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## 5 WELDING

### 5.1 GENERAL

#### 5.1.1 Scope

- 1 This Part specifies the requirements for welding associated with structural steelwork.

#### 5.1.2 References

- 1 The following standards are referred to in this Part:

BS 3923.....Methods for ultrasonic examination of welds  
BS 4570.....Fusion welding of steel castings  
BS 4872.....Approval testing of welders when welding procedure approval is not required  
BS 5135.....Process of arc welding of carbon and carbon manganese steels  
BS 5289.....Code of practice for visual inspection of fusion welded points  
BS 6072.....Method for magnetic particle flaw detection  
BS 6443.....Penetrant flaw detection  
  
EN 287 .....Qualification test of welders  
EN 288 .....Approval of welding procedures for metallic materials (ISO 15611)  
ISO 9606-1 .....Qualification testing of welders — Fusion welding — Part 1: Steels  
ISO 15614-1 .....Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys

#### 5.1.3 System Description

- 1 Welding shall be a metal arc process in accordance with BS 5135 and BS 4570, as appropriate, together with other clauses contained in this section, unless otherwise specifically permitted by the Engineer.
- 2 Welding consumables used shall be chosen to ensure that the mechanical properties of the weld metal are not less than those required for the parent metal.
- 3 Joints shall be prepared in accordance with BS 5135. Precautions shall be taken to ensure cleanliness of the connection prior to welding.

## 5.2 WELDER QUALIFICATION

### 5.2.1 Testing

- 1 Welders shall be tested to meet the requirements of EN 287 Part 1(ISO 9606-1) but, in the case of welders engaged on fillet welding only, BS 4872 Part 1 is an acceptable alternative.
- 2 As an alternative, when permitted by the Employer, welders may be tested to meet the requirements of the American Society of Mechanical Engineers, ASME IX, or the American Welding Society, AWS DI.1.

### 5.2.2 Certification

- 1 Welder testing shall be witnessed and certificates endorsed by an independent Inspection Authority.

- 2 The certification shall remain valid providing it complies with the conditions for re-approval of certification specified in EN 287 Part 1(ISO 9606-1).

### **5.3 WELDING PROCEDURES**

#### **5.3.1 Preparation of Procedures**

- 1 Approved written welding procedures shall be available in accordance with BS 5135, and tested in accordance with EN 288 Part 3 (ISO 15614-1) by the Contractor.

#### **5.3.2 Approval of Procedures and Procedure Tests**

- 1 Procedures and tests shall be approved by an independent Inspection Authority.

#### **5.3.3 Availability of Welding Procedure Sheets**

- 1 Welding Procedure sheets shall be made available to the welder prior to the commencement of the work and shall be available to the Engineer and Inspection Authority on request.

### **5.4 ASSEMBLY**

#### **5.4.1 Fit-up**

- 1 Joints shall be fitted up to the dimensional accuracy required by the welding procedure, depending on the process to be used, to ensure that the quality in Table 5.2 is achieved.

#### **5.4.2 Jigs**

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

#### **5.4.3 Tack Welds**

- 1 Tack welds shall be made using the same procedures as for the root runs of main welds. The length of the tack shall be the lesser of 4 times the thickness of the thicker part or 50 mm, unless demonstrated by a weld procedure qualification.
- 2 Tack welds which are not defective may be incorporated into main welds provided that the welder is qualified as in Clause 5.2 of this Part. However, where joints are welded using an automatic or mechanised process, the suitability of the tack weld used for incorporation into automatic processes shall be demonstrated in the weld procedure qualification.
- 3 Where tack welds are made in circumstances other than those identified above, they must be removed.

#### **5.4.4 Distortion Control**

- 1 The sequence of welding a joint or a sequence of joints shall be such that distortion is minimised (see Part 7 of this Section).

#### **5.4.5 Fabrication or Erection Attachments**

- 1 Welding of attachments required for fabrication or erection purposes shall be made in accordance with the requirements for a permanent weld.
- 2 When removal 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 thicknesses are greater than 20 mm it shall also be checked by magnetic particle inspection. Acceptance criteria are as set out in Table 5.2. Attachments shall not be removed by hammering. (See Clause 3.4.2 of this Section).

#### **5.4.6 Extension Pieces**

- 1 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 surface ground smooth.

#### **5.4.7 Production Test Plates**

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

### **5.5 NON-DESTRUCTIVE TESTING OF WELDS**

#### **5.5.1 Record of Testing**

- 1 The test results shall be recorded and be available for inspection by the Engineer.

#### **5.5.2 Visual Inspection of Welds**

- 1 Visual inspection shall be made in accordance with guidance given in BS 5289 over the full length of the weld and before NDT inspection is performed (see Tables 5.1 and 5.2). Any welds which will be rendered inaccessible by subsequent work shall be examined in accordance with Tables 5.1 and 5.2 prior to the loss of access.
- 2 A suitably qualified person for visual inspection of welds may be a welding inspector or a welder who can provide evidence of having been trained and assessed for competence in visual inspection of the relevant types of welds.

#### **5.5.3 Surface Flaw Detection**

- 1 Where a closer examination of a weld surface is required in accordance with Table 5.1, magnetic particle inspection (MPI) shall be used in accordance with the recommendations given in BS 6072.
- 2 If magnetic particle inspection equipment is not available, dye penetrant inspection (DPI) may be used in accordance with the recommendations given in BS 6443.
- 3 Final surface flaw detection of a welded joint shall be carried out not less than 16 hours from the time of completion of the weld to be inspected, or not less than 40 hours in the case of welds to Design Grade 55 material. The Contractor shall note that 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.
- 4 A suitably qualified person for surface flaw detection of welds may be a welding inspector or a welder who holds a current certificate of competence in surface flaw detection of the relevant types of work, from a nationally recognised authority.

#### **5.5.4 Ultrasonic Examination**

- 1 Where ultrasonic examination is required in accordance with Tables 5.1 and 5.2, it shall be made in accordance with BS 3923 Part 1, Level 2B. Examination shall be carried out not less than 16 hours from the time of completion of the weld to be inspected, or not less than 40 hours in the case of butt welds thicker than 40 mm or any welds to Design Grade 55 material.
- 2 Operators carrying out final ultrasonic examination of the weld shall hold a current certificate of competence from a nationally recognised authority.

#### **5.5.5 Scope of Inspection**

- 1      The scope of inspection shall be in accordance with Table 5.1.

#### **5.5.6    Acceptance Criteria and Corrective Action**

- 1      Acceptance criteria, corrective action and re-testing shall be in accordance with Table 5.2 for components subject to static loading.
- 2      The acceptance criteria shown in Table 5.2 are not intended to apply to bridges, offshore structures, or other dynamically loaded structures.

### **5.6      SHEAR STUD WELDING**

#### **5.6.1    Method**

- 1      Shear studs shall be welded in accordance with the manufacturer's recommendations for materials, procedures and equipment.

#### **5.6.2    Trial Welding**

- 1      When specified by the Engineer and before production welding of studs commences, 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. The samples of materials and studs shall be agreed with the Engineer.
- 2      Where primers are to be applied to the work prior to the welding of studs they shall be applied to the sample material before the procedure trials are made.

#### **5.6.3    Tests and Inspection**

- 1      All studs are to be visually inspected. They shall show a full 360° collar.
- 2      At locations agreed with the Engineer a minimum of 5% of studs which have satisfied the visual inspection shall have a bend test. The bend test shall be made by striking the head of the stud with a 6kg hammer until it is displaced laterally a distance of about one quarter of the height of the stud. The stud weld shall not show any signs of cracking or lack of fusion.
- 3      Studs subjected to the bend test shall not be straightened.

#### **5.6.4    Defective Studs**

- 1      Studs with defective welding shall be removed in the manner described in Clause 5.4.5 of this Part and replaced and re-tested as in Clause 5.6.3 of this Part.

Table 5.1

Welds - Scope of Inspection

The requirements of this table shall not preclude the use of Non-Destructive Testing outside the limits shown should the results of visual inspection or NDT indicate that a lapse in quality may have occurred in specific joints.

<b>PART A.</b>		<b>VISUAL INSPECTION</b> Prior to Non-Destructive Testing all welds to be visually inspected by a suitably qualified person (See Clause 5.5.2 of this Part)			
<b>PART B.</b>		<b>THICKNESS WHEN NON-DESTRUCTIVE TESTING BECOMES MANDATORY</b> (all dimensions in mm)			
Weld Type		Butt (full, partial penetration and with reinforcing fillets)			
Joint Type		In-line	Tee and Cruciform	Corner	
Procedures		Single sided	Double sided and single sided plus backing	Single sided	Double sided and single sided plus backing
Examples					
Design Grade					
MPI	43/50	$t_{max} < 10$	$t_{max} < 12$	$t_{max} \leq 20$	$t_{max} \leq 20$
	55	$t_{max} < 10$	$t_{max} < 10$	$t_{max} \leq 15$	$t_{max} \leq 15$
U/S	43/50	$t_{max} \leq 10$	$t_{max} \leq 12$	$t_{max} \leq 12$	$t_{max} \leq 30$
	55	$t_{max} \leq 10$	$t_{max} \leq 10$	$t_{max} \leq 10$	$t_{max} \leq 20$
Notation		MPI - Magnetic Particle Inspection (see Clause 5.5.3 of this Part) U/S - Ultrasonic Examination (see Clause 5.5.4 of this Part)			
		$<$ - Less than $\leq$ - Less than or equal to			

Table 5.1 (Continued)

Welds - Scope of Inspection

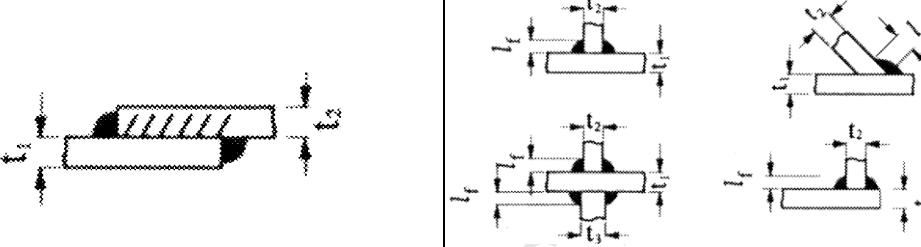
<b>PART B. (Cont.)</b>		<b>THICKNESS WHEN NON-DESTRUCTIVE TESTING BECOMES MANDATORY</b> (all dimensions in mm)	
Weld Type		Fillet	
Joint Type		Lap	Tee and Cruciform
Procedures		All	All
Examples			
Design Grade			
MPI	43/50	$t_{max} \leq 20$	$t_{max} \leq 20$
	55	$t_{max} \leq 15$	$t_{max} \leq 15$
U/S	43/50	Not Mandatory	$t_{max} \leq 20$
	55	Not Mandatory	$t_{max} \leq 15$
Notation		MPI - Magnetic Particle Inspection (see Clause 5.5.3 of this Part) U/S - Ultrasonic Examination (see Clause 5.5.4 of this Part) < - Less than $\leq$ - Less than or equal to	

Table 5.1 (Continued)

Welds - Scope of Inspection

PART C	FREQUENCY OF TESTING OF JOINTS IDENTIFIED IN PART B		
Connection Zones	Shop Welds	First 5 identified joints of each type having same basic dimensions, material grades and weld geometry and welded to the same procedures . Thereafter 1 in 5 joints of each type ( if the first 5 have complied with Table 5.2 )	
	Site Welds	All identified joints	
Member Zones	Built up Members	Traverse butts in web and flange plates before assembly	As for shop welds in Connection Zones
		Transverse fillet welds at ends of cover plates	
		Longitudinal welds	0.5 m in each 10 m or part thereof
	Secondary Attachment Welds	e.g. for fixing purlins side rails, buckling stiffeners etc.	1 in 20 Attachments
Note :- 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 .			
<p><b>DEFINITION OF ZONES AND WELD ORIENTATIONS</b></p> <ul style="list-style-type: none"> <li><input checked="" type="checkbox"/> Connection zones - all welds transverse</li> <li><input type="checkbox"/> Member zones - welds transverse or longitudinal</li> </ul> <p>T = Transverse to Member Axis (any direction) L = Longitudinal (parallel to Member Axis)</p>			
Notation	MPI - Magnetic Particle Inspection (see Clause 5.5.3 of this Part) U/S - Ultrasonic Examination (see Clause 5.5.4 of this Part) < - Less than ≤ - Less than or equal to		

Table 5.2

Weld Quality Acceptance Criteria and Corrective Actions

PARAMETER	WELD TYPE	PARTICULAR CONDITIONS	ACCEPTANCE REQUIREMENTS (all dimensions in mm)		REMEDIAL ACTION FOR NON-CONFORMING WELDS (see Note 2)  Fig
			(see Note 1 and 5 )		
<b>WELD GEOMETRY</b>					
Location	All		As specified on drawings		Repair
Weld Type	All		As specified on drawings		Refer to Engineer
Length	All		$\geq$ As specified on drawings		Repair
<b>PROFILE</b>					
Throat	Butt		$t_b \geq$ As drawing (Av.50)	b,c	Repair
Thickness	Fillet		$t_f \geq$ As drawing (Av.50) $\leq$ As drawing + 5	a	Repair or grind and MPI after grinding
Leg Length	Fillet		$l_f \geq$ As drawing	a	Repair
Toe Angle	All		$\theta \geq 90^\circ$	a	Grind and MPI after grinding
Cap/Root Bead (Height or concavity)	Butt	Butt Joint	$-1 \leq C_b \leq 4$	b	Repair or grind
Misalignment	Butt	Butt Joint	$m \leq$ As drawing + 0.25t $\leq$ As drawing + 3	d	Refer to engineer
	All	Cruciform Joint	$m \leq$ As drawing + 0.50t and $\leq$ As drawing + 6	e	
<p>Notes:-</p> <ol style="list-style-type: none"> <li>Where there are two limits for one dimension both shall apply All limits are peak values unless indicated as average</li> <li>Where a repair is necessary an approved procedure must be used. 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.</li> <li>May be accepted up to the limits for slag lines if the joint is subjected to longitudinal shear only.</li> <li>All welds to the same procedure.</li> <li>Abbreviations: Av. 100 or Av.50 indicates the average value over 100mm or 50mm length <ul style="list-style-type: none"> <li><math>\geq</math> Equal or greater than</li> <li><math>\leq</math> Equal or less than</li> <li><math>\Sigma</math> Sum of</li> </ul> </li> </ol>					

Table 5.2 (Continued)

Weld Quality Acceptance Criteria and Corrective Actions

PARAMETER	WELD TYPE	PARTICULAR CONDITIONS	ACCEPTANCE REQUIREMENTS (all dimensions in mm)		REMEDIAL ACTION FOR NON-CONFORMING WELDS (see Note 2)
			(see Note 1 and 5 )	Fig	
			SURFACE DISCONTINUITIES		
Undercut	All	Longitudinal Weld	$U_1 + U_2 \leq 0.1t$ (Av.100) And $\leq 2$	D,e D,e	Repair
		Transverse Weld	$U_1 + U_2 \leq 0.05t$ (Av.100) And $\leq 1$	D,e D,e	
Root Penetration (lack of)	Single Sided	Longitudinal Weld	$r_p \leq As$ drawing+0.1t(Av.100) and $\leq As$ drawing +3	c	Repair and double scope of Ultrasonic inspection if root is inaccessible
	Butt	Transverse Weld	$r_p \leq As$ drawing+0.05t(Av.100) and $\leq As$ drawing +2	c	
Porosity	All	All Welds	$d \leq 3$	f	Repair
		Longitudinal Weld	$\sum d \leq 20$ in 100 (length)	f	
		Transverse Weld	$\sum d \leq 10$ in 100 (length)	f	
Lack of Fusion and Cracks	All		Not Permitted		Repair and increase MPI to 100% (Note 4)

Notes:-

6. Where there are two limits for one dimension both shall apply  
All limits are peak values unless indicated as average
7. Where a repair is necessary an approved procedure must be used. 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.
8. May be accepted up to the limits for slag lines if the joint is subjected to longitudinal shear only.
9. All welds to the same procedure.
10. Abbreviations: Av. 100 or Av.50 indicates the average value over 100mm or 50mm length
  - $\geq$  Equal or greater than
  - $\leq$  Equal or less than
  - $\Sigma$  Sum of

Table 5.2 (Continued)

Weld Quality Acceptance Criteria and Corrective Actions

PARAMETER	WELD TYPE	PARTICULAR CONDITIONS	ACCEPTANCE REQUIREMENTS (all dimensions in mm)		REMEDIAL ACTION FOR NON-CONFORMING WELDS (see Note 2)  (see Note 1 and 5 ) Fig
			(see Note 1 and 5 )	Fig	
<b>SUB-SURFACE DISCONTINUITIES</b>					
Slag Lines and Lack of Fusion/Root Penetration	All	All Welds	$h \leq 3 + \text{As drawing}$ $1 \leq 10$ if $h < 6$ $1 \geq 10$	e,g g g	Repair and double scope of U/S Inspection
		Longitudinal Weld	$\Sigma 1 \leq 6t$ in 200 (length)	g	
		Transverse Weld	$\Sigma 1 \leq 3t$ in 200 (length)	g	
Root Gap	Fillet or Partial Pen Butt	Tee, Cruciform, Corner and Lap Joints	$r_g \leq 2(\text{Av } 100)$ and $\leq 3$	a,e a,e	Repair and double scope of U/S Inspection
Cracks	All		Not permitted		Repair and increase U/S Inspection to 100%
Lamellar Tears	All	Tee, Cruciform, Corner and Lap Joints	Not Permitted ( Note 3)		Refer to Engineer and increase U/S Inspection to 100%

Notes:-

11. Where there are two limits for one dimension both shall apply  
All limits are peak values unless indicated as average
12. Where a repair is necessary an approved procedure must be used. 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.
13. May be accepted up to the limits for slag lines if the joint is subjected to longitudinal shear only.
14. All welds to the same procedure.
15. Abbreviations: Av. 100 or Av.50 indicates the average value over 100mm or 50mm length
  - $\geq$  Equal or greater than
  - $\leq$  Equal or less than
  - $\Sigma$  Sum of

Table 5.2 (Continued)

Weld Quality Acceptance Criteria and Corrective Actions

DIMENSIONAL SYMBOLS DEFINITION OF MEASUREMENTS	
(a)	
(b)	
(c)	
(d)	
(e)	
(f)	
(g)	
(h)	
Notes:-	
16. Where there are two limits for one dimension both shall apply All limits are peak values unless indicated as average	
17. Where a repair is necessary an approved procedure must be used. 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.	
18. May be accepted up to the limits for slag lines if the joint is subjected to longitudinal shear only.	
19. All welds to the same procedure.	
20. Abbreviations: Av. 100 or Av.50 indicates the average value over 100mm or 50mm length $\geq$ Equal or greater than $\leq$ Equal or less than $\Sigma$ Sum of	

END OF PART