



# **Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings**

## **Part 1: Paint coatings**



This Australian Standard® was prepared by Committee MT-014, Corrosion of Metals. It was approved on behalf of the Council of Standards Australia on 18 November 2014. This Standard was published on 19 December 2014.

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The following are represented on Committee MT-014:

- Australasian Corrosion Association
  - Australian Chamber of Commerce and Industry
  - Australian Electrolysis Committee
  - Australian Industry Group
  - Australian Paint Manufacturers' Federation
  - Australian Pipeline Industry Association
  - Austroads
  - Bureau of Steel Manufacturers of Australia
  - CSIRO Materials Science & Engineering
  - Galvanizers Association of Australia
  - Galvanizing Association of New Zealand
  - Materials Australia
  - New Zealand Heavy Engineering Research
  - SA Water
  - Water Services Association of Australia
- 

This Standard was issued in draft form for comment as DR AS/NZS 2312.1.

Standards Australia wishes to acknowledge the participation of the expert individuals that contributed to the development of this Standard through their representation on the Committee and through the public comment period.

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Australian Standard®

# **Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings**

## **Part 1: Paint coatings**

Originated in Australia as part of MA 1.5—1967.  
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## PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee MT-014, Corrosion of Metals, to supersede, in part, AS/NZS 2312:2002, *Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings*.

- A1 | Amendment No. 1 to this Standard was prepared by the Australian members of the Joint Standards Australia/Standards New Zealand Committee MT-014, Corrosion of Metals. As a consequence of Amendment No. 1, which is published as an Australian-only amendment, the designation of this Standard has been changed from AS/NZS 2312.1:2014 to AS 2312.1:2014.

*This Standard incorporates Amendment No. 1 (October 2017). The changes required by the Amendment are indicated in the text by a marginal bar and amendment number against the clause, note, table, figure or part thereof affected.*

The objective of this Standard is to provide guidance for architects, engineers, builders, the surface coating industry and users of protective services in general, on paint coating systems for the protection of steel work against corrosion. The designer can choose from a selection of systems based on expected service life to first maintenance for various environments. The systems recommended herein are based on good industrial practice and usage; however, local knowledge of any corrosion problem should influence the decisions taken. In providing recommendations on up-to-date protection systems, the Committee is aware of the large number of systems used commercially, but, to avoid confusion, has included only a limited range of systems for each type of environment.

It is necessary to refer to each Section of this Standard when a specification for an appropriate system is being prepared.

- A1 | This Standard is part of a series for the protection of steel from corrosion as follows:
- AS 2312.1 *Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings*, Part 1: *Paint coatings* (this Standard)
  - AS/NZS 2312.2 *Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings*, Part 2: *Hot dip galvanizing*

The revision of AS/NZS 2312:2002 is in three Parts. This Standard is Part 1 and it covers paint coating systems only, that is, liquid-applied paints whose main purpose is corrosion mitigation. Section 5 in the 2002 edition, which covered metallic coatings, has been deleted, along with other specific references to metallic coatings. Section 7 in the 2002 Standard, which covered factors influencing coating selection, has been moved to Section 5. Section 8, which covered powder coatings and tapes, has been edited and moved to Appendix H. These coatings may be covered by an additional part to AS/NZS 2312 in the future. Section 13 in the 2002 edition, which covered health and safety, has been deleted, as the Committee felt this important topic is too complex to cover in this guide. This Standard has also updated recommended coating systems and deleted some rarely used systems.

In preparing this revision, cognizance was taken of the International Standards in the ISO 12944 series, *Paints and varnishes—Corrosion protection of steel structures by protective paint systems*. These Standards were not adopted as the Committee felt the present document is more appropriate to Australian and New Zealand industry conditions and is more user-friendly.

This Standard has been prepared as a guide only, to provide advice and recommendations for paint coating of steelwork. Clauses in this document are written using informative terminology and should not be interpreted otherwise. Coating requirements should be determined for the individual application. This Standard should be used in conjunction with the relevant surface preparation and inspection Standards.

The term 'informative' has been used in this Standard to define the application of the appendix to which it applies. An 'informative' appendix is only for information and guidance.

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## STANDARDS AUSTRALIA

**Australian Standard****Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings****Part 1: Paint coatings**

## SECTION 1 SCOPE AND GENERAL

**1.1 SCOPE**

This Standard provides guidelines for the selection and specification of paint coating systems for the protection of structural steel work against atmospheric corrosion. Part 2 and Part 3 of the AS/NZS 2312 series of Standards cover metallic coatings.

This Standard specifically covers the following subjects:

- (a) Guidance on the use of the Standard.
- (b) Classification of atmospheric and non-atmospheric environments.
- (c) Planning and design for corrosion protection.
- (d) Surface preparation treatments.
- (e) Factors influencing coating selection.
- (f) Paint coating systems and methods of paint application.
- (g) Maintenance of protective coating systems.
- (h) Inspection and testing.
- (i) Guidance on the preparation of coating specifications.

This Standard does not cover paint coating systems for light structural steel, such as purlins, roofing or similar sections. Recommendations for paint coating these sections are available from manufacturers. Recommendations for paint coating hot dip galvanized articles are available in AS/NZS 2312.2.

The coating systems described may also be specified for the protection of items of equipment manufactured from steel which are exposed to exterior atmospheric conditions.

This Standard provides advice on, to a limited extent, the protection of steel work which is completely immersed in water or buried in soil, or which is subject to atmospheres severely contaminated with acidic or other chemical vapours such as may be encountered in some chemical manufacturing plants, and also the protection of ships. The systems recommended in this Standard can also be used on internal structures where wet or damp areas exist.

This Standard does not cover in detail powder coatings and wrapping tapes that may be used on steel in internal or external environments. These are briefly described in Appendix H.

It is necessary to understand that the systems recommended have been selected for guidance only and that life expectancy to first major maintenance is an estimate only. In practice, some minor maintenance will be required.

Because particular coating formulations and microclimates vary, the user of this Standard is advised to confirm with the manufacturer or supplier, that the selected system is suitable for the task and can be reasonably expected to protect the steel for a specified time.

## 1.2 NEED FOR CORROSION PROTECTION

It is important at the design stage of structural steelwork to determine the prime reasons for the need for corrosion protection, as these can influence the type of protection system required. For instance, there are many situations where corrosion protection may be neither necessary nor economically feasible because the corrosion rate is too low to affect the integrity of the structure, or an appropriate section thickness has been designed to allow for corrosion.

Protection against structurally damaging corrosion may not be required for the following situations:

- (a) Temporary steelwork.
- (b) Interiors of most closed buildings.
- (c) Steel exposed for short periods in mild environments.
- (d) Steel fully surrounded by an adequate thickness of concrete.
- (e) Underground piling in undisturbed soil depending on the surface soil conditions (see AS 2159).
- (f) Hermetically sealed interiors of hollow steel members (see Clause 3.3.4.3).
- (g) Structures which are approaching the end of their economic lives.

The treatment of steel can be carried out for reasons other than the prevention of structural damage caused by corrosion, including the following:

- (i) Aesthetics. The decorative painting of the interiors of buildings where low corrosive conditions normally prevail is covered by AS/NZS 2311 whereas this Standard deals with more corrosive situations.
- (ii) Increasing the level of light in work areas.
- (iii) The protection of inaccessible points in marginally corrosive situations.
- (iv) A form of insurance in situations regarded basically as being of low corrosivity but where there is some doubt about this assessment.

## 1.3 USE OF THIS STANDARD

Guidance on the use of this Standard is given in Appendix A.

## 1.4 REFERENCED DOCUMENTS

The following documents are referred to in this Standard:

AS

- |            |                                                                                                                                                            |
|------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1318       | Use of colour for the marking of physical hazards and the identification of certain equipment in industry (known as the SAA Industrial Safety Colour Code) |
| 1319       | Safety signs for the occupational environment                                                                                                              |
| 1345       | Identification of the contents of pipes, conduits and ducts                                                                                                |
| 1580       | Paints and related materials—Methods of test                                                                                                               |
| 1580.102.1 | Method 102.1: Sampling procedure                                                                                                                           |
| 1580.481.3 | Method 481.3: Coatings—Exposed to weathering—Degree of corrosion of coated metal substrates                                                                |
| 1580.601.1 | Method 601.1: Colour—Visual comparison                                                                                                                     |

## AS

- 1627 Metal finishing—Preparation and pretreatment of surfaces
- 1627.0 Part 0: Method selection guide
- 1627.1 Part 1: Removal of oil, grease and related contamination
- 1627.2 Part 2: Power tool cleaning
- 1627.4 Part 4: Abrasive blast cleaning of steel
- 1627.5 Part 5: Pickling
- 1627.6 Part 6: Chemical conversion treatment of metals
- 1627.9 Part 9: Pictorial surface preparation standards for painting steel surfaces
- 2159 Piling—Design and installation
- 2700 Colour standards for general purposes
- 2832 Cathodic protection of metals (all parts)
- 2832.1 Part 1: Pipes and cables
- 3600 Concrete structures
- 3894 Site testing of protective coatings
- 3894.1 Part 1: Non-conductive coatings—Continuity testing—High voltage ('brush') method
- 3894.2 Part 2: Non-conductive coatings—Continuity testing—Wet sponge method
- 3894.3 Part 3: Determination of dry film thickness
- 3894.4 Part 4: Assessment of degree of cure
- 3894.5 Part 5: Determination of surface profile
- 3894.6 Part 6: Determination of residual contaminants
- 3894.7 Part 7: Determination of surface temperature
- 3894.9 Part 9: Determination of adhesion
- 3894.10 Part 10: Inspection report—Daily surface and ambient conditions
- 3894.11 Part 11: Equipment report
- 3894.12 Part 12: Inspection report—Coating
- 3894.13 Part 13: Inspection report—Daily blast and paint
- 3894.14 Part 14: Inspection report—Daily painting
- 3978 Non-destructive testing—Visual inspection of metal products and components
- 4036 Corrosion of metals—Dissimilar metals in contact in seawater
- 4100 Steel structures
- 4312 Atmospheric corrosivity zones in Australia
- 4361 Guide to lead paint management
- 4361.1 Part 1: Industrial applications
- 4361.2 Part 2: Residential and commercial buildings
- 4506 Metal finishing—Thermoset powder coatings
- 4848 Application specifications for coating systems
- 4848.1 Part 1: Single coat inorganic (ethyl) zinc silicate—Solvent-borne
- AS/NZS
- 1554 Structural steel welding (series)
- 1580.481 Paints and related materials—Methods of test
- 1580.481.1.9 Method 481.1.9: Coatings—Exposed to weathering—Degree of blistering
- 1594 Hot-rolled steel flat products

## AS/NZS

- 2041 Buried corrugated metal structures
- 2041.1 Part 1: Design methods
- 2310 Glossary of paint and painting terms
- 2311 Guide to the painting of buildings
- 2312 Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings
- 2312.2 Part 2: Hot dip galvanizing
- 2633 Guide to the specification of colours
- 3678 Structural steel—Hot-rolled plates, floorplates and slabs
- 3679 Structural steel
- 3679.1 Part 1: Hot-rolled bars and sections
- 3679.2 Part 2: Welded I sections
- 3750 Paints for steel structures
- 3750.1 Part 1: Epoxy mastic (two-pack)—For rusted steel
- 3750.2 Part 2: Ultra high build paint
- 3750.3 Part 3: Heat resisting—Exterior
- 3750.5 Part 5: Acrylic full gloss (two-pack)
- 3750.6 Part 6: Full gloss polyurethane (two-pack)
- 3750.9 Part 9: Organic zinc-rich primer
- 3750.10 Part 10: Full gloss epoxy (two-pack)
- 3750.12 Part 12: Alkyd/micaceous iron oxide
- 3750.13 Part 13: Epoxy primer (two-pack)
- 3750.14 Part 14: High-build epoxy (two-pack)
- 3750.15 Part 15: Inorganic zinc silicate paint
- 3750.16 Part 16: Waterborne primer and paint for galvanized, zinc/aluminium alloy-coated and zinc-primed steel
- 3750.18 Part 18: Moisture-cure urethane (single-pack) systems
- 3750.19 Part 19: Metal primer—General purpose
- A1 | 3750.22 Part 22: Full gloss enamel—Solvent-borne
- 4020 Testing of products for use in contact with drinking water
- 4536 Life cycle costing—An application guide

## NZS

- 3101 Concrete structures standard
- 3101.1 Part 1: Code of practice for the design of concrete structures
- 3101.2 Part 2: Commentary on the design of concrete structures
- 3404.1 Steel Structures Standard

## ISO

- 8501 Preparation of steel substrates before application of paints and related products—Visual assessment of surface cleanliness
- 8501-1 Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings
- 8501-3 Part 3: Preparation grades of welds, edges and other areas with surface imperfections
- 8501-4 Part 4: Initial surface conditions, preparation grades and flash rust grades in connection with high-pressure water jetting

## ISO

- 8502 Preparation of steel substrates before application of paints and related products—Tests for the assessment of surface cleanliness
- 8502-4 Part 4: Guidance on the estimation of the probability of condensation prior to paint application
- 8502-6 Part 6: Extraction of soluble contaminants for analysis—The Bresle method
- 8502-9 Part 9: Field method for the conductometric determination of water-soluble salts
- 9223 Corrosion of metals and alloys—Corrosivity of atmospheres—Classification, determination and estimation
- 11127 Preparation of steel substrates before application of paints and related products—Test methods for non-metallic blast-cleaning abrasives
- 11127-6 Part 6: Determination of water-soluble contaminants by conductivity measurement
- 12944 Paints and varnishes—Corrosion protection of steel structures by protective paint systems
- 12944-1 Part 1: General introduction
- 12944-3 Part 3: Design considerations
- 12944-5 Part 5: Protective paint systems
- 12944-8 Part 8: Development of specifications for new work and maintenance

## A1

## APAS

- 0015 Alkyd enamel (Buildings)
- 0024 Full gloss oil and petrol resistant enamel
- 0032 Metal primer
- 0043/2 Heat resistant paint for equipment to 200°C full gloss finish
- 0156 Epoxy mastic high build 2-pack coating for rusted steel (series)
- 0280 Exterior waterbased paint for buildings (series)
- 2908 Inorganic zinc coating for the long term protection of steel
- 2910 MIO or aluminium pigmented coating for the protection of steel
- 2911 Polyurethane coatings for the protection of steel
- 2911/2 Polyurethane coatings for the protection of steel, high durability
- 2916 Organic zinc-rich coating for the long term protection of steel
- 2917 Catalysed polyester coating for protection of steel (series)
- 2919 Catalysed acrylic coating for protection of steel
- 2920 Siloxane and polysiloxane coatings for the long term protection of steel and masonry (series)
- 2921 Durable air drying alkyd or oleoresinous primer for the protection of steel
- 2930 Single pack moisture cure urethane coating for the long term protection of steel
- 2971 Durable two-pack epoxy primer for the long term protection of steel
- 2972 Epoxy low build 2-pack coating for the long term protection of steel
- 2973 Medium build 2-pack epoxy coating for the long term protection of steel
- 2975 Epoxy ultra high build two-pack coating for the long term protection of steel

SSPC

SSPC VIS3 Guide and Reference Photographs for Steel Surfaces Prepared by Hand and Power Tool Cleaning

## 1.5 DEFINITIONS

For the purpose of this Standard, the definitions below and those given in AS/NZS 2310 apply.

### 1.5.1 Actual dry film thickness

The measured dry film thickness as applied.

### 1.5.2 Corrosivity

A measure of the ability of the environment to cause corrosion.

### 1.5.3 Durability

The time elapsed before the first major maintenance (recoating or patch repairs, see Section 8) of a coating system becomes necessary, to arrest corrosion.

### 1.5.4 Environment

Surrounding region which contains one or more corrosive agents.

### 1.5.5 Inspector

The person responsible for ensuring conformity with the specification.

### 1.5.6 Intermediate coat

Any coat between the primer and finish/top coat.

### 1.5.7 Nominal dry film thickness (NDFT)

The dry film thickness specified for each coat or for the whole paint system to achieve the required durability.

## 1.6 DURABILITY CONSIDERATIONS

As the protection provided by the coating systems covered by this Standard is usually shorter than the expected service life of the structure, due consideration should be given to maintenance or renewal requirements at the planning and design stage.

Any components of the structure which are not accessible after assembly should be provided with a corrosion protection system that will remain effective for the service life of the structure. If this cannot be achieved by means of a protective coating system, other measures, such as manufacturing from a corrosion-resistant material, designing for replacement or specification of a corrosion allowance, should be taken.

This Standard expresses durability in terms of the following five ranges, which are an expansion of the three ranges given in ISO 12944-1:

|                  |                |
|------------------|----------------|
| Short term:      | 2 to 5 years   |
| Medium term:     | 5 to 10 years  |
| Long term:       | 10 to 15 years |
| Very long term:  | 15 to 25 years |
| Extra long term: | 25+ years      |

NOTE: Because the durability of many coatings may be considerably longer than 25 years, the advice of the coating supplier should be sought.

Durability is expressed in terms of coating life to first major maintenance, assuming that the coating has been applied according to the requirements of this and other appropriate Standards, and to the recommendations of the coating manufacturer. A range is given, not only for the uncertainty in obtaining such lifetimes, but also because there is a range of corrosivities within a corrosivity category (see Section 2). A properly applied coating should achieve the lower figure of the durability range at all sites within a given corrosivity category and the upper figure of the range under the most favourable conditions in the less aggressive regions of the corrosivity category.

Note that coating type is only one factor in determining the durability of a protective coating system. Surface preparation, application procedures, design, local variations in environment and other factors will also influence the durability of coatings.

### 1.7 WARRANTY CONSIDERATIONS

The durability range is not a 'warranty time'. Durability is a technical consideration that can help the owner set up a maintenance programme. A warranty time is a consideration that is the subject of clauses in the contract. Although there are no definite rules that link the two periods of time, a warranty of about one-quarter to one-third of the estimated durability should be the maximum expected.

A warranty may be provided to protect against a fault in the coating product, or the workmanship of the application, rather than the durability of the coating system. Some issues with long warranties are:

- (a) They are often too simple or conversely too complex, and there may be difficulties in enforcing them.
- (b) They may be used as a commercial tool so written to prevent any liability.
- (c) After a longer time period, it will be difficult to determine who is at fault.
- (d) It may require a lengthy and costly court case to recover costs.
- (e) Long warranties are likely to attract a price premium.
- (f) Warranties are usually provided on a diminishing scale with only small percentage of the value at the end of the warranty term.
- (g) The coating manufacturer typically warrants its product only and the applicator separately warrants they have correctly applied the coating manufacturer's product.

When preparing warranties, the specifier should take note of the following:

- (i) There should be a clause regarding ordinary wear and tear. This needs to be clarified as the definition of wear and tear can depend on the party.
- (ii) It needs to be clear what will be supplied in the event of a failure. A warranty may simply cover the cost of paint, but the cost of re-application may be many times this figure.
- (iii) Reference area or areas (see Clause 9.5) will assist in determining whether the failure was caused by inappropriate specification, defective workmanship or coating material. For warranty claims, such areas should be mandatory and coordinated by the owner/owner's representative.
- (iv) To overcome possible disagreements regarding coating failures, allow for the appointment of an independent referee.
- (v) A warranty is intended to protect against a fault in coating product or its application, which would be expected to manifest itself early in the life of the coating system. It is therefore not realistic to expect a commercial warranty to cover the entire durability expectations noted in this Standard.

An owner concerned about long-term durability of a coating system should consider taking out a maintenance contract.

## 1.8 DESIGNATION OF PROTECTION SYSTEMS

A1 | A protection system is designated by the number of this Australian/New Zealand Standard, i.e. AS 2312.1, followed by a slash consisting of a series of three letters to describe the top coat, followed by a one-digit number to indicate the paint system based on the top coat.

As an exception, the letters HR followed by a one-digit number designates systems for high temperature applications.

*Examples of designation:*

A1 | AS 2312.1/ACL2, AS 2312.1/IZS3, AS 2312.1/HR6.

## 1.9 HEALTH, SAFETY AND ENVIRONMENTAL PROTECTION

It is the duty of clients, specifiers, contractors, paint manufacturers, inspectors and all other personnel involved in a project to carry out the work for which they are responsible in such a manner that they do not endanger the health and safety of themselves or others.

They should comply with all the statutory requirements of the country, state and region in which their work, or any part of their work, is to be carried out.

## SECTION 2 CLASSIFICATION OF ENVIRONMENTS

### 2.1 GENERAL

This Section classifies atmospheric environments in Australia and New Zealand which affect the corrosion of steel and the life of a coating system. When selecting an appropriate protective coating system, the overall environment in the location of the intended structure requires consideration. A structure situated in an aggressive environment will require a much higher standard of corrosion protection than one in a benign environment. The environment can affect both the steel and the coating system. Of prime importance is the effect the environment has on the corrosion of steel.

Corrosion of steel in pH neutral environments generally requires the presence of moisture and oxygen. As long as a layer of moisture is present, corrosion rates are often controlled by the rate at which oxygen can get to the surface although soluble contaminants such as salts also have a major influence on corrosion rates. Steel corrosion rates are therefore very low in dry environments, higher in damp environments and very high in the presence of moisture and salt or other contaminants. In acidic environments, the corrosion rate of steel increases as the pH decreases. Alkaline environments generally give low corrosion rates for steel, except at very high pHs.

The effect of the environment on protective coatings can be different to its effect on steel. Some organic coatings are damaged by extremes of pH, while others can resist such environments. High ultraviolet (UV) radiation, high humidity, intense rainfall and damp conditions can affect certain organic coatings. Tropical environments, for example, with high UV and humidity which influences mould and fungal growth, are far more aggressive to organic coatings than the corrosion rate of steel would suggest. The colour of a paint may influence its performance in some environments.

NOTE: The major factors which affect atmospheric corrosion, and hence atmospheric corrosivity categories based on ISO 9223, are given in AS 4312. For Australia, AS 4312 also provides maps and other information indicating geographic distribution of corrosion environments. For New Zealand, refer to NZS 3404.1.

### 2.2 MICRO-ENVIRONMENTS

In addition to climatic effects, the local environmental effects (micro-environment or microclimate) produced by the erection of a structure or installation of equipment need to be taken into account. Such on-site factors require additional consideration because a mildly corrosive atmosphere can be converted into an aggressive environment by microclimatic effects. For example, a significant acceleration of corrosion rate can occur in the following circumstances:

- (a) At locations where the metal surface remains damp for an extended period, such as where surfaces are not freely drained or are shaded from sunlight.
- (b) On unwashed surfaces, i.e. surfaces exposed to atmospheric contaminants, notably coastal salts, but protected from cleansing rain.

Other microclimatic effects which may accelerate the corrosion of the substrate or the deterioration of its protective coating include acidic or alkaline fallout, cooling tower mist, industrial chemicals and solvents, airborne fertilizers and chemicals, prevailing winds which transport contamination, hot or cold surfaces and surfaces exposed to abrasion and impact. These effects can often outweigh those of the macroclimatic categories described in Clause 2.3, especially in the low corrosivity categories.

As a result of microclimatic effects it is very difficult, if not impossible, to predict accurately the aggressiveness of a given environment and a certain amount of educated judgement is required to assess its influence on coating life. However, if such microclimatic factors are significant, assessing the service as a more severe corrosivity category is recommended. The presence of bad design features in a structure, such as those outlined in Clause 3.3.1, would also generally mean assessing the environmental as a more severe category.

Interior environments are included in the categories but are very difficult to classify. Few surveys have been carried out; however, it is known that microclimatic effects can be significant. Many indoor environments such as office buildings will have very low corrosivity, but some manufacturing premises are frequently very corrosive, depending on the process involved, and will require specialist assessment to determine applicable coating systems. The examples for indoor environments given in the categories listed in Clause 2.3 should be assessed allowing for the local micro-environment.

### 2.3 ATMOSPHERIC CORROSIVITY CATEGORIES

Atmospheric environments are classified into the following six atmospheric corrosivity categories based on the corrosion rates of mild steel given in ISO 9223, plus one tropical category which is not determined by corrosion rate. The ISO 9223 and AS 4312 designations C1 to C5 have been adopted by this version of the standard, replacing the A to E categories used in previous version. Also, following AS 4312, the inland tropical category is now referred to as T. Table 2.1 gives details of the corrosivity categories, along with the first year corrosion rates for steel and zinc as defined in ISO 9223.

*Category C1: Very low.* Environments in this category are most commonly found inside heated or air conditioned buildings with clean atmospheres, such as most commercial buildings. They may also be found in semi-sheltered locations remote from marine or industrial influence and in unheated or non-air conditioned buildings. The only external environments in Australia or New Zealand are some alpine regions although generally these environments will extend into Category C2.

*Category C2: Low.* Environments in this category include dry, rural areas as well as other regions remote from the coast or sources of pollution. Most areas of Australia and New Zealand beyond at least 50 km from the sea are in this category, which can however extend as close as one kilometre from seas that are relatively sheltered and quiet. Typical areas occur in arid and rural inland regions, most inland cities and towns such as Canberra, Ballarat, Toowoomba, Alice Springs and Hamilton (NZ), and suburbs of cities on sheltered bays, such as Melbourne and Hobart. Unheated or non-air conditioned buildings, where some condensation may occur, such as warehouses and sports halls, can be in this category. Proximity to the coast is an important factor.

*Category C3: Medium.* This category mainly covers coastal areas with low salinity. The extent of the affected area varies significantly with factors such as winds, topography and vegetation. Around sheltered seas, such as Port Philip Bay, Category C3 extends beyond about 50 m from the shoreline to a distance of about one kilometre inland. For a less sheltered bay or gulf, such as near Adelaide, this category extends from 100 metres from the shoreline to about 3 to 6 km inland. Along ocean front areas with breaking surf and significant salt spray, it extends from about 1 kilometre inland to between 10 to 50 km inland, depending on the strength of prevailing winds and topography. Much of the metropolitan areas of Wollongong, Sydney, Newcastle, the Gold Coast, Auckland and Wellington are in this category. In South Australia, the whole of the Yorke Peninsula falls within this or a more severe category, and in the south-east of the state, from Victor Harbour to the Victorian border, this category extends between 30 and 70 km inland. Such regions are also found in urban and industrial areas with low pollution levels exist for several kilometres around major industries, such as smelters and steelworks, and in the geothermal areas of New Zealand. Micro-environmental effects, such as result from proximity to airports and sewage treatment works, may also place a site into this category. Interior environments with Category C3 corrosivity can occur in humid production rooms, such as food-processing plants, laundries, breweries, printing works and dairies.

*Category C4: High.* This category occurs mainly on the coast. Around sheltered bays, Category C4 extends up to 50 m inland from the shoreline. In areas with rough seas and surf, it extends from about several hundred metres inland to about one kilometre inland. As with Categories C2 and C3, the extent depends on winds, wave action and topography. Industrial regions may also be in this category, but in Australia and New Zealand these are only likely to be found within 1.5 km of the plant. This category extends inside the plant where it is best considered as a micro-environment. Damp, contaminated interior environments such as occur with swimming pools, dye works, paper manufacturers, foundries, smelters and chemical processing plants may also extend into this category.

*Category C5: Very High. (C5-I: Industrial C5-M: Marine)* This category is common offshore and on the beachfront in regions of rough seas and surf beaches. The region can extend inland for several hundred metres. (In some areas of Newcastle, for example, it extends more than half a kilometre from the coast.) This category may also be found in aggressive industrial areas, where the environment may be acidic with a pH of less than 5. For this reason, Category C5 is divided into marine and industrial for purposes of coating selection. Some of the damp and/or contaminated interior environments in Category C4 may occasionally extend into this category.

*Category Cx: Extreme:* This new category (not covered in the 2008 edition of AS 4312) was introduced to ISO 9223 in 2012 to account for some regions with corrosion rates greater than those in C5. These regions are found at some surf beach shoreline regions with very high salt deposition. Such corrosion rates would also be found in severe acidic industrial environments. Because of limited experience with this category as well as its severity, durability of coating systems exposed to this environment is not listed in this Standard. If a site has been identified as being in this extreme corrosivity zone, durability of the selected coating system will be less than that given for C5M or C5I, and users of this Standard should seek professional advice.

*Category T: Inland Tropical.* A tropical environment is found in coastal areas of north Queensland, Northern Territory, north-west Western Australia, Papua New Guinea and the Pacific Islands, except where affected by salinity. Corrosivity in inland regions is generally low (similar to that of Category C2), but the aggressiveness of the environment to organic coatings means durability is lower than for the C2 category.

If a site is considered to be in more than one category, for example, an industry on the coast in a tropical region, then a selected coating should be capable of resisting the most severe of the environments involved.

## 2.4 OTHER ENVIRONMENTS

Steelwork may be immersed in water, buried in soil, or exposed to other environments not specifically defined in any of the categories listed in Clause 2.3. Structures in such environments are subject to corrosion problems often of a completely different nature to atmospheric corrosion. Not only are different coating systems sometimes used, but a number of other corrosion prevention options, such as cathodic protection or selection of different materials should be considered. The selection of such prevention methods requires specialist advice and is outside the scope of this Standard.

NOTE: Appendix B discusses factors that influence corrosion in these environments and Appendix C provides some examples of coating systems which may be considered.

**TABLE 2.1**  
**ATMOSPHERIC CORROSIVITY CATEGORIES**

| Corrosivity categories       | Former AS/NZS 2312 Category | Corrosion rate for steel $\mu\text{m}/\text{year}$ | Corrosion rate for zinc $\mu\text{m}/\text{year}$ | Typical exterior environment | Examples of interior environments          |
|------------------------------|-----------------------------|----------------------------------------------------|---------------------------------------------------|------------------------------|--------------------------------------------|
| C1: Very low                 | A                           | <1.3                                               | <0.1                                              | Few alpine areas             | Offices, shops                             |
| C2: Low                      | B                           | 1.3 to 25                                          | 0.1 to 0.7                                        | Arid/rural/urban             | Warehouses, sports halls                   |
| C3: Medium                   | C                           | 25 to 50                                           | 0.7 to 2.1                                        | Coastal                      | Food processing plants, breweries, dairies |
| C4: High                     | D                           | 50 to 80                                           | 2.1 to 4.2                                        | Sea-shore (calm)             | Swimming pools, livestock, buildings       |
| C5-I: Very high (Industrial) | E-I                         | 80 to 200                                          | 4.2 to 8.4                                        | Within chemical plants       | Plating shops, chemical sites              |
| C5-M: very high (Marine)     | E-M                         | 80 to 200                                          | 4.2 to 8.4                                        | Sea-shore (surf)/offshore    | —                                          |
| CX                           | —                           | 200 to 700                                         | 8.4 to 25                                         | Shoreline (severe surf)      | Adjacent to acidic processes               |
| T: Inland Tropical           | F                           | —                                                  | —                                                 | Non-coastal tropics          | —                                          |

## SECTION 3 PLANNING, DESIGN AND FABRICATION FOR CORROSION PROTECTION

### 3.1 SCOPE AND GENERAL

This Section provides guidance for the design and fabrication of steelwork for protection against atmospheric corrosion. The objective of designing a structure is to ensure that the structure is suitable for its function, has adequate stability, strength and durability, is constructed at an acceptable cost and is aesthetically pleasing. Corrosion can be reduced and the effectiveness of the protection system greatly increased by paying attention to detail and correct planning at the design stage.

It is important for the designer to develop awareness for potential corrosion hazards. Design features which promote corrosion should be recognized and, where possible, eliminated.

In terms of corrosion protection, the overall design should be planned to facilitate surface preparation, coating, inspection and maintenance.

Modern coatings can provide protection in heavy industrial and marine environments for up to 25 years with a minimum of maintenance, provided that the structure is soundly engineered with respect to corrosion protection, and that the coating system chosen is appropriate for the environmental conditions and has been correctly applied.

Because the design and application of the initial protective system and its subsequent maintenance may be costly in terms of manpower, money and materials, cost factors need to be weighed against the cost of the total structure. A high cost treatment may be unwarranted for a structure required to have a short-term working life. Bearing in mind its function and service life, the importance of properly designed steelwork and the selection of the optimum protective system for the particular structure cannot be overstressed. It is also important to avoid the possibility of over-designing a structure, e.g. where it is known that corrosion rates are minimal, as the cost of an extensive coating system may be totally unwarranted. The possibility of over-designing should also be kept in mind where the service life of the structure is limited by factors other than corrosion, e.g. abrasion, high temperatures and short-term occupancy.

Consideration should be given at the design stage to optimize efficiency and minimize the overall cost of steel and painting, both initially and for maintenance. In certain cases it may be more economical to pay more for the steel and less for the painting. A choice can often be made between a thin section with large dimensions or a thicker section with smaller dimensions for compression members, where a minimum cross-sectional area of steel is sought for a given load-carrying capacity or radius of gyration. This principle could also be considered for different sections of beams and the design of base plates.

Fabrication activities such as cutting, welding and fastening can also have a significant effect on painted steelwork durability.

### 3.2 PLANNING

While this Standard includes guidance on good practices as well as practices that are not recommended, there are other factors, not within its scope, which require consideration and planning in the design of steelwork. These factors include the following:

- (a) Site limitations, e.g. interior surfaces of steel structures may be exposed to the environment during construction and may require suitable protection.
- (b) Availability of equipment, painting materials and experienced labour for the initial application of a protective system, its inspection and its subsequent maintenance.

- (c) Availability of adequate finance to apply the system.
- (d) Time factors involved in the initial construction and the subsequent protection of the construction.

The time allotted should allow for the correct application of the specified coating system, e.g. from the surface preparation stage through to the application of various coats of paint. It should also allow for adequate drying time between coats of paint.

Time losses due to touch up and repair requirements should also be considered.

- (e) Function and type of structure required.
- (f) Method and sequence of construction.
- (g) Steel stored in coastal locations or transported by sea as deck cargo may become contaminated with salts and require special surface preparation methods.
- (h) Life of the structure.

NOTE: Often structures initially designated to be temporary, later become permanent.

Adequate planning and attention to details recommended in this Standard are important to enable the structure to realize its full potential working life.

Corrosion failures may be very costly in plants where continuous operation is essential, and can be minimized by ensuring that adequate protection has been planned at the design stage.

### 3.3 DESIGN

#### 3.3.1 General

The corrosion protection of structural steelwork should be planned in the early stages of design to ensure that the best performance is achieved from the system chosen. Designs should be simple and excessive complexity should be avoided.

The shape of a structure can influence its susceptibility to corrosion. A good design will exclude pockets in which water and foreign matter may lodge, because pockets can retain moisture for long periods of time and thus accelerate the failure of coatings.

Other details to be avoided in a design include the following:

- (a) Narrow crevices.
- (b) Depressions.
- (c) Ledges.
- (d) Undrained flat surfaces.
- (e) Flat surfaces in loose contact where moisture can be drawn in between them by capillary action.
- (f) Poor air circulation.
- (g) Sharp edges and corners.
- (h) Intermittent welding.

Where necessary, drainage holes should be provided for water removal. Joints, connections and other details should be kept as simple as possible with a minimum number of component parts.

NOTE: Sound economic structural detailing will be found to be synonymous with good corrosion protection.

The main features influencing coating selection, which should be considered in the early stages of design, are as follows:

- (i) The exposure environment.
- (ii) Materials of construction.
- (iii) Shape and details of the structure.
- (iv) Required service life.

### **3.3.2 Exposure environment**

The design should take into account the exposure environment. Atmospheric environments are classified, discussed, and listed in order of increasing severity in Clause 2.3. The design should also take into account microclimatic effects. The contours of exposed surfaces should be as smooth as possible and be free from unnecessary cavities, recesses and protuberances to avoid the entrapment of contaminants.

With regard to the environment, it is important to consider not only the environmental conditions that the structure will be subjected to during its normal life, but also the conditions which may be introduced during commissioning, cleaning and non-operation. Care is required to ensure that the corrosion behaviour of the selected materials under all exposure conditions is fully understood.

### **3.3.3 Materials of construction**

#### **3.3.3.1 General**

The choice of materials for a particular environment should be made at the design stage. The selection process requires a thorough knowledge of the environment and the expected life and cost of the structure. Generally, the most cost-effective material should be selected taking corrosion resistance, mechanical, aesthetic, manufacturing and other considerations into account. Metallic coated steels (e.g. AS/NZS 2312.2), alloy and stainless steels, non-ferrous metals, plastics, ceramics, wood and concrete can all be used with advantage in many situations.

This Standard applies to structures made from ferrous materials, although it is recognized that other materials will often be incorporated and can have a significant effect on the corrosion of the steel. Some problems with steel in contact with soil and porous materials are dealt with in Clauses 3.3.4.14 and 3.3.4.15.

#### **3.3.3.2 Galvanic corrosion**

A serious potential problem with different materials in contact with steel is galvanic corrosion arising from dissimilar metals in electrical contact and bridged by an electrolyte. Galvanic corrosion occurs because a potential difference between metals causes a current to flow. One metal becomes an anode and its corrosion rate will increase, while the other becomes the cathode and its corrosion rate will decrease. A list of metals, known as the galvanic series, can indicate the anode and cathode in any metallic couple. Table 3.1 lists a number of metals which are cathodic to mild steel and cast iron and three which are anodic. The cathodic metals in ascending order have an increasing potential difference to steel and will cause an increasing galvanic corrosion tendency if in contact with steel. Further information on the corrosion tendencies of dissimilar metals in contact is given in AS 4036 and in AS/NZS 2312.2.

Other factors which contribute to the extent of galvanic corrosion are area ratio (cathode to anode), environment and distance effects, as follows:

- (a) The ratio of the area of the cathodic metal to the anodic metal, when wet, can influence corrosion. If the anode is small in proportion to the cathode, corrosion will be accelerated at the anode. One example is the rapid corrosion of attached fasteners which will occur if they are anodic to the structural metal. Fasteners should always be of the same metal as the structure or be cathodic to the structure. Another example occurs when painted steel is joined to a noble metal such as copper or stainless steel; in this case, corrosion will be concentrated at coating flaws, causing pitting.
- (b) The environment also influences galvanic effects. In a dry environment (such as inside buildings) the effects are minimal; however, they become increasingly serious as the environment becomes more aggressive (see Section 2).
- (c) Galvanic attack decreases with increasing distance from a dissimilar metal junction.

If the design requires the use of dissimilar metals, the contacting surfaces should be electrically isolated, for example, by coating the surface of both metals. If it is only possible to coat one of the metals adjacent to the junction, it is best to coat the cathode.

**TABLE 3.1**  
**PARTIAL GALVANIC SERIES**

| Relationship to mild steel and cast iron | Metals and alloys in galvanic series |
|------------------------------------------|--------------------------------------|
| Increasingly cathodic                    | Austenitic stainless steel           |
|                                          | Nickel-chromium-iron alloys          |
|                                          | Nickel                               |
|                                          | Gunmetal                             |
|                                          | Monel                                |
|                                          | Copper                               |
|                                          | Phosphor bronze                      |
|                                          | Ferritic stainless steel             |
|                                          | Brass 60/40                          |
|                                          | Aluminium bronze                     |
|                                          | Lead                                 |
|                                          | Chromium                             |
|                                          | Tin                                  |
|                                          | <i>Mild steel, cast iron</i>         |
| Increasingly anodic                      | Aluminium alloys                     |
|                                          | Zinc                                 |
|                                          | Magnesium                            |

### 3.3.3.3 Structural and pressure vessel steels

Ordinary weldable grades of structural steel, carbon-manganese steels for boilers and pressure vessels, and cold-rolled unalloyed low carbon steel will have a similar propensity to corrode under the same conditions; the rate being dependent on the conditions of exposure (see Section 2).

Some alloy steels that contain chromium, molybdenum and nickel may have better corrosion resistance than plain carbon steels.

#### 3.3.3.4 *Weather-resistant (weathering) steels*

Compared to plain carbon steels, weather-resistant steels have superior resistance to atmospheric corrosion. These characteristics are due to the addition of appropriate amounts of alloying elements such as phosphorus, chromium, nickel and copper. Their superior corrosion resistance is the result of the formation, under favourable conditions, of a dense, tough, uniform and tightly adherent protective layer of oxide which seals the surface and prevents further significant corrosion. In the absence of wetting and drying, this protective layer does not form.

The rate at which the protective layer is formed depends chiefly on the frequency of alternate wetting and drying, the nature of the environment and the geographic orientation. Weathering steels in the early stages of exposure corrode as rapidly as plain carbon steels, but the rate of oxidation can steadily decrease to a slow, constant rate.

Contamination of such steels by oil, grease, concrete and paint should be avoided to ensure an acceptable visual appearance after weathering.

Weathering steels offer no advantage over plain carbon steels in aggressive industrial or marine environments, as an effective protective layer will not form in the presence of surface contaminants. Cavities and crevices which allow build-up of dirt and moisture, and sheltered surfaces subject to contamination with salts and chemicals and which are not exposed to rinsing by rainwater, should be avoided.

Specifications for weathering grade steels are contained in AS/NZS 1594 and AS/NZS 3678.

NOTE: Water running from the surfaces of weathering steels may cause staining of adjacent surfaces.

#### 3.3.3.5 *Stainless steels*

Stainless steels as a class offer great resistance to atmospheric corrosion. They owe this ability to the presence of stable chromium oxides which form on the surface and render the steel passive. Any treatment or condition which causes stainless steel to lose its passivity, e.g. crevices in which the supply of surface oxygen is restricted, or the presence of chlorides, will cause premature failure of these steels.

There is a wide range of stainless steels available with varying mechanical properties and corrosion resistance. In general, the more highly alloyed the steels are, the greater is their corrosion resistance. In marine environments, special grades containing molybdenum are used.

Because of their corrosion resistance, stainless steels normally do not require surface coatings, and such coatings would generally not be recommended. However, in certain instances, such as for aesthetic purposes, when joined to a more active metal in the galvanic series or to provide greater corrosion resistance, a coating may be required.

Austenitic stainless steels that are covered by insulation can be subject to chloride stress corrosion cracking and may require a suitable paint coating applied to the stainless steel.

Coating of stainless steels can inadvertently reduce their durability. Where the painting of stainless steel is necessary, the surface should be abraded with non-metallic abrasives. It is often necessary to apply a non-inhibitive epoxy paint coat prior to the application of the desired topcoat.

#### 3.3.3.6 *Cast iron*

Cast irons generally contain more than 2% carbon. The corrosion resistance of ordinary grades of cast iron is similar to that of mild steel in the same environment. The same protective coatings recommended for steel can be used for cast iron, with the exception of inorganic zinc silicates. Various cleaning techniques may be employed before coating;

however, dry abrasive blast cleaning followed by the use of an appropriate primer is recommended before applying a finishing coat. Care is required to ensure that the item is completely dry prior to applying a coating.

#### **3.3.3.7 Concrete**

Steel that is partially embedded in concrete may be susceptible to corrosion within the concrete near the entry point and should be protected. The coating on the steel should be non-conductive and extend a minimum of 50 mm into the concrete and 100 mm above. Uncoated surfaces should be cleaned to remove loose rust, loose mill scale, dirt, oil and grease immediately before concreting.

Where reinforcement is to be used in concrete, reference should be made in Australia to AS 3600 and in New Zealand to NZS 3101.1 and NZS 3101.2.

### **3.3.4 Major design considerations**

#### **3.3.4.1 General**

Careful consideration should be given at the early stages of design to prevent corrosion problems occurring. Examples of undesirable design features and suggested solutions are illustrated in Figure 3.1.

#### **3.3.4.2 Cavities and crevices**

Natural cavities such as upturned channels and angles, and crevices formed by various methods of joining, should be avoided because corrosion is accentuated at these areas due to the retention of moisture and dirt.

Joints and fasteners should be arranged to give clear, uninterrupted lines to prevent the collection of dirt and moisture, to assist with the ease of maintenance, and to facilitate painting.

In critical design, areas which are not accessible for inspection and maintenance, crevices formed by situations such as back-to-back structural steel sections, and welded, bolted or riveted lap joints should be protected by the application of a suitable coating or sealing system. The use of sealing compounds or continuous welds (see Figure 3.1) may be required depending on the joint design and method of fabrication.

#### **3.3.4.3 Hollow sections**

Moisture condenses and collects on the surface of steel as a result of surface temperatures dropping below the dew point, typically caused by daily fluctuations in air and steel temperature. The quantity of water which actually condenses is dependent on the relative humidity at the time the structure is cooling as well as factors such as orientation and section thickness.

Box, hollow and tubular sections should be either permanently sealed hermetically to prevent the entrapment of moisture or be protected internally with a corrosion protection coating. Where it is not possible to adequately seal or protect internal surfaces of hollow sections, it is recommended that drainage holes be provided to allow condensed moisture to drain away.

In marine or industrial environments, where the design or local conditions allow salt or other chemicals to deposit on interior surfaces, a protective coating of equal durability to the external coating will be necessary. In such situations, it is far better to redesign to prevent chemical deposition, or to ensure that regular rain-washing of affected surfaces can take place.

If hollow members with closed ends have bolt holes and/or inspection or access ports, these may allow scale, abrasive or metal particles to contaminate the painted surface. If metallic abrasive is then released from the voids during transport, erection or service it may lead to

significant rust staining on painted surfaces. To avoid this, all openings into hollow members should be temporarily closed off during surface preparation activities.

Any such openings should only be temporary and then fully sealed off for long-term performance.

#### **3.3.4.4** *Drainage*

Poorly drained areas, which result in entrapment of water and contaminants, provide ideal conditions for attack on the existing coating and on bare metal; consequently, good drainage is important. Structural members such as angles, channels and universal sections should be arranged to avoid the entrapment of liquids. Where this is not possible, suitably sited drainage holes and drip points should be provided, and care taken to ensure that these features do not become blocked or do not continually run drainage water onto lower members.

#### **3.3.4.5** *Ventilation*

Adequate ventilation to allow air circulation for the drying and curing of coatings and to provide safe working conditions is essential. Solvents or other volatile organic compounds (VOC) evolved during the curing or drying of coatings can form explosive mixtures in a confined air space if the ventilation is inadequate. In addition, the air change should be sufficient to remove toxic gases, stale air and bacterial build-up which may scavenge oxygen from the atmosphere.

NOTE: For guidance on volatile organic compounds, see Appendix F.

Good ventilation is needed in open areas as well as in confined spaces to prevent the formation of condensation. For this reason, tanks, cool rooms and storage containers should be designed to allow free circulation of air.

#### **3.3.4.6** *Accessibility for coating and maintenance*

The design should permit easy access to all parts of the structure and thereby make it possible to apply, inspect and maintain the protective system without difficulty. Thus any falsework, screens or hoardings that would impair access should be made readily removable.

It is necessary to ensure that areas painted in the shop do not become inaccessible when installed. Providing access for maintenance at a later date is important and the designer should indicate clearly how it is to be provided. Surfaces which will be in contact or near contact after fabrication or erection should receive their specified surface preparation and coating system prior to assembly. Such coatings should be thoroughly cured before assembly.

Where necessary, the design should provide for the inclusion of special fittings such as lugs, hooks, anchorages and guide rails, for the attachment of scaffolding, painting gantries, powered platforms and, if applicable, awnings to shield maintenance work from bad weather. Such fittings should be robust, placed where they can be maintained without risk of accident and, if damaged during use, will not affect the performance of the applied coating system.

Special attention should be paid to ensure access to openings in box members and tanks. The openings should be of sufficient size to allow safe access for operators and their equipment, including safety equipment (see Figure 3.3).

General information on typical distances required for tools used for corrosion protection and minimum dimensions for narrow spaces between surfaces is contained in ISO 12944-3.

Areas that become inaccessible after installation should be treated before assembly. If this is not possible, consideration should be given to the use of a corrosion resistant material.

#### 3.3.4.7 *Geometrical considerations*

A cross-section with circular characteristics can be cleaned more easily, gives better continuity of surface, will hold and maintain an even coating thickness, and has more resistance to corrosive influences. It is easier to protect large flat areas than it is to protect complicated shapes because large flat areas offer fewer problems in initial protection and in maintenance servicing.

#### 3.3.4.8 *Load-bearing members*

If the design permits, load-bearing members should be located where corrosive conditions are the least severe.

#### 3.3.4.9 *Services*

The locations of service pipes, cables and ducts attached to the structure, or passing through girders, should be agreed to by all interested parties before detail drawings are prepared.

Failure to consider such matters may lead to the creation of corrosion points which may arise, for example, where pockets are formed by not keeping conduits clear of steelwork, or where steam and other exhausts from pipes are allowed to impinge on the steelwork.

The time needed to carry out a successful painting operation, or the maintenance of an initial coat, may be prolonged if service equipment has to be moved before work can begin.

#### 3.3.4.10 *Bolts, nuts and washers*

Unless able to be replaced as part of a maintenance program, bolts, nuts and washers ideally need to be protected against corrosion to the same level of durability as required by the structure as a whole. However in practice this may not be achievable.

Pre-painting bolts, nuts and washers will result in the coating being damaged during installation, from tightening.

Bolts on sub-assemblies that are in place before overall surface preparation is carried out may be treated in the same way as the work piece, but this will leave the hidden shank and threads untreated. If oversize or slotted holes are present, these will be difficult to treat properly and may also capture abrasive or other debris during painting.

On-site painting of bolts after erection and assembly will usually be limited to power tools cleaning, and may not reach the same standard of quality and durability as the shop-painted surfaces. After tensioning of the fastener, suitable surface preparation, such as solvent degreasing and hand or power tool cleaning is required prior to site touch-up and completion of the specified coating system.

The coating should be specified and applied in a manner that minimizes damage during assembly of the articles, and to provide surfaces which are easily prepared for site touch-up. See Clause 3.4.2 for advice on repair of coating damage.

Use of hot dip galvanized (HDG) bolts, nuts and washers will be effective in providing all-over protection that will generally withstand erection procedures. Where the durability of HDG is lower than for the painted system, inspection and replacement as necessary may be a more economical solution than more frequent maintenance re-painting. If the corrosion protection provided by the galvanized coating is sufficient, painting is not necessary and would only be for aesthetic reasons. Other proprietary metallic/ceramic coatings exist which may provide good performance. Electroplated bolts are not likely to provide significant exterior durability (see AS/NZS 2312.2 for more information on durability).

- A1 | Bolts, nuts and washers may also be further protected by the use of proprietary LDPE caps designed and engineered to fit snugly over the fixings.

Use of stainless steel bolts, nuts and washers can provide extended durability if the correct grade is selected, but will result in accelerated corrosion of the surrounding mild steel due to dissimilar metal (galvanic) corrosion unless fully isolated by means of insulating washers (top-hat washers if contact with the shank is likely). Self-tapping stainless steel screws cannot be isolated from mild steel substrates. Socket cap or countersunk stainless steel bolts will also be difficult to isolate effectively. Painting stainless steel bolt or screw heads will mitigate galvanic corrosion to some extent by reducing the size of the cathode but should not be relied on in aggressive environments.

#### **3.3.4.11** *Surfaces under fasteners*

The coating system around bolted connections should be specified to prevent coating damage occurring during tensioning of joint fasteners. It should be expected that the use of power tools such as torque power wheels and rattle guns will produce a greater degree of coating damage compared with hand torque wrenches.

Cracking will arise which cannot be adequately repaired to the required standard in the field. To prevent coating damage ideally the coating system around bolted connections should consist of a single primer coat of no more than 125 µm. The primer coat should be inorganic zinc silicate, zinc rich epoxy or zinc phosphate and should typically be that of the overall structure. In all joint types, a very snug fit is produced between the mating members which will exclude the elements of atmospheric corrosion (air, oxygen and electrolyte) such that the primer coat is adequate to protect these surfaces from corrosion.

When bolting a multi-coat system, washers are required under both the bolt head and nut, and site repairs will probably be necessary. Multiple coat specifications should also include requirements for the masking of bolt holes after application of the primer coat.

A single coat inorganic zinc coating system is an option for bolted structures due to its durability, toughness, resistance to damage and minimal touch up requirements. Hot dip galvanized fasteners are compatible with such coating systems.

#### **3.3.4.12** *Faying surfaces*

The faying surfaces of friction-type bolted joints need to meet special high strength friction grip requirements (see AS 4100—1998, Appendix J or NZS 3404.1 Appendix K, as applicable and certified by an International Laboratory Accreditation Cooperation (ILAC) or an Asia Pacific Laboratory Accreditation Cooperation (APLAC) accredited third party laboratory).

The following surfaces usually have a satisfactory coefficient of friction for mating:

- (a) Bare steel surfaces which are clean and free from oil and grease. These surfaces may be abrasive blast cleaned to remove rust and mill scale; however, steel in this condition is subject to crevice corrosion and rust staining.
- (b) Steel surfaces painted with inorganic zinc silicate. The paint when dry is 50 µm to 125 µm thick. The slip factor for this coating is affected by thickness and surface profile and should be tested to the relevant standard.

NOTE: Refer to paint reference numbers C01a, C01b and C01c in Table D1 of Appendix D.

- (c) Steel surfaces painted with a zinc rich epoxy coating tested to AS 4100—1998, Appendix J. The slip factor for this coating is affected by thickness and surface profile and should be tested by a laboratory accredited by signatories to the International Laboratory Accreditation Corporation (ILAC) through their Mutual Recognition Arrangement (MRA) for the specific tests described in this Standard. The appropriate logo or further details of the ILAC (MRA) signatory is required to be noted on the document.

NOTE: In Australia, ILAC (MRA) accredited bodies include National Association of Testing Authorities (NATA) and in New Zealand they include International Accreditation New Zealand (IANZ).

- (d) Steel surfaces coated with galvanized or thermal sprayed metallic coatings tested to AS 4100—1998, Appendix J. Typically, galvanized coatings wire brushed or grit blasted will provide a satisfactory slip factor.

Any crevices that may not be bridged effectively by the coating system should be filled with a compatible sealant.

Most organic-based protective coatings, including strippable coatings, oils and waxes, greatly reduce the slip-factor below the acceptable values for properly prepared steel.

There is no restriction on the use of protective coatings with bearing-type joints (see AS 4100 or NZS 3404.1 as applicable).

#### **3.3.4.13** *Cathodic protection*

Cathodic protection for the corrosion protection of metals applies to buried or submerged structures only. For effective operation it is necessary that the structures being protected have electrical continuity and that the system is applied in coordination with other adjacent underground metallic structures. The AS 2832 series of Standards provides information on this practice such as selection of coatings and resistance to cathodic disbondment and also on the requirements of regulatory bodies.

#### **3.3.4.14** *Sections in contact with soil*

For preference, structural steel sections should not make direct contact with soil. Wherever possible, such sections should be embedded in or bear on concrete, or be otherwise protected.

NOTE: These comments do not apply to steel piling which is normally protected only in the aerated zone of the soil, i.e. from ground level to approximately 1.5 m to 2 m below ground level (see AS 2159). Information on soil corrosion is given in Appendix B.

Concrete poured around steel structures should be continuous and not cast in sections.

#### **3.3.4.15** *Sections in contact with porous materials*

During the course of design, every attempt should be made to keep steel from contacting porous materials to prevent steel corrosion. For instance, where steel is in contact with wood it is necessary to provide suitable insulation, such as thick coatings applied to contacting surfaces to ensure that water cannot penetrate into their contact faces.

The use of large washers under nuts and bolt heads is recommended to prevent damage to the timber surface. In addition, it may be advantageous to treat the timber with a proven impregnation system to retard rotting when in an aggressive service environment. Some such timber preservatives contain copper ions which, if washed onto a steel or a galvanized surface, or otherwise brought into contact with it, can cause corrosion. The protection of a metal surface from such corrosion is essential.

#### **3.3.4.16** *Joint and cavity sealants*

Elastomeric, rigid and mastic materials can be used in crevices and cavities (see Clause 3.3.4.2) to insulate or encapsulate steel against damp or otherwise corrosive situations. An extensive range of products is available and optimum selection will depend upon the particular application (see AS/NZS 2311). Advice for selection of sealants should be sought from the coating manufacturer.

Generally, most joint or cavity sealants are not able to provide corrosion protection in their own right. It is recommended that an appropriate coating system be applied to all exposed or accessible areas of the substrate prior to assembly. A cavity sealant can be applied after assembly to minimize the ingress of moisture, contaminants or an electrolyte.

### 3.4 FABRICATION

#### 3.4.1 General

There are a number of factors regarding fabrication which require consideration during project specification.

Of paramount importance is that the necessary preparation and coating requirements of a structure are communicated by the architect, engineer, and coating supplier to the fabricator and paint applicator so as to achieve the corrosion protection and finish intended.

Examples of weld and edge preparation are illustrated in Figure 3.2. ISO 8501-3 defines certain fabrication imperfections and preparation grades for such areas.

#### 3.4.2 Preparation of welds prior to coating

Before and during any on-site welding, protection should be provided for all painted surfaces that may be damaged by spatter, hot metal or sparks and any other debris from welding. Coatings may be damaged on surfaces within 150 mm of the weld, including the reverse side.

All welds should comply with the requirements of AS/NZS 1554 series or the applicable code of construction. However, structurally compliant welds may still have discontinuities that will impair coating performance. Both the fabricator and paint applicator should carry out visual inspection to determine if any defects are present from fabrication which may be deleterious to coating performance. If present, such defects need to be identified, corrected and re-inspected. For example:

- (a) Sharp projections or crests on a weld should be ground smooth and all weld spatter should be removed by chipping, grinding or similar. Use of a spatter inhibitor spray (if permitted) may reduce the incidence of weld spatter but this will itself require subsequent removal by solvent degreasing.
- (b) Weld undercut should be reduced by blending/grinding or additional welding as these areas cannot be effectively cleaned and coated and will trap air and moisture leading to early coating breakdown. Welding, especially manual metal arc, flux cored arc or submerged arc welding, may leave tightly adhering slag deposits which should be removed by chipping, grinding or similar as they will impair coating systems.

Porosity in welds should not be painted over as this will create pinholes in the coating and these need to be filled or repaired before painting.

Welds and adjacent parent metal should not be coated before cleaning, checking and acceptance of the weld.

Clause 8.6 covers site preparation and coating of welds.

#### 3.4.3 Sharp edges

Sharp edges cause premature coating breakdown as paint coatings tend to pull away from such regions and they may not be covered by the full coating thickness. Ideally, the edges should be radiused to a minimum of 2 mm. Where it is not possible to radius edges, they should be chamfered (see Figure 3.2). If the paint specification requires sharp edges and corners to be rounded or bevelled prior to surface preparation, this needs to be identified as a note on the drawing documentation and in the specification provided to the steel fabricator.

Many fabricated elements, including slit sections or welded beams and the non-specified radius areas of rolled sections to AS/NZS 3679 may not have radiused corners as a result of their manufacturing process. These areas require the same treatment for edge radius as cut edges.

Where exposed, holes for bolts or other fixings should also have their edges radiused to ensure even coating thickness in these corrosion-sensitive areas.

Treating edges is expensive and labour intensive and may not be necessary in mild environments. Such areas should be nominated in contractual documentation.

#### **3.4.4 Shelling and laminations**

Surface laminations, shelling and other surface defects such as rolled-in mill scale, can be found in rolled steel product, and can be removed by grinding. For architecturally exposed structural steelwork, these defects may require filling by welding or by use of solventless epoxy filler or fairing compound recommended by the paint manufacturer.

#### **3.4.5 Gouges or raised nibs**

Clamps used for lifting steel members and physical impacts from tools or machinery can create gouges in the steel. Any gouge or raised nibs resulting from steel handling should be smoothed off to ensure the corrosion protection is not compromised. If aesthetics are important these may also need to be filled and sanded before finish coating.

#### **3.4.6 Responsibility for repair of fabrication defects**

It is essential that the extent of repair of defects and the responsibility for the finish of the steelwork to meet the coating life requirements are addressed in the architect/engineer specification and documentation. This includes the repair of fabrication and handling defects, which should be covered by the contractual relationship between the fabricator and applicator.

The steel fabricator is responsible for fabrication and welding and should bear the cost of any rectification where the steelwork does not meet the specification. Ideally defects should be detected and repaired before shipping to the coating applicator. The coating applicator has a responsibility to point out unacceptable fabrication defects to the fabricator before commencing the paint application.

Some unacceptable defects may not be detected until the steel has been blast cleaned which may create excessive delays. The applicator's quality control system should include inspection for fabrication defects, with repairs to be carried out before or after priming as appropriate, and as contracted with the fabricator.

#### **3.4.7 Rectification procedures**

Porosity in welds, minor undercutting and other defects are often not visible until after abrasive blast cleaning. If porosity is within the acceptance criteria of AS/NZS 1554, rectification may be carried out after priming by filling with a suitable solventless epoxy filling compound.

Gouges and intermittent weld crevices may also be filled with a rigid solventless epoxy compound after priming. Filling crevices with an elastomeric sealant should only be performed after all paints have been applied.

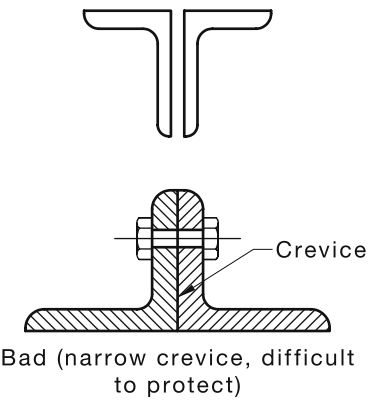
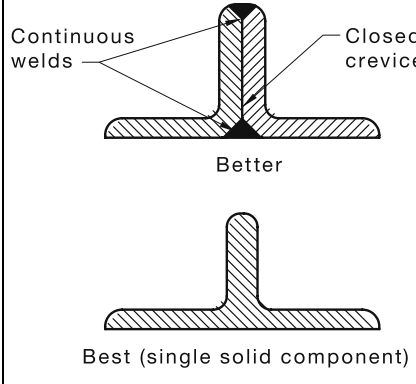
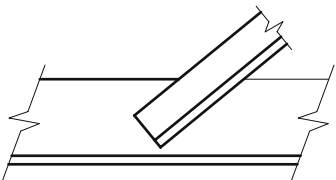
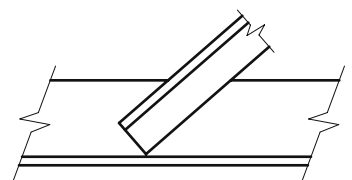
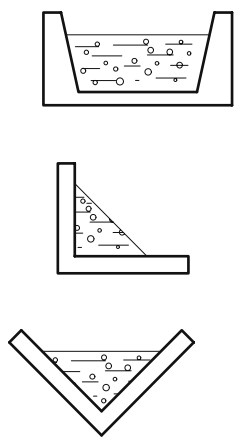
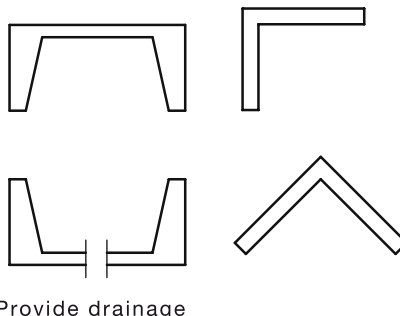
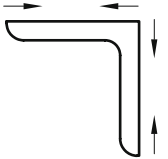
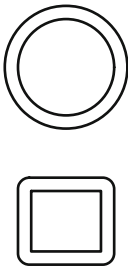
| Problem                                                                                                                                                                                                                                       | Typical application                                                                                                                                                                                                     | Solution                                                                                                                                                                                                       |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>(a) Backs of double angles cannot be easily painted and maintained</p>  <p>Bad (narrow crevice, difficult to protect)</p>                                 | Double angle truss; bearing member                                                                                                                                                                                      | <p>Design as single angle truss, or use T section</p>  <p>Better</p> <p>Best (single solid component)</p>                    |
| <p>(b) Lower end of angle could collect dirt and moisture</p>                                                                                               | Web member of truss                                                                                                                                                                                                     | <p>Invert angle</p>                                                                                                         |
| <p>(c) Channels or angles may collect rubbish and moisture</p>                                                                                             | Sheeting girt, tie or strut member                                                                                                                                                                                      | <p>Invert section</p>  <p>Provide drainage</p>                                                                             |
| <p>(d) Sharp corners cause concern about possible loss of protection due to paint draw-back at edges</p>  <p>Arrows indicate paint draw-back direction</p> | <p>All Structural members generally. Mill edges on rolled sections are only rounded where specified. The other edges and edges for slit plate can be relatively sharp and the required radius needs to be specified</p> | <p>Specify rounded edges and stripe coating. Consider use of circular hollow sections or rectangular hollow sections</p>  |

FIGURE 3.1 (in part) TYPICAL DESIGN PROBLEMS AND SOLUTIONS

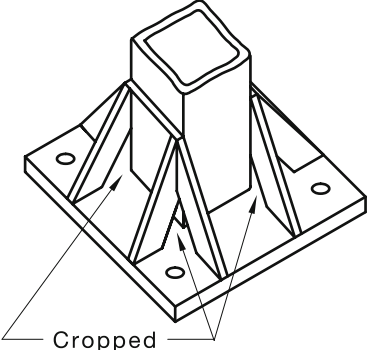
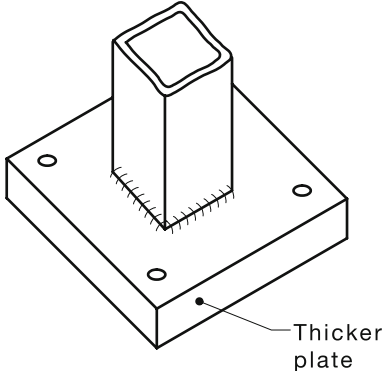
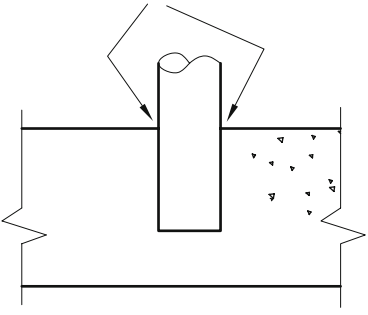
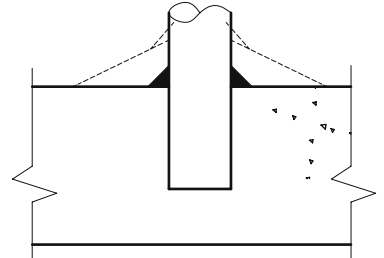
| Problem                                                                                                                                          | Typical application                       | Solution                                                                                                                                                                                                                                |
|--------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>(e) Gussets cause pockets for dirt and moisture</p>          | Column baseplate                          | <p>Design without gussets</p>                                                                                                                         |
| <p>(f) Corrosion point where steel member enters concrete</p>  | Stanchion for handrail or light structure | <p>Provide mastic sealant coving or sheath. Slope and seal concrete near stanchion. Apply coating to a minimum depth of 50 mm into the concrete</p>  |

FIGURE 3.1 (in part) TYPICAL DESIGN PROBLEMS AND SOLUTIONS

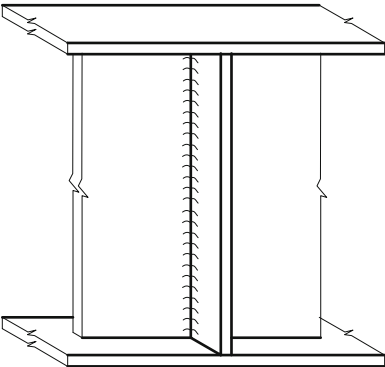
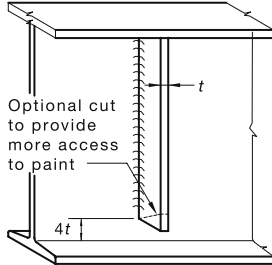
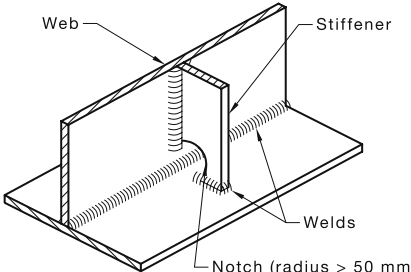
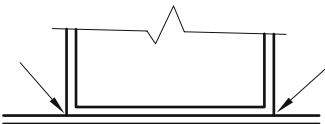
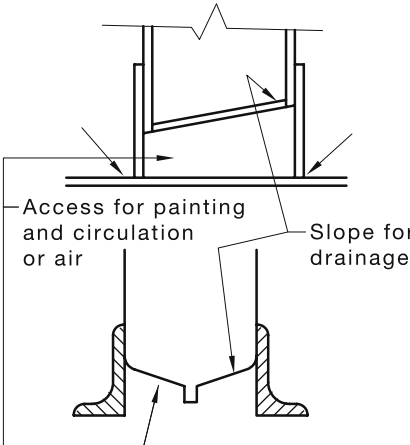
| Problem                                                                                                                                                                                                                         | Typical application                                           | Solution                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>(g) Intermediate web stiffener on plate girder may cause pocket for dirt and moisture and could be a point of initiation for corrosion</p>  | <p>Bridge girder, support beam for machinery or equipment</p> | <p>Stop stiffener short of bottom flange (obtain approval from the designer before making optional cut)</p>  <p>Optional cut to provide more access to paint</p>  <p>Optional cut or notch to provide more access to paint. Notch should have a radius greater than 50 mm</p> |
| <p>(h) Plates in loose contact may encourage capillary ingress of moisture</p>                                                               | <p>Service tank sitting on steel structure</p>                | <p>Locate tank, hoppers on legs</p>  <p>Access for painting and circulation or air</p> <p>Slope for drainage</p>                                                                                                                                                                                                                                                |

FIGURE 3.1 (in part) TYPICAL DESIGN PROBLEMS AND SOLUTIONS

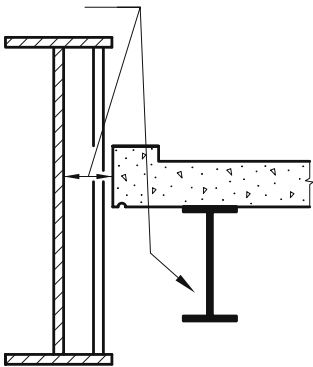
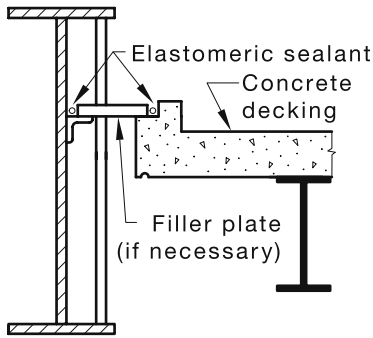
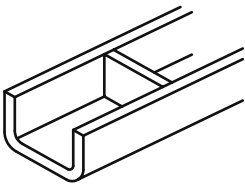
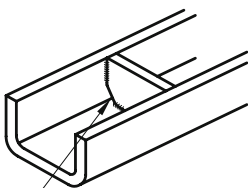
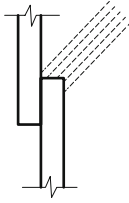
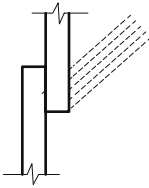
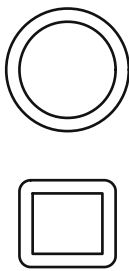
| Problem                                                                                                                                           | Typical application          | Solution                                                                                                                                                           |
|---------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (i) Limited access for maintenance painting<br>                  | Bridge decking               |  <p>Elastomeric sealant<br/>Concrete decking<br/>Filler plate (if necessary)</p> |
| (j) Strengthening gussets may restrict drainage<br>              | Open sections                |  <p>Adequately-sized cropped corner on strengthening gusset</p>                 |
| (k) Lapped joint creates ledge<br>                             | Shell of tank, bin or hopper | <p>Arrange joint so that ledge is not on the weather side</p>                 |
| (l) Insides of hollow sections not accessible for painting<br> | Tubular structures           | <p>Prevent entry of air by sealing with suitable welded end plates. These can often be incorporated into the design, e.g. column base and cap plates</p>           |

FIGURE 3.1 (in part) TYPICAL DESIGN PROBLEMS AND SOLUTIONS

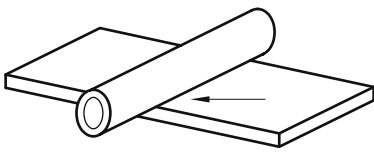
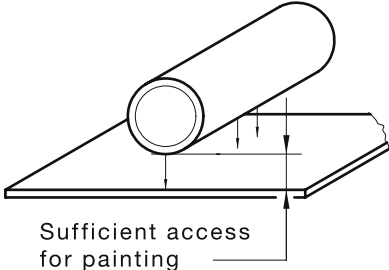
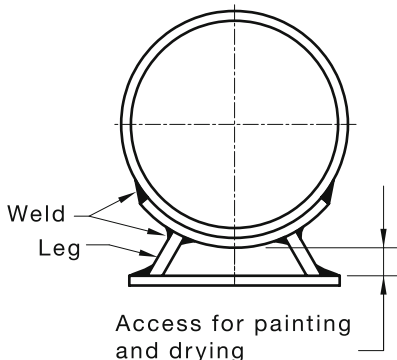
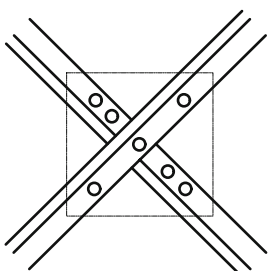
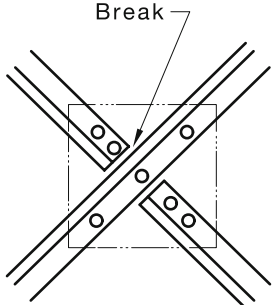
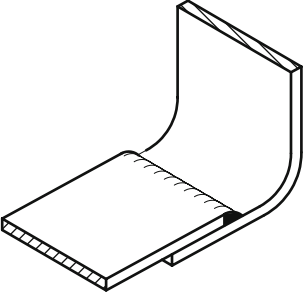
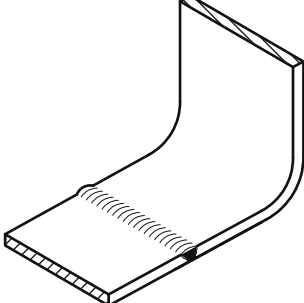
| Problem                                                                                                                                                       | Typical application                                                       | Solution                                                                                                                                                                                                                                                                                                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>(m) Pipe creates pocket when lying close to flat surface</p>              | <p>Service pipes running along structural members, tank plating, etc.</p> | <p>Keep pipe away from surface</p>  <p>Sufficient access for painting</p>  <p>Weld<br/>Leg</p> <p>Access for painting and drying</p> |
| <p>(n) Angles butted together cannot be easily painted and maintained</p>  | <p>Junction plate angles</p>                                              | <p>Prevent retention of water or dirt at junction plates by means of a break</p>  <p>Break</p>                                                                                                                      |
| <p>(o) Blast cleaning and painting of welds (lap welds)</p>                | <p>Joined structural members</p>                                          | <p>Butt welds are easier to blast clean and paint</p>                                                                                                                                                               |

FIGURE 3.1 (in part) TYPICAL DESIGN PROBLEMS AND SOLUTIONS

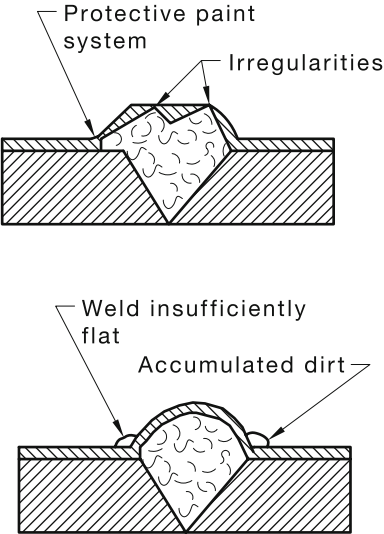
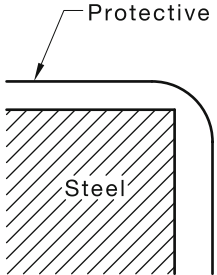
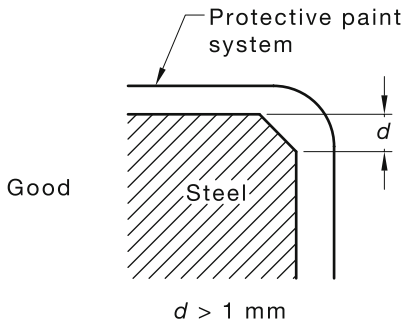
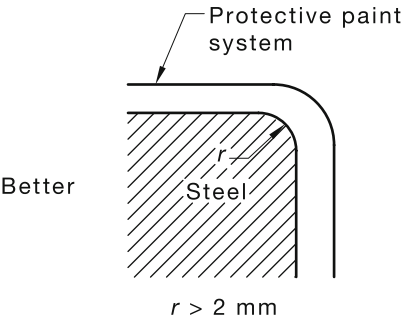
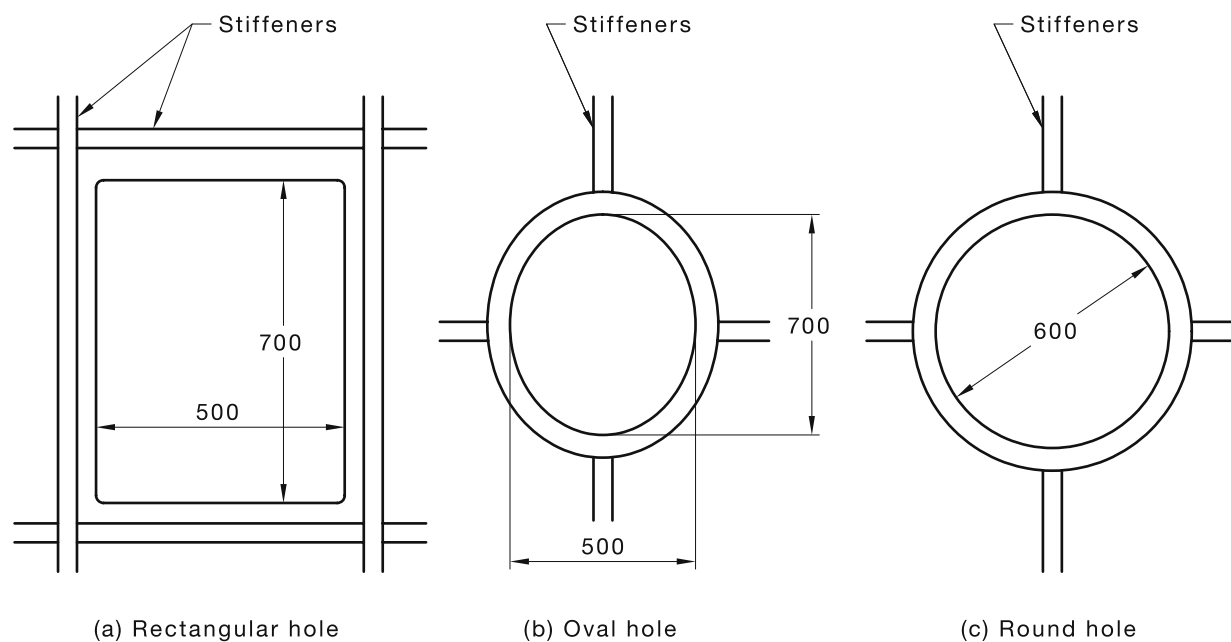
| Problem                                                                                                                                                    | Typical application       | Solution                                                                                                                                                                                                                                                                                                                                                                                              |
|------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>(a) Poor weld finish affecting surface coating</p>                     | Joined structural members | <p>Satisfactory weld preparation</p>                                                                                                                                                                                                                                                                                |
| <p>(b) Insufficient edge preparation prior to painting (sharp edge)</p>  | Cut and fabricated steel  | <p>Chamfer or round edges prior to painting as per coating specification, e.g. chamfer to 1 to 2 mm.</p> <p>Good <math>d &gt; 1</math> mm<br/>Better <math>r &gt; 2</math> mm</p>  <p>Chamfered edge</p>  <p>Rounded edge</p> |

FIGURE 3.2 TYPICAL FABRICATION PROBLEMS AND SOLUTIONS



DIMENSIONS IN MILLIMETRES

FIGURE 3.3 RECOMMENDED MINIMUM DIMENSIONS OF OPENINGS  
FOR ACCESS TO CONFINED AREAS

## SECTION 4 SURFACE PREPARATION

### 4.1 GENERAL

The protection that a coating system can give to steel depends largely on the type and thoroughness of the preparatory treatment given to the steel surface prior to its application.

It is essential that the surface preparation method selected is compatible with the selected coating system. For example, inorganic zinc silicate paint can only be applied to an abrasively blast cleaned steel surface. If such treatments are not carried out, premature failure of the protective system will result.

In general, the steel should be cleaned of all grease, dirt, processing oils, soil, fingerprints, salt residues, welding slag, corrosion products, loose millscale and any other foreign particles or residues which are likely to affect the performance of any subsequent protective system. As-manufactured hot-rolled steels are covered with a tightly adherent layer of millscale which during normal storage and handling operations may become damaged, allowing rusting of the exposed steel surface to commence. On prolonged exposure, the scale eventually separates leaving a fully rusted surface. Consequently, when a fabricated steel item is ready for painting, its surface can vary from being completely scale-covered to having a rust and scale-free surface. Steel held in stock for a considerable period of time under unfavourable storage conditions may be heavily pitted.

Removal of rust and millscale is essential for high performance coatings. This usually requires the use of abrasive blast cleaning.

Wherever possible, reference should be made to the relevant part of AS 1627, which covers a range of treatments for the preparation and pretreatment of steel surfaces prior to protective coating by painting.

### 4.2 SURFACE PREPARATION METHODS

#### 4.2.1 Treatment of fabrication defects

The first stage of any surface preparation should be treatment of fabrication defects such as sharp edges and correction of welding defects such as spatter and rough weld beads. Weld spatter, weld scale, roughness and sharp edges are best treated by power tool cleaning. Disc grinding, sanding discs or bristle blasters are normally used, with wire brushes only for removal of dust and dirt. Removal of spatter, smoothness of welds and other treatments should achieve the specified finish (see Clause 3.4).

#### 4.2.2 Cleaning with solvents or alkaline solutions (see AS 1627.1)

The following methods are used to remove oil and grease from surfaces—

- (a) alkaline degreasing;
- (b) solvent degreasing;
- (c) emulsion degreasing; and
- (d) high pressure water washing.

Some of these cleaning processes may be selected for the preliminary cleaning of the surface before the removal of rust, rust-scale, millscale or paint. If oil or grease contaminants are present, their complete removal should precede commencement of surface preparation. This is particularly important if abrasive blast cleaning or power tool cleaning is to be used, as these methods can drive contaminants into the substrate profile.

Solvent cleaning is not a suitable process for the removal of corrosive salts or detrimental weld flux. The degreasing of a large area is seldom completely achieved by liquid solvent cleaning. Its use, however, may be justified on small areas if care is exercised.

Experience has shown that the use of aqueous alkaline detergent cleaners with high pressure water cleaners, water jetting or scrubbing equipment is the most efficient way of emulsifying and removing oil and grease and particulate matter from structural steel.

NOTE: Methods of test to determine whether a surface is free of oil and grease are given in AS 3894.6.

#### 4.2.3 Abrasive blast cleaning (see AS 1627.4)

Abrasive blast cleaning is the most effective process for removing millscale and rust and for producing an anchor pattern or surface profile for a paint system and is usually used where long-term protection is required. Anchor pattern is produced by abrasive particles propelled with high force onto the steel surface in either the wet or dry condition. Such processes use a wide variety of blasting media, either applied by a closed recirculating system or by open blasting.

All surfaces should be cleaned free of oil and grease before processing.

The choice of the abrasive blasting medium is important and needs to be considered in conjunction with the protective coating system. Angular abrasives predominantly cut the surface whereas rounded abrasives shot-peen the surface. Surface profile requirements for atmospheric paint coating systems in Table 6.3 are normally in the range 40 to 75 µm with a sharp angular profile. Higher build systems may require a greater profile. If the profile is outside of the specified range, refer to the coating supplier. AS 3894.5 covers profile measurement. The use of rounded abrasives (shot) for many coating systems will not be satisfactory because they result in a lesser degree of keying for the coating.

A pictorial representation of four different initial rust grades on steel is given in ISO 8501-1. The nature of these rust grades is as follows:

- (a) *Grade A* A Grade A steel surface is covered completely with adherent millscale and little, if any, rust.
- (b) *Grade B* A grade B steel surface has begun to rust and the millscale has begun to flake.
- (c) *Grade C* A grade C steel surface has the millscale either rusted away or removable by scraping; little pitting is visible to the naked eye.
- (d) *Grade D* A grade D steel surface has the millscale rusted away and has considerable pitting visible to the naked eye.

These four grades may be abrasive blast cleaned to any one of the following four classes, again represented in ISO 8501-1 and described in AS 1627.4 as follows:

- (i) *Sa 1* is 'light' blast cleaning which removes loose millscale, rust and foreign matter.
- (ii) *Sa 2* is 'thorough' blast cleaning which removes some millscale, rust and foreign matter particles such that grey metal is visible.
- (iii) *Sa 2½* is 'very thorough' (commonly called 'near white') blast cleaning which removes millscale, rust and foreign particles to the extent that only traces remain.
- (iv) *Sa 3* is 'visually clean' (commonly called 'white metal') blast cleaning, by which visible millscale, rust and foreign particles are entirely removed and the cleaned surface has a uniform metallic colour but may show varying shades of grey when viewed from different angles.

Abrasive blast cleaning may cause distortion of thinner sections, less than approximately 3 mm.