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GUIDELINES FOR FABRICATION AND ERECTION OF STEEL BRIDGES

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GUIDELINES FOR FABRICATION AND ERECTION OF STEEL BRIDGES

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GUIDELINES FOR FABRICATION AND ERECTION OF STEEL BRIDGES

INTRODUCTION

A need was felt during the deliberation on IRC:24 to have some Guidelines for Fabrication and Erection of Steel Bridges, since more and more steel bridges are being fabricated and erected for road use in our country.

The present document has been prepared for fabrication, incorporating the various items like testing of materials, preparatory works for fabrication and joining by welding, riveting and bolting.

It has also been considered necessary to add a few chapters on erection dealing with precautions safety measures, loads and forces to be taken note of and other issues considered relevant.

The Personnel of the Steel and Composite Structures Committee (B-5) is given below:

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Secretary General, Indian Roads Congress	

The B-5 Committee finally approved the draft document in its meeting held on 19.7.2014 for placing before the BSS Committee. The Bridges Specifications and Standards Committee (BSS) approved the draft document in its meeting held on 8th August 2014. The Executive Committee in its meeting held on 18th August 2014, approved the same document for placing it before the Council. The IRC Council in its 203rd meeting held at New Delhi on 19th and 20th August 2014, approved the document "Guidelines for Fabrication and Erection of Steel Bridges" for publishing.

1 FABRICATION

1.1 General

Fabrication shall be carried out as per the drawings issued by the Engineer. Work should be executed as per the relevant IS: Codes. Safe working procedure should be adopted at all time of the work. Working procedures should be environment friendly. Proper care should be taken to handle and store the raw-materials, in process materials and fabricated materials, so that they are easily identifiable. Work should be carried out by qualified personnel. Stage inspection should be carried out for ensuring proper quality. Joining methodology for welding, bolting and riveting should be carried out as per the clauses of the relevant IS Codes or as specified in the drawing and subsequently accepted by the engineer as per the Quality Assurance Plan (QAP).

1.2 Materials and Properties

The material properties given in this clause are nominal values, as given by various IS codes defining the material properties.

Structural Steel

All structural steel shall, before fabrication comply with the requirements of the latest revisions of the following Indian Standards.

IS 808	Dimensions for hot rolled steel beam, column, channel and angle sections
IS 1161	Steel Tubes for structural purposes
IS 1239 (Pt.1)	Steel tubes, tubular and other wrought steel fitting Part-1 Steel tubes
IS 1239(Pt.2)	Mild steel tubes, tubular and other steel fittings : Part-2 Steel pipe fittings
IS 1730	Dimensions for steel plates, sheets, strips and flats for general engineering purposes
IS 1732	Steel bars, round and square for structural and general engineering purposes
IS 1852	Rolling and cutting tolerances for hot rolled steel products
IS 2062	Hot rolled low medium and high strength structural steel
IS 4923	Hollow steel sections for structural use

IS 11587	Structural weather resistant steels
IS 12778	Hot-rolled parallel flange steel sections for beams, columns and bearing piles

Other Steels

Except where permitted with the specific approval of the authority, steels for machined parts and for uses in other than structural members or elements shall comply with the following or relevant Indian Standards.

IS 1875	Carbon Steel billets, blooms, slabs and bars for forgings
IS 6911	Stainless Steel Plate, Sheet and Strip

Casting and Forgings

Steel casting 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 and bars for forgings
IS 2004	Carbon steel forgings for general engineering purposes
IS 2644	High tensile steel castings
IS 2708	1.5 percent manganese steel castings for general engineering purposes
IS 4367	Alloy Steel forgings for general industrial use

Fasteners

Bolts, Nuts, Washers, and Rivets shall comply with the following or relevant IS standards, as appropriates :

IS 1148	Steel Rivets bars (Medium and high tensile) for structural purposes
IS 1149	High tensile steel rivet bars for structural purposes
IS 1363 (Pt.1 to Pt.3)	Hexagon heads bolts, screws, and nuts of products grades C (size range M 5 to M 64)
IS 1364 (Pt.1 to Pt.3)	Hexagon heads bolts, screws, and nuts of products grades A & B (size range M 1.6 to M 64)
IS 1367 (Pt.1 to Pt.18)	Technical supply conditions for threaded steel fasteners
IS 1929	Hot forges steel rivets for hot closing (12 to 36 mm diameter)
IS 2155	Cold forges solid steel rivets for hot closing (6 to 16 mm diameter)
IS 3640	Hexagon fit bolts

IS 4000	High strength bolts in steel structures – code of practice
IS 5369	General requirements for plain washers & lock washers
IS 5370	Plain washes with outside dia 3 x inside dia
IS 5372	Taper washers for channels (ISMC)
IS 5374	Taper washer for I beams (ISMB)
IS 5624	Foundation bolts
IS 6610	Heavy washers for steel structures
IS 6623	High strength structural nuts
IS 6649	Hardened and tempered washers for high strength structural bolts and nuts
IS 7002	Prevailing torque type steel hexagon nuts

Welding Consumables

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

IS 814	Covered electrodes for manual metal arc welding of carbon and carbon manganese steel
IS 1395	Low and medium alloy, steel covered electrodes for manual metal arc welding
IS 3613	Acceptance tests for wire flux combination for submerged arc welding
IS 6419	Welding rods and bare electrodes for gas shielded arc welding of structural steel
IS 6560	Molybdenum and chromium – molybdenum low allow steel welding rods and bare electrodes for gas shielded arc welding
IS 7280	Bare wire electrodes for submerged arc welding of structural steels

Welding

IS 812	Glossary of terms relating to welding and cutting of metals
IS 816	Code of practice for use of metal arc welding for general construction in mild steel
IS 822	Code of procedure for inspection of welds
IS 1024	Code of practice for use of welding in bridges and structures subject to dynamic loading
IS 1182	Recommended practice for radiographic examination of fusion welded butt joints in steel plates

IS 4853	Recommended practice for radiographic inspection of fusion welded butt joints in steel pipes
IS 5334	Code of practice for magnetic particle flaw detection of welds
IS 7307(Pt.1)	Approval tests for welding procedures : Part-1 fusion welding of steel
IS 7310 (Pt.1)	Approval tests for welders working to approved welding procedures Part-1 fusion welding of steels
IS 7318 (Pt.1)	Approval test for welders when welding procedure is not required : Part-1 fusion welding of steel
IS 9595	Recommendations for metal arc welding of carbon and carbon manganese steels

Wire Rope and Cables

These shall conform to the following or relevant Indian Standards except where use of other types is specifically permitted by the authority

IS 1785 (Pt.1)	Plain hard-drawn steel wire for prestressed concrete : Part-1 Cold drawn stress relived wire
IS 1785 (Pt.2)	Plain hard drawn steel were for pesteressed concrete : Part-2 As drawn wire
IS 2266	Steel wire ropes and strands for general engineering purposes
IS 2315	Thimbles for wire ropes
IS 9282	Wire ropes and strands for suspension bridges

1.3 Material Control

The structural steel to be used shall conform to IS: 2062 or as mentioned in the drawing.

All the steel sections used in the fabrication must have mill test certificate clearly indicating the specification to which the steel conforms.

All the cast mark numbers/heat mark numbers shall be recorded along with the numbers of the plate in a register, after receiving the steel in the fabrication shop and before starting the work.

Sample test pieces from the steel of each cast mark shall be cut and sent for testing from an independent test house, approved by the engineer. The steel shall be used for fabrication after co-relation with Mill Test Certificate (MTC), received from the manufacturer, and test report from the test house.

Any steel, other than the quality mentioned above, shall be accepted by the engineer before use.

Identification of the steel shall be as per the Quality Assurance Plan (QAP). The quantum of inspection and the number of samples, for co-relation, shall be agreed by the engineer and the record shall be maintained for his scrutiny.

While transferring the mark, hard stamping shall be carried out in those area that are allowed by the engineer.

1.4 Storage and Handling of Materials

Raw steel shall be stored free from dirt, foreign matter and shall be protected from corrosion and distortion. All materials and consumables, including raw steel, shall be stored specification wise and size wise above the ground. The materials shall be stored on platforms, skids or on other supports. Floors shall have a light slope to allow proper drainage of water. Fabricated components shall be stacked neatly above ground with clear visibility of the match mark as shown in the part list. The electrodes shall be stored in dry and warm condition and in properly designed racks, specification wise. The bolts, nuts, washers and other fasteners shall be stored on racks above the ground in gunny tags and with protective oil coating. The paint shall be stored under cover in airtight container. Raw steel shall be handled by using lifting beam with proper slings in a manner so as to cause minimum damage or distortion of the plates and structural. Fabricated components shall be handled and stacked in a manner that is not subject to any deformation.

1.5 Workmanship and Quality Assurance Plan

QAP shall be prepared according to the nature of fabrication. QAP shall elaborate nodal points of checking and inspection during different stages of fabrication. This shall be submitted to the engineer for his approval. Fabrication shall be taken up after the approval of the QAP by the Engineer. All fabricated components shall carry mark number and the serial number. Method of marking shall commensurate with the process of manufacturing and shall ensure retention of identity at all stages.

1.6 Straightening and Flattening

Steel materials such as plates and structural's shall have straight edges, flat surface and be free from twist. Straightening/flattening of the plates and structural's are required to be carried out for making good of deformation and distortion that may have occurred during rolling or handling operation. Structural sections can be straightened by presses, preferably hydraulic. Plates can be flattened by presses or straightener consisting of series of rollers. Pressure applied for straightening of flattening shall be such that it does not injure the material. Hammering shall not be permitted. Deformations caused at the time of handling can be removed by application of heat, hydraulic/gradually applied mechanical force.

Heating temperature shall not be more than 650ºC. Heating and cooling rate shall be pre-determined and applied to steel only after consultation with the engineer.

1.7 Layout for Camber

A full scale layout for the girder shall be done on a leveled bed and as per the drawing on the basis of nominal length of the members. Jigs for gussets and members shall be made from the layout. The position of the holes and their angular settings shall be as per the nominal layout. In case of small plate girders, where camber is not provided, the length of the members shall be taken from the drawing.

Long span of open web girders have provision of camber. The drawings show two diagrams. One is the diagram for nominal layout and the other is the camber diagram. A full scale layout for the girder shall be done on leveled bed, as per the diagram for nominal layout in the drawing. Jigs for gussets and members shall be made from the nominal layout. The position of the holes and their angular settings shall be as per the nominal layout. The length of the members shall be manufactured as per the corresponding length in the camber diagram. The machining of the ends shall be done to ensure proper contact of the members at the joints.

1.8 Bending

1.8.1 *Cold Bending*

Cold bending of steel having yield stress 360 MPa or more shall not be done. The bend plate orientation shall be done in a manner that the bend line shall be approximately perpendicular to the direction of rolling. Materials with non specified kinks or sharp bends, cracks, large dents or visible reductions of section (necking) shall not be used. Visual inspection of all the load points and for suspected damaged places, magnetic particle testing shall be done. For bend plates, the use of the largest bend radius that is permissible shall be ensured.

1.8.2 *Heating and Bending*

Heating shall be done before painting. The stresses due to pre-load (including loads induced by member weights) shall be limited to 0.5 f_y where f_y is the normal yield strength (y/s) of the materials. When jacks are used, the load shall be applied and locked off before applying heat. For heating, orifice tip shall be fixed for neutral flame and its tip size shall be proportional to the thickness of the materials used. The heating torches shall be manipulated to guard against over-heating. When V-shaped/straight regular heat patterns are used, the patterns shall be marked on the steel prior to heating. The steel shall be brought to planned heating temperature as rapidly as possible without over-heating. Care shall be taken against buckling when thin or wide plates are heated. The temperature shall be monitored with temp. – sensitive crayons, pyrometer or infra-red non-contact thermometers. The temperature shall be measured within 5-10 seconds after the heating flame leaves the test area. Cooling of the steel with compressed air, passing through dryers for removing moisture, is permitted only after the steel has cooled below 315ºC. Cooling shall not be done with water or mist.

Steel shall be allowed to cool below 120ºC before applying another set of heating pattern.

For curving or cambering by V-shaped heating pattern, a location shall be re-heated after completion of three sets of heating patterns at adjoining locations. Application temperature shall be done under controlled procedure and not more than 650ºC. Accelerated cooling shall not be done unless approved by the Engineer-in-charge.

Material to be heated shall be properly supported. The material shall not yield before or during application of heat.

1.8.3 *Heat Curving of Bridge Member*

The procedure of application of heat shall be approved by the engineer. Care should be taken to ensure that the stress due to pre-load does not exceed 0.5 f_y where f_y is the normal

y/s of the material. Heat curving shall be done before attaching longitudinal stiffener. When radius is more than 300 Meters for heat curving, pre-loading of the web shall be done prior to heating. When the web is heat curved in vertical position, sufficient support shall be given to avoid lateral deflection during heat curving process. The member should not over turn or twist. To prevent buckling and excessive local deformation, intermediate catch blocks should be maintained. Heating pattern shall be planned and applied along the length of the member to produce the specified curvature. Enough patterns shall be used to eliminate visually detectable chording effect. Heat curving shall not be done when the radius of curvature is less than 300 meters, flange thickness exceeds 75 mm or when the flange width exceeds 750 mm.

For rolled sections heat curving methods can be applied after taking approval of heating procedure from engineer. It is not possible to give camber by heating in plate girders. Web should be cut to prescribed camber. Suitable allowance for shrinking due to cutting and welding should be provided.

1.9 Cutting and Edge Preparation

Edge preparation shall be done by anyone of the following prescribed methods for Plate and Structural's.

Shearing, cropping, sawing, flame cutting with subsequent grinding.

Wherever possible, the edges shall be cut in shearing machine which will take the whole length of the plate in one cut. Sheared edges of plate shall be ground to a smooth profile for secondary use such as stiffeners and gussets. When used as stiffeners, they shall be ground so that the maximum gap is less than 0.2 mm in 60 percent of contact area.

Sawing can be effectively used for structural Steel.

1.9.1 Flame Cutting

Hardness of cut edge should not exceed 350 BHN after flame cutting. The material to be removed after flame cutting shall be to the extent of 2 mm or minimum necessary to ensure that the edge is less that 350 BHN hardness. When hardness increases beyond acceptable limit, even after material removal, the flame cut edge shall be heat-treated by the method approved by the Engineer for bringing the hardness to 350 BHN. It has to be ensured by dye penetration or magnetic particle test that cracks have not developed at the cut edges. All flame cut edges shall be ground to obtain reasonably clean, square and true edges. Drag lines produced by flame cutting shall be removed. Outside edge of plates and sections, which are prone to corrosion, shall be smoothened by grinding.

Use of flame cutting machine, having multiple oxy acetylene torches, is desirable for reducing the distortion due to cutting operation and for higher productivity. Plasma-arc-cutting method is preferable as this process offers less heat input and causes less distortion.

1.10 Planing and Machining

Machining of the edges or surface shall be carried our when specified in the drawings or where specifically instructed by the Engineer. Plates and Sections up to a thickness of 12 mm

shall be cut to a size 3 mm or more and in plates and sections exceeding 12 mm, a thickness of 6 mm or more than the finished size shall be cut for carrying out the finishing operations.

After completion of fabrication the butting ends of the members shall be smoothened by an end milling process to ensure uniform gap/proper contact as may be necessary. In the case of compression members the machined faces should be at right angle to the axis of the members and in contact as specified.

At the discretion of the Inspecting Officer, a tolerance of 0.4 mm may be permitted at isolated places on the butting line.

1.11 Rivet and Bolt Holes

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 or rivets up to 25 mm Ø and 2.0 mm for bolt & rivets more than 25 mm Ø.

All holes shall be drilled except for secondary members such as, floor plate, handrails etc., and the members which do not carry the main load. The punching shall be done in materials whose yield stress, f_y, does not exceed 360 MPa and thickness does not exceed (5600/f_y) mm.

When holes are required to be made in a pack of plates/plates and structural's in material grade E250 (FE 410 w) with thickness more than 20 mm or grade E350 (FE 440) with thickness more than 16 mm, the drilling shall be done up to a diameter which is 3 mm less than the required size of the hole. The under sized holes shall then be reamed to full diameter. The reaming of materials shall be done after assembly.

For bolts of close tolerance or turn fitted bolts, the diameter of the holes shall be upto + 0.15 mm to 0 mm, of the diameter of the bolt shank. The members to be connected with close tolerance or turn fitted bolts shall be firmly held together by service bolts, clamped and drilled through all thickness in one operation. The reaming to required size within the specified limit of accuracy, shall be done subsequently.

For HSFG joints, 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 2.0 mm larger than those of bolts. For more than three plies in grip, the diameters of hole in outer plies shall be as above and diameter of holes in inner plies shall be not less than 1.5 mm and not more than 3.0 mm larger than the bolt diameter, unless otherwise specified by Engineer.

1.12 Bolted Connection

All joint surfaces, for bolted connection, shall be free of scale, dirt, burrs, foreign material and all such defects that prevent solid seating of parts. The slope of surface of bolted parts in contact with bolt head and nuts shall not exceed 1:20, in the plane normal to bolts otherwise suitable tapered washer shall be used.

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

Each fastener of joint shall be tightened by hand wrenches/impact wrenches. Calibrated torque wrenches (manual/digital) shall be used for final tightening.

When turn of nut method is used for tightening the bolts in joint, first all bolts shall be brought to “snug tight” condition, (that is tightening by full effort of man using ordinary wrench or by few impacts of any impact wrench). All bolts in the joint shall then be tightened additionally by applicable amount of nut rotation specified below for guidance.

Table 1 Tightening the Bolts By Nut Rotation

Bolt Length (from Underside of Head to Edge)	Disposition of Outer Faces of Bolted Parts	
	Both Face Normal to Bolt Axis	One Face Normal to Bolt Axis & other Face Sloped Less that 1:20
Up to and including 4 dia	1/3 turn	1/2 turn
Over 4 dia but less than 8 dia	1/2 turn	2/3 turn
Over 8 dia but less than 12 dia	2/3 turn	5/6 turn

1.13 High Strength Friction Grip (HSFG) Bolted Connections

The various requirement of chemical and physical properties of bolts nuts and washers shall be as per relevant IS specifications unless otherwise mentioned in the drawing or required by the Engineer. Bolted connections of joints using high tensile friction grip bolts shall comply with requirements mentioned in IS:4000. Bolted Connections.

Reference should be made to **Appendix-J** for selection, usage, installation and testing procedures.

1.14 Riveted Connection

Assembled riveted joint surfaces including those adjacent to the rivet head shall be free of scale, dirt, loose scale, burrs, other foreign material and defects that would prevent solid seating of parts.

The part/members to be riveted shall be firmly drawn together with bolts, so that the sections riveted are in close contact throughout. Every third hole of the joint shall have assembly bolts till riveted. Drift shall be used only for matching of holes of the parts/members but not to the extent as to distort the holes.

While riveting built-up members, great care should be taken to ensure that the set of holes for field rivets in each flange of the built up member, is aligned dead-square in relation to that in the other flange and not abrogated. Use of assembly fixture shall be made to ensure this drift of larger size than the diameter of the drilled holes shall not be used.

Rivets shall be heated uniformly to a “light cherry red color” between 650ºC to 700ºC for hydraulic riveting and “orange colour” for pneumatic riveting of mild steel rivets. High tensile steel rivets shall be heated upto 1100ºC. The head of the rivet, particularly in long rivets, shall be heated more than the point. Sparking or burnt rivets shall not be used.

Rivet shall be driven in hole when hot so as to fill the hole as completely as possible and shall be of sufficient length to form a head of the standard dimension. When countersunk head

is required the head shall fill the countersunk hole. Projection after countersinking shall be ground off where necessary.

The riveting shall be done by hydraulic or pneumatic machine unless otherwise specified by Engineer. The head can be held by pneumatic holding device. Where, it is impossible to back up by normal method of holding up, double gunning method may be resorted to. The working pressure to be applied, when using pneumatic or hydraulic tools, shall be approved by the engineer.

Any rivet due to defect in head size or head driven off the centre shall be removed and replaced. The method of removal of the defective rivet shall ensure that, the members of the joint are not damaged in the process.

The parts not riveted in the shop shall be secured by bolts to prevent damage during transportation and handling.

1.15 Welded Connection

1.15.1 *General*

Over welding is a common defect in fabrication industry. Excessive welding does not necessarily increase the strength of a welded joint. On the contrary, it increases the stresses in a highly restrained joint. There are many criteria for the selection of an edge preparation and they are :

* Ease of assembly.
* Resistance to lamellar tearing.
* Weld inspection by radiography, ultrasonic etc., testing methods.

The joint preparation must be designed.

* To allow full approach of electrode.
* To have minimum deposition of weld metal.
* To have access for welding and inspection.
* To be linked to the welding process.

1.15.2 *Weldability of Steel*

The weldability of steel depends on its susceptibility to cracking during and after welding. The amount of carbon in the metal has a considerable influence on the weld ability of structural steel. The weldability is expressed by Carbon Equivalent (CE) of the material based on ladle analysis. The CE is determined from the following expressions:

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

The lower the CE better is the weldability. For general structural steel, the CE value should preferably be not more that 0.45 to ensure good weldability. Steel with higher CE are also weldable with special electrodes, weld designs and procedures. Though CE does not take

into account, Sulphur and Phosphorus, the presence of more that 0.06 percent of these constituents will have deleterious effect on welding.

If the Carbon Equivalent exceeds a particular limit, there exist a possibility of cracking in the Heat-Affected Zone (HAZ). Hard, brittle martensite, cracks are likely to develop. This phenomenon is called under bead cracking. The high thermal cycles accelerate the formation of HAZ cracking. Presence of hydrogen in the weld is another potential factor in the formation of under bead cracking. The principal factors governing the risk of HAZ cracking in steel are :-

* Compatibility of Weld metal composition with parent metal.
* Pre-heat temperature according to CE (carbon equivalent).
* Hydrogen Content in the form of ingredients in the flux.
* Cooling rate (heat input, joint type, thickness).

Table 2 shows the recommended preheat and inter pass temperature for different type of structural steel.

Table 2 Recommended Pre-Heat and Inter Pass Temperature

Steel Type	Welding Process	Thickness of Thickest Part of Welding (mm)	Temp ºC (Min[m])
Mild steel with some restriction	Manual metal arc with electrodes other than low hydrogen type	Upto 19 incl. 19 to 38 incl. 38 to 64 incl. Over 64	None 66 107 150
Mild & Medium Tensile steel	Manual metal arc with electrodes of low hydrogen type, submerged-arc, cored wire	Upto 19 incl. 19 to 38 incl. 38 to 64 incl. Over 64	None 10 66 107
Higher tensile as-rolled or normalized steel	Manual metal arc with electrodes of low hydrogen type, Submerged-Arc cored wire	Up to 19 incl. 19 to 38 incl. 38 to 64 incl. Over 64	10 66 107 150

1.15.3 *Welding Procedure Sheet*

The symbols for welding used on the drawings and procedure sheets shall be in accordance with IS:812. If other symbols are used, a complete explanation of their meaning shall be given.

The welding procedure sheets prepared for direction of the welding shall include the following information:

a) Specification of the Parent metal, Electrodes, Wires and/or wire-flux combination.

b) Locations, sizes, actual lengths and details, i.e. form of joint, angle between fusion faces, gap between parts, etc., of all welds.

c) Whether welds are to be made in shop or field.

d) Current, voltage and other relevant parameters.

e) Welding procedure, like welding sequence, pre-heating, post heating etc.

f) Details of testing and inspection requirements.

1.15.4 *Welding Processes*

Generally, Manual Metal Arc-welding, Submerged-Arc Welding, (Automatic & Semi Automatic) Gas shielded Arc welding etc., are used in bridge fabrication.

The various types of welds are Fillet, Butt, Plug, Spot and Seam welds. The two most popular types of welding for structural purpose are fillet and butt joints.

1.15.5 *Fusion Faces*

The preparation of fusion faces, angle of preparation root radius and root face shall be as specified in IS:9595 and IS:4353. Where the gap between the root faces of a butt joint is excessive, the gap shall not be bridged since this procedure often leads to cracking. The fusion faces of the joint shall be built-up with weld metal to give the appropriate gap before the weld is commenced.

The preparation of fusion faces, angle of bevel, root radius and root face shall be such that the limits of accuracy required by the appropriate application standard can be achieved. When however, no appropriate application standard exists and this guide lines is itself to be used, it is recommended that, for manual welding, the tolerances on limits of gap and root face should be ± 1 mm on the specified dimensions for material upto and including 12 mm thick and ± 2 mm for material over 12 mm thick. The tolerance on the included angle between the fusion faces of a V preparation is recommended to be ± 5 degree and for U and J preparations ± 10 degree. For an automatic process, closer limits are necessary and particular requirements depend on the characteristics of the process.

It shall be ensured, if necessary, by suitable non-destructive tests that the fusion faces and adjacent surfaces shall be free from cracks, notches or other irregularities which might be the cause of defects or would interfere with the deposition of the weld.

Fusion faces and the surrounding surfaces shall be free from heavy scale, moisture, oil, paint or any other substance which might affect the quality of the weld or impede the progress of welding. Certain proprietary protective coatings are specially formulated with the intention that they should not interfere with welding. The use of such coatings is not excluded by the requirements of this clause but shall be demonstrated by means of specimen welds that the coating complies with the above requirements.

1.15.6 *Assembly for Welding*

Parts to be welded shall be assembled such that the joints are easily accessible and visible to the operator. Jigs and manipulators shall be used, where practicable, so that the welding

can be carried out in the most suitable position. Jigs shall maintain the alignment with the minimum restraint so as to reduce the possibility of locked in-stress.

1.15.7 *Structural Details*

Changes in section shall be gradual and notch-like corners shall be avoided.

Attachment of fittings and making openings at locations of severe fatigue stress shall preferably be avoided.

Packing's - Where a packing is used between two parts, the packing and the welds connecting it to each part shall be capable of transmitting the load between the parts, except where the packing is too thin to carry the load or permit the provision of adequate welds, when it shall be trimmed flush with the edges of the narrower part and the load shall be transmitted through the welds alone, the welds being increased in size by an amount equal to the thickness of the packing.

1.15.8 *Arrangement of Welds*

Fillet welds at right angles to the lines of principal stresses in a plate subjected to tension shall be avoided in dynamically loaded structures.

Accumulation of weld joints in a single location shall be avoided (See **Appendix H, Fig. H-20**)

Sizes or lengths of fillet welds shall be sufficient to provide for better distribution of stress. Excessive sizes or lengths shall not be specified.

1.15.9 *Safety Precautions*

Provisions of IS:818, IS:1179 and IS:3016 shall generally apply for safety and health requirements during welding operations.

1.15.10 *Approval and Testing of Welding Procedures*

Welding procedure test shall be carried out in accordance with IS:7307 (Part-1) to demonstrate, by means of a specimen weld of adequate length on a steel representative of that to be used, so as to confirm that satisfactory weld is achievable with the welding procedure to be used for fabrication.

Provisions of IS:9595 and IS:4353, shall generally be followed, as applicable, for welding procedure, details of workmanship, correction of weld faults, penning, painting, etc. In case any of the provisions contained therein contravene the provisions made in this guideline, the code shall be followed.

In addition to the provisions of IS:4353 the Inspector may, where deemed necessary, require a sample joint having the same cross-section as the joint to be used in construction and a length of at least 300 mm to be welded with the wire, flux current, arc voltage and speed of travel that are proposed to be used and a macro etched cross section of the welded joint prepared as a demonstration that the specified requirements will be met, when the welding current, arc voltage and speed of travel are established by a test made in accordance with requirements of this clause, they shall be kept within the following limits of variations:

Welding current ± 10%

Arc Voltage ± 7%

Speed of travel ± 15%

1.15.11 *Approval and Testing of Welders*

The welders shall be trained in accordance with IS:817. The welders shall be subjected to appropriate qualifying tests specified in IS:7310 (Part-1).

1.15.12 *Welding Procedures*

Welding work shall be given to an agency who does produce satisfactory evidence of his ability to handle the work in a competent manner. The agency shall also prove the ability of the operator/welders employed by him to produce welds of the required strength. The agency shall employ a competent welding supervisor to ensure that quality of materials and the standard of workmanship comply with the requirements laid down in this guideline.

The sizes and length of welds shall not be less than those specified in the drawings nor shall they be substantially in excess of the requirements without prior approval of the Engineer. The location of welds shall not be changed without prior approval of the Engineer. Welds shall preferably be made in flat position.

In case of welds in structures subjected to dynamic loading, adequate means of identification, either by identification stamp or other records shall be provided to enable each weld to be traced to the welding operator by whom it was made.

During the cooling of the weld the joints shall not be subjected to any external forces or shocks.

Freedom of movement of one member of a joint shall be allowed wherever possible. No butt joint shall be welded without allowing one component, freedom of movement of the order of 1.5 mm.

In making welds under conditions of severe external shrinkage restraint, the welding shall be carried out with electrodes having type 6 covering as per IS:814.

In case of welding using direct current, earthing on the work piece to be welded shall be connected carefully at more than one location with a view to avoid “Arc Blow” during welding.

All welds should be done by submerged arc welding process either fully automatic or semi-automatic. Carbon-dioxide (CO_2) welding or manual metal arc welding may be done only for welds of very short runs or of minor importance or where access of the locations of weld does not permit automatic or semi-automatic welding.

Neither the depth of fusion nor the maximum width in the cross section of weld metal deposited in each weld pass shall exceed the width of the face of the weld pass. (**Appendix-H, Figs. H-21 & H-22**).

1.15.13 *Sequence of Welding*

The sequence of welding shall be such that when possible the members, which offer the greatest resistance to compression, are welded first.

The welding in the thinnest element of a section (usually the web in case of beams) shall be done prior to the welding of the thicker elements (usually the flanges in case of beams).

In making butt welded joints in rolled shapes, the sequence and procedure of welding shall take into account unequal amount of expansion or contraction in elements being welded.

Splices in each component part of a solid web girder or built-up member shall be made before such component part is welded to other component part of the member.

1.15.14 *Position of Welding*

For fabrication of steel bridge girders the following positions of welding shall be adopted.

i) Flat and horizontal position for Submerged Arc Welding (SAW)

ii) Horizontal or horizontal-vertical position for welding done using Manual Metal Arc Welding (MMAW) or Co_2 Welding.

Note: Different positions have been shown diagrammatically in **Appendix-H, Fig. H-23**.

All butt welds by the submerged arc process shall be made in the flat position. Fillet welds may be made in either flat or horizontal-vertical position. The size of the single pass fillet welds made in the horizontal-vertical position shall not exceed 8 mm.

1.15.15 *Tack Welds*

Tack welds shall be not less than the throat thickness or leg length of the root run to be used in the joint. The length of the tack weld shall not be less than four times the thickness of the thicker part or 50 mm whichever is the smaller.

Where a tack weld is incorporated in a welded joint, the shape, size and quality shall be suitable for incorporation in the finished weld and it shall be free from all cracks and other welding defects. Tack welds, which are prone to cracking, shall be cut out and re-welded.

Tack welds shall not be made at extreme ends of joints.

1.15.16 *Inter-Run Cleaning*

Each run of weld bead shall be thoroughly cleaned to remove particles of slag, spatters, etc. before the subsequent bead is super-imposed during multi-pass welding. Similarly, each layer of weld should be thoroughly cleaned of slag, spatters, etc, before depositing subsequent layers of weld with particular reference to thorough cleaning of toes of the welds. Visible defects, such as cracks, cavities and other deposition faults, if any, shall be removed to sound metal before depositing subsequent run or layer of weld.

1.15.17 *Stray Arcing on Work*

Stray arcing shall be avoided as this can leave local hard spots or cracking which are to be removed by mechanical means and be checked by inspection depending upon the application.

1.15.18 *Butt Welding*

a) Forms and details - All details of butt welded joints shall be in accordance with IS:9595 and IS:4353 as applicable.

b) Unsealed butt welds of single V,U,J and bevel types and incomplete penetration butt welds shall not be used. Sketches of different types of butt weld are given in (**Appendix-H, Fig. H-1**)

c) Intermittent butt welds shall not be used.

Sealing or Backing

a) Single V, U, J bevel or square butt welds shall generally be completed by depositing a sealing run of weld metal on the back of the joints.

b) Where it is not practicable to deposit a run of weld metal on the back of the joint, then single V, bevel or square butt welds, welded from one side only, may be permitted, provided that another steel part of the structure or a special steel backing strip is in contact with the back of the joint and the edges of the steel parts of the joint are prepared as specified in IS:9595 or IS:4353, whichever is applicable, to ensure complete fusion of the parts to be joined.

c) In all full penetration butt welds which are to be welded from both sides, the back of the first run shall be gouged out by suitable means to clean sound metal, before welding is started on the gouged out side (**Appendix-H, Fig. H-2**).

Butt Welding Parts of Unequal Cross-Section

a) In butt welding steel parts in line with each other which are intended to withstand dynamic forces, and which are of unequal width, or where the difference in thickness of the parts exceeds 25 percent of the thickness of the thinner part or 3 mm whichever is greater, the dimensions of the wider or thicker parts shall be reduced at the butt joints to those of the smaller part, the slope being not steeper than 1 in 5 (**Appendix-H, Fig. H-3**). Where the difference in thickness of the parts does not exceed 25 percent of the thickness of the thinner part or 3 mm whichever is greater, the transition of thickness shall be accomplished by sloping weld faces (**Appendix-H, Fig. H-4**) by chamfering the thicker part or by combination of the two methods (**Appendix-H, Fig. H-5**), at an angle not steeper than 1 in 5.

b) Where the reduction of the dimensions of the thicker part is impracticable, and/or where structures are not designed to withstand dynamic forces, the weld metal shall be built-up at the junction with the thicker part to dimension at-least 25 percent greater than those of the thinner part, or alternatively, to the dimensions of the thicker member (**Appendix-H, Fig. H-6**).

Butt Welded T Joints - Butt weld in T joint shall be reinforced by welding as shown in (**Appendix-H**, **Fig. H-7**). Flange to web connection will also fall under this category.

Ends of butt welds - The ends of butt joint shall be welded so as to provide the full throat thickness. This shall be done, in all cases of parent metal more than 20 mm thick and preferably in other cases also, by extending the ends of the butt welds past the edges of the parts joined by the use of run-on and run-off plates with a similar joint preparation and of reasonable thickness not less than the thickness of the part joined and of the length not less than 40 mm (**Appendix-H, Fig. H-8**). If run on and run off plates are removed after completion of the welds, the ends of the weld shall be finished smooth and flush with the edges of the abutting parts. Run on and run off plates are to be removed after completion of welds by abrasive cut off or by hacksaw blade .To avoid thermal stress as well as heat affected zone, Oxy-acetylene cut should not be permitted. If the parent metal is not more than 20 mm thick, the ends of the butt welds may be chipped or cut back to sound metal and then filled-up with welds having a width not less than one and half time the 'V' opening and having the same reinforcement as adopted for the faces of the butt weld. (**Appendix-H, Fig. H-9**).

Reinforcement of butt welds - Sufficient convexity not exceeding 3 mm, shall be provided as reinforcement to ensure full cross sectional area at the joint. Where a flush surface is required, the butt welds shall be first built up as specified above and then dressed flush.

1.15.19 *Fillet Weld*

Types of fillet welds

Normal Fillet Weld – A normal fillet weld is one in which the depth of penetration beyond the root is less than 2.4 mm (**Appendix-H, Fig. H-10**).

Deep Penetration Fillet Weld – A deep penetration fillet weld is one in which the depth of penetration beyond the root is 2.4 mm or more (**Appendix-H, Fig. H-10**). It shall be used only by agreement between engineer and contractor, and tests shall be agreed between engineer and contractor to verify that the requisite route penetration is being obtained.

The size of normal fillet weld shall be taken as the minimum leg length (**Appendix-H, Fig. H-11**). The size of a deep penetration fillet weld shall be taken as the minimum nominal leg length plus 2.4 mm (**Appendix-H, Fig. H-12**) The minimum size of the first run or of a single run fillet welds shall be as given in **Table 3**. Minimum size of fillet weld shall be as given in **Table 4** to avoid the risk of cracking in the absence of pre-heating.

Table 3 Minimum Size of First Run or of a Single Fillet Weld

Thickness of Thicker Part	Minimum Size (mm)
6 mm upto and including 20 mm	5
Over 20 mm upto and including 32 mm	6
Over 32 mm upto and including 50 mm	8

Table 4 Minimum Size of Fillet Weld

Thickness of Thicker Part	Minimum Size (mm)
upto and including 6 mm	3
Over 6 mm upto and including 12 mm	4
Over 12 mm upto and including 18 mm	6
Over 18 mm upto and including 36 mm	8
Over 36 mm upto and including 56 mm.	10
Over 56 mm upto and including 150 mm	12
Over 150 mm	16

Note:

1. When the minimum size of the first run of fillet weld and/or minimum size of the fillet weld as given in **Table 3** and **Table 4** is greater than the thickness of the thinner part, the minimum size of the weld shall be equal to the thickness of the thinner part. The thicker part shall be adequately pre-heated to prevent cracking of the weld.
2. Where the thicker part is more than 50 mm in case of steel to IS: 2062 special precautions like pre-heating as per IS:9595 shall be taken to ensure weld soundness.

Effective Throat Thickness - The effective throat thickness of a fillet weld shall be taken as 'K' times fillet size where 'K' is a constant, given in as per (**Appendix-H, Fig. H-13**), for different angles between fusion faces. All fillet welds shall have a flat or convex face. In no case, except at the outside of a corner joint shall the convexity exceed the value given by the formula 0.1S + 0.76 mm, where S is size of weld in mm.

Angle Between Fusion Faces - Fillet weld shall not be used for connecting parts, whose fusion faces form an angle of more than 120º or less than 60º, unless such welds are demonstrated by practical tests to develop the required strength.

Effective Length - The effective length of fillet weld shall be that length only, which is of the specified size and required throat thickness. It shall be taken to be the actual length of the weld minus twice the weld size. This deduction need not be made in the case of end and side fillets, which are returned continuously around the corner for a minimum length of twice the weld size.

Effective Area - The effective area of a fillet weld shall be the effective length times the effective throat thickness.

Minimum Length - The effective length of a fillet weld designed to transmit loading shall not be less than four times the size of the weld, subject to minimum of 40 mm.

1.15.20 *Intermittent Fillet Welds*

Intermittent fillet welds may be used in structures not subjected to dynamic loading, to transfer calculated stress across a joint when the strength required is less than that developed by a continuous fillet weld of the smallest allowable size for the thickness of the parts joined.

Load carrying intermittent fillet welds shall not be used in members subjected to dynamic loading, except for connecting intermediate stiffeners to webs of beams and girders, subject to the provisions of such connections as stipulated.

Intermittent fillet welds shall not be used where they would result in the formation of rust pockets.

Chain intermittent welding is to be preferred to stagger intermittent welding.

The distance along an edge of a part between effective lengths of consecutive intermittent fillet welds, whether the welds are in line or staggered on alternate sides of the edge, shall not exceed 12 times the thickness of the thinner part and shall in no case exceed 150 mm.

In a line of intermittent fillet welds, there shall be a weld at both ends of the parts connected. For staggered welds, this shall apply to both sides.

In built-up members in whose parts are connected by intermittent filled welds, continuous longitudinal fillet welds shall be used at the end for a length not less than the width of the part concerned.

1.15.21 *Fillet Welds Applied to the Edge of a Plate or Section*

Where a fillet weld is applied to the square edge of a part, the specified size of the weld shall generally be at-least 1.5 mm less than the edge thickness, in order to avoid melting down of the outer corner (**Appendix-H, Fig. H-14**).

Where a fillet welds is applied to the rounded toe of a rolled section, the specified size of the weld shall generally not exceed 3/4 of the thickness of the section at the toe (**Appendix-H Fig. H-14**).

Where a fillet weld equal in size to the thickness of the section at the toe of a rolled section or at the square edge of a plate is required from design considerations and is specially designated in the drawing, the toe or edge shall be specially built-up with weld metal in such a manner as to ensure full throat thickness, full fusion area and no injury to the parent metal (**Appendix-H, Figs. H-15 & H-16**).

End fillets - When end fillets are used alone, each fillet shall be returned as a side fillet for a minimum length equal to twice the size of the weld, and this returned length shall be disregarded in calculating the strength of the joint.

1.15.22 *Fillet Welds in Slots or Holes*

When welding inside a slot or a hole, in a plate or other part, in order to join the same to an underlying part, fillet welding may be used along the wall or walls of the slot or the hole, but the latter shall not be filled with weld metal or partially filled in such a manner as not to form a direct weld metal connection between opposite wall.

The dimensions of the slot or hole shall comply with the following limits in terms of the thickness of the steel part in which the slot or hole is formed.

i) The width or diameter to be not less than three times the thickness or 25 mm whichever is greater.

ii) Corners at the enclosed ends of slots to be rounded with a radius not less than 1.5 times the thickness or 12 mm whichever is greater.

iii) The distance between the edge of the part and edge of the slot or hole or between adjacent slots and/or holes not to be less than twice the thickness when measured along the direction of stress and five times the thickness when measured normal to the direction of stress.

End Returns - Fillet welds terminating at the ends or sides of parts or members shall be returned continuously around the corner for a distance of not less than twice the size of the weld. This provision shall apply particularly to side and end fillet welds joining brackets, beam seating's and similar attachments at the tension side of such connections.

Bending about a Single Fillet - A single fillet weld shall not be subjected to bending moment about the longitudinal axis of the fillet (**Appendix-H, Fig. H-17**).

1.15.23 *Lap Joints*

The minimum overlap of parts in stress carrying lap joints shall be four times the thickness of the thinner part. Unless opening out of the parts is prevented, they shall be connected by at least two transverse or two longitudinal fillet welds (**Appendix-H, Fig. H-18**).

If longitudinal fillet welds are used alone in lap joints of end connections, the length of each fillet weld shall be not less than the perpendicular distance between them. The transverse spacing of longitudinal fillet welds used in end connections shall not exceed sixteen times the thickness of the thinner part connected. The longitudinal fillet welds may be in slots in addition to those along the edges, to comply with this provision.

1.15.24 *Plug Weld*

Plug welds shall not normally be provided and in any case shall not be designed to carry stresses. Where unavoidable, the procedure laid down in **Appendix-G** shall be followed.

1.15.25 *Combination of Welds*

If butt and fillet welds are combined in a single joint, the allowable capacity of each shall be separately computed with reference to the axis of the group in order to determine the allowable capacity of the combination.

Butt welds in parts or members, subjected to dynamic loading, shall not be supplemented by splice plates attached by fillet welds.

1.15.26 *Welding of Stud Shear Connectors*

a) The stud shear connectors shall be welded in accordance with the manufacturer's instructions including pre-heating.

b) 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, galvanized or chrome-plated prior to welding.

c) Welding shall not be carried out when temperature is below 0ºC or surface is wet.

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

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

1.15.27 *Stress Relieving and Peening*

The members which are indicated in the contract or specified by Engineer, to be annealed or stress relieved shall have finish machining, boring etc. done subsequent to heat treatment. The stress relief treatment shall conform to the following unless specified by Engineer.

a) The temperature of the furnace shall not be more than 300ºC at the time welded assembly is placed in.

b) The rate of heating shall not be more than 220ºC per hour divided by max. metal thickness subject to max. 220ºC per hour.

c) After max. temperature of 600ºC is reached, the assembly shall be held within specified limit of time based on weld thickness. The temperature shall be maintained uniformly throughout the furnace during holding period such that temperature at no two points on the member will differ by more than 80ºC.

d) The cooling shall be done in closed furnace when temperature is above 300ºC at the maximum rate of 260ºC per hour divided by maximum metal thickness. The local stress relieving shall be carried out in specified procedure and approved by Engineer.

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

i) If specified, peening may be done on each weld layer, except the first run.

ii) The peening shall be carried out after weld has cooled by light blows from a hammer, using a round nose tool. Care shall be taken to prevent scaling or flecking of weld and base metal from over peening.

1.15.28 *Cope Holes*

Cope hole is a semi circular notch in between web plate and flange plate to disconnect junction of welds (**Appendix-H, Fig. H-19**).

Provision of cope hole in welded girders is not required when the following conditions are satisfied:

a) Butt welds in flanges and web are made by automatic sub-merged arc welding prior to assembling web and flanges together.

b) Weld reinforcement is dressed flush both at top and bottom by grinding/ machining and

c) Weld is tested by radiographic/ultrasonic method.

1.16 Inspection and Testing for Fabrication and Assembly

1.16.1 *General*

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 quality and correctness of fabrication. An inspection Register (**Appendix-A**) should be maintained throughout the fabrication process.

1.16.2 *Testing of Material*

Structural steel shall be tested for mechanical and chemical properties as per various Indian Standards as may be applicable and shall confirm to requirements specified in IS:2062.

Rivets, bolts, nuts, washers, welding consumables, steel forging, casting and stainless steel shall be tested for mechanical and chemical properties as applicable and shall conform to requirements, as specified in the appropriate Indian Standard.

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

Ultrasonic test shall be mandatory for plates of thickness of 25 mm and above for checking defects like laminations etc. Flame cut edges without visual signs of laminations need not be tested for unless specifically suggested by the engineer.

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 Engineer for his decision.

Ultrasonic testing shall be used to determine depth of imperfection. For dynamically loaded structures recommended criteria for allowable discontinuities for edge defects and the repair procedure shall be as given in **Table 5**, until and unless specified otherwise. The weld procedure shall be as per the requirement of the material being used.

Table 5 Discontinuities for Edge Defects and Repair Procedure

S. No.	Discontinuity	Repairs Required
1)	Discontinuities of 3 mm in max. depth, any length for material thickness up to 200 mm	None
2)	Discontinuities of 3 mm to 6 mm in depth and over 25 mm in length for thickness upto 100 mm and 6 mm to 12 mm depth, over 50 mm in length for thickness 100 mm to 200 mm	Remove. Need not be welded
3)	Discontinuities of 6 mm to 25 mm in depth, over 25 mm in length for thickness upto 100 mrn and 12 mm to 25 mm in depth, over 25 mm in length for thickness over 100 to 200 mm	Remove and weld. No single repair shall exceed 20 percent of edge being repaired
4)	Discontinuities over 25 mm in depth, any length for thickness 100 to 200 mm	With approval of Engineer remove to depth of 25 mm and repair by weld
5)	On edges cut in fabrication, discontinuities of 12 mm maximum depth any length	None

1.16.3 *Measurement of Curvature and Camber*

Horizontal curvature and vertical camber shall not be measured for final acceptance before completion of welding and heating operations and cooling down of the job. Horizontal curvature shall be checked with girder in the vertical position by measuring offsets from a string line or wire attached to both flanges or by any other suitable means. Camber shall be checked by the method specified by the engineer.

1.16.4 *Tolerance for Drilled and Reamed Holes*

Acceptable deviation in holes drilled and reamed for mild steel and high strength rivets, bolts of normal accuracy and also for high strength friction grip bolts shall be as per appropriate Indian Standard.

1.16.5 *Bolted Connections*

Bolted connection joints with black bolts and high strength bolts shall be inspected for compliance of requirements as per relevant IS codes.

The Engineer shall observe the installation and tightening procedure of the bolts. Inspection for initial snug tightening and in final tightening shall be carried out.

The tightness of bolts in connection shall be checked by calibrated torque Wrench.

Tightness of 10 percent bolts, but not less than two bolts, selected at random in each connection shall be checked by calibrated torque wrench. 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 retightened.

Bolts, and bolted connection joints with high strength friction grip bolts shall be inspected and tested according to IS:4000/IRC:24.

Checks after second stage tightening: After the second stage of tightening, following shall be checked:

100 percent bolts shall be checked and certified to have been turned through the requisite amount by verifying the permanent marks on the nut and the bolt.

1 percent of the bolts, subject to minimum of 10 per size of bolts shall be checked for gross under-tightening as per procedure given in **Annexure-D of IS 4000**.

1.16.6 *Riveted Connections*

Rivets and riveted connection shall be inspected and tested for compliance.

The firmness of the 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.

Loose rivets and rivets with cracked, badly formed or deficient heads or with heads which are unduly eccentric with shanks, shall be cut-out and replaced, preferably, by rivet busters

or chisels. If rivet heads are removed by gas cutting, adequate care should be taken so that no damage is caused to any of the member of the joint.

1.16.7 *Alignment of Joints*

The alignment of plates at all bolted splice joint and welded butt joints shall be checked. Testing of flame cut and sheared edges is to be done where the hardness criteria is mentioned in QAP. Hardness testing shall be carried out on, at least, six specimens.

1.16.8 *Inspection and Testing of Welded Joints*

The Inspector designated by the purchaser shall ascertain that fabrication by welding is performed in accordance with the requirements of this guideline. Inspection of welds shall also be carried out in accordance with this guideline. For the provisions which are not incorporated in this guideline, IS:822 “Code of Procedure for Inspection of Welds” shall be followed.

Inspector shall be furnished with complete detailed drawings showing the size, length, type and location of all welds, which are required to be made. The weld size shall be checked with fillet weld gauges as shown in (**Appendix-H, Fig. H-29**).

He shall be notified in advance of the start of any welding operations.

He shall have free access to the work being done at all reasonable times by the Contractor and facilities shall be provided so that during the course of welding he may be able to inspect any layer of weld metal. He shall be at liberty to reject any material that does not conform to the provisions of this code and to require any defective welds to be removed and re-welded. A suggested proforma for welding records is shown in **Appendix-C**.

1.16.9 *Inspection Prior to Welding*

Parent metal

a) All plates and sections shall be inspected in the contractor’s works before fabrication. Verification of the quality of parent metal shall be carried out by reference to the relevant test certificate. The Inspector may, at his discretion, ask for spot checks to be made on the chemical composition and physical properties of the material.

b) Freedom from harmful defects such as cracks, surface flaws, laminations, and rough, jagged or imperfect edges shall be verified by visual examination of the material prior to welding. Dimensions of parts shall be checked by measurement.

c) Edge preparation shall conform to the relevant drawings and meet the requirements of this guideline.

d) After the parts are assembled in position for welding, the Inspector shall check for incorrect root gap, improper edge preparation and other features that might affect the quality of the welded joint.

Verification of operator’s qualification - Welding shall be permitted to be performed only by welders and welding operators who are qualified.

e) The Contractor shall, if so required, prescribe the welding procedure to be followed. Before any welding on the actual job is allowed under the contract, the Inspector shall verify whether the welding procedure is in accordance with the provisions of IS:9595 and IS:4353 as applicable.

1.16.10 *Inspection During Welding*

Filler material - Filler material shall be tested periodically to ensure that the specified quality is being consistently maintained.

While welding is in progress, visual examination shall be employed to check the details of work, such as proper arc, arc length, speed of weld deposit, sequence of welding, cleaning of slag after each run in multi-run welding, electrode spattering, manipulation of the electrode, employment of proper current and voltage etc. Particular care shall be taken during the early stages of the work.

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

Adequate means of identification either by an 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 in compliance with the provision of IS:9595.

The method of inspection shall be according to 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.

1.16.11 *Procedure Tests*

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

One or more of following methods may be applied for inspection or non-destructive testing of weld.

1.16.12 *Visual Inspection*

For visual inspection of defects, the weld surface shall be thoroughly cleaned of oxide layers and adherent slag. If chipping hammer is used to remove slag, care shall be taken to see that hammer marks do not obscure the evidence of fine cracks. Brushing with a stiff wire-brush or grit blasting shall normally be followed.

Welding Profile - The finished welds shall be visually inspected and shall conform to the size and contour specified in the drawings (Acceptable and defective weld profiles are illustrated in **Appendix-H, Figs. H-24 to H-28**. Conformity of fillet welds as to size and contour shall be determined by the use of gauges (**Appendix-H, Fig. H-29**) Concavity and excessive convexity of fillet welds shall be marked for correction.

1.16.13 *Acceptance Levels for Quality of Welds*

Welds shall meet acceptance levels as per **Appendix-F**.

Dimensional Check- The weld met shall be inspected for dimensional accuracy (including war page) and shall be within the tolerances specified.

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:

The weld has no crack.

There is adequate fusion between weld and base-metal and between adjacent layers of weld metal.

Weld profiles are in accordance with requisite clauses of IS: 9595 or as agreed with Engineer. The weld shall be of full cross-section, except for the ends of intermittent fillet welds outside of their effective length.

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

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 under size portion of the weld does not exceed 10 percent of the length of the weld. On the web-to-flange welds on girders, no under run is permitted at the ends for a length equal to twice the width of the flange.

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.

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.

1.16.14 *Magnetic particle and Radiographic Inspection*

Weld 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 may be carried out as per IS:1182 and IS:4853.

1.16.15 *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 by Engineer.

1.16.16 *Liquid Penetrant 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 or more of the methods described by Engineer.

All transverse butt weld in tension flange.

a) 10 Percent of length of longitudinal butt welds in tension flange.

b) 5 percent of the length of longitudinal and transverse butt welds in compression flanges.

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

The particular length of welds to be tested shall be agreed with the Engineer, in case of (b) and (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 shall be ultrasonically tested after fabrication.

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

1.16.17 *Marking of Defective Welds*

The marking shall be positive and clear and in accordance with the method of marking followed and understood by the Inspector and shop personnel involved in making the repairs.

Marking shall be permanent enough to be evident until the repair is carried out and the inspection completed.

After the repair has been done, it shall be inspected again and properly marked to indicate whether the repair is satisfactory or not.

The testing of weld for cast steel shall be carried out as may be agreed by the Engineer.

1.16.18 *Testing of Stud Shear connectors*

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

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

The studs which have failed the tests given above shall be replaced.

1.16.19 *Final inspection of components*

The fabricated member/component made out of rolled and built-up section shall be checked for compliance of the tolerances given in **Appendix-B**, Inspection of member/components for tolerances and the check for deviations shall be made over the full length. During checking

the inspection equipment shall be placed in such a manner that local surface do not influence the results. Out-of-plane deviations for plates and other flat surfaces shall be checked at right angle to the surface over the full area.The relative cross girder or cross frame deviation shall be checked over the middle third of length of 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.

1.16.20 *Inspection Stages*

The inspection to be carried out for compliance of tolerances for completed parts, component members on completion of fabrication and before surface preparation for painting and, erection. 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. For cross girders and frames, cantilevers in orthotropic decks and other parts, 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.

1.17 Bearings

Specification and tolerances for roller and knuckle bearings are indicated in **Appendix-D**.

1.18 Painting and Metallising

1.18.1 *General*

No part of the work shall be painted or coated, packed or dispatched, until it has been finally inspected and approved by the Inspecting Officer. Dry film thickness shall be measured by Paint coat meter (Preferably digital) or any other approved method.

When so specified, the whole of the work except machined surfaces, shall be given protective coating using one of the systems of painting or metalizing. Prior to the application of protective coating, the surface or work shall be carefully prepared removing mill scale, rust, etc., using wire brushes, shot or grit blasting as stipulated and approved by the Engineer.

1.18.2 *Surface Preparation*

Remove oil/grease from the metal surface by using petroleum hydro-carbon solvent as per IS:1745.

Prepare the surface by shot/grit blasting to Sa 2.5 (Swedish Standard SIS 055900) to ensure proper surface cleanliness and roughness.

1.18.3 *Metalizing and Painting*

For locations where the girders are subjected to salt spray such as in close vicinity of the sea and/orover creeks etc., protective coating by metalizing with sprayed aluminium followed by

painting as per painting schedule given below may be applied. The metalizing should be as per **Appendix-E**.

Primer Coat - One Coat of etch primer to IS:5666.

For locations where girders are exposed to corrosive environment i.e girders in industrial, sub-urban or coastal areas, components of the girders shall be given protective coating by metalizing followed by painting using epoxy based paints as per the following painting schedule.

Primer Coat- Brush/Airless Spray of Two Coats of Epoxy Zinc Phosphate primer of 60 microns min. dry film thickness (DFT) and giving sufficient time gap between two coats to enable the first coat of primer to hard dry.

Intermediate Coat - One Coat of Zinc Chrome Primer to IS:104.

Finishing Coat - Two coats of aluminium paint to IS:2339 brushing or spraying as required. One coat shall be applied before the fabricated steel work leaves the shop. After the steel work is erected at site, the second finishing coat shall be applied after touching up the primer and the finishing coat if damaged in transit.

Intermediate Coat- Brush/Airless Spray of One Coat of Epoxy Micaceous Iron Oxide paint of DFT 100 microns and allowed to hard dry.

Finishing Coat- Brush/Airless Spray of Two Coats of Polyurethane Aluminium Finishing for coastal locations or Polyurethane Red Oxide (Red Oxide to IS:146) for other locations of 40 microns minimum DFT giving sufficient time gap between two coats to enable the first coat to hard dry. The finishing coats shall be applied in shop and touched after erection, if necessary.

Where the life of protective coating is required to be longer to avoid frequent paintings, because of the accessibility of locations and where metalizing or epoxy based painting is recommended but there are no facilities available for the same, protective coating by painting as per following painting schedule may be applied.

Primer Coat - One coat of ready mixed paint zinc chrome priming to IS:104 followed by one coat of ready mixed paint red oxide zinc chrome priming to IS:2074.

Intermediate - Two coats of Zinc Chromate Red Oxide Primer to IS:2074.

Finishing Coat - Two finishing coats of Aluminium paint to IS:2339 or of any other approved paint shall be applied over the primer coats. One coat shall be applied before the fabricated steel leaves the shop. After the steel work is erected at site, the second finishing coat shall be applied after touching up the primer and the finishing coat if damaged in transit.

2 ERECTION

2.1 Transportation, Handling and Erection

2.1.1 *General*

The handling, transportation and erection of bridges and their components should be done which utmost care & safe procedures.

The actions to be taken for various operations in handling, transportation in shop floor and in transit, should be done with safe working procedures and be intimated to the engineer.

2.1.2 *Transportation to Site and Handling*

Packing, placement, fastening of components and their transportation to site shall be carried out with care and it shall be ensured that damages or undue distortion do not occur.

Before deciding the mode of transportation, the route shall be surveyed and local restriction considered. Instructions for proper handling during transportation and storage shall be issued.

All component shall be securely lashed during transportation to ensure that they do not fall/slide or endanger other traffic. All possible safety measures shall be adopted.

In case of heavy and unusual structures, availability of the transportation medium shall be checked in advance and arrangements tied up.

Stability of the members shall be checked and ensured during loading and transportation.

Protruding members shall be specially protected during transit. Threaded and machined portion of fabricated structures shall be oiled/greased against corrosion and carefully protected against damage.

Loose or sub - assembled items shall have clear mark number as per the erection drawing. Critical items shall be given special care.

Small items such as nuts, bolts, washers, packing plates, rivets, electrodes shall be dispatched in container and their details shall be fully listed to ensure proper receipt and storage.

Under loaded consignments shall be normally avoided.

All consignments of steel work shall carry dispatch advice/challan to maintain the correlation between fabricated components and components sent to site for erection.

For access to the erection site it may be necessary to construct temporary road/bridges which allow safe movement of the fabricated materials & equipment.

2.1.3 *Storage and Handling at Site*

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

The site store should be provided with adequate handling equipment such as mobile crane, gantries, derricks, chain-pulley blocks, winch and other lifting tools and tackles of adequate capacity.

Stacking area shall be properly leveled and shall have access tracks for movement of cranes. Racks, sleeper stands and requisite open space for storage shall be available. Storage shall be planned to avoid damage or distortion of the components and availability to suit the erection sequence.

Fabricated materials shall be stored in such a way that erection marks are visible and shall have accessible to handling equipment. They should be stored in such a way that they do not come in contact with earth surface or water.

Small fittings, hand tools etc., are to be kept in containers in covered stores.

Safety requirement for equipment should be as per IS:7293, and for storage IS:7969 shall be followed. For useful information about Cranes see **Appendix-K**.

2.2 Erection Scheme and Erection Procedure

2.2.1 *General Considerations*

The construction methodology, types of equipment to be used use and other relevant information relating to the erection scheme shall be intimated to the engineer for his approval.

While preparing erection scheme, provision for wind loads shall be made according to local conditions. Ground conditions should be stable enough to ensure that the temporary supports do not settle during erection.

Span erected upon staging shall be supported upon suitable blocks and camber jacks. Care shall be taken to ensure that the girders are erected at the correct elevation, alignment and camber, when completed.

When chains are used for lashing, care must be taken to protect the edges of members from denting and distortion.

Proper method shall be used for lifting and slinging of flexible members to ensure that permanent deformations are not made.

Erection work shall start only when resources, as per approved scheme, are available at site and the foundations for supports are ready for taking the load.

In works of erection involving high volume, mechanization to the possible extent, shall be adopted.

The structure shall be divided into modules. Before erection the modules shall be pre-assembled in a suitable yard/platform and its matching with members of the adjacent module shall be checked.

Where erection has to be carried out on a difficult terrain, the trial assembly of the girder should be done and simulated load shall be applied to study the effect.

The supporting structure shall be set out to the required lines and levels. Sufficient packing materials should be available at site to start erection. The erection of the girder shall be completed with sufficient drifts and bolts and in the required position.

2.2.2 *Plants and Equipment*

Capacity chart for each crane configuration and boom length should be studied in detail and placement of the crane planned accordingly.

Periodical inspection of the crane and other lifting equipment shall be made to ensure that the equipments are in working order. The lifting gear and machinery should have the periodical load testing certificate and declared fit for service by authorized personnel only.

Prior to actual commencement of erection all equipment, machinery, tools, tackles, shall be load tested and witnessed by the engineer, to ensure their efficient working.

Appendix-I, illustrates some typical lifting tools, tackles and lifting methods.

2.2.3 *Temporary Works*

All temporary work shall be properly designed and constructed for construction loads. Temporary bracing shall be provided to take care of rigidity during erection.

2.2.4 *Inspection and Testing Prior to Erection*

Visual inspection is essential in vulnerable areas to detect displacements, distress, damages etc.

Deflection tests shall be conducted in respect of supporting structures, launching truss as also the structure under erection. Any looseness of fittings or unusual behavior shall be noted and adequate precautions taken.

Safety requirements shall conform to IS:7205 and IS:7293.

Organized “Quality Surveillance” checks shall be exercised intermittently.

For erection Inspection checklist see **Appendix-L**.

2.2.5 *Lifting and Assembling*

Planned systems for achieving and maintaining stability at all times during construction shall be fully detailed in the method statement which should contain precise step-by-step instructions.

These shall be indicated on the detailed working drawings and given to the erection supervisor.

Any special or unusual features of the structural design which may affect stability during erection shall be highlighted and emphasized on drawings which shall form part of the method statement.

The ground on which the crane shall stand must be firm, leveled and free from obstruction. All outriggers must be fully extended, jacked and locked.

The crane shall be leveled before attempting the lift and in many cranes there may be ‘level bubble’ which can be used to satisfy this condition.

Before using the equipment the safe working load shall be considered and shall be inspected for defects, if any including excessive wear and tear.

2.2.6 *Bearing and Anchorages*

Bed plates shall be set to required level and fixed accurately in position by giving full and even bearing by setting them on a layer of cement sand and cast iron chips as approved and directed by the engineer.

The holes shall be drilled , where necessary, and the anchor bolts set. The bolts shall be set accurately and fixed with cement grout or any other grouting material, as approved by the Engineer to completely fill the holes.

2.2.7 *Cambering for Erection of Open Web Girders*

The joints of the chords shall be drifted, bolted and preferably riveted to their geometric outline.

All other members are to be elastically strained into position by external forces, so that as many holes as possible are fair when filled with rivets.

Drifting of joints shall be avoided as far as possible, and when necessary, should be done with great care and under close expert supervision. Hammers not exceeding one kg in weight shall be used with turned barrel drifts and a number of holes drifted simultaneously, the effect of the drifting shall be checked by observation of adjacent unfilled holes.

The first procedure during erection consists of placing camber jacks in position on which the structure shall be supported. The camber jacks shall be set with their tops level, and with sufficient run out to allow for lowering of panel points except the centre by the necessary amounts to produce the required camber in the main girders. It is essential that the camber is accurately maintained throughout the process of erection and it should be constantly checked. The jacks shall be spaced so that they shall support the ends of the main girders and the panel points. The bottom chord members shall then be placed on the camber jacks, carefully leveled and checked for straightness and the joints made and riveted up.

The vertical and diagonal web members, except the posts, shall then be erected in their proper positions on the bottom chords It is recommended that temporary top gussets, the positions of the holes in which are corrected for the camber change of length in the members, should be used to connect the top ends of the member this will ensure that the angles between the members at the bottom joints are as given by the nominal outline of the girders. The vertical and diagonal shall then be riveted/bolted to the lower chords.

All panel points, except the centre, shall now be lowered by amounts to produce the correct camber in the main girders as shown on the camber diagram.

The top chord should be erected piece by piece working symmetrically from the centre outwards, and the joint made by straining the members meeting at the joint and bringing the holes into correct position.

The temporary gussets, if used, shall be replaced by the permanent gussets in the same sequence as the erection of the top boom members.

The end posts shall be erected last. The upper end connection should preferably be made first and if there is no splice in the end raker, the final closure made at the bottom end connection. If there is a splice, the final closure should be made at the splice.

When cantilever method of erection is used, the above procedure does not apply.

2.3 Joints

2.3.1 *Bolted Joints*

No joint shall be assembled for bolting until the contact surface have been properly inspected to ensure that they are free from dirt ,scales and other foreign materials.

Each bolt and nut shall be assembled with at least one washer. A washer, conforming to **Clause 502.4** of IRC:24, shall be placed under the rotating component.

Where the angle between the axis of the bolt and the joints surface is more that 3 degree off normal, a tapered washer shall be used against the tapered surface. The non-rotating components shall preferably be placed against the tapered washer.

The nut should be placed so that the mark to identify a high strength nut is visible after tightening.

Packing shall be provided wherever necessary to ensure that the load transmitting plies are in effective contact when the joint is tightened to the 'snug-tight' condition. All packing shall be of steel with a surface condition similar to that of the adjacent material.

The holes in the parts to be joined shall be aligned to permit the bolts to be positioned without damage to the threaded portion of the bolt. Drifting to align holes shall not distort the metal or enlarge the holes.

Snug tightening and final tensioning of the bolts shall proceed from the stiffest part of the joint towards the free edges.

High strength bolts, conforming to IS:3757, may be used temporarily during erection to facilitate assembly. They shall not be finally tensioned until all bolts in the joint are snug-tight in their correct sequence.

Re-tensioning of bolts which have been fully tensioned shall be avoided wherever possible. If re-tensioning must be carried out it shall only be permitted once and only when the bolt remains in the same hole in which it was originally tensioned and with the same grip.

Under no circumstances shall bolts, which have been fully tensioned, be reused in another hole.

2.3.2 *Riveted Joints*

All rivets shall be properly and uniformly heated to straw heat for the full length of the shank. The head of the rivet, particularly in long rivets, shall be heated more than the point. Sparking or burnt rivets shall not be used. Pneumatic/hydraulic operated dolly and riveting gun should be used for holding the rivet head and forming the rivet head at the point end.

Where support is not available to hold the rivet head by pneumatic/hydraulic operated dolly or any other mechanical method, head forming of the rivet should be done by utilizing two riveting gun, operating simultaneously, from both ends of the rivet.

Gauges for rivet dimensions and contours shall be provided by the contractor for the use of the Inspecting Officer.

Rivets when driven shall completely fill the hole. The formed head of the rivet should be concentric with the shanks and shall be in full contact with ply surface. Driven rivets shall be free from movement or vibration, when struck sharply on the head with the 110 gm. Rivet testing hammer. While riveting built-up members great care should be exercised to ensure that the set of holes for field rivets in each flange of the built-up member, is aligned dead-square in relation to that in the other flange and not abrogated.

All loose, burnt, head cracked, badly formed, eccentric and deficient head rivets shall be cut out and replaced. Rivets shall also be cut out when required for the examination of the work. Actual method of cutting out shall be approved by the Engineer.

Recapping and caulking should not be done.

Riveting shall be started when the Engineer gives permission after personally satisfying himself about the correctness of the assembly, the suitable cambering and proper alignment of the girder and ensuring about the tightening of service bolts and concentricity of field rivet holes.

Special care should be taken that service bolts are frequently re-tightened as the riveting proceeds. All field rivets shall be tested as directed by the Engineer.

Where practicable all riveting shall be done by pneumatic or hydraulic riveting machine. The working pressure to be used for the riveting shall be accepted by the Engineer.

Hand riveting shall only be done when sanctioned by the Engineer. In such cases, means shall be adopted to ensure the rivets being used fill the rivet holes completely, the snap is used only to give the correct head formation.

When all the rivets of joints have been finally passed, they shall be painted as under:

One coat of ready mixed Zinc Chrome Primer to IS:104 followed by one coat of ready mixed paint red oxide zinc chrome primer to IS:2074.

Finishing coat should be done at the time of final painting.

2.3.3 *Welded Joints*

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

Weld Procedure Specifications (WPS) shall be prepared and got approved by the engineer. All weldings are to be carried out as per IS 816/IS 9595 with suitable consumables, as approved in the WPS. All welds shall be sound and shall conform to **Clause No 512.4.4** of IRC:24.

For welded connections, welders qualification are to be done as per relevant IS code.

Non-destructive tests (NDT) 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 should be kept.

APPENDIX - A

(Inspection Register)
(Refer Clause 1.16.1)

A 1 JIGS REGISTER

This register shall be maintained for keeping records of details of jigs, their approval and modification/rectification to the jigs. One page should be allotted for each jig and details mentioned in the following Proforma :

a) Description of Jigs:
b) Jig No.
c) Shipping mark of the components for which jig is made.
d) Drawing No. for the component.

Date of Inspection	Observation/inspection Notes	Compliance action	Initial of supervision in-charge
1	2	3	4

In the beginning of Register, a statement of jigs shall also be placed in the following proforma.

Jig No.	Description of Jig	Shipping mark of the component	Drg. No. as per which jigs is made/modified	Inspecting official's approval details
1	2	3	4	5

A 2 RIVET CHECKING REGISTER

This register shall be maintained for keeping records of rivet quality checking and replacement of defect rivets. Register shall be maintained in the following proforma :-

Component description	Date of riveting	Rivetting party	Number & nature of defective rivets	Number of defective rivets replaced	Initial of Supervision in-Charge
1	2	3	4	5	6

After riveting, component has been inspected and defective rivets have been replaced, the Supervisor-in-charge of riveting should put a stencil mark on the component to this effect.

A 3 MATERIAL OFFERING AND INSPECTION REGISTER

This register shall be maintained separately for each work order for keeping record of material offered for inspection, inspection remarks and passing details. One page should be allotted for individual members or fittings. Proforma shall be under:

a) Description of component/fitting:
b) Shipping mark :
c) Quality required per span.

Span No.	Initial of Supervisor offering material for inspection	Inspecting official Remarks	Compliance action	Seal & initial of inspecting official	Despatch & consignee details
1	2	3	4	5	6

A 4 INSPECTION NOTES AND COMPLIANCE REGISTER

This register shall be maintained for record of compliance action taken Engineer Inspection notes. In this register one copy of the inspection note received from Engineer shall be pasted and compliance action record against each item.

A 5 WELDING PROCEDURE DATA REGISTER

In this register complete details of welding of welded girders shall be maintained in the proforma under :

Name of Work _____

Contract/ Work Order No. _____

Span No. _____

Date of Welding	Girder component & its Sl. No.	Welding joint description	Name of welder/ Ticket No.	WPSS No. followed
1	2	3	4	5

Welding consumable used		Welding Parameters			Weld repair details	Run on/Run off tabs. No. if any	Radiography No. if any	Initial of Supervisor in-charge
Electrode / Wire	Flux	Current (Amp.)	Arc Voltage (Volt)	Travel Speed (m/min)				
6	7	8	9	10	11	12	13	14

The welding data record to be submitted to Engineer while offering the welded girders for inspection, shall be prepared based on the details recorded in this register.

A6 RADIOGRAPHIC INSPECTION REGISTER

Record of radiographic inspection of welded girders shall be maintained in the register in the Proforma given below :-

Name of work	Span No.	Girder Part	Weld joint description	Date of radiographic inspection	Radiograph No.	Obser-vation	Result	Initial of Supervisor-In-charge
1	2	3	4	5	6	7	8	9

A 7 RADIOGRAPHIC INSPECTION REGISTER

Record of radiographic inspection of welded girders shall be maintained in the register in the proforma given below :

Name of Work _____

Contract/Work Order No. _____

Span No. _____

Girder component description & identification No.	Type & Sized of rolled section	Material Test Certificate No.	Cast No.	Steel quantity as per the test certificate	Steel Manufacturer Supplier	Initial of Supervisor-In-charge.
1	2	3	4	5	6	7

One page should be allotted for each span.

APPENDIX - B

(Manufacturing Tolerance)
(Refer Clause 1.16.19)

B 1 PLATE GIRDER

			Tolerance in mm		Notation in the Fig. B-1
			(Plus)	(Minus)	
	a)	Overall length of the girder	6	3	A
	b)	Distance between centers of Bearings	1	1	B
	c)	Depth over Angles	3	1	C
	d)	Corner of flange angle to edge of web at any place	0	2	D
	e)	Diagonal at either end of the assembled span	3	3	E
	f)	Centres of intersection of diagonals with girder flange measured along the girder flange	3	3	F
	g)	Butting of Compression ends			
		i) Throughout	0	0.15	G
		ii) Locally	0	0.25	G
	h)	Butting edge at web splices	0	1	H
	i)	Straightness of girder bottom laid on the ground and checked with piano wire			
		i) Vertical Plane Convexity Concavity ii) Horizontal Plane	 0 0 2	 3 0 2	 j j j

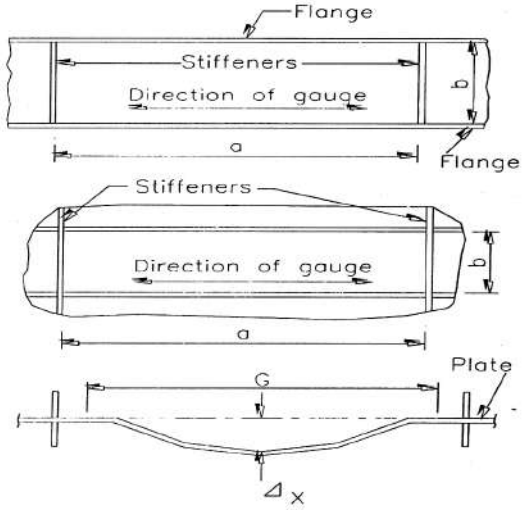
B 2 OPEN WEB GIRDER

	a)	Overall length of Girders	1	1	K
	b)	Distance between centre to centre of bearings	1	1	L
	c)	Cross diagonals of assembled bays	1	1	M
	d)	Centre to centre of cross girders	1	1	N
	e)	Centre to centre of Rail bearer	1	1	P
	f)	Panel length in lateral bracing system	1	1	Q
	g)	Distance between inter section line of chords vertical & horizontal	1	1	R
	h)	Butting edges of compression members i) Throughout ii) Locally	 0 0	 0.15 0.25	 S S
	i)	Twist in members	0	0	T
	j)	Lateral distortion between points of lateral support	.001L	.001L	U

B 3 HOLES

	a)	Between any two holes in group	0.5	0.5	V
	b)	Between holes of one group and another	1	1	W
	c)	Edge distance	0.5	0.5	X
	d)	Distance of 'GO' gauge open holes in two or more thickness	0	0.8	Y

B 4 SPECIAL FABRICATION TOLERANCE AS APPLICABLE TO WELDED PLATE GIRDER

	Description	Tolerance in mm
1.	Depth at the centre of web	+ 2 to -1
2.	Flange out of square for compression member and beams	1/200 or 3 max. from edge whichever is less
3.	Displacement of vertical axis of the web with reference to flange	2
4.	Box width of member	0 to + 3
5.	Verticality of stiffener or diaphragm out of plumb	2
6.	Overall length of girder	+ 6 to - 3
7.	Depth of the girder at the ends	+ 3 to - 1
8.	Depth of the girder at the centre of span	+ 2 to - 1
9.	Distance between centre of bearings	+ 1 to - 1
10.	Diagonal at either ends of assembled span	+ 3 to - 3
11.	An allowable limit for web buckling or undulation shall be flatness at right angles to plate surface measured parallel to longer side in either direction calculated from the formulae $\Delta_x = \frac{G}{165}\sqrt{\frac{\sigma_y}{355}}$ or 4mm which ever is the lesser. Where Δ_x = Maximum deviation from straightness within a specific gauge length other values are constant σ_y = Yield stress of steel in N/mm^2 G = length of measuring gauge in meter (G= a where a<2b and G=2b where a>2b)  	

MANUFACTURING TOLERANCES IN GIRDERS

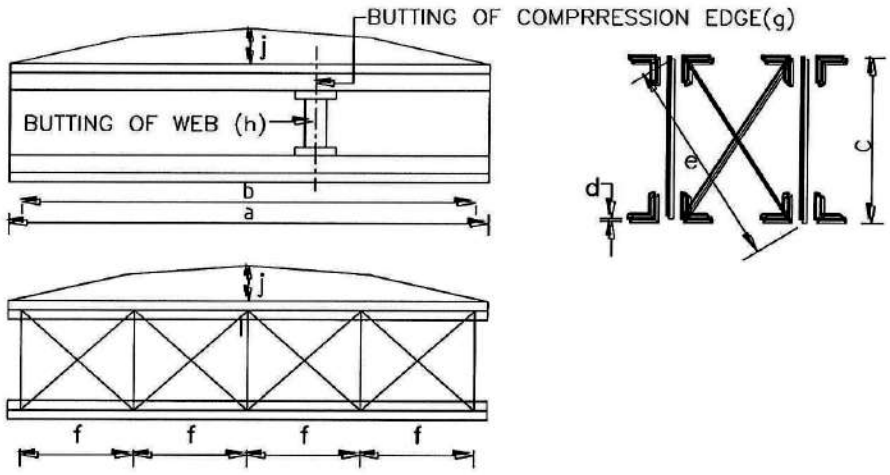
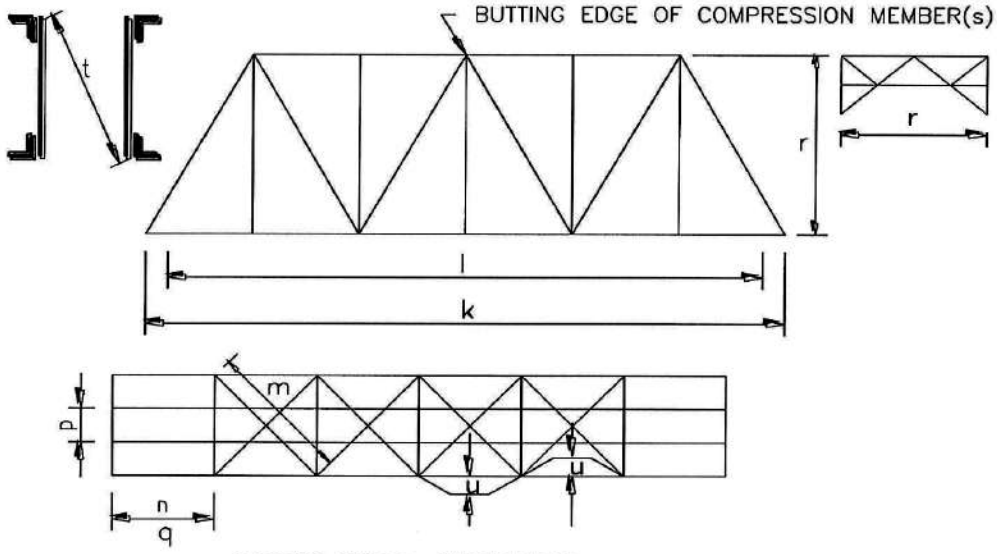
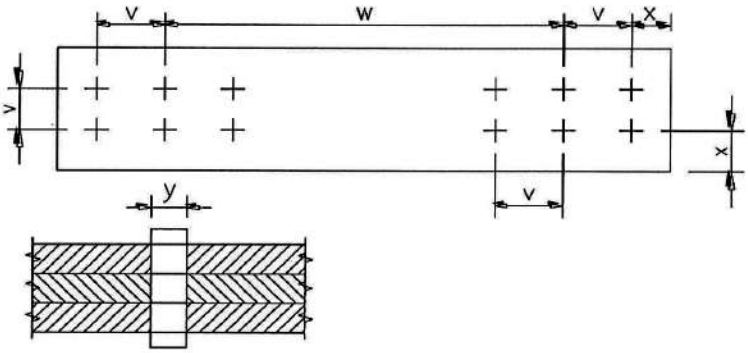


PLATE GIRDERS



OPEN WEB GIRDERS



HOLES IN MEMBERS

Fig. B-1

APPENDIX - C

(Welding Records)

(Refer Clause 1.16.8)

C1. PROFORMA FOR WELDING PROCEDURE SPECIFICATION SHEET

Name & Address of Fabricator :

Welding Procedure Specification No. :

C.1.1 Welding Joint Description :

C.1.2 Base Metal :

C.1.3 Base Metal :

C.1.4 Welding Process :

C.1.5 Welding Position :

C.1.6 Welding Consumables :

C.1.7 Electrode/Wire Class :

Dia :

Drying Method :

C.1.8 Flux. Class :

Type :

Drying method :

C.1.9 Shielding gas :

C.1.10 Base Metal preparation :

Joint design details :

(Give sketch showing arrangement of parts, welding groove details Weld passes & their sequence etc.,)

C.1.11 Joint preparation : Type :

C.1.12 Welding current : Polarity :

C.1.13 Welder qualification :

C.1.14 Welding parameters and technique :

C.1.15 Welding Parameters :

Weld Pass No.	Electrodeswire dia (mm)	Current (Amp.)	Arc Voltage (Volt)	Wire Feed Speed (m/min)	Travel Speed (m/min)	Electrical stick out (mm)	Gas flow rate (liter/ min.)
1	2	3	4	5	6	7	8

C.1.16 Welding sequence and technique :

(Give sketch showing sequence and direction of welding).

C.1.17 Provision of run in and run-off tabs :

C.1.18 Cleaning of weld bead before laying next weld bead :

C.1.19 Root preparation before welding other side of groove weld :

C.1.20 Preheating and inter pass temperature :

C.1.21 Peening :

C.1.22 Post weld treatment :

C.1.23 Rectification of weld defects :

C.1.24 Inspection of weld :

C.1.25 Any other relevant details :

C2. PROFORMA FOR WELDING PROCEDURE QUALIFICATION RECORD

Name & Address of Fabricator :

C.2.1 Description of Weld Joint :

C.2.2 Welding Procedure Specification No. :

C.2.3 Name of Welder :

C.2.4 Date of preparation of test piece :

C.2.5 Dimension of test piece :

C.2.6 Base Metal :

C.2.7 Welding Process :

C.2.8 Welding Position :

C.2.9 Welding Current : Type : Polarity :

C.2.10 Weld joint design details :

C.2.11 Welding consumables :

C.2.11.1 Electrode/Wire Class : Dia : Drying method :

C.2.11.2 Flux : Type : Drying method :

C.2.11.3 Shielding gas :

C.2.12 Welding Parameters

Weld Pass No.	Electrodes/ wire dia (mm)	Current (Amp.)	Arc Voltage (Volt)	Wire Feed Speed (m/min)	Travel Speed (m/min)	Electrical stick out (mm)	Gas flow rate (liter/ min.)
1	2	3	4	5	6	7	8

C.2.13 Pre-heating and inter pass temperature :

C.2.14 Results of Qualification Test :

Test	Specification No.	Results
1	2	3
Non-destructive Tests : i) Visual Examination ii) Dye Penetrate test iii) Magnetic particle test iv) Radiographic/Ultrasonic test Destructive Test: i) Micro-examination ii) Hardness survey iii) Fillet weld fracture test iv) Transverse tensile test Tensile strength Yield Stress Location of fracture v) All-weld tensile test Tensile strength Yield stress Elongation % vi) Guided bend test Root bend test Face bend test Side bend test vii) Any other test		

Signature _____

Designation _____

APPENDIX - D

Tolerance and Specifications for Roller and Knuckle Bearings

(Refer Clause 1.17)

D 1. ROLLER

No roller shall vary in diameter, from that shown on the contract drawings, by more that ± 0.04 mm.

D 2. KNUCKLE CASTINGS AND PINS (INTERCHANGEABLE WORK)

The diameter shall not be greater than D, not less that D-0.2 mm.

Knuckle Castings.

The knuckle castings must be bored greater that D, but not greater than D + 0.3 mm.

Where D, in all cases is the diameter given on the contract drawings.

D 3. KNUCKLE CASTINGS AND PINS (NON-INTERCHANGEABLE WORK)

If sets of bearings are not made inter-changeable but are made separately and the pins and knuckles all fitted together than the minus tolerance on the pin, and the plus tolerance on the bore on the knuckles may bed varied provided that the difference between the diameter of the pin and the diameter of the knuckle does not exceed 0.5 mm also in this case all sets of bearing are to be given a consecutive number and each component part shall have this allotted number stamped upon it and encircled in white paint in the manner shown on the sketch.

D 4. MARKING

Accurate centre marks should be made on the four sides of the bottom slab of the bearing to facilitate positioning during erection.

D 5. THICKNESS OF CASTINGS (INTERCHANGEABLE AND NON-CHANGEABLE WORK)

No minus tolerance will be allowed in the thickness of any part of any of the castings. The edges of all ribs shall be of the thickness shown on the contract drawing and shall be parallel throughout their length.

APPENDIX - E

Specification for Metallising with Sprayed Aluminium for Bridge Girders

(Refer Clause 1.18.3)

E 1 SURFACE PREPARATION

The surface shall be thoroughly cleaned and roughened by compressed air blasting or centrifugal blasting with a suitable abrasive material in accordance with **Clause 3** of IS:6586 immediately, before spraying. It shall be free from grease, scale, rust, moisture or other foreign matter. It shall be comparable in roughness with a reference surface produced in accordance with **Appendix-A** of IS:5905 and shall provide an adequate key for the subsequently sprayed metal coating.

E 2 METAL SPRAYING

The metal spraying shall be carried out as soon as possible after surface preparation but in any case within such period that the surface is still completely clean, dry and without visible oxidation. If deterioration in the surface to be coated is observed by comparison with a freshly prepared metal surface of similar quality which has undergone the same preparation, the preparation treatment should be repeated on the surface to be coated.

The wire method shall be used for the purpose of metallising, the diameter of the wire being 3 mm or 5 mm. Specified thickness of coating shall be applied in multiple layers and in no case less than 2 passes of the metal spraying unit shall be made over every part of the surface. At least one layer of the coated to the specified thickness within 8 hours of blasting.

The chemical composition of aluminum to be sprayed shall be 99.5 percent aluminium conforming to IS:2590. The surface of the sprayed coating shall be of uniform texture and free form lumps, coarse areas and loosely adherent particles. The nominal thickness of the coating shall be 150 μ (microns). The minimum local thickness, determined in accordance with procedure given in **Clause E.5.1** below, shall be not less than 110 μ (microns).

E 3 SHOP PAINTING

Any oil, grease or other contamination should be removed by through washing with a suitable thinner until no visible traces exist and the surfaces should be allowed to dry thoroughly before application of paint. The coatings may be applied by brush or spray. If sprayed, pressure type spray guns must be used. One coat of wash primer, one coat of Zinc chrome primer to IS:104 with the additional provision that Zinc chrome to be used in the manufacture of primer shall conform to type 2 of IS:51, shall be applied. After hard drying of zinc chrome primer, one coat of Aluminum paint to IS:2339 (brushing or spraying as required) shall be applied.

E 4 SITE PAINTING

After the steel work is erected at site a second cover coat of Aluminum paint to IS:2339 (brushing or spraying as required) shall be applied after touching up the primer and the cover coat given in the shop if damaged in transit.

E 5 INSPECTION

E 5.1 Equipment

Any magnetic or electro-magnetic thickness meter that will measure local thickness of a known standard with an accuracy of ± 10 percent shall be used. The meter shall be checked on one of the following standards.

i) A soft brass shim, free form burrs, in contact with the grit blasted surface of the base metal prior to its being sprayed. The thickness of the shim shall be measured by micrometer and shall be approximately the same as the thickness of the coating.

ii) A sprayed metal coating of uniform known thickness of approximately the same as the thickness of the sprayed coating to be tested, applied to a base of similar composition and thickness.

E 5.2 Procedure

For each measurement of local thickness, an appropriate number of determinations shall be made, according to the type of instrument used. With instrument measuring the average thickness over an area of not less than 0.645 cm^2, the local thickness shall be the result of the one reading. With instruments having one or more pointed or rounded probes, the local thickness shall be the mean of three readings within a circle of 0.645 cm^2 area. With meters having two such probes, each reading shall be the average of two determinations with the probes reversed position.

E 5.3 Method of Test for Adhesion

Using a straight edge and hardened steel scriber which has been ground to a sharp 30 degree point, scribe two parallel line at a distance apart equal to approximately 10 times the average coating thickness. In scribing the two lines, apply enough pressure on each occasion to cut through the coating to the base metal in a single stroke. If any parts of the coating between the line breaks away from the base metals, it shall be deemed to have failed the test.

Articles, which have been rejected shall have the defective sections blasted clean of all sprayed metal prior to re-spraying. Where the rejection has been solely due to too thin a coating, sprayed metal of the same quality may be added provided that the surface has been kept dry and is free from visible contamination.

APPENDIX - F

Acceptance Levels for Welds

(Refer Clause 1.16.13)

Defect Type			Permitted, Maximum
F1) Planar defects			
a) Cracks and lamellar tears			not permitted
b) Root concavity			0.1t or 1.2 mm whichever is less
c) Lack of root fusion			not permitted
d) Lack of side fusion			not permitted
e) Lack of inter-run fusion			not permitted
f) Lack of root penetration			not permitted
F2) Cavities			
a) Isolated pores (or individual pores in a group)			$\phi \leq t/4$ and also less than
			(i) 1.5 mm for t upto and including 25 mm; or
			(ii) 3.0 mm for t over 25 mm upto and including 50 mm; or
			(iii) 4.5 mm for t over 50 mm upto and including 75 mm; or
			(iv) 6.0 mm for t over 75 mm
b) Uniformly distributed or localized porosity			One percent by area (as seen in a radio graph) for $t \leq 25$ mm and pro-rata for greater thicknesses
c) Linear porosity			Linear porosity parallel to the axis of the weld may indicate lack of fusion or lack of penetration and is, therefore, not permitted
d) Worm holes, isolated			$l \leq 6$ mm $w \leq 1.5$ mm
e) Worm holes, aligned			same as for linear porosity
f) Crater pipes			$l \leq 6$ mm $w \leq 1.5$ mm
F3) Solid Inclusions (Slag Inclusions)			
a) Individual and parallel to weld axis (as seen in the radiograph)			
	t	l	w
i)	≤ 18 mm	≤ t/2 and ≤ 6 mm	≤ 1.5 mm
ii)	> 18 mm and ≤ 75 mm	≤ t/3	≤ 1.5 mm
iii	> 75 mm	≤ 25 mm	≤ 1.5 mm
b) Linear group*			Aggregate length should not exceed 8 percent of length of group, which in turn should not exceed 12t in length.
c) Individual and randomly oriented (Not parallel to weld axis)			Maximum dimension in any direction: 6 mm.
F4) Copper inclusions			
(Detected by visual examination or by radiography)			Not permitted

F5) Profile defects	
a) Undercut	Slight intermittent undercut permitted, provided it does not form a sharp notch ; depth should not exceed 0.4 mm.
b) Shrinkage grooves and root concavity	Same as for under cut, depth should not exceed 1.2 mm.
c) Excess penetration	H ≤ 3 mm. Occasional local slight excess is allowable
d) Reinforcement shape	The reinforcement shall blend smoothly with the parent metal and dressing shall be as specified in drawing or required for NDT techniques.
e) Overlap	Not permitted
f) Linear misalignment	H ≤ t/10 and ≤ 3 mm

Symbols:

t = Thickness of parent metal. In the case of dissimilar thicknesses t applies to the thinner component

w = Width of defect , l = Length of defect , h = Height of defect , ϕ = Diameter of defect

* Individual inclusions within the group should not exceed the sizes in 3(a) above. A linear group is defined as a number of inclusions in line and parallel to the weld axis where the spacing between their adjacent ends does not exceed 6 times the length of the longest inclusion within the group. With parallel groups, all inclusions count towards the aggregate.

APPENDIX - G

Procedure for Providing Plug Welds

(Refer Clause 1.15.24)

The holes shall be tapered to ensure adequate root penetration.

Welding shall generally be carried out in flat position using a copper block plate of 25 mm minimum thickness as a backing surface. This plate shall have a depression of about 3 mm at the center and in the line of the hole.

For welds to be made in the flat position, the arc shall be carried round the root of the joint and then carried along spiral path to the center of the hole fusing and depositing a layer of weld metal in the root and bottom of the joint. The arc shall then be carried to the periphery of the hole and the procedure repeated, fusing and depositing successive layers to fill the hole. The slag covering the weld metal shall be kept molten, or nearly so, until the weld is finished. If the arc is broken, except briefly for changing the electrodes, the slag must be allowed to cool and be completely removed before starting the weld.

For welds to be made in the vertical position, the arc shall be started at the root of the joint, at the lower side of the hole, and carried upwards along a zig zag path depositing a layer about 5 mm thick on the exposed face and fused to the side of the hole. After cleaning the slag from the weld, subsequent layers shall be similarly deposited to fill the hole.

For welds to be made in the overhead position, the procedure shall be the same as for the flat position except that the slag shall be allowed to cool and shall be completely removed after depositing each layer until the hole is filled.

All plug welds shall be finished with reinforcement of about 3 mm which shall then be dressed flush.

APPENDIX - H

Weld Details

(Refer Clause 1.15 and 1.16)

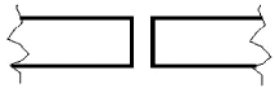
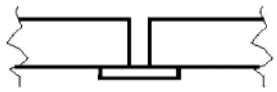
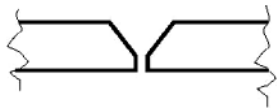
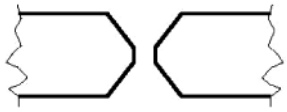
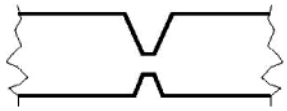
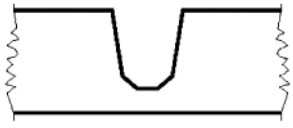
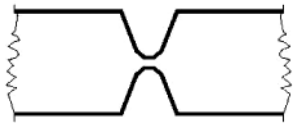
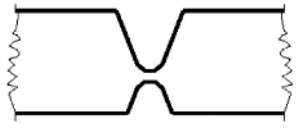
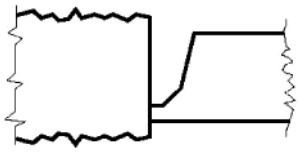
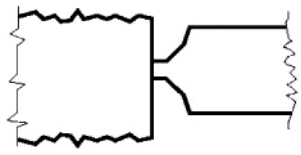
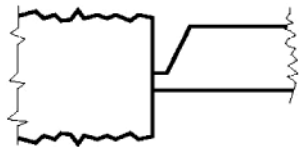
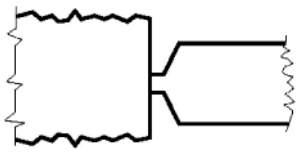
 (a) Open Square Butt Weld (without Backing)	 (b) Open Square Butt Weld (with Backing)	 (c) Single V Butt Weld (without Backing)
 (d) Single V Butt Weld (with Backing)	 (e) Double V Butt Weld	 (f) Asymmetric Double V Butt Weld
 (g) Single U Butt Weld	 (h) Double U Butt Weld	 (i) Asymmetric Double U Butt Weld
 (j) Single J Butt Weld	 (k) Double J Butt Weld	 (l) Single Bevel Butt Weld
 (m) Double Bevel Butt Weld		

Fig. H-1 Different Types of Butt Weld

(i) (ii)

(a) First Side Welded

(i) (ii)

(b) Back of First Run Gouged
To Clean Metal

(i) (ii)

(c) Second Side Welded

Fig. H-2 Diagrammatic Representation Method of Gouging out Complete Penetration Butt Joints Welded From Both Sides

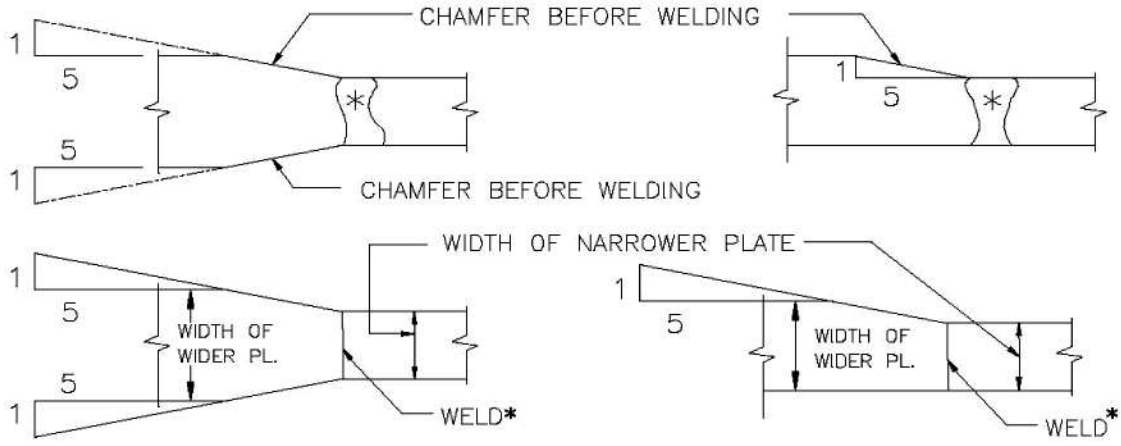


Fig. H-3 Transition by Chamfering Thicker or Wider Part

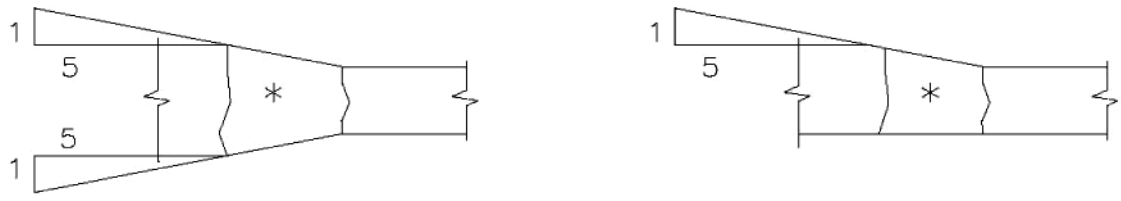


Fig. H-4 Transition by Sloping Weld Surface

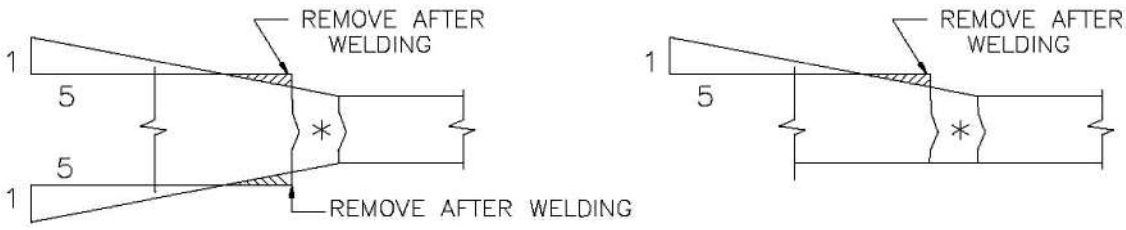


Fig. H-5 Transition by Sloping Weld Surface and Chamfering

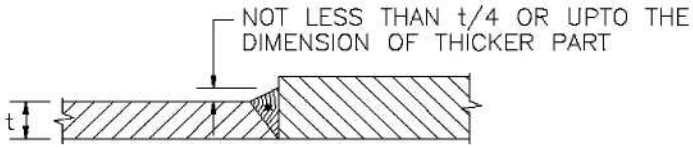


Fig. H-6 Butt Weld Where Transitioning is Not Practicable

Note:

1. * Weld may be of any Permitted or Qualified Type & Detail
2. Transition Slopes Shown are the Maximum Permitted

BUTT WELDING PARTS OF UNEQUAL CROSS SECTION

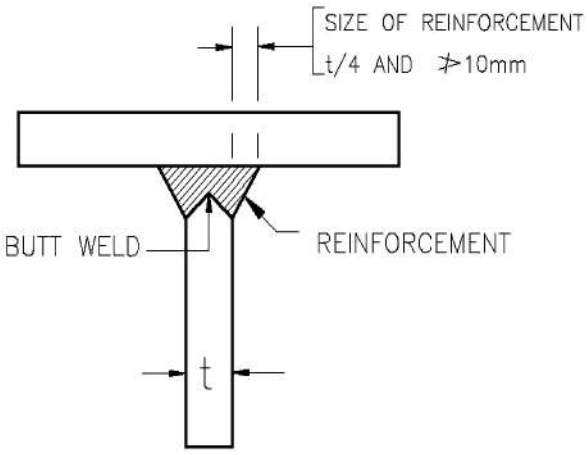


Fig. H-7 Butt Welded T Joint

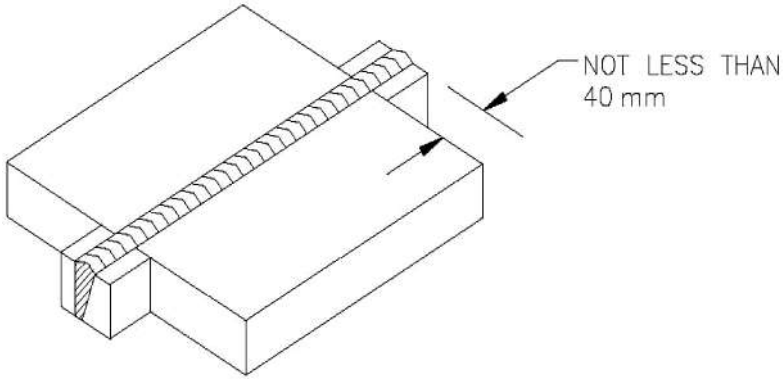


Fig. H-8 Butt Welded Joint with Run-on and Run-Off Plates

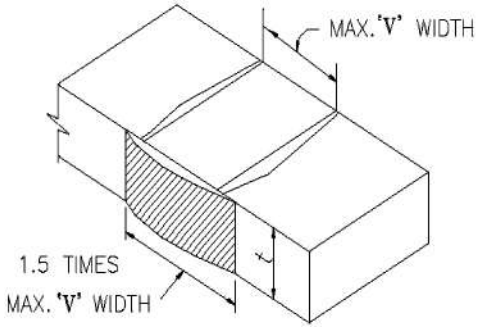


Fig. H-9 Butt Weld End Reinforcement

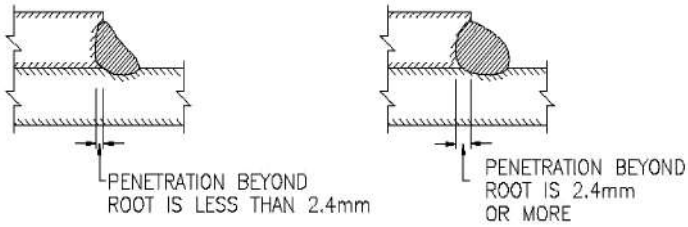


Fig. H-10 Types of Fillet Weld

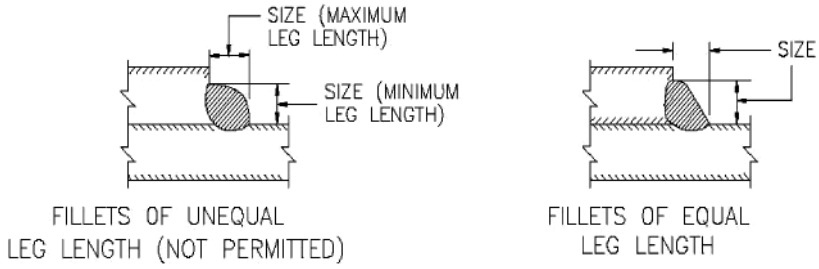


Fig. H-11 Size of Normal Fillet Welds

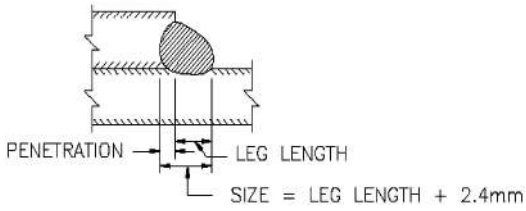


Fig. H-12 Size of Deep Penetration Fillet Weld

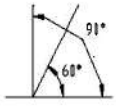
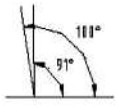
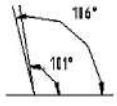
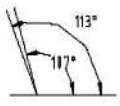
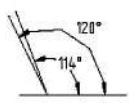
ANGLE BETWEEN FUSION FACES	60°–90°	91°–100°	101°–106°	107°–113°	114°–120°
					
CONSTANT 'K'	0.70	0.65	0.60	0.55	0.50

Fig. H-13

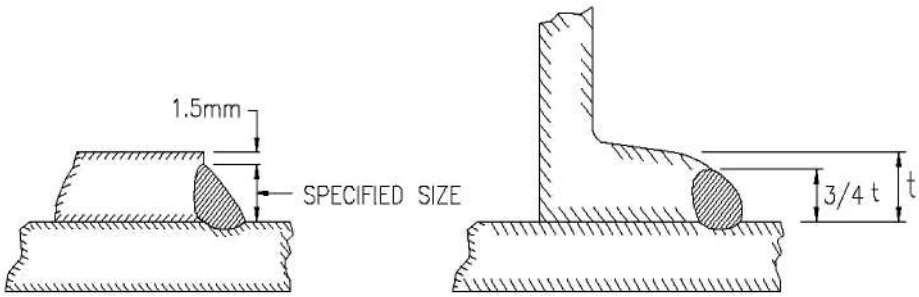


Fig. H-14 Fillet Weld Applied to Square
Edge of Plate or Round Toe of Rolled Section

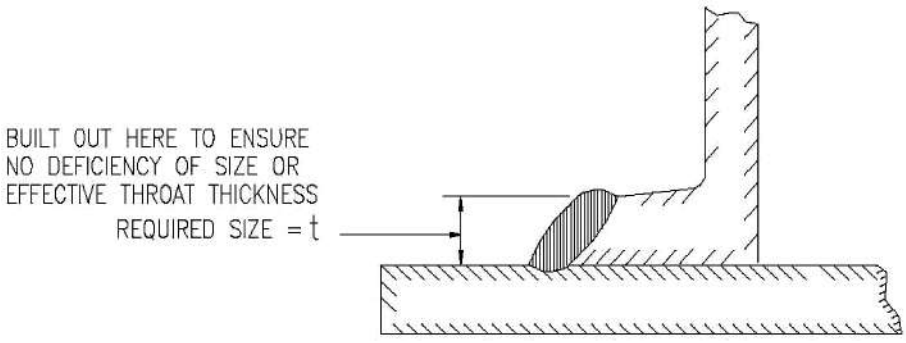


Fig. H-15

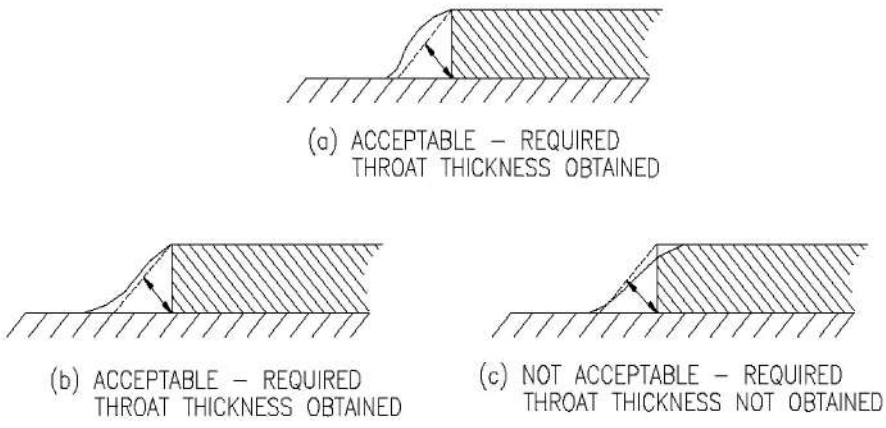


Fig. H-16 Fillet Weld Equal to the Size of Plate or Section

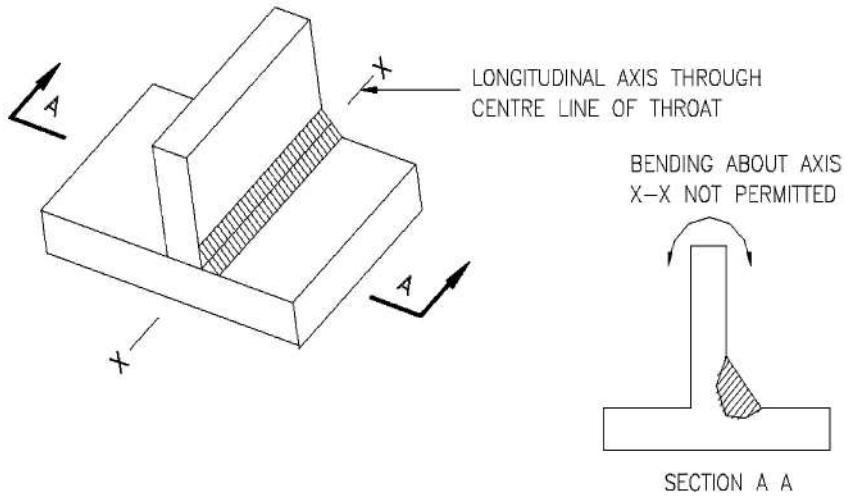


Fig. H-17 Single Fillet Weld Bending

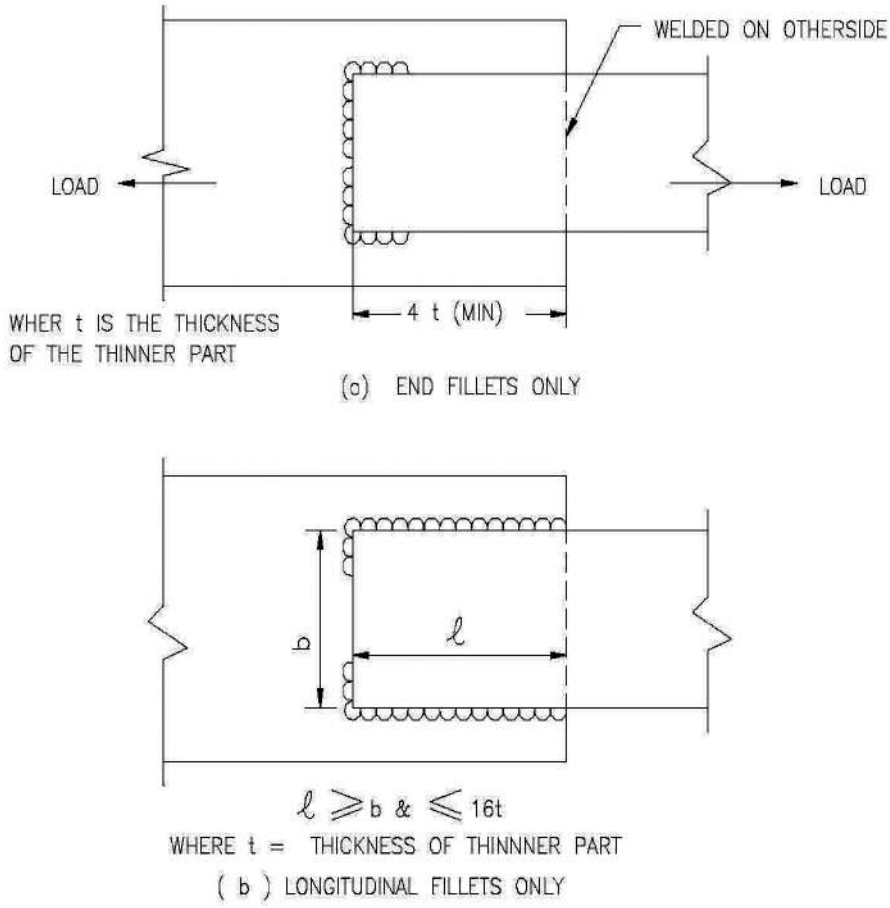


Fig. H-18 Fillet Welds in Lap Joints

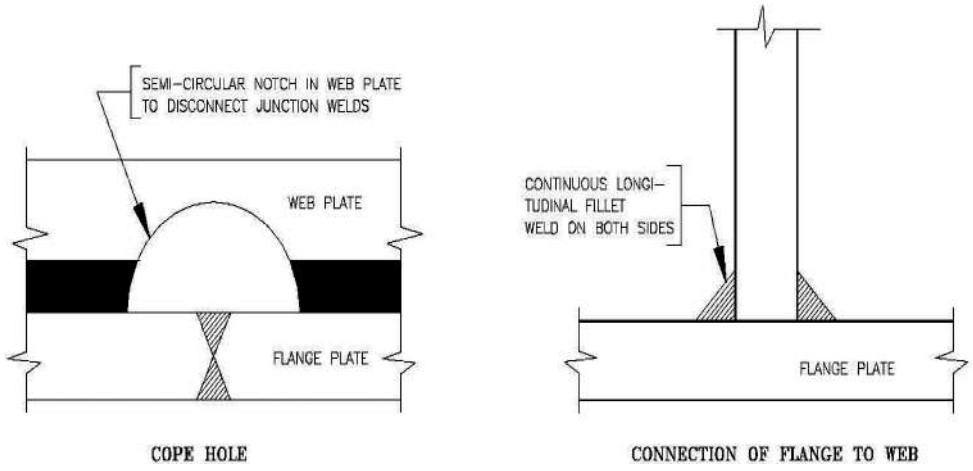


Fig. H-19

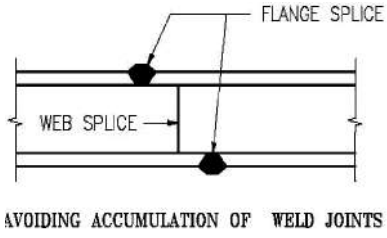


Fig. H-20 Avoiding Accumulation of Weld Joints

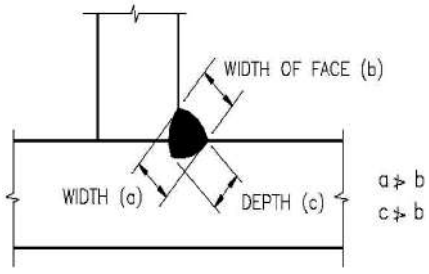


Fig. H-21 Diagram of Weld Pass in Fillet Weld Showing Depth of Fusion Width in Cross Section and Width of Face

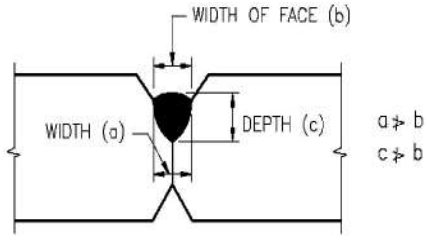


Fig. H-22 Diagram of Weld Pass in Butt Weld Showing Depth of Fusion in Cross Section and Width of Face

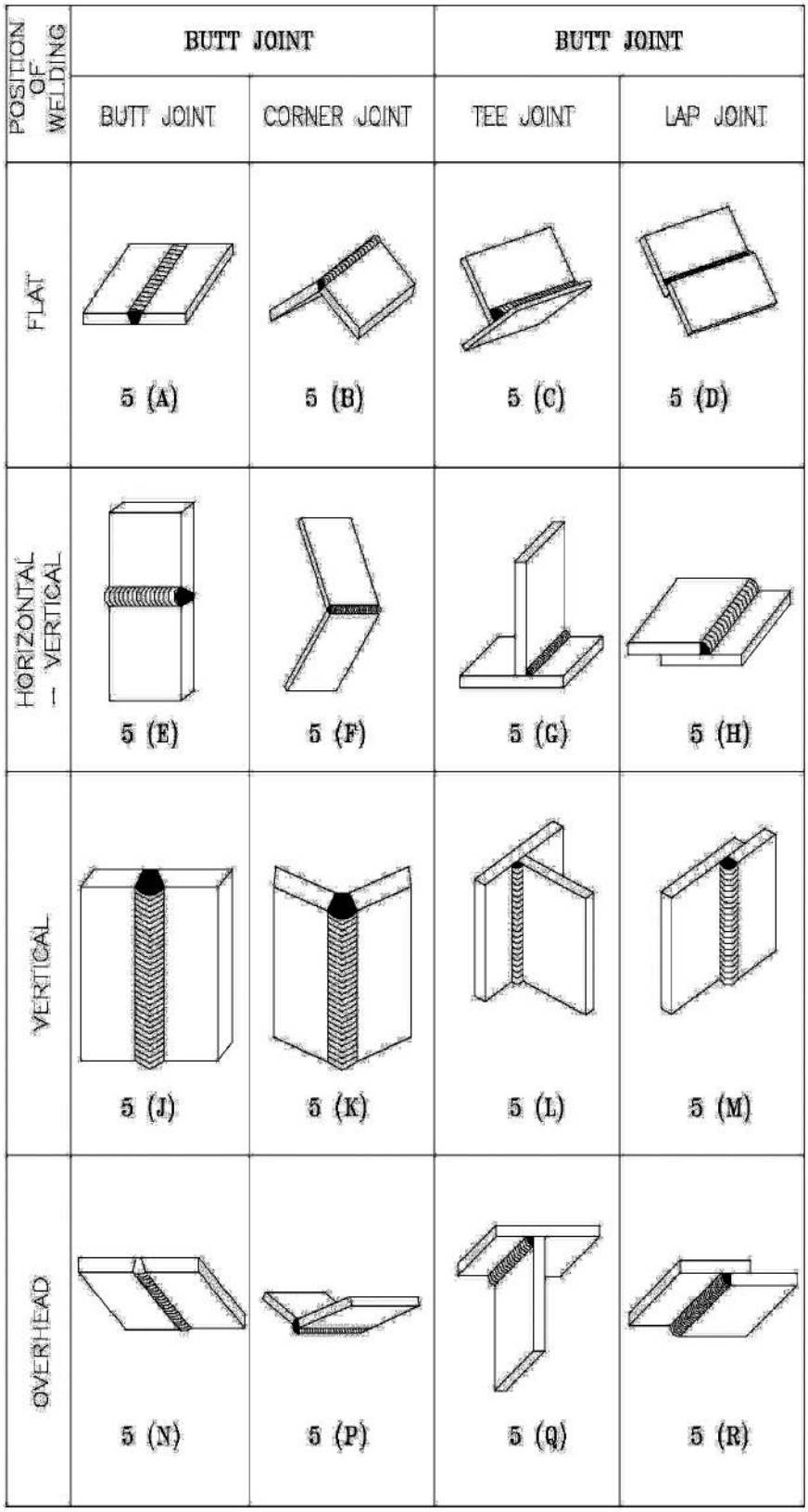


Fig. H-23 Position of Welding

ACCEPTABLE AND DEFECTIVE WELD PROFILES

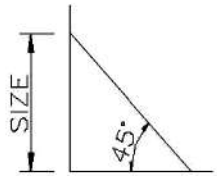


Fig. H-24 Desirable Fillet Weld Profile

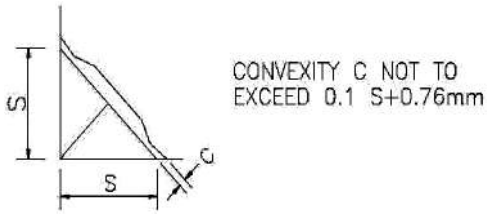


Fig. H-25 Acceptable Fillet Weld Profile

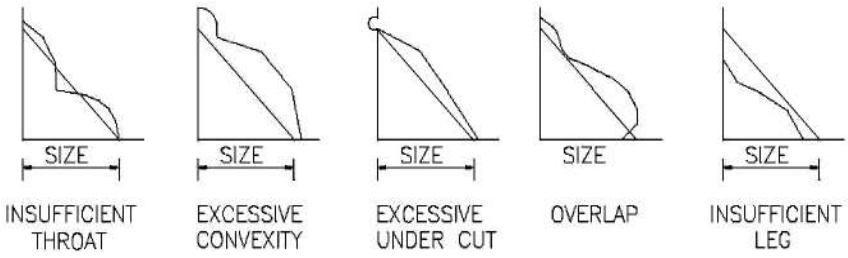


Fig. H-26 Defective Fillet Weld Profile

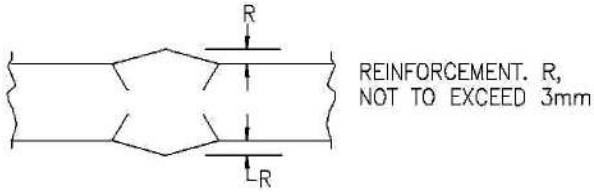


Fig. H-27 Acceptable Butt Weld Profile

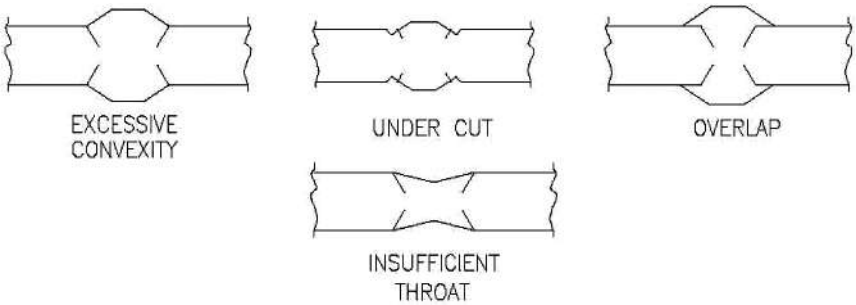
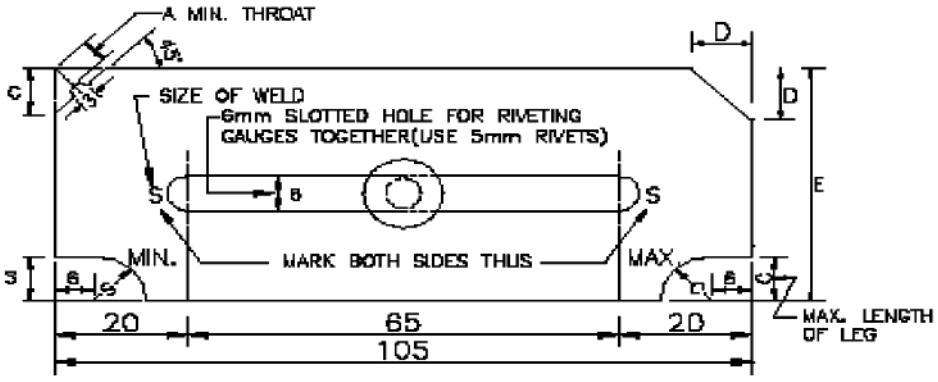


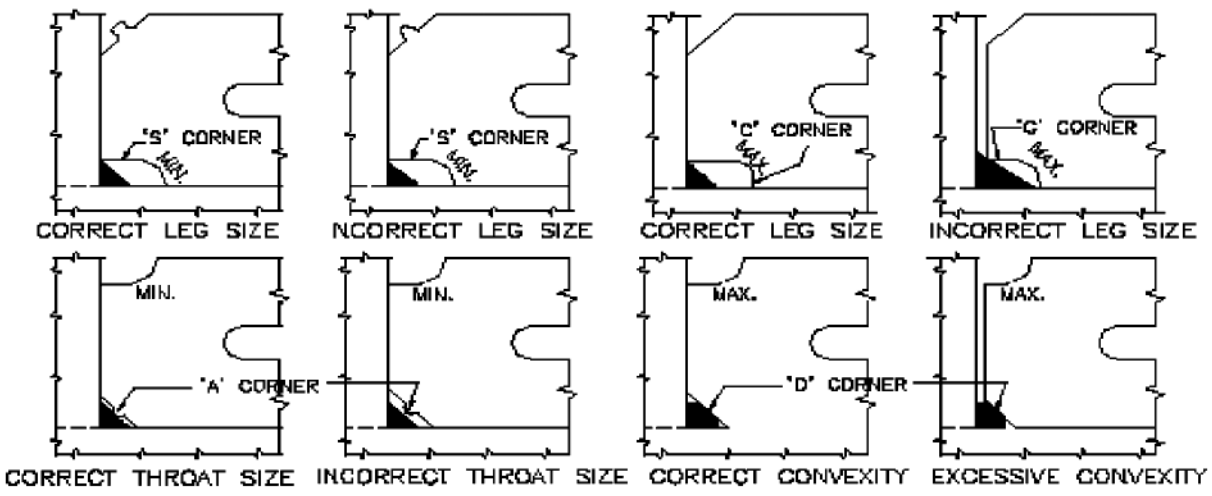
Fig. H-28 Defective Butt Weld Profiles

FILLET WELD GAUGES AND THEIR APPLICATION



DIMENSION IN mm	WELD SIZE										
	5	6	8	10	12	14	16	18	20	22	25
A	3.5	4.2	5.7	7.1	8.5	9.9	11.3	13.9	14.2	15.6	17.5
S	5.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	25.0
C	6.0	7.0	9.0	11.0	13.0	15.0	17.0	19.0	21.0	24.0	26.0
D	6.7	7.8	10.3	12.4	14.8	17.2	19.3	21.6	23.7	26.3	30.3
E	40.0	40.0	40.0	50.0	50.0	50.0	50.0	50.0	65.0	65.0	65.0

METHOD OF GAUGE APPLICATION



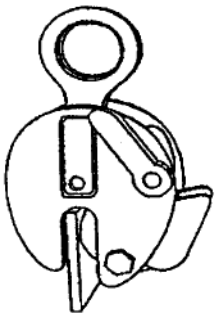
1. ALL DIMENSIONS ARE IN MILLIMETRES.
2. GAUGE FOR EACH WELD SIZE TO BE MANUFACTURED TO THE DIMENSIONS GIVEN IN THE TABLE ABOVE
3. WELD GAUGE SIZE TO BE MARKED AT LOCATION 'S' IN 3mm LETTERS. OTHER MARKING IN 2mm LETTERS
4. ALL MARKINGS TO BE DONE ON BOTH FACES.
5. THESE GAUGES ARE SUITABLE FOR INSPECTION OF NORMAL FILLET WELD OF SIZES 5 TO 25mm WITH ANGLE BETWEEN FUSION FACE OF 90° FOR DEEP PENETRATION WELD AND FOR ANY OTHER ANGLE BETWEEN FUSION FACES, SPECIAL GAUGES MAY BE MADE.

Fig. H-29

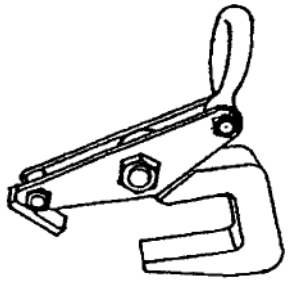
APPENDIX - I

Lifting Tools, Tackles and Suggested Methods

(Refer Clause 2.2.2)



Vertical Type Plate



Horizontal Type Plate Clamp.

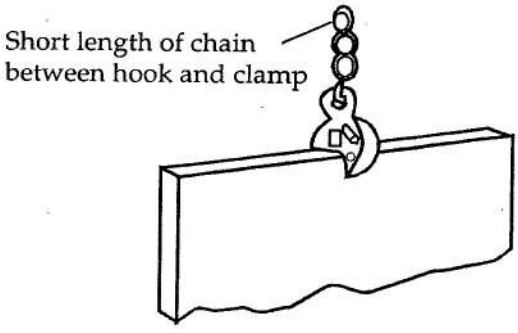


Fig. I-1 Clamp with Short Chain Length

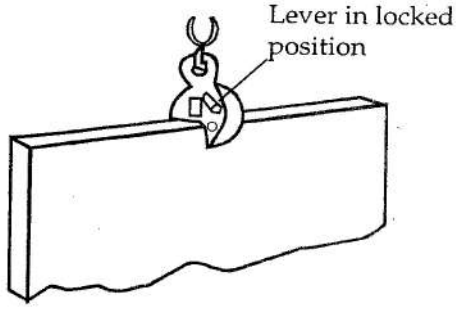


Fig. I-2 Clamp Lever in Locked Position

When two clamps are used to raise or lower a plate by gripping one edge, the clamp shoud be applied so that the centerlines are in line with the respective sling legs.

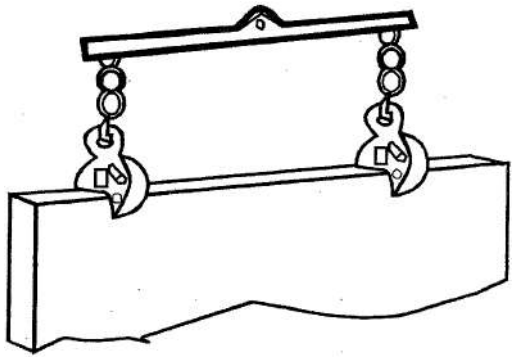


Fig. I-3

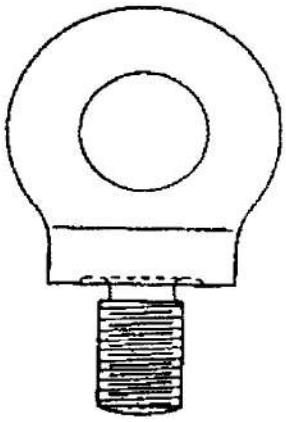


Fig. I-4 Collar Eyebolt

Eye Bolts for Lifting

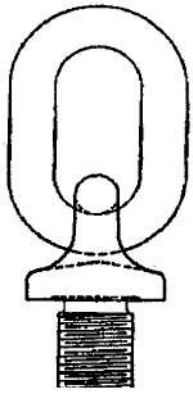


Fig. I-5 Collar Eyebolt

Collar eye blots are normally used for permanent attachment to heavy equipment and are usually fitted in pairs.

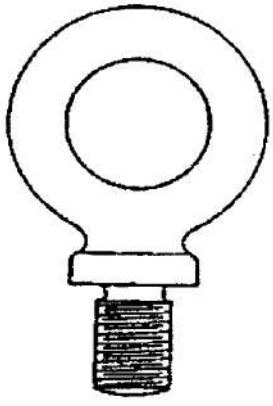


Fig. I-6 Eyebolt with Link

The link is an integral part of the eyebolt and is large enough to accept a hook. This type is regarded as general purpose eyebolts and are used in preference to the collar bolts whenever the lifting axis cannot be confined to the vertical plane.

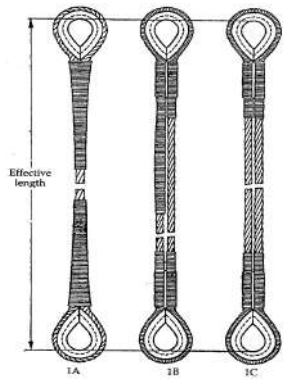


Fig. I-7 Dynamo Eyebolts

Eyebolt of this type is designed for vertical lifting only and must not be used for off-centre lift. The eye of the Dynamo should be large enough to allow direct entry of hook. It should be ensured that the lifting device is directly above the eyebolt before rising the load and avoid pushing of pulling the load into position since this load into position since this may produce an off-centre lift.

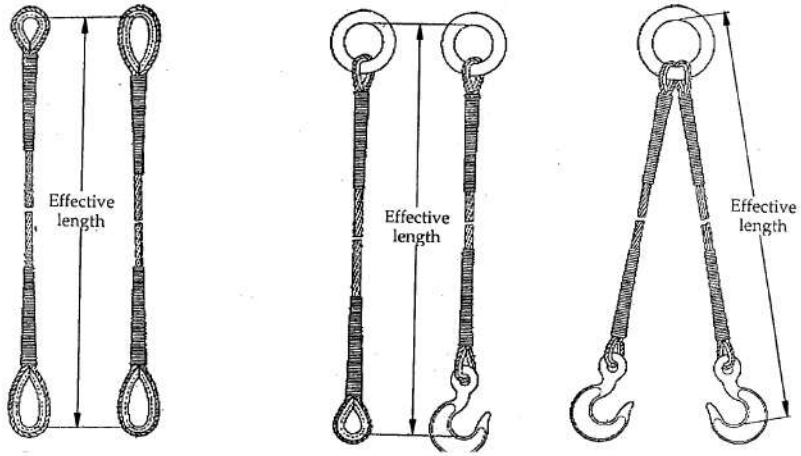
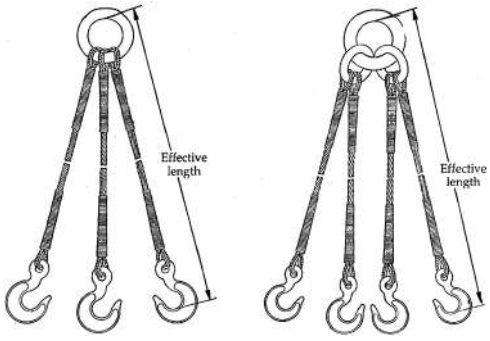


Fig. I-8

One Leg Wire Rope Slings with Ordinary Thimble at One End & Reeving Thimbles at Both ends

One Leg Wire Rope Slings with Ring, Ordinary Thimble & Hook.

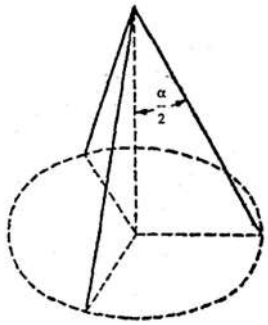
Two Leg Wire Rope Slings with Ring at One End Hooks at other end



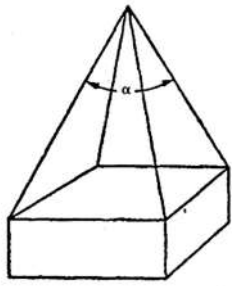
a. Three-Leg Wire rope Sling with Main Ring One End, Hooks at other end

b. Four-Leg Wire Rope Sling with Main and Intermediate Rings at One End, Hooks at other end

Fig. I-9 Three and Leg Wire Rope Slings



Three Leg Wire Rope Sling with Main Ring at One end, Hooks at Other end.



Four-Leg Wire Rope Sling with Main and Intermediate Rings at One end, Hooks at Other end.

Fig. I-10 Three and Leg Wire Rope Slings

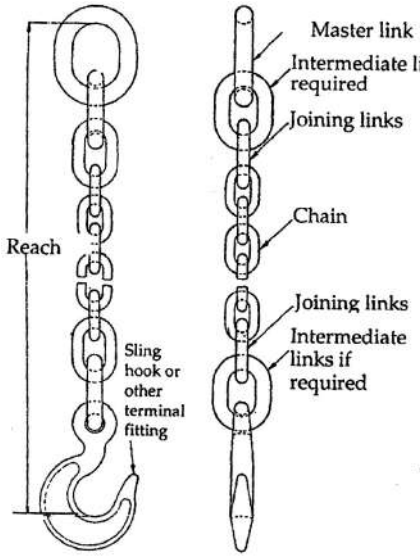


Fig. I-11 Single-leg Sling

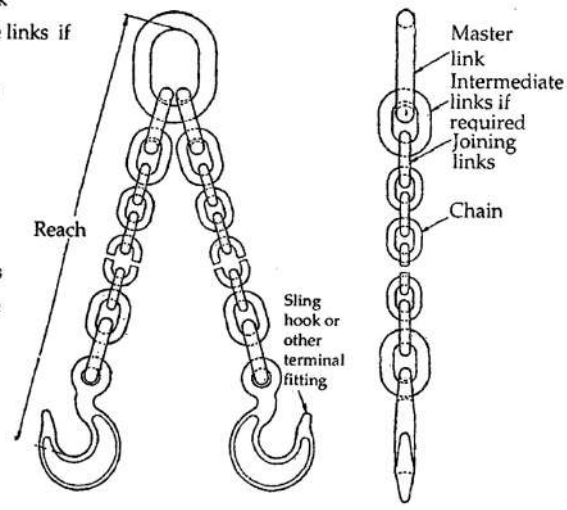


Fig. I-12 Two-leg Sling

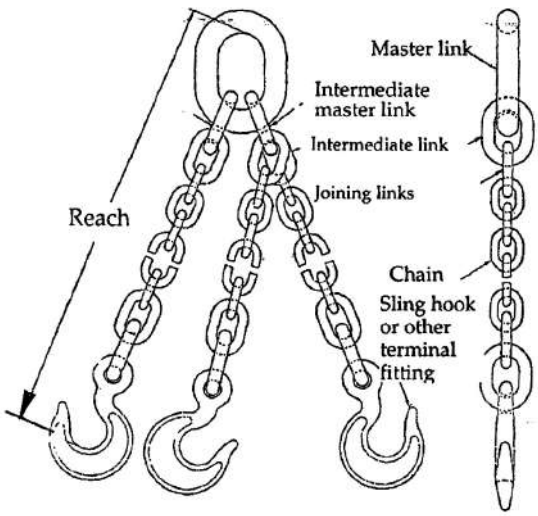


Fig. I-13

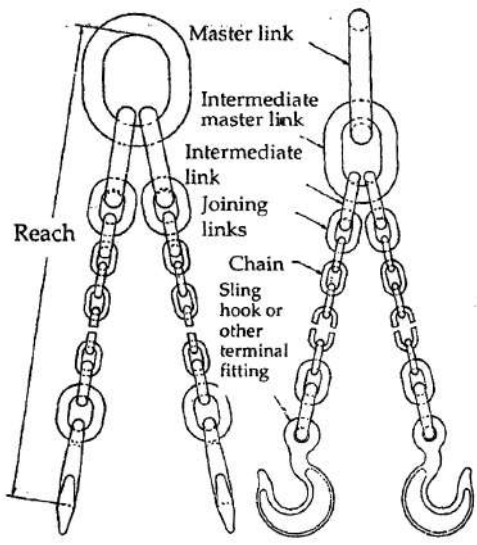
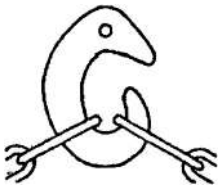
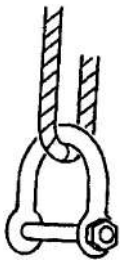
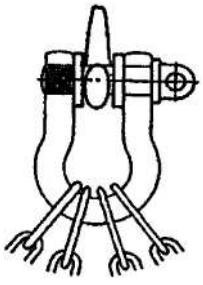
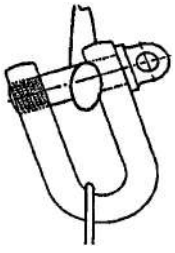
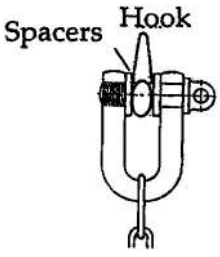


Fig. I-14

Sl. No.	Condition	Desirable/Undesirable	Reasons
1.		×	Never carry material on the point of hook
2.		×	Carrying load in this manner will cause the hook to stretch and break
3.		√	Load is supported in the saddle or seat of the hook
4.		×	Never leave unwanted slings hanging from the hook. Only the sling in use must be on the hook
5.		×	The ring of the sling and point of the hook may be damaged because the lifting ring is too small
6.		√	Use shackle to connect the eye of separate slings before placing the hook

Sl. No.	Condition	Desirable/Undesirable	Reasons
7.		×	Placing the pin of the shackle against a moving surface should be avoided
8.		×	Avoid passing a rope around a shackle in this way because of the crushing effect on the rope strands due to very tight radius
9.		√	Proper gathering the eyes of a double or multiple leg sling in a shackle before placing it on a crane hook
10.		×	Always avoid eccentric loading of the shackle
11.		√	Proper way of lifting by placing spacers in the gaps between hook and shackle

APPENDIX - J

HSFG Bolt and Installation Process

(Refer Clause 1.13)

J 1 Types of Bolts: For the purpose of HSFG connections, only high strength structural bolts can be used. IS 4000 gives two property Classes : 8.8 and 10.9 for the same. Bolts shall conform to IS 3757. The bolts have the following characteristics:

J 2 Property Class: A property class has two parts separated by a decimal in the form x.y. The first part, x, indicates 1/100 of the nominal tensile strength in Newton per sq. mm and y indicates ten times the ratio of the lower yield stress and nominal tensile strength. For example, property Class 8.8 means that the bolt will have nominal Ultimate Tensile strength of 800 N/mm^2, and lower yield stress of 80 percent of 800 N/mm^2, i.e. 640 N/mm^2.

J 3 Identification: The property class of bolts (8.8 or 10.9) shall be embossed or indented as 8S or 10S respectively on the top of head along with the manufacturer's identification symbol. Alternately, marking '8.8 S' or '10.9 S' are also acceptable. The suffix 'S' here denotes that the bolt is high strength structural bolt with a large series hexagon.

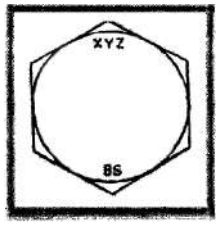


Fig. J-1 Typical Marking on Bolt Heads

J.1.3 Diameter: IS 4000 gives diameters of HSFG bolts as M16, M20, M24, M30 and M36. Other sizes given in IS 1367 include M18, M22 and M27 (Referred to as 'non-preferred' sizes also). For bridge works, these can be used and M22 size is readily available in the market.

J.1.4 Length: The length of bolt shall be chosen such as to hold the steel members in position, with provision for the nut, washer(s) and some projection beyond the bolt. Along with the overall length of the bolt, the thread length has to be specified. At least 4 full threads shall remain clear between the bearing surface of the nut and unthreaded part of the shank 3 (This means that at least 4 threads shall extend into the members being joined by the bolt). Further, minimum one full thread pitch must protrude from the nut after tightening. The minimum length of bolt shall be worked out on the basis of maximum grip length covering maximum limits of ply thickness plus an additional allowance given in **Table 1** of IS: 4000. Table 1 of IS 4000 is reproduced below:

Table J.1

Nominal Size of Bolt	Nominal Dia of Bolt (mm)	Allowance for Grip in mm
M 16	16	26
M 20	20	31
M 24	24	36
M 30	30	36
M 36	36	48

For M 22 bolts, the allowance for grip shall be 34 mm. Most manufacturers have ready tables for the bolt lengths depending upon the steel plates to be gripped. Still, it will be prudent on the part of the field Engineer to cross check the computations before ordering the bolts. Maximum grip length of all plies, including packing's and packing washers, shall not exceed 10 times the nominal diameter of the bolt.

J 1.5 Surface Finish: All bolts shall be supplied with coating consisting of zinc phosphate that is used in conjunction with suitable oil of rust preventive type as per IS 1367 (Part XII).

J 1.6 Other Types of Bolts: There are other types of bolts, called twist-off bolts which have an additional stem at the end, which are tightened using double acting torque wrenches and the additional leg twists off when the desired torque is reached. The twist off occurs due to the torque applied and is not a direct indicator of the force in the bolt. For rusted bolts, the value of force in bolt may be appreciably less than that indicated by torque, hence these bolts are not preferred.

J.2 Nut: Each bolt shall be tightened using a high strength nut, conforming to IS:6623. The nut has to be strong enough to be able to impart the necessary torque to the bolt and also withstand the force during the life of the structure. Further, the threads in nut shall be matching with the threads in the HSFG bolt and the nut shall be free running on the threads of the HSFG bolts.

J.2.1 Property Class: Nuts are designated by property class designation, which is equal to 1/100 of the minimum tensile strength in Newton per square mm of the bolt. For HSFG bolts, the property classes to be used are 8, and 10 as specified in IS:1367 (Part 6), suitable for bolts of property Class 8.8 and 10.9 respectively. The nuts shall be hardened and then tempered at a temperature of at least 425ºC. Normal height of nut shall be more than 0.8 times the nominal bolt diameter.

J.2.2 Identification of Nut: The nuts have the following markings:

a) Manufacturer's Identification Symbol.

b) Property class, marked as '8S' or '10S'. (The suffix 'S' denotes a high strength structural nut with a large series hexagon.) Alternately, '8.8 S' or '10.9 S' are also acceptable.

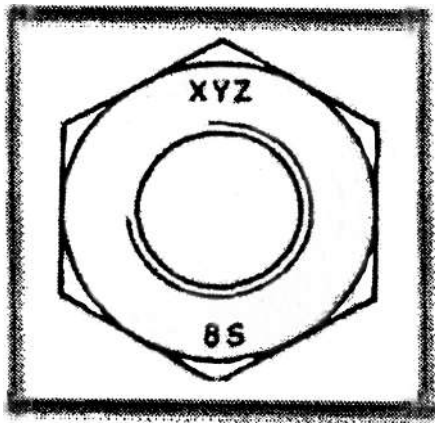


Fig. J-2 Typical Marking on Nuts

The marking shall be either on the top or the bottom face of double chamfered nuts and shall be either indented or embossed on non bearing surface of washer faced nuts.

J.2.3 Surface of Nut: All nuts shall be supplied with coating consisting of zinc phosphate that is used in conjunction with suitable oil of rust preventive type as per IS:1367 (Part XII).

J.2.4 Position of Nut in Bolt: HSFG bolt cannot be easily opened out except by use of torque wrench. Still, as an additional precaution, it may be ensured that the nut is not easily accessible for opening out by anti-social elements, the same shall be provided preferably as follows:

In Girder Web: Towards outside of the girder

In Flanges: Towards bottom (Except when in composite construction)

In Composite Construction: Towards inside of concrete

In Bracing: Towards the rolled section side so that the space for rotation of the nut is not readily available

Where tapered washer is used, the nut shall preferably be on the other side

J.3 Holes for HSFG Bolts: Normal holes in the steel members being connected by the rivets shall be used for HSFG bolts also, subject to the following:

J.3.1 Making of holes: The holes shall be made by drilling only.

J.3.2 Nominal Diameter of Hole: The nominal diameter of hole shall be 2 mm more than the bolt diameter i.e. for 20 mm Ø HSFG bolt, the hole shall be 22 mm in diameter.

J.3.3 Oversize Holes: In case the bolts are to be provided in existing structure, the maximum size of hole shall not 1.25 d or d + 4 mm whichever is less i.e. for 16 mm Ø bolt, the maximum diameter of hole shall not exceed 20 mm and for 24 mm Ø bolt, the maximum diameter shall not exceed 28 mm.

Use of Hardened Washers: In case the hole diameter exceeds the bolt diameter by 2 mm, hardened washer shall be used in place of normal washers.

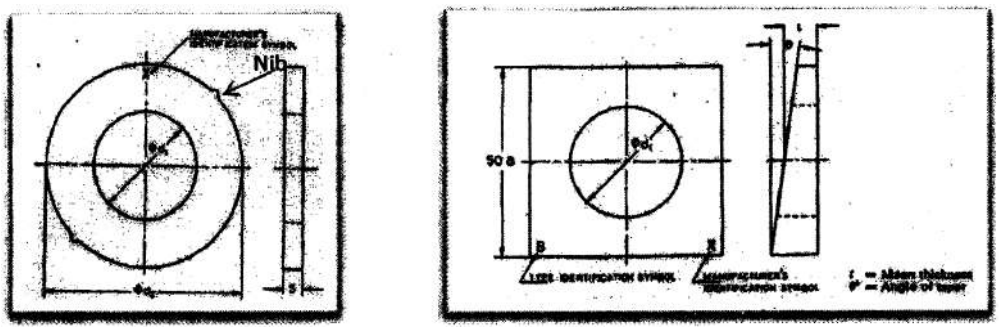
J.4 Washer: Annular rings which are provided between the bolt head/ nut and the members being joined are washers. Washers for HSFG bolts shall conform to IS 6649. The washers have the following characteristics:

Type A: Plain Hole Circular Washers

Type B: Square Taper Washers for use with Channels (6º Taper)

Type C: Square Taper Washers for use with I-Beams (8º Taper)

J.4.1 Identification: Type A washers shall be identified by provision of two nibs (small projections) and manufacturer's identification symbol in indented character. The Type B and C washers shall be identified by the type identification Symbol, B or C and the manufacturer's identification symbol.



Fig, J-3 Typical markings/Shapes on Plain and Tapered Washers

J 4.2 Washer : HSFG bolts shall be provided with minimum one washer. Normally, plain washer is provided. The washer(s) is (are) provided to prevent wear of the steel members being joined and coating there on during the tightening of bolt. If the bolt is longer than required, packing washers may be used. However, the maximum number of packing washers shall be limited to 3, with maximum total combined thickness of 12 mm. For over-size holes, hardened washers shall be used. These washers are required to prevent punching of the nut in the annular space around the bolt shank.

Note : IS:6649 specifies only one type of washers, which are through hardened and tempered.

Where the angle between the axis of bolt and the joint surface is more than 3 degree off normal, a tapered washer shall be used against the tapered surface. Non rotating surface shall preferably be placed against tapered washer. All washers (except DTIs) shall be supplied with coating consisting of zinc phosphate that is used in conjunction with suitable oil of rust preventive type as per IS:1367 (Part XII). All washers shall be flat with a maximum deviation not exceeding 0.25 mm from straight edge laid along a line passing through the center of the hole.

The Direct Tension Indicators (DTI) are special type of washers with indentations which get pressed when tension is applied. The pressing of indentations to required level indicates that the required tension has been applied in the bolts. Resemblance of DTIs with washers is incidental. In fact, these are precision engineered mechanical load cell which is the reliable method for checking HSFG bolt tensioning. As shown in figure below, DTIs have multiple projections, between which the feeler gauge is to be inserted to check if the bolt has been sufficiently tightened or not. Complete closing of the projections, however, may indicate either over tightening or poor quality material in DTI.

DTIs are very good method of ensuring that the bolts are tightened properly, and this method of tightening shall be preferred over the method with plain washers. The DTIs normally are patented products and shall be supplied preferably with zinc phosphate coating, but alternatively can be with any other corrosion prevention treatment given to the surface as specified by the manufacturer. These shall normally be provided below the head of the bolt (with projections towards bolt head) in case nut is rotated. In case the bolt is to be rotated, DTI shall be provided under nut (with projections towards nut) and in this case, an additional washer shall be provided on the DTI side to protect the protrusions from damage due to the

abrasion during bolt tightening. Measuring the amount by which the indentations have been pressed indicate if the bolts have been tightened to the desired tension level.

The DTIs used shall be the ones which are compatible metallurgically and also suitable for the bolts of property Class 8.8 and 10.9. Suitable markings identifying the bolt manufacturer, property class of DTI and its diameter shall be engraved suitably on the DTI. Action of DTIs is as indicated below:

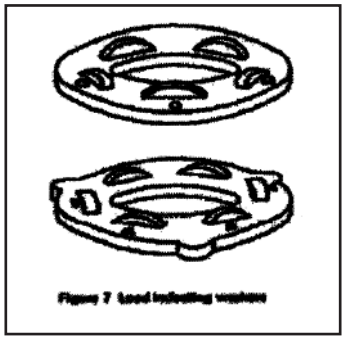


Fig. J-4 Direct Tension Indicator Washers

There are other proprietary tension indicators such as those having squirting action in which material squirts off and those having rubber projections which shear off when required tension load is applied. These tension indicators have not been considered in these guidelines.

Each bolt of property Class 8.8 shall have minimum one plain washer, which shall be provided in the part being rotated. Mostly the nut is rotated, but if space constraint is there, the reverse is true.

For Class 10.9 bolts, two washers shall be provided, one against head and one against the nut. The two washers are required in this case because of very high tension is imparted to the bolt, which can damage the steel members.

One DTI shall be used in one bolt. In case DTI is being provided, the same will count as one washer and in Class 10.9 bolts, one DTI and one plain washer shall be provided. In class 8.8 bolts only one DTI washer needs to be provided. If the nut is rotated, the DTI shall be provided under the head, and if the head is rotated, the DTI is to be provided under the nut. If DTI is used under the nut, washer faced nut as per IS:6623 shall be provided.

J.5 Surface Preparation for Steel Interface before Providing HSFG Bolts

The steel interface between the plies which form a joint having HSFG bolts shall have special surface preparation so that sufficient slip factor is available. The following surface preparation shall be done.

The interface between the plies which are connected together by the HSFG bolts shall be “Aluminium metalized without any over coating”. The aluminium metalizing shall have a nominal thickness of 150 µm.

The interface of plies in old structures which are to be replaced by the HSFG bolts shall be cleaned by wire brushing/flame cleaning. The surfaces shall be cleaned to remove all loose

rust and paint layers (Only isolated patches of coatings/ rust can remain). If, however, in existing structures, rivets are to be replaced by bolts but no surface preparation is possible, the slip factor shall be suitably reduced.

J.6 Installation of Bolts

The HSFG bolts work on the principle of applying a specified pre-load on the joint such that the plies in the joint are joined together without any gap. The tightening of HSFG bolts is to be done at stress level which is beyond the yield point, i.e. the plastic flow of material shall take place. This is important because the yield point of bolt material is well defined and after this level, the strain increases without increase in stress, as shown in **Fig. J-5** below:

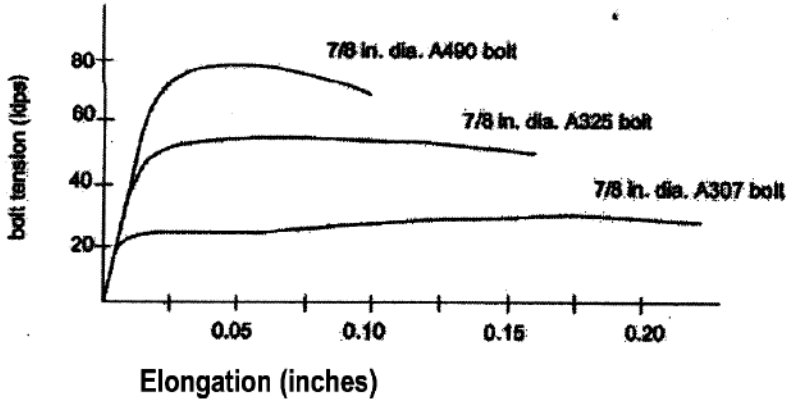


Fig. J-5 Tension - Elongation Screw

The bolt shall be tightened to minimum loads specified in IS:4000. For bolts subject to only tension, the force shall be as specified in **Table 2** of IS:4000. For other joints, the same shall be as per **Table 3** of IS:4000, reproduced below (**Table J.2**).

Table J. 2

Nominal Size of Bolt	Minimum Bolt Tension in KN for Bolts of Property Class	
	8.8	10.9
M 16	94.5	130
M 20	147	203
M 24	212	293
M 30	337	466
M 36	490	678

For M 22 bolts, which are non standard as per IS codes, the minimum bolt tension shall be 182 KN for Class 8.8 and 251 KN for property Class 10.9.

The holes shall be brought in alignment by using drifts etc such, that the bolt threads are not damaged during insertion of bolts. Drifting shall not distort the metal or enlarge the holes. The members being joined shall be held in position by insertion of few HSFG bolts (tightened to first stage only). These bolts shall not be tightened to second stage till all the bolts in a joint are inserted and tightened to first stage (**Fig. J-6**).

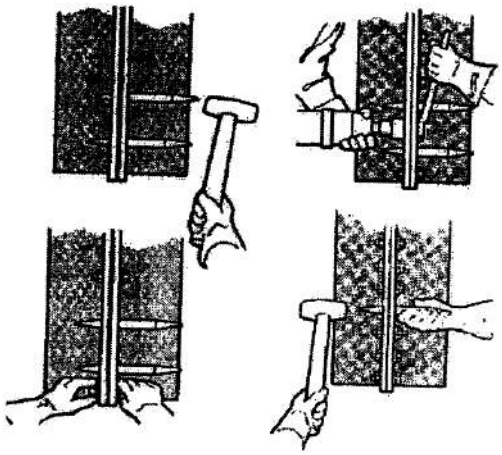


Fig. J-6 Installation of HSFG Bolts

The bolts shall be inserted and tightened up to first stage of tightening. The drifts inserted as above shall also be removed one by one. The final tightening shall not proceed until the gap between the plates has been closed such that the residual gap, if any, is less than 2 mm at edges. There shall, however, be no gap in the central portion. In case the central portion is not in close contact or gap at edges is more than 2 mm, straightening of members may be done after opening out the bolts inserted and the entire procedure shall be repeated. During tightening of bolts also, the steel members can continue to deform and hence the tightening of subsequent bolts can lead to loosening of already tightened bolts. In order to minimize the loosening of already tight bolts, tightening in the two stages shall be done starting from the stiffest part to the free edges. Stiffest parts of joint are generally towards the center of the joint.

J.7 Procedure for Installation of HSFG Bolts Using Direct Tension Indicator: This is the preferred method of installation of HSFG bolts.

Calibration of Direct Tension Indicator: Before the DTI are brought to site, the same shall be tested in the presence of Engineer. Three numbers of bolt of similar diameter and property class, as shall be used in the work, shall be taken and installed with DTI. The installation procedure to be followed shall be similar to the one given for plain washers. On full tightening, the projections on DTI washers shall meet the requirements of checks specified after second stage tightening using DTIs. Only the DTIs which satisfy the calibration shall be brought to site for work.

As a first stage, all bolts in the joint shall be tightened to ‘snug tight’ condition. Snug tight condition means the nut is tightened using an ordinary wrench by an average worker, applying maximum force on the wrench. This stage is required to bring the plies in close contact. After first stage of tightening, the joint shall be checked to see if the plies are in close contact and the clearances are not exceeded.

During the second stage of tightening, torque wrench is used to tighten the bolts until the indentations on the DTI indicate full tightening, feeler gauge of 0.40 mm thickness shall be used to check 100 percent of the bolts for proper tightening. The feeler gauge shall be used

to determine if the bolt has been sufficiently tightened, as follows:

Table J.3

Number of Indicator position in DTI Washer	Minimum Number of Feeler Gauge Refusals
4	3
5	3
6	4
7	4
8	5
9	5
No more than 10 percent of the indicators in a connection bolts group shall exhibit full compression of the indicator.	

The procedure for checking the proper tightening of bolt using DTI is shown in the **Fig. J-7** below:

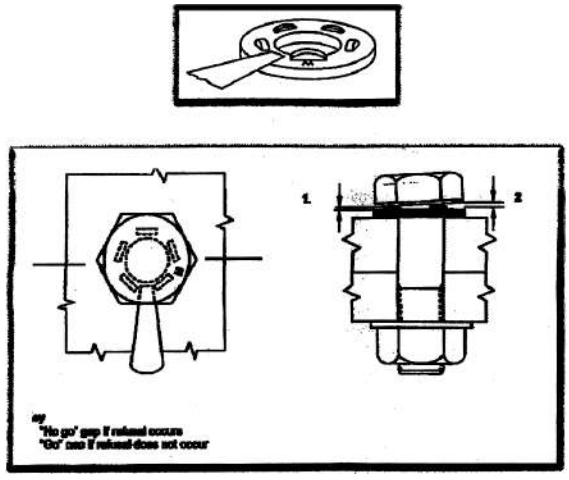


Fig. J-7 Method of Checking the Correct Tensioning Using DTI

The total number of indicators in a bolt connection shall be counted and it shall be ensured that not more than 10 percent exhibit full closure i.e. zero gap after tightening.

In the first stage, a calibrated wrench with an accuracy of ± 10 percent shall be set to 75 percent of the torque computed for the complete tightening of the bolt. All the bolts in the joint shall be tightened to this torque. After checking all bolts after the first stage, permanent marks shall be made with suitable marker on the bolt as well as nut to indicate the relative position of the two. The mark shall be such that the same shall be visible for inspection upto 1 year after the date of installation.

The steel members that make up the plies of the joint with HSFG bolts shall be checked for proper contact. 10 percent bolts shall be checked with a separate calibrated wrench set at 75 percent of the proof load for the bolt and bolt turning by more than 15 degrees during the test, shall be reworked. If the loose bolts thus found are more than 5 but less than 1 percent of the total, another 10 percent of the bolts shall be checked. If the total loose bolts thus found

exceed 1 percent of the total, the torque wrench shall be calibrated afresh and the entire lot shall be checked for tightness. The bolts shall be turned by a further amount as specified below (**Table J.4**).

Table J.4

Total Nominal Thickness "t" of Parts to be Connected (Including all Packing and Washers) d = dia of Bolt	Further Rotation to be Applied, During the Second Stage of Tightening	
	Degrees	Part Turns
t < 2d	60	1/6
2d ≤ t < 6d	90	1/4
6d ≤ t < 10d	120	1/3

After the second stage of tightening, 100 percent bolts shall be checked and certified to have been turned through the requisite amount by verifying the permanent marks on the nut and the bolt. 1 percent of the bolts, subject to minimum of 10 per size of bolts shall be checked for gross under-tightening as per procedure given in **Annexure-D** of IS:4000.

J.8 Retensioning of Bolts

The HSFG bolts are tightened beyond yield stress level and undergo plastic deformation once tightened fully. If the bolt is opened out after complete tightening, its length gets increased permanently as compared with the initial length. The initial few threads which transfer the load from the nut to the bolt suffer the maximum damage. Therefore, a bolt completely tightened shall not be re-used under any circumstances.

The bolt tensioned completely can be identified by damage to the threads especially near the front end of nut where most of the load is transferred. The coating, if any, may also show signs of damage. The free running of the nut on the threads may also be affected. A fully tensioned bolt, opened out for any reason whatsoever, needs to be rejected and removed from the site of work. Along with the bolt, the nut, washer(s) and DTI(s) used on that bolt also need to be rejected and removed from the site of work. A bolt which has been snug tightened or partially tightened and then opened out will not be considered to have been re-tensioned and reuse of such bolts will be permissible in the same or different holes, as required.

Except for works of minor nature where number of HSFG bolts to be installed is very less, only mechanical torque wrenches (pneumatic, hydraulic, electronic etc.) shall be used for tightening of bolts. For small quantum of work, manual torque wrenches may be used. Calibrated torque wrenches, accompanied with a certificate to the effect, shall be brought to site. Torque wrenches shall be calibrated periodically, once in a year, to an accuracy of ± 10 percent. These shall be re-calibrated in case of any incidence involving the wrench during use resulting in heavy impact (such as fall, mishandling etc.). The procedure for calibration of torque wrench shall be as specified by the manufacturer.

There are other methods of tensioning, but only the two methods outlined above have been found to be suitable as per the field conditions.

APPENDIX - K

Utilization of Crane and Safety

(Refer Clause 2.1.3)

The following knowledge of cranes will be of help in Fabrication and Erection of Steel Bridges:

K.1 Basic Types and Configuration

Within broad category of mobile cranes there have evolved the following basic types and configurations:

Lorry Loaders

Industrial Yard Cranes

Truck Mounted Lattice Boom Crane

Crawler Mounted Lattice Boom Crane

Truck Mounted Telescopic Boom Crane

Rough Terrain Cranes

Mobile Tower Cranes

Heavy Lift Mobile cranes

K.2 Basic Operational Characteristics

There are many types of design to satisfy both the general needs of construction and industrial operations. However the basic operational characteristics of all mobile cranes are essentially the same.

They include

Adjustable boom length

Adjustable boom angle

Ability to lift and lower loads

Ability to slew loads

Ability to travel about the job site under their own power

K.3 Principles of Operation

The crane manual should be strictly followed and referred for Load vs operating radius chart and Do's & Dont's for Safe operation of the crane.

There are four quadrants of operation. The forward quadrant of 90º degrees is made up of 45º spread on either side of the centre line of the crane in the forward direction. Similarly the backward quadrant on the backward direction. The remaining two quadrants will be side quadrants. As far as the stability is concerned, the safety of the crane is comparatively more

while the boom is operating in the forward quadrant i.e. over the front compared to those operating in other quadrants like over the back or over the side.

The pressure acting on the ground below the crane due to the reaction from the crane is never uniform. Generally, it is tapered and increasing towards the tipping point. Before lifting is started the ground is to be judged for its capacity to provide the required reaction. Most of the time the ground is reinforced with wooden sleepers, steel sections etc. The force from the outrigger pads are to be passed to the ground through appropriately arranged grillage.

Special care should be taken while operating the crane on freshly filled and or not properly compacted soil. Also care must be taken while working on embankment particularly near the slopes as machine weight and vibrations can cause them to collapse. Stability failures are foreseeable.

Structural failure often occurs before stability failure If load is added beyond its rated capacity the crane fails structurally before there is any sign of tipping. Structural failure includes all permanent damages such as over-stressing, bending and twisting of any of the components of the crane . When the crane is over-stressed the damage is not usually apparent. Nevertheless a structural failure might have occurred. The over-stressed component is liable to have a catastrophic failure at some future time. So care should be taken to avoid the over-loading of the crane.

K.4 Assembly, Disassembly and Transportation of Crane and it's Components

While transporting the crane, care should be taken to arrest the movement of the swinging parts. Attaching slings to the main chord should be avioded and the fittings at the ends of the main chords should be used. Synthetic web slings should be used preferably and, if wire ropes are used, the boom sections should be padded well to prevent damage. The boom sections should be suitably blocked while loading on to trucks. Chain binders should be avoided, as they may damage or bend the boom.

For assembly of booms, the manufacturer's procedure and the instructions should be followed, assembly of the crane should be done on a level area and should be done in such a way that the boom is in the quadrant of maximum stability. All outrigger beams should be fully extend laterally and outrigger's lifting cylinders should lift the wheels off the ground and level the carrier.

The amount of counter-weight required should be checked from the crane manual for the maximum value of the load that will be lifted and the length of boom that will be installed. The swing lock should be set when the assembly is being done. No attempt should be made to raise the boom, while assembly, until all boom insert connection pins (splicing bolts) are installed. Wind velocity should be checked before lifting the boom off the ground.

K.5 Signaling

The signal men must be used when the operator is not in a position to see the load and its movement. Hand signals can be used when the distance between the operator and the

signalman is not more and conditions allow for clear visibility. Standard hand signaling should be adopted. It is always preferable to use walkie-talkie.

K.6 Multiple Crane Lifts

A multiple crane lift should be meticulously planned and every eventuality taken into consideration. Lift must be planned and carried out under qualified supervisors. For a multiple crane lift, no crane should be loaded to 75 percent of its net capacity. The lift, swing and boom speeds of both the cranes should be matched. Wherever possible the cranes should not travel with load. Sufficient communication should be ensured (preferably by walkie-talkie) amongst the Supervisor and Crane Operators. Supervisor should be positioned to view the total operation and be able to communicate with both the operators. The movement of the load should be jerk free and smooth. Use of equalizer beam is preferable.

K.7 Working Near a Electric Line

If power line exists in the erection area, the electric department should be intimated in advance regarding the time and place of crane use. The limit of operating distance should be above 6 m from 33 KVA live line. Dry polypropylene ropes should be used for tag line. All safety precautions shall be ensured to avoid electrocution.

K.8 Load Charts

Load chart of the crane shall be referred to for assessing the lifting capacity of the crane at the required radius and height of erection. Engineers should adjust the lifting capacity of the crane basing on the machine condition, crane type ,wind speeds and other site conditions.

K.9 Wire Ropes

All wire ropes should be thoroughly inspected before use and inspection of all ropes must be made at regular intervals. A rope which has not been used for a long period should be given a thorough inspection before it is put back into service, after proper lubrication. Wire ropes shall be inspected for kinks, wear, fatigue, abrasion and corrosion.

Ropes, having six or more randomly distributed broken wires in one rope lay, three or more broken wires in one strand in one rope lay or having more than one broken wire near an attached fitting should not be used.

In running ropes if there is any evidence of wire breaks in the valleys between strands in one rope lay or having wear exceeding 1/3 of the diameter of the individual wires should not be used.

All ropes having signs of severe stretch, having noticeable corrosion in the vicinity of fittings, having Crushed, Flattened or Jammed Strands should be replaced. The replacement of rope for all the above conditions should be made to correct specification.

APPENDIX - L

Erection Inspection Checklist

(Refer Clause 2.2.4)

Part - 1 (Drawing)

PLAN: To scale plan of work area showing supporting structures, roads, railroads, waterways, over-head and underground utilities, adjacent structures, etc., and framing plant with member shipping marks (match those used on shop drawings) & field splice locations if applicable.

- □ Location of temporary supports, falsework, holding cranes
- □ Location of crane positions on plan showing pick radii
- □ Elevation view of crane & members □ Included □ Not Applicable
  Crane Support Method: barrages, mats, □ Included □ Not Applicable
- □ Member Delivery Location & Orientation

DETAILS : Details and arrangement of member rigging, show sizes, capacities, and location of centre of gravity of each pick.

- □ Falsework and temporary support details show sizes and capacities.
- □ Crane capacity chart indicating crane type, lifting capacity at given radius and orientation, counter-weight requirements and boom length.
- □ Pick weight chart indicating weight of member, plus rigging and any attachments.
- □ Written procedure indicating erection sequence for primary and secondary members (cross frames, diaphragms, etc.) including the following, method of tie down of individual pieces, time and method of connections of diaphragms, lateral bracing, and field splices.

Part - 2 (Calculations)

- □ Calculations' for load capacity and stability of temporary supports for structure (falsework, tie downs, lifting beams, spread beams etc.).
- □ Calculations indicating capacity of temporary crane supports, □ Included □ Not Applicable.
- □ Calculations to substantiate structural integrity and stability of members prior to completion of bridge assembly.
- □ Calculations indicating structural integrity of any partially bolted primary splice after release of external support system.
- □ Calculations to substantiate structural integrity of abutments and retaining walls affected by surcharge from crane.

Erection Inspection Checklist

Part - 1 (Pre-Erection)

□ **Erection Procedure - Approved**

- □ Site Preparation - access road, crane pads, bearing pedestals, finish and elevation, anchor bolts survey, falsework foundation pads, all obstacles noted.
- □ **Personnel**

  Foreman – Competent Person

  Crane Operators – Qualified, Licensed, Trained, Medical

  Welders – Certification current, Qualified for positions

  Any required training and instruction complete
- □ **Lifting Equipment**

  Crane Inspection – current, schedule during project

  Lifting devices and rigging certification inspection
- □ **Bolted Connections**

  Check bolt quality, size & lengths, certifications

  Installation procedure, method of tensioning

  Impact Wrenches – conditions, proper size and capacity

  Torque Wrenches – calibration
- □ **Welded Connections**

  Weld Procedure Specifications (WPS) Approved

  Welding Equipment – Sufficient capacity, grounding

  Welding Consumables – proper storage, drying ovens
- □ Safety/Fall Protection – Nets, lifeline lanyards, platforms, scaffolds, man lifts, floats, emergency boat
- □ Co-ordination Items – Rail Roads Local Agencies, Emergency service etc.

Erection Inspection Checklist

Part - 1 (Inspector Responsibility)

- □ Check all Personnel Certifications – Crane Operator, Welders etc.,
- □ Check all Equipment Certifications – Crane etc.,
- □ Check all Protection Requirements, Installation
- □ Check Crane Radii
- □ Check Temporary Supports Installed as per Erection Procedure
- □ Check Assembly Marks – Proper Location and Orientation
- □ Check Minimum Number of Bolts and Pins Installed before release of Crane/ Temporary Supports

- □ Monitor Bolt Installation Procedure
- □ Check field weld size/geometry, consumables, and variables per WPS and NDT results
- □ Check Bearing alignment/adjustment

Part - 2 (Erector Responsibility)

- □ **Provide for Inspector –** Prior to Erection

  Framing Plan, Erection Procedure

  Crane Operators Qualifications

  Welder Certifications

  Crane Inspection Certifications

  Bolt manufacture certifications

  Weld Procedure Specifications

- □ **Provide for Inspector –** During Erection

  Access to work – Ladders, Man Lift, Scaffold, or Platform

  Torque Wrench

  Temperature Indication Crayons

Part - 3 (Associate Data)

- □ Manufacturer's cut sheets for rigging devices (beam clamps, slings, wire rope, shackles, turnbuckles, chains, straps, etc.,) and pre-engineered flasework, if applicable.
- □ Statement as to status of co-ordination with parallel entities requiring review Railways, Irrigation, State PWD, Electricity Board, Public Health Services etc.

Acknowledgements

1)	RDSO	IRS B1-2001, Indian Railway Standard Specification for Fabrication and Erection of Steel Girder Bridges Locomotive Turn Table.
2)	RDSO	RDSO Report No.BS-III (Guideline for use of HSFG Bolts on Bridges).
3)	INSDAG	Guide Book for Fabrication and Erection of Steel Structure.
4)	AASHTO/NSBA Steel Bridge Collaboration	Steel Bridge Erection Guide Specification.
5)	AASHTO/NSBA Steel Bridge Collaboration	Steel Bridge Erection Guide Specification.