1900

Structural Steel

1901. DESCRIPTION

This work shall include furnishing, fabricating, transporting, erecting and painting structural steel, rivet steel, cast steel, steel forgings, cast iron and other incidental metal construction of the kind, size and quantity in conformity with the drawings and these specifications or as desired by the Engineer.

1902. GENERAL

General requirements relating to the supply of material shall conform to the specifications of IS:1387, for the purpose of which the supplier shall be the Contractor and the purchaser shall be the Engineer.

Finished rolled material shall be free from cracks, flaws, injurious seams, laps, blisters, ragged and imperfect edges and other defects. It shall have a smooth and uniform finish, and shall be straightened in the mill before shipment. They shall also be free from loose mill scale, rust, pits or other defects affecting its strength and durability.

The acceptance of any material on inspection at the mill i.e. rolling mills, foundry or fabricating plant where material for the work is manufactured, shall not be a bar to its subsequent rejection, if found defective.

Unless specified otherwise, high tensile steel rivet conforming to IS:1149 shall be used for members of high tensile steel conforming to IS:961 and shall not be used for mild steel members.

Unless specified otherwise, bolted connection of structural joints using high tensile friction grip bolts shall comply with requirements of IS:4000.

Cast iron shall not be used in any portion of the bridge structure, except where it is subject to direct compression.

1903. MATERIALS

1903.1. All materials shall conform to Section 1000. Special requirements are given below :

Mild steel for bolts and nuts shall conform to IS:226 but have a minimum tensile strength of 44 kg/sq. mm. and minimum percentage elongation of 14. High tensile steel for bolts and nuts shall conform to IS:961 but with a minimum tensile strength of 58 kg/sq. mm. High strength friction grip bolts shall be permitted for use only on satisfactory

evidence of performance to the requirements (not covered by these specifications) specified by the Engineer or included in the special provisions.

For cast steel, the yield stress shall be determined and shall not be less than 50 per cent of the minimum tensile strength.

Plain washers shall be of steel. Tapered or other specially shaped washers shall be of steel, or malleable cast iron.

Parallel barrel drifts shall have a tensile strength not less than 55 kg/sq.mm. with elongation of not less than 20 per cent measured on a gauge length of $4\sqrt{So}$ (So = cross sectional area).

1903.2. Materials for castings and forgings, fasteners and welding consumables shall be as under :

1903.2.1. Castings and Forgings : Steel castings and forgings shall comply with the requirements of the following Indian Standards, as appropriate :

IS:1030 Carbon Steel Castings for General Engineering purposes

IS:1875 Carbon Steel Billets, blooms, slabs, bars for forgings

IS:2004 Carbon Steel Forgings for General Engineering purposes

IS:2644 High Tensile Steel Casings

IS:4367 Alloy & tool steel forgings for general industrial use

1903.2.2. Fasteners : Bolts, nuts, washers and rivets shall comply with the following or relevant IS Standards as appropriate :

IS:1929 Hot forged steel rivets for hot closing (12-36mm dia)

IS:2155 Cold forged steel rivets for hot closing (6-16mm dia)

IS:1363 Hexagon head bolts, screw and nuts product grade C

IS:1364 Hexagon head bolts, screw & nuts product grade A & B

IS:1367 Technical supply conditions for threaded steel fastener (Parts 1 to 18)

IS:3640 Hexagon fit bolts

IS:3757 High tensile friction grip bolts

IS:6623 High strength structural nuts

IS:6639 Hexagon bolts for steel structure

IS:5624 Foundation bolts

IS:7002 Prevailing torque type steel hexagon lock nuts

IS:5369 Plain washers and lock washers - general requirements

IS:5370 Plain washers with outside dia = 3 X inside dia

IS:5372 Taper washers for channels (ISMC)

IS:5374 Taper Washers for I beams (ISMB)

IS:6610 Heavy washers for steel structures

IS:6649 Hardened and tempered washers for high strength structural bolts and nuts

1903.2.3. Welding consumables

Welding consumables shall comply with the following Indian Standards as appropriate :

IS:814 (Part 1) Covered Electrodes for Metal Arc Welding of structural steel for welding other than sheets

IS:814 (Part 2) For welding sheets

IS:1278 Filler rods and wires for gas welding

IS:1395 Low and medium alloy Steel covered electrodes for manual Metal Arc Welding

IS:3613 Acceptance Tests for wire flux combinations for submerged arc welding of structural steel

IS:7280 Bare wire electrodes for gas shielded arc welding of structural steel

IS:6419 Welding rods and bare electrodes for gas shielded arc welding of structural steel

IS:6560 Molybdenum and chromium-molybdenum low alloy steel welding rods and bare electrodes for gas shielded arc welding

1903.3. In aggressive environment, corrosion resistant steel can be used. These are low-alloyed steels containing a total of 1 per cent - 2 per cent alloys, in particular, copper, chromium, nickel and phosphorous.

1903.4. Paints

All materials for paints and enamels shall conform to the requirements specified on the drawings or other special provisions laid down by the Engineer.

The type of paints which can be used shall be as follows :

a) Ordinary i.e. paints based on drying oils, alkyd resin, modified alkyd resin, phenolic varnish epoxy

b) Chemical Resistant - one pack type (ready for use) and two pack type (mixed before use).

c) Vinyl

d) Chlorinated rubber

e) Bituminous

f) Epoxy

g) Polyurethane

h) Zinc rich

Unless otherwise specified, paints shall conform to the relevant IS specifications. The paints which have been tested for the following qualities as per specifications given in the relevant IS codes only shall be used :

- Weight test (weight for 10 litre of paint, thoroughly mixed)
- Drying time
- Consistency
- Dry thickness and rate of consumption.

1904. FABRICATION

1904.1. General

All work shall be in accordance with the drawings and as per these specifications with care being taken that all parts of an assembly fit accurately together. All members shall carry mark number and item number and, if required, serial number.

Unless specifically required under the contract, corresponding parts need not be interchangeable, but the parts shall be match marked as required under Clause 1904.7.

Templates, jigs and other appliances used for ensuring the accuracy of the work shall be of mild steel; where specially required, these shall be bushed with hard steel. All measurements shall be made by means of steel tape or other device properly calibrated. Where bridge materials have been used as templates for drilling, these shall be inspected and passed by the Engineer before they are used in the finished structure.

All structural steel members and parts shall have straight edges and blunt surfaces. If necessary, they shall be straightened or flattened by

pressure unless they are required to be of curvilinear forms. They shall also be free from twist. Pressure applied for straightening or flattening shall be such as would not injure the materials. Hammering shall not be permitted. Adjacent surfaces or edges shall be in close contact or at uniform distance throughout.

The Contractor shall submit his programme of work to the Engineer for his approval at least 15 days before the commencement of fabrication. This programme shall include the proposed system of identification and erection marks together with complete details of fabrication and welding procedures.

The Contractor shall prepare shop drawings for fabricating any member and obtain approval of the Engineer before the start of work. Complete information regarding the location, type, size and extent of all welds shall be clearly shown on the shop drawings. These drawings shall distinguish between shop and field welds.

1904.2. Preparation of Edges and Ends

All structural steel parts, where required, shall be sheared, cropped, sawn or flame cut and ground accurately to the required dimension and shape.

End/edge planing and cutting shall be done by any one of the following prescribed methods or left as rolled :

a) Shearing, cropping, sawing, machining, machine flame cutting.

b) Hand flame cutting with subsequent grinding to a smooth edge.

c) Sheared edges of plate not more than 16 mm thick with subsequent grinding to smooth profile, which are for secondary use such as stiffeners and gussets.

If ends of stiffeners are required to be fitted, they shall be ground, so that the maximum gap over 60 per cent of the contact area does not exceed 0.25 mm.

Where flame cutting or shearing is used, at least one of the following requirements shall be satisfied.

a) The cut edge is not subjected to applied stress.

b) The edge is incorporated in weld.

c) The hardness of cut edge does not exceed 350 HV30.

d) The material is removed from edge to the extent of 2 mm or minimum necessary, so that the hardness is less than 350 HV 30.

e) Edge is suitably heat treated by approved method to the satisfaction of the Engineer and shown that cracks had not developed by dye penetrant or magnetic particle test.

f) Thickness of plate is less than 40 mm for machine flame cutting for materials conforming to IS:226 and IS:2062. The requirement of hardness below 350 HV 30 of flame cut edges should be specified by the Engineer.

Wherever specified by the Engineer, the flame cut edges shall be ground or machined over and above the requirement (a) to (f).

Where machining for edge preparation in butt joint is specified, the ends shall be machined after the members have been fabricated.

Outside edges of plate and section, which are prone to corrosion shall be smoothed by grinding or filing.

In the case of high tensile steel at least 6 mm of the material from the flame cut edge shall be removed by machining.

Longitudinal edges of all plates and cover plates in plate girders and built-up members shall be machined except in the following cases :

a) Rolled edges of single universal plates or flats may not be machined.

b) Covers to single flange plates may be left unmachined.

c) Machine flame cutting instead of machining is acceptable for edges of single plates in compression and for edges of single plates, 25 mm or less thick, in tension.

d) Edges of single shaped plates over 25 mm thick not capable of being machined by ordinary method may be machine flame cut and the end surface ground.

e) Edges of universal plates or flats of the same nominal width used in tiers may be left unmachined, if so authorised by the Engineer.

All edges of splice and gusset plates 12 mm thick and over shall be machined and those less than 12 mm thick may be sheared and ground.

The ends of plates and sections forming the main components of plate girders or of built-up members shall be machined, machine flame cut, sawn or hand flame cut and ground.

Where ends of stiffeners are required to be fitted, they shall be machined, machine flame cut, sawn, sheared and ground, or hand flame cut and ground.

The ends of lacing bar shall be rounded unless otherwise required.

Other edges and ends of mild steel parts may be sheared and any burrs at edges shall be removed.

1904.3. Preparation of Holes

1904.3.1. Drilling and punching : Holes for rivets, black bolts, high strength bolts and countersunk bolts/rivets (excluding close tolerance and turn fitted bolts) shall be either punched or drilled. The diameter

of holes shall be 1.5 mm larger for bolts/rivets less than 25 mm dia and 2.0 mm for more than or equal to 25 mm.

All holes shall be drilled except for secondary members such as, floor plate, hand rails etc. Members which do not carry the main load can be punched subject to the thickness of member not exceeding 12 mm for material conforming to IS:226.

Holes through more than one thickness of material or when any of the main material thickness exceeds 20 mm for steel conforming to IS:2062 or 16 mm for steel conforming to IS:961, IS:8500, shall either be sub-drilled or sub-punched to a diameter of 3 mm less than the required size and then reamed to the required size. The reaming of material more than one thickness shall be done after assembly.

Where several plates or sections form a compound member, they shall, where practicable, be firmly connected together by clamps or tacking bolts, and the holes be drilled through the group in one operation. Alternatively, and in the case of repetition work, the plates and sections may be drilled separately from jigs and templates. Jigs and templates shall be checked at least once after every 25 operations. All burrs shall be removed.

In the case of repetition of spans, the erection of every span shall not be insisted upon, except where close tolerance or turned bolts are used, provided that methods are adopted to ensure strict interchangeability. In such cases, one span in ten or any number less than ten of each type shall be erected from pieces selected at random by the Engineer and should there be any failure of the pieces to fit, all similar spans shall be erected complete. In the event of spans being proved completely interchangeable, all corresponding parts shall carry the same mark so that sorting of the materials at site is facilitated.

1904.3.2. Block drilling : Where the number of plates to be riveted exceeds three or the total thickness is 90 mm or more, the rivet holes, unless they have been drilled through steel bushed jigs, shall be drilled out in place 3 mm all round after assembling. In such cases, the work shall be thoroughly bolted together.

1904.3.3. Size of holes : The sizes of holes in millimetres are given in Table 1900-1 below:

TABLE 1900-1 : DIAMETER OF HOLES FOR RIVETS

Nominal dia of Rivets (mm)	Dia of Holes (mm)
12	13.5
14	15.5
16	17.5
18	19.5
20	21.5
22	23.5
24	25.5
27	29.0
30	32.0
33	35.0

1904.3.4. Close tolerance bolts and barrel bolts : Holes for close tolerance and turn fitted bolts. The diameter of the holes shall be equal to the nominal diameter of the bolt shank minus 0.15 mm to 0.0 mm.

The members to be connected with close tolerance or turn fitted bolts shall be firmly held together by service bolts or clamped and drilled through all thicknesses in one operation and subsequently reamed to required size within specified limit of accuracy as specified in IS:919 tolerance grade H8.

The holes not drilled through all thicknesses at one operation shall be drilled to smaller size and reamed after assembly.

1904.3.5. Holes for high strength friction grip bolts : All holes shall be drilled after removal of burrs. Where the number of plies in the grip does not exceed three, the diameters of holes shall be 1.6 mm larger than those of bolts and for more than three plies in grip, the diameters of hole in outer plies shall be as above and dia of holes in inner plies shall not be less than 1.6 mm and not more than 3.2 mm larger than those in bolts, unless otherwise specified by the Engineer.

1904.3.6. Removal of burrs : The work shall be taken apart after drilling and all burrs left by drilling and the sharp edges of all rivet holes completely removed.

1904.4. Rivet and Riveting

The diameter of rivets shown on the drawings shall be the size before heating. Each rivet shall be of sufficient length to form a head of the standard dimensions as given in IS handbook on Steel Sections, Part I. It shall be free from burrs on the underside of the head.

When countersunk heads are required, the heads shall fill the countersunk. The included angle of the head shall be as follows :

a) For plates over 14 mm thickness 90 degrees

b) For plates upto and including 14 mm thickness 120 degrees

The tolerance on the diameter of rivets shall be in accordance with IS:1148 and IS:1149 for mild steel rivets and high tensile steel rivets respectively and unless otherwise specified, the tolerance shall be minus tolerance.

Rivets shall be driven when hot so as to fill the hole as completely as possible and shall be of sufficient length to form a head of standard dimension. When counter-sunk head is required, the head shall fill the counter-sunk hole. Projection after counter-sinking shall be ground off wherever necessary.

Rivets shall be heated uniformly to a "light cherry red" colour between 650 degrees Celsius to 700 degrees Celsius for hydraulic riveting and "orange colour" for pneumatic riveting of mild steel rivets and shall be red hot from head to the point when inserted and shall be upset in its entire length so as to fill the hole as completely as possible when hot. Rivets, after being heated and before being inserted in the hole shall be made free from scale by striking the hot rivet on a hard surface.

Wherever possible, the rivets shall be machine driven, preferably by direct acting riveters. The driving pressure shall be maintained on the rivets for a short time after the upsetting is completed. High tensile steel rivets shall be heated upto 1100 degrees Celsius. Any rivet whose point is heated more than prescribed, shall not be driven.

Where flush surface is required, any projecting metal shall be chipped or ground off.

Before riveting is commenced, all work shall be properly bolte up so that the various sections and plates are in close contact throughout. Drifts shall only be used for drawing the work into position and shall not be used to such an extent as to distort the holes. Drifts of a larger size than the nominal diameter of the hole shall not be used. The riveting shall be done by hydraulic or pneumatic machine unless otherwise specified by the Engineer.

Driven rivets, when struck sharply on the head by a quarter pound rivet testing hammer, shall be free from movement and vibrations. Assembled riveted joint surfaces, including those adjacent to the rivet

heads, shall be free from scale, dirt, loose scale, burrs, other foreign materials and defects that would prevent solid seating of parts.

All loose or burnt rivets and rivets with cracked or badly formed defective heads or with heads which are unduly eccentric with the shanks, shall be removed and replaced. In removing rivets, the head shall be sheared off and the rivet punched out so as not to injure the adjacent metal and, if necessary, they shall be drilled out. Recupping or recaulking shall not be permitted. The parts not completely riveted in the shop shall be secured by bolts to prevent damage during transport and handling.

1904.5. Bolts, Nuts and Washers

1904.5.1. Black bolts (black all over) : Black bolts are forged bolts in which the shanks, heads and nuts do not receive any further treatment except cutting of screw threads. They shall be true to shape and size and shall have the standard dimensions as shown on the drawings.

1904.5.2. Close tolerance bolts : Close tolerance bolts shall be faced under the head and turned on the shank.

1904.5.3. Turned barrel bolts : The diameter of the screwed portion of turned barrel bolts shall be 1.5 mm smaller than the diameter of the barrel unless otherwise specified by the Engineer. The diameter of the bolts as given on the drawing shall be the nominal diameter of the barrel. The length of the barrel shall be such that it bears fully on all the parts connected. The threaded portion of each bolt shall project through the nut by at least one thread. Faces of heads and nuts bearing on steel work shall be machined.

1904.5.4. High strength friction bolts and bolted connections : The general requirement shall be as per relevant IS specifications mentioned in clause 5.3 of (Fasteners) of IRC:24. Unless otherwise specified by the Engineer, bolted connections of structural joints using high tensile friction grip bolts shall comply with requirements mentioned in IS:4000.

1904.5.5. Washers : In all cases where the full bearing area of the bolt is to be developed, the bolt shall be provided with a steel washer under the nut of sufficient thickness to avoid any threaded portion of the bolt being within the thickness of the parts bolted together and to prevent the nut when screwed up, from bearing on the bolt.

For close tolerance or turned barrel bolts, steel washers whose faces give a true bearing shall be provided under the nut. The washer shall have a hole diameter not less than 1.5 mm larger than the barrel and

a thickness of not less than 6 mm so that the nut when screwed up, will not bear on the shoulder of the bolt.

Taper washers with correct angle of taper shall be provided under all heads and nuts bearing on bevelled surfaces.

Spring washers may be used under nuts to prevent slackening of the nuts when excessive vibrations occur.

Where the heads or nuts bear on timber, square washers having a length of each side not less than three times the diameter of bolts or round washers having a diameter of $3^1/_2$ times the diameter of bolts and with a thickness not less than one quarter of diameter shall be provided.

1904.5.6. Studs : Ordinary studs may be used for holding parts together, the holes in one of the parts being tapped to take the thread of the stud. Counter-sunk studs may be used for making connections where the surfaces are required to be clear of all obstruction, such as protruding heads of bolts or rivets, studs may also be welded on the steel work in the positions required.

1904.5.7. Service bolts : Service bolts shall have the same clearance as black bolts and where it is required that there should be no movement prior to final riveting, sufficient drifts or close tolerance bolts shall be used to locate the work.

1904.5.8. Tightening bolts : Bolted connection joints with black bolts and high strength bolts shall be inspected for compliance of codal requirements.

The Engineer shall observe the installation and tightening of bolts to ensure that correct tightening procedure is used and shall determine that all bolts are tightened. Regardless of tightening method used, tightening of bolts in a joint should commence at the most rigidly fixed or stiffest point and progress towards the free edges, both in initial snugging and in final tightening.

The tightness of bolts in connection shall be checked by inspection wrench, which can be torque wrench, power wrench or calibrated wrench.

Tightness of 10 per cent bolts, but not less than two bolts, selected at random in each connection shall be checked by applying inspection torque. If no nut or bolt head is turned by this application, connection can be accepted as properly tightened, but if any nut or head has turned all bolts shall be checked and, if necessary, re-tightened.

1904.5.9. Drifts : The barrel shall be drawn or machined to the required diameter for a length of not less than one diameter over the combined thickness of the metal through which the drifts have to pass. The diameter of the parallel barrel shall be equal to the nominal diameter of the hole subject to a tolerance of +0 mm and -0.125 mm. Both ends of the drift for a length equal to $1^1/_2$ times the diameter of the parallel portion of the bar shall be turned down with a taper to a diameter at the end equal to one-half that of parallel portion.

1904.6. Pins and Pin Holes

1904.6.1. Pins : The pins shall be parallel throughout and shall have a smooth surface free from flaws. They shall be of sufficient length to ensure that all parts connected thereby shall have a full bearing on them. Where the ends are threaded, they shall be turned to a smaller diameter at the ends for the thread and shall be provided with a pilot nut, where necessary, to protect the thread when being drawn to place.

Pins more than 175 mm in length or diameter shall be forged and annealed.

1904.6.2. Pin holes : Pin holes shall be bored true to gauge, smooth, straight at right angles to the axis of the member and parallel with each other, unless otherwise required. The tolerance in the length of tension members from outside to outside of pin holes and of compression members from inside to inside of pin holes shall be one millimetre. In built-up members, the boring shall be done after the members have been riveted or welded.

The specified diameter of the pin hole shall be its minimum diameter. The resulting clearance between the pin and the hole shall not be less than 0.5 mm and not more than 1.0 mm.

1904.7. Shop Erection and Match Marking

Before being dispatched, the steel work shall be temporarily erected in the fabrication shop for inspection by the Engineer either wholly or in such portion as the Engineer may require so that he may be satisfied both in respect of the alignment and fit of all connections. For this purpose, sufficient number of parallel drifts and service bolts tightly screwed up shall be employed. All parts shall fit accurately and be in accordance with drawings and specifications.

The steel work shall be temporarily assembled at place of fabrication.

Assembly shall be of full truss or girder, unless progressive truss or girder assembly, full chord assembly, progressive chord assembly or special complete structure assembly is specified by the Engineer.

The field connections of main members of trusses, arches, continuous beams, spans, bends, plate girders and rigid frame assembled, aligned, accuracy of holes and camber shall be checked by Engineer and then only reaming of sub-size holes to specified size shall be taken up.

After the work has been passed by the Engineer and before it is dismantled, each part shall be carefully marked for re-erection with distinguishing marks and stamped with durable markings. Drawings showing these markings correctly shall be supplied to the Engineer.

Unloading, handling and storage of steel work as per these specifications shall be the responsibility of the Contractor. The cost of repairs or of rejected material, its removal and the cost of transporting replacement material to the site shall be borne by the Contractor.

Where close tolerance or turned barrel bolts are used for those cases where interchangeability is not insisted upon, each span shall be erected and members of each span marked distinctly.

1904.8. Welding

1904.8.1. All welding shall be done with the prior approval of the Engineer and the workmanship shall conform to the specifications of IS:823 or other relevant Indian Standards as appropriate.

When material thickness is 20 mm or more, special precautions like preheating shall be taken as laid down in IS:823. Surfaces and edges to be welded shall be smooth, uniform and free from fins, tears, cracks and other discontinuities. Surface shall also be free from loose or thick scale, slag rust, moisture, oil and other foreign materials. Surfaces within 50 mm of any weld location shall be free from any paint or other material that may prevent proper welding or cause objectionable fumes during welding.

The general welding procedures including particulars of the preparation of fusion faces for metal arc welding shall be carried out in accordance with IS:9595.

The welding procedures for shop and site welds including edge preparation of fusion faces shall be submitted in writing in accordance with Clause 22 of IS:9595 for the approval of the Engineer before commencing fabrication and shall also be as per details shown on the

drawings. Any deviation from above has to be approved by Engineer. Preparation of edges shall, wherever practicable, be done by machine methods.

Machine flame cut edges shall be substantially as smooth and regular as those produced by edge planing and shall be left free of slag. Manual flame cutting shall be permitted by the Engineer only where machine cutting is not practicable.

Electrodes to be used for metal arc welding shall comply with relevant IS specifications mentioned in IRC:24. Procedure test shall be carried out as per IS:8613 to find out suitable wire-flux combination for welded joint.

Assembly of parts for welding shall be in accordance with provisions of IS:9595.

The welded temporary attachment should be avoided as far as possible, otherwise the method of making any temporary attachment shall be approved by the Engineer. Any scars from temporary attachment shall be removed by cutting, chipping and surface shall be finished smooth by grinding to the satisfaction of the Engineer.

Welding shall not be done when the air temperature is less than 10 degrees Celsius. Welding shall not be done when the surfaces are moist, during periods of strong winds or in snowy weather unless the work and the welding operators are adequately protected.

1904.8.2. For welding of any particular type of joint, welders shall qualify to the satisfaction of the Engineer in accordance with appropriate welders qualification test as prescribed in any of the Indian Standards IS:817, IS:1966, IS:1393, IS:7307 (part I), IS:7310 (Part I) and IS:7318 (part I) as relevant.

1904.8.3. In assembling and joining parts of a structure or of built-up members, the procedure and sequence of welding shall be such as to avoid distortion and minimise shrinkage stress.

All requirements regarding pre-heating of parent material and interpass temperature shall be in accordance with provision of IS:9595.

1904.8.4. Peening of weld shall be carried out wherever specified by the Engineer :

a) If specified, peening may be employed to be effective on each weld layer except first.

b) The peening should be carried out after weld has cooled by light blows from

a power hammer using a round nose tool. Care shall be taken to prevent scaling or flaking of weld and base metal from over peening.

1904.8.5. Where the Engineer has specified the butt welds are to be ground flush, the loss of parent metal shall not be greater than that allowed for minor surface defects. The ends of butt joints shall be welded so as to provide full throat thickness. This may be done by use of extension pieces, cross runs or other means approved by the Engineer. Extension pieces shall be removed after the joint has cooled and the ends of the weld shall be finished smooth and flush with the faces of the abutting parts.

The joints and welds listed below are prohibited type, which do not perform well under cyclic loading.

a) Butt joints not fully welded throughout their cross-section

b) Groove welds made from one side only without any backing grip

c) Intermittent groove welds

d) Intermittent fillet welds

e) Bevel-grooves and J-grooves in butt joints for other than horizontal position.

f) Plug and slot welds

1904.8.6. The run-on and run-off plate extension shall be used providing full throat thickness at the end of butt welded joints. These plates shall comply with the following requirements.

(i) One pair of "run-on" and one pair of "run-off" plates prepared from same thickness and profile as the parent metal shall be attached to start and finish of all butt welds preferably by clamps.

(ii) When "run-on" and "run-off" plates shall be removed by flame cutting, it should be cut at more than 3 mm from parent metal and remaining metal shall be removed by grinding or by any other method approved by the Engineer.

1904.8.7. Welding of stud shear connectors : The stud shear connectors shall be welded in accordance with the manufacturer's instructions including preheating.

The stud and the surface to which studs are welded shall be free from scale, moisture, rust and other foreign material. The stud base shall not be painted, galvanised or cadmium plated prior to welding.

Welding shall not be carried out when temperature is below 10 degrees Celsius or surface is wet or during periods of strong winds unless the work and the welder is adequately protected.

The welds shall be visually free from cracks and shall be capable of developing at least the nominal ultimate strength of studs.

The procedural trial for welding the stud shall be carried out when specified by the Engineer.

1904.9. Tolerances

Tolerances in dimensions of components of fabricated structural steel work shall be specified on the drawings and shall be subject to the approval of the Engineer before fabrication. Unless specified, all parts of an assembly shall fit together accurately within tolerances specified in Table 1900-2.

A machined bearing surface, where specified by the Engineer, shall be machined within a deviation of 0.25 mm for surfaces that can be inscribed within a square of side 0.5 m.

TABLE 1900-2 FABRICATION TOLERANCES

A.	INDIVIDUAL COMPONENTS	
1.	Length	
	a) Member with both ends finished for contact bearing	± 1 mm
	b) Individual components of members with end plate connection	+ 0 mm - 2 mm
	c) Other members	
	i) Upto and including 12 M	±2 mm
	ii) Over 12 M	±3.5 mm
2.	Width	
	a) Width of built-up girders	±3 mm
	b) Deviation in the width of members required to be inserted in other members	+0 mm -3 mm
3.	Depth	
	Deviation in the depths of solid web and open web girders	+3 mm -2 mm
4.	Straightness	
	a) Deviation from straightness of columns	L/3000 subject to a maximum of 15 mm where L is length of member
	i) In elevation	+5 mm -0 mm
	ii) In plan	L/1000 subject to a maximum of 10 mm
5.	Deviation of centre line of web from centre line of flanges in built-up members at contact surfaces	3 mm

6.	Deviation from flatness of plate of webs of built-up members in a length equal to the depth of the member	0.005 d to a maximum of 2 mm where d is depth of the member
7.	Tilt of flange of plate girders	
	a) At splices and stiffeners, at supports, at the top flanges of plate girders and at bearings	0.005 b to a minimum of 2 mm where b is width of the member
	b) at other places	0.015 b to a maximum of 4 mm where b is width of the member
8.	Deviation from squareness of flange to web of columns and box girders	L/1000, where L is nominal length of the diagonal
9.	Deviation from squareness of fixed base plate (not machined) to axis of column. This dimension shall be measured parallel to the longitudinal axis of the column at points where the outer surfaces of the column sections make contact with the base plate	D/500, where D is the distance from the column axis to the point under consideration on the base plate
10.	Deviation from squareness of machined ends to axes of columns	D/1000, where D is as defined in 9 above
11.	Deviation from squareness of machined ends to axes of beams or girder	D/1000, where D is as defined in 9 above
12.	Ends of members abutting at joints through cleats or end plates, permissible deviation from squareness of ends	1/600 of depth of member subject to a maximum of 1.5 mm

1905. ERECTION

1905.1. General

The provisions of this item shall apply to erection of steel bridge superstructures or main members of bridge superstructures, composed of steel, which span between supports.

If the sub-structure and the superstructure are built under separate contracts, the department will provide the substructure, constructed to correct lines, dimensions and elevations properly finished and will establish the lines and the elevation required for setting steel.

The Contractor shall erect the structural steel, remove the temporary construction, and do all the work required to complete the construction included in the contract in accordance with the drawings and the specifications and to the entire satisfaction of the Engineer.

1905.2. Organisation and Equipment

The Contractor shall submit erection plans prepared by the fabricator, showing a method and procedure of erection, compatible with the details of fabrication.

A detailed scheme must be prepared showing stage-wise activities, with complete drawings and working phase-wise instructions. This should be based on detailed stage-wise calculation and take into account specifications and capacity of erection equipment machinery, tools, tackles to be used and temporary working loads as per Codal provisions.

The scheme should be based on site conditions e.g. hydrology, rainfall, flood timings and intensity, soil and sub-soil conditions in the river bed and banks, maximum water depth, temperature and climatic conditions and available working space, etc.

The scheme should indicate precisely the type of temporary fasteners to be used as also the minimum percentage of permanent fasteners to be fitted during the stage erection. The working drawings should give clearly the temporary jigs, fixtures, clamps, spacer supports, etc.

Unless otherwise provided in the contract, the contractor shall supply and erect all necessary falsework and staging and shall supply all labour, tools, erection plant and other materials necessary to carry out the work complete in all respects.

The Contractor shall supply all rivets, bolts, nuts, washers, etc. required to complete erection at site with an allowance for wastage, etc., of 12 $^{1}/_{2}$ per cent of the net number of field rivets, bolts, washers required, or a minimum of five number of each item.

Service bolts and nuts, ordinary platters, washers and drifts for use in the erection of work shall be supplied at 60 per cent (45 per cent bolts and 15 per cent drifts) of the number of field rivets per span in each size (this includes wastage). A reduction in the quantities of service bolts, etc., may however, be specified by the Engineer if more than one span of each type is ordered.

Prior to actual commencement of erection all equipment, machinery, tools, tackles, ropes, etc. need to be tested to ensure their efficient

working. Frequent visual inspection is essential in vulnerable areas to detect displacements, distress, drainages, etc.

Deflection and vibratory tests shall be conducted in respect of supporting structures, launching truss as also the structure under erection and unusual observations reviewed; looseness of fittings are to be noted.

For welded structures, welders' qualificatons and skill are to be checked as per standard norms. Non-destructive tests of joints as per designer's directives are to be carried out.

Precision non-destructive testing instruments available in the market should be used for noting various important parameters of the structures frequently and systematic record is to be kept.

Safety requirements should conform to IS:7205, IS:7273 and IS:7269 as applicable and should be a consideration of safety, economy and rapidity.

Erection work should start with complete resources mobilised as per latest approved drawings and after a thorough survey of foundations and other related structural work. In case of work of magnitude, maximum mechanisation is to be adopted.

The structure should be divided into erectable modules as per the scheme. This should be pre-assembled in a suitable yard/platform and its matching with members of the adjacent module checked by trial assembly before erection.

The structure shall be set out to the required lines and levels. The stocks and masses are to be carefully preserved. The steelwork should be erected, adjusted and completed in the required position to the specified line and levels with sufficient drifts and bolts. Packing materials are to be available to maintain this condition. Organised "Quality Surveillance" checks need to be exercised frequently.

Before starting work, the Contractor shall obtain necessary approval of the Engineer as to the method adopted for erection, the number and character of tools and plants. The approval of the Engineer shall not relieve the Contractor of his responsibility for the safety of his method or equipment or from carrying out the work fully in accordance with the drawings and specifications.

During the progress of work, the Contractor shall have a competent Engineer or foreman in charge of the work, who shall be adequately experienced in steel erection and acceptable to the Engineer.

1905.3. Handling and Storing of Materials

Suitable area for storage of structures and components shall be located near the site of work. The access road should be free from water logging during the working period and the storage area should be on levelled and firm ground.

The store should be provided with adequate handling equipments e.g road mobile crane, gantries, derricks, chain pulley blocks, winch of capacity as required. Stacking area should be planned and have racks, stands sleeper, access tracks, etc., and properly lighted.

Storage should be planned to suit erection work sequence and avoid damage or distortion. Excessively rusted, bent or damaged steel shall be rejected. Methods of storage and handling steel, whether fabricated or not shall be subject to the approval of the Engineer.

Fabricated materials are to be stored with erection marks visible, such as not to come into contact with earth surface or water and should be accessible to handling equipment.

Small fitting hand tools are to be kept in containers in covered stores.

All materials, consumables, including raw steel or fabricated material shall be stored specification-wise and size-wise above the ground upon platforms, skids or other supports. It shall be kept free from dirt and other foreign matter and shall be protected as far as possible from corrosion and distortion. The electrodes shall be stored specification-wise and shall be kept in dry warm condition in properly designed racks. The bolts, nuts, washers and other fasteners shall be stored on racks above the ground with protective oil coating in gunny bags. The paint shall be stored under cover in air-tight containers.

IS:7293 and IS:7969 dealing with handling of materials and equipments for safe working should be followed. Safety nuts and bolts as directed are to be used while working. The Contractor shall be held responsible for loss or damage to any material paid for by the Department while in his care or for any damage to such material resulting from his work.

1905.4. Formwork

The formwork shall be properly designed, substantially built and maintained for all anticipated loads. The Contractor, if required, shall submit plans for approval to the Engineer. Approval of the plans, however, shall not relieve the Contractor of his responsibility.

1905.5. Straightening Bent Material

The straightening of plates, angles and other shapes shall be done by methods not likely to produce fracture or any injury. The metal shall not be heated unless permitted by the Engineer for special cases, when the heating shall not be to a temperature higher than that producing a dark "cherry red" colour, followed by as slow cooling as possible. Following the straightening of a bend or buckle the surface shall be carefully investigated for evidence of fracture. Sharp kinks and bends may be the cause for rejection of material.

1905.6. Assembling Steel

The parts shall be accurately assembled as shown on the drawings and match marks shall be followed. The material shall be carefully handled so that no parts will be bent, broken or otherwise damaged.

Hammering which will injure or distort the members shall not be done. Bearing surface or surfaces to be in permanent contact shall be cleaned, before the members are assembled. The truss spans shall be erected on blocking, so placed as to give the proper camber. The blocking shall be left in place until the tendon chord splices are fully riveted and all other truss connections pinned and bolted. Rivets in splices of butt joints of compression members and rivets in railings shall not be driven until the span has been swung.

All joint surface for bolted connections including bolts, nuts,washers shall be free from scale, dirt, burrs, other foreign materials and defects that would prevent solid seating of parts. The slope of surface of bolted parts in contact with bolt head and nut shall not exceed 1 in 20, plane normal to bolt axis, otherwise suitable tapered washer shall be used.

All fasteners shall have a washer under nut or bolt head whichever is turned in tightening.

Any connection to be riveted or bolted shall be secured in close contact with service bolts or with a sufficient number of permanent bolts before the rivets are driven or before the connections are finally bolted. Joints shall normally be made by filling not less than 50 per cent of holes with service bolts and barrel drifts in the ratio 4:1. The service bolts are to be fully tightened up as soon as the joint is assembled. Connections to be made by close tolerance or barrel bolts shall be completed as soon as practicable after assembly.

Any connection to be site welded shall be securely held in position by approved methods to ensure accurate alignment, camber and elevation before welding is commenced.

The field riveting, welding, bolted and pin connection shall conform to the requirements of Clause 1904 as appropriate.

The correction of minor misfits involving harmless amounts of reaming, cutting and chipping will be considered a legitimate part of erection. However, any error in the shop fabrication or deformation resulting from handling and transportation which prevents proper assembling and fitting up of parts by moderate use of drifts or by a moderate amount of reaming and slight chipping or cutting shall be reported immediately to the Engineer and his approval of the method of correction obtained. The correction shall be made in the presence of the Engineer.

1905.7. Field Inspection

1905.7.1. General

All materials, equipment and work of erection shall be subject to the inspection of the Engineer who shall be provided with all facilities including labour and tools required at all reasonable times. Any work found defective is liable to be rejected.

1905.7.2. No protective treatment shall be applied to the work until the appropriate inspection and testing has been carried out. The stage inspection shall be carried out for all operations so as to ensure the correctness of fabrication and good quality. Girder dimensions and camber shall not be finally checked until all welding and heating operations are completed and the member has cooled to a uniform temperature.

1905.7.3. Testing of material : Structural steel shall be tested for mechanical and chemical properties as per various IS codes as may be applicable and shall conform to requirements specified in IS:226, IS:2062, IS:11587, IS:1977, IS:8500 and IS:961, etc.

Rivets, bolts, nuts, washers, welding consumables, steel forging, casting and stainless steel shall be tested for mechanical and chemical properties in the appropriate IS Code.

Rolling and cutting tolerance shall be as per IS:1852. The thickness tolerance check measurements for the plate and rolled sections shall be taken at not less than 15 mm from edge.

Laminations in plates shall be carried out by ultra-sonic testing or any other specified methods.

Steel work shall be inspected for surface defects and exposed edge laminations during fabrication and blast cleaning. Significant edge laminations found shall be reported to the Engineer for his decision.

Chipping, grinding, machining or ultrasonic testing shall be used to determine depth of imperfection.

1905.7.4. Bolted connections : Bolts and bolted connection joints with high strength friction grip bolts shall be inspected and tested according to IS:4000.

Rivets and riveted connection shall be inspected and tested for compliance of codal requirements.

The firmness of joint shall be checked by 0.2 mm filler gauge, which shall not go inside under the rivet head by more than 3 mm. There shall not be any gap between members to be riveted.

Driven rivets shall be checked with rivet testing hammer. When struck sharply on head with rivet testing hammer, rivet shall be free from movement and vibration.

All loose rivets and rivets with cracks, badly formed or deficient heads or with heads which are eccentric with shanks, shall be cut out and replaced.

The alignment of plates at all bolted splice joints and welded butt joints shall be checked for compliance with codal requirements.

Testing of flame cut and sheared edges is to be done, where the hardness criteria given in the code are adopted. Hardness testing shall be carried out on six specimens.

1905.7.5. Welding and welding consumables : Welding procedure, welded connection and testing shall be in compliance with codal requirements.

All facilities necessary for stage inspection during welding and on completion shall be provided to the Engineer or their inspecting Authority by manufacturer.

Adequate means of identification either by identification mark or other record shall be provided to enable each weld to be traced to the welder(s) by whom it was carried out.

All metal arc welding shall be in compliance with IS:9595 provisions.

The method of inspection shall be in accordance with IS:822 and extent of inspection and testing shall be in accordance with the relevant standards or in the absence of such a standard, as agreed with the Engineer.

Procedure tests

The Destructive and Non-Destructive test of weld shall be carried out according to IS:7307 (Part I).

Non-Destructive Testing of Welds

One or more of the following methods may be applied for inspection or testing of weld :

(i) Visual Inspection : All welds shall be visually inspected, which should cover all defects of weld such as size, porosity, crack in the weld or in the HAZ (Heat Affected Zone) etc. Suitable magnifying glass may be used for visual inspection. A weld shall be acceptable by visual inspection if it shows that :

a) The weld has no cracks.

b) Through fusion exists between weld and base metal and between adjacent layers of weld metal.

c) Weld profiles are in accordance with requisite clauses of IS:9595 or as agreed with the Engineer.

d) The weld shall be of full cross section, except for the ends of intermittent fillet welds outside their effective length.

e) When weld is transverse to the primary stress, undercut shall not be more than 0.25 mm deep in the part that is undercut and shall not be more than 0.8 mm deep when the weld is parallel to the primary stress in the part that is undercut.

f) The fillet weld in any single continuous weld shall be permitted to under run the nominal fillet weld size specified by 1.6 mm without correction provided that undersize portion of the weld does not exceed 10 per cent of the length of the weld. On the web-to-flange welds on girders, no underrun is permitted at the ends for a length equal to twice the width of the flange.

g) The piping porosity in fillet welds shall not exceed one in each 100 mm of weld length and the maximum diameter shall not exceed 2.4 mm, except for fillet welds connecting stiffeners to web where the sum of diameters of piping porosity shall not exceed 9.5 mm in any 25 mm length of weld and shall not exceed 19 mm in any 300 mm length of weld.

h) The full penetration groove weld in butt joints transverse to the direction of computed tensile stress shall have no piping porosity. For all other groove welds, the piping porosity shall not exceed one in 100 mm of length and the maximum diameter shall not exceed 2.4 mm.

(ii) Magnetic Particle and Radiographic Inspection: Welds that are subject to radiographic or magnetic particle testing in addition to visual inspection shall have no crack.

Magnetic particle test shall be carried out for detection of crack and other discontinuity in the weld according to IS:5334.

Radiographic test shall be carried out for detection of internal flaws in the weld such as crack, piping porosity inclusion, lack of fusion, incomplete penetration, etc. This test mat be carried out as per IS:1182 and IS:4853.

Acceptance Criteria : The weld shall be unacceptable if radiographic or magnetic particle testing shows any of the type of discontinuities indicated in the code.

(iii) Ultrasonic Inspection : The Ultrasonic testing in addition to visual inspection shall be carried out for detection of internal flaws in the weld such as cracks, piping porosity inclusion, lack of fusion, incomplete penetration, etc. Acceptance criteria shall be as per IS:4260 or any other relevant IS Specification and as agreed to by the Engineer.

iv) Liquid Penetration Inspection : The liquid penetrant test shall be carried out for detection of surface defect in the weld, as per IS:3658, in addition to visual inspection.

The non-destructive testing of following welds be carried out using one of the method or methods described at (ii),(iii) and (iv) above, as may be agreed to by the Engineer.

a) All transverse butt welds in tension flange

b) 10 per cent of the length of longitudinal and transverse butt welds in tension flanges.

c) 5 per cent of the length of longitudinal and transverse butt welds in compression flanges.

d) All transverse butt welds in webs adjacent to tension flanges as specified by the Engineer.

The particular length of welds in webs to be tested shall be agreed with the Engineer, in case of (b) or (c).

Where specified by the Engineer, bearing stiffeners or bearing diaphragms adjacent to welds, flange plates adjacent to web/flange welds, plates at cruciform welds, plates in box girder construction adjacent to corner welds or other details shall be ultrasonically tested after fabrication.

Any lamination, lamellar tearing or other defect found shall be recorded and reported to Engineer for his decision.

Testing of Welding for Cast Steel : The testing of weld for cast steel shall be carried out as may be agreed to by the Engineer.

Stud Shear Connectors : Stud shear connectors shall be subjected to the following tests :

a) The fixing of studs after being welded in position shall be tested by striking the side of the head of the stud with a 2 kg hammer to the satisfaction of the Engineer.

b) The selected stud head stroked with 6 kg hammer shall be capable of lateral displacement of approximately 0.25 the height of the stud from its original position. The stud weld shall not show any sign of crack or lack of fusion.

The studs whose welds have failed the tests given in (a) and (b) shall be replaced.

1905.7.6. Inspection requirement : The fabricated member/component made out of rolled and built-up section shall be checked for compliance of the tolerances given in Table 1900-2. Inspection of member/components for compliance with tolerances, and the check for deviations shall be made over the full length.

During checking, the inspection requirement shall be placed in such a manner that local surface irregularities do not influence the results.

For plate, out-of-plane deviation shall be checked at right angle to the surface over the full area of plate.

The relative cross-girder or cross frame deviation shall be checked over the middle third of length of the cross girder or frame between each pair of webs and for cantilever at the end of member.

The web of rolled beam or channel section shall be checked for out-of-plane deviation in longitudinal direction equal to the depth of the section.

During inspection, the component/member shall not have any load or external restraint.

Inspection Stages : The inspection to be carried out for compliance of tolerances shall include but not be limited to the following stages:

a) For completed parts, component/members on completion of fabrication and before any subsequent operation such as surface preparation, painting, transportation, erection.

b) For webs of plate and box girder, longitudinal compression flange stiffeners in box girders and orthotropic decks and all web stiffeners at site joints, on completion of site joint.

c) For cross girders and frames, cantilevers in orthotropic decks and other parts in which deviations have apparently increased on completion of site assembly.

Where, on checking member/component for the deviations in respect of out-of-plane or out-of-straightness at right angles to the plate surface, and any other instances, exceed tolerance, the maximum deviation shall be measured and recorded. The recorded measurements shall be submitted

to the Engineer who will determine whether the component/member may be accepted without rectification, with rectification or rejected.

1906. PAINTING

1906.1. General

Unless otherwise specified, all metal work shall be given approved shop coats as well as field coats of painting. The item of work shall include preparation of metal surfaces, application of protective covering and drying of the paint coatings and supply of all tools, scaffolding, labour and materials necessary.

Coatings shall be applied only to dry surfaces and the coated surfaces shall not be exposed to rain or frost before they are dry. The coatings shall be applied to all surfaces excluding shear connectors and inner surfaces of fully sealed hollow sections. Care shall be taken during coating of adjacent surfaces to build up primer on the shear connectors.

1906.1.1. Types of paints

(i) Ordinary Paints

These include paints based on drying oils, alkyd resin, modified alkyd resin, phenolic varnish epoxy, etc.

Alkyd resin paints for the protection of steel structures are based partly on natural oils and partly on synthetic resins. These paints shall be used for steel structures in atmospheres which are not too aggressive.

Oil based paints can be used for steel structures in cases where the surface preparation cannot be ideal. Ordinary painting can generally be sub-divided into two groups :

a) Primary Coats

This shall be applied immediately after the surface preparation and should have the properties of adhesion, corrosion inhibition and imperviousness to water and air.

b) Finishing Coats

These are applied over the primary coat and should have the properties of durability, abrasion resistance, aesthetic appearance and smooth finish.

(ii) Chemical Resistant Paints

The more highly corrosion resistant paints can be divided into two main groups :

a) One pack paints (ready for use)

b) Two pack paints (mixed before use)

The two pack paints shall be mixed together immediately before use since they are workable thereafter only for a restricted period of time and dry up as a result of a reaction between their components and yield hard tough films with resistance to abrasion.

(iii) Vinyl Paints

These are based on polyvinyl resins such as polyvinyl-chloride (PVC) and polyvinyl-acetate, etc.

Certain types of vinyl resin paints yield thick, relatively soft and rubber like coatings with good chemical resistance. They can be repainted without difficulty.

(iv) Chlorinated Rubber Paints

These paints also have good chemical resistance. The main fields of applications shall be in aggressive environments. In general, chlorinated rubber paints do not have a high gloss.

(v) Bituminous Paints

As a paint vehicle, bituminous is inferior, but because of the low price, this should be applied in greater thickness (upto several millimetres) and may be suitable for some situations. A significant advantage of bitumen paints is their impermeability to ingress of water. However, bituminous paints do not withstand effectively detrimental effects of oil.

(vi) Epoxy Paints

These resin paints have good adherence to a well prepared sub-strata. They are mechanically strong and resistant to chemicals. A disadvantage of epoxy resin paints is that it can rapidly become dull when exposed to strong sunlight. These disadvantages do not, however, greatly influence their protective power.

(vii) Polyurethane Paints

The chemical and mechanical behaviour of polyurethane paint resembles those of epoxy paint very much. However, polyurethane paint retains its gloss for a longer period. Because of the high price of

polyurethane paint, a combination of the two viz., polyurethane and epoxy paints may sometimes be used.

(viii) Zinc Rich Paints

Instead of introducing an inhibitive pigment into paint, metallic zinc can be used and such paints can provide cathodic protection to steel.

1906.1.2. Surfaces which are inaccessible for cleaning and painting after fabrication shall be painted as specified before being assembled for riveting.

All rivets, bolts, nuts, washers etc., are to be thoroughly cleaned and dipped into boiling linseed oil conforming to IS:77.

All machined surfaces are to be well coated with a mixture of white lead conforming to IS:34 and Mutton Tallow conforming to IS:887.

For site paintings, the whole of the steel work shall be given the second cover coat after final passing and after touching up the primer and cover coats, if damaged in transit.

1906.1.3. Choice of painting system

The choice of suitable painting system is dependent on factors such as:

- Available application methods viz. brush, roller or spray
- Durability in a specific environment
- Availability of skilled manpower
- Cost / benefit etc.

It is therefore necessary to consult various manufacturers of paint and ascertain the above aspects while deciding on the appropriate choice of painting system.

1906.1.4. Quality of paint : The paints which have been tested for the following qualities as per the specifications given in the relevant IS codes should only be used :

- Weight Test (weight per 10 litre of paint thoroughly mixed)
- Drying time
- Flexibility and Adhesion
- Consistency
- Dry thickness and rate of consumption

1906.1.5. Unless otherwise specified, all painting and protective coating work shall be done in accordance with IS:1477 (Part 1).

1906.2. Surface Preparation

Steel surface to be painted either at the fabricating shop or at the site of work shall be prepared in a thorough manner with a view to ensuring complete removal of mill scale by one of the following processes as agreed to between the fabricator and the Engineer :

a) Dry or wet grit / Sand blasting

b) Pickling which should be restricted to single plates, bars and sections

c) Flame cleaning

Primary coat shall be applied as soon as practicable after cleaning and in case of flame cleaning, primary coat shall be applied while the metal is still warm.

All slag from welds shall be removed before painting. Surfaces shall be maintained dry and free from dirt and oil. Work out of doors in frosty or humid weather shall be avoided.

1906.3. Coatings

Prime coat to be used shall conform to the specification of primers approved by the Engineer. Metal coatings shall be regarded as priming coatings. Primer shall be applied to the blast cleaned surface before any deterioration of the surface is visible. In any case, the surface shall receive one coat of primer within 4 hours of abrasive blast cleaning.

All coats shall be compatible with each other. When metal coatings are used, the undercoat shall be compatible with the metal concerned. The undercoat and finishing coat shall preferably be from the same manufacturer. Successive coats of paints shall be of different shades or colours and each shall be allowed to dry thoroughly before the next is applied. Particular care shall be taken with the priming and painting of edges, corners, welds and rivets. Typical guidelines for epoxy based paints and the conventional painting system for bridge girders as given below may be complied with :

a) **Epoxy Based Painting**

i) Surface preparation : Remove oil/grease by use of petroleum hydrocarbon solution (IS:1745) and Grit blasting to near white metal surface.

ii) Paint system: 2 coats of epoxy zinc phosphate primer = 60 micron ; Total 5 coats = 200 micron

b) **Conventional Painting System for areas where corrosion is not severe**

Priming Coat :

One heavy coat or ready mixed paint, red lead primer conforming to IS:102

or

One coat of ready mixed zinc chrome primer conforming to IS:104 followed by one coat of ready mixed red oxide zinc chrome primer conforming to IS:2074.

or

Two coats of zinc chromates red oxide primer conforming to IS:2074

Finishing Coats :

Two cover coats of red oxide paint conforming to IS:123 or any other approved paint shall be applied over the primer coat. One coat shall be applied before the fabricated steel work leaves the shop. After the steel work is erected at site, the second coat shall be given after touching up the primer and the cover coats if damaged in transit.

c) **Conventional Painting System for areas where corrosion is severe**

Priming Coat :

Two coats of ready mixed red lead primer conforming to IS:102

or

One coat of ready mixed zinc chrome primer conforming to IS:104 followed by one coat of zinc chromate conforming oxide primer to IS:2074.

Finishing Coats :

Two coats of aluminum paint conforming to IS:2339 shall be applied over the primer coat. One coat shall be applied before the fabricated steel work leaves the shop. After the steel work is erected at site, the second coat shall be given after touching up the primer and the cover coats if damaged in transit.

1906.4. Painting in the Shop

All fabricated steel shall be painted in the shops after inspection and acceptance with at least one priming coat, unless the exposed surfaces are subsequently to be cleaned at site or are metal coated. No primer shall be applied to galvanised surfaces.

Shop contact surfaces, if specifically required to be painted, shall be brought together while the paint is still wet.

Field contact surfaces and surfaces to be in contact with cement shall be painted with primer only. No paint shall be applied within 50mm of designed location of field welds. Paint shall be completely dried before loading and transporting to site.

Surface not in contact but inaccessible after shop assembly shall receive the fully specified protective treatment before assembly.

Where surfaces are to be welded, the steel shall not be painted or metal coated within a suitable distance from any edges to be welded if the specified paint or metal coating would be harmful to welders or is expected to impair the quality of site welds.

Exposed machined surfaces shall be adequately protected.

1906.5. Painting at Site

Surfaces which will be inaccessible after site assembly shall receive the full specified protective treatment before assembly.

Surfaces which will be in contact after site assembly shall receive a coat of paint (in addition to any shop priming) and shall be brought together while the paint is still wet.

Damaged or deteriorated paint surfaces shall be first made good with the same type of coat as the shop coat.

Where steel has received a metal coating in the shop, this coating shall be completed on site so as to be continuous over any welds, bolts and site rivets.

Specified protective treatment shall be completed after erection.

1906.6. Methods of Application

The methods of application of all paint coatings shall be in accordance with the manufacturer's written recommendation and shall be as approved by the Engineer. Spray painting may be permitted provided it will not cause inconvenience to the public and is appropriate to the type of structure being coated. Areas hard to gain access to for painting and areas shaded for spray application shall be coated first by brushing.

Oil based red lead primers must be applied by brush only, taking care to work into all corners and crevices.

The primer, intermediate and finishing coats shall all be applied so

as to provide smooth coatings of uniform thickness. Wrinkled or blistered coatings or coatings with pinholes, sags, lumps or other blemishes shall not be accepted. Where the Engineer so directs, the coating shall be removed by abrasive blast cleaning and replaced at the Contractor's expense.

1906.7. Guideline of Specifications for Protective Coating System in Different Environments

Since the seriousness of the problem of corrosion depends upon atmospheric conditions and these vary enormously, there is no single protective system or method of application that is suitable for every situation.

However, as a guide, broad recommendations are given in Table 1900-3 for various types of coatings in various environmental conditions which should be complied with. Approximate life to first maintenance is also indicated and can be used as a guide.

TABLE 1900-3 : RECOMMENDATIONS FOR TYPES OF PROTECTIVE COATINGS

	System	Environment
i)	Wire brush to remove all loose rust and scale; 2 coats drying oil type primer; 1 under coat alkyd type paint; 1 finishing coat alkyd type. Total dry film thickness = 150 μm	Suitable for mild conditions where appearance is of some importance and where regular maintenance is intended. This system may deteriorate to a marked extent if it is exposed to moderate aggressive atmospheric conditions for lengthy period
ii)	Wire brush to remove all loose rust and scale; 2 coats drying oil type primer; 2 under coats micaceous iron oxide (MXO) pigmented phenolic modified drying oil. Total dry film thickness = 170 μm	Similar to (i) but where appearance is not very important provides longer life in mild condition. Will provide upto 5 years life to first maintenance in polluted inland environment
	'lean the surface; 2 coats ring primer; paint; 1 pe. ness :	Compared to (i), this would provide a longer life in mild conditions and could be used in less mild situation e.g. inland polluted, where maintenance could easily be carried out at regular intervals
	an the surface; 2 coats of g type oil primer; 1 undercoat icaceous iron oxide pigmented drying oil type paint. Total dry film thickness : 165 - 190 μm	Suitable for general structural steel work exposed to ordinary polluted inland environments where appearance is not of primary importance.

v)	Blast clean the surface; 2 coats of metallic lead pigmented chlorinated rubber primer, 1 undercoat of high build chlorinated rubber; 1 finishing coat of chlorinated rubber. Total dry film thickness : 200 μm	Suitable for structures in reasonably aggressive conditions e.g. near the coast. Will provide long-term protection than (iv) in non-coastal situations. Also suitable for aggressive interior situations such as industrial areas.
vi)	Blast clean the surface; 350 - 450 μm thickness. coal tar epoxy.	Suitable for sea water splash zones or for conditions of occurrence of frequent salt sprays.
vii)	Pickle; hot dip galvanised (Zinc). Total thickness : 85 μm	Suitable for steel work in reasonably mild conditions Life of 15-20 years before first maintenance could be expected in many situations
viii)	Grit blast, hot dip galvanised. (Zinc). Total thickness = 140 μm	Provides a longer life than (vii) because of thicker zinc coating
ix)	Grit blast; 1 coat of sprayed zinc/ aluminum followed by suitable sealer Total thickness = 150 μm	Expected to provide long term protection approx 15-20 years in aggressive atmosphere

1907. TESTS AND STANDARDS OF ACCEPTANCE

The materials shall be tested in accordance with relevant IS specifications and necessary test certificates shall be furnished. Additional tests, if required, shall be got carried out by the Contractor at his own cost.

The fabrication, furnishing, erecting, painting of structural steel work shall be in accordance with these specifications and shall be checked and accepted by the Engineer.

1908. MEASUREMENTS FOR PAYMENT

The measurements of this item shall be in tonnes based on the net weight of metal in the fabricated structure computed on the basis of nominal weight of materials.

The weight of rolled and cast steel and cast iron shall be determin from the dimensions shown on the drawings on the following b

- Rolled or cast steel : 7.84×10^{-3} kg/cu. cm.
- Cast Iron : 7.21×10^{-3} kg/cu. cm.

Weight of structural sections shall be nominal weight

Weight of castings shall be computed from the dimensions show on the drawings with an addition of 5 per cent for fillets and over-runs.

Weight of weld fillets and the weight of protective coatings shall not be included.

Weight of rivet heads shall be computed by taking the weight of 100 snap heads as given in Table 1900-4.

When specially agreed upon, allowance for snap heads may be taken as a flat percentage of the total weight. This percentage may be taken as 3 per cent or modified by mutual agreement.

TABLE 1900-4 : WEIGHT OF RIVET HEADS

Dia of Rivet as manufactured mm	Weight of 100 snap heads kg
12	1.3
14	2.1
16	3.4
18	4.45
20	6.1
22	8.1
24	10.5
27	15.0
30	20.5
33	27.2

The Contractor shall supply detailed calculation sheets for the weight of the metal in the fabricated structure.

No additions shall be made for the weight of protective coating or weld fillets.

Where computed weight forms the basis for payment, the weight shall be calculated for exact cut sizes of members used in the structure, deductions being made for all cuts, except for rivet holes. Additions shall be made for the rivet heads as mentioned above.

When specially agreed upon, the basis for payment may be the bridge weight complete, according to specifications included in special provisions of the Contract.

1909. RATE

The contract unit rate for the completed structural steel work shall include the cost of all materials, labour, tools, plant and equipment required for fabrication, connections, oiling, painting, temporary erection, inspection, tests and complete final erection as shown on the drawings and as specified in these Specifications.