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Indian Standard

RECOMMENDED DESIGN PRACTICE FOR CORROSION PREVENTION OF STEEL STRUCTURES

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Indian Standard

RECOMMENDED DESIGN PRACTICE FOR CORROSION PREVENTION OF STEEL STRUCTURES

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 25 April 1979, after the draft finalized by the Corrosion Protection Sectional Committee had been approved by the Structural and Metals Division Council.

0.2 The effect of design as a factor in the prevention of corrosion is very important, as good design of structures help to keep the maintenance costs low in relation to competitive materials. For the best results, the prevention of corrosion should begin at the drawing-board stage and it is important that designers, engineers, architects and others should constantly have in mind the avoidance of details that may aggravate corrosion or interfere with the effective application of protective systems and their subsequent maintenance. Design used in this context means not only the physical shape or form of the component or structure but also includes the materials of construction, the service environment, and the protective system to be used as well. This standard shall help the designers to identify and design out potential corrosion hazards.

0.3 In the preparation of this standard, assistance has been derived from the following publications:

Shreir (LL), *Ed.* Corrosion, 2.1976. Newnes — Butterworths, London.

BS 5493 : 1977 Code of practice for protective coating of iron and steel structures against corrosion. British Standards Institution.

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1. SCOPE

1.1 This standard lays down the principles governing design that shall prevent or reduce the risks of corrosion.

2. SERVICE ENVIRONMENT

2.1 The choice of corrosion prevention method depends largely on the intended service environment and it should be thoroughly assessed before making a choice of the protective systems, since the corrosive factors to be considered shall vary according to the type of environment and the materials used. Broadly, exposure to the conditions given in **2.1.1** to **2.1.4** may arise.

2.1.1 *Exposure to External Atmospheres* — The rate of corrosion depends primarily on the type of metal or alloy, rainfall, humidity, temperature, degree of atmospheric pollution and the angle and extent of exposure to the prevailing wind and rain.

2.1.2 *Exposure to Internal Atmospheres* — Internal atmospheres in buildings may vary; exposure in the occasionally hot, steamy atmosphere of a kitchen or bathroom is more severe than in other rooms. Condensation may occur in roof spaces or cavity walls.

2.1.3 *Exposure to Water* — Many details in building construction may permit rain water to enter and this may be retained in crevices in metal surfaces, or between a metallic and some other surface. Water may drip on to metal surfaces. These conditions which involve a greater risk of corrosion than exists where a metal is exposed to the normal action of the weather, are more severe when the water contains corrosive agents derived from the atmosphere or from materials with which the water comes into contact.

2.1.3.1 For structures, submerged in water, the factors affecting the corrosion rate are dissolved gases, salts, *p*H, temperature, rate of flow and the film-forming characteristics of the water.

2.1.4 *Embedment in Soil* — For structures, embedded in soil, the important factors affecting the rate of corrosion are compactness, electrical conductivity, moisture retention, oxygen content, heterogeneity of the soil, and presence of stray currents.

3. MATERIALS OF CONSTRUCTION

3.1 Use of Unstressed Metal — Metals, exposed to corrosive environments, should preferably be used in an unstressed condition, as stressed steel adjacent to unstressed steel may result in the formation of a galvanic cell.

3.1.1 Residual stresses, if present, should be in a direction to oppose those occurring in service, especially if the conditions are likely to induce stress-corrosion susceptibility.

3.1.2 The possibilities of stress-corrosion cracking may be reduced by use of protective coatings on the steel or by inducing compressive surface stresses by means of shot peening, rolling or swaging.

3.2 Contact with other Materials

3.2.1 *Other Metals* — Electrochemical corrosion may occur at contact surfaces between different metals. Some metals, like nickel and copper aggravate the corrosion of steel, whereas more electronegative metals, like aluminium and zinc, reduce it. The danger of bimetallic corrosion is most serious for immersed structures but should also be considered when designing atmospheric or buried structures. The possibility of bimetallic corrosion may be prevented by one or more of the following methods:

a) Insulating the contact surfaces;

b) Making the joints water-tight and using an impermeable coating to keep out the electrolyte;

c) Applying a metallic coating to the steel so as to reduce the potential difference between the non-ferrous metal and it, and

d) Applying overall cathodic protection for buried or immersed structures.

3.2.2 *Different Types of Steel* — Contacts between mild steels and/or low alloy steels may not affect corrosion appreciably, if they are free from millscale. Trouble might arise, however, at contacts between these steels and stainless steels.

3.3.3 *Concrete* — Portland cement concrete is highly alkaline and tends to inhibit rusting, moreover, the reaction of the carbon dioxide in air with the cement leads to effective sealing of the surface layer of dense well-made concrete. However, corrosion of steel embedded in Portland cement concrete may take place under certain conditions. Reference may be made to IS : 9077-1979* for suitable preventive measures.

3.3.4 *Timber* — Where steel is in contact with timber under corrosive conditions, the faces of both materials should be coated with hot tar or with bitumen bedding compound containing asbestos or other fillers, immediately before they are brought together. An insulating sheet of plastic, for example, polythene, may also be used.

3.3.4.1 Large washers of neoprene or similar material should be fitted under nuts and bolt-heads to prevent water entering the wood. The nuts and bolt-heads should be coated in the same way as the bolts.

*Code of practice for corrosion protection of steel reinforcement in RB and RCC construction.

3.3.5 *Other Materials* — Suitable insulation should be provided where steel touches other corrosive materials like gypsum plaster and penetration of water should be prevented.

4. DESIGN DETAILS FOR CORROSION PREVENTION

4.0 Corrosion may be reduced by correct planning of the structural layout and the arrangement of details, particularly of those parts most liable to corrosive attack. Some typical examples of details that have been found to initiate local corrosion and of alternative arrangements to avoid this, are given in **4.1** to **4.3.3**.

4.1 Entrapment of Moisture and Dirt

4.1.1 *Corrosion Points* — Corrosion is most likely where rain, condensed moisture and dust collect. To avoid such corrosion points (*see* Fig. 1) the whole surface should be kept as smooth as possible, without sharp edges, sharp corners, cavities or unnecessary protruberances. Welded tubular construction is at an advantage in this respect.

4.1.2 *Joints* — Joints should be arranged to give clean, uninterrupted lines. Generally, welds are preferable to bolts or rivets, butt welds to lap welds, and continuous welds to spot welds. If lap joints have to be used, appropriate welding or filling with mastic may be necessary.

4.1.3 *Fasteners* — Care is needed in the design of fasteners and the choice of material for them. The faying surfaces of friction grip bolts need special treatment. Spraying them with aluminium results in the highest slip factor (coefficient of friction) and helps to protect the shanks of the bolts as well.

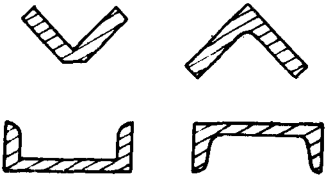
4.2 Cavities and Crevices

4.2.1 *Filling* — Cavities and crevices should be avoided or, if unavoidable, filled in by welding or mastic (*see* Fig. 2).

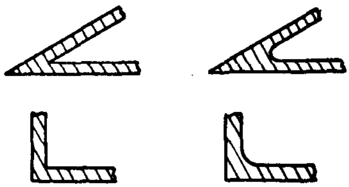
4.2.1.1 Any large cavity that may be inaccessible when the structure is completed should be sealed with weld metal; where required, the sealing should be tested by internal air pressure. Another method is to fill the cavities with concrete, vibrated into position. Small spaces may be filled with mastic or rust inhibitive paste or steel packings coated with an inhibitive paint.

4.2.2 *Hollow Structures* — If box sections, tubular steel parts and similar hollow structures may be properly sealed, so as to pass an air pressure test, their internal surfaces should not need protection.

POOR DESIGN GOOD DESIGN REMARKS

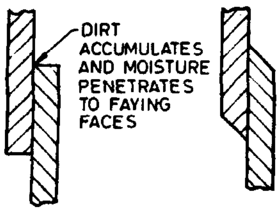


Shapes on the left retain moisture and dirt, and should be avoided. Those on the right are better arrangements.

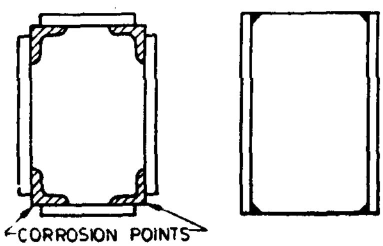


Dirt is more easily removed from the sections on the right.

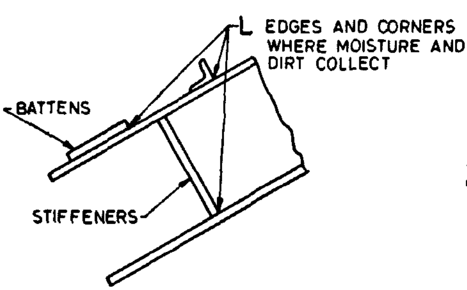
The lower pair are more accessible for painting.



The welded lap joint is preferable to the rivetted or bolted joint.



Corrosion points in box sections are avoided by grinding the welds flush to avoid retention of water.



Inclined members. These present particular difficulties.

Retention of water is avoided by providing drainage holes (*see also* Fig. 5).

FIG. 1 DESIGN DETAILS TO AVOID CORROSION

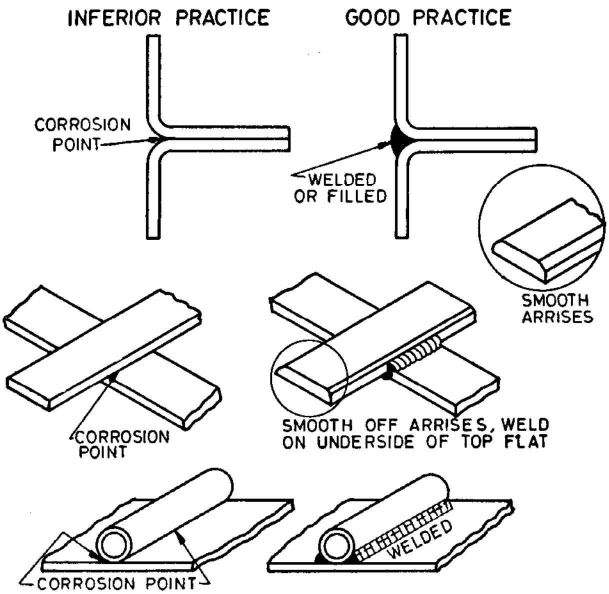


FIG. 2 CREVICES

4.2.2.1 Where hermetic sealing is impracticable, these surfaces are subjected to alternating condensation and evaporation of moisture caused by the 'breathing' of the enclosed space and the fluctuating difference between the internal and external temperatures. In the circumstances provision of drainage holes and painting of internal surfaces may be necessary.

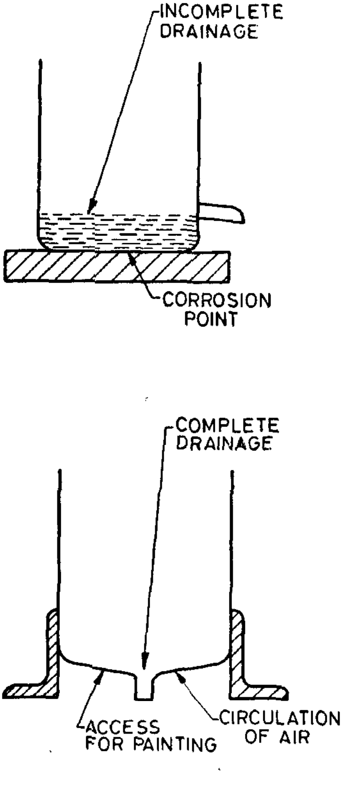
4.2.2.2 Protection may be prolonged by using desiccants to reduce the internal humidity. Silica-gel, used at the rate of 250 g/m^3 of void, is effective for 2 to 3 years inside a reasonably well-sealed structure, if the manholes are kept closed. The desiccant should be renewed at intervals and it should not be relied on solely if its presence is likely to be forgotten.

4.2.3 *Enclosed Steelwork* — When steelwork is enclosed in brickwork, boarding, plaster or other materials, the first essential is that the surrounding space should be kept dry, that is below the critical humidity for rusting. If this is not possible, an effective protective coating may be needed, particularly for steel surfaces in outer walls and behind dry casings or false ceilings. In some buildings, these may be exposed to process fumes.

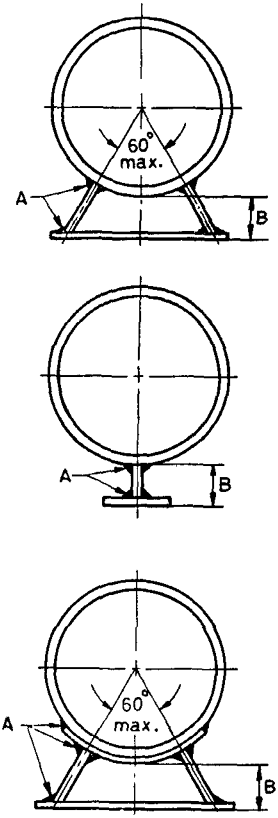
4.2.3.1 Careful design is needed to avoid corrosion of steel panelling on the cold side of air spaces, whether filled with insulation or not. An air space should be left between the steel and the insulation and arrangements made for warm inside air to flow up through this.

4.3 Circulation of Air, Drainage and Waterproofing

4.3.1 *Circulation of Air* — Free circulation of air round and through the structure should be arranged (*see* Fig. 3). This hastens the drying of surfaces after rain or dew.



Storage tanks (Schematic)



Fixed pipelines
A Continuous fillet weld
B Sufficient clearance for cleaning and painting

FIG. 3 AIR CIRCULATION

4.3.1.1 Protective coatings break down exceptionally quickly on sheltered surfaces, such as the eaves of buildings, where evaporation of moisture is retarded. Design features of this type should be either avoided or additional protection provided at the sheltered areas (*see* Fig. 4).

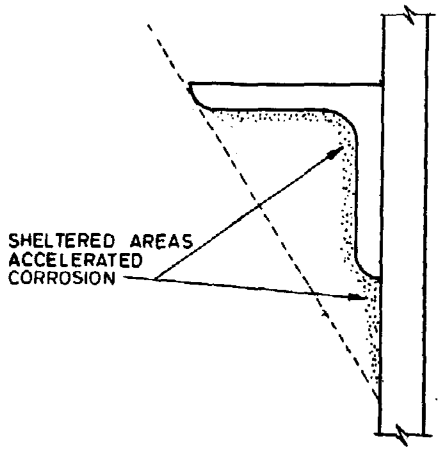
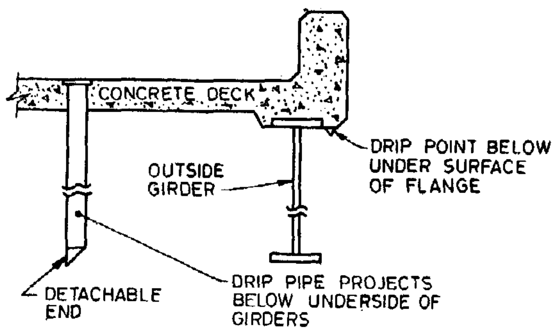


FIG. 4 EFFECT OF SHELTERING

4.3.2 *Drainage* — Arrangements should be made for shedding dripping water and condensation. Where necessary, lengths of pipe should be attached to the drain holes to carry the water clear and prevent its being blown back on to the structure (*see* Fig. 5).



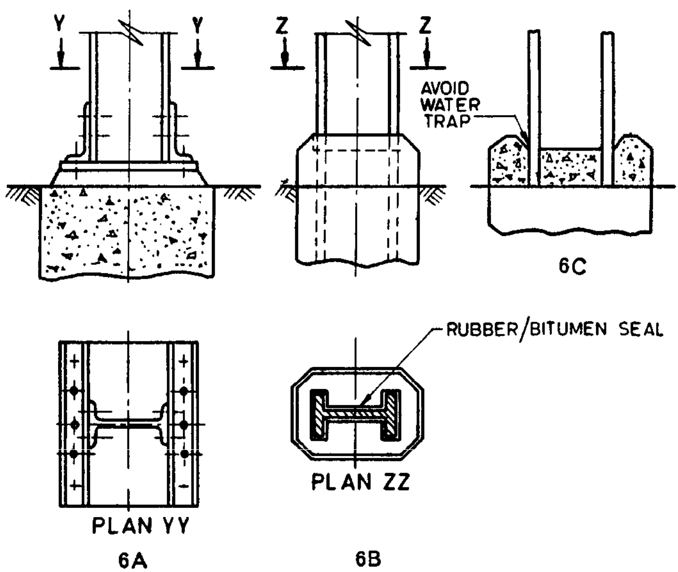
NOTE — Arrangement at outside girder of a concrete bridge deck.

FIG. 5 DRAINAGE

4.3.2.1 The design of storage tanks should permit of their being drained completely (Fig. 3) or a sump should be provided from which condensed water may be pumped. To avoid water traps, the floor should be as smooth as possible. Welded joints should be ground flush and any stiffeners, fitted outside the plates. Storage tanks should be raised from the ground to allow air circulation and access for maintenance.

Extra protection should be given to the most vulnerable areas by coating the bottom and 30 cm up the sides.

4.3.2.2 Water traps should be avoided where steel stanchions enter the ground or are embedded in a concrete base (*see* Fig. 6).



6A Best practice, where possible
Column base plate and stalk of the column, well clear of the danger line at ground level. Holding down bolts not exposed to corrosion.

6B Better practice
Column base below ground level.
Concrete brought well up above ground level.
Rubber/bitumen seal at steel/concrete joint.
The steelwork and concrete surfaces 150 mm above and below the column base should be protected by a suitable coating, for example, bitumen or tar pitch.

6C Inferior practice

FIG. 6 CORROSION PREVENTION OF COLUMN BASES

4.3.3 *Waterproofing* — Many structures, particularly bridges, are of steel and reinforced concrete. The prevention of corrosion and deterioration depends on careful waterproofing (*see* Fig. 7) and correct design of the concrete details to keep the water away from the steel.

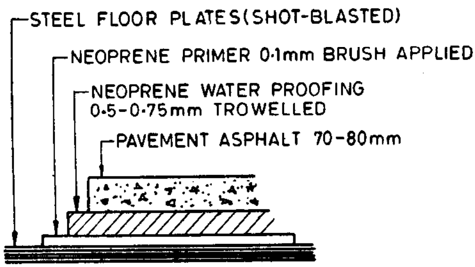


FIG. 7 WATERPROOFING OF BRIDGE DECK FOR CORROSION PREVENTION

5. CORROSION PREVENTION METHODS

5.0 In general, corrosion prevention methods may be generally classified into four main groups:

a) Treatment of the environment to render it non-corrosive,
b) Protective coatings,
c) Cathodic protection, and
d) Use of corrosion resistant structural steels.

5.1 Choice of Protective Schemes — The choice of the corrosion protection method should be made at a very early stage, and the following inter-related points should be considered in arriving at a decision:

a) Importance of the structure or component,
b) Proposed life of structure or component,
c) Shape and size of structure or component,
d) Service environment,
e) Periods required or permissible between maintenance,
f) Accessibility for maintenance,
g) Fabrication methods, and
h) Protection during transport or storage.

5.2 Coating Applications

5.2.1 *Ease and Efficiency of Coating* — The designer should ensure that protective coatings may be applied with ease and efficiency so as to achieve a continuous, uniform coating everywhere. Consequently, details, such as back to back angles, recesses, deep corners and behind holes should be avoided (*see* Fig. 8).

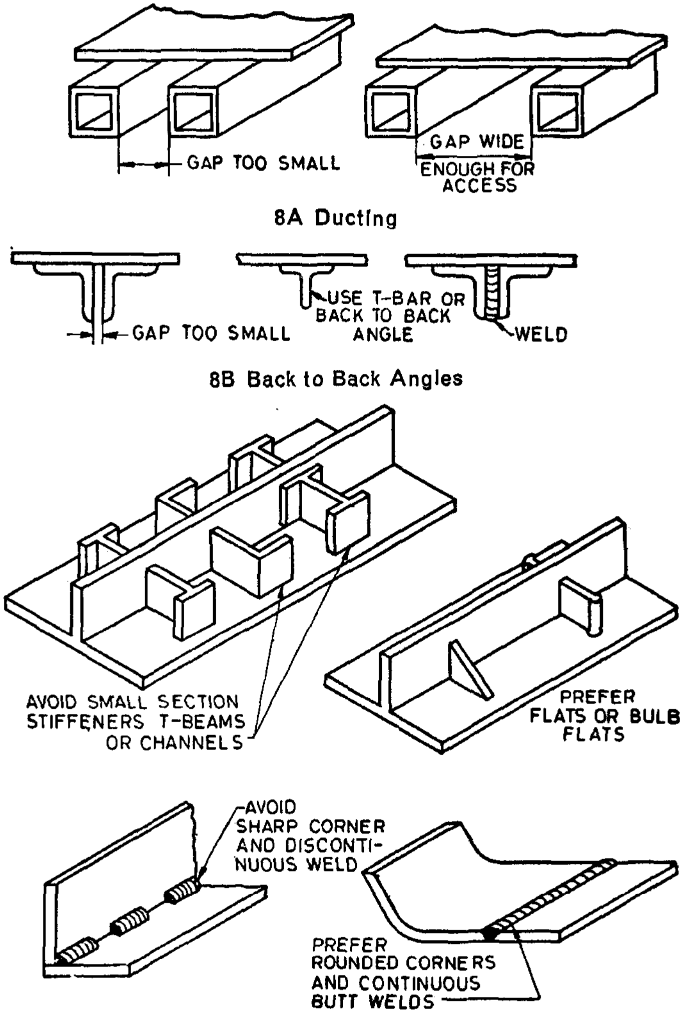


Fig. 8 Design for Coating

5.2.2 *Avoidance of Sharp Edges and Corners* — Rounded contours and corners are preferable to sharp edges and corners, which are difficult to coat evenly (*see* Fig. 9). Moreover, coatings are particularly liable to damage at edges. Tubular sections are better than I or H sections in these respects.

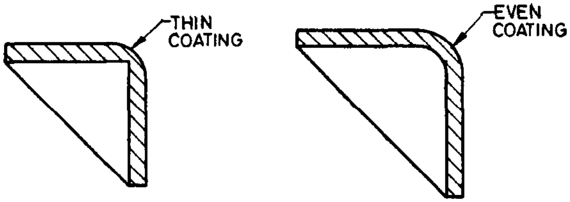


FIG. 9 EFFECT OF DESIGN ON PAINT APPLICATION

5.2.3 *Galvanizing and Dip-painting* — Vent-holes and drain-holes should be provided in assemblies that are to be hot-dip galvanized or dip-painted to avoid internal pressures and air-locks during immersions, and to ensure that molten zinc or paint is not retained in pockets on withdrawal.

5.2.4 *Faying Surfaces* — Coatings on faying or flexing surfaces are particularly vulnerable to damage. For example, the failure of outdoor pipelines is most frequently due to the abrasion of the coating through the expansion and contraction of bearing surfaces. One possible remedy is to provide graphite pipe slides.

5.3 Cathodic Protection — Where cathodic protection is to be applied, the design should ensure good electrical conductivity throughout and, if necessary insulation from neighbouring structures (*see also* IS : 3068-1976*).

5.4 Treatment of the Environment — The environment may be treated either, to remove the corrosive constituents from the environment or to add inhibitor to the environment to render it non-corrosive.

6. GENERAL DESIGN FEATURES

6.1 General Structure Design — The general design of a structure may effect the performance of a protective scheme. It is much easier to protect tubular construction than lattice work. Tubes may be better than wires for guys and similar supports.

6.2 Access — The design should admit easy access to all parts of the structure and thereby make it possible to inspect and renew the protective

*Code of practice for cathodic protection.

scheme without difficulty. Thus, any falsework, screens or loadings that would impair access to the erected structure should be made readily removable (*see* Fig. 10).

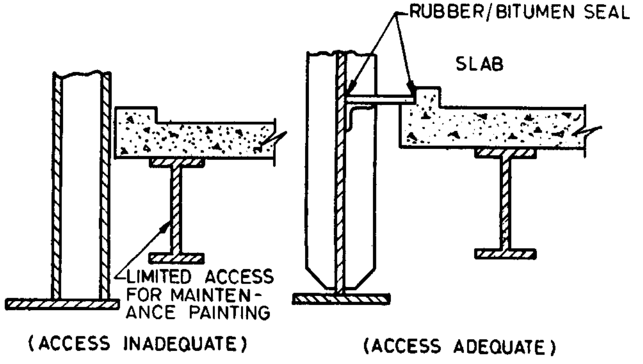


FIG. 10 ACCESS FOR MAINTENANCE

6.3 Load-Bearing Members — If the design permits, load-bearing members should be located where the corrosive conditions are least intense. For example, the members supporting the roof of a tank for corrosive chemicals should be fitted to the outside.

6.4 Services — The locations of service pipes, cables and ducts attached to the structure, passing through box girders should be agreed between all interested parties before preparation of detail design drawing. Lack of attention to such matters may lead to the creation of corrosion points. These arise, for example, where pockets are formed by not keeping conduits clear of the steelwork or where steam and other exhausts from pipes are allowed to impinge on it. The time required for maintenance is uneconomically prolonged if the service equipment has to be moved before starting maintenance work.

INDIAN STANDARDS

ON

CORROSION

IS:

3531-1968	Glossary of terms relating to corrosion of metals
3618-1966	Phosphate treatment of iron and steel for protection against corrosion
4180-1967	Code of practice for corrosion protection of light gauge steel sections used in building
4777-1968	Performance tests for protective schemes used in the protection of light gauge steel against corrosion
5555-1970	Code of procedure for conducting field studies on atmospheric corrosion of metals
6005-1970	Code of practice for phosphating of iron and steel
7808-1975	Code of procedure for conducting studies on underground corrosion of metals
8062 (Part I)-1976	Code of practice for cathodic protection of steel structures: Part I General principles
8062 (Part II)-1976	Code of practice for cathodic protection of steel structures: Part II Underground pipelines
8062 (Part III)-1977	Code of practice for cathodic protection of steel structures: Part III Ships' hulls
8221-1976	Code of practice for corrosion prevention of metal components in packages
8629 (Parts I to III)-1977	Code of practice for protection of iron and steel structures from atmospheric corrosion