14 FABRICATION AND ERECTION

14.1 DIMENSIONS AND TOLERANCES OF SECTIONS

The dimensions and tolerances of hot rolled sections and cold-formed sections shall be in accordance with the essential requirements of the reference standards given in Annex A1.8.

14.2 WORKMANSHIP – GENERAL

14.2.1 Identification

At all stages of fabrication, each piece or package of similar pieces of steel components shall be identifiable by a suitable system. Completed components shall be identified so as to correspond to material certificates or test results. Completed components shall be marked with a durable and distinguishing erection mark in such a way as not to damage the material.

14.2.2 Handling

Steelwork shall be bundled, packed, handled and transported in a safe manner so as to avoid permanent distortion and minimise surface damage. Particular care shall be taken to stiffen free ends and adequately protect all machined surfaces.

14.2.3 Cutting

Unless the Responsible Engineer specifies otherwise, cutting may be performed by sawing, shearing, cropping, plasma arc cutting, laser cutting, flame cutting or machining. Hand-held flame cutting shall only be used where it is impractical to use machine flame cutting, and the resultant cut faces shall be dressed to remove irregularities.

The hardness of cut edges shall not exceed 380 Hv when tested in accordance with the requirements of the reference standards as given in Annex A1.8. This shall be demonstrated by a series of indentations across the cut face. The indentations shall be equally spaced and sampled along the centre of the plate edge. Cut surface shall be prepared carefully (avoiding heat or excessive material removal) so as not to affect metallurgically the hardness of the surface tested.

Cut edges shall be dressed to remove dross, burrs and irregularities. Sharp edges shall be dressed.

Re-entrant corners shall be rounded off with a minimum radius of 5 mm.

For steel with a design strength greater than 355 N/mm^2, shearing may only be used for material of thickness up to 10 mm unless special requirements are taken. In other cases, the cut face shall be ground down or machined to at least a depth of 0.5 mm to remove any significant defects.

Where steel with a design strength exceeding 460 N/mm^2, the cut faces shall be dressed to a depth of at least 0.5 mm irrespective of the plate thickness.

Columns and compression members designed to be in direct bearing shall be fabricated to the accuracy given in section 15.

14.2.4 Shaping and forming

Steel may be bent or pressed into shape either by hot or cold forming processes, provided that the properties of the worked material are not reduced below those specified.

Hot and cold forming shall conform to the relevant requirements of the relevant reference standards.

However, hot forming of quenched and tempered steel or cold formed thin gauge members and sheeting is not permitted.

14.2.5 Holing

14.2.5.1 Holes

Unless the Responsible Engineer specifies otherwise, round holes for fasteners or pins shall be drilled, punched or plasma cut. Slotted holes shall be punched, plasma cut or formed by drilling two holes and completed by cutting. Holes shall be dressed as required to remove burrs and protruding edges.

14.2.5.2 Tolerances on hole diameters

The tolerances on hole diameters shall be in accordance with the requirements given in Table 14.1.

Table 14.1 - Tolerances on hole diameters

Range of hole diameters (mm)		Tolerances for particular situation (mm)		
Above	Up to and including	Punched holes	Drilled Holes	Holes for fitted bolts
-	3	0.14	0.1	0.06
3	6	0.18	0.12	0.075
6	10	0.22	0.15	0.090
10	18	0.27	0.18	0.11
18	30	0.33	0.21	0.13
30	50	0.39	0.25	0.16
50	80	0.46	0.3	0.19

Note: Tolerances on holes are positive only i.e. negative tolerance is not permitted.

14.2.5.3 Matching

All matching holes for fasteners or pins shall register with each other so that fasteners can be inserted freely through assembled members in a direction at right angles to the faces in contact. Drifts may be used but holes shall not be distorted.

14.2.5.4 Drilling through more than one thickness

Where the separate parts are tightly clamped together, drilling shall be permitted through more than one thickness. The parts shall be separated after drilling and any burrs removed.

14.2.5.5 Punching full size

Punching full size is not permitted in material with a design strength exceeding 460 N/mm^2. Punching full size shall only be permitted in material with a design strength not exceeding 460 N/mm^2 when all the following conditions are satisfied:-

(a) The tolerance on distortion of the punched hole does not exceed that shown in section 15.

(b) The holes are free from burrs that should prevent solid seating of the parts when being tightened.

(c) Thickness is less than 25 mm for steel with a design strength not exceeding 355 N/mm^2 and not greater than 10 mm for higher grade steel.

(d) The thickness is also not greater than the diameter of the hole being punched.

(e) In spliced connections, the holes in mating surfaces shall be punched in one direction in all members.

14.2.5.6 Punching and reaming

If the above conditions are not satisfied, punching may be used provided that the holes are punched at least 2 mm less in diameter than the required size and the hole is reamed to the full diameter.

14.2.5.7 Fitted bolts and pins

Holes for fitted bolts and pins may either be match drilled together or reamed in situ. When they are reamed in situ, they shall initially be made at least 3 mm smaller in diameter by drilling or punching. Where the fastener is to fit through multiple plies, the components shall be held firmly together during drilling or reaming.

Pins shall be parallel throughout and shall have a smooth surface free from flaws. They shall be of sufficient length to ensure that all parts connected thereby bear fully on them. Where the ends are threaded, they shall be provided, where necessary, with a pilot nut to protect the thread.

The pin holes shall be bored smooth, straight and true to gauge and at right angles to the axis of the member. Boring shall be done only after the member is fully riveted, bolted or otherwise agreed with the Responsible Engineer.

For pins with diameter not exceeding 25 mm, the diameter of the pins shall be within tolerance of -0.25 mm to -0.4 mm and the diameter of the pin hole shall be within a tolerance of 0mm to +0.15 mm.

For pins with diameter exceeding 25 mm, the clearance between the pin and pin hole shall be not less than 0.4 mm and not more than 0.75 mm.

14.2.5.8 Countersunk holes

Countersinking of normal round holes for countersunk bolts and screws shall be carried out after holing. If countersunk bolts are identified as being for use in tension or preloaded applications, to allow for adverse tolerances, the nominal depth of countersinking shall be at least 2mm less than the nominal thickness of the outer ply.

14.2.6 Assembly

Connected elements shall be drawn together such that they achieve firm contact consistent with the requirements for fit up or direct bearing.

Drifting of holes to align the components shall be permitted, but must not cause damage or distortion to the final assembly.

Any requirements for camber or presets for incorporation in fabricated components shall be checked after completion of fabrication.

14.2.7 Curving and straightening

Curving or straightening components during fabrication, shall generally be performed by one of the following methods:-

(i) mechanical means, taking care to minimise indentations, or change of cross-section. Cold bending may be applied provided the plastic strains induced do not exceed 3% and no welding takes place subsequently on the strained region, unless it complies with the requirements as given in clause 11.7.5. For bending of steels with design strength up to 460 N/mm^2 such that strains in excess of 3% are produced, either the bending shall be carried out hot at temperatures in the range 850 to 900°C or the component shall be heat treated by normalising after cold bending. Any materials subject to curving or straightening involving plastic strains in excess of 3% shall be demonstrated to retain the specified mechanical properties by a procedure test sample.

(ii) the local application of heat, ensuring that the temperature of the metal is carefully controlled, and does not exceed 650°C.

(iii) the induction bending process with careful temperature control.

Methods for curving and straightening which involve increased temperatures shall not be used for quenched and tempered steel.

After curving or straightening, welds within the area of curving or straightening shall be visually inspected. Non-destructive examination of welded joints, where required, shall be carried out after any curving or straightening.

14.2.8 Inspection

Sufficient components shall be checked for dimensional accuracy and conformity to design requirement to demonstrate that the manufacturing process is working satisfactorily.

14.2.9 Storage

14.2.9.1 Stacking

Fabricated components, which are stored prior to being transported or erected, shall be stacked clear of the ground and arranged, so that water cannot accumulate. They shall be kept clean and supported in such a manner as to avoid permanent distortion.

14.2.9.2 Visible markings

Individual components shall be stacked and marked in such a way as to ensure that they can be identified.

14.3 WORKMANSHIP – WELDING

14.3.1 General

All welding operations shall be consistent to one set of standard as given in Annex A1.4.1 and shall be applied strictly throughout the whole course of development. Welding shall be a metal arc process in accordance with other clauses given in this section and the requirements as given in Annex A1.4.1. In case of ambiguity, the more stringent requirements shall apply.

Joints shall be prepared in accordance with the requirements as given in Annex A1.4.1. Precautions shall be taken to ensure cleanliness of the connection prior to welding.

Welding of higher strength steel is covered by this section but account should be taken of the difference in procedures that will be required for these materials and possible defects, e.g. weld metal hydrogen cracking.

14.3.2 Welder qualification

14.3.2.1 Certification of welder test

Welder test shall be witnessed by a qualified welding inspector and certificates endorsed by an independent testing body. Welders shall be tested to meet the requirements as given in Annex A1.4.3.

14.3.3 Welding procedure specifications

14.3.3.1 Preparation of procedure specifications

Welding procedure specifications (WPS) shall be prepared in accordance with the requirements as given in Annex A1.4.2 and made available to the Responsible Engineer. They shall comply with the guidance to avoid hydrogen cracking and to provide adequate toughness in the heat affected zone.

Table 14.2a - Requirements for submission of welding procedure specifications

Weld Type	Weld Size	Approval of Welding Procedure
Butt Weld	≤ 4 mm	Not necessary
	> 4 mm	By a qualified welding inspector.
Fillet Weld	≤ 4 mm	Not necessary
	> 4mm	By a qualified welding inspector.

14.3.3.2 Approval of procedure specifications and procedure tests

All welding procedure tests shall be witnessed by a qualified welding inspector and all Welding Procedure Approval Records (WPAR) shall be endorsed by a qualified welding personnel. WPAR shall record all relevant information, including original material certificates (showing the carbon equivalent value), mechanical tests data and non-destructive test results.

14.3.3.3 Availability of welding procedure specifications

WPS shall be submitted for the approval of the Responsible Engineer prior to the commencement of the works.

WPS shall be provided for the welders prior to the commencement of the works and shall be made available to the concerned parties on request.

14.3.3.4 Avoidance of lamellar tearing- requirement for through thickness properties

The welding procedures should be chosen so as to minimise the risk of lamellar tearing. If necessary, material with through-thickness properties shall be used. Guidance on the choice of procedures and through-thickness grade is given in Annex A1.4.1.

14.3.3.5 Centreline segregation

Centreline segregation is a material deficiency that may exist within the centre of plate (concast) products and some sections. It can lead to local reductions in toughness and weldability that can cause cracking in tee butt and cruciform weld configurations.

The use of good welding practice and details may avoid this phenomenon, for example,

- Avoiding tee, butt or cruciform welds in which the attachment plate is thicker than the through plate;
- Minimising through-thickness tension especially at the edges of plates;
- Dressing any cut edges to remove any areas of increased hardness;
- Using smaller weld volumes;
- Developing weld details and processes that minimise the restraint to welds;
- Following the guidance on the avoidance of hydrogen cracking.

Where it is essential to avoid this phenomenon, either additional tests shall be carried out or the continuous casting route shall not be used to produce the material.

14.3.4 Assembly

14.3.4.1 Fit-up

Joints shall be fitted up to the dimensional accuracy required by the welding procedure to ensure that the quality in clause 14.3.6.7 is achieved.

14.3.4.2 Jigs

Fabrications assembled in jigs may be completely welded in the jig, or may be removed from the jig after tack welding.

14.3.4.3 Tack welds

Tack welds shall be made using the same procedure as the main weld (single run) or the root run of multi-run welds. Alternatively, they may be made using a satisfactory welding procedure test based on the proposed length of tack weld to be used. The minimum length of the tack shall be the lesser of 4 times the thickness of the thicker part or 50 mm.

Tack welds, which are made by a qualified welder and found satisfactory by visual inspection, may be incorporated into main welds.

Where tack welds are made in circumstances other than those identified above, they must be removed.

14.3.4.4 Distortion control

The sequence of welding a joint or a sequence of joints shall be such that distortion is minimised.

14.3.4.5 Fabrication or erection attachments

Welding of attachments required for fabrication or erection purposes shall be made in accordance with the requirements for a permanent weld.

When removal of attachments is necessary, they shall be flame cut or gouged at a point not less than 3 mm from the surface of the parent material. The residual material shall be ground flush and the affected area visually inspected. When parent metal thickness is greater than 20 mm it shall also be checked by magnetic particle inspection. Acceptance criteria are as set out in clause 14.3.6.7. Attachments shall not be removed by hammering.

14.3.4.6 Extension pieces

Where the profile of a weld is maintained to the free end of a run by the use of extension pieces, they shall be of material of a similar composition, but not necessarily the same grade, as the component. They shall be arranged so as to provide continuity of preparation

and shall be removed after completion of the weld and the end surface of the weld ground smooth.

14.3.4.7 Production test plates

Where production test plates are required for testing purposes, they shall be clamped in line with the joint. The grade of material, carbon equivalent value, and rolling direction shall match the parent plate, but need not be cut from the same plates or cast.

14.3.5 Non-destructive testing of parent material

Unless agree with the Responsible Engineer, areas of material thicker than 25 mm in tee and cruciform connections within 150 mm of the weld shall be ultrasonically inspected prior to welding. The qualified welding inspector shall report any laminations or any significant variations in attenuation.

14.3.6 Non-destructive testing of welds (NDT)

14.3.6.1 Scope and frequency of inspection

Visual inspection shall be carried out at all welds by a qualified welding inspector (see clause 14.3.6.3).

The scope and frequency of inspection using non-destructive testing (NDT) shall be in accordance with Table 14.3a. Inspection requirements may be reduced at the discretion of the Responsible Engineer, based upon satisfactory performance in the initial production demonstrated against the requirements. Conversely, where testing indicates that weld quality problems have occurred (in similar materials, assembly methods or welding procedures), non-destructive testing requirements should be increased and should be extended to non-mandatory components.

Where the requirement for inspection is less than 100%, the joints for testing shall cover all the different joint types, material grades and weld equipment. Apart from this the selection should be random.

14.3.6.2 Record of testing

Results of visual inspection, surface flaw detection and ultrasonic examination shall include the minimum requirement stipulated by the relevant standard and shall be available for inspections.

14.3.6.3 Visual inspection of welds

Visual inspection shall be made in accordance with guidance given in Annex A1.4.4 over the full length of all welds. Such inspection shall be performed before any required NDT inspection.

Any welds which will be rendered inaccessible by subsequent work shall be examined in accordance with the Code prior to the loss of access.

A suitably qualified person for visual inspection of welds may be a welding inspector who can provide evidence of having trained and assessed for competence in visual inspection of the relevant types of welds.

14.3.6.4 Hold time before final NDT

Owing to the risk of delayed cracking, a hold time period of at least 16 hours should generally be allowed before the final inspection is made of as-welded fabrications. This hold time should be reduced for thin materials whose yield strength is less than 690 N/mm^2 or should be increased for materials of combined thickness greater than 50 mm or of a yield strength over 690 N/mm^2. Typical hold times conforming with this requirement are illustrated in Table 14.2b. The hold time is the waiting time normally required after completion of welding. In high restraint situations (e.g. cruciform welds), the hold time might need to be increased; with evidence of continual satisfactory production, hold times might be reduced.

For material with a yield strength greater than 690N/mm^2, the hold time should be submitted by the Responsible Engineer based on the advice of a welding engineer or the supplier of the welding consumables, and Table 14.2b should not be used.

Table 14.2b - Illustrative hold times

Nominal Carbon Equivalent Value (CEV)(2)	Σt (3) < 30mm	Σt (3) ≤ 60mm	Σt (3) ≤ 90mm	Σt (3) > 90mm
≤ 0.40	None	8 hours	16 hours	**40 hours (1)**
≤ 0.45	8 hours	16 hours	**40 hours (1)**	**40 hours (1)**
≤ 0.48	16 hours	**40 hours (1)**	**40 hours (1)**	**40 hours (1)**
≤ 0.65	**40 hours (1)**	**40 hours (1)**	**40 hours (1)**	**40 hours (1)**
> 0.65	**48 hours (1)**	**48 hours (1)**	**48 hours (1)**	**48 hours (1)**

Notes:

(1) Where the figures are in bold, generally, the advice of a welding engineer or the supplier of the welding consumables should be sought.

(2) The carbon equivalent value is that of the parent material to the International Institute of welding (IIW) formula and is calculated as follows:

$$CEV = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \qquad \text{(T14.1)}$$

(3) Σt is the combined thickness as shown in Figure 14.1.

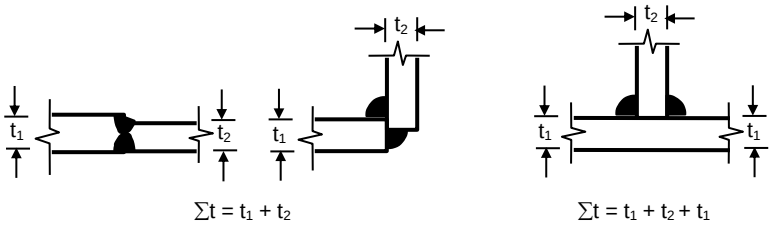


Figure 14.1 - Combined thickness

Whatever hold-time period is to be used shall be stated in the inspection records.

14.3.6.5 Surface flaw detection

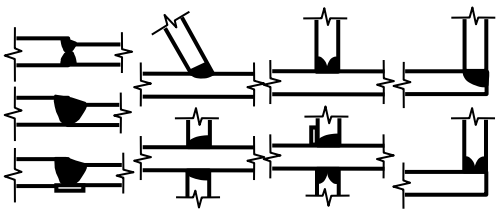
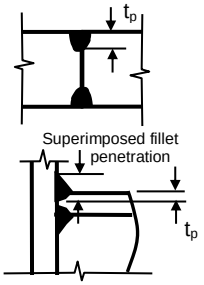
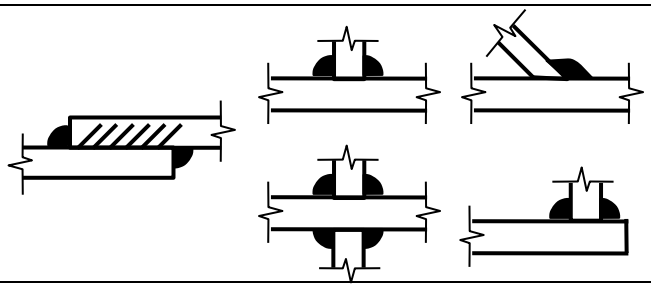
Where a closer examination of a weld surface is required in accordance with Table 14.3a, magnetic particle inspection (MPI) shall be used. If magnetic particle inspection equipment is impractical, dye penetrant inspection (DPI) may be used.

Final surface flaw detection of a welded joint shall be carried out after completion of the weld in accordance with the hold time given in Table 14.2b.

Where a welding procedure requires an inspection after initial weld runs before further welding is performed, such inspections may be carried out when the weld metal has cooled to ambient temperature.

A suitably qualified person for surface flaw detection of welds may be a welding inspector or a welder, who holds a valid certificate of competence in surface flaw detection of the relevant types of welds, from BA or a nationally recognised authority.

Table 14.3a - Scope and frequency of inspection (NDT)

<table>
<tr><td colspan="2">PART A</td><td colspan="2">VISUAL INSPECTION Prior to Non-Destructive Testing (NDT)
all welds to be visually inspected by a suitably qualified person (See clause 14.3.6.3)</td></tr>
<tr><td colspan="2">PART B</td><td colspan="2">THICKNESS FOR MANDATORY NDT AND FREQUENCY OF TESTING (all dimensions in mm)</td></tr>
<tr><td colspan="2" rowspan="2">WELD TYPE</td><td colspan="2">BUTT</td></tr>
<tr><td>FULL PENETRATION</td><td>PARTIAL PENETRATION</td></tr>
<tr><td colspan="2"></td><td>  </td><td> 
</td></tr>
<tr><td rowspan="2">MPI</td><td>Thickness</td><td>All thickness</td><td>All thickness</td></tr>
<tr><td>Frequency</td><td>100%</td><td>20%</td></tr>
<tr><td rowspan="2">U/S</td><td>Thickness</td><td>$t_{max} \geq 10$</td><td>$t_p \geq 8$</td></tr>
<tr><td>Frequency</td><td>100%</td><td>20%</td></tr>
<tr><td colspan="2">WELD TYPE</td><td colspan="2">FILLET</td></tr>
<tr><td colspan="2"></td><td colspan="2">  </td></tr>
<tr><td rowspan="2">MPI</td><td>Thickness</td><td colspan="2">All thickness</td></tr>
<tr><td>Frequency</td><td colspan="2">10%</td></tr>
<tr><td rowspan="2">U/S</td><td>Thickness</td><td colspan="2">Leg length$\geq$ 15</td></tr>
<tr><td>Frequency</td><td colspan="2">10%</td></tr>
</table>

Notes:

1 Longitudinal welds are those made parallel with the member axis. All other welds are transverse.

2 The size of fillet weld is identified in the table by the leg length.

3 MPI Magnetic Particle Inspection (see clause 14.3.6.5).

4 U/S Ultrasonic Examination (see clause 14.3.6.6).

5 For steels with a yield strength greater than 500N/mm^2 the frequency of testing should be 100% unless agreed otherwise by the Responsible Engineer.

14.3.6.6 Ultrasonic examination

Where ultrasonic examination (U/S) is required, it shall be made in accordance with the requirement as contained in Annex A1.4.4. Records of the inspection procedure shall be kept, connection types and locations shall be clearly identified and shall be available for inspection unless otherwise agreed by the Responsible Engineer.

Ultrasonic examination of the welded joint shall be carried out after completion of the weld in accordance with the hold time given in Table 14.2b.

Note: In addition to weld examination, through-thickness ultrasonic examination of the parent material may be necessary for weld geometries susceptible to lamellar tearing.

Operators carrying out final ultrasonic examination of the weld shall hold a valid certificate of competence from BA or a nationally recognised authority.

14.3.6.7 Acceptance criteria and corrective action

Unless otherwise specified, the acceptance criteria for welds shall meet the minimum requirement as contained in Table 14.3b. Welds that do not comply with the requirement shall be repaired.

The position of welds shall be within 10 mm of that shown on the drawings. The length of weld shall be not less than that shown on the drawings and should not exceed the specified length by more than 10 mm.

Any repairs shall be carried out in accordance with approved welding repair procedures.

Any corrected welds shall be inspected again with increased hold times and shall meet the requirements of the original welds.

In cases where fatigue can occur, acceptance standards more stringent than these minima shall be required. In such a case, the Responsible Engineer shall specify the additional acceptance requirements.

Table 14.3b - Acceptance criteria for welds in steel structures

Feature	Parameter	Weld type	Particular conditions[a]		Figure reference in Table 14.3d	Acceptance criteria for normal quality[b c] (All dimensions in mm)	Remedial action for non-conforming welds[d]
Overall weld geometry	Location[e]	All	—		—	$D \pm 10$	E
	Weld type	All	—		—	D	E
	Extent (length)	All	—		—	D +10 - 0	E
Profile discontinuities	Actual throat thickness	All	—		i, ii, iii	$a, s \geq D$ (50) $a, s \leq D + 5$	R DS
	Leg length	Fillet	—		i	$z \geq D$ (50)	E
	Toe angle (interface and inter-run)	All	Transverse Longitudinal		i, ii i, ii	$\theta \geq 90^{\circ}$ $\theta \geq 90^{\circ}$	DS/R DS/R
	Excess weld metal	Butt	Transverse Longitudinal		ii ii	$h \leq 6$ $h \leq 6$	DS DS
	Incomplete groove or concave root	Butt	Transverse Longitudinal		ii ii	$h \leq 0$ (50) $h \leq 0.1t$	R E
	Linear misalignment	Butt All All	Transverse butt Transverse cruciform Longitudinal		iv v iv, v	$h \leq D + 0.2t$ $h \leq D + 0.4t$ $h \leq D + 0.4t$	E E E
Surface breaking discontinuities	Undercut[f]	All Fillet All	Transverse (not lap joint) Transverse (lap joint) Longitudinal		iv, v v iv, v	$h_1 + h_2 \leq 0.05t$ l – NL $h_1 + h_2 \leq 0.03t$ $l \leq 10$ $h_1 + h_2 \leq 0.1t$	R R R R R
	Lack of root penetration	S/S Butt	Transverse Longitudinal		iii iii	*NP* *NP*	R R
	Porosity	All	Transverse Longitudinal		vi vi	$d \leq 2$ $\sum d \leq 10$ [100] $d \leq 2$ $\sum d \leq 20$ [100]	R R R R
	Lack of fusion	All	—		vii	NP	R
	Cracks	All	At crater Not at crater		vii	NP NP	R R
			All		vii	$h \leq 3$	R
Sub-surface discontinuities	Lack of fusion/root penetration, slag lines	Butt	Transverse	Full depth $h_1 < 6$ $h_1 > 6$	vii vii vii	$\sum l \leq 1.5t$ [100] $l \leq 10$ $l_1 \geq 10$ l – NL l_1 – NL	R R R R R
			Longitudinal	Full depth $h_1 < 6$ $h_1 > 6$	vii vii vii	$\sum l \leq 3t$ [100] l – NL l_1 – NL l – NL l_1 – NL	R R R R R
—	Root gap	Fillet P/P Butt	—		i, v	$h \leq 2$ (100), 3	R
—	Cracks	All	—		—	NP	R
—	Lamellar tears	All	Transverse Longitudinal		—	NP[g]	E

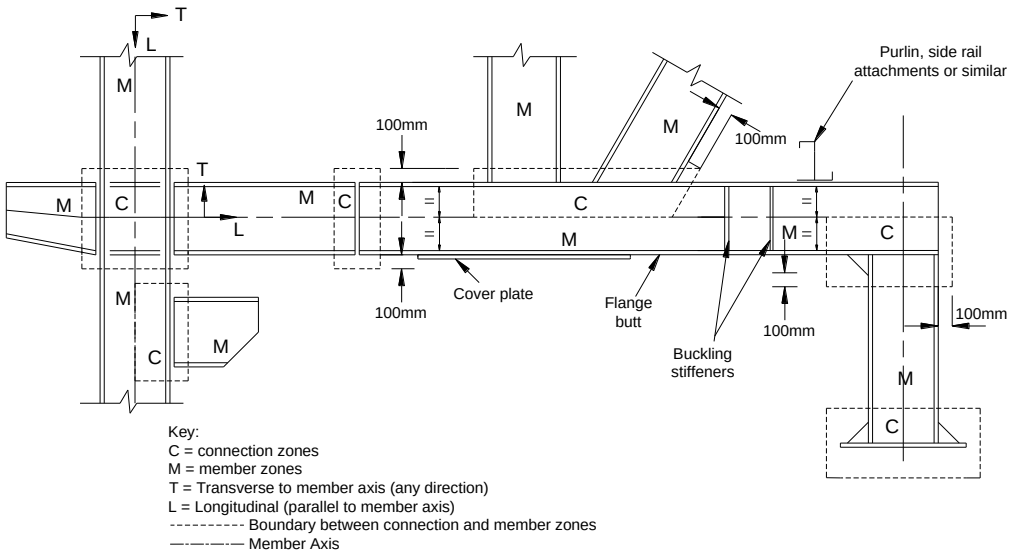
Table 14.3b - Acceptance criteria for welds in steel structures (cont'd)

Abbreviated terms			
D	As specified on drawings	a	For definition of orientation see Table 14.3c.
DS	Dress smoothly	b	Thickness applies to minimum member thickness at weld in question. For thicknesses greater than 20 mm "*t*" shall be taken as 20 mm. Where permitted size "*h*" if a discontinuity is related to "*t*" the maximum permitted value shall be not less than 0.3 mm in any case.
E	Refer to engineer	c	Where more than one requirement is given both shall apply. Where a repair is necessary an approved procedure shall be used.
NL	No limit	d	If on increasing the scope of inspection, further non-conformances are found, the scope shall be increased to 100% for the joint type in question.
NP	Not permitted (applies to discontinuities which are detectable by NDT methods in Table 14.3a)	e	Subject to any other locational requirements.
R	Repair by welding to approved procedure	f	"Lap" shall apply to any fillet welded attachment whose length in the longitudinal direction exceeds 50 mm.
≥	Greater than or equal to (i.e. not less than)	g	Lamellar tears may only be accepted in the longitudinal welds if the extent does not exceed limits for lack of fusion in transverse welds.
≤	Less than or equal to (i.e. not greater than)		
∑	Sum of		
( )	Length of weld over which measurement may be averaged (mm)		
[ ]	Length of weld over which the summation is made (mm)		
L	Length parallel to the weld axis		
S/S	Single sided butt weld		
P/P	Partial penetration butt weld		

Table 14.3c - Definition of zones and weld orientation

Categories of joint types according to location and orientation in structure (see figure below)			Frequency of testing[a]
Connection zones	Shop welds		See table 14.3a
	Site welds		See table 14.3a
Member zones	Built-up members	Transverse butts in web and flange plates before assembly	See table 14.3a
		Transverse fillet welds at ends of lap joints	
		Longitudinal welds	See table 14.3a
	Secondary attachment welds	e.g. for fixing purlins, side rails, buckling stiffeners etc.	See table 14.3a

Definition of zones and weld orientation



NOTE:- All welds in connection zones to be treated as transverse.

[a] Where only partial inspection is required, the joints for testing shall be selected on a random basis, but ensuring that sampling covers the following variables as widely as possible: joint type, material grade and welding equipment.

Table 14.3d - Characteristic defects of welds in steel structures

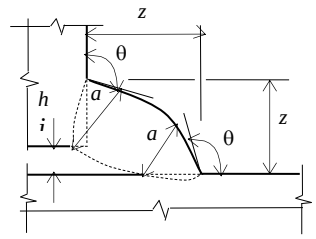


Figure (i)

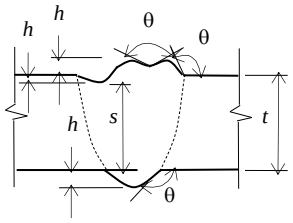


Figure (ii)

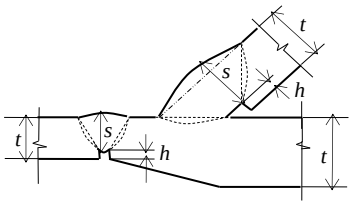


Figure (iii)

a and s are minimum distances

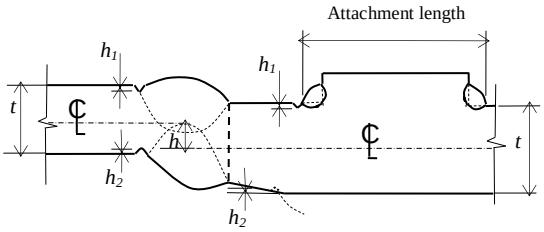


Figure (iv)

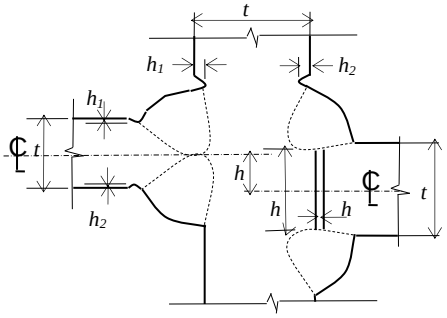
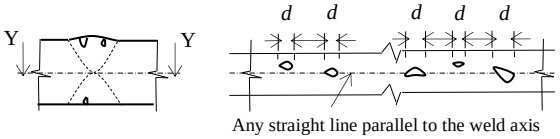
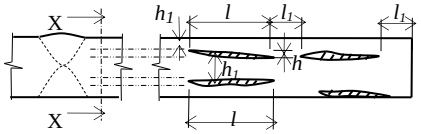


Figure (v)



Y - Y

Figure (vi)



X - X

Figure (vii)

14.3.7 Shear stud welding

14.3.7.1 Method

Except where there are specific requirements in this section, shear studs shall be welded in accordance with the requirement given in Annex A1.4.1. Adequate earth return connections shall be made local to the area being stud welded.

14.3.7.2 Trial welding

When specified by the Responsible Engineer and before commencement of welding of studs, procedure trials shall be carried out. The trials shall be made on samples of material and studs representative of those to be used in the work.

At the start of each shift when stud welding is in progress, each welder shall perform the fixing of at least two trial studs.

14.3.7.3 Tests and inspection

All studs are to be visually inspected. They shall show a full 360° collar.

After a satisfactory visual inspection, bend tests shall be made at locations agreed with the Responsible Engineer. A minimum of 5% of the studs, but not less than two studs per beam shall be tested. The bend test shall be made by bending the head of the stud towards the nearer end of the beam, by means of a steel tube placed over the stud, until it is displaced laterally a distance of one quarter of the height of the stud. The stud weld shall not show any sign of cracking or lack of fusion.

If any stud is found to be defective, studs on either side shall be tested. Should either of the two additionally tested studs fail, then all studs shall be considered to be at risk until further testing deems them to be acceptable.

Studs subjected to the bend test shall not be straightened.

14.3.7.4 Defective studs

Studs with defective welding shall be replaced and re-tested as in clause 14.3.7.3.

If it is necessary to remove the defective stud, it shall be detached and the surface checked as described in clause 14.3.4.5.

14.4 WORKMANSHIP – BOLTING

14.4.1 General

This section covers bolting in the shop and on site. Bolts with an ultimate tensile strength exceeding 1000 N/mm^2 should not be used unless test results demonstrate their acceptability in a particular design application.

Separate components forming part of a common ply shall not differ in thickness by more than 2 mm generally or 1mm in preloaded applications. If steel packing plates are provided to ensure that the difference in thickness does not exceed the above limit, their thickness shall not be less than 2 mm.

Packing plates shall have compatible corrosion behaviour and mechanical strength with the adjacent plate components of the joint.

14.4.2 Ordinary bolted assemblies

14.4.2.1 Hexagon bolt / nut combinations for ordinary (non-preloaded) assemblies

The combinations of bolts and nuts which may be used are given in Table 14.4.

Table 14.4 - Matching bolt, nut and washer standards for ordinary bolts

Standard	Grade	Bolt	Nut	Washer
European/ISO	4.6	BS EN ISO 4018 or BS EN ISO 4016	BS EN ISO 4034 (class 4 d>M16, class 5 d≤M16)	BS EN ISO 7091 (100HV)
	8.8(1)	BS EN ISO 4017 or BS EN ISO 4014	BS EN ISO 4032 (class 8)	BS EN ISO 7091 (100HV)
	10.9(2)	BS EN ISO 4017 or BS EN ISO 4014	BS EN ISO 4032 (class 10)	BS EN ISO 7091 (100HV)
British	4.6	BS 4190 BS 7419	BS 4190 (Grade 4)	BS 4320
	8.8	BS 4190 BS 7419	BS 4190 (Grade 8)	BS 4320
	10.9	BS 4190	BS 4190 (Grade 10)	BS 4320
American	Equivalent to 8.8	ASTM A325	ASTM A563	ASTM F436
		F1852	ASTM A563	ASTM F436
		ASTM A490	ASTM A563	ASTM F436
Australian	4.6/S	AS/NZS 1111	AS/NZS 1111	AS/NZS 1111
	8.8/S	AS/NZS 1252	AS/NZS 1252	AS/NZS 1252
	8.8/TB	AS/NZS 1252	AS/NZS 1252	AS/NZS 1252
	8.8/TF (6)	AS/NZS 1252	AS/NZS 1252	AS/NZS 1252
PR China	Normal bolt	GB1228	GB1229	GB1230
	High strength bolt	GB1231	GB1231	GB1231
	High strength bolt for torsion / shear type	GB3632 GB3633	GB3632 GB3633	GB3632 GB3633
Japanese JIS	4.6 6.8	JIS 1051 JIS 1051	JIS 1051 JIS 1051	JIS 1051 JIS 1051

Notes: Any bolt assemblies which are seized when being tightened shall be replaced.
Normally, same strength grade of bolt and nut should be used together. Nuts of higher strength grade may be substituted for nuts of a lower strength grade.
When a thick protective coating is applied to a bolt of grade 8.8 or 10.9, which requires the nut thread to be overtapped, the next higher grade of nut should be used. That is,
(1) nuts for galvanized or sheradized 8.8 bolts shall be class/grade 10;
(2) nuts for sheradized 10.9 bolts shall be class/grade 12.

14.4.2.2 Cup and countersunk head bolt / nut assemblies

The combination of cup and countersunk bolts and nuts which may be used should be from matching acceptable standards as given in Annex A1.3.

14.4.2.3 Differing bolt grades

Different bolt grades of the same diameter shall not be used in the same structure.

14.4.2.4 Bolt length

For 8.8 grade bolts, the bolt length shall be chosen such that at least one complete thread in addition to the thread run-out that shall remain clear between the nut and the unthreaded shank of the bolt after tightening. For higher grades, at least five clear threads shall remain.

In all cases, at least one clear thread shall show between the nut and the end of the bolt after tightening.

14.4.2.5 Washers

When the members being connected have a finished surface protective treatment which may be damaged by the nut or bolt head being rotated, a washer shall be placed under the rotating part.

A suitable plate, or heavy duty washer shall be used under the head and nut when bolts are used to assemble components with oversize or slotted holes.

14.4.2.6 Taper washers

When the bolt head or nut is in contact with a surface which is inclined at more than 3° from a plane at right angles to the bolt axis, a taper washer shall be placed to achieve satisfactory bearing.

14.4.2.7 Nuts

Nuts shall be checked after being galvanized or sheradized for free running on the bolt and re-tapped if necessary to ensure a satisfactory tightening performance. Nuts of grade 8 or lower may be galvanized or sheradized while nuts of grade 10 or higher should only be sheradized.

14.4.2.8 Tightening of assemblies with non-preloaded bolts

The connected components shall be drawn together such that they achieve firm contact. Shims may be used to adjust the fit. For thicker gauge material ($t \geq 4$ mm for plates and $t \geq 8$ mm for sections), residual gaps up to 2 mm may be left between contact faces unless full contact bearing is specified.

During this process, each bolt assembly shall be brought into a snug-tight condition without overloading the bolts. In large bolt groups, this process shall be carried out progressively from the middle of the group to the outside. Additional cycles of tightening shall be carried out, if necessary, to achieve a uniform snug-tight condition. Sufficient precautions shall be taken so as not to overload short bolts (i.e. of length less than 3 times the diameter) and M12 or smaller bolts during tightening.

Note: the term snug-tight can generally be identified as that achievable by the effort of one man using a normal sized spanner without any extension arm, and can be set as the point at which a percussion drill starts hammering.

The snug tight tension in the bolt should not exceed the value at which bolt shear capacity reduces. Values of torque recommended by a typical bolt manufacturer to achieve suitable tensions for grade 8.8 bolts are as follows:

Table 14.5 - Recommended tightening torques and approximate bolt tensions for ISO grade 8.8 bolts (Assumes bolts oiled)

Nominal bolt diameter	Tightening torque (Nm)	Approximate bolt load (kN)
M16	55	17
M20	100	25
M22	110	25
M24	120	25
M27	135	25
M30	150	25
M33	165	25
M36	180	25

14.4.2.9 Fitted bolts

Precision bolts may be used as fitted bolts when holes are drilled or reamed after assembly so that the clearance in the hole is not more than 0.3 mm.

14.4.2.10 Reaming

Where parts cannot be brought together by drifting without distorting the steelwork, rectification may be made by reaming, provided the design of the connection will allow the use of larger diameter holes and bolts.

14.4.3 Pre-loaded bolt assemblies

14.4.3.1 Bolt / nut / washer combinations

The combination of pre-loaded bolt and nut and washers which may be used shall be from matching acceptable standards as given in Annex A1.3. The hardened washer is to be

placed under the nut or head being turned. Where oversized or slotted holes are present in the outer plies, suitable cover plates and/or additional hardened washers shall be used.

14.4.3.2 Other pre-loaded assemblies

The combination of pre-loaded assemblies shall be in accordance with manufacturer's recommendations.

14.4.3.3 Tightening of pre-loaded bolt assemblies

The use of friction grip bolts shall comply with the specification as contained in Annex A1.3.

Connected parts intended to transfer force in friction shall be firmly drawn together with all bolts partially tightened in a similar manner to assemblies with non-preloaded bolts. The joint shall then be examined to establish if there is any remaining gap which may affect the integrity of the joint. If so, then the joint shall be taken apart and a pack inserted before recommencing the tightening procedure. Tightening procedures shall be carried out progressively from the middle of each bolt group to the free edges. Additional cycles of tightening shall be carried out, if necessary, to achieve uniform preloading.

Unless specified by the Responsible Engineer, tightening, which shall comply with requirements in Annex A1.3, may be achieved by the torque control method, part-turn method, direct tension indicators or following the manufacturer's recommendations.

14.4.3.4 Bolt length

For normal grade HSFG bolts, the bolt length shall be chosen such that at least three complete threads in addition to the thread run-out that shall remain clear between the nut and the unthreaded shank of the bolt after tightening.

For higher grade, at least five clear threads shall remain.

In all cases, at least one clear thread shall show above the nut.

14.4.3.5 Calibration of torque equipment

Torque spanners and other devices shall have a calibration check at least once per shift, and shall be re-calibrated where necessary.

14.4.3.6 Discarded bolt assemblies

If, after complete tightening, a bolt or nut has to be slackened off, the whole bolt assembly is to be scrapped.

14.4.3.7 Reaming

Where parts cannot be brought together by drifting without distorting the steelwork, rectification can be made by reaming, provided that the design of the connection will allow the use of larger diameter bolts.

Calculations shall be made to demonstrate that the connection remains adequate for the forces in the connection.

14.5 WORKMANSHIP – ERECTION

14.5.1 Erection method statement

An erection method statement shall be prepared and shall be checked in accordance with the design rules, notably against resistance of the partly erected structure to erection and other temporary loading. It shall describe the procedures to be used for safe erection of the steelwork by taking into account the technical requirements on the safety of the works.

14.5.2 Handling and storage

Components shall be handled and safely stacked in such a manner as to minimise the risk of surface abrasion and damage. Fasteners and small fittings shall be stored under cover in dry conditions.

14.5.3 Damaged steelwork

Any steelwork damaged during off-loading, transportation, storage or erection shall be abandoned unless it is restored to conform to the standards of manufacture as given in the Code.

14.5.4 Column base plates and slabs

Steel packings shall be supplied to allow the structure to be properly lined and levelled and of sufficient size to avoid local crushing of the concrete.

Base packings shall be placed so that they do not prevent subsequent grouting to completely fill all spaces directly under the base plates. Base packings may be left permanently in place.

14.5.5 Grouting

Grouting shall not be carried out under column base plates until a sufficient portion of the structure has been aligned, levelled, plumbed and adequately braced.

Immediately before grouting, the space under column base plates shall be clean and free of all extraneous matter.

14.5.6 Stability

Throughout the erection of the structure, the steelwork shall be securely bolted or fastened in order to ensure that it can adequately withstand all loading to be encountered during erection, including, where necessary, those from the erection plant and its operation. Any temporary bracing or temporary restraint shall be left in position until erection is sufficiently advanced to leave the remaining structure in a stable and safe condition.

14.5.7 Alignment of part of the structure

Each part of the structure shall be aligned as soon as practicable after it has been erected. Permanent connections shall not be made between members until a sufficient part of the structure has been aligned, levelled, plumbed and temporarily connected to ensure that members will not be displaced during subsequent erection or alignment of the remainder of the structure.

14.5.8 Temperature effects

Due account shall be taken of the effects of temperature on the structure and on tapes and instruments when measurements are made for setting out, during erection, and for subsequent dimensional checks. The reference temperature shall be 20°C.

14.5.9 Site welding

Site welding shall be carried out in accordance with clause 14.3.

In all cases, precautions are to be taken so that the welding current does not damage the components it passes through and adequate earth return connections are made local to the area being welded.

Welding shall not be permitted during inclement weather, unless adequate protective measures are taken.

14.5.10 Site bolting

Bolting shall be carried out in accordance with clause 14.4.

14.6 PROTECTIVE TREATMENT

14.6.1 General

14.6.1.1 Specification

The specification should comply with the appropriate regulatory requirements on environmental protection.

Unless otherwise agreed, a single source of coating supply shall be used.

14.6.1.2 Method statement

Before the application or reapplication of protective coating, a detailed method statement shall be prepared.

14.6.1.3 Coating procedures

Coating materials shall be prepared and applied to surfaces in accordance with the manufacturer's recommendations.

14.6.1.4 Transportation, handling and storage of coated steelwork

The procedures for the transportation, handling and storage of coated steelwork shall be so arranged as to minimise the risk of damage to the coating.

14.6.2 Materials

14.6.2.1 Metallic blast cleaning abrasives

Abrasives used for blast cleaning shall be capable of achieving the specified level of cleanliness and surface roughness. Where metal abrasives are used, they shall comply with the specification as given in Annex A1.9.

14.6.2.2 Surface coatings

Paint materials and other coatings shall be in accordance with the appropriate European, ISO or other standard recognised in Hong Kong.

14.6.2.3 Sheradized coatings

Sheradized coatings shall be in accordance with the specification as given in Annex A1.9.

14.6.2.4 Galvanized materials

The composition of zinc in the galvanizing bath shall be in accordance with the specification as given in Annex A1.9.

14.6.3 Surface preparation

14.6.3.1 Surface cleanliness

At the time of coating, the surface cleanliness of the steelwork to be coated shall be in accordance with the grade specified and general local practice or BA's requirements.

14.6.3.2 Surface profile

The surface profile of the steelwork shall be that recommended by the coating manufacturer as compatible with the coating when graded.

14.6.3.3 Measurement of surface profile

Measurement of the surface profile of steelwork to be coated shall be made using the methods given in Annex A1.8.

14.6.3.4 Surface defects

Surface defects revealed during surface preparation shall be rectified accordingly.

14.6.4 Sprayed metal coatings

14.6.4.1 Procedures

Zinc or aluminium sprayed coatings shall be applied to the surface as required to a thickness given in the project specification or in the design drawings.

14.6.4.2 Reinstatement of damaged coating

All reinstatement of damaged coatings shall be made good to the standard of the original works using the same methods and materials.

14.6.4.3 Sealing before painting

Where a sprayed metal coating is to be overcoated subsequently, it shall be sealed before the application of the overcoating.

14.6.5 Hot-dip galvanizing

14.6.5.1 Procedures

Galvanizing shall be carried out in accordance with the requirements as contained in Annex A1.9.

14.6.5.2 Vent holes

The Steelwork Fabricator shall agree with the Responsible Engineer the position of vent and drainage holes in hollow members and requirements for subsequent sealing.

14.6.6 Paint treatments

14.6.6.1 Surface preparation prior to painting

Steelwork shall be prepared for coating to the standard specified.

14.6.6.2 Painting of site weld areas and fasteners

Site weld areas and fasteners which are not suitably protected shall be painted with an approved paint system to ensure similar properties, performance and compatibility with the protective treatment system being used on the surrounding surfaces.

Fasteners and bolt assemblies, which are supplied with a protective treatment that is equivalent to the protective treatment on the steelwork, need not be painted.

14.6.7 Inspection and testing

The method statement (clause 14.6.1.2) shall include proposals for inspection and testing to demonstrate compliance with the specified system.