tension at any one torque level and torque could not be used to provide a reliable method for gauging the required minimum bolt tension specified in AS 4100 before bolt fracture occurred. Bolt failures in torsion resulted from the high friction between the as-galvanized bolt and nut threads. Accordingly, AS 4100 does not recognise the use of the torque control method for tensioning galvanized or zinc plated bolts, as discussed under '**Full tightening**'.

Lubricated coatings on threads

Because of the poor torque/induced tension relationship of galvanized or zinc plated high strength bolt/nut assemblies AS 1252 specifies that supplementary lubrication must be provided. Lubricants should be pre-applied by the manufacturer.

Effectiveness of lubricants is checked by an assembly test which requires the bolt to withstand a minimum of between 180° and 420° from a snug position, depending on bolt length, before bolt fracture occurs.

Even when lubricant coated, galvanized and zinc plated high strength bolt/nut assemblies produce a wide scatter in induced tension for a given level of torque during tightening. Therefore only part-turn tightening or direct tension indicator tightening methods may be used as discussed under '**Part-turn tightening**' and '**Direct tension indicator tightening**'.

Structural bolts and bolting techniques

Three main types of metric bolt are used in structural engineering in Australia:

- **Commercial bolts** to AS 1111, strength grade 4.6
- **Medium strength or tower bolts** to AS 1559, strength grade 5.6
- **High strength structural bolts** to AS 1252, strength grade 8.8

Design provisions for structural bolts are contained in Australian Standard 4100-1998 'Steel structures'. This standard, in limit states design format, supersedes AS 1250 which was in a working stress format. AS 4100 also incorporates the design and installation clauses of high strength bolts from AS 1511 which it also supersedes.

Relevant Australian Standards

Relevant material standards referenced by Australian Standard 4100 are the current editions of:

AS 1110	'ISO metric hexagon precision bolts and screws'
AS 1111	'ISO metric hexagon commercial bolts and screws'
AS 1112	'ISO metric hexagon nuts, including thin nuts, slotted nuts and castle nuts.
AS 1252	'High strength steel bolts with associated nuts and washers for structural engineering'
AS 1275	'Metric screw threads for fasteners'
AS 1559	'Fasteners – bolts, nuts and washers for tower construction'

Strength designations, metric bolts

The strength of metric structural bolts is specified in terms of the tensile strength of the threaded fastener and defined according to the ISO strength grade system which consists of two numbers separated by a point, for example 4.6. The first number of the designation represents one hundredth of the nominal tensile strength (MPa) and the number following the point represents the ratio between nominal yield stress and nominal tensile strength.

For example a Property Class 4.6 bolt has:

Tensile strength of 4 x 100 = 400 MPa
Yield stress of 0.6 x 400 = 240 MPa

Galvanized commercial grade bolts

Metric commercial grade low carbon steel bolts used in the structural steel industry are manufactured to Australian Standard 1111 'ISO metric hexagon commercial bolts and screws' which calls for a tensile strength of 400 MPa minimum, with the Property Class designation 4.6. Design stresses are specified in AS 4100.

Identification of commercial bolts

Commercial bolts Property Class 4.6 carry the maker's name and the metric M on the bolt head. Nuts generally are supplied to Strength Grade 5 and carry no markings.

Galvanized tower bolts

Transmission towers are designed as critically stressed structures and the very large number of towers used provided the incentive to reduce weight and cost by application of the plastic theory basis for design. This design concept calls for a higher strength bolt than the standard commercial 4.6 bolt. The medium strength tower bolt to Australian Standard 1559 'Fasteners – bolts, nuts and washers for tower construction' was developed to meet this need. Property Class is 5.6 and galvanizing is the standard finish to provide corrosion protection matched to the structure.

As maximum shear strength values are required the thread is kept out of the shear plane. Transmission towers are often erected in high snow country and it is also necessary to have a bolt with good low temperature notch toughness. Short thread lengths and specified notch ductility meet these requirements.

AS 1559 calls for the following properties:

Tensile strength minimum	480 MPa
Yield stress, minimum	340 MPa
Stress under proof load	320 MPa
Charpy V-notch impact at 0°C:	
Average of 3 tests, minimum	27J
Individual test, minimum	20J

Nut locking of tower bolts

Transmission towers are constructed from galvanized structural sections using single bolted joints, and positive prevention of nut loosening is necessary in critical situations. This requirement is met by effective initial tightening and some additional measure to ensure nut locking, such as punching and distortion of the bolt thread at the outer nut face after tightening, or the use of galvanized prevailing torque type lock nuts.

Identification of tower bolts

Galvanized metric tower bolts carry the metric M on the bolt head together with the letter T for Tower, and the maker's name. Property Class 5 nuts are normally used, without markings.

Galvanized high strength structural bolts

The use of high strength structural bolts to AS 1252 in appropriate structural designs provides improved economy and efficiency in the fabrication of galvanized structures by permitting:

1. Smaller bolts of higher strength
2. Fewer bolts and bolt holes, resulting in:
3. Lower fabrication cost for members
4. Faster erection and reduced erection cost

AS 1252 calls for the following properties

Tensile strength, minimum	830 MPa
Yield stress, minimum	660 MPa
Stress under proof load	600 MPa
Minimum breaking load: M20 nominal diameter M24 nominal diameter	 203 kN 293 kN

In structural applications galvanized high strength structural bolts are commonly used in M20 and M24 metric diameter in both flexible and rigid connections. M30 diameter is less used in structural applications, particularly when full tightening is required to AS 4100, because of the difficulty of on-site tensioning to achieve specified minimum bolt tensions. M36 should never be specified if full tensioning to AS 4100 is required.

Galvanized high strength nuts

Nut threads are tapped oversize after galvanizing to allow for the increased thread diameter of the galvanized bolt. To ensure that nut stripping strength is adequate after oversize tapping, galvanized high strength nuts are manufactured from steel with a higher specified hardness than other high strength nuts, as discussed under '**Oversize tapping allowances for galvanized nuts**'.

AS1252 specifies the following mechanical properties

Nut type	Proof load stress MPa	Rockwell hardness HRC		HRB	Vickers hardness HV	
		Max	Min	Min	Max	Min
Galvanized	1165	36	24	-	353	260
All others	1075	36	-	89	353	188

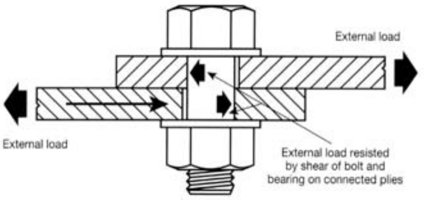
Identification of high strength bolts, nuts and washers

Galvanized high strength bolts to AS 1252 Property Class 8.8 can be identified by three radial lines on the bolt head, with the maker's name and the metric M. Nuts to Property Class 8 for use with structural bolts can be identified by three circumferential lines on the face of the nut. Relative to nominal thread size, high strength structural bolt heads and nuts are visibly larger than commercial bolts and nuts. Flat round washers for use with high strength structural bolts can be identified by three circumferential nibs.

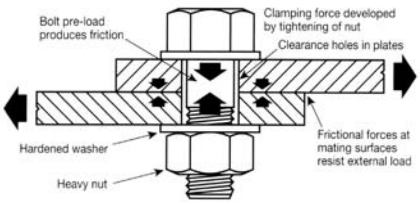
Modes of force transfer in bolted joints

In the design of individual bolts in bolted structural connections, there are three fundamental modes of force transfer:

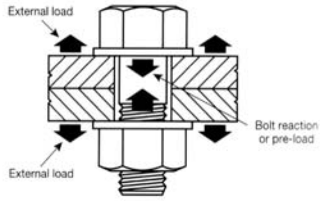
1. **Shear/bearing mode.** Forces are perpendicular to the bolt axis and are transferred by shear and bearing on the connecting plies – bolting categories 4.6/S, 8.8/S and 8.8/TB described below.



2. **Friction mode.** Forces to be transferred are perpendicular to the bolt axis as in shear/bearing mode, but load carrying depends on the frictional resistance of mating surfaces – bolting category 8.8/TF



3. **Axial tension mode.** Forces to be transferred are parallel to the bolt axis – may apply in combination with other bolting categories.



Bolting category system

The following bolting category identification system is based on that used in AS4100:

Category 4.6/S – Commercial bolts used snug tight

Category 8.8/S – High strength structural bolts used snug tight

Category 8.8/TF – High strength structural bolts fully tightened in friction type joints

Category 8.8/TB – High strength structural bolts fully tightened in bearing type joints

This category designation system is derived from the Strength Grade designation of the bolt, for example 8.8, and the bolting design procedure which is based on the following supplementary letters:

S represents snug tight

TF represents fully tensioned, friction type joint

TB represents fully tensioned, bearing type joint

Category 4.6/S refers to commercial bolts of Strength Grade 4.6 tightened snug tight as described under **'Tightening procedures' for high strength structural bolts.** (Snug tight is the final mode of tightening for bolting categories 4.6/S and 8.8/S, and the first step in full tensioning for bolting categories 8.8/TF and 8.8/TB).

Category 8.8/S refers to high strength structural bolts of Strength Grade 8.8 used snug tight.

High strength structural bolts in the snug tight condition my be used in flexible joints where their extra capacity can make them more economic than commercial bolts. The level of tightening achieved is adequate for joint designs where developed bolt tension is not significant. Behaviour of the bolt under applied loads is well known and accepted.

Category 8.8T refers to both categories 8.8/TF and 8.8/TB

Category 8.8/TF refers to high strength structural bolts Strength Grade 8.8 used in friction type joints, fully tensioned in a controlled manner to the requirements of AS 4100.

AS 4100 specifies that friction type joints must be used where no slip is acceptable. They should also be used in applications where joints are subject to severe stress reversals or fluctuations as in dynamically loaded structures such as bridges, except in special circumstances as determined by the engineer. Where the choice is optional, bearing type joints are more economic than friction type.

Category 8.8/TB refers to high strength structural bolts Strength Grade 8.8 used in bearing type joints, fully tensioned in a controlled manner to the requirements of AS 4100.

Variation in design values with bolt strength and joint design

Design values vary with joint design, bolt type and level of bolt tightening. The table below indicates the range of design values in shear which apply to bolts of the same nominal diameter (M20) in varying strength grades, used in various joint designs, in standard size holes (Kh=1), in accordance with AS 4100

Bolt and joint designation	Design value in shear, kN	
	Threads included in shear plane	Threads excluded from shear plane
4.6/S	44.6	62.3
8.8/S	92.6	129
8.8/TF	35.5	35.5
8.8/TB	92.6	129

Design for bolted structural joints

A summary of structural design procedure to AS 4100 has been produced by the Australian Steel Institute.

Design for high strength bolting

AS 4100 specifies conditions for the application of high strength structural bolts in both friction type and bearing type joints. Bolts are tightened to the same minimum induced tension in both types of joint.

Tension type joints

For joints in which the only force is an applied tensile force in the direction of the bolt axes, the tensile force on any bolt should not exceed the following table.

Maximum permissible bolt tension, kN

Nominal diameter of bolt, mm	Static load:
M16	104
M20	163
M24	234
M30	373

Bolt types and bolting categories

Bolting category	Bolt strength grade	Minimum tensile strength (MPa)	Minimum yield strength (MPa)	Name	Australian Standard	Method of tensioning/remarks
4.6/S	4.6	400	240	Commercial	AS 1111	Use snug tight. Least costly and most commonly available 4.6 grade bolt.
8.8/S	8.8	830	660	High strength structural	AS 1252	Bolts used are snug tight. The high strength structural bolt has a large bolt head and nut because it is designed to withstand full tensioning. It can also be used in a snug tight condition.
8.8/TF	8.8	830	660	High strength structural bolt, fully tensioned friction type joint	AS 1252	For categories 8.8/TF and 8.8/TB bolts are fully tensioned to the requirements as AS 4100. Cost of tensioning is an important consideration in the use of these bolting categories.
8.8/TB	8.8	830	660	High strength structural bolt, fully tensioned bearing type joint	AS 1252	

Friction type joints subject to shear, and combined shear and tension.

High strength hexagon head bolts are used as described under '**Galvanized high strength structural bolts**'.

Shear joints

In joints subject to shear only in the plane of the friction faces the number of high strength bolts and their disposition should be such that the resulting load at any bolt position does not exceed the value:

Slip factor* x number of effective interfaces x minimum bolt tension

*Slip factor is the coefficient of friction on the mating surfaces and can be defined as the ratio of the shear force between two plies required to produce slip, to the force clamping the plies together.

AS 4100 provides that the slip factor for clean as-rolled steel surfaces shall be taken as 0.35. When protective coatings are present on mating surfaces, AS 4100 specifies that the slip factor applied in design must be that of the protective coatings, based on test evidence as discussed under '**Slip factors of galvanized coatings**'.

Joints subject to external tension in addition to shear

An externally applied tension in the direction of the bolt axis reduces the effective clamping action of the bolt. To allow for this effect, the Interaction Equation of AS 4100 (Rule 9.3.3.3)

$$\left(\frac{V^*_{sf}}{øV_{sf}}\right) + \left(\frac{N^*_{tf}}{øN_{tf}}\right) \leq 1.0$$

Where:

V^*_{sf}	=	design shear force on the bolt in the plane of the interfaces
N^*_{tf}	=	design tensile force on the bolt
ø	=	capacity factor
V_{sf}	=	nominal shear capacity of the bolt
N_{tf}	=	nominal tensile capacity of the bolt

Bearing type joints subject to shear and combined shear and tension

In bearing type joints, design follows conventional practice based on allowable tension, shear and bearing values as specified in AS 4100. Design of a joint as bearing type infers that some slip into bearing may take place.

AS 4100 specifies that shear or moment connections subject to stress reversal, or where slip would not be acceptable shall be designed as friction type joints. Bearing type joints must be designed in accordance with AS 4100 using the allowable forces detailed in the table below. Provided joint surfaces are free from oil, dirt, loose scale, loose rust, burrs or defects which would prevent solid seating, AS 4100 permits the use of applied coatings without change in design values.

Joints subject to shear force only

Bearing type joints subject to shear force only, and which are less than 500 mm long in the direction of the applied shear force, shall be proportioned so that the shear force on any bolt does not exceed the maximum permissible shear force, permitted by the table.

For joints greater than 500 mm long refer to clause 9.3.2.1 of AS 4100.

Joints subject to shear and tensile forces

Bearing type joints subject to shear and tensile forces shall be proportioned so that the tensile force on any bolt does not exceed that permitted by the Parabolic Interaction Equation of AS 4100 (Rule 9.3.2.3)

$$\left(\frac{V^*_f}{øV_f}\right)^2 + \left(\frac{N^*_{tf}}{øN_{tf}}\right)^2 \leq 1.0$$

Where:

ø	=	capacity factor
V_f	=	nominal bolt shear capacity
N_{tf}	=	nominal tensile capacity of the bolt

Maximum permissible applied forces using metric bolts to AS 1252

Diameter of bolt, mm	Maximum permissible tension: Friction type and bearing type joints	Maximum permissible applied forces bearing type joints, kN		
		Shear note (1)		Bearing on projected area
		Threaded portion	Unthreaded portion	
16	104	59	83	Refer Clause 9.3.2.4 of AS 4100
20	163	93	129	
24	234	133	186	
30	373	214	291	

Note (1) Threaded portion – based on core are A_c defined in AS 1275.
Unthreaded portion – based on area of shank (nominal diameter)

Tightening procedures for high strength structural bolts

The installation and tightening of a high strength structural bolt/nut assembly is at least as costly as the bolt/nut assembly itself, and the selection of bolt type and bolt tightening procedure is an important consideration in the economics of high strength bolted structures.

Snug tightening

Snug tight is defined in AS 4100 as the full effort of a man on a standard podger spanner, or the point at which there is a change in note or speed of rotation when a pneumatic impact wrench begins impacting solidly. Podger spanners are graded in length in relation to bolt size and strength, and are, for example, of the order of 450mm long for M20 high strength structural bolts, and 600mm long for M24 high strength structural bolts.

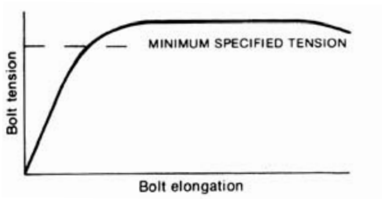
Snug tightening is applied in the following situations;

1. The final level of bolt tightening in general structural bolting using commercial bolts – **Category 4.6/S**
2. A final level of bolt tightening using high strength structural bolts – **Category 8.8/S**. Different design values must be applied than for procedures 8.8/TF and 8.8/TB using the same bolts, as discussed in **'Variation in design values with bolt strength and joint design'**.
3. An intermediate level of bolt tension applied as the first stage in full tightening – **Categories 8.8/TF and 8.8/TB**.

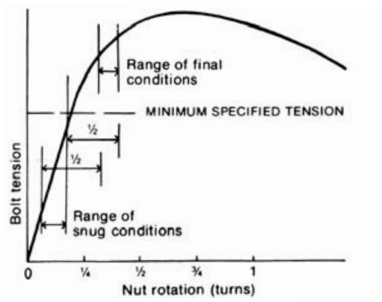
The growing popularity of high strength structural bolts to AS 1252 used in a snug tight condition leads to the situation where bolts may require full tightening to AS 4100 in one application and only snug tightening in another. **To prevent confusion and ensure correct tightening the designer must indicate clearly the level of tightening required, in both drawings and specifications**. Steps must be taken to ensure that this information is conveyed to all those involved in installation, tightening and inspection.

Snug tightening

When snug tightening is used as the first stage for full tightening in procedures 8.8/TF and 8.8/TB, the intention is to bring the plies into 'snug' contact ready for final tightening. The clamping force applied by snug tightening is highly variable as illustrated below, but is not significant when bolts are subsequently fully tightened – since the bolt tension/bolt elongation curve is relatively flat, variations in the snug tight condition result in only small variations in final bolt tension.



Bolt tension/bolt elongation curve for a typical high strength structural bolt.



The range of final bolt tensions after part turn tightening exceeds minimum specified bolt tension despite variability in snug tightening.

Full tightening (minimum bolt tension)

For joints designed in accordance with AS 4100, either as 8.8/TF friction type or 8.8/TB bearing type, bolts must be fully tightened to the following minimum tensions:

Nominal bolt diameter	Minimum bolt tension, kN
M16	95
M20	145
M24	210
M30	335
M36*	490

* If M36 bolts are specified the part turn method of tightening should be used only after special investigation into the capacity of the available equipment.

To attain these bolt tensions AS 4100 permits galvanized or zinc plated bolts to be tightened by either the part turn of nut method, or by the direct tension indicator method. Torque control tightening of galvanized or zinc plated bolts and nuts is prohibited in AS 4100 because of the variable torque/induced tension relationship of zinc coatings even when lubricant coated.

Nut rotation from the snug-tight condition AS 4100

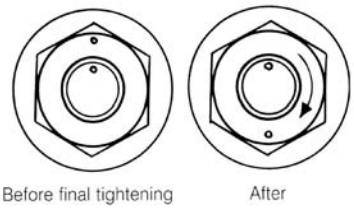
	Disposition of outer face of bolted parts Notes1, 2, 3 and 4		
Bolt length (underside of head to end of bolt)	Both faces normal to bolt axis	One face normal to bolt axis and other sloped	Both faces sloped
Up to and including 4 diameters	1/3 turn	1/2 turn	2/3 turn
Over 4 diameters but not exceeding 8 diameters	1/2 turn	2/3 turn	5/6 turn
Over 8 diameters but not exceeding 12 diameters (see Note 5)	2/3 turn	5/6 turn	1 turn

Note:

1. Tolerance on rotation: for 1/2 turn or less, one-twelfth of a turn (30°) over and nil under tolerance; for 2/3 turn or more, one-eighth of a turn (45°) over and nil under tolerance.
2. The bolt tension achieved with the amount of nut rotation specified above will be at least equal to the specified minimum bolt tension.
3. Nut rotation is the rotation relative to the bolt, regardless of the component turned.
4. Nut rotations specified are only applicable to connections in which all material within the grip of the bolt is steel.
5. No research has been performed to establish the turn-of-nut procedure for bolt lengths exceeding 12 diameters. Therefore, the required rotation should be determined by actual test in a suitable tension measuring device which simulates conditions of solidly fitted steel.

Part turn tightening

1. Line up holes with drift pins to maintain dimensions and plumbness of the structure
2. Fit bolts in remaining holes. Use taper washers if surface slope exceeds 3° and use flat washers under the rotating component.
3. Tighten all bolts to snug tight position, progressing systematically from the most rigid part of the joint to the free edges.
4. On large joints take a second run to check all bolts are snug tight.
5. Match mark installed nuts and bolts using a punch to show that snug tightening is complete. These marks can then be used for final tightening and inspection.



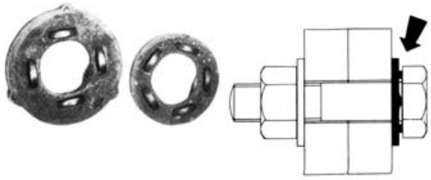
Part turn tightening. When tightening by hand or for permanent indication of tightening bolts and nuts should be match marked.

6. Complete tightening using the part turn method according to the table on page 56. Tightening should proceed systematically from the most rigid part of the joint to its free edges. Wrench sockets should be marked at position 180° apart to guide the operator in tightening.
7. Knock out drift pins, replace with bolts
8. Bring these bolts to snug tight position as in step 3, match mark as in step 5 and complete tightening as in step 6.
9. Mark joint to indicate tightening has been completed. One method is to draw lines with crayon between each bolt head forming a squared pattern.

Direct tension indicator tightening

Several direct tension indicating devices have been developed to provide a simple method of checking that minimum bolt tension has been developed. The most commonly used in Australia is the load indicator washer.

The load indicator is similar in size to a normal circular washer, with four to seven protrusions depending on size, on one face. It is assembled under the bolt head so that the protrusions bear on the underside of the head. As the bolt is tightened the protrusions are flattened, and reduction of the gap by a specified amount indicates that minimum bolt tension has been reached. For use with galvanized structural bolts load indicator washers are supplied with a galvanized finish.



Load indicating washers fitted under bolt head. Note gap which is reduced as nut is tightened.

Tightening procedure with load indicator washers

1. Ensure that the bolts are high strength bolts to AS 1252
2. Place load indicator on the bolt with protrusions abutting the underside of the bolt head or abutting a structural flat washer if the bolt head is to be turned in tightening.
3. Fit the bolt into place and assemble with nut and standard hardened washer. If a taper washer is required it is preferable that this be fitted under the nut but alternatively it may be placed between the load indicator and the structural steel.

4. Carry out a preliminary tightening to snug tight position, using a podger spanner or pneumatic impact wrench. It is important to begin tightening at the most rigid part of the joint progressing systematically to the free edges. On large joints take a second run over bolts to check that all are snug tight.
5. Carry out final tightening by reducing the gap between bolt head and load indicator to approximately 0.25 mm for galvanized bolts. In aggressive exposure conditions the gap may be fully closed to exclude moisture.

Should a nut be slackened after being fully tightened a new load indicator must be fitted before the second tightening.

Fitting load indicator under nut

In applications where it is necessary to rotate the bolt head rather than the nut, the load indicator can be fitted under nut using a special nut face washer which is heat treated to the same hardness as the bolt. Care must be taken that the nut face washer is fitted concentric with the nut and the correct way up, otherwise it may turn relative to the load indicator resulting in inaccurate load indication due to damage to the protrusions.

Experience has shown that on medium to large projects the extra cost of load indicators is offset by major savings in installation, supervision, and inspection of high strength joints.

Inspection of high strength bolted joints

Because of the increasing use of high strength structural bolts in the snug tight condition the designer must clearly indicate the level of tightening required in drawings and specifications, and he must ensure that this information is conveyed to all those involved in installation, including the inspector.

In structural joints using either 4.6/S or 8.8/S procedures the site inspector need only be concerned that the correct bolt type and number of bolts have been used in the joint. Since the level of tightening required is snug tight, this would have been achieved during erection.

In joints using galvanized bolts and 8.8/TF or 8.8/TB procedures, only visual inspection is necessary. The inspector should check that the correct fasteners and washers have been used and correctly installed, and that none show physical damage which might indicate they have been driven into mis-aligned holes.

Galvanized bolts which have been tightened by the part turn of nut method can be checked by their match markings. Where load indicating washers have been used for final tightening, inspection is greatly simplified.

Tightening of bolts by the torque control method has been deleted from AS 4100. For guidance on the use of a torque wrench for inspection refer to AS 4100 Supplement 1-1999, Appendix CK.

Flush spliced structural joints in galvanized steel

The increasing popularity and used of hot dip galvanizing as a stand alone or bare finish for structural steel members means that a consistency in the overall finish is desirable. This can be affected by the type of connections used. Welding, while practical, requires coating touch up which may spoil the visual continuity of the galvanized coating in some applications. Conventional bolted connections, are versatile and economic as is the method of flush splice connections.

A method of flush-splicing structural steel members was conceived by Arthur Firkins, formerly Director of Technical services, Australian Institute of Steel Construction.

The connection uses flat-head countersunk Unbrako high strength socket screws through beam flanges into threaded holes in the flange and web connecting members. The result is a flush finish to beam flange surfaces without protruding bolt heads or nuts, in a joint with the performance characteristics needed in structural applications.

Structural performance

In order to investigate joint behaviour, a test specimen was subjected to tensile testing at the University of Sydney to determine the flange force transfer capacity of a typical splice. Test results showed that the splice conformed to the requirements of Australian Standard 4100 'Steel Structures'. The test results also confirmed the designed capacity of the flange beam calculated in accordance with AS 4100. As a result of this testing, structural engineers can now incorporate unobtrusive flush-spliced structural connections, confident that their design will meet the requirements of AS 4100.

Fasteners and threads

The fasteners employed are Unbrako high strength flat-head socket screws, ISO metric series, mechanically zinc plated to a coating thickness of 25µm to give adequate corrosion protection.

The specification for these bolts is:

Material:	Unbrako high-grade alloy steel*
Hardness:	Re36-44
Ultimate tensile strength:	1100MPa
0.2% yield stress:	990MPa
Thread class	4g

* In the international method of designating bolt strength these bolts would be classified as Grade 10.9

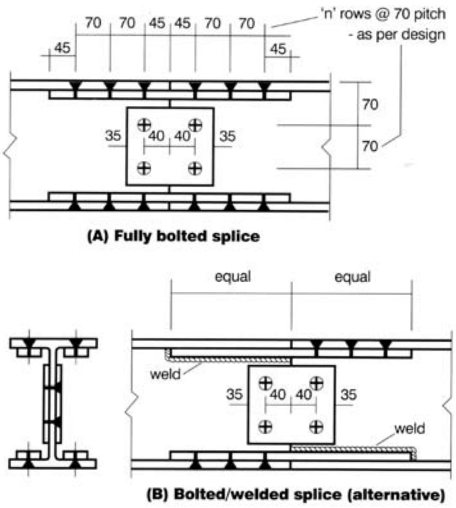
M12, M16 and M20 screw sizes are used.

Design of flush-bolted splices

Dimensional criteria for connections in commonly used beams are given in the table below. These criteria apply to both fully-bolted splices (Drawing A) and bolted/welded splices (Drawing B). This system will allow relatively large flange force transfer in members of all types and sizes. Splice plates should be at least equal to flange or web thickness and not less than screw diameter.

Installation procedures

Procedures for the installation of Unbrako socket head screws is contained in the product manual published by Unbrako.



Fully-bolted splice, drawing A, and bolted/welded splice, drawing B.

Dimensional criteria

	Member		Flange plates		Web plates		Bolts* Flange	Web
Size	Flange tf	Web tw	Width mm	Thick mm	Width mm	Thick mm	Size	Size
UB Sections								
200 UB 30	9.6	6.3	50	20	150	6	M16	M12
250 UB 37	10.9	6.4	50	20	150	6	M16	M12
310 UB 40	10.2	6.1	50	20	150	6	M16	M12
360 UB 51	11.5	7.3	50	20	150	6	M16	M12
410 UB 54	10.9	7.6	50	20	150	8	M16	M12
460 UB 67	12.7	8.5	50	20	150	8	M20	M16
530 UB 82	13.2	9.6	75	20	150	10	M20	M16
UC Sections								
250 UC 73	14.2	8.6	100	20	150	8	M20	M16
200 UC 46	11.0	7.3	75	20	150	8	M20	M12

* Unbrako flat head socket screws Grade 10.9

1. Suggested criteria in the table should be verified for specific design load cases.
2. For serviceability state, "Ply in bearing (beam flange) will usually govern design" (AS 4100 9.3.2.4(2)).
3. Ultimate failure in the test was the flange plate component failing in tension.
4. Flange plate component thickness should be greater than flange thickness and equal to or greater than bolt diameter.
5. Web plate component thickness should be greater than web thickness.
6. "n" = number of rows of bolts in flange or web as required by design – see Drawing (A). Note: Bolt shear strength (10.9) will rarely govern.
7. Bolts should be specified as "Unbrako flat-head socket screws Grade 10.9, mechanically zinc/tin plated to a coating thickness of 25µm".
8. Holes in flange plates should be tapped 0.1mm oversize to allow for the coating thickness on screw threads.
9. Tapped threads should be plugged during the galvanizing process using bolts of appropriate diameter (Grade 4.6 hex head uncoated).

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CHAPTER 5

Welding Galvanized Steel

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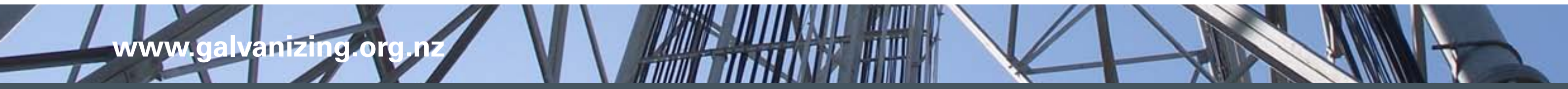
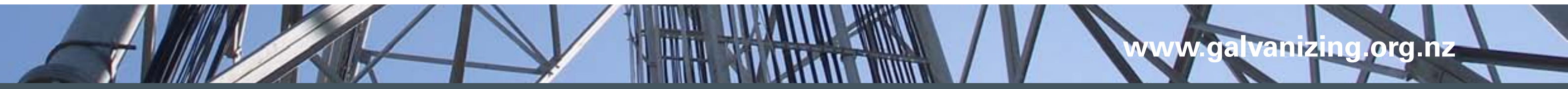


Welding Galvanized Steel

Galvanized steels are welded easily and satisfactorily by all commonly practised welding techniques. Closer control of welding conditions than for uncoated steel is usually necessary but procedures are simple and well established. This chapter details procedures for all suitable welding techniques for galvanized steel including GMA (gas metal arc), carbon arc, GTA (gas tungsten arc), manual arc, and oxyacetylene welding. The welding of galvanized reinforcement for concrete is discussed in **'Galvanized steel reinforcement for concrete'**.

Work sponsored by International Lead Zinc Research Organization, New York and carried out by E N Gregory of The Welding Institute, Cambridge, England, has been used in recommendations on GMA welding and manual metal arc welding. Recommendations are based on Australian practice and terminology. Information has also been supplied by Liquid Air Australia Limited and Welding Industries of Australia.



GMA welding galvanized steel

GMA (gas metal arc) welding, also known as CO_2 - or MIG/MAG welding, is a versatile semi-automatic welding process which is convenient and easy to use. It is particularly suited to the welding of thinner materials.

Welding galvanized steel vaporizes the zinc near the arc (zinc boils before steel melts). The zinc oxidises in the air to a fine white powder. Prolonged breathing of these fumes can cause side effects which lasts about 24 hours. As with all welding proper ventilation and fume exhaust is of first priority (please see Chapter 13 of WTIA Technical Note 7).

In the GMA welding of galvanized steel the presence of the zinc coating has no effect on weld properties although some weld spatter is produced as discussed under '**Appearance of GMA welds in galvanized steel**'. Arc stability is excellent and is not affected by the galvanized coating. Some reduction in welding speed is required, see 'Welding conditions' at top right.

The GMA welding process

The weld takes place in a protective gas shield. A small diameter consumable wire electrode of 0.8mm to 1.6mm is fed automatically to the weld torch. The high current density resulting from the small diameter of the wire is in the region of 200 amperes per square millimetre.

The constant voltage type power sources employed offer instantaneous self adjustment of the arc so that the arc length remains constant even when the operator varies the distance between the electrode and the work piece – power sources are designed to increase welding current as the arc length shortens and the wire burns off at a higher rate to maintain the original arc length. When the arc is lengthened, current is reduced and the wire is consumed at a lower rate, again maintaining the original pre-set arc length.

Welding parameters provide for two different types of metal transfer in GMA welding:

1. Spray transfer, in which globules of metal are detached magnetically from the wire and propelled across the arc. This is the high current/high voltage form of the process which is used in the flat position on plate thick enough to prevent burn-through.
2. Short circuiting transfer sometimes known as 'dip transfer', in which lower currents and voltages are used. The end of the wire dips into the molten weld pool while a globule of metal is being transferred. Short circuiting transfer occurs about 100 times per second producing a characteristic buzzing sound. The process is used for welding thin sheet and for positional welding of all thicknesses.

Shielding gas for GMA welding galvanized steel

Galvanized steel is welded satisfactorily using the GMA process and pure carbon dioxide shielding gas which provides excellent weld penetration, but considerable weld spatter. The use of a spatter release compound as discussed under "**Appearance of GMA welds in galvanized steel**", may be worthwhile.

Alternatively, the more expensive argon/CO_2 or argon/CO_2/O_2 mixes provide adequate weld penetration, a superior weld bead, and far less spatter. A 92% Ar/5% CO_2/3% O_2 mixture has been found to provide excellent results on galvanized sheet up to 3.0mm thickness.

Conditions for GMA welding galvanized steel using a short circuiting arc and both Ar/CO_2 and CO_2 shielding gases are given below.

Welding conditions

GMA welding speeds should be lower than on uncoated steel as specified in the weld conditions tables, to allow the galvanized coating to burn off at the front of the weld pool. The reduction in speed is related to the thickness of the coating, the joint type and the welding position, and is generally of the order of 10 to 20 per cent.

Fillet welds in steel with thicker galvanized coatings may be welded more readily if the current is increased by 10 amps. The increased heat input helps to burn away the extra zinc at the front of the weld pool.

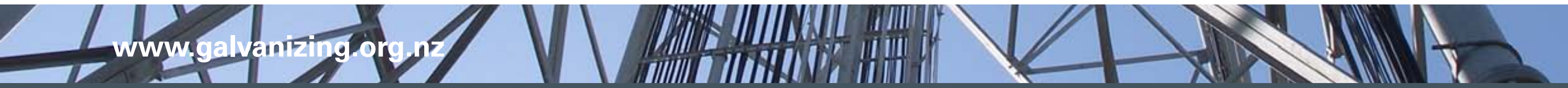
Penetration of the weld in galvanized steel is less than for uncoated steel so that slightly wider gaps must be provided for butt welds. A slight side to side movement of the welding torch helps to achieve consistent penetration when making butt welds in the flat position.

Effect of welding positions in GMA welding galvanized steel

To achieve complete penetration in the overhead position on sheet with 600g/m^2 coatings, weld current should be increased by 10 amps and voltage by 1 volt.

Welds in the vertical downwards position may require a speed reduction of 25 to 30 percent 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 overhead and horizontal-vertical positions require little reduction in speed because the zinc vapour rises away from the weld area.



Appearance of GMA welds in galvanized steel

Surface appearance of GMA welds in galvanized steel is satisfactory although a certain amount of weld spatter is generated, regardless of whether CO_2 shielding gas or an argon/ CO_2 mixture is used.

Minor coating damage occurs and repairs to the weld area should be carried out as detailed in **Reconditioning weld-damaged surfaces**.

Adhesion of weld spatter to the gun nozzle, and to the work piece with resulting marring can be prevented by application before welding of an aerosol spray petroleum base or silicone base spatter release compound available from welding consumables suppliers. Any adhering spatter particles can then easily be brushed off. Silicone-based compounds may interfere with paintability.

Spatter may also build up in the nozzle of the torch interrupting the flow of shielding gas, in extreme cases causing weld porosity and erratic feeding of filler wire. The application of a spatter release compound to the welding torch nozzle reduces the adherence of spatter particles and with the help of a small wire which can be rubbed inside the nozzle.

GMA braze welding

An extension of the GMA process, GMA braze welding utilises a filler metal with a lower melting point than the parent metal. The joint relies neither on capillary action nor on intentional melting of the parent metal. Shielding gases of argon/oxygen type are the most suitable, the low oxygen level being sufficient to permit excellent edge wash and a flat weld without causing surface oxidation. The low heat input minimises damage to the coating on the underside of the parent plate, enables the corrosion resistant bronze filler to cover any of the coating damaged by the arc, and minimises the level of distortion when welding sheetmetal components.

Finishing costs of sheetmetal components such as automotive panels can therefore be reduced substantially.

Manual metal arc welding galvanized steel

Manual metal arc welding is recommended only for galvanized steel of 1.6mm thickness or thicker, as difficulty may occur with burning through on light gauges. GMA, GTA, or carbon arc welding are recommended for sheet lighter than 1.6mm.

In general manual metal arc welding procedure for galvanized steel sheet is the same as for uncoated steel although the following points should be noted:

1. The welding electrode should be applied a little more slowly than usual with a whipping action which moves the electrode forward along the seam in the direction of progression and then back into the molten pool. All volatilisation of the galvanized coating should be complete before bead progress, after which welding is the same as for uncoated steel.
2. A short arc length is recommended for welding in all positions to give better control of the weld pool and to prevent either intermittent excess penetration or undercutting.
3. Slightly wider gaps up to 2.5mm are required in butt joints in order to give complete penetration.
4. For operator comfort adequate ventilation should be provided and the use of a respirator is recommended in confined spaces (See '**Welding fumes**')
5. Grinding of edges prior to welding will satisfactorily reduce fuming from the galvanized coating. Welding schedules will then be the same for uncoated steel.
6. Repairs to the coating should be carried out. See '**Reconditioning weld-damaged surfaces**'.

Electrodes for manual metal arc welding galvanized steel

In general, 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.

With metal recovery rates of between 110 and 130 per cent, both rutile and basic coated iron powder electrodes perform satisfactorily on galvanized steel, giving a good weld profile with freedom from undercutting, and easy slag removal.

In butt joints in plate with vee edge preparation, an electrode should be chosen which limits the tendency to produce a peaky or convex deposit run since this can cause slag entrapment which will not be removed by subsequent weld runs.

Undercutting in fillet welds is reduced if rutile coated electrodes with a less fluid slag are used since these produce a concave weld profile. Electrodes with very fluid slags tend to produce concave weld profiles with more prevalent undercutting, which is difficult for the welder to rectify.

Different brands of electrodes complying with the same specification may behave differently when used in welding galvanized steel and it may be advisable to carry out simple procedure tests before commencing production welding.

Physical properties of arc welds in galvanized steel

Extensive tensile, bend, radiographic and fatigue testing at the Welding Institute* Cambridge, UK, for International Lead Zinc Research Organisation has shown the properties of sound GMA welds and manual metal arc welds in galvanized steel to be equivalent to those of sound welds in uncoated steel. Test welds were made without removing the galvanized coating from edges to be welded.

The presence of any weld porosity due to volatilisation of the galvanized coating during welding has no effect on joint properties except in loss of fatigue strength which can be avoided as discussed under 'Effect of porosity on fatigue strength', below.

Properties of sound welds in galvanized steel

General properties

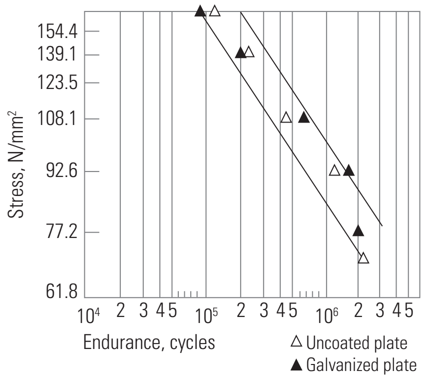
When welding conditions are chosen to give sound welds in galvanized steel, the tensile, bend and charpy impact properties are equivalent to those of welds in uncoated steel. Tests showed that the presence of zinc at the levels occurring in the weld metal does not affect tensile, bend or impact properties.

Fracture toughness

Crack opening displacement (COD) measurements and drop weight tests established that fracture toughness properties of welds are unaffected by the presence of galvanized coatings.

Fatigue strength

The fatigue strength of arc welds in galvanized steel is equivalent to welds in uncoated steel as shown by the test results below. Fatigue tests were carried out on fillet welded cruciform joints made by CO_2 GMA welding with low silicon filler metal of the AWS Classification AWS A5.18:ER70S-2



SN curves showing results of fatigue tests on cruciform joints. CO_2 short circuiting GMA welds on 13mm uncoated and galvanized Lloyds Grade A steel, AWS A5.18:ER70S-2 filler metal. EN Gregory, 'The mechanical properties of welds in zinc coated steel'

Properties of welds containing porosity

General effects

Porosity will occur in certain joint designs in galvanized steel, depending on coating thickness, due to volatilisation of the zinc coating and entrapment of gas in the weld.

The type of joint affects pore formation since gases cannot readily escape from tee joints and lap joints or from butt joints in thick materials. In the case of butt joints, a vee edge preparation or provision of a gap between square edges facilitates the escape of gases, minimising porosity.

Pore formation is also influenced by the thickness of the galvanized coating relative to the steel base.

Close attention to welding conditions will reduce the extent of porosity but complete elimination is not always possible and it is important to consider the effect of porosity on static strength, fatigue strength and cracking of the weld joint.

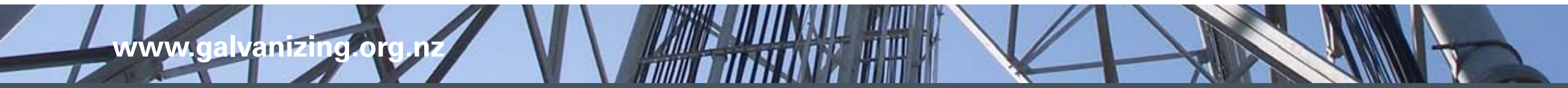
Effect of porosity on fatigue strength

When joints are subject to fatigue loading, welds in galvanized steel should be made oversize to reduce the influence of any porosity in the weld metal.

When a fillet weld in galvanized steel is large enough relative to plate thickness to fail by fatigue from the toe of the weld in the same manner as in uncoated steel, the presence of porosity in the weld does not reduce the fatigue strength of the joint. Where the dimensions of a weld are just large enough to cause fatigue failure from the toe in a sound weld, a weld containing porosity at the root may fail preferentially through the throat of the weld.

Cracking

Intergranular cracking of fillet welds containing porosity, sometimes referred to as zinc penetrator cracking, does not significantly affect the strength of non-critical joints. For more critical stressed applications however, it is advisable to carry out procedural tests on material and samples.



GTA brazing galvanized steel

GTA (gas tungsten arc) process, also known as argon arc, provides an excellent heat source for braze welding.

In GTA brazing, the weld area is shielded from the atmosphere by a protective flow of inert argon gas. A non-consumable tungsten electrode is employed with a separate 'Cusilman' (96% Cu, 3% Si, 1% Mn) filler wire, as used for carbon arc welding. The argon barrier prevents oxidation of the electrode or the weld pool and welds of excellent appearance result. The process allows continuous welding at very high speeds, particularly with mechanised arrangements.

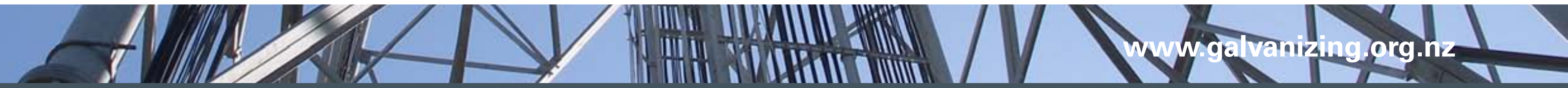
In the GTA brazing of galvanized steel the arc should be played on the filler wire rather than on the weld area to prevent undue coating damage.

The following variations in welding technique are also recommended to minimise contamination of the tungsten electrode by traces of zinc oxide fume:

1. Hold the weld torch at a 70° angle rather than the 80° angle normally used for uncoated steel
2. Increase shielding gas flow form 6 to 12 L/min to flush zinc oxide fume from the electrode area.

Corrosion resistance of GTA brazed joints made in galvanized steel is excellent. During the welding operation the corrosion resistant brazed metal tends to wet and flow out over the small area from which the galvanized coating has been volatilised, so 'healing' the coating.

GTA welding is recommended only as a heat source for brazing galvanized steel, not as a fusion welding technique. When used for fusion welding the tungsten electrode is fouled rapidly by zinc oxide fume.



Oxyacetylene welding galvanized steel

Oxyacetylene welding galvanized steel sheet either with or without a filler rod is generally carried out on the lighter gauges. Because zinc volatilises at about 900°C while steel melts at about 1500°C, the necessary welding temperature usually results in coating damage and the need for subsequent treatment of damage areas. (See below)

Brazing

Coating damage may be overcome by adopting brazing techniques. Brazing employs much lower temperatures (900°C), producing very little coating damage in the area adjacent to the weld. The weld metal itself is corrosion resistant and tends to wet and cover all bare steel in the weld area so that joints are normally acceptable without further treatment.

The suggested filler rod is a copper-zinc-silicon alloy, such as Austral Tobin Bronze (63% Cu, 37% Zn, 0.3% Si, 0.15% Sn). Prior to brazing, the edges of components should be painted for about 6mm back with a flux such as Comweld Copper and Brass Flux or Liquid Air 130 Flux.

The lowest practical heat input is desirable and flame adjustment must be oxidising, as this helps to reduce local loss of zinc in the weld zone. Butt welds are preferred to lap joints and the gap in such welds should be equal to half the thickness of the sheet.

Some welding fume will be given off during brazing and forced ventilation or fume extraction must be provided in confined spaces. (See '**Welding fumes**')

Reconditioning weld-damaged surfaces

Weld damage

When severe damage to the galvanized coating has occurred during welding or when the weld area will be exposed to corrosive service conditions, protection must be restored. Width of the weld-damaged zone will depend on heat input during welding, being greater with a slow process such as oxyacetylene welding than with high speed arc welding.

In the manual metal arc welding and oxyacetylene welding of galvanized steel, the weld metal itself will corrode in most atmospheres and the application of a protective coating is essential. Suitable materials for coating the weld metal and adjacent damaged areas of the coating are zinc rich paints, and in some circumstances, zinc metal spraying as discussed above right and in '**Reconditioning damaged surfaces in galvanized steel**'.

Coating damage due to rough handling or abrasion

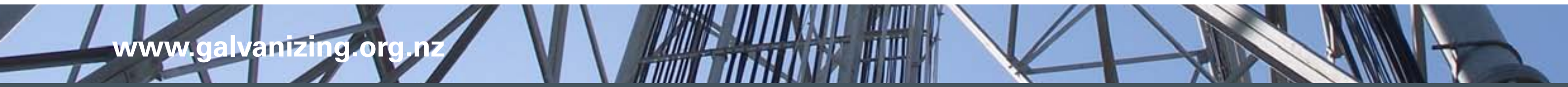
Small areas of the basis steel exposed through mechanical damage to galvanized coatings are protected from corrosion cathodically by the surrounding coating and may not need repair, depending on the nature of the product and the environment to which it is exposed. Small exposed areas normally have little effect on the life of the coating as discussed under '**Bare spots**' and '**Cathodic protection**'.

Larger damaged areas require coating repair.

Repair methods

Appropriate coating repair methods are detailed in '**Reconditioning damaged surfaces in galvanized steel**'. The methods described are in accordance with Australian/New Zealand Standard 4860 - Part 8 'Repair After Galvanizing'.

In the case of weld repairs, surface preparation consists of removal of any welding slag with a chipping hammer followed by vigorous wire brushing.



Welding fumes

Arc and oxyacetylene welding

In the arc welding or oxyacetylene welding of galvanized steel, provision must be made for control of welding fumes when planning procedures. Due to the relatively low melting point of zinc a proportion of the coating is volatilised and given off as a white zinc oxide fume. The presence of any fume evolved is obvious and this permits simple observation of the efficiency of the ventilation or extraction system.

When welding is carried out in accordance with normal industrial practice with provision for adequate ventilation and air circulation, the non-toxic zinc fumes will cause no inconvenience. If adequate ventilation is not available, supplementary ventilation using air extraction equipment or forced air circulating equipment, should be provided.

Although welding fumes from galvanized steel are not toxic, operators welding in a confined space should always be provided with suitable respirators to minimise possible discomfort. Fume development and consequent coating damage may often be minimized with certain joint designs in flat sheet by the use of copper chill bars. The chill bars are used as a backing strip or clamped on the weld side of the joint to absorb some of the heat generated during welding.

GMA welding

Welding fume extraction guns for GMA welding galvanized steel are available from major welding equipment suppliers. These guns are very effective in removing weld fumes and have negligible effect on weld quality.

GMA welding tests were conducted by the Welding Institute, Cambridge, England for International Lead Zinc Research Organisation Inc. Using CO_2 shielding gas at a flow rate of 15 L/min, a horizontal-vertical fillet weld in 6 mm thick batch galvanized steel was free from porosity. Tests with the same CO_2 flow rate and the fume extractor in operation produced a fillet field on the same plate sample containing only two small pores in 150 mm of weld, showing that disturbance of the shielding gas is extremely small.

Plasma cutting of galvanized steel

Plasma cutting using compressed air as the cutting gas allows high speed cutting of galvanized steels in thicknesses from 0.5 to 10 mm, with reduced distortion. The high cutting speed and concentrated arc results in very limited coating damage and minimal fume generation.

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CHAPTER 6

Painting Galvanized Steel

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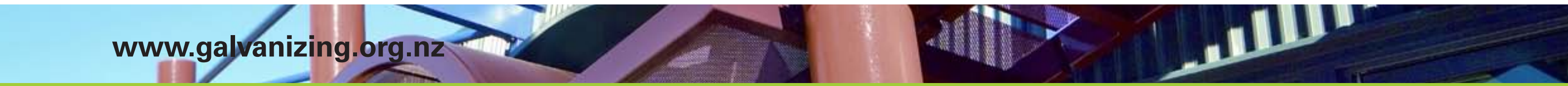
GALVANIZING ASSOCIATION



Painting Galvanized Steel

Prepared by Don Bartlett of CTI Consultants in collaboration with Galvanizers Association of Australia

The painting of hot dip galvanized steel is an orthodox and well-proven practice in outdoor environments, both in Australia (AS/NZS 4680[1]) and internationally[2]. However, there are examples of early failures of paints over galvanizing due to incorrect specifications and poor practice. This chapter aims to avoid such failures by directing specifiers and applicators to the paint systems, surface preparation and application practices that will provide a durable paint finish over galvanizing in a broad range of service conditions.

While good painting practices and generic products for the various exposure conditions have been nominated, this does not preclude the possibility of other paints and methodologies also performing satisfactorily. However, in selecting alternative products, specifiers are urged to select products only from those with verified records of satisfactory long-term performance in equivalent or more severe service conditions.

This is a general guide only and requires strict compliance with the individual paint manufacturers detailed application instructions for each proprietary product.

Painting objectives

Reasons for painting galvanized steel are primarily:

- Decorative - to create an aesthetic colour and gloss or provide an identifying colour.
- Enhanced durability - to increase service life.
- Wider chemical resistance – in a situation where galvanizing alone may be vulnerable, such as outside the pH the range 6 to 12.

Decorative painting

In outdoor service, remote from the coastal fringe and isolated areas of industrial pollution, hot dip galvanizing is inherently durable. This contrasts with paints and other organic materials, which are degraded by solar radiation. Therefore, in most conditions of atmospheric exposure, little is to be gained from painting galvanizing of a coating thickness $300g/m^2$ or more unless aesthetic or colour considerations are important.

In benign internal situations, and particularly conditions of extreme impact or hard wear, unless a change in colour or gloss is considered necessary, galvanizing is usually best left unpainted.

A great deal of galvanizing is painted on a casual basis, with conventional latex or suitably primed solvent-based alkyd paint[3]. Choice of this primer is crucial and requires a clear recommendation from the paint manufacturer. In particular, the use of an alkyd primer in direct contact with the galvanizing risks delamination of the paint due to its saponification.

It is important to note that because these paint systems are quite thin, typically 70 - 120 micrometres for a three coat system, the characteristic spangle profile and localised areas of increased zinc thickness, such as at edges, may be visible in the finish, much in the same way as the grain is visible in painted timber. If this is a problem, then higher build paints can be used, as part of the painting specification.

While acknowledging the lesser absolute demands of conventional (DIY) decorative paints, strict adherence to the appropriate surface preparation and prime coat specification are a key to reliability.

The paint systems detailed under Service Conditions 1 and 2 in the following pages are essentially decorative paint systems.

Painting for enhanced durability

It is perhaps obvious that in circumstances where the galvanized coating is slowly being attacked by a corrosive environment, the application of a suitable coating which insulates the zinc from that environment will prolong the galvanizing's life. Indeed, a synergistic increase in service life of paints over galvanizing has been well documented[5]. Therefore, in severe coastal service and unwashed coastal conditions such as under verandas and in severe industrial service[4], the over painting of galvanizing can significantly extend service life. Even in quite benign outdoor service conditions where galvanizing might last for many decades, it can be prudent to paint areas that are sheltered from the cleansing influence of rain to extend the service life of the structure even further.

In similar vein, while a galvanized structure might be essentially exposed to the atmosphere at some points it may be in ground contact or may be exposed to intermittent or continuous ponding of rainwater. In such situations localised over painting may be needed to avoid premature corrosion in these areas.

The paint systems detailed under Service Requirements 3-5 in the following pages are essentially paint systems intended to provide enhanced durability performance, resistance to wear and trafficking and more aggressive atmospheric service conditions. The paints range from two-pack epoxies and polyurethanes to powder coatings. Most paints have specific restrictions in how they are applied and cured. For example, below about 8^oC latex paints will not usually dry and many two-pack coatings have a limited recoating time. Powder coatings, because they are hard cured as soon as they are stoved, can offer logistical benefits. In addition, because they can be applied electrostatically, more uniform coverage can be achieved with intricate shapes than is possible with conventional paints. However, judicious selection of pretreatment and application by competent operators is critical to performance.

It is important to note that for effective protective coatings over galvanizing, the thickness of the paint system must be increased, as the environment becomes more corrosive. An effective corrosion inhibitive primer is usually another prerequisite. Indeed, many failures of paint systems over galvanizing can be traced to either an inappropriate primer or an inadequate total paint thickness[6].

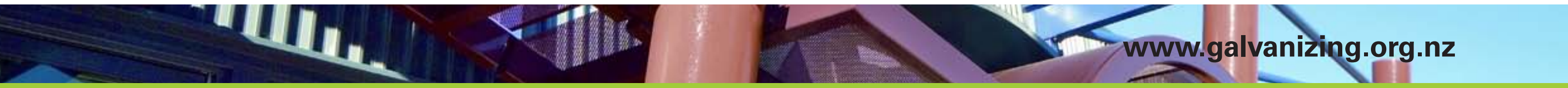
The paint systems detailed under Service Requirements 3-5 also provide options for situations where an aesthetic finish is also needed.

Painting for enhanced chemical resistance

Galvanizing is used within the pH range 6 to 12. Outside this range, its service life is likely to be unacceptable. This includes exposure to strong acids and alkalis and salts of strong acids and weak bases and vice versa. Galvanizing may also catalyse the deterioration of certain organic chemicals that are exposed to it. This phenomenon is rare and causes no damage to the galvanizing.

Just as coatings provide enhanced protection in corrosive atmospheric service, judiciously selected paint systems can also protect galvanizing from aggressive chemicals. Such approaches are usually only taken where the chemical exposure is low or moderate, as the safe principle to adopt in extreme situations is to use a substrate material that is inherently inert. In such situations, stainless steels and plastic composites often find advantage.

In specific chemical exposure, the recommendations of an expert or an established successful case history should always be sought[7].



Surface preparation

When painting galvanizing, as when painting any other surface, the cleanliness and condition of the surface are of critical importance and a high proportion of paint failures on galvanized steel can be attributed to inappropriate or inadequate surface preparation.

In preparing galvanizing for painting, the basic requirements are largely the same as for other surfaces. Namely, anything that prevents the paint wetting out or adhering to the surface needs to be removed. Therefore oils, dirt, dust, salts, corrosion products and other friable material and soluble salts must be removed as a precursor to any subsequent treatment. Refer to AS/NZS 2312[8] Section 4 and AS 1627[9]. The difficulty of removing some contaminants should not be underestimated and for severely corroded galvanizing, in particular, reinstatement may be impractical, because of the extensive preparation required.

For the removal of oil and grease, water based emulsifiers, alkaline cleaners of pH less than 12 or organic solvents are variously appropriate. Where oils and grease are removed by solvent-soaked cloths these need to be changed frequently, as oil contaminated cloths only serve to spread the contamination.

Apart from the removal of dirt, dust and grease, which are common to all substrates, it is important to recognise that all sophisticated coatings intended for extended durability service, require high standards of surface preparation for maximised performance.

One important issue for galvanized surfaces is the time lapse between galvanizing and painting. The best advice is to paint galvanizing as soon as possible, for the sooner it is painted the less likely it is to be contaminated by dust, salts and corrosion products. Conversely, the longer the time lapse and the more severe the conditions of exposure prior to painting, the more difficult and costly the preparation will be. In extreme cases, such as where surfaces have been close packed in humid or damp conditions and suffered wet storage staining, brushing with 1-2% ammonia, or in extreme cases one part citric or acetic acid to 25 parts water, may be required[10].

A second consideration, which needs to often be addressed with galvanizing, is the smooth, glossy surface that emerges from the galvanizing bath. This can inhibit paint adhesion. In the past, two methods of dealing with this problem were to etch the surface with an aggressive salt solution or mineral acid or allow the zinc to weather for some time before painting. These techniques have long been discredited.

For painting unweathered galvanizing with conventional low build paints (see Service Requirements 1 and 2) cleaning and degreasing is normally adequate, although light scuffing with sandpaper will invariably enhance paint adhesion. For higher build paints and under conditions of more arduous wear, brush (whip) abrasive blasting is favoured (see Service Requirements 3-6)

This process lightly roughens the surface without removing a significant amount of galvanizing and provides a key to promote adhesion of the paint film. This procedure should be carried out using a soft abrasive, by impacting the surface at a glancing angle and operating at low air pressure.
The following criteria are included in both AS/NZS 4680[1] and AS1627.4[9] are recommended[11]:

- Blast pressure 280 kPa (40 psi.)
- Abrasive Grade 0.2- 0.5 mm (clean ilmenite)
- Angle of blasting to surface 45°
- Distance from surface 300-400 mm
- Nozzle type min. 10 mm of venturi type.

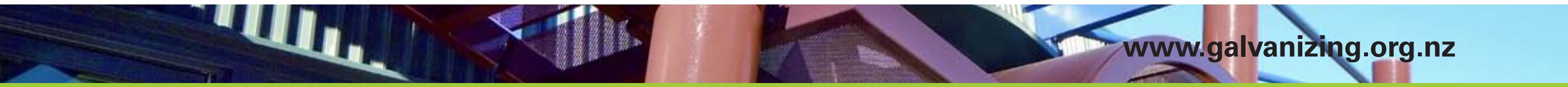
Painting systems

The following pages provide guidance on paint systems suitable for use in industrial and commercial situations under six different "service requirements" as follows:

Service Requirement 1	Low corrosivity conditions & medium term service.
Service Requirement 2	Low corrosivity conditions & high resistance to wear & trafficking/long term service.
Service Requirement 3	Medium corrosivity conditions & high resistance to wear & trafficking/long term service.
Service Requirement 4	High corrosivity conditions & high resistance to wear & trafficking/long term service.
Service Requirement 5	Very high corrosivity conditions & high resistance to wear & trafficking/long term service.
Service Requirement 6	Specific industrial chemical or solvent exposure.

Notes

- Medium and long term service are typically of 5-10 years and 10-15 years respectively for a maintenance repainting cycle to retain aesthetic performance.
- The corrosivity condition assessment is based upon the guidelines of AS/NZS 2312[8], which essentially relate corrosivity in terms of distance from the seacoast and need careful interpretation.
- Specific typical commercial products relevant to each specification are listed in Appendix 1, which follows these specifications.
- Application should be strictly in accordance with the paint manufacturer's written instructions and the relevant recommendations of AS/NZS 2311 in the case of Service Requirement 1 and to AS/NZS 2312 in the case of Service Requirements 2 - 6.



Service requirement 1

Low Corrosivity Conditions (Refer Note 1) & Medium Term Service (Refer Note 2)

Clean Degrease >	1 coat of Latex Primer (to AS 3730.15 or APAS 00134) >	1 coat of 100% Acrylic Gloss Latex (to AS 3730.10 or APAS 0280/1) >	1 coat of 100% Acrylic Gloss Latex (to AS 3730.10 or APAS 0280/1)

Note 1	AS/NZS 2312 Corrosion Categories A (Very Low) and B (Low). These locations range from more than 50km from a surf beach down to about 1km from quiescent seawater. It also includes Category C (Medium) locations, provided the structure is totally exposed to the cleansing influence of rainwater or is subject to an appropriate regular hosing with fresh water, as unwashed areas in Category C can be quite corrosive.
Note 2	Typically 5-10 year maintenance repainting cycle to retain aesthetic performance.
Note 3	For enhanced resistance to wear and trafficking and staining adopt "Service Requirement 3". Lower gloss 100% acrylic latex finishes may be used, as aesthetics demand.
Note 4	Application should be strictly in accordance with the paint manufacturer's written instructions and consistent with the relevant recommendations of AS/NZS 2311 "Guide to the painting of buildings"

Service requirement 2

Low Corrosivity Conditions (Refer Note 1) & Long Term Service (Refer Note 2)

Clean Degrease >	1 coat of 2 pack inhibitive epoxy primer – min DFT 50µm see Appendix product (i) >	1 coat of 100% Acrylic Gloss Latex (to AS 3730.10 or APAS 0280/1)

Note 1	AS/NZS 2312 Corrosion Categories A (Very Low) and B (Low). These locations range from more than 50km from a surf beach down to about 1km from quiescent seawater. It also includes Category C (Medium) locations, provided the structure is totally exposed to the cleansing influence of rainwater or is subject to an appropriate, regular hosing with fresh water, as unwashed areas in Category C can be quite corrosive.
Note 2	Typically 10 -15 year maintenance repainting cycle to retain aesthetic performance
Note 3	For enhanced resistance to wear and trafficking or staining adopt "Service Requirement 3"
Note 4	Powder Coatings covered under Service Requirement 3 are also appropriate.

Service requirement 3

Medium Corrosivity Conditions (Refer Note 1)
High Resistance to Wear & Trafficking/Long Term Service (Refer Note 2 & 3)

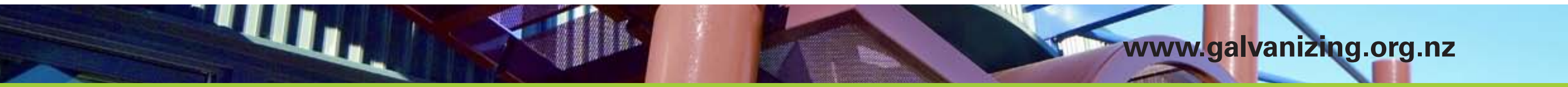
Clean Degrease >	Brush Blast >	1 coat of 2 pack inhibitive epoxy primer min. DFT 50µm see Appendix products (i) >	2 coats of 2 pack polyurethane or 2 pack acrylic at min DFT 50µm/coat min system DFT 200µm – see Note 4 & Appendix products (ii) & (iii)
POWDER COATING	**Clean, coat and cure in accordance with the powder coating manufacturers written instructions using the appropriate polyester powder coating to a cured thickness of not less than 70 micrometres (Note 5) Refer Appendix products (iv)**		
Note 1	AS/NZS 2312 Corrosion Category C (Medium). These locations range from more than 1km from a surf beach and down to about 50 metres from quiescent seawater, except in tropical locations where Service Requirement 4 is more appropriate. It also includes Category D (High) locations, provided the structure is totally exposed to the cleansing influence of rainwater or is subject to an appropriate, regular hosing with fresh water, as unwashed areas in Category D can be very highly corrosive.		
Note 2	Wear & Trafficking is defined as surfaces subject to mild abrasion and scuffing, such as occurring in public thoroughfares, kitchens and other work areas.		
Note 3	Typically 10 -15 year maintenance repainting cycle to retain aesthetic performance.		
Note 4	Where decorative finish is not required polyurethane or acrylic may be replaced by high build 2 pack epoxy to equivalent dry film thickness – refer Appendix product (v) or (vi)		
Note 5	For enhanced performance or in the more corrosive areas within the Category C zone a higher minimum total cured film thickness may be prudent.		

Service requirement 4

High Corrosivity Conditions (Refer Note 1)
High Resistance to Wear & Trafficking/Long Term Service (Refer Note 2 & 3)

Decorative Finish			
Clean Degrease >	Brush Blast >	2 coats of high build of 2 pack epoxy min. DFT 250µm per coat see Appendix 1 product (v) >	2 coats of 2 pack polyurethane or 2 pack acrylic at min. DFT 50µm min. system DFT 350µm – see Note 4 & Appendix products (ii) & (iii)

Industrial Finish		
Clean Degrease >	Brush Blast >	3 coats 2 pack high build MIO epoxy – min. system DFT 350µm – see Appendix products (vi)
Note 1	AS/NZS 2312 Corrosion Category D (High). These include locations more than 200 metres from surf and down to the seashore in quiescent seawater, tropical coastal service and indoor swimming pools.	
Note 2	Wear & Trafficking is defined as surfaces subject to mild abrasion and scuffing, such as occurring in public thoroughfares, kitchens and other work areas.	
Note 3	Typically 10 - 15 year maintenance repainting cycle to retain aesthetic performance.	
Note 4	Where decorative finish is not required polyurethane or acrylic may be replaced by a further coat of high build 2 pack epoxy of equivalent thickness – refer Appendix product (iv)	



Service requirement 5

Very High Corrosivity Conditions (Refer Note 1)
High Resistance to Wear & Trafficking/Long Term Service (Refer Note 2 & 3)

Decorative Finish				
Clean Degrease >	Brush Blast >	1 coat of inhibitive 2 pack epoxy primer – min. DFT 50µm see Appendix 1 product (i) >	1 or more coats of high build 2 pack epoxy min. DFT 200µm/coat see Appendix 1 product (v) >	2 coats of 2 pack polyurethane or acrylic, min. DFT 50µm/coat min system DFT 400µm – see Note 4 & Appendix products (ii) & (iii)

Industrial Finish			
Clean Degrease >	Brush Blast >	1 coat of inhibitive 2 pack epoxy primer – min. DFT 100µm see Appendix 1 product (i) >	3 coats of 2 pack high build MIO epoxy min. DFT 150µm/coat, total DFT 400µm see Appendix products (vi)

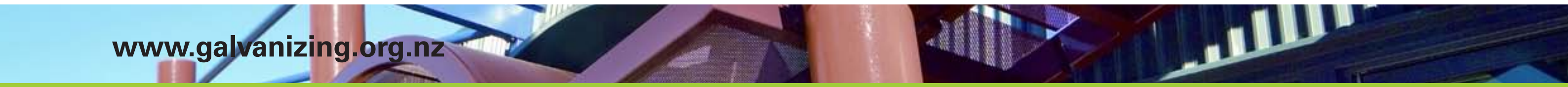
Note 1	AS/NZS 2312 Corrosion Categories E (Very High). These locations are offshore and on the beachfront in regions of rough seas and surf. It also applies in a few aggressive industrial areas.
Note 2	Wear & Trafficking is defined as surfaces subject to mild abrasion and scuffing, such as occurring in public thoroughfares, kitchens and other work areas.
Note 3	Typically 10 -15 year maintenance repainting cycle to retain aesthetic performance.
Note 4	Polyurethane finish preferred unless OH &S considerations prohibit isocyanates.

Service requirement 6

Specific Industrial Chemical or Solvent Exposure (Refer Note 1)

Decorative Finish			
Clean Degrease >	Brush Blast >	1 coat of inhibitive 2 pack epoxy primer – min. DFT 100µm see Appendix 1 product (i) >	Finish coat subject to manufacturer's technical advice – typical min. system DFT 300µm (Note 3)

Note 1	While the requirements for surface cleaning and brush blasting are mandatory, the specific paint system and its total system thickness are dependent upon the type and concentration of the chemical/solvents exposure and the manufacturer's advice.
Note 2	Typically 10 -15 year maintenance repainting cycle to retain aesthetic performance.
Note 3	Typically polyurethanes are specified for resistance to acids and organic solvents and epoxies for resistance to alkalis. Where strong acid or alkali contact is envisaged, alternative construction materials should be considered.



Appendix 1 Typical paints

Products (i) – 2 Pack Inhibitive Epoxy Primer

Product	Paint Supplier	Nominal Dry Film Thickness per coat µm (Note 1)
Penguard Special	Jotun Paints	100
Intergard 251	International Paints	50
Sigma EP Universal Primer	Wattyl	50 - 75

Note: For low/very low corrosivity 50 µm DFT adequate

Products (ii) – 2 Pack Acrylic Polyurethane

Product (Note 2)	Paint Supplier	Nominal Dry Film Thickness per coat µm
Hardtop Ultra	Jotun Paints	50
Imperite 300	Jotun Paints	50
Interthane 990	International Paints	50
Sigmadur 400	Wattyl	50

Note 2: Imperite preferred to Hardtop Ultra where maximised resistance to graffiti is required

Products (iii) – 2 Pack Acrylic

Product	Paint Supplier	Nominal Dry Film Thickness per coat µm
Jotacote 371T	Jotun Paints	50
Interfine 629	International Paints	50
Sigmadur 540	Wattyl	50

Products (iv) – Powder Coating

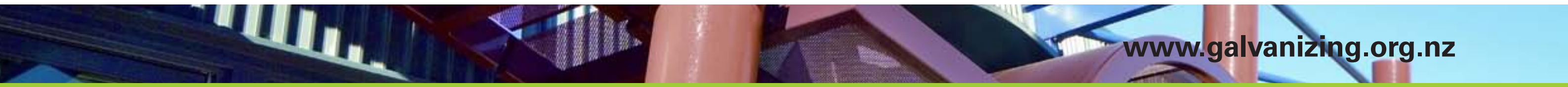
Product	Paint Supplier	Nominal Dry Film Thickness per coat µm
Corr-Cote Polyester Powder PEF	Jotun Paints	As specified by the manufacturer, but not less than 70 µm
Interpon D610 Excel Polyester Powder	International Paints	As specified by the manufacturer, but not less than 70 µm

Products (v) – 2 Pack High Build Epoxy – Normal

Product	Paint Supplier	Nominal Dry Film Thickness per coat µm
Jotacote 605	Jotun Paints	150
Intergseal 670HS	International Paints	150
Sigmacover DTM 800	Wattyl	150

Products (vi) – 2 Pack High Build Epoxy – Mio Pigmented

Product	Paint Supplier	Nominal Dry Film Thickness per coat µm
Jotacote 910	Jotun Paints	150
Intercure 420	International Paints	150
Sigmacover DTM 800 MIO	Wattyl	150



Sample specification

The following provides guidelines for preparing an appropriate specification for painting galvanizing. Specific projects may need to encompass additional requirements not included in this generalised specification and Section 12 of AS/NZS 2312 provides additional advice.

Note: For powder coating, while the general specification format would be appropriate, the technical requirements, notably surface preparation and application and cure conditions will be considerably different and need to be consistent with the guidelines of the specific powder coating manufacturer.

1. Introduction

1.1 Purpose

This Specification defines the technical requirements for surface preparation and application of protective coatings that have been hot-dip galvanized in accordance with AS/NZ 4680. It does not cover powder coatings, which require specific recommendations regarding surface preparation and coating system selection, application and cure.

(accurately describe location and scope of items to be painted)

1.2 Definitions/Glossary of Terms

For a glossary of paint and painting terms, refer to AS 2310.

2. Reference Documents

The following documents have been referred to in this Specification:

2.1 Standards/Codes

AS/NZS 4680	Hot-dip galvanized (zinc) coatings on fabricated ferrous articles.
AS 1627	Metal Finishing - Preparation and Pre-Treatment of Steel Surfaces
AS 1627.4	Part 4: Abrasive Blast Cleaning (Note I)
AS 2310	Glossary of Paint & Painting Terms
AS 3894	Site Testing of Protective Coatings
AS/NZS 2311	Guide to the painting of Buildings (Note II)
AS/NZS 2312	Guide to the Protection of Iron and Steel Against Exterior Atmospheric Corrosion

Note I Not relevant to Service Requirement 1
Note II Not relevant to Service Requirements 2-6

3. Technical Requirements – Coatings

3.1 General

(i) Surface preparation treatments, inspection and testing and health and safety shall comply with statutory requirements and the guidelines of AS/NZS 2311 or AS/NZS 2312 as appropriate.

(ii) All cutting, welding and other physical working of the metal shall be completed before surface preparation and these shall be completed off-site, except for repairs made necessary because of damage during transport, storage and construction.

(iii) All paint forming part of the one paint system shall be from the same paint manufacturer.

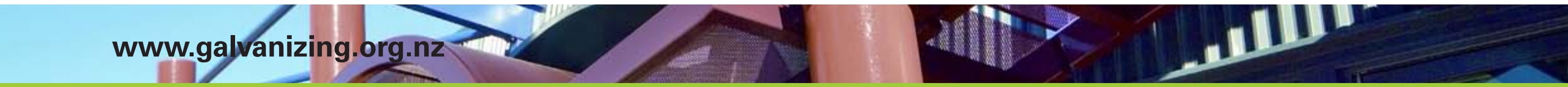
(iv) No paint shall be used after the expiration of its shelf life or its pot life and all paint shall be mixed, thinned as appropriate and applied in strict accordance with the manufacturer's written instructions.

(v) Apply the first (prime) coat to the clean, dry surface as soon as practicable after it has been prepared for coating.

(vi) Coating application shall only proceed when the surface temperature is greater than $15^{\circ}C$ and at least $3^{\circ}C$ above the dew point of the surrounding air.

(vii) Coating application procedures and the time elapsed between coats shall be consistent with this specification and strictly in accordance with the manufacturer's written recommendations.

(viii) Where repairs to the coated finish are necessary and permitted by the Project Manager, they shall be carried out using the system approved by the manufacturers of the original system, and to a standard which will not compromise the protective performance of the overall coating system.



(ix) The Project Manager reserves the right to check each and every stage of the coating process to determine the cleanliness of surfaces, degree of cure, adhesion, time between application and coating thickness, colour gloss and finish. When tested in accordance with AS 3894.3 each coat and the total coating thickness shall be not less than the specified minimum.

(x) After the completion of all painting works, all equipment and materials used in painting activities and all paint debris shall be removed from the site, which shall be restored to its original condition.

3.2 Surface Preparation

(i) Remove any oil, grease or wax in accordance with the relevant method described in AS 1627 Part 1.

(ii) Remove all dirt, dust, water-soluble salts and other contaminants by appropriate methods consistent with the requirements of AS1627.

(iii) Remove or smooth out all sharp edges, dags, weld spatter and laminations in a manner that such physical imperfections in the galvanized surface shall not thwart the even build up of the subsequent paint system.

(iv) **Service Requirements 3-6 only**
Lightly (brush or whip) blast all galvanized steel using a soft abrasive, such as limestone or aluminium magnesium silicate in a manner that profiles the surface without removing a significant amount of zinc from the surface.

3.3 Painting

(i) The first coat of paint shall be applied to the clean, dry prepared surface as soon as practicable after it has been prepared for coating and at least within 4 hours. Immediately prior to coating, the surface shall be air blasted or dusted off to remove any surface dust.

(ii) The prime coat shall be ....
Refer systems and products detailed in Painting systems.
(Detail at least product name and minimum dry film thickness)

(iii) As soon as practicable after the minimum recoat time for the primer, apply ....
Refer systems and products detailed in Painting systems.
(Detail at least the product name, the minimum dry film thickness for each coat to be applied and the minimum total dry film thickness of the paint system and colour/ gloss of final finish)
The final finish shall be smooth and uniform in colour and gloss consistent with best industry practice for the products specified.

(vi) Damage or other defects in the coating system shall be feathered back to a smooth transition and patch repaired with the same products to not less than the specified, dry film thickness.

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Case Studies

- Art
- Tropical Environments
- Coastal Environments
- Resources
- Sustainability
- Stadiums
- Carparks
- Swimming pools
- Galvanized Reinforcement
- Bridges
- Water Treatment
- Architecture

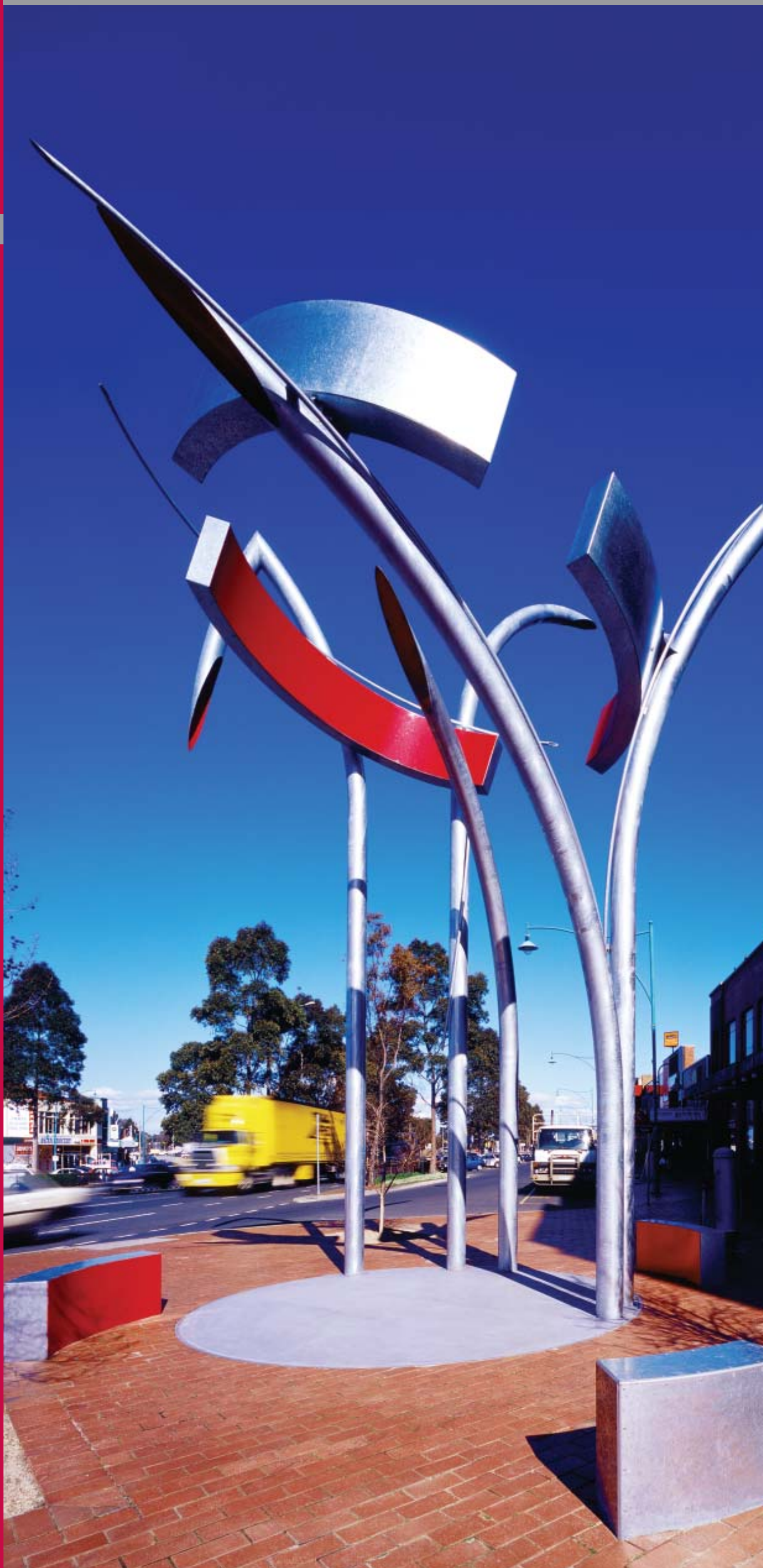
OTHER CHAPTERS

GALVANIZING ASSOCIATION

galvanize 63
January 2006

HOT DIP GALVANIZING

AESTHETICS AND PERFORMANCE FOR AN INNOVATIVE NEW SCULPTURE



'Reverie' 2005 by Paul D Johnson
Photographer: Mark Wilson
Acknowledgements – City of Greater Dandenong, Victoria

The Project – 'Reverie'

In 2004, the City of Greater Dandenong and the Dandenong Development Board formed a partnership to commission an iconic artwork to be sited in a high profile area on one of the city's busiest intersections, providing a focal point for motorists and pedestrians.

Queensland artist Paul Johnson's concept was chosen from a short listed pool of four artists. Johnson is an accomplished artist who has completed a number of innovative light-based artworks in Queensland.

Reverie commands attention during the day with its contemporary hot dip galvanized finish and contrasting red elements and at night engages pedestrian life with its vibrant, interactive laser composition.

Comments from the Artist

"The reasons for the galvanised finish on this 2 tonne sculpture were both aesthetic and pragmatic. The sculpture needed to be part of the commercial/industrial landscape yet different from it. While it has visual links with the poles supporting traffic lights and various signages, it differs significantly in form. It both belongs there, and yet does not. This ambivalence is a calculated attempt to insert something large and strange without arousing the predictable cries of horror and visual pollution.

The work was built in Queensland, with units weighing more than 200 kgs each. A painted surface was not going to survive the 2000 kilometre journey without damage. The galvanized surface, however, showed no signs of abrasion."

Comments from the City of Greater Dandenong

Grissel Walmaggia, Cultural Planning Officer, said "Dandenong is undergoing significant change and revitalisation with a number of major developments within the central business district. 'Reverie' contributes to this revitalisation and is a significant and innovative city landmark that will provide interest and build on the sense of excitement as the city enters a new era."

Editorial
George Thomson
Rosemary Scott
Prepared by
Galvanizers Association of Australia

DAINTREE **DISCOVERY** CENTRE

Atmospheric steel corrosion in Australasia is complex and varied due to Australia's great size and diverse climatic zones.

After-fabrication galvanizing has a wide range of capabilities in service and this Far North Queensland location demanded performance in some of the most extreme conditions possible. After considerable research into serviceability and environmental impact, after-fabrication galvanizing was chosen as the most appropriate form of corrosion protection.

Daintree Discovery Centre – An accredited wet tropics information centre

This Discovery Centre is unique and provides an ideal introduction to a remarkable pocket of rainforest in Far North Queensland.

With advanced eco tourism accreditation, the centre is well recognised as a leader in its field and caters for visitors of all ages at this striking rainforest wilderness.

The centre consists of:

The Aerial Walkway

This provides for intimate rainforest viewing at a mid level while connecting the built units of the centre.

Canopy Tower

The tower stands to a height of 23 metres and offers spectacular views over the top of the tree canopy of the surrounding forest. It is cyclone rated and can accommodate 70 people on 5 viewing platforms.

The interpretative display centre

This offers the latest interactive experiences and a wide range of information on such topics as evolution, ecology, flora, fauna and fungi with a useful library component.

A DVD theatre: this provides films introducing creatures from Cassowaries to Crocodiles.

An Elevated Boardwalk

This structure gives access through the forest floor promoting close interaction by enabling visitors to comfortably experience the rainforest at an intimate and elevated level.

Eco Shop: provides souvenirs of this extraordinary experience.

The Daintree Discovery Centre was built in 1989 and is a private enterprise.

Over the 6 years it has been active, the Centre has gained a most impressive record of awards including:

- State Winner 2005 Telstra Queensland Small Business of the Year Award
- Winner 2005 Telstra Queensland Small Business of the Year – MYOB Award
- Winner 2005 North Queensland Best Small Employer of the Year Award
- Winner 2004 Tourism Tropical North Queensland Ecotourism Award
- Winner 2004 Tourism Tropical North Queensland Most Outstanding Submission Award
- Winner 2004 QMBA Tropical North Queensland Tourism & Hospitality Facility under $2 million
- Finalist 2004 Queensland Tourism Awards

Designing and Building The Centre

Building the Daintree Discovery Centre was an undertaking in the face of the most severe limitations and obstacles of nature.

Prevailing conditions included the difficulties of unmade roads, material load restrictions to manual carrying, a site without power, water or support services and where heavy lifting plant and equipment could not be permitted.

To contain impact on the surroundings, normal welding and hot work were minimized by the use of bolted connections. A stable foundation to achieve no-sway platforms and walkways for the assurance of visitors to this tree top zone was a further design feature.

An innovative 3D design by Quadratec Pty Ltd was instrumental in coordinating the complex design activity.

The project planning required a return to construction fundamentals on the imperative of not damaging the environment whilst building access to experience the location.

The difficulty of this compromise of construction progress and site preservation is well illustrated by the record of regular auxiliary power cuts due to rodents chewing through the wiring.

Weather Conditions

Annual average rainfall varies from 1.2 metres to about 4.2 metres with some areas receiving up to 9.1 metres. These conditions are accompanied by 100% humidity, elevated temperatures and high levels of UV exposure.

The occurrence and type of this rainforest is dependent on both the total and spread of the rainfall throughout the year. The rainfall is higher than anywhere else in Australia and is often referred to as the wet tropics, creating the most difficult construction conditions.

Design and Durability Planning – Steel Construction and Protection.

Given the structural height and span of the various platforms and walkways, steel members were an obvious choice.

However as many protective systems for steel require regular maintenance to meet their required service life, the design had to address upgrading steel protection or alternatively to provide access for regular maintenance and replacement.

In this instance the latter was not a practical option, particularly since product warranties are, in such conditions, strictly limited or often unavailable.

The only course of action therefore was to seek substantive proof of use of products successful in similar environments. Hot dip galvanizing has a long history in Far North Queensland, going back as far as 130 years.

In this context severe steel corrosion is often illustrated as being only at the ocean's edge, in surf or high seas; however the complex environment of this tropical forest includes high salinity, long surface wet time, mould growth, elevated temperatures, and intense UV exposure, all conditions which can contribute to high rates of corrosion within the constant erosion and attack of an undisturbed cycle of life, decay and regeneration.

From an engineering standpoint, the preservation of building materials in this situation is a challenge and permanence hard to achieve.

Summary

Seldom is site delivery and installation of permanent structures as demanding, complex and restrictive of normal construction practice, so it is not surprising that the concept and its execution has won so much acclaim for innovation.

The client's requirements were for damage free coating at installation as well as long service life. **After-Fabrication Galvanizing was the predominant choice of protection for steel elements in this installation.**

Galvanizing's basic characteristics of steel hardness, increased edge cover, cathodic protection, surface patina development, inhibitive properties and UV immunity all come into play in this undertaking.

The Daintree is the oldest continuous rain forest on earth for which this striking Discovery Centre provides an educational gateway to the Queensland World Heritage Region.

*Acknowledgements – Ron Birkett, Director
Daintree Discovery Centre*

Salcey Treetop Walk, Northamptonshire

Back to nature

By Iqbal Johal

A spectacular walk on high towers through mature woodland has been created by Forestry Civil Engineering (FCE)*. It is suitable for all abilities and provides a unique experience for all ages. The structural concept incorporates new innovative techniques, (some based on new UK research) and uses sustainable materials, recycled steel and traceable timber, to provide an engineered environmental harmony.

The objective of this project was to create a free-to-use experience to enthuse the public, particularly children, about trees and forests and at the same time take advantage of new government funding aimed at improving the nation's health. The designers used Mechanical Stress Lamination within the project, to demonstrate an innovative way of making large structures from small timbers by building an arch bridge and the first Stress Laminated Timber (SLT) roof in the UK.

The walkways and platforms were made from local timber, however to ensure minimum maintenance and maximum strength, the main towers and spans were all built from galvanised steel.

This provided stability with slender members which reflected the scale of the surrounding trees.

The walkway starts at ground level and rises to 15m above the ground via a number of 24m span bridges at a 1 in 12 slope.

These spans are made from off-the-shelf aerial galvanised mast towers to form bridge beams (a structure patented by the designer). This span structure has a fundamental natural frequency of 2.8Hz which provides an eventful shaky walk loved by children.

The top tower has a platform at 20m which is accessed by an external stair. This adds to the fear factor!

A minimum number of trees were felled during construction so that the completed

experience is walking up and under the trees and eventually out through the canopy.

The towers were made triangular so that every span exited the tower in a different direction so that each span was a unique walking experience with trees at both ends.

Adjacent spans are all set out at an angle to each tower to ensure overall stability of the walkway, with the individual spans deliberately designed to give a lively dynamic response for the enjoyment of users. This also helped the stability of the overall structure.

The slatted deck and handrails are made from treated but unpainted local timber, which should require a minimum of maintenance since they do not retain any standing water and are exposed so that rain will dry off rapidly.

The manufacturer of the patented aerial mast system became the fabricator of the main towers. A good fit at high-level demonstrated the need for accurate setting out, accurate fabrication and good design to ensure that the use of tolerances could be maximised.

Well-fabricated galvanized steel proved to be an excellent product choice for the project as it allowed the design team to keep to an increasingly tight construction deadline.

The walkway has a spectacular entrance over the Elephant bridge – so named because it curves around and over a pond built during the 2nd World War for zoo elephants borrowed to haul timber as part of the war effort.

The bridge has a 30m clear span and is hung from 20mm diameter ropes all suspended from one mast. The bridge structure was built in galvanised steel and was designed and constructed in two months.

This innovative structure has become a local attraction and is available to the public, free of charge, 365 days a year.

*This project would not have been possible without the commitment and determination of Dr Freedman of FCE.

Photos: Dr. Geoff Freedman, Forestry Civil Engineering

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Announcing the 1st Asia Pacific Edition

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54 April 2001

GALVANIZING IN A MARINE ENVIRONMENT

In this issue

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CHANNEL ISLAND POWER STATION

MIDDLE ARM, DARWIN HARBOUR, NORTHERN TERRITORY

The growth of the City of Darwin heralds increasing Australian links with South East Asia and has brought with it the need for development of infrastructure in similar coastal tropical climatic conditions. This South East Asian link has been highlighted by the development of oil and gas resources in the Timor Gap, with significant expansion of this activity now on the move. Likewise the progressive increase in the Defence Force presence in the North has added to infrastructure and urban expansion. This growing port city was given further impetus recently as the base for Australian and United Nations involvement in East Timor and the many support facilities involved. A continuing growth in the need for electricity has been addressed by the recent installation of an ice thermal storage system at the Channel Island Power Station operated by the Territory Government's Power and Water Authority. The project was a cooperation of Baltimore Aircoil Australia Pty Limited, White Refrigeration and Tafair.

Location Darwin Harbour is some 1000 square kilometres, an area 18 times larger than Sydney Harbour, and is affected by tides of up to 8 metres. Channel Island is located in one of the three arms of the harbour and although there is very little wave action and certainly no surf, the tropical environment and the proximity of the power station buildings to the harbour makes the location an ISO Category 3 or 4 area. In Darwin, daily maximum temperatures typically range from thirty-one to thirty-five degrees Celsius and there is heavy reliance on air-conditioning in modern office blocks that serve the increasing number of companies based in the Territory's capital and the large hotels that cater for growing tourist numbers. The new gas turbine plant installed at Channel Island is designed to accommodate this need. To do so it has to meet the dual effect of the period of highest daytime temperatures, which both increases the use of air-conditioning and lowers the electricity output of conventional plants. In summary, the use of the new ice thermal storage system is an innovative solution to this problem of three coinciding factors:

- peak day temperatures
- drop in electricity generation.
- maximum air conditioning demand

Inlet Air Cooling for Gas Turbine Plant Details The Channel Island Power Station has five Frame 6 gas turbines, built by John Brown Engineering under licence from General Electric, plus one Mitsubishi steam turbine. Two of the gas turbines are fitted with heat recovery steam generators (HRSG's) and the steam produced in the HRSG's drives the Mitsubishi steam turbine. The output of this high efficiency combined cycle block is ninety-six Megawatts. Inlet air-cooling is fitted to the other three gas turbines, increasing output of each gas turbine to thirty-eight Megawatts for up to five hours per day, compared to their site rating of thirty-two Megawatts without cooling. The inlet air-cooling system utilises refrigeration to produce approximately 1500 tonnes of ice in two concrete tanks. Each tank is 15.2 metres by 13.8 metres wide by 7 metres high and is filled with water to a depth of 6.5 metres. The refrigerant system passes through a bank of coils stacked inside each concrete tank and ice forms on the outside of the coils to a thickness of sixty-five millimetres. More than 55% of the water in each concrete tank is converted to ice when a full complement of ice has been made. To build this capacity of ice takes sixteen hours, normally overnight using excess off-peak capacity. Upstream of the air filter of each gas turbine, a 'wet air cooler' has been constructed, where combustion air for the gas turbine is drawn through a cooling tower fill in counter-flow to the chilled water. The 'wet air cooler' is basically a large evaporative cooler, which uses chilled water for maximum cooling. In 'ice cooling' mode, chilled water from the concrete tanks is pumped to the 'wet air cooler' and gravitates through the cooling tower fill, then is collected in a sump at the bottom of the 'wet air cooler', after which it is pumped back to the concrete tanks. Chilled water is delivered to the wet air coolers at approximately two degrees Celsius and the return water is typically twelve to fourteen degrees Celsius.

Cost The capital cost of the ice thermal storage system and the associated inlet air-cooling plant was approximately 70% of that of an additional generating unit to provide a similar increase to power station capacity. Steel structures are a substantial part of the installation at this marine location. Major units of steel items include:

- Freezer Coils
- Structural Steel
- Roof Purlins
- Pipe Work

After-Fabrication Galvanizing was selected on economic grounds and to withstand the greater risk of condensation on steel work, due to the cooler temperatures around the ice tank and on general proof of performance at similar locations around Darwin. Finally as added security, the steel reinforcement of the ice tank was galvanized to ensure very long service life. The galvanizing work involved several companies and was sourced from Northern Territory, Queensland, New South Wales and South Australia.

. The use of galvanizing in a harsh coastal environment
. The optimum in pedestrian "hard-wear"

CHRISTIES BEACH HIGH SCHOOL

Client Department of Education, Training & Employment, South Australia
Architect Woods Bagot Pty Ltd
Contractor Stevens Construction Pty Ltd

Location Christies Beach High School, a large suburban high school, is located some 25 kilometres south of the Adelaide city centre in South Australia and 3 kilometres from the southern beaches of St Vincent's Gulf. The average temperature in summer is 30°C with temperatures above 38°C not uncommon. The area experiences strong prevailing winds from the sea both in the winter and summer seasons.

History This significant high school redevelopment was undertaken to consolidate two existing campuses and to provide up to date facilities to cater for current education trends and the growing number of students in Adelaide's southern suburbs.

Architect, David Spencer of Woods Bagot, comments that: "The basic criteria for the school design was to incorporate low maintenance, robust building materials that were functional, attractive and long wearing. Chosen materials had to be able to withstand the harsh climatic environment and the wear and tear that large senior schools generate. The sea front exposure and very high levels of U.V. have a significant impact on material choice. Materials selected include aluminium, glass, brick and galvanized steel. All of these materials are long wearing and will not deteriorate in such environments. Christies Beach High School was designed with considerable use of steel for its open colonnade walkways, contempory roof shelters, outdoor assembly areas and fencing features. To meet visual, functional and operational requirements, after-fabrication galvanizing was used as a steel finish to ensure maximum zinc alloy thickness and reliability. A close collaboration between the architect, the school, the contractor and the steel galvanizer during the design and fabrication stages addressed the 50 year design service life, as well as the initial quality finish and the requirement for the elimination of steel maintenance.

From an aesthetic point of view, there is inherent lasting respectability in the appearance of clean, natural metal, as well as levels of durability well beyond that offered by applied synthetic materials which demand regular maintenance. The clever architectural solutions and approach to material selection evident at Christies Beach High School has resulted in a campus which expresses a quiet dignity underlining its education purpose and suggesting a campus of substance."

IZA INDUSTRY SUPPORT

The International Zinc Association has commenced a program of promotional support for the hot dip galvanizing industry in Asia. This will be achieved, where possible, through Galvanizing Associations and aims to increase the total market through the presentation of credible case history evidence of long term steel protection. Since convincing field data of notable construction projects or manufacturing achievements are easy to recognize by technical specifiers, the long-standing industry work of GAA is being used while we are now actively recruiting project reports on the wide use of galvanizing in Asia for inclusion in future issues.

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GALVANIZING – SUSTAINABILITY AND THE ENVIRONMENT

Special Feature
EPA Victoria/GAA Partnership

CAROUSEL PAVILION GEELONG WATER FRONT

Carousel Pavilion

Photo courtesy of City of Greater Geelong

The Pavilion is a classic example of how steel can cost effectively form the basis of a visually striking building.

Project details

Client:	City of Greater Geelong
Architect:	McGlashan Everist Pty Ltd
Consulting Engineer:	Meinhardt (Vic) Pty Ltd
Fabricator:	North Steel Pty Ltd
Builder:	Wycombe Constructions Pty Ltd

Steampacket Place, Quay

Site: Designed to protect and showcase a restored and operating 19th century steam carousel, complete with steam engine and band organ, the steel and glass Carousel Pavilion plays a cornerstone role in the revitalised Geelong Waterfront.

Design: The steel frame of the building comprises six umbrella forms of 12 x 12 metres in a 3 x 2 array. The steel structure is exposed and utilises a range of hollow sections. The cross-linked main arms of the umbrellas are fabricated box sections sculpted to reflect roof loads with minimal use of material. The diagonal arrangement of the mainframes and the combined arching effect develops an inherently stiff structure which eliminates the need for diagonal bracing in roof or walls.

The structure was refined using a 3D software package for analysis, steel design and generation of bills of quantities to compare the cost effectiveness of design permutations. Close attention to connection detailing was important as the structure was prefabricated and fully bolted, contributing to aesthetics, integrity of protection and cost control.

Environment: Sited on the sea wall and exposed to very high wind loading, designers carried out a detailed analysis using Australian Wind Code recommendations for strength limit state conditions. Window mullions are structural and stiffened with a horizontal truss which forms the lower roof edge of the Pavilion.

Sea spray and chloride deposition on the structure were judged to require special attention for steel protection. On careful assessment of the area, top grade after-fabrication galvanizing to AS/NZS4680 (ISO 1461) was used on all structural steel.

Expanded metal cladding on the cantilevered perimeter of the roof had a cost benefit and provided the desired shading with minimum wind resistance.

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BRIDGES IN ASIA

Recent vigorous economic growth in South East Asia has redistributed population and expanded industry and infrastructure building.

Development of rural and remote regions required innovative engineering solutions to gain right of way to new land for extractive purposes, industry, urban development and the critical arteries of commerce – roads.

Chung Cheng Overpass, Taiwan

Chung Cheng Overpass

In countries where, historically, seaports and rivers were the main outlets, roads and bridges emerged to provide heavy load capability and more reliable and productive transport.

In this respect steel bridges were found well suited to the pace of development and challenging terrain. Offsite completion, orthodox freight to site and relatively simple erection were invaluable aids to the rapid expansion of the time.

The use of steel in bridge construction is not new, and knowledge of the manufacture and behaviour of this material is well understood where advancing design use of steel has resulted in economical and aesthetically pleasing bridge structures. Steel offers particular advantages in that it can be shop fabricated, under controlled conditions, to almost any desired cross sectional geometry to meet the specific strength requirement at each site, often at completely undeveloped locations.

However corrosion prevention is one essential factor in the economic utilisation of steel where provision of the appropriate protective coating can influence initial and whole of life cost, eliminate maintenance and lost service time, and defer the replacement date of structures.

A wide variety of products have been used for this purpose, however, many bridges require permanent maintenance teams to sustain adequate steel protection.

In most environments, after-fabrication galvanizing provides very suitable corrosion protection for steel and has a range of coating characteristics which make it unique. These include an alloy hardness greater than mild steel, a self-inspecting process discipline and predictable life directly proportional to its heavy coating thickness. These result in a surface alloy with competitive cost, resistance to severe impact, extended service life and in turn reliability for use in engineering calculations.

This issue of *'galvanize!'* features the widespread use of hot dip galvanized steel bridges in the development of a number of South East Asian countries. Twenty-five years on, these are a tribute to many people and to the value of galvanized steel.

Linkou Bridge – Taipei (above, above right)

Note the corrosion distress on painted storage tanks of the power generating station immediately behind the bridge

Taiwan

The Ma Tsao Bridge in Mount Yang Ming, North Taiwan, the earliest bridge to utilize after-fabrication hot dip galvanized steel, was opened in 1992. From then on, approximately 30 000 tonnes of steel and around 30–40 bridges have been hot dip galvanized. The most representative of these bridges are the Chung Cheng Overpass and the Linkou Bridge. There are now approximately 25 000 tonnes of bridges under construction which are the result of work by the galvanizing industry, with government and academia, in presenting proof of service of the hot dip galvanizing process, where security, low cost and reliability were crucial factors.

Taipei – Linkou Bridge

The Linkou Bridge is an 8-lane overpass bridge, 22.6 metres in width and 1065 metres in length, located in a non-sheltered environment adjacent to the seafront on the northeast coast of Taiwan. This girder type bridge utilized 7300 tonnes of galvanized 2 metre girders as well as 3030 tonnes of galvanized steel reinforcement to provide long-term corrosion protection in the salt-laden atmosphere of the Taiwan Strait.

Authority: Taiwan Highway Bureau

Taipei – Chung Cheng Overpass Bridge

The Chung Cheng Overpass Bridge, opened in 1996, has 6 lanes, is 24.9 metres wide, 1672 metres in length and utilizes 7000 tonnes of hot dip galvanized steel girders. Heavy vehicular usage across the bridge and roads beneath, and the confined nature of the location with buildings in such close proximity, would make any bridge maintenance a major logistical problem.

Authority: Taiwan Provincial Housing and Urban Department Bureau

Designer: China Engineering Consulting Inc

Construction: RET-SER Engineering Agency and Evergreen Heavy Industrial Corp.

Chung Cheng Overpass

The Ngon Bridge – Laos

Single-Lane Permanent Span C-Class Truss, multi-span

Indonesia - Cambodia Malaysia - Myanmar - Laos

Transfield-MBK Steel Bridging Systems

Organisation

An outstanding infrastructure bridge achievement throughout the region was the introduction in 1980 of the Transfield prefabricated bridge systems.

Transfield Constructions were the provider of the Transfield MBK bridging system throughout the South East Asia region. This included Transfield's Joint Venture Company in Indonesia, P.T. Trans-Bakrie.

Clients included Government contracts, local authorities and private companies. In flow-on contracts, Transfield-MBK designed and supplied steelwork for a 235 metre double lane suspension bridge over the Mamberamo River in Irian Jaya and a Twin Suspension Bridge over the Barito River in South Kalimantan (each 420.5 metres in length with a 60 metre deck top truss bridge at the Banjarmasin End).

The original series of these bridges were fabricated and galvanized at Transfield Galvanizing - Seven Hills Plant Sydney, but were progressively manufactured by the developing fabrication and galvanizing industry in Asia.

Double-Lane Permanent Span A-Class Truss

Standard Truss Bridging

Standard Girder Bridging

Transpanel Single-Lane

Design

Designers of the systems were consulting engineers, Cardno MBK (formerly McMillan Britton Kell Pty Ltd) of Sydney, a firm with more than 50 years experience in bridge projects.

These bridges were designed for simple and rapid erection by untrained labour using only basic equipment augmented by special components incorporated as part of the system.

No falsework or intermediate supports were needed for construction.

The six bridging systems available cover span lengths from 10 to 120 metres.

Three of the systems provided permanent bridges while three were for semi-permanent or temporary purposes. Design complies with the AASHTO and Austroads Standards.

Key transport linkages were achieved at a wide range of remote coastal and inland waterway locations where a steel protective system was required with wide suitability for the many service exposures involved.

Some 3500 spans covering all six bridges systems have been installed since their inception.

All components were after-fabrication galvanized for maximum corrosion protection and complement this particular design use of steel.

Long Span Truss Bridging

Singapore

JLN Bukit Timah Pedestrian Bridge

Bukit Timah Pedestrian Road Bridge

This bridge is estimated at 56 metres in length and 2.2 metres wide and is composed of 33 tonnes of steel. After-fabrication galvanizing steel protection was chosen to provide a superior finish and to prolong the life span of the steel. Ability to withstand the hard wear of constant pedestrian traffic was important and a duplex colour topcoat was applied over the galvanizing to provide an aesthetically pleasing architectural finish.

Update

As an update to these case histories we can report further bridge announcements in South East Asia.

Twelve Provinces Bridge Replacement Project

The Indonesian Ministry of Settlement and Regional Infrastructure has just awarded the "Twelve Provinces Bridge Replacement Project" to the Trans Bakrie-DSD Joint Operation. This contract comprises the supply of 73 bridge spans which will be erected in 12 separate provinces of Sumatra and Java.

Trans Bakrie won this tender with a modified design, by Cardno MBK, to the AASHTO LRFD Bridge Code. The proven principles of the Transfield-MBK bridging system remained unchanged.

Trans Bakrie's partner is DSD Dillinger Stahlbau, an established German contracting company that is part of the MAN and Ferrostahl Groups.

Eastern Indonesia Region Transport Project – Procurement of Steel Bridging

Trans Bakrie has just received formal award of the IBRD (World Bank) funded steel bridge supply contract from the Ministry of Settlement and Regional Infrastructure.

This important project named the "Eastern Indonesia Region Transport Project – Procurement of Steel Bridging" is for the design, fabrication and supply of 77 spans of bridging ranging from 40m to 100m in length. Total weight of supply is 9150 tonnes and these bridges are all destined to be erected in Eastern Indonesia over a large geographic area from Central Kalimantan to Irian Jaya.

The same Cardno MBK design will be used and all fabrication and galvanizing will be carried out at Trans Bakrie's Sumuranja facility. Completion date is January 2003.

GAA records its thanks for the history and data in this issue to

Richard Woods – Cardno MBK Consulting Engineers, Sydney, NSW

Tony Caristo – Transfield Pty Ltd

George Walker – P.T.Trans Bakrie – Indonesia

Pasminco Metals

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Editorial
George Thomson
Rosemary Scott

Chairman of GAA
Andrew Bohn

Associate of International Zinc Association

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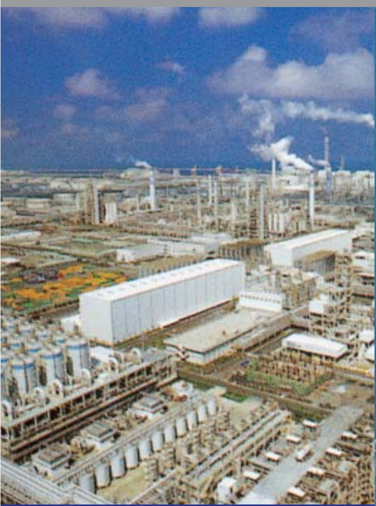
April 2004

NO 6 NAPHTHA CRACKING PLANT OFF-SHORE INDUSTRIAL ZONES TAIWAN



In this issue
Galvanizing as an Architectural Finish (refer back page)

300,000 tonnes of galvanized steel has been used in this industry development

Client
Formosa Plastics Group

Editorial
George Thomson
Rosemary Scott

Prepared by
Galvanizers Association of Australia

Editors wish to thank the following for their generous assistance in preparing this case study.

- Formosa Plastics Group
- Taiwan Galvanizers Association

Petrochemicals in their various forms are represented in a wide range of industry, domestic and luxury goods such as clothing, containers, decorative products, toys, vehicles, building materials and many other utility items. In addition to traditional plastics and fibre, petrochemicals have become an important component of electronics, aerospace and other high technology industries.

The rationale for this industry development in Taiwan arose from the land scarcity, dense population and the need for an economic vehicle to accommodate these characteristics.

In this respect petrochemicals matched the available resources well as it offered accelerated employment growth and value added product opportunities, while occupying relatively little land.

Initially however an acute shortage of basic petrochemicals in Taiwan had impeded development of this logical downstream activity.

To this end a major petrochemical plant was designed by the Formosa Plastics Group and a search for a suitable site undertaken. After wide community debate the project was located in Yunlin County on a vast land reclamation site on the west coast of Taiwan.

This vast project has had a major impact on Taiwan's development and has been called "the locomotive of national economic growth."

Location – "Head of the windstorm and end of the water flow"

The Mailiao and Haifong zones that hold No 6 Cracking Plant extend from the Chuoshui River estuary, nearly 8km north on the coast and approximately 4km seaward, with large areas of the site below sea level for much of the time.

Design included geological considerations and strengthening for the security and safety of the refinery foundations.

Service Environment

The atmospheric conditions are affected by the north east monsoon winds for six months of the year which made land reclamation engineering a most difficult undertaking.

Taiwan has been the subject of a corrosion survey by the Industrial Technology Research Institute (ITRI) and the national Tsing Hua University, where it was established that the coastal zone referred to rated more severe than the C5 zone within ISO 14713 1999, being influenced by the peculiar topography and resulting climate of the Taiwan Strait.

Wind farm structures on site are further evidence of the magnitude of onshore winds with attendant salinity and hostile corrosive influence.

In this context heavy duty galvanizing was predominantly employed on the project.

Elements of the development

Mailiao Port

This will be Taiwan's deepest port with a median depth of 24 metres taking vessels up to 260,000 tonnes and 60 million tons of cargo per annum.

The port will also better serve the surrounding and developing region.

Independent Power Plant

Five generating units will provide up to 600,000kw of electricity with arrangement to also contribute to Taiwan's national power grid.

Oil Refining

The refinery unit will have a capacity of 21 million tons of crude oil per annum or 450,000 barrels per day and will produce 3,840,000 tons of naphtha exclusively for in-house plants.

Naphtha Cracking Plant

The two naphtha plants will have combined annual output of 1.35 million tons of ethylene rising to 1.7 million tons to meet the demand for petrochemicals to develop new product opportunities.

Co-Generation Plant

This unit provides electricity, steam, hyperpure and industrial water, nitrogen, oxygen and compressed air for use throughout the plants. A further 500 T/H boiler is being installed to guarantee the supply of steam.

Machinery Shop & Boiler Shop

This facility provides for the manufacturing and installation of reactors, towers, pressure vessels and tanks, and the latest 600mw independent power unit construction.

Water Fabrication Plant

This plant is owned jointly by Formosa Plastics, Asia-Pacific Investment and Komatsu Electronics of Japan and produces 8 inch wafers with annual output of 2.4 million pieces. The plant is ISO 14001 approved.

Formosa Asahi Spandex Co Ltd

This company is a joint venture of Formosa Plastics and Asahi Kasei and now produces 10,000mt of polytetramethylene glycol (PTMG).

Naphtha Cracking Project Phase 3

Construction projects to expand No 1 & 2 have continued including a plasma display plant, ethylene glycol plant and styrene monomer plant.

This work is proceeding in tandem with development of 18 phase 1 and phase 2 petrochemical and co-generation plants.

Environment Protection

In this major industrial development environmental protection and pollution control have rated an equal emphasis with economics.

International input by leading academic consultants and engineers will be monitored by the Environmental Protection Authority to ensure compliance with relevant Standards.

Public Responsibility

Plans are underway to contribute to the associated community needs and to raise quality of life in terms of recreation, medical services, transport, culture and welfare in general.

Formosa Plastics aims to contribute to this improvement and to build a model industrial park in Yunlin's offshore zones that embrace these principles.

New Town in Mailiao

Given the progress of the No 6 Cracking Plant, influence on the local community will include an advance in living standards from the building of this township.

Yunlin County Government has put in train a 3000 hectare new town development for the region.

This will provide not only for residential and health amenities but also inter-industry commerce, technology links, improved logistics and balanced regional development.

Summary

Seldom does a project provide so much support for an entire national economy.

Concept, planning and execution have been to world's best standards carried out in the face of enormous difficulties.

Critical match of workforce capabilities with its industrious culture has put in place a strong foundation for future development.

Statistics

- Total reclamation area 2601 hectares
- Piles of 4.5 million metres
- Concrete 6.4 million m^3
- Piping 3000km
- Increase from 38% to 92% in Taiwan's self sufficiency in basic petrochemicals
- Total project cost: Stages 1, 2 & 3 NT$542 billion
- Tonnes of steel galvanized: 300,000

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GALVANIZED STEEL

BUILDING THE FUTURE: WATER SUSTAINABILITY DURABILITY ECONOMICS

Black Rock Water Reclamation Plant, Barwon Water – Victoria

Editorial
Emmanuel Pimentel

Prepared by
Galvanizers Association of Australia

Black Rock Water Reclamation Plant, Barwon Water – Victoria, Australia

Water: it is difficult to think of a more important issue facing Australia. The current situation has society, government and industry focusing on programs incorporating recycling, sustainability and environmental responsibility with a previously unknown urgency. Despite the apparent recent focus on water as an issue, water authorities, and their engineers and operators have quietly been working to constantly improve their service and play their part in minimising the impact of our development on future generations.

Designers are treating water reclamation plants holistically in terms of their contribution to the sustainability of wider society: they gather sewage; treat this sewage; and produce an added value end product in an environmentally and economically sustainable manner.

Protecting our sewerage assets while minimising the impact on the environment and future generations involves two major principals. First, the process should be as environmentally friendly as possible. This includes reducing or totally removing the use of chemicals and other materials. Second, the infrastructure should be robust, utilising materials that are readily available, durable, require minimal maintenance and are, ideally, recyclable. The Black Rock water reclamation plant managed by Barwon Water on Victoria's south-west coast, meets these criteria.

The plant incorporates hot dip galvanized steel, stainless steel and aluminium to help meet the criteria of sustainability, durability and low maintenance.

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BLACK ROCK WATER RECLAMATION PLANT

Barwon Water and the Geelong region

Barwon Water is responsible for managing water supply and sewerage services in the Geelong region. It operates nine water reclamation plants servicing urban communities: Aireys Inlet, Anglesea, Apollo Bay, Bannockburn, Black Rock, Colac, Lorne, Portarlington and Winchelsea.

The largest of these plants is the Black Rock water reclamation plant at Connewarre, located between Barwon Heads and Torquay. The Black Rock plant treats about 85% of the sewage in the Geelong region.

The Black Rock water reclamation plant

The Black Rock water reclamation plant in its current configuration commenced operation in 1989 and was further upgraded in 1995. Barwon Water is committed to the use of recycled water for suitable purposes.

Archimedean screws carrying sewage to milliscreening plant

Galvanized pipes carrying air to aeration tanks

A key part of its strategy is not only the use of recycled water as part of a sustainable plan for the future, but it must also be commercially viable. Recycled water is considered a valuable resource and part of responsible management of water as a finite resource.

About 55 megalitres of sewage is treated at the Black Rock water reclamation plant daily. Approximately 99.5% of this sewage is water. The balance is made up of bacteria, organic fats, solids and various chemicals. This sewage comes from both domestic and non-domestic sources.

When the sewage arrives at the treatment plant, it is lifted to the milliscreening facility via large Archimedean screws. These Archimedean screws produce the required pressure to continue through the treatment process.

The sewage first passes through a coarse screen and then progresses to the milliscreening plant. The milliscreens have fine apertures of only 3mm. During this process, solids are removed from the water.

This waste contains mainly paper pulp and vegetable matter. Once it is separated, it is transported off site to a waste disposal facility.

The remaining effluent then flows to the facility's selector tanks and is mixed with recirculated "liquor" (activated sludge) from the aeration tanks. This "liquor" is rich in the bacteria that digests the sewage.

These tanks work on a four-hour cycle, staggered by one hour. Air is pumped via hot dip galvanized pipes into the tanks for two hours to encourage the growth of the bacteria so they can do their work. The aeration then stops and the sludge is allowed to settle for one hour. At the end of the process, the water left in the decanting tank is suitable for agricultural and horticultural purposes.

An Environmentally Good IDEA

The process implemented by the Black Rock water reclamation plant is appropriately called IDEA: Intermittently Decanted Extended Aeration. It uses a natural biological process rather than chemicals. It removes pollutants from the sewage in a simple, cost-effective and sustainable manner. The bacteria use organics in the sewage as a food source and no environmentally harmful chemicals are required. These bacteria are constantly monitored to make sure they are the "good" bacteria and that they are there in the required numbers.

Underneath the facility - Galvanized pipes carrying air to aeration tanks

Corrosion Protection

Water reclamation plants are highly corrosive environments and only the most robust materials can survive. The Black Rock water reclamation plant judiciously uses a mix of hot dip galvanized steel, stainless steel and aluminium to achieve maximum durability and economic efficiencies.

The actual process of aerating the tanks means the pipework can not only come into contact with sewage, but also has the impacts of salt air, and high temperatures caused by the friction of the aeration process. All of these factors not only cause corrosion, but also accelerate corrosion. The incoming untreated sewage can contain and generate hydrogen sulphide (H_2S). Long-term case studies from the United States of America have shown hot dip galvanizing performs very well in environments with high levels of H_2S in the atmosphere, such as in close proximity to sedimentation or aeration tanks.

All of the main piping that delivers the heated air to the aeration tanks is hot dip galvanized due to its resistance to corrosion and ability to withstand the heat generated by the process. Where the steelwork is required to be immersed in the tanks, then stainless steel is utilised. This is achieved by joining the stainless steel pipe to the galvanized steel pipe just above the surface of the sewage using rubber couplings, which separate the two different types of metals to prevent bimetallic corrosion.

Gratings, chains, railings and various other steel furniture are also hot dip galvanized. Most of this steelwork has been installed for around 10 years and is performing well and above expectations. Some of the hot dip galvanized steel in the milliscreening and pressing plant has been installed for more than 15 years and has performed well. This includes electrical cable trays, structural steel, gratings, platforms and enclosures. The steelwork in direct contact with the fluid in the aeration tanks is stainless steel.

In addition to the normal harsh environment of a water reclamation plant, the Black Rock water reclamation plant's corrosivity levels are further increased by the fact that it is located on the coast. The combination of a water reclamation plant in a high chloride environment means only the most robust and corrosive resistant materials will survive.

The harsh conditions are further exacerbated by the fact that the local birdlife appear to find the tanks used in the process an attractive environment. Unfortunately, they are not toilet-trained with much of their waste ending up on the steelwork and this can also be very corrosive! Hot dip galvanizing is a significant part of the solution used by Barwon Water and it is meeting the challenge of durability and corrosion resistance.

Uses of recycled water

The recycled water produced at the end of the process contains residual nutrients and is ideal for use in horticultural and agricultural crop irrigation. Barwon Water has been supplying the valuable resource of recycled water to commercial projects. Businesses supplied by the Black Rock facility include a turf production business, a flower farm, a lucerne share farm and a potato farm in the area. Barwon Water also provides recycled water to commercial tree plantations and on-site tree lots at its other water reclamation plants. Barwon Water is continually investigating further opportunities to use this important resource.

Aeration tank – note Bass Strait in the background

Conclusion

Water recycling is an increasing part of securing Australia's future. Sustainability and economics demand only the most environmentally-friendly and durable materials should be considered for such projects.

Barwon Water has engineered the Black Rock water reclamation plant to ensure it has the least impact possible on the surrounding environment and this has meant ruling out the use of materials and processes that are not only costly to use, but can cause further problems when they degrade.

The successful implementation and operation of the plant using a judicious selection of hot dip galvanized steel, stainless steel and aluminium has ensured the facility has a relatively trouble-free life without impacting on its sensitive environs.

ZINC

Associate of International Zinc Association

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April 2003

Asia Pacific Edition

Zinc Galvanizing in Mining

WORSLEY ALUMINA EXPANSION PROJECT

FEATURED IN THIS ISSUE:

After-fabrication galvanizing plays a critical role in value engineering design by influencing:

- schedules
- quality
- project control
- contract co-ordination
- risk reduction

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WORSLEY ALUMINA EXPANSIONPROJECT Western Australia

Outline of Objectives

The purpose of the Worsley Joint Venture extension was to increase refinery capacity from 1.88mt/pa to 3.1mt/pa at minimal cost, within the shortest project duration. To achieve the objectives required innovative process and plant design, creating an obvious opportunity to introduce the latest technology.

During the feasibility study for the new plant, existing construction practices were carefully scrutinized with the object of finding maximum efficiencies to establish economic justification.

Existing methods and materials were re-examined and previous industry standards challenged to find the optimum specification.

Planning and Construction

As reported by the Australian Steel Institute's Manager for Western Australia and South Australia, Rupert Grayston,

"The construction manager for the project was the Kaiser Bechtel Joint Venture (KBJV) with United Constructions, the main steel fabricator, being part of the integrated team.

The project was completed without interrupting the operation of the existing plant where work included extension of currently operating units.

Accurate and timely supply was critical to meet the tight requirements of the program, which included the delivery of 8000 tonnes of structural steel work over a 12-month period.

The success of this planning was confirmed by achievement of a series of key performance measures ranging from high quality fieldwork through to time and material savings.

KBJV used 3D structural modelling software coordinating with detailing and fabricator's software to manage stocks and for numeric controlled process machinery".

According to Chief Structural Engineer, Paul Rushton, "The 3D technology applied simultaneously to design and detailing allowed the structures to be built in 'virtual reality' in the design office, with concurrent referencing of the models from the other disciplines. In this way no surprises occurred later on-site, and fit-up to existing structures was excellent."

"The design process was completed by re-importing the steel detail model back into the 3D process. In this way, clashes with the components of other disciplines such as chutes, equipment, piping etc were eliminated," said Rushton.

Steel Protection

In the context of the design upgrade, past practice had been to avoid metallic coatings for steel protection. This had been done on a precautionary basis and with respect to the chemicals used in the alumina process.

However on examination of existing galvanized items dispersed throughout the plant, such as cable trays and other steel auxiliaries, excellent service life was proven, prompting its consideration in the reassessment.

Particular value was found in galvanized steel handling capability, solar radiation (UV) immunity, sharp edge protection and other characteristics complementary to the design capability of steel.

Also of significance, after-fabrication galvanized coating confers environmental cleanliness, sustainability and a wholly Australian content system.

Collectively these contributed to construction efficiency and to low life cycle cost and led to its adoption for the project.

Summary

Rupert Grayston commented that "The Worsley experience has shown that an intense focus on Total Installed Cost is the meaningful project management parametric of the new workflow.

In addition to the cost benefits, this new approach offers:

- Schedule improvements
- Quality improvements
- Improved project control
- Contracting flexibility
- Reduced risk

The Worsley Expansion Project has represented a significant step forward in new technology utilisation for the steel construction industry. As software products and integration techniques continue to advance, and as subsequent projects further push the boundaries, the performances of Australian projects and industry will continue to improve."

Acknowledgements:

Paul Rushton, Chief Structural Engineer, Kaiser Bechtel Joint Venture (KBJV)

Rupert Grayston, Western Australia and South Australia State Manager, Australian Steel Institute

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Olympic Edition 2000

galvanize
53 August 2000

GALVANIZING ADDS SUSTAINABLE INTEREST TO STEEL

Staging the Sydney 2000 Olympic and Paralympic Games requires a major logistical and facilities management endeavour with the Olympic Coordination Authority of the New South Wales Government responsible for developing the new Olympic venues and administering a capital investment budget of about $3.5 billion. Providing the infrastructure and associated competition and public facilities embraces complex and diverse challenges. In addition urban renewal, design excellence, building innovation and ecologically sustainable development are guiding principles enshrined in OCA's charter.

Galvanizing's universal applications

Sydney International Archery Park

Three projects which reflect the unique building demands and architectural character to which galvanized steel construction has made a notable contribution, are detailed in this edition. The galvanizing finish is also used in its traditional role for services and with respect to pedestrian use for safety and security.

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Sydney International Shooting Centre Mark Sheldon of architects, Group GSA Pty Ltd, comments "Our brief was to produce the best shooting centre in the world and to embody an Australian vernacular in our building. We interpreted that as being simplified and rustic in form and relating to the topography. The structure and geometric rigour of the building reflects shooting in that it is very linear and long, has precise lines and is a very simple, direct response to the brief. Because shooting is a sport that comes off the land, we have used strong exposed materials, steel windows and door frames with a raw galvanized finish, a concrete floor and recycled timber cladding."

Olympic Shooting Centre, Cecil Park, Sydney (***Top*** *Photograph courtesy of Group GSA Pty Ltd*)

The International Shooting Centre incorporates three Olympic shooting ranges, a fully enclosed 10-metre indoor range for air rifle, air pistol and moving target disciplines, a 25-metre range, a 50-metre range and a finals range able to accommodate all disciplines. The 280-metre long main complex has a sweeping angled roof reaching to nine metres above the ground and is positioned to nestle into the surrounding landscape of the Cumberland woodland. Such is the anticipated level of interest that the permanent seating for 1250 people will be augmented to 10 000 during the games. Rifle and pistol events will be held on a purpose-built range with a scoreboard and a 2500-seat grandstand. There are also outdoor facilities for trap events, where the clay targets move away from the competitors, and skeet events where the target travels across the line of vision. One of the most important legacies of this project, like other Olympic preparations, is the way it addressed global environmental issues. There are site issues, but more especially environmental issues in terms of materials selection, recycling and materials which did not consume excessive amounts of energy during production. The whole world can benefit from such an emphasis on environmental design in buildings. The complex is designed to enable safe and convenient access for people with special needs, in accordance with OCA's access strategy. Access features include adjustable shooting platforms to accommodate wheelchairs. Future expansion needs of the Shooting Centre have also been addressed having the potential to expand with a fully baffled 300-metre range and associated noise barriers for large calibre firearms.

Sydney International Shooting

NSW Tennis Centre, Homebush Bay

NSW Tennis Centre, Homebush Bay The world class Tennis Centre in the heart of Homebush Bay is a further achievement of the outcomes of the Olympics and Paralympic facility projects. Representing a $39 million investment, funding has been provided by the NSW State Government, Tennis NSW and Tennis Australia to create a 10 000 seat capacity circular centre-court stadium. Architects, Lawrence Nield & Partners, with the assistance of international consultants the UK's Building Design Partnership, also responsible for the new No. 1 Court at Wimbledon, and tennis great John Newcombe provided specialist input. The design feature is a lightweight metal roof which provides shade to 70 percent of the seats. Weighing only 15 kgs per square metre, it has the court lighting incorporated within, avoiding the need for light towers. Adjoining the centre court facility are two show courts, seven match courts and six practice courts all with Rebound Ace playing surfaces. Extensive use of structural steel was treated in a high surface quality galvanized finish for long term protection and as an aesthetic feature of the structure. Service facilities within the tennis complex cover administration, meeting and changing rooms and retail facilities together with a gymnasium and physiotherapy centre, and a small club for members, with dining and function capacity. A tennis museum houses much of the historical material accumulated by Tennis NSW.

NSW Tennis Centre, Homebush Bay *(Photographs courtesy of Bligh Voller Nield)*

During the Games competition, 7400 temporary seats will be added to accommodate spectator demands from ten consecutive days of Olympic tennis, destined to draw the world's best The Tennis Centre is close to the new Olympic Park station, bus routes and public transport access and private parking will be unavailable during the games period, to encourage all spectators to use public transport.

Centre

Sydney International Archery Park, Homebush Bay

Sydney International Archery Park, Homebush Bay Modern archery is a precise, high technology sport and the purpose built facilities for the Olympic & Paralympic competitions will become the permanent home for the sport in New South Wales.

Sydney International Archery Park, Homebush Bay *(Photograph courtesy of the Olympic Co-ordination Authority–Bob Peters)*

Post the Olympics, it will become the venue for competitions, training and sport under the aegis of the Archery Society of NSW. The 6.5 hectare site adjoins the Haslams Creek and Mangrove Creek wetland areas in Homebush Bay, and is part of a network of open space design. Environmental consideration by Architects included a dismantling and re-assembly facility, material selection on low embodied energy ratings, water efficiency, non toxic finishes, light optimisation and climate considerations. Representing an investment of $3 million, a distinctive building has been created, flanked by natural mangrove wetland fringes and two sculptural forests made from 185 recycled electricity poles ranging from 3 to 11 metres in height. The 183 by 100 metre archery field is flat with a subsoil draining system. Architects Stutchbury & Pape conceived the elegant archery pavilion which is aligned to ensure competitors have the best shooting positions. The Sydney International Archery Park has embraced the use of direct metal finishes in all aspects of the building's detail

Nine modules beneath the distinctive twisting roof, provides shade and protection for competitors and spectators as well as administration, canteen, changing rooms, first aid and storage facilities. Under Olympic and Paralympic conditions the archery field is divided into a competition area and an adjoining training and warm-up area. Temporary buildings will be provided to meet the special demands of the competition period, such as media, scoring and video screen facilities plus a 4000 seat temporary grandstand. The Archery Centre is a striking component of the total development of the Millennium Parklands, a 450 hectare area surrounding Homebush Bay's sporting facilities.

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October 2006

GALVANIZED STEEL

ENVIRONMENTAL SENSITIVITY AND PERFORMANCE

Lake Vasto, Perth WA

In this issue

Lake Vasto, Western Australia

The Australian Garden, Victoria

Editorial
Emmanuel Pimentel

Prepared by
Galvanizers Association of Australia

Architectual engineering and landscape designers are great innovators. Innovative designs require materials and protection technologies that are versatile and sensitive to all environments, yet are durable and minimise the need for ongoing maintenance. After-fabrication hot dip galvanizing technology has been used to protect steel for over 170 years. In fact, hot dip galvanizing has been used to protect almost every type of steel structure and fabrication imaginable. In Australia, there are examples of hot dip galvanizing that have managed to survive in the harshest conditions for 130 years.

As our cities become denser and expand, the selection of materials for use in the built environment will require innovative and sensitive design that should not only be aesthetically pleasing, but will also need to withstand the rigours of everyday use by those in the community. Designers are beginning to appreciate the fact that galvanized steel is a material with superior corrosion resistance, abrasion resistance and environmentally friendly qualities.

When designers opt for the superior durability of hot dip galvanized steel, they are using a natural material with aesthetic and protective capabilities that maximises the use of public capital and space. The vision of inspired designers can be realised without compromising their environmental integrity.

In this issue of galvanize!, we look at two case studies separated by 3,500km, but similar in their efforts to promote environmental awareness and responsibility.

Australian Garden, Cranbourne VIC

LAKE VASTO PERTH WA

Cities and their councils are constantly looking for ways to incorporate practical development solutions into their built environment whilst taking care to meet society's ever more demanding environmental standards. Lake Vasto, in Perth's Ozone Reserve, has managed to incorporate a number of uses and benefits, not least being its environmentally sustainable utilisation of water rources.

Lake Vasto is named after Perth's Sister City, Vasto, a port city on Italy's Adriatic Coast. The lake was opened in 2004 by the Lord Mayor of Perth, Dr. Peter Nattrass, and the Mayor of Vasto, Dr. Filippo Pietrocola.

Lake Vasto has a key role to play in a more environmentally friendly irrigation system for foreshore parks and reserves in Perth. It is filled with water collected from a 300m deep artesian supply beneath Langley Park. This water is then used to irrigate most of the City of Perth's 70 hectares of foreshore parkland.

A key contributor to maintaining its environmental friendliness while improving aesthetics is a new water treatment and pumping facility that reduces the level of iron staining on surrounding footpaths and buildings – an unsightly consequence of using bore water for irrigation in an urban setting.

The benefits of the systems are not only environmental and aesthetic, they are also economic and raise efficiency. This is achieved through an automated, in-ground irrigation system that replaces inefficient and labour-intensive travelling irrigators and above-ground hoses.

The City of Perth also had a vision to make the area visually appealing and to promote its use to the public. Part of this involved the design and construction of a boardwalk along the shores of the lake. The boardwalk was constructed by combining timber and galvanized steel, two natural, durable and earthy materials.

The boardwalk was designed by landscape architect, Stuart Pullyblank of TRACT in Perth. Stuart often uses natural and robust materials such as galvanized steel in his work. He said that choosing galvanized steel was easy.

"I like the raw quality. It's simple to use and I haven't had any problems with it."

The virtual elimination of maintenance costs through the use of galvanized steel also appeals to designers. Stuart says that one of the main advantages is that, "Galvanizing is very durable. There is no damage to the coating during transport and installation like there is with other coatings such as powder coating and paint."

Environmental and visual concerns were also an issue since this was a waterway. "Once in use," says Stuart, "And in this particular application, we couldn't afford a coating that falls or chips off into the water."

"Galvanized steel is tough and durable in public traffic situations, but warm enough that people accept its presence."

Acknowledgments and further information:
Roger Blackburn, Project Manager – City of Perth
Stuart Pullyblank, TRACT (WA)

THE AUSTRALIAN GARDEN

ROYAL BOTANIC GARDENS CRANBOURNE, VICTORIA

The Australian Garden is a source of natural environmental knowledge and also contains various demonstrations of sustainable practices for home gardeners. This relevance to everyday life will show visitors how the latest research and designs can help them to make their gardens more environmentally sustainable. Issues such as water conservation, native plant home gardens and "the future garden" are examined.

Other features include the Kid's Backyard, which rejects the usual artificial "plastic" equipment and encourages children to use their imagination and explore using organic materials such as a red-gum timber Hortasaurus, a large animal made from salvaged timber.

The Australian Garden is also home to some stunning artworks. These include the Ephemeral Lake, which introduces the story of water in our vast and arid continent, and the Escarpment Wall, which is inspired by the red sandstone escarpments such as those found at Uluru and King's Canyon. The huge 100m long Escarpment Wall Sculpture runs along the Rockpool Waterway and is made up of striking red-rusted weathering steel.

The use of steel and timber throughout the Australian Garden contributes to its earthy, natural feel. Galvanized steel was used to build the bridge that spans the water where the Rockpool Waterway ends. Galvanized steel is also used with timber to create a shelter for visitors either looking for a place to rest or sit and eat.

The Royal Botanic Gardens Board Victoria (RBGBV) plays a leading role in the conservation of plants and improving the understanding of plants. It does this though biodiversity research, conservation and education programs and the study of habitats. The RBGBV is responsible for the administration of two major gardens: 363 hectares of remnant bushland and wetland at Royal Botanic Gardens Cranbourne; and 38 hectares of heritage landscapes at Royal Botanic Gardens Melbourne.

The education and visitor programs have recently been expanded with the opening of the first stage of the Australian Garden within the Cranbourne site. The Australian Garden will showcase much of the remarkable plant and animal life unique to the Australian environment.

The Australian Garden was designed by landscape architects, Taylor Cullity Lethlean, in conjunction with respected plant designer, Paul Thompson. It has won a number of design awards, with the Australian Institute of Landscape Architects jury saying in 1998 that the garden elevated, "…the notion of floral displays to those of whole ecosystems, underlying soil and water systems manifest and inspiring further exploration."

The Australian Garden also seeks to explore the relationship between the living environment and our daily life. Humans have a significant impact on the Australian environment and this facility will offer a greater understanding of this interaction.

Galvanized steel has been a part of the rural environment in Australia for over 130 years. It was used for shelter, water collection and fencing. Anyone travelling through our continent will be familiar with the iconic visual and functional status of galvanized steel. It is appropriate that galvanized steel has been used in the Australian Garden in conjunction with other traditional and natural materials.

The Australia Garden is located in Cranbourne and is approximately a 50 min drive from Melbourne. It has a visitor centre, a Gardens Shop, and a café. Guided tours and education programs are also available to visitors.

The second stage is planned to commence in late 2006 and will cover 15 hectares. It is expected to take three years to design and construct.

Acknowledgments and further information:
Eleanor Bridger – Royal Botanic Gardens Melbourne

Attenborough Nature Reserve

Ecological Design

By Iqbal Johal

The Visitor Centre at Attenborough Nature Reserve is an exemplary low-energy carbon neutral building which utilises sustainable resources and timber construction. At the same time it is graceful and beautifully detailed. The Visitor Centre provides a focal point for the public and visiting school groups. It is a Site of Special Scientific Interest (SSSI) and has high wildlife value. The centre is expected to attract 120 000 visitors annually and was officially opened by Sir David Attenborough.

Client's Brief

Nottinghamshire Wildlife Trust (NWT) wished to create a flagship focus for the partnership's organisation. Some of the specific functions for the centre were:

- to cater specifically for young people through the provision of a high quality educational facility
- to be eco-friendly, appropriate to its surroun dings, affordable and viable in the long-term to meet the requisite criteria for a floodplain resource
- to provide access for all where this does not compromise the ecological integrity of the site.

Design Objectives and Requirements

The visitor centre is the first permanent, purpo-se-built visitor and educational facility NWT has constructed.

It had to be as 'green' as possible, demonstra-ting, where feasible, environmentally friendly practices which could enthuse and serve as a model to visitors.

The facility is sited within a floodplain and had to be elevated to be above the level of a 1 in 100 year flood event.

As the building would have a significant impact on the local landscape sensitive design was critical, a minimal footprint of the centre was paramount.

The building consists of a reception/display area, educational area and has an enclosed viewing area with immediate access onto an exposed viewing platform.

Environmental Issues

Timber used in the construction had to be from sustainable sources with a documented chain of supply. Prior to the selection of any materials or products the architect had to show they had evaluated the environmental consequences of the selection.

As the nature reserve is a SSSI it is subject to statutory protection. The timing of operations had to take into consideration bird breeding and times of maximum flood risk.

Off site pre-fabrication of materials had to be maximised to minimise the impact of construc-tion noise and avoid contamination.

A key design strategy was to utilise renewable energy sources that would meet the annual energy needs of the building in normal use, thus providing zero net greenhouse gas emissions.

Specific features included:

- Super-insulation of the building envelope. The high levels of insulation in the walls, floor and roof will minimise heating require ments, resulting in an overall heat loss of only 15kW for the whole building.
- Electricity is generated by an array of photo voltaic panels on the south-facing roof.
- A "heat-pump" is used to provide heating and hot-water, taking low-grade heat from the lake by circulating water in plastic pipe-work sunk in the bottom of the lake.
- Additional heat is provided by roof mounted hot-water solar panels, on a butterfly shaped roof made from 90% recycled steel.

- The building envelope is designed to be maintenance free. This meant that all the support steel for the footbridge and steel floor plate for the centré are, all galvanized.

Security

The site is very isolated at night and vulnerable to vandalism. To minimise this possibility the building is imaginatively sited on a purpose built island connected to the main parking area by a "glass/steel bridge".

The bridge incorporates a hydraulically operated lifting section which when raised at night makes it extremely difficult for intruders to access the building.

The inclusion of galvanizing for the steelwork provides both an excellent sustainable protective coating as well as a system that will combat the most determined vandal.

Architects: Groundworks Architects LLP

Photos: Martine Hamilton Knight

Asia Pacific Edition
Zinc Galvanizing in Car Parks

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October 2003

THE ARCHITECTURAL INTEGRATION OF CAR PARKS

The modern car park provides the transition from personal to public transport. These transport hubs link car use to anything from pedestrian thoroughfares to flying. Inner city dwelling is also a growing factor in the need to park cars more efficiently. "Galvanize" case studies in this issue highlight the architectural achievements evolving from upgrading strictly utility structures to unobtrusive and functional civic buildings.

Above: A galvanized pedestrian bridge structure

Right: Federation Square Car Park designed for light and transparency

Editorial
George Thomson
Rosemary Scott
Chairman of GAA
John Gucciardo

Innovative structural and landscaping links, have turned one of the world's busiest traffic interchanges into a most attractive city precinct.

Project details

Client:
Federation Square Corporation

Construction Manager:
Multiplex

Design and Construction:
Alfasi Projects and Services

Federation Square Car Park and Rail & Pedestrian Bridge

Concept: Federation Square is a world-class architectural celebration of many things, including the innovative use of galvanized steel, which is complemented in this latest city development.

The access facilities from the southern Yarra River, parklands and city sports domain have now conjoined the city, the Square and the riverbanks. This is achieved by innovative steel design capturing a city vision of these Melbourne features so long obscured from view. Other suburbs are also provided for by the on-site Flinders Street Railway Station and the new multi-story car park.

The car park takes up the levels between the river and Federation Square ground floor, while pedestrian bridges and walkways cater for the many people who enter the facility or the city from the south. The car park accommodates 500 vehicles and allows access from Federation Square, Flinders, Russell or Exhibition Streets.

The 600 tonnes of steel in the car park is heavy duty galvanized as are much of the access ways and water front structural features.

Design: The design and construct package for the entire car park was ably carried out by Alfasi Projects and Services to achieve a series of important considerations including harmony with the surroundings and availability of the inviting riverbank parkland aspect. The low profile building concept achieves this outcome where, in addition, the open span galvanized steel structure provides both the extra security of clear sight lines and a soft merging of the transport activities and the treed river side.

Of importance were the factors of low maintenance, hard wearing, light and reflective surfaces where the perforated metal side panels create virtual transparency through the structure. This makes a valuable contribution to personal and vehicular security as well as ease of access and lack of obstruction during entry or egress.

The innovative structural and landscaping links, created by this community facility, have turned one of the world's busiest traffic interchanges into a most attractive city precinct.

Ayala Avenue, Makati City, Manila, Philippines

This car park structure is situated in Makati, the main commercial center of metropolitan Manila.

The development was in response to the urgent need for additional car parking in Makati due to the rapid increase of commercial offices and shopping malls in the district.

Accompanying shopping and residential apartment complexes created a modern and prestigious neighborhood into which this highly visible car park structure has been tastefully located.

The need to build within a minimum site area in an already well developed location, while allowing fast track schedules, led to design of a bolted steel structure capable of minimum erection time.

This car park seems to epitomize the design achievements of traffic interchanges in Asia, where elevated roads mounted on galvanized steel columns play a major role in easing traffic congestion.

In particular the car park's 7 meter beam lengths and 3.5 meter vertical column height, create extra headroom, light and ventilation and a valuable 5000 square meters of floor space in this heavily built up area.

This design also offers the capacity to add to or dismantle and relocate the structure.

For this purpose galvanized steel offered unique suitability both from the standpoints of long service life and its metallic alloy abrasion resistance during steel handling.

In summary, steel design provides not only efficiency in maximizing space, light and security but offers advantages in time and cost during construction and future planning.

The final architectural appearance achieves fine harmony with its community surroundings.

Details:

Location: 6748 Ayala Avenue, Makati City
Capacity: 434 cars
Supplier/Contractor: JFE Civil Engineering & Construction Corporation (Japan) / RIOFIL Corporation (Philippines)
Construction: 1998

United Parking Car Park
Melbourne Airport

This car park project was awarded to Pritchard (Builders) Pty Ltd to design and construct accommodation for 1000 vehicles, required by Nic Saraceno of United Parking Pty Ltd to provide a quality service for patrons of the nearby Tullamarine Airport.

This facility is located 3kms from the main departure terminal on the corner of Melrose Drive and Trade Park Drive and is serviced with an “on demand” courtesy bus service to transfer patrons to and from the terminal. It provides a specialist valet airport link for business travellers whose time efficiency is often of critical importance. Four levels of cost saving parking is available which requires a minimum diversion on the part of patrons leaving or returning to the airport. Facilities include self parking, full security, TV lounge and a business service center with some unique services such as wide space parking lots and Mercedes coaches to the airport.

The galvanized steel framed building is light and spacious and makes good use of the wide open span structure. The design brief prepared by Stephen Dean, Pritchard’s Business Development Manager, was implemented by United’s Development Manager, Robert Whitwell. The successful delivery was ensured by Pritchard’s Project Manager Hok Tan.

Stephen Dean’s D & C experience and commercial awareness encouraged a review and market assessment of the three typical construction systems

- Structural steel and composite concrete deck
- Post tensioned insitu concrete structure
- Precast hollow core system

The decision to adopt a composite steel construction was supported by several key issues principally time and cost benefits coming to the fore, ensuring the full delivery including all design, permits and construction for less than the $10 million anticipated projected cost. Once the construction method was agreed, detail design was explored into a variety of cost benefits between 3 and 4 car park bays, applied finish versus hot dip galvanizing and external façade systems.

The final outcome was a 3 car park grid comprising hot dip galvanized primary and secondary beams with Stramit™ Conndeck structural composite formwork system and prefinished perforated façade screens to the exposed elevations.

The use of hot dip galvanizing was adopted on the support and recommendation of Trojan Specialised Steel Structures, with support from Engineering Group, Gillion Consulting in Hughesdale.

The facility, constructed over four levels, comprises floor plates of 5000 square meters and provides for an additional level to be constructed at a future date. The joint cooperative approach involving fabricator, engineer and the entire project team guaranteed the success and realistically saved eight weeks of time in the overall delivery program.

The project comprised 700 tonnes of 300 plus grade structural steel supplied by Smorgon Steel, cut to length and predrilled prior to transfer to Smith Welds for precambering and galvanizing. The other significant design application was the 2.48m clear height requirement to enable the courtesy bus full access to each level for both drop off and pick up of travellers.

Cambridge Leisure Multi-storey car park

By Iqbal Johal

Situated on the outskirts of Cambridge SMC CovellMatthews architects inherited a high public profile site that required the highest level of professional design management to satisfy the ambitious and environmental concerns of the local council and work within the client's commercial constraints.

The Cambridge Leisure development project is on an old cattle market site to the south of Cambridge city centre. It occupies the north west corner of the site and is adjacent to the railway line opposite Cambridge station. The project's core comprises a leisure centre, which includes a 9 screen cinema, 28 lane bowling alley, a health & fitness unit and several restaurant/bar units. In addition to this are a hotel, a mixed-use retail and residential area and the site even includes an estate agent with auction rooms. To give the development an additional youthful buzz an existing youth arts centre, has been refurbished, and extended.

A multi storey car park completes the scheme. Unlike many other schemes SMC CovellMatthews have ensured that the multi storey cark park not only fits into the overall remit laid out by the local authority and clients but that it stands in its own right as a well designed structure that adds value to the whole project. It is not just an add-on block of concrete to provide parking.

Programme considerations and the desire to achieve clear span decks were the principal factors influencing the consideration of the building as a steel framed structure. Other design considerations were the wish for, as far as possible, a naturally lit interior during the day, the achievement of a 'secure car park' award and the avoidance of light pollution from the upper car decks while still achieving adequate levels of illumination at night.

A total of 560 spaces are provided on 6 pairs of parallel level decks running north/south, cross linked by ramps allowing cars to circulate past all spaces. A principal stair/lift access tower is sited at the southern end of the building with a secondary escape tower at the northern end. The main framing for the structure is a series of columns with cellular beams across the decks and deep plate girders to the elevations; these are tapered on the short elevations following the crossfall on the car decks. This framing supports floor slabs of precast concrete planks with in-situ topping.

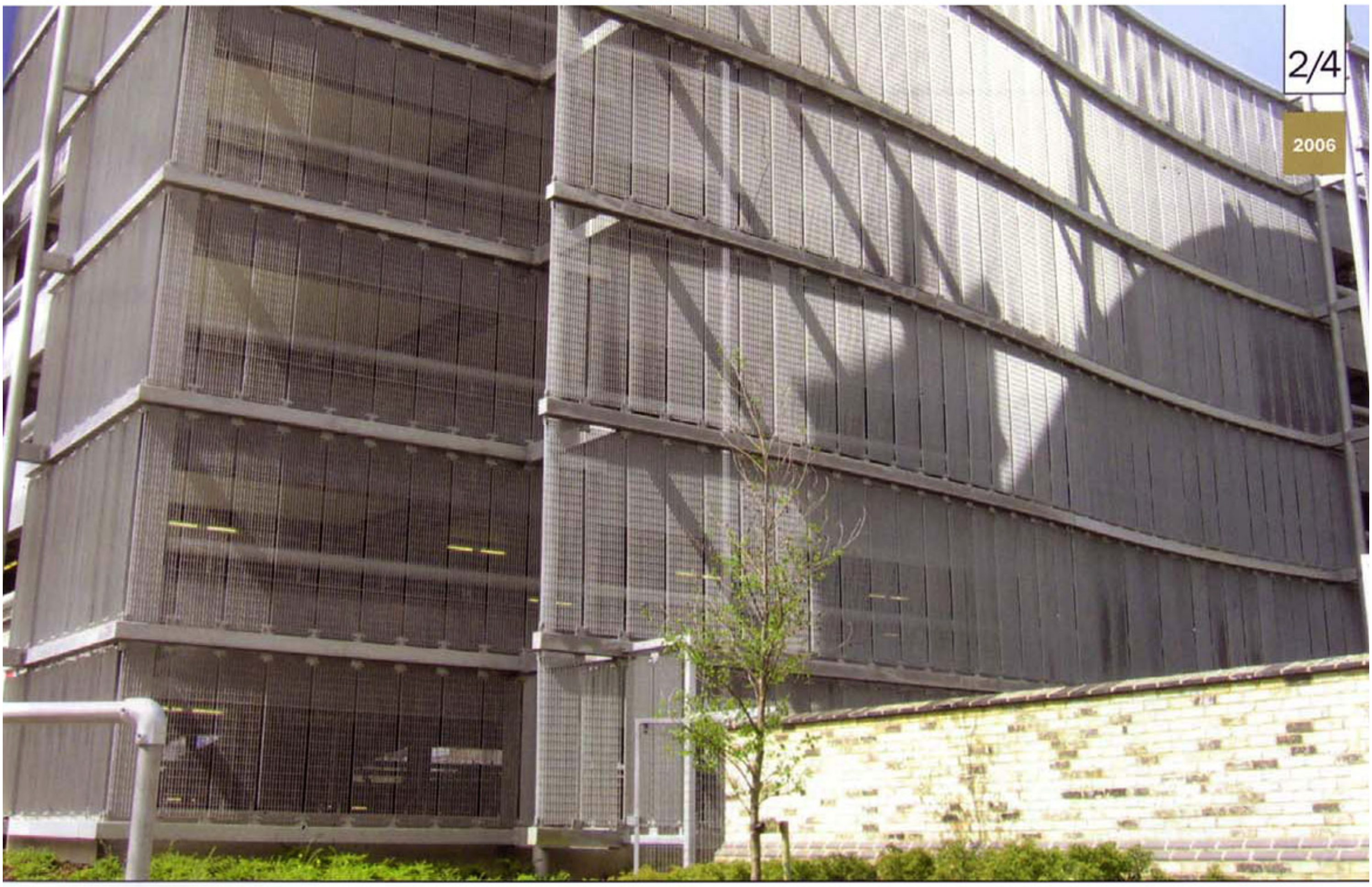
One of the aspects that make the design stand out is the cloaking of the main frame with a secondary layer of screening. This is formed using a series of overlapping curved elements to the long elevations with linear returns to the short elevations - principally a series of horizontal double curved 200mm SHS sections supported on 220mm diameter vertical CHS columns. The elevation is completed by infilling the main frame with narrow vertically oriented sections of a standard strip and bearer bar floor mesh.

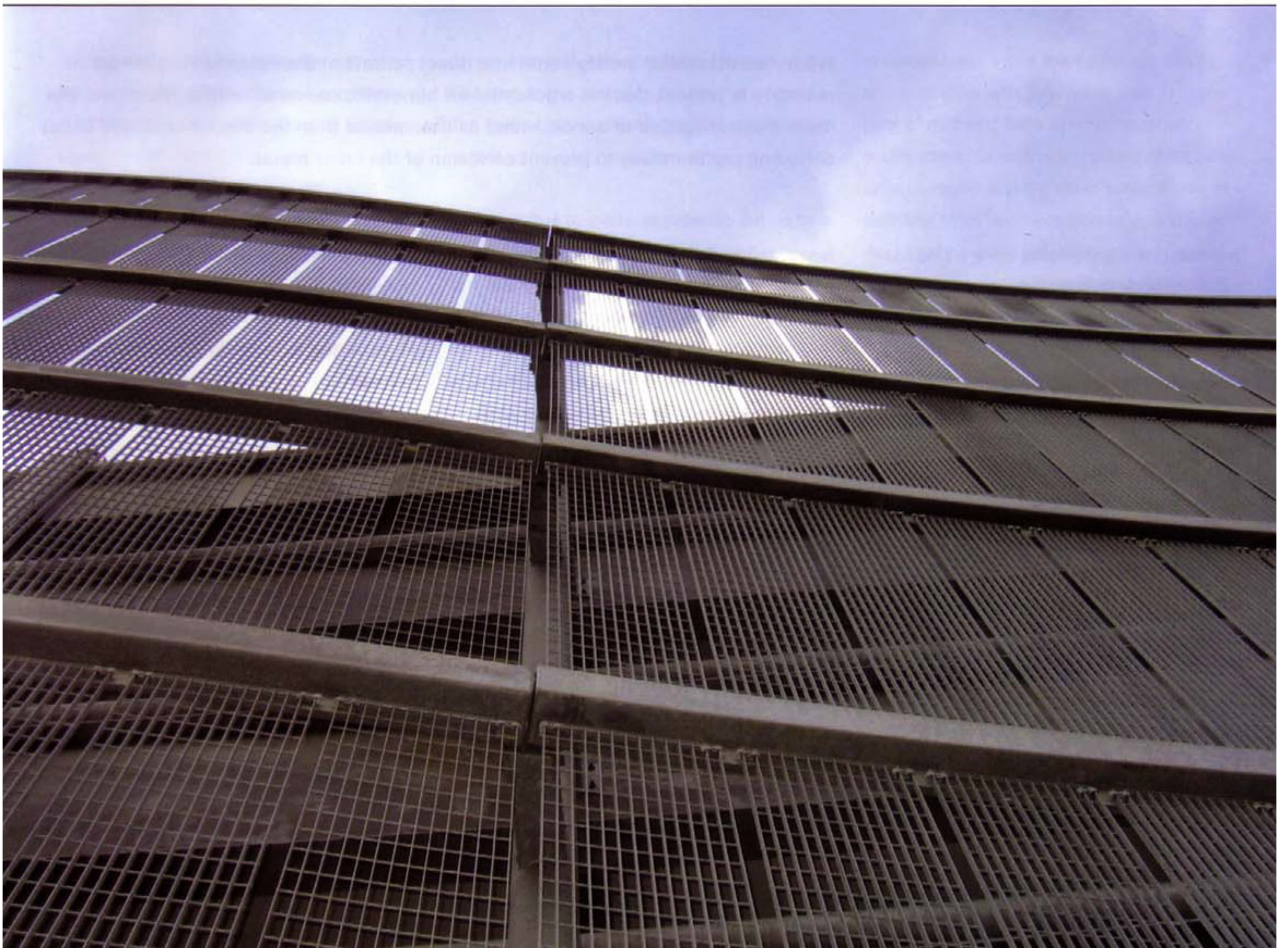
The screening is intended to soften the rectangular form of the building and diffuse light emanating from it. The nature of the mesh gives a varying degree of transparency/obscuration depending on the angle from which the building is viewed. This has resulted in interesting animated views of the building, particularly from trains arriving/departing Cambridge station.

For long term durability and the soft grey aesthetic - the mesh a sparkling silver on a bright day - galvanizing was the obvious choice of finish for all steelwork. In fact the only other finish that was used was for the stair towers, which are wrapped in blockwork finished in a complimentary rich blue acrylic, render.

Architect: SMC CovellMatthews

Photos: Tanya Cordner, SMC CovellMatthews





Associate of International Zinc Association

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March 2005

INDOOR SWIMMING POOLS

In this issue

Aquatics: Growth of indoor swimming pools.

Westpac Call Centre

Editorial
George Thomson
Rosemary Scott

Prepared by
Galvanizers Association of Australia

Editors wish to thank the following for their generous assistance in preparing this case study.

- Prior + Cheney Pty Ltd – Architects
- Anthony John Group
- Ceccato Hall & Associates
- S-Square
- SW Healey and Associates
- M & S Steel Buildings
- Smorgon Steel Tube Mills

Lakeside Leisure Centre, Port Stephens, NSW

Hot dip galvanizing steel

The sport of swimming has flourished in recent years, when Olympic publicity in particular has brought its popularity to a wide section of the community.

The significant development of hydrotherapy and aquatic exercise treatments has extended the value of 'swimming' to people of all ages. The requirement for facilities to best accommodate their variety of lifestyles has been well addressed by many public authorities and resulted in major aquatic centre projects.

The principle has often been further extended to cover gymnasiums and other dry-sport games in total leisure complexes within local government civic centres.

Economic and planning projections require extensive architectural design development having regard to the growing levels of community participation.

Design

The level of participation and economic analysis are important features of design and require study of community needs and interests.

As major capital investment and large running costs are involved, a fair return to owners and public authorities is needed to justify the investment and to provide for future expansion.

In this context careful asset management plans, with a low maintenance regime, are essential.

Incorporating such factors in a complex requires a structure able to accommodate a number of forms, shapes and site limitations where the use of steel is frequently selected as the most suitable structural material.

Steel's most important attributes are:

- Long-spanning capability with open site lines
- Low structural presence and space occupation
- Design flexibility for future additions
- Many suitable connecting methods such as bolting, welding and pinning.

These features lend themselves particularly well to such structures, however a design adjustment is required to counter the fact that warm water in a pool generates humid chlorine-laden air from water treatment and with it constant surface wetness of the steel.

Heated pools need a raised temperature for swimmer comfort but the resulting evaporation creates corrosive conditions for steel and the need for upgraded steel protection.

The design task described requires the engineering considerations of such features as insulation, ventilation and top quality corrosion control in an environment analogous to marine exposure. The value of a protective coating is measured by its prior proof of suitability, intact installation and long term reliability.

Front cover: Lakeside Leisure Centre, Port Stephens, NSW

Queanbeyan Aquatic Centre, NSW

Queanbeyan Aquatic Centre, NSW

Lakeside Leisure Centre, Port Stephens, NSW

Maintenance

Pool maintenance includes ensuring water quality, services to the public and fabric preservation, all within a high level of surface wear and impact. The need for maintenance derives not only from these conditions but also the degradation of organic paint coatings by UV radiation.

Galvanizing is immune to UV, has outstanding abrasion resistance and good evidence of over 30 years to first maintenance.

Community

Mr Peter Smith, Associate Director of Prior + Cheney Architects summarises by saying, "swimming facilities require highly detailed research to offer a large community segment maximum utility and fulfilment from this enjoyable activity."

This company, whose work is now featured in *galvanize!,* has been designing aquatic facilities for over 18 years and has produced many examples of steel frame structures used in a striking and attractive manner.

Even in Australia's climate, such facilities have become an invaluable aid to our good health and athletic aspirations and have achieved increasingly wide appeal.

ZINC

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Asia Pacific Edition

GALVANIZING IN ENGINEERING AND THE ENVIRONMENT

GALVANIZED REINFORCEMENT

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August 2005

In this issue

Galvanized Reinforcement in Major Infrastructure Engineering

Industry Environmental Leadership Project

International Zinc Association Sustainability Charter

Editorial
George Thomson
Rosemary Scott

Prepared by
Galvanizers Association of Australia

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Galvanized reinforcement in major infrastructure

Where it is considered that normal reinforced concrete will not have adequate durability, galvanized reinforcement is often used in preference to conventional steel reinforcement.

While concrete itself provides natural corrosion protection to steel this may be lost as a result of aggressive species from more severe environments through the coating cover.

Galvanized steel reinforcement was first used on marine piers in 1953 and has become widely used for increased protection in such circumstances.

The following article is an example of this use.

Hot dip galvanized coatings are usually applied to steel that is already fabricated. However, in a major project now under construction in Singapore, this convention is being reversed. For this project, steel in the form of loosely-coiled wire bar, is being galvanized then formed around large mandrels into cages that become the steel reinforcement for sections of large diameter concrete pipe.

The pipes are part of the Deep Tunnel Sewage System (DTSS) which was conceived as a long term solution to meet the needs for used water collection, treatment and disposal to serve the development of Singapore through the 21st century.

An integral part of the project is a large treatment plant at Changi from where a deep-sea outfall will discharge treated effluent into the Straits of Singapore at a distance of 5km from shore. The outfall comprises two parallel under-sea pipelines, constructed from reinforced concrete sections laid end-to-end in a trench in the sea-bed. Each concrete pipe section measures 3m in diameter and 8.0m in length and contains 7-8mt of galvanized reinforcing bar (rebar). In all, the pipelines will require 1300 individual pipe sections and will use a total of 10,000mt of galvanized rebar.

The project has presented many engineering and technical challenges for both contractors and suppliers. In the case of the ocean out-falls the need to ensure integrity and longevity of the pipelines under the service conditions encountered has required serious consideration and a deal of ingenuity.

The corrosivity of seawater coupled with the need to design for a service life of 100 years, dictated that the rebar should be coated to protect it against corrosion that could lead to spalling of the concrete, compromising pipeline integrity. The choice of galvanizing to coat the rebar was not made lightly as any coating had to be capable of withstanding site handling as well as being formed into the circular cage shape before placement in the moulds used to cast the concrete pipe sections. The method of forming the reinforcement cages required that the rebar was of reasonable length and so it was decided to use coils of rebar rather than straight lengths.

Considerable work by both the contractor and the galvanizer was necessary before the optimum rebar size was established. The decision to use coils as the start material required specialised handling techniques through the galvanizing process but too large a bar diameter would make the coils too “inflexible” for galvanizing. On the other hand, too small a diameter would not provide the rigidity required of the cage when the rebar was formed. Further, formability of the rebar was an issue as dimensional consistency of the finished cages was important to ensure the correct thickness of concrete cover.

Galvanizing was finally chosen over other alternative coatings because of its resistance to site handling damage and the ability to provide long sections of rebar that would minimise joints and cuts that could potentially compromise corrosion protection.

The Changi outfall contract was awarded to the Dutch dredging contractor Boskalis International bv with pipeline construction by its affiliate Archirodon Group nv.

INDUSTRY ENVIRONMENTAL LEADERSHIP PROJECT

NSW Environment Protection Authority Cleaner Production

Industry Partnership Program

Department of Environment and Conservation (NSW) and Galvanizers Association of Australia's NSW member companies

Introduction

These Partners initiated an industry-wide process of education, methods of assessment, environmental cleanliness and cleaner production improvement for all plants.

The galvanizing industry's objective was to improve resource use and reduce waste generation. This was achieved through the commitment of members and with the assistance of consultants, Environment Essentials, with the staunch support of the Department of Environment and Conservation (NSW).

A major aim of the work was to develop ownership of the program in shop floor operators. This reinforced the total commitment of member companies from the ground up. The responsibility across all employees for environmental management and awareness has been a significant factor in the galvanizing industry's progress in this area over the past 15 years.

The galvanizing industry has been operating for about 170 years and is committed to making a socially responsible contribution to our community and the environment.

As an illustration of our progress, we have recorded some typical improvements in NSW which are leading to measurable efficiencies as well as a cleaner industry.

General Outcomes

Four plants achieved considerable reductions in resource usage during the program. Two other companies previously involved also achieved a parallel drop in waste generation and had already made resource and efficiency gains at the earlier entry point.

The progress achieved from the training program by our consultants included plant maintenance and adjustments, procedural improvements and strict retention of process tanks at appropriate chemical concentrations.

This discipline and diligence included detailed attention to zinc recovery from the galvanizing process.

A further successful innovation was the integration of environmental and safety procedures data into existing production and quality management systems, to which some basic milling mechanics facilitated further recoveries; work which is still proceeding.

Redesign and replacement of insulation equipment reduced gas consumption per tonne of steel galvanized.

Aggregate annual saving over the audited period

	Resource usage
Zinc	89 tonnes
Acid	97.6 kL
Water	5.4 ML
Natural gas	1590 GJ
Green house gas	94 tonne CO_2-e
Electricity	32.3 MWhr
Green house gas	47 tonne CO_2-e

Annual reduction – Waste generation

Dross	33.3 tonnes
Ash	11 tonnes
Waste acid	225 kL

Galvanizers Association of Australia has been engaged with both State and Commonwealth environmental authorities since the late 1980's in a proactive endeavour to pursue a publicly responsible position on both environmental and sustainable practice.

In this we have been considerably assisted by the progress of our European and North American galvanizing colleagues and the research and development input of the world's major zinc producers through the International Zinc Association (IZA).

Galvanizing Industry Environmental and Cleaner Production – Continuous Improvement

South Australia	Clean air production grant	1999
	Industry cleaner production program	2002-2003
Western Australia	Waste management & recycling contract for cleaner production	2002-2003
Victoria	Cleaner production assessment and action • Environmental Management Module • Environmental Accounting Module • Energy Management Module	2001-2002
	Cleaner Production Partnership Program	2002-2003
New South Wales	Profiting from Cleaner Production – Industry Partnership Program	2003-2005
Queensland and Northern Territory	Progressive plant environmental improvements and process efficiencies	

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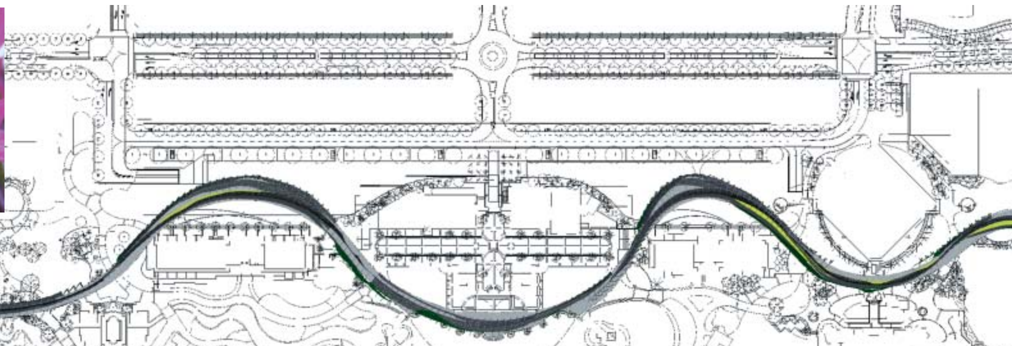
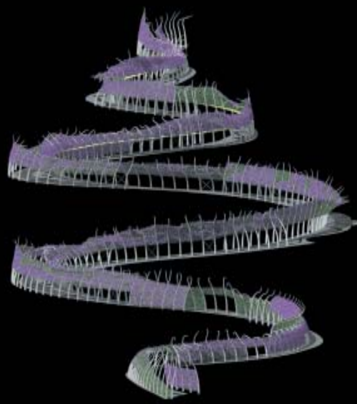
March 2000





GRANDARBOUR

SOUTHBANK BRISBANEQUEENSLAND

It is said that many of our cities have succumbed to functional concrete jungle design. Social reformers working to reverse this world trend will be impressed by the ingenuity of the South Bank Corporation in Queensland, which has provided clear direction for some inspired architectural work, bringing the vision and rhythm of the Australian Hinterland into the heart of the City of Brisbane. It is refreshing to see the commercial growth of this vibrant city, accompanied by matching concern for its people and the environment.

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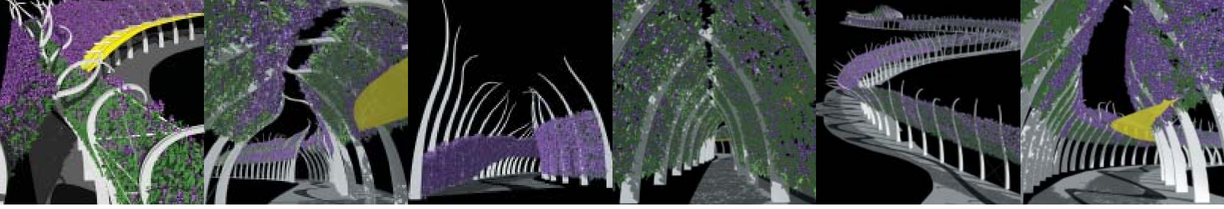
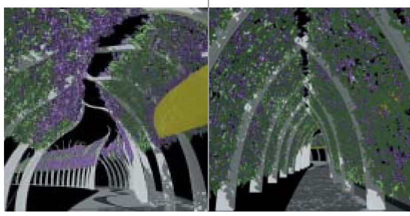
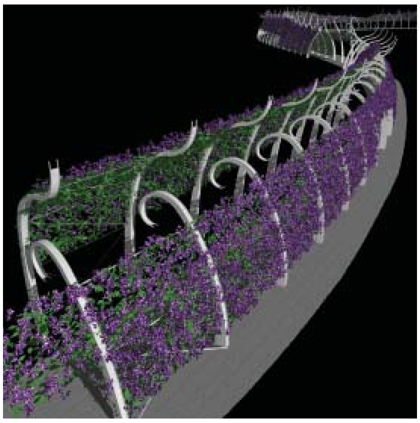


GRAND ARBOUR SOUTH

Redevelopment of World Expo 88 Site The South Bank Corporation is a body corporate established by the Queensland Parliament as gazetted on May 8th 1989, with more recent amendments reflecting the growing role of the Corporation in the further management of this city area. The mission of the Corporation is to facilitate the development and operation of a successful world-class leisure, business and residential precinct, for the enjoyment of visitors and the general benefit of the Brisbane community.





Master Plan
Denton Corker Marshall

The master plan of the expo site and some adjoining neighbourhood, comprises approximately 43 hectares along the Brisbane River, directly opposite the central business district.

In addition to the Brisbane Convention and Exhibition Centre, South Bank features an international hotel, high quality corporate office development, selected academic facilities, residential apartments and a range of restaurants, retail outlets, a swimming lagoon with its own beach and a tropical arbour linking the entire development.

Parkland

The 17 hectare South Bank Parklands stretches along one kilometre of the river bank, where further development includes placement of tropical rainforest trees, surrounding open green spaces of ground vegetation; a soothing contrast to city activity.

Vision

The success of the development has arisen from the adage that enthusiasm is infectious.
In this case, it has also been innovative and inspired.

A cooperative team of experts have created a city development equal to any in the region, with an admirable balance of community consideration, appropriate function, environmental concern and aesthetic appeal.

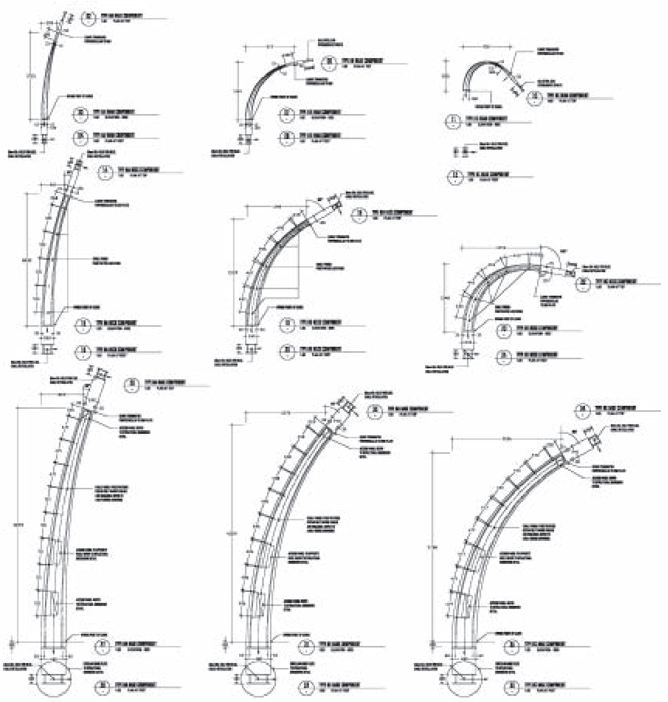
Even yet, the project is not considered closed, where clearly opportunity is being provided for further development for the future growth of the area.

The Arbour Denton Corker Marshall's project report comments: "The Grand Arbour is a 1km long architectural and sculptural installation, providing a physical and visual link between the many facilities of the South Bank precinct. A central aspect of the masterplan development, the Arbour mediates with the new open parkland to the west, while providing a sheltered north-south route through the entire site. Sinuous steel posts, up to 10 metres high, support a band of purple bougainvillea, either above, to the side or entirely enveloping the curving path. The juxtaposition of the various post configurations creates a diversity of spaces from tight and enclosed to wide and expansive. Overlapping steel panels form a plated yellow ribbon canopy along half of the Arbour's length. A total of 406 galvanized steel posts are spaced at 4m nominal centres. A unique architectural and urban gesture, the Grand Arbour is designed to offer Brisbane a new, distinctive and memorable landmark.

HBANK BRISBANE QUEENSLAND

Modular components

The height of the posts (10m) meant that they would have to be in parts for ease of transportation and assembly. A kit of parts, made up of a small range of components was the solution. The posts were divided into 3 unequal lengths - Base, Neck and Head. 3 variants were devised for each part (A, B, C) resulting in a total of only 9 different components. Any Base component could be connected to any Neck and any Neck with any Head. They could also be rotated 180 degrees. This allowed for a possible 108 different permutations for the post profiles, varying from 10m high gently undulating to head height expressively curving.



Computer Model

The complexity and non-linear nature of the project meant that traditional documentation techniques would be insufficient.

Advanced Computer Aided Design for all stages including design, documentation and construction was utilised. The entire Arbour was simulated as a full scale 3D computer model, from which all plans, elevations and sections were extracted.

Specially written computer programmes analysed the CAD model and automatically generated schedules for the Arbour setout and post components.

Finishes

Hot dip galvanizing was selected as the finish for the posts. Corten steel (a pre-rusted finish) had been considered in the early stages, but concerns over run-off staining of the path (and pedestrians) negated its use. Furthermore its rusty brown colour would give the impression that the posts were imitating trees. The Arbour, while being organic, was clearly to be a man-made insertion into the landscape, not an imitation of nature. The grey metallic finish of the hot dip galvanizing provided the desired artificiality and industrial ruggedness, in addition to a low level of maintenance."

GAA would like to thank Denton Corker Marshall and South Bank Corporation for their assistance in preparing this case study.

Masterplanner and Architect Denton Corker Marshall **Client** South Bank Corporation **Master Architect** John Simpson **Landscape Architect** Gillespies Australia **Project Manager** Resource Co-ordination Partnership **Structural & Civil Engineer** Connell Wagner **Lighting Consultant** Barry Webb & Associates **Main Contractor** Walter Construction Group **Steel Fabrication Sub-Contractor** Schmider Engineering Group

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Galvanizing in Architecture

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November 2001

FEDERATIONSQUAREMELBOURNE

The essence of the city, it is said, is embraced in the architecture of Federation Square. Whether defined as encompassing the basic nature, or an indispensable quality, much of it is to be found in these visionary structures. Melbourne has been nominated the world's most liveable city and has now gained a futuristic precinct, which defines both its appeal and its welcome.

Taking the city to the river

The Atrium from Flinders Street

Vision "Federation Square is one of the most ambitious and complex projects ever undertaken in Victoria. It is a complete new city block, the first ever to physically connect the central business district with the Yarra River. Situated at the heart of central Melbourne, Federation Square will be a fusion of arts and events, leisure, hospitality and promenading."

Federation Square Management – The State Government of Victoria has established a management company, Federation Square Management Pty Ltd, to act as client and director of the project and run Federation Square in perpetuity on a commercial basis. The company comprises of a board of three directors, its management team and staff.

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Three main cladding materials have been used

Atrium courtyard looking south

DESIGN: Federation Square's design is the product of an international architectural competition won in July 1997 by Lab architecture studio of London in association with Bates Smart Architecture of Melbourne. Atelier One were appointed Project Structural Engineers. The judging panel said of the winning design: "It draws its inspiration from the unique characteristics of Melbourne's arcades and laneways, and transforms these elements into a new form of organization, celebrating the city. The design will invite pedestrians to explore a complex and urban linkage of open and closed spaces, a set of different amenities brought together in the architectural equivalent of Federation"

FEDERATIONSQUAREMELBOURNE

As Federation Square Management describes, "The area is designed with extensive flow, integrating activities across the site, and forming links within it, as well as with the Yarra River, Arts Centre, Southgate and the Central Business District. Federation Square's architectural intent is to generate visual harmony for the site while maintaining differences between its civic, cultural and commercial buildings. The approach creates distinctions through a high degree of surface and material variation. The creative use of the 'pin wheel' triangular grid, in which every panel is exactly the same size with only the orientation changing, as the modular basis for this system allows both façade cladding and frame shapes to be treated in a continually changing visually dynamic way. On the main buildings three cladding materials have been used – sandstone, zinc and glass.

View from South East 2001

Forming a north-south link from Flinders Street to the Yarra River, the Atrium is a large, high volume public thoroughfare and covered meeting space. This glass-enclosed galleria provides a sheltered extension of the Plaza, and acts as the forecourt to the National Gallery of Victoria: Australian Art. Open at the northern end, the Atrium allows 24-hour access across Federation Square linking the city to the river. The southern half of the Atrium steps down from the elevated level of the riverside promenade, and has been designed to operate as a casual chamber amphitheatre, with an acoustic tuned interior. The open-frame structure of the Atrium has been developed using parts of the same triangular geometry as the facades, but forms a three-dimensional framing system, glazed both inside and outside. The 7,500m^2 Plaza has been designed as the new civic focus for Melbourne, capable of holding about 10,000 people. The Plaza will be paved with sandstone from the Kimberley region of Western Australia, featuring striking reds, maroons, purple and gold surfaces. Federation Square utilises an environmentally sensitive building design. Innovative air-conditioning has been integrated within the building design to achieve significant, long term cost savings. Underneath the Plaza, traditional passive cooling technologies on a large scale eliminate the need for energy-hungry air-conditioning for the glazed Atrium."

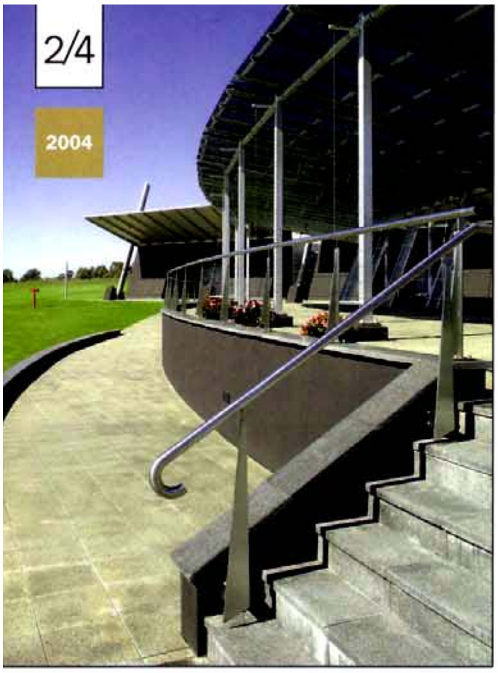
Part of a liveable city

Steel structures and window spaces

Lab + Bates Smart – Architects Federation Square
Architects: Donald L. Bates – Director
Peter Davidson – Director

Lab architecture studio was founded in London, UK in 1994 by architects Peter Davidson and Donald L. Bates (both directors having first moved to London between 1981-3). Upon being awarded the project for Federation Square (July 1997), Lab established a studio in Melbourne, Australia, to design, document and supervise the construction of this large project, which is now in the last year of its construction.

GAA would like to thank the following companies for their assistance and content: Federation Square Management Pty Ltd, Lab + Bates Smart Pty Ltd and Riband Steel Pty Ltd.



High-tech winery

Tempus Two, Pokolbin, Australia

By David Baron

Suters Architects' new Tempus Two vineyard and winery at Pokolbin in the Hunter Valley wine country, is some two hours drive from Sydney, Australia. The new building houses a cellar door, cafe, retail outlet, wine storage and display area. It utilises pewter and black colour schemes and material finishes to highlight the Tempus Two image of a quality wine.

The site

The gently sloping greenfield site is on a prominent corner location in the heart of the Pokolbin wine district. A natural drainage depression, which includes an established dam and lake, runs diagonally across the site. As the land was previously under vines, there are no trees on the site, only grass cover. Also, being a corner site, with roads on two sides, it presented a special challenge in designing the project to suit the brief.

The brief

The new winery would be a significant visitor attraction that would harmoniously blend in with the landscape. It would house wine making facilities, a cellar door and bars, restaurants and a market hall.

Outside, an area for relaxation, seating, dining and entertaining between the winery and the vines would be established. There would also be an outdoor, grassed amphitheatre for "music in the vines" type entertainment. Finally, the new building would be enveloped within a new vineyard.

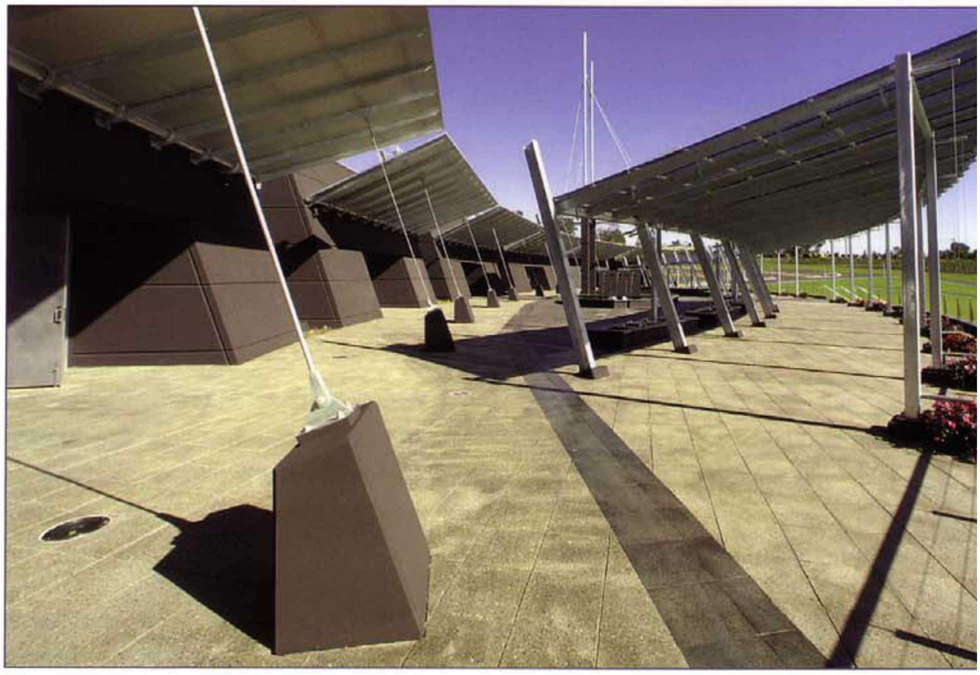
The concept

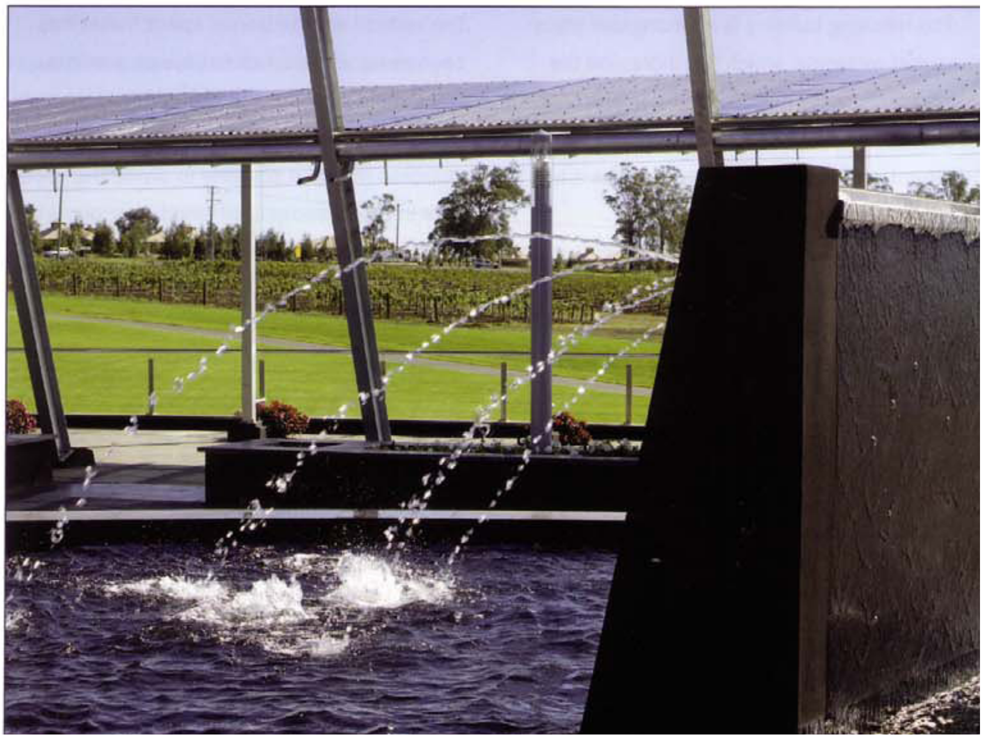
A formal, central axis and entry driveway from Broke Road was developed to echo the traditional vineyard approach of the classic French vineyards. The winery buildings - designed to look like a group of buildings and not one large, single building - were arranged in a semi-circular shape so that they would nestle into the natural gully shape of the landscape and would not intrude on the horizon when viewed from the approach roads. The existing dam was retained and upgraded as an important part of the water conservation/reusage concept for the site. Car parks and bus parks were placed at the sides of the development, while the service areas for the winery and restaurant were situated to the rear of the buildings, neatly tucked into an excavation in the hillside. Extensive and strategically placed landscaping would be used to further screen and soften these areas.

Design features and materials

Each pavilion is a modern interpretation of a simple traditional country shed and consists of a galvanized steel portal frame construction clad with an insulated zinc/aluminium coated steel panel system. The exposed steel frame retains its natural zinc finish, with both the interior and exterior surfaces of the insulated roof and wall panels kept as natural zinc/aluminium sheeting.

The entrance to each pavilion has been designed to give the sensation of walking into a cellar. Each pavilion façade to the plaza incorporates a dark, masonry, sloping wall with a deeply recessed pair of pewter clad entry doors. A deep awning roof over each





entrance adds to the sense of enclosure. The unpainted metallic finish also discourages the growth of yeast mould, a common problem with painted buildings in the wine industry. The plaza area, which links all pavilions with the amphitheatre area, incorporates an extensive galvanized steel framed pergola with a polycarbonate/vine covered roof for both weather and shade protection. The design of the pergola follows the partial semi-circular design concept and reflects the design elements from the main pavilions. The plaza also incorporates a tower structure, which acts as a focal point to the development.

The plaza area links the buildings to the vineyard via extensive covered areas providing an indoor/outdoor relationship.

Air-conditioning ducts have been exposed externally at the rear of the pavilions to express the utilitarian and functional nature of the buildings. Air conditioning condensers and fan coil units have been neatly disguised behind galvanized, expanded mesh screens.

The interior shells of each building also express the raw functional nature of the pavilions with the galvanized structure exposed in its natural form and finish.

The floors are generally highly worked, steel trowel concrete finishes, with a silica fume additive to provide a hardwearing impervious surface.

PROJECT DETAILS:

Client: Tempus Two

Architects: Suters Architects

Main Contractor: W. Stronach

Structural Engineer: Low & Hooke

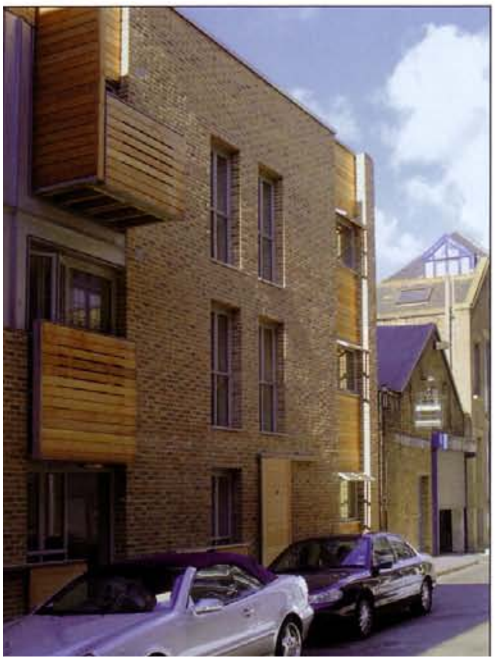
Photos: Greg Callan, Newcastle, Australia

Bermondsey Wall West

Residential Development

By Iqbal Johal

BUJ Architects' design of the Bermondsey Wall West Residential Development brings together a specific local industrial aesthetic and locally used materials. The site sits between brick warehouses that have been converted for residential use and large industrial storage facilities, lying alongside the River Thames. The site stretches back inland from the foreshore either side of Chambers Street in Bermondsey.



The new development sits partially within a Conservation Area, requiring that part of the scheme to reflect, in its use of traditional materials, scale and massing the adjacent warehouses. However the remaining part of the proposal is less restrained in its use of materials and in its appearance, adopting a more contemporary aesthetic. At an early stage BUJ made the decision to reflect the industrial heritage of the adjacent warehouses and surrounding industrial buildings through a modern interpretation of the warehouse aesthetic acknowledging the simply observed structural design of these buildings and the contingent non 'reflective' nature of their elevations.

The project involved bringing together four distinct phases:

(1) the refurbishment of an existing riverside brick built warehouse.
(2) straddling of the boundary between inside and outside of the conservation area.
(3) abutting the service yard to an 8-storey concrete framed industrial storage facility.
(4) separating the remaining development from a school by providing a visual barrier between the development and the school playground.

At a very early stage of the project BUJ decided upon a design prerequisite, when specifying finishes and materials for the project.

It centred on the principle of providing a palette of aesthetically powerful, robust, low maintenance materials, which would age and mellow over time.

All the resultant material choices were required to resist a relatively hostile environment due to the waterfront location and city centre pollution levels and exhibit high levels of durability.

Phase two, the most centrally placed of the phases, set the theme for the surrounding phases. The inclusion on elevation of a series of stacked 6m x 3m prefabricated galvanized steel frames provided a direct reference to the exposed concrete framed structure of the adjacent storage facility. Within this rigid grid various planes can be pushed in to form terraces, or pulled out to form projecting elements of the façade, the interpretation of a contingent industrial aesthetic. Among this grid of robust galvanized steel frames, further durable materials were chosen to provide a simple, repetitive, but interesting palette of materials.

Brick has been chosen in order to visually tie the new buildings with the surrounding older structures, although a more modern texture and colour was chosen to distinguish the new build. Cedar cladding was used to wrap the projecting boxes, the timber providing a suitable transition between the brick tone and the galvanized finish, whilst again being reminiscent of the loading platforms of the adjacent warehouses. Some of these boxes, particularly at roof level on phase three, are designed to add drama and scale to the development.

The end box on Chambers Street cantilevers some 5 metres beyond the face of the building, a bold and striking reference to the sites' industrial past. Within the part of the development facing the conservation area, a large fragment of the galvanized steel frames, used on Chambers Street elevation, is embedded within the

Bermondsey Wall West elevation, a stark visual reference to the remainder of the development. A number of the finer detailed elements of the elevations have also been finished using a similar selection of materials. Glass balconies sit within galvanized supporting frames which themselves lie between timber handrails and timber decked floors, while sliding/folding metal screens, on galvanized steel frames, allow privacy and give additional interest to the street elevations. The overall appearance of the completed building is that of a harmonised palette of materials, which complement each other, whilst projecting a modern, crisp industrial aesthetic.

BUJ Architects have responded to the challenges of the site creating a new development that borrows from the past but also extends its influences to encompass contemporary aesthetics and design. The influence of the project has extended to a local school where a piece of Artwork designed by its pupils, in the De-Stil style, has been constructed using exposed metal framing and coloured infill panels.

Architects: BUJ Architects

Photos: Dave Stewart