

INTERNATIONAL STANDARD

ISO
12944-3

First edition
1998-05-15

Paints and varnishes — Corrosion protection of steel structures by protective paint systems —

Part 3: Design considerations

*Peintures et vernis — Anticorrosion des structures en acier par systèmes
de peinture —*

Partie 3: Conception et dispositions constructives

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Reference number
ISO 12944-3:1998(E)

ISO 12944-3:1998(E)**CONTENTS**

	Page
1 Scope.....	1
2 Normative references	1
3 Definition.....	1
4 General.....	2
5 Basic design criteria for corrosion protection purposes.....	2
5.1 Accessibility	2
5.2 Treatment of gaps.....	3
5.3 Precautions to prevent retention of deposits and water	3
5.4 Edges.....	3
5.5 Welding surface imperfections.....	3
5.6 Bolted connections	3
5.7 Box members and hollow components.....	4
5.8 Notches.....	4
5.9 Stiffeners.....	4
5.10 Prevention of galvanic corrosion	4
5.11 Handling, transport and erection.....	5
Annex A Accessibility - Typical distances required for tools in corrosion protection work.....	6
Annex B Recommended minimum dimensions of openings for access to confined areas	7
Annex C Minimum dimensions for narrow spaces between surfaces	8
Annex D Design features which may be used to avoid deposits accumulating or water being trapped	10

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Printed in Switzerland

FOREWORD

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO Technical Committees. Each member body interested in the subject for which a Technical Committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work, ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the Technical Committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75% of the member bodies casting a vote.

International Standard ISO 12944-3 was prepared by Technical Committee ISO/TC 35, *Paints and varnishes*, Subcommittee SC 14, *Corrosion protection of steel structures by protective paint systems*.

ISO 12944 consists of the following parts under the general title *Paints and varnishes – Corrosion protection of steel structures by protective paint systems*:

- *Part 1: General introduction*
- *Part 2: Classification of environments*
- *Part 3: Design considerations*
- *Part 4: Types of surface and surface preparation*
- *Part 5: Protective paint systems*
- *Part 6: Laboratory performance test methods*
- *Part 7: Execution and supervision of paint work*
- *Part 8: Development of specifications for new work and maintenance*

Annexes A to D of this part of ISO 12944 are for information only.

INTRODUCTION

Unprotected steel in the atmosphere, in water and in soil is subjected to corrosion that may lead to damage. Therefore, to avoid corrosion damage, steel structures are normally protected to withstand the corrosion stresses during the service life required of the structure.

There are different ways of protecting steel structures from corrosion. ISO 12944 deals with protection by paint systems and covers, in the various parts, all features that are important in achieving adequate corrosion protection. Additional or other measures are possible but require particular agreement between the interested parties.

In order to ensure effective corrosion protection of steel structures, it is necessary for owners of such structures, planners, consultants, companies carrying out corrosion protection work, inspectors of protective coatings and manufacturers of coating materials to have at their disposal state-of-the-art information in concise form on corrosion protection by paint systems. Such information has to be as complete as possible, unambiguous and easily understandable to avoid difficulties and misunderstandings between the parties concerned with the practical implementation of protection work.

This International Standard - ISO 12944 - is intended to give this information in the form of a series of instructions. It is written for those who have some technical knowledge. It is also assumed that the user of ISO 12944 is familiar with other relevant International Standards, in particular those dealing with surface preparation, as well as relevant national regulations.

Although ISO 12944 does not deal with financial and contractual questions, attention is drawn to the fact that, because of the considerable implications of inadequate corrosion protection, non-compliance with requirements and recommendations given in this standard may result in serious financial consequences.

ISO 12944-1 defines the overall scope of all parts of ISO 12944. It gives some basic terms and definitions and a general introduction to the other parts of ISO 12944. Furthermore, it includes a general statement on health, safety and environmental protection, and guidelines for using ISO 12944 for a given project.

This part of ISO 12944 gives guidance on how to minimize the risk of corrosion by appropriate design measures for steel structures to be coated by protective paint systems.

Paints and varnishes — Corrosion protection of steel structures by protective paint systems —

Part 3: Design considerations

1 SCOPE

This part of ISO 12944 deals with the basic criteria for the design of steel structures to be coated by protective paint systems in order to avoid premature corrosion and degradation of the coating or the structure. It gives examples of appropriate and inappropriate design, indicating how problems of application, inspection and maintenance of paint systems can be avoided. Design measures which facilitate handling and transport of the steel structures are also considered.

2 NORMATIVE REFERENCES

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 12944. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 12944 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

- ISO 1461: -¹⁾, *Hot dip galvanized coatings on fabricated ferrous products - Specifications.*
- ISO 8501-1:1988, *Preparation of steel substrates before application of paints and related products - Visual assessment of surface cleanliness - Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings.*
- ISO 12944-1:1998, *Paints and varnishes - Corrosion protection of steel structures by protective paint systems - Part 1: General introduction.*
- ISO 12944-2:1998, *Paints and varnishes - Corrosion protection of steel structures by protective paint systems - Part 2: Classification of environments.*
- ISO 12944-5:1998, *Paints and varnishes - Corrosion protection of steel structures by protective paint systems - Part 5: Protective paint systems.*
- ISO 14713: -²⁾, *Protection against corrosion of iron and steel in structures - Guidelines.*

3 DEFINITION

For the purposes of this part of ISO 12944, the following definition applies in addition to those given in ISO 12944-1.

3.1 design (noun): The way in which a structure is built up, as represented by a detailed plan of the structure, considering corrosion protection.

1) To be published. (Revision of ISO 1459:1973 and ISO 1461:1973)

2) To be published.

4 GENERAL

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.

The overall design shall be planned to facilitate surface preparation, painting, inspection and maintenance.

The shape of a structure can influence its susceptibility to corrosion. Therefore structures should be designed such that corrosion cannot easily establish a foothold (a corrosion trap) from which it can spread. It is therefore strongly recommended that the designer consults a corrosion protection expert at a very early stage in the design process. Ideally, the corrosion protection system should be selected at that time, with due consideration to the type of service of the structure, its service life and maintenance requirements.

The shapes of the structural elements and the methods used to join them should be such that fabrication, joining and any subsequent treatment will not promote corrosion. Similarly, consideration should be given to the shape of the structure and its elements with respect to the category of its environment (see ISO 12944-2) when specifying a protective paint system.

Designs should be simple and excessive complexity should be avoided. Where steel components are in contact, embedded or enclosed in other building materials, e.g. brickwork, they are no longer accessible, therefore, the corrosion protection measures shall be effective throughout the service life of the structure.

Steelwork to be hot-dip galvanized shall be designed in accordance with the requirements of ISO 1461 and ISO 14713.

5 BASIC DESIGN CRITERIA FOR CORROSION PROTECTION PURPOSES

The surfaces of steel structures exposed to corrosion stresses should be small in extent. The structure should have the smallest possible number of irregularities (e.g. overlaps, corners, edges). Joints should have preferably been made by welding, rather than bolting or rivetting, to achieve a smoother overall surface. Discontinuous welds and spot welds should only be used where the corrosion risk is negligible.

5.1 Accessibility

Steel components should be designed to be accessible for the purpose of applying, inspecting and maintaining the protective paint system. This can be facilitated, for example, by the provision of fixed walkways, powered platforms or other auxiliary equipment. The accessories which will be required for carrying out maintenance work safely (e.g. hooks, lugs and anchorages for scaffolding, guide rails for blast-cleaning and paint application vehicles) should be provided at the design stage.

Providing access for maintenance at a later date is difficult and if not included in the design the designer should indicate clearly how it can be provided in the future.

All surfaces of the structure which have to be coated should be visible and within reach of the operator by a safe method. Personnel involved in surface preparation, painting and inspection should be able to move safely and easily on all parts of the structure in conditions of good lighting. Surfaces which are to be treated should be sufficiently accessible to allow the operator adequate space to work in (see annex A).

Special attention should be paid to ensure access to openings in box members and tanks. The openings shall be of sufficient size to allow safe access for operators and their equipment, including safety equipment (see annex B). In addition, supplementary ventilation holes should be at a location and of a size which permits the application of the protective paint system.

Narrow spaces between elements should be avoided whenever possible. Where it is not possible to avoid narrow spaces for structural and practical reasons, the advice given in annex C should be followed.

Components which are at risk to corrosion and are inaccessible after erection should either be made of a corrosion resistant material or have a protective coating system which shall be effective throughout the service life of the structure. Alternatively, an allowance for corrosion (thicker steel) should be considered.

5.2 Treatment of gaps

Narrow gaps, blind crevices and lap joints are potential points for corrosion attack arising from retention of moisture and dirt, including any abrasive used for surface preparation. Potential corrosion of this kind should normally be avoided by sealing. In the most corrosive environments the space should be filled with shim steel which protrudes from the sections and is welded all round. Mating surfaces should be sealed by continuous welds to prevent entrapment of abrasives and the ingress of moisture (see annex D, figure D.3).

Special attention should be paid to points of transition from concrete to steel, particularly in the case of composite structures subject to severe corrosion stresses (see annex D, figure D.4)

5.3 Precautions to prevent retention of deposits and water

Surface configurations on which water can be trapped, and thus in the presence of foreign matter increase the corrosive stress, should be avoided. The designer should also be aware of the possible effects of run-off, for example from mild steel on to austenitic or ferritic stainless steel under a rust deposit, with the resulting corrosion of the stainless steel. Suitable precautions to meet these objectives are:

- designs with inclined or chamfered surfaces;
- the elimination of sections open at the top or their arrangement in an inclined position;
- the avoidance of pockets and recesses in which water and dirt can be trapped;
- the drainage of water and corrosive liquids away from the structure.

Suitable design features which may be used to avoid deposits or water being trapped are illustrated in annex D, figure D.1.

5.4 Edges

Rounded edges are desirable in order to be able to apply the protective coating uniformly and to attain adequate coating thickness on sharp edges (see annex D, figure D.5). Coatings on sharp edges are also more susceptible to damage. Therefore, all sharp edges from the fabrication process should be rounded or chamfered and burrs around holes and along other cut edges should be removed.

5.5 Welding surface imperfections

Welds should be free from imperfections (e.g. asperities, undercutting, blowholes, craters, splatter) which are difficult to cover effectively with a protective paint system (see annex D, figure D.6).

5.6 Bolted connections

5.6.1 Slip-resistant connections with high-tensile bolts

The friction surfaces in slip resistant connections shall be blast-cleaned, prior to assembly, to a minimum preparation grade of Sa 2 ½ as defined in ISO 8501-1, with an agreed roughness. A coating material with a suitable friction factor can be applied to the friction surface.

5.6.2 Preloaded connections

Particular care shall be taken in the specification of paint films for preloaded bolted connections. See ISO 12944-5:1998, subclause 5.6.

5.6.3 Bolts, nuts and washers

Bolts, nuts and washers shall be protected against corrosion to the same durability as the corrosion protection of the structure.

5.7 Box members and hollow components

Since they minimize the surface area exposed to atmospheric corrosion, box members (interior accessible) and hollow components (interior inaccessible) have, for corrosion purposes, a particularly suitable cross-section at shape, provided that the requirements given below are fulfilled.

Open box members and hollow components which are exposed to surface moisture shall be provided with drain openings and effectively protected against corrosion.

Sealed box members and sealed hollow components shall be impervious to air and moisture. For this purpose, their edges shall be sealed by means of continuous welds and any opening shall be provided with sealing covers. During the assembly of such components, care shall be taken to ensure that no water is trapped.

Where the components are required to be hot-dip-galvanized prior to painting, the design requirements to enable galvanizing to be carried out must be met (see ISO 1461 and ISO 14713). This is particularly important to prevent the risk of explosions when galvanizing hermetically welded components and to avoid ungalvanized spots.

5.8 Notches

Notches in stiffeners, webs or similar building components should have a radius of not less than 50 mm (see annex D, figure D.7) to allow adequate surface preparation and application of a protective paint system. Where the plate in which the notch is cut is thick (e.g. > 10 mm), the thickness of the surrounding plate should be reduced to facilitate surface preparation and paint application.

5.9 Stiffeners

When stiffeners are required, for example between a web and a flange (see annex D, figure D.7), it is essential that the intersection between the stiffener and the abutting components is welded all round to prevent the formation of gaps. The design of stiffeners should not allow the retention of deposits or water (see 5.3) and shall allow access for surface preparation and application of a protective paint system (see annex C).

5.10 Prevention of galvanic corrosion

Where an electrically conducting joint exists between two metals of different electrochemical potential in conditions of continuous or periodic exposure to moisture (electrolyte), corrosion of the less noble of the two metals will take place. The formation of this galvanic couple also accelerates the rate of corrosion of the less noble of the two metals. The corrosion rate depends on, amongst other factors, the potential difference between the two metals connected, their relative areas and the nature and period of action of the electrolyte.

Therefore, care shall be taken when joining less noble (i.e. more electronegative) metal components to more noble metal components. Particular care shall be taken where the less noble metal component has a small surface area in comparison with that of the more noble metal. There is no objection to the use, under less severe conditions, of fasteners of small surface area made of stainless steel in components made from less noble metals. Spring washers (e.g. lock washers, serrated washers) shall, however, not be used as they may seriously impair the long-term performance of the joint by rendering it prone to crevice corrosion.

If the design is such that galvanic coupling cannot be avoided, contacting surfaces should be electrically isolated, for example by painting the surfaces of both metals. If it is only possible to paint one of the metals adjacent to the junction, it shall as far as feasible be the more noble metal. Alternatively, cathodic protection can be considered.

5.11 Handling, transport and erection

The handling, transport and erection of a structure should be taken into account at the design stage. Consideration should be given to the method of lifting, and lifting points included in the design where necessary. The need for jigs to support components during lifting and transport should be considered and the appropriate precautions taken to prevent damage to the protective paint system during lifting, transport and on-site operations, e.g. welding, cutting and grinding.

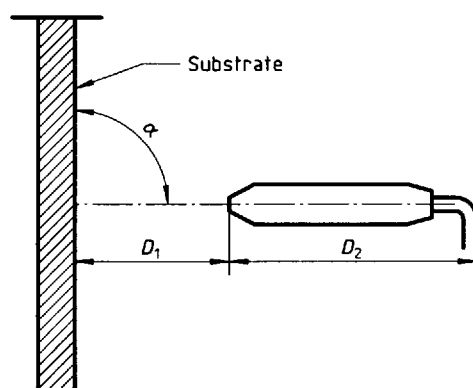
The corrosion protection, both temporary and permanent, of connection points between prefabricated sections should be considered at the design stage.

Annex A

(informative)

ACCESSIBILITY – TYPICAL DISTANCES REQUIRED FOR TOOLS IN CORROSION PROTECTION WORK

Operation	Length of tool (D_2) mm	Distance between tool and substrate (D_1) mm	Angle of operation (α) degrees
Abrasive blast-cleaning	800	200 to 400	60 to 90
Power-tool cleaning - by needle gun - by rubbing/grinding	250 to 350 100 to 150	0 0	30 to 90 -
Hand-tool cleaning - by brushing / chipping	100	0	0 to 30
Metal spraying	300	150 to 200	90
Paint application - by spraying - by brush - by roller	200 to 300 200 200	200 to 300 0 0	90 45 to 90 10 to 90



α angle made by the axis of the tool with the substrate
 D_1 distance from tool to substrate
 D_2 length of tool

Figure A.1

Annex B (informative)

RECOMMENDED MINIMUM DIMENSIONS OF OPENINGS FOR ACCESS TO CONFINED AREAS

Dimensions in millimetres

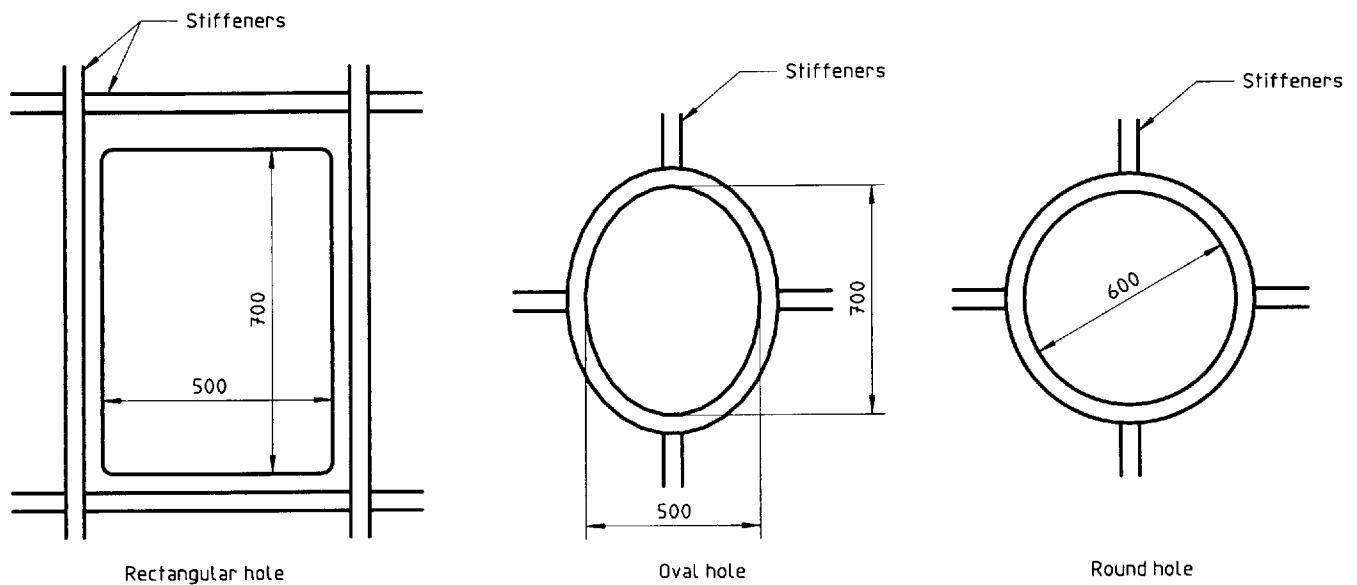
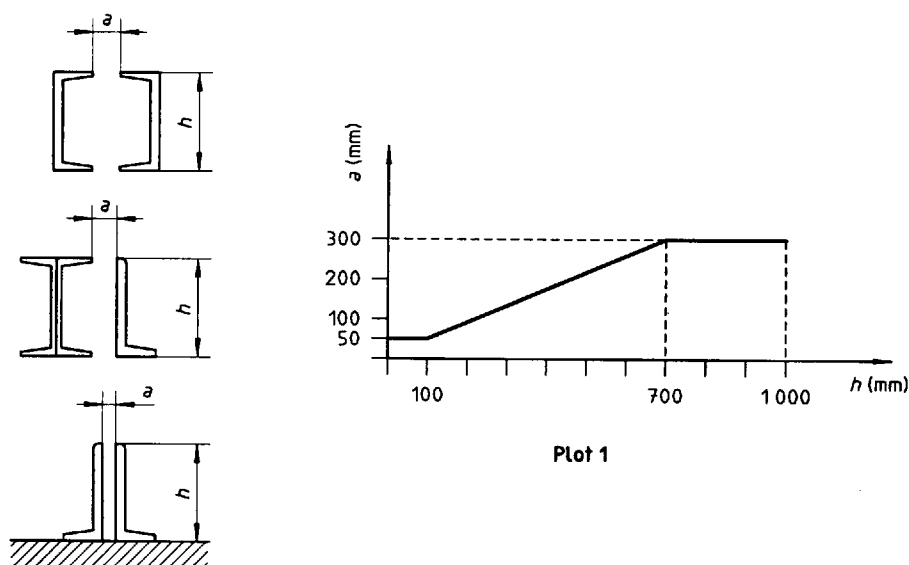


Figure B.1

Annex C (informative)

MINIMUM DIMENSIONS FOR NARROW SPACES BETWEEN SURFACES

To make it possible to prepare, paint and maintain a surface, an operator must be able to see and reach that surface with his tools. The criteria which are therefore important are access to see the surface and access to reach the surface.



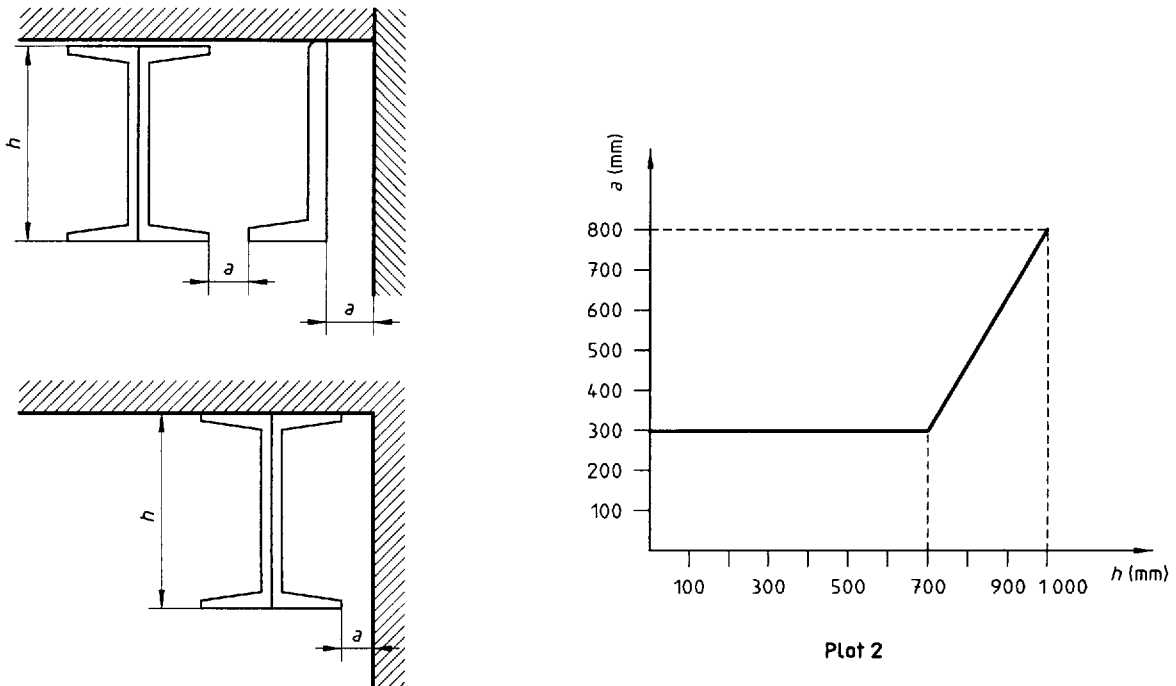
Plot 1

a : Minimum permitted distance between sections or between a section and an adjacent surface (mm).

h : Maximum distance an operator can reach into a narrow space (mm).

The minimum permitted distance a between the two sections is given by plot 1 for h up to 1 000 mm.

Figure C.1



The minimum permitted distance a between the section and the adjacent surface is given by plot 2.

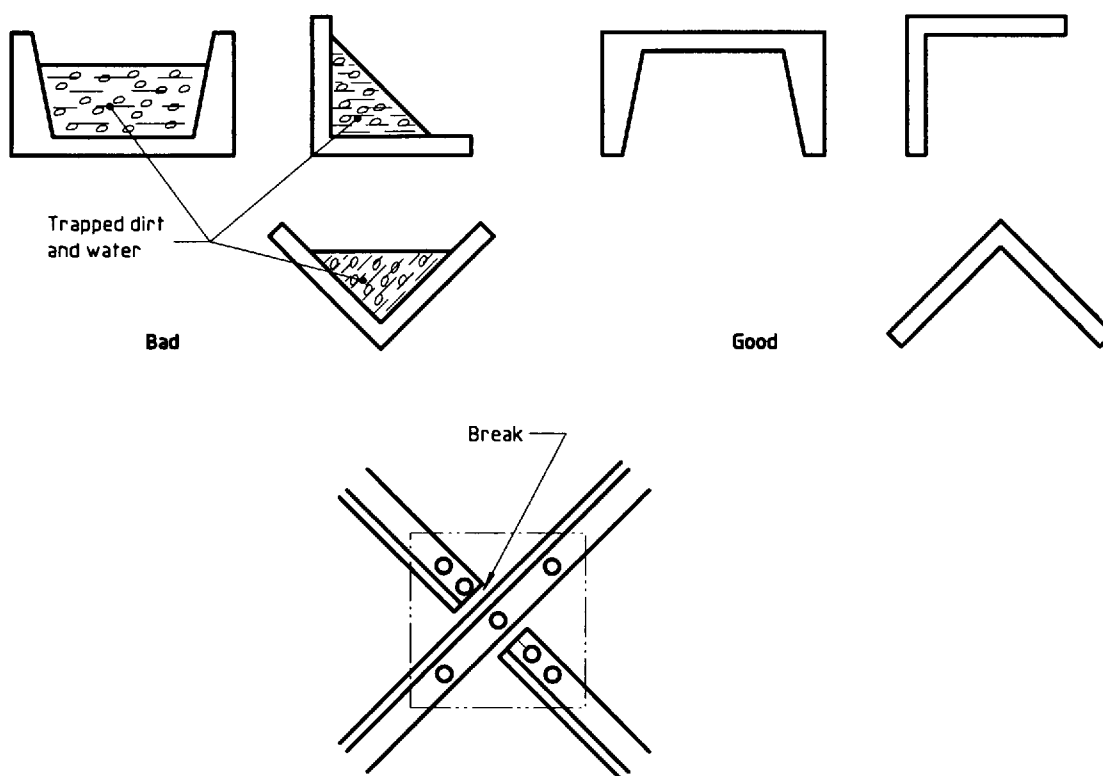
Figure C.2

- Note 1: If the operator has to reach distances greater than 1000 mm, a in plot 2 should preferably be at least 800 mm.
- Note 2: Where the designer cannot comply with the above recommendations, special measures will need to be taken.

Annex D (informative)

DESIGN FEATURES WHICH MAY BE USED TO AVOID DEPOSITS ACCUMULATING OR WATER BEING TRAPPED

Drain holes, drip noses, drip spouts or breaks may be used to avoid deposits forming or water being trapped. Consideration should be given to the possibility of droplets of water being blown into a trap by the wind. When de-icing solutions are expected to be used, drainage pipes are particularly recommended to drain the solution off the structure.



Prevention of retention of water or dirt at junction plates by means of a break.

Figure D.1 — Avoidance of dirt and water traps

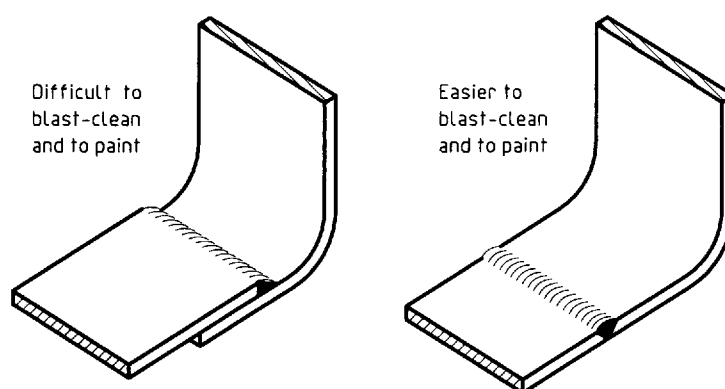
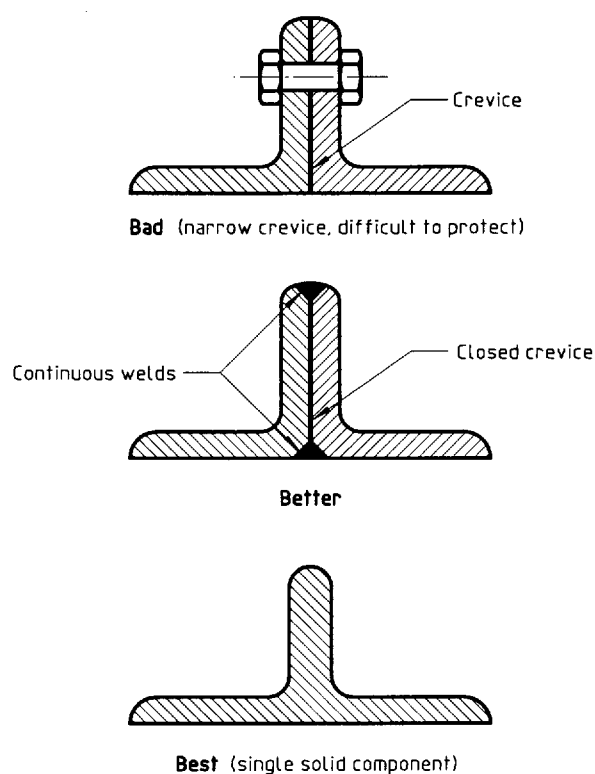


Figure D.2 — Design of welds



Note 1: These examples are shown only to illustrate the principles.

Note 2: In the case of hot-dip galvanizing, see also 5.7, last paragraph.

Figure D.3 — Treatment of gaps

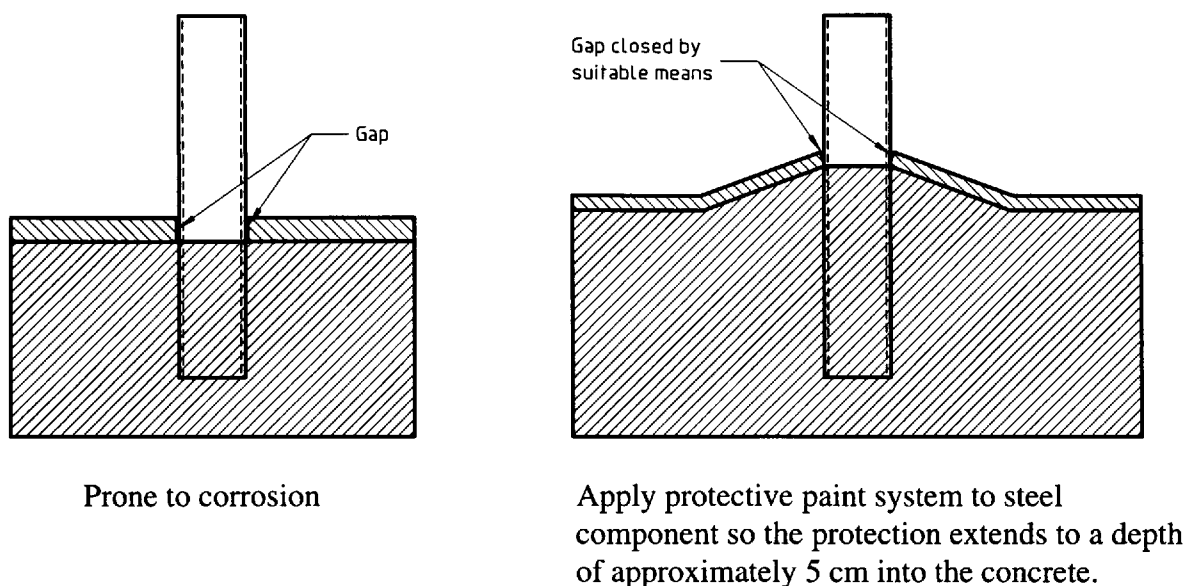


Figure D.4 — Composite steel / concrete structure

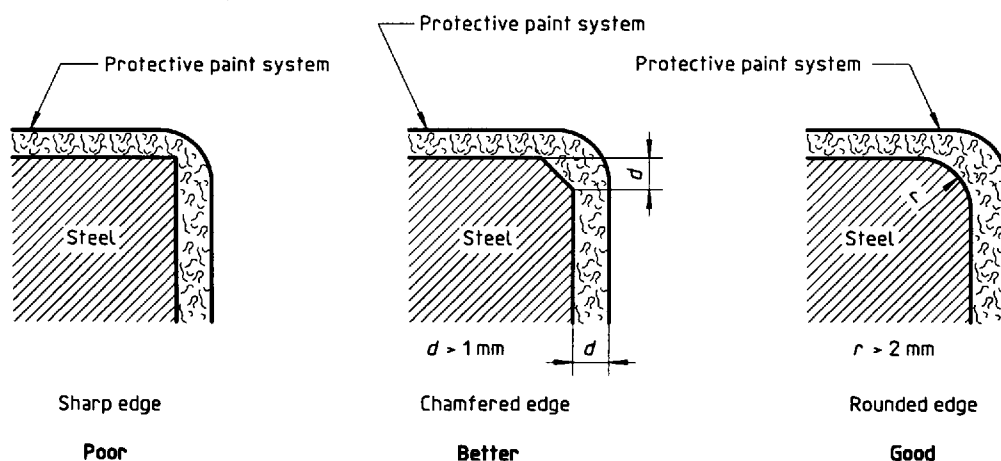


Figure D.5 — Avoidance of sharp edges

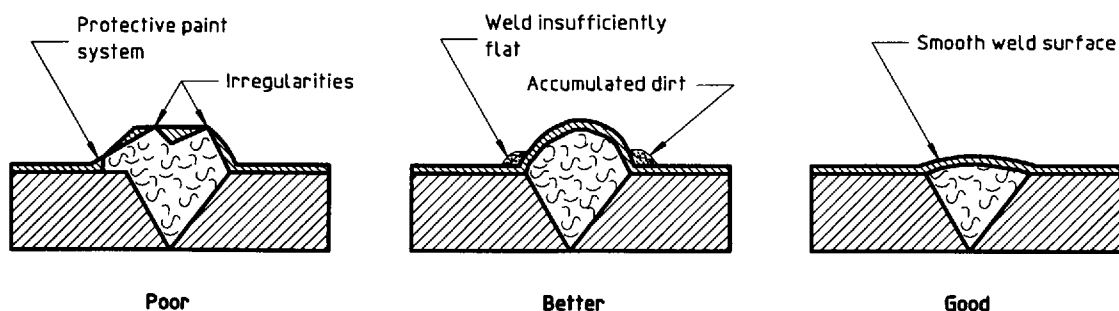
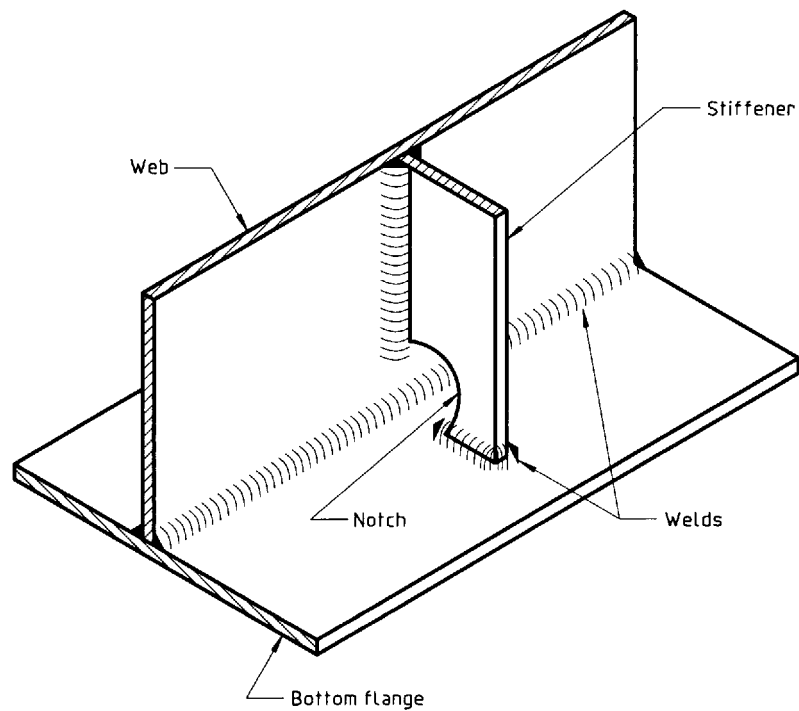


Figure D.6 — Avoidance of welding surface imperfections



For notches, $r \geq 50$ mm

Figure D.7 — Stiffener design recommended for corrosion protection

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Descriptors: paints, varnishes, steel construction, corrosion, corrosion prevention, protective coatings, paint coats, design.

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