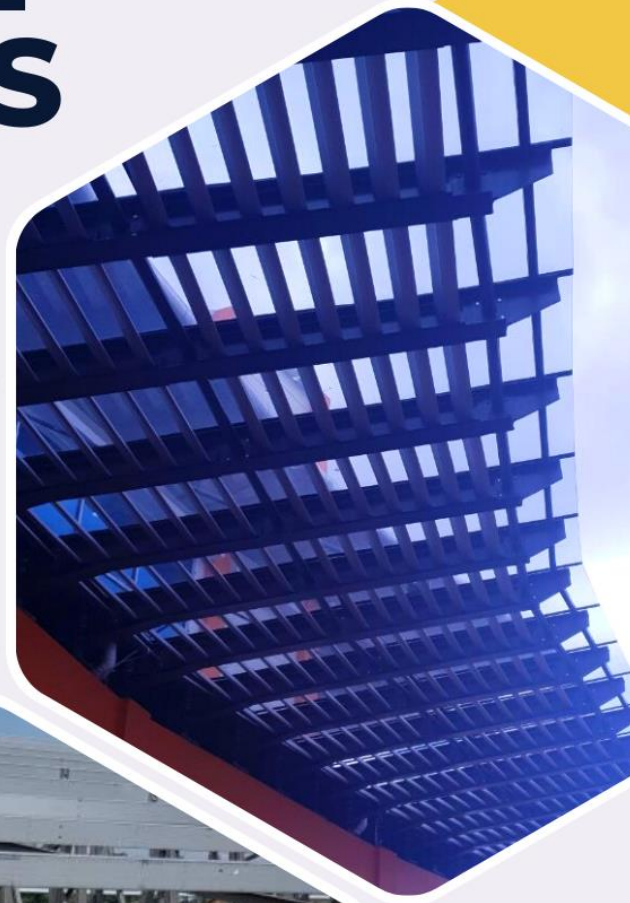




# SPECIFICATION FOR **STRUCTURAL STEELWORKS**





## TABLE OF CONTENTS

<b>FOREWORD .....</b>	<b>iv</b>
<b>SCOPE .....</b>	<b>v</b>
<b>DEFINITIONS .....</b>	<b>vi</b>
<b>ABBREVIATION .....</b>	<b>xiii</b>
<b>1.0 GENERAL .....</b>	<b>1</b>
<b>2.0 SAFETY AND HEALTH .....</b>	<b>1</b>
<b>3.0 QUALITY ASSURANCE .....</b>	<b>1</b>
3.1 Quality System .....	1
3.2 Inspections and Tests.....	2
3.3 Records .....	2
<b>4.0 MATERIALS.....</b>	<b>3</b>
4.1 General.....	3
4.2 Material Qualities.....	3
4.3 Material Testing .....	3
4.4 Mill Test Certificates .....	3
4.5 Dimensions and Tolerances .....	3
4.6 Surface Condition .....	4
4.7 Substitution of Material or Section Form of Component .....	4
4.8 Welding Consumables.....	4
4.9 Structural Fasteners .....	5
4.10 Shear Studs.....	7
4.11 Reinforcement steel bar .....	7
4.12 Protective Treatment Materials.....	8
4.13 Proprietary Items .....	8
<b>5.0 DRAWINGS.....</b>	<b>15</b>
5.1 General.....	15
5.2 General Arrangement of Components.....	15
5.3 Foundation and Steelwork Interface Connection Drawings .....	16
5.4 Shop Drawings .....	16
5.5 Drawing Approval or Information Review .....	19
5.6 As-built Drawings.....	20
<b>6.0 WORKMANSHIP – GENERAL .....</b>	<b>21</b>
6.1 Identification .....	21
6.2 Handling .....	22
6.3 Cutting And Shaping.....	22
6.4 Machining .....	23
6.5 Dressing .....	24

6.6	Holing.....	24
6.7	Assembly.....	26
6.8	Curving and Straightening.....	26
6.9	Inspection.....	27
6.10	Storage .....	28
<b>7.0</b>	<b>WORKMANSHIP – WELDING.....</b>	<b>30</b>
7.1	General .....	30
7.2	Welder Qualification .....	30
7.3	Welding Procedures Specification (WPS) .....	31
7.4	Assembly.....	33
7.5	Non-destructive Testing of Welds .....	35
7.6	Shear Stud Welding .....	43
7.7	Welding of Reinforcement Steel to Structural Steel .....	44
<b>8.0</b>	<b>WORKMANSHIP – BOLTING .....</b>	<b>53</b>
8.1	Ordinary (non-preloaded) Bolt Assemblies .....	53
8.2	Fit-up If Using Non-Preloaded Bolt Assemblies .....	56
8.3	Preloaded Bolt Assemblies .....	56
8.4	Fit-Up If Using Preloaded Bolts Assemblies.....	59
<b>9.0</b>	<b>WORKMANSHIP – ACCURACY OF FABRICATION.....</b>	<b>60</b>
9.1	Permitted Deviations .....	60
9.2	Permitted Deviations in Rolled Components after Fabrication (Including Structural Hollow Sections) .....	60
9.3	Permitted Deviations for Elements of Fabricated Members ( $\Delta$ ).....	62
9.4	Permitted Deviations in Plate Girder Sections ( $\Delta$ ).....	65
9.5	Permitted Deviation in Box Sections ( $\Delta$ ) .....	69
9.6	Permitted Deviations for Lattice Components ( $\Delta$ ) .....	71
<b>10.0</b>	<b>WORKMANSHIP – ERECTION .....</b>	<b>73</b>
10.1	General .....	73
10.2	Site Conditions .....	74
10.3	Safety .....	75
10.4	Stability .....	75
10.5	Erection Loads .....	76
10.6	Lining and Levelling .....	76
10.7	Site Welding.....	76
10.8	Site Bolting.....	76
10.9	Certification of Completion .....	77
<b>11.0</b>	<b>WORKMANSHIP – ACCURACY OF ERECTED STEELWORK .....</b>	<b>78</b>
11.1	Inspection of Foundation and Holding Down Bolt.....	78
11.2	Steelwork .....	78
11.3	Deviations .....	79

11.4	Information for Other Contractors .....	79
11.5	Permitted Deviations for Foundations, Walls and Foundation Bolts ...	79
11.6	Permitted Deviations of Erected Components .....	81
<b>12.0</b>	<b>PROTECTIVE TREATMENT (CORROSION AND FIRE).....</b>	<b>90</b>
12.1	General.....	90
12.2	Method Statement .....	90
12.3	Paint Systems.....	91
12.4	Intumescent Systems .....	92
12.5	Surface Preparation.....	94
12.6	Application And Inspection of Coatings .....	98
12.7	Coating of Surfaces to Be Encased in Concrete.....	105
12.8	Hot Dip Galvanising.....	105
12.9	Metal Spraying.....	109
<b>APPENDIX 1</b>	<b>.....</b>	<b>115</b>
	Appendix 1.1: List of Design Requirements.....	115
	Appendix 1.2: List of Workmanship Requirements.....	116
	Appendix 1.3: List of Erection Requirements.....	116
	Appendix 1.4: List of Protective Treatment Requirements .....	117
	Appendix 1.5: List of Construction Work Programme Requirements.....	117
<b>APPENDIX 2</b>	<b>.....</b>	<b>118</b>
	Technical Data Sheet of Proposed Fire Protection Material .....	118
<b>NORMATIVE REFERENCES</b>	<b>.....</b>	<b>119</b>
<b>ACKNOWLEDGEMENTS</b>	<b>.....</b>	<b>127</b>

## FOREWORD

This specification was revised from Specification for Structural Steelworks (JKR 20601-0191-12), which was adopted and adapted from the National Structural Steelwork Specification for Building Construction published by Steel Construction Institute U.K. for the purpose of advancing the design, manufacture and construction of the structural steel buildings in Public Works Department (PWD) projects.

The primary objective of this specification is to provide PWD engineers, consultants and contractors sufficient information on quality assurance, materials, workmanship, fabrication, erection, construction procedures and protective treatment in accordance with regulations, codes of practice and good engineering practices.

Users of this specification are encouraged to offer comments to *Pengarah Kanan, Cawangan Kejuruteraan Awam dan Struktur* on the contents of this publication and suggestions for improvements in the next edition.

## **SCOPE**

This specification covers structural steelwork designed in accordance with MS EN 1993.

It can be used for all types of building construction designed for static loading. It is not intended to be used for steelwork in bridges, offshore structures or other dynamically loaded structures unless appropriate amendments are made.

## DEFINITIONS

The following terms and definitions apply for the purpose of this Specification:

Certification Body	Government body (regulators)/ organisation accredited by Department of Standards Malaysia (DSM) for a sector and can provide compliance certificate. Certification Body are accredited according to ISO/IEC Guide 65.
Connection Design	The design of bolts, welds, cleats, plates and fittings required to provide an adequate load path between the end of a member and the component it connects to shall be prepared by the Contractor unless provided by the S.O.
Contractor	The company appointed to fabricate and/ or erect the structural steelwork. Where required, the Contractor may also be responsible for design.
Design Calculations	Calculations showing the design and analysis of the structure, including computer data sheets.
Design Drawings	Fully dimensioned drawings showing all members with their size and material grades, the forces to be developed in their connections, any cambers and eccentricities and other information necessary for the design of the connections and completion of Fabrication and Erection Drawings.
Erection Drawings	Drawings, prepared by the Contractor, showing details to amplify the information given in the Contractor's erection method statement and showing details of any temporary steelwork.
Fabricator	Company that use various techniques (shot blasting, cutting, bending, welding, coating, etc) to turn basic steel sections into predefined shapes, ready to be installed in construction.
Fabrication Data	Numerical control tapes, computer discs, data bases or other electronic means of communication for automatic methods of fabrication.
Fabrication Drawings	Drawings, prepared by the Contractor, showing all necessary information required to fabricate the structural steelwork.



Faying surface	One of the surfaces that are in contact at a joint. Faying surfaces may be connected to each other by bolts, adhesives or welding.
Fittings	Plates, flats or rolled sections which are welded or bolted to structural steel components.
Foundation Plan	Drawings indicating location of column bases, column service loads and details of foundation connections to the steelwork.
Fine Grain Steel	Fine Grain Steel have good formability, weldability and toughness. The formation of fine grain structure is due to the low-carbon content and micro-alloying elements. The mechanical properties such as yield strength, fatigue strength, tensile strength, hardness and impact strength will increase when the size of weldable fine grain structural steels is reduced.
General Arrangement Drawings	Drawings showing plans, cross sections and elevations, main dimensions and the erection marks of component.
Inspection Body	Government body (regulators), organisation or independent body accredited by Department of Standards Malaysia (DSM) which examine material, process or installation and determination of its conformity with specific requirements. Inspection Body is commissioned according to ISO/IEC 17020.
Inspection Report	Report of inspection issued by Inspection Body.
Manufacturer	Company that makes steel.
Non-Alloy Steel	Non-alloy steels use carbon as the alloying element. These steels do include other elements such as manganese, silicon, sulphur and phosphorus but the content of these elements is so low that they do not impact the material properties. Example wrought iron.
Ordinary Bolts	A bolt used in a non-preloaded bolt assembly which is designed to carry forces in shear, bearing or tension.

Product Standard	Normative standard which prescribed specification for a product.
Production Test Plate	A plate used for testing purposes, which is made of the same material and using the same procedures as the joint in a component.
Professional Engineer with Practicing Certificate (PEPC)	An appointed PEPC by the Contractor, who has a valid registration with the Board of Engineers Malaysia (BEM) and permitted to practice in the registered field. The PEPC is responsible for the structural design, reviewing and accepting the detail drawings and erection method statement.
Perakuan Pematuhan Standard (PPS)	Certificate issued by CIDB for a particular product that has complied with standard(s) specified by CIDB for regulatory purpose under Lembaga Pembangunan Industri Pembinaan Malaysia (Amendment of Fourth Schedule) Order 2021.
Quality Assurance	Activities concerned with the provision of systems, equipment and personnel necessary to achieve the required level of quality.
Site	The area defined within which the construction works will be conducted.
Sijil Kompetensi Kemahiran Pembinaan (SKKP)	Certificate issued by CIDB through a construction competency training and assessment program.
Supplier	Company that supply steel sections and other related steel products
Test Report	Report of test results issued by an accredited testing body containing the results of the test according to standard requirements.
The Works	As defined in the Contract Document but limited in the context of this document to the structural steelwork.
Workshop	A fabrication factory where all steel components are manufactured in a controlled environment.

Weathering Steel	Low carbon steels that have additional alloying elements mixed in with the carbon and iron atoms. The alloying elements give weathering steel better strength and more corrosion resistance than typical low carbon steel.
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### **Fire Protection:**

Primer	Interface coatings between the intumescent coating and the substrate.
--------	---

Intumescent coat	Coating which reacts under the influence of heat by swelling in a controlled manner to many times its original thickness and producing a layer of carbonaceous char or foam which acts as an insulating layer for the substrate.
------------------	--

Top sealer coat	Material applied to the surface of the intumescent coating as a protection against environmental degradation.
-----------------	---

Decorative coat	Material used for decorative purposes only.
-----------------	---

### **Material:**

HR (British/ French) Bolt	High resistance bolt.  Use thick nuts and long thread lengths in the bolt assembly to obtain ductility predominantly by plastic elongation of the bolt.
---------------------------	---

HRC Bolt	Tension control bolts which offer excellent clamping force and completion bolt fastening can be confirmed by the shear-off of the notched end of the bolt.
----------	--

HV (German) Bolt	Use thinner nuts and shorter thread lengths to obtain the ductility by plastic deformation of the threads within the nuts.
------------------	--

Galvanising	Process of immersing steel or iron in a bath of molten zinc to produce a corrosion resistant.
-------------	---

Mill test certificate	Chemical and mechanical features of a steel product and its compliance to code of practice and specification.
-----------------------	---

Sherardising	Process of galvanisation of ferrous metal surfaces, also known as vapour galvanising and dry galvanising. Rotating drum is used to vaporise the zinc which then clings to the steel. Sherardising is suitable for small parts, irregular shape and parts that require coating of inner surface.
--------------	---

**Welding:**

Capping runs	The process of applying a layer of weld metal to the entire weld joint using a welding rod.
--------------	---

Crater crack	Cracks occur when the welding operator stops welding prior to finishing a pass on a weld joint, leaving a wide, thin depression at the end.
--------------	---

Cold-lapping	Type of weld defect which occurs when molten metal does not completely fuse with the cold plate surface. This produces a crack like defect, often very small, which is parallel to the plate.
--------------	---

De-slagged	Removal of slag. Slag is a byproduct of arc welding processes. Slag is the solidified remaining flux after the weld area cools. Slag shall be removed to prepare the surface for the next layer of welding, coatings and visual appearance.
------------	---

Fillet Weld	A weld, other than a butt or edge weld, which is approximately triangular in transverse cross section and which is generally made without preparation of the parent material.
-------------	---

Full Penetration Weld	A weld between elements which may be in-line, in the form of a tee, or a corner in which the weld metal achieves full penetration throughout the joint thickness.
-----------------------	---

Full Strength Weld	Any of the above welds designed to develop the full strength of the element which it connects.
--------------------	--

Gouging	To remove defective or old welds through intense heat of an arc created between a carbon electrode and workpiece.
NDT Level 2	A qualified person to set up and calibrate equipment, perform NDT, interpret and evaluate results as per codes, standards and specifications. Shall be familiar with technique limitations. Organise and report the results.
NDT Level 3	A qualified person to develop, qualify and approve procedures, establish techniques, interpreting codes, standards and specifications. Shall have sufficient practical background in materials, fabrication and product technology.
Partial Penetration Weld	A weld formed using a technique which ensures a specified penetration which is less than the depth of the joint.
Procedure Qualification Record (PQR)	Record of the actual weld test parameters used and is used to produce WPS sheets for production welds. PQR document is created first and is needed to create WPS.
Responsible Welding Coordinator (RWC)	A person who control and supervise all welding activities and ensure the steel structures meet the adequate levels of mechanical resistance, stability, serviceability and durability.
Stray arcs	Local damage to the surface of the parent metal adjacent to the weld resulting from arcing or striking the arc outside the weld groove.
Visual Inspector	A person who examine every weld to ensure the quality and safety.
Welder	A person who performs manual or semi-automatic welding.
Welding Operator	A person who operates adaptive control, automatic, mechanised or robotic equipment.

Welding Procedure Qualification Record (WPQR)	Document of inspection and test results that qualifies the Welding Procedure Specification.
---	---

Welding Procedure Specification (WPS)	Formal written document describing welding procedures, which provides the welder or welding operators for making sound and quality production welds as per the code requirements.
---------------------------------------	---

**Workmanship:**

Drifting	Operation of forming or enlarging a hole by use of tapered punch. Normally punches are used first to drive a hole through the metal being forged followed by a drift.
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Reaming	Cutting process that involves the use of rotary cutting tool to create smooth interior walls in an existing hole in a workpiece. The rotary cutting tool used in reaming is reamer.
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Punching	Cutting process in which material is removed from a piece of sheet metal or plate by applying high shearing force. Hole punching uses hardened tools with sharp edges and an applied force to shear out the unwanted material.
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Slotted Holes	Slotted holes are used in bolted connections of steel structures to compensate for tolerances during the erection to allow one type of endplate for more connected members and to enable a slip.
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## ABBREVIATION

ASTM	American Society for Testing and Materials
ASFP	Association for Specialist Fire Protection
AWS	American Welding Society
BCSA	British Constructional Steelwork Association
BIM	Building Information Modelling
CD	Compact Disc
CJP	Complete Joint Penetration
CIDB	Construction Industry Development Board
CIS	Construction Industry Standard
DAC	Distance Amplitude Curve
DFT	Dry Film Thickness
DOSH	Department of Occupational Safety and Health
DSM	Department of Standards Malaysia
EN	European Standard/ European Norm
FMA	Factories and Machineries Act
ISO	International Organization for Standardization
ITP	Inspection and Test Plan
JBPM	Jabatan Bomba dan Penyelamat Malaysia
MAG	Metal Active Gas Welding
MIG	Metal Inert Gas Welding
MMA	Manual Metal Arc Welding
MT	Magnetic Testing
NDT	Non-Destructive Test
NSSS	National Structural Steelwork Specification for Building Construction
OSHA	Occupational, Safety and Health Act
PPS	Perakuan Pamatuhan Standard
PEPC	Professional Engineer with Practicing Certificate
PGI	Post Galvanised Inspection
PT	Penetrant Testing
WPS	Welding Procedure Specification
PQR	Procedure Qualification Record
RT	Radiography Testing
RWC	Responsible Welding Coordinator
SIRIM	Standard and Industrial Research Institute of Malaysia
SKKP	Sijil Kompetensi Kemahiran Pembinaan
S.O.	Superintending Officer
SS	Steel Shot
UT	Ultrasound Testing
VI	Visual Inspection
WQT	Welder Qualification Test





## **1.0 GENERAL**

- 1.1** All materials shall conform to the latest Malaysian Standard, European Standards, British Standards or any relevant international standards with the approval of the S.O.
- 1.2** In the event where the Contractor is required to provide the design, the Contractor shall engage an approved structural steelwork fabricator to design any structural member/ truss, connection, temporary support system and other associated works. The design responsibilities shall be borne by the Contractor.
- 1.3** The list given in Appendix 1 set out the information to be shown on the drawings or given by the Contractor.

## **2.0 SAFETY AND HEALTH**

The Contractor or the Steelwork Sub Contractor carrying out the Works shall comply with all relevant regulations given in the Factories and Machinery Act 1967 (Act 139) and Occupational Safety and Health Act 1994 (Act 514).

## **3.0 QUALITY ASSURANCE**

### **3.1 Quality System**

#### **3.1.1 System Requirements**

The Contractor shall have a management system to ensure that his responsibilities for design, detailing, fabrication and erection of steel components and structures conform to the requirements of the Contract and this Specification.

#### **3.1.2 Scope**

The system shall cover all procedures including:

- i) Project management and planning;
- ii) Design control;
- iii) Documentation control;
- iv) Material purchasing;
- v) Detail drawing preparation;
- vi) Fabrication;
- vii) Inspection and testing;
- viii) Surface preparation and protective treatment;

- ix) Erection;
- x) Safety and health;
- xi) Records.

#### 3.1.3 System Acceptance

The system shall be open to audit by the S.O. or registered by an approved certified body such as SIRIM for compliance with Quality Management ISO 9000 certification.

### **3.2 Inspections and Tests**

The Contractor shall provide the necessary facilities for any inspections and tests as requested by the S.O.

### **3.3 Records**

All records related to the Works shall be available for the S.O. to examine during the contract period.

## **4.0 MATERIALS**

### **4.1 General**

All steel products shall be procured from the manufacturer or supplier with *Perakuan Pematuhan Standard* (PPS) from Construction Industry Development Board (CIDB) as per Amendment of Fourth Schedule of Act 520, CIDB.

### **4.2 Material Qualities**

4.2.1 Material shall be steel in ROLLED SECTION, STRUCTURAL HOLLOW SECTIONS, PLATES or BARS and shall comply with the appropriate standards shown in Table 4.1 and Table 4.2.

4.2.2 Materials not covered by the standards listed in Table 4.1 shall have their properties specified. The relevant properties shall be those given in Clause 5.1 of BS EN 1090-2 or any relevant international standards with the approval of the S.O.

4.2.3 Materials suitable for cold forming shall comply with the appropriate standards shown in Table 3: Product Standards for Sheet and Strip Suitable for Cold Forming of BS EN 1090-2 or any relevant international standards with the approval of the S.O. Stainless steel products shall comply with the appropriate standards shown in Table 4: Product Standards for Stainless Steels of BS EN 1090-2 or any relevant international standards with the approval of the S.O.

4.2.4 Materials for use in the manufacture of structural profiled sheeting shall conform to the appropriate standards listed in Table 1 of BS EN 1090-4 or any relevant international standards with the approval of the S.O.

### **4.3 Material Testing**

All steel shall have been specifically tested in accordance with the appropriate material quality product standard shown in Table 4.1.

### **4.4 Mill Test Certificates**

The Contractor shall obtain the manufacturer's Mill Test Certificates and submit to the S.O. before any structural steel can be approved.

### **4.5 Dimensions and Tolerances**

Dimensions and tolerances shall comply with the appropriate standards shown in Table 4.1.

## 4.6 Surface Condition

- 4.6.1 Steel surface when used shall not be more heavily pitted or rusted than Grade C of BS EN ISO 8501-1.

*Note:*

*Rust Grade C – Steel surface on which the mill scale has rusted away or from which it can be scrapped but with little pitting visible to the naked eyes.*

- 4.6.2 Surface defects in hot rolled sections, plates and wide flats revealed during surface preparation which are not in accordance with the requirements of BS EN 10163-1 shall be rectified accordingly. Plates and wide flats shall meet class A2 of BS EN 10163-2. Sections shall meet class C1 of BS EN 10163-3.

- 4.6.3 Surface defects in hot rolled hollow and cold formed hollow sections revealed during surface preparation which are not in accordance with the requirements of BS EN 10160 shall be rectified accordingly.

## 4.7 Substitution of Material or Section Form of Component

Material quality or section form of components may, with the approval of the S.O. be substituted if it can be demonstrated that the structural properties are not less suitable than the designed component and compatible with the original design intent.

## 4.8 Welding Consumables

### 4.8.1 Standards

- 4.8.1.1 Consumables for use in metal arc welding shall comply with MS ISO 14171, BS EN ISO 2560, BS EN ISO 14341, BS EN 14174 or BS EN ISO 17632 as appropriate.
- 4.8.1.2 The yield strength, tensile strength and minimum elongation of a weld should be taken as equal to respectively the minimum yield strength  $R_{eL}$  or  $R_{p0.2}$ , and tensile strength  $R_M$  and minimum percentage elongation on a five diameter gauge length to the product standard (Table 4.9).
- 4.8.1.3 Consumables used for completing welding of steels to BS EN 10025-5 shall have a weather resistance at least equivalent to the parent metal. The options given in Table 6: Welding Consumables to Be Used with Steels According to EN 10025-5 of BS EN 1090-2 may be used. Alternatively, Carbon-Manganese (C-Mn) consumables may be used for the body of the weld with capping runs for the surface layers using a suitable consumable with improved atmospheric corrosion resistance.

#### 4.8.2 Storage and Handling

The welding consumables to be stored, handled and used shall be in accordance with BS EN 1011-1 and manufacturer's recommendations. Welding consumables showing signs of damage or deterioration shall be discarded.

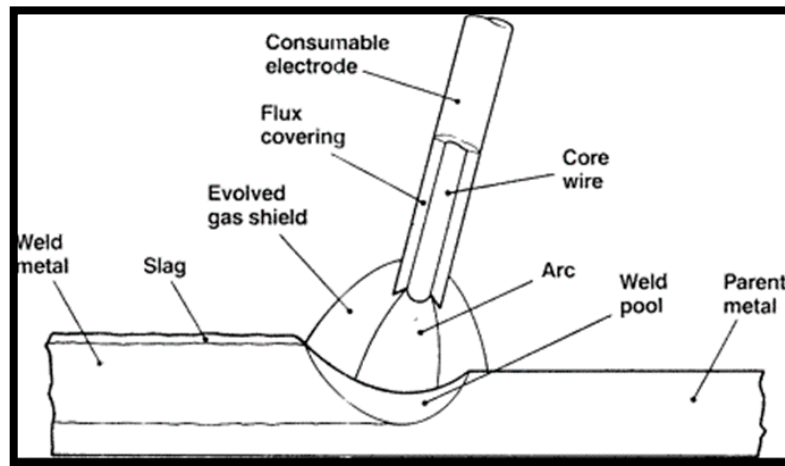


Figure 4.1: Welding consumables

### 4.9 Structural Fasteners

#### 4.9.1 Ordinary (non-preloaded) Bolts Assemblies

Ordinary bolt and nut (and washer if used) assemblies for use without preloading shall conform to the requirements of BS EN 15048-1 and Table 4.3. The preloaded bolt assemblies in Table 4.4 may also be used without preloading in non-preloaded applications. Ordinary tie bar assemblies and matching ordinary tie bar assemblies shall conform to the requirements in Tables 4.5 and 4.6 respectively.

#### 4.9.2 Preloaded Bolts Assemblies

4.9.2.1 Preloaded HR/HRC bolt assemblies shall be as given in Table 4.4.

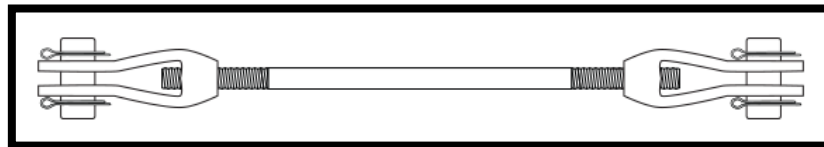
4.9.2.2 Preloaded HV assemblies to BS EN 14399-4 or BS EN 14399-8 with complete specification may be used if stated in the drawings.

4.9.2.3 Bolts and nuts from the two different systems (HR and HV, in accordance with parts 3 and 4 of BS EN 14399, respectively) shall not be mixed.

- 4.9.2.4 Plain washers to BS EN 14399-5 and/or plain chamfered washers to BS EN 14399-6 may be used as given in Table 4.4

#### 4.9.3 Tie Bar Assemblies

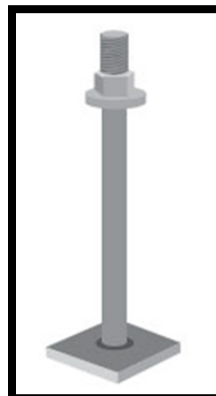
Ordinary tie bar assemblies shall be as given in Table 4.5. Tie bar assemblies are threaded bars supplied with nuts and, if required, washers, and are suitable for non-preloaded applications. Recommended bolt and nut combinations are given in Table 4.6.



*Figure 4.2: Tie bar assemblies*

#### 4.9.4 Holding Down Bolts

Holding down bolt assemblies shall be as given in Table 4.7, see 5.4.8 for additional washers to holding down bolt assemblies.



*Figure 4.3: Foundation/ holding down bolts*

#### 4.9.5 Cup and Countersunk Bolts

Cup and countersunk bolts for use in non-preloaded applications shall be as given in Table 4.8.

*Note: Countersunk bolts are used when a smooth surface is required. Common applications include walkways and decking.*



*Figure 4.4: Cup and countersunk bolt*

#### 4.9.6 Washers

Metal washers shall be as given in Table 4.3 or Table 4.4.

#### 4.9.7 Lock Nuts for Bolt Assemblies

Lock nuts used with ordinary bolt assemblies shall be in accordance with BS EN ISO 4035 or BS EN ISO 4036.

*Note: Lock nuts are used to prevent the loosening of components due to vibration and rotation.*



*Figure 4.5: Nylon lock nut*

#### 4.9.8 Fastener Coatings

If specific coatings are required, they shall be provided by the fastener manufacturer and shall comply with the appropriate part of BS 7371, BS EN ISO 4042 (electroplating) or BS EN ISO 10684 (hot dip galvanising).

### 4.10 Shear Studs

4.10.1 Shear studs shall be in accordance with BS EN ISO 13918. Shear studs that do not conform to BS EN ISO 13918 shall be treated as special fasteners to BS EN 1090-2.

4.10.2 Proprietary studs used in composite construction shall be the headed type with the following properties after being formed:

- i) Minimum yield strength of 350N/mm<sup>2</sup>;
- ii) Minimum ultimate tensile strength of 450N/mm<sup>2</sup>;
- iii) Elongation of 15% on a gauge length of  $5.65 \sqrt{A}$ , where A is the area of the test specimen.

### 4.11 Reinforcement steel bar

4.11.1 Reinforcement steel bars to be welded to structural steels shall be suitable for welding according to MS EN 10080.

## 4.12 Protective Treatment Materials

### 4.12.1 Metallic Blast Cleaning Abrasives

Details are given in Section 12 for blast cleaning requirements.

### 4.12.2 Surface Coatings

Paint materials and other coatings supplied shall be in accordance with the relevant British Standard. Details are given in Section 12 for paint requirements.

### 4.12.3 Sherardised Coatings

Sherardised coatings shall be in accordance with BS 7371-8.

### 4.12.4 Galvanizing Materials

The composition of zinc in galvanizing baths shall be in accordance with ISO 1461 and, unless agreed otherwise, the following percentage weight limits:

- i) Tin (Sn) not greater than 0.1%;
- ii) Lead (Pb) +10 x Bismuth (Bi) not greater than 1.5%.

*Note: The galvanizer should measure and record the composition of the zinc in the bath. Guidance on design of steel articles being sent for hot dip galvanizing is set out in BS EN ISO 14713-2.*

## 4.13 Proprietary Items

4.13.1 All proprietary items shall be used in accordance with the manufacturer's recommendations and instructions.

4.13.2 Proprietary items include connectors, couplers and turnbuckles.



TABLE 4.1 - MATERIAL & DIMENSION STANDARDS					
Form	Steel Material Quality			Dimensions	Tolerances on Shape and Dimensions
	Non-alloy	Fine grain	Weathering Steel		
Universal Beams & Columns	MS EN 10025-2	MS EN 10025-3 or MS EN 10025-4	MS EN 10025-5	BS EN 10365	BS EN 10034
Joists				BS EN 10365	BS EN 10024
Channels				BS EN 10365	BS EN 10279
Angles				BS EN 10056-1	BS EN 10056-2
Plates (Reversing Mill) (1)				BS EN 10029	
Plates (Cut from Coil) (1)				BS EN 10051	
Wide Flats				ISO 9034	
Hollow Sections (Hot Finished) (2)	MS EN 10210-1		BS 7668	MS EN 10210-2	
Hollow Sections (Cold Formed) (2)	MS EN 10219-1		-	MS EN 10219-2	
Galvanized Open Sections & Strip	BS EN 10346			Not applicable	BS EN 10143
Notes: 1. The scope of BS EN 10029 covers plates of 3mm up to 250mm rolled in a reversing mill process, whereas BS EN 10051 covers plates up to 25mm de-coiled from continuously hot-rolled uncoated flat products. 2. Except if cold formed hollow sections to MS EN 10219-1 are specifically identified on drawings, hollow sections are to be hot finished to MS EN 10210-1 or BS 7668. 3. Any relevant international standards may also be used with approval from the S.O.					

<b>TABLE 4.2 – STEEL GRADE</b>
MS EN 10025
S275
S355
S460

<b>TABLE 4.3 MATCHING ORDINARY (NON-PRELOADED) ASSEMBLIES</b>			
<b>Property class</b>	<b>Bolt</b>	<b>Nut <sup>(1)</sup></b>	<b>Washer</b>
<b>Incorporating full threaded length bolts</b>			
4.6	BS EN ISO 4018	BS EN ISO 4034 (property class 5) <sup>(3)</sup>	BS EN ISO 7091 (100HV)
8.8	BS EN ISO 4017 <sup>(2)</sup>	BS EN ISO 4032 <sup>(2)</sup> (property class 8) <sup>(3)</sup>	BS EN ISO 7091 (100HV)
10.9	BS EN ISO 4017 <sup>(2)</sup>	BS EN ISO 4032 <sup>(2)</sup> (property class 10) <sup>(3) (4)</sup>	BS EN ISO 7091 (100HV)
<b>Incorporating part threaded length bolts</b>			
4.6	BS EN ISO 4016	BS EN ISO 4034 (property class 5) <sup>(3)</sup>	BS EN ISO 7091 (100HV)
8.8	BS EN ISO 4014 <sup>(2)</sup>	BS EN ISO 4032 <sup>(2)</sup> (property class 8) <sup>(3)</sup>	BS EN ISO 7091 (100HV)
10.9	BS EN ISO 4014 <sup>(2)</sup>	BS EN ISO 4032 <sup>(2)</sup> (property class 10) <sup>(3) (4)</sup>	BS EN ISO 7091 (100HV)
<ol style="list-style-type: none"> <li>1. Nuts of a higher property class may also be used.</li> <li>2. Bolts of property classes 8.8 and 10.9 to BS EN ISO 4014 or BS EN ISO 4017 (dimensions and tolerances of BS EN ISO 4016 or BS EN ISO 4018) may also be used, with matching nuts of the same property classes to BS EN ISO 4032 (dimensions and tolerances of BS EN ISO 4034).</li> <li>3. Nuts for galvanised or sherardised bolts shall be tapped over-size to tolerance 6AZ to accommodate the thickness of galvanising/sherardising. This over-tapping reduces the strength of the nut and therefore a nut that has a proof load higher than the minimum ultimate tensile load of the assembly shall be used. Nuts for galvanised or sherardised 4.6 bolts shall be property class 8; nuts for galvanised or sherardized 8.8 bolts shall be property class 10 and nuts for galvanised or sherardised 10.9 bolts shall be property class 12 to BS EN ISO 4033.</li> <li>4. The BS EN ISO 4033 nut standard does not include sizes M22, M27, M33 or sizes greater than M36. It is therefore not possible to supply assemblies in these diameters which comply with this Specification for property class 10.9 in the hot dip galvanised or sherardised condition.</li> <li>5. Any relevant international standards may also be used with approval from the S.O.</li> </ol>			

TABLE 4.4 MATCHING PRELOADED ASSEMBLIES			
	System HR		System HRC
	Hexagon bolt	Countersunk bolt	HRC bolt <sup>(3)</sup>
<b>Bolt/nut assembly</b>	BS EN 14399-3	BS EN 14399-7	BS EN 14399-10
Bolt marking	HR	HR	HRC
Nut marking	HR	HR	HR or HRD
Property classes	8.8/8; 8.8/10 or 10.9/10	8.8/8; 8.8/10 or 10.9/10	10.9/10
<b>Washers</b>	BS EN 14399-5 or BS EN 14399-6		
Washer marking	H		
DTI <sup>(4)</sup> , nut and bolt face washers	BS EN 14399-9		At user's discretion
DTI marking <sup>(4)</sup>	H8 or H10		
Nut face washer marking	HN		
Bolt face washer marking	HB	Not applicable	
<div>1. In terms of suitability for preloading, fasteners shall meet the test requirements of BS EN 14399-2 and any additional testing specified in the product standard.</div> <div>2. Bolt lengths shall be selected to ensure that a minimum number of four full threads (in addition to the thread run-out) remain clear between the bearing surface of the nut and the unthreaded part of the shank.</div> <div>3. Commonly known as a “tension control bolt”. BS EN 14399-10 system HRC assemblies with calibrated preload depend on accurate control of the torque-tension characteristics to achieve the specified axial tensile loads as with other torque methods.</div> <div>4. DTI = Direct Tension Indicator.</div> <div>5. HR = High Resistance Bolt.</div> <div>6. Any relevant international standards may also be used with approval from the S.O.</div>			

<b>TABLE 4.5 ORDINARY TIE BAR ASSEMBLIES</b>		
<b>Element / Parameter</b>		<b>Conformance Criteria</b>
Thread	Tolerance Class	6g or 8g <sup>(1)</sup>
	Standards	BS 3643-1 and BS 3643-2
Mechanical properties	Property classes	$d \leq 39\text{mm}$ : 4.6, 8.8, 10.9
	Standard	BS EN ISO 898-1
Tolerance	Product grade	C <sup>(2)</sup>
	Standard	BS EN ISO 4759-1
Associated nuts BS EN ISO 4033 <sup>(3)</sup>	Standards	BS EN ISO 4032, BS EN ISO 4033 and BS EN ISO 4034 <sup>(3)</sup>
	Property classes	5, 8, 10, 12 <sup>(3)</sup>
	Standard	BS EN ISO 898-2
	Thread Tolerance	6H, 7H or 6AZ
	Standards	BS 3643-2 or BS ISO 965-5
Associated washers (if required)	Standards	BS EN ISO 7091
	Alternative washers	To be agreed <sup>(4)</sup>
Suitability test	Standard	BS EN 15048-2
<p>1. The tolerance class is the option of the manufacturer, depending on the manufacturing method, and applies before hot dip galvanising or coating with any thick protective coating.</p> <p>2. Recommended bolt and nut combinations are shown in Table 4.6.</p> <p>3. Any relevant international standards may also be used with approval from the S.O.</p>		

<b>TABLE 4.6 MATCHING ORDINARY TIE BAR ASSEMBLIES</b>		
<b>Property class Tie Bar</b>	<b>Nut (1)</b>	<b>Washer (if required)</b>
4.6	BS EN ISO 4032 <sup>(2)</sup> (property class 5) <sup>(3)</sup>	BS EN ISO 7091 (100HV) <sup>(5)</sup>
8.8	BS EN ISO 4032 <sup>(2)</sup> (property class 8) <sup>(3) (4)</sup>	BS EN ISO 7091 (100HV) <sup>(5)</sup>
10.9	BS EN ISO 4032 <sup>(2)</sup> (property class 10) <sup>(3) (4)</sup>	BS EN ISO 7091 (100HV) <sup>(5)</sup>
<ol style="list-style-type: none"> <li>1. Nuts of a higher property class may also be used.</li> <li>2. Nuts of property classes to BS EN ISO 4032 with the dimensions and tolerances of BS EN ISO 4034 may also be used.</li> <li>3. Nuts for galvanised or sherardised tie bars shall be tapped over-size to tolerance 6AZ to accommodate the thickness of galvanising/sherardising. This over-tapping reduces the strength of the nut and therefore a nut that has a proof load higher than the minimum ultimate tensile load of the assembly shall be used. Nuts for galvanised or sherardised 4.6 tie bars shall be property class 8; nuts for galvanised or sherardised 8.8 tie bars shall be property class 10 and nuts for galvanised or sherardised 10.9 tie bars shall be property class 12 to BS EN ISO 4033.</li> <li>4. The BS EN ISO 4033 nut standard does not include sizes M22, M27, M33 or sizes greater than M36; it is therefore not possible to supply assemblies in these diameters which comply with the Model Specification for the Purchase of Structural Bolting Assemblies and Holding Down Bolts for property class 10.9 in the hot dip galvanised or sherardised condition.</li> <li>5. Any relevant international standards may also be used with approval from the S.O.</li> </ol>		

<b>TABLE 4.7 HOLDING DOWN ASSEMBLIES</b>			
<b>Property class</b>	<b>Bolt</b>	<b>Nut <sup>(1)</sup></b>	<b>Washer <sup>(4)</sup></b>
4.6	BS 7419	BS EN ISO 4032 <sup>(2)</sup> (property class 5) <sup>(3)</sup>	BS EN ISO 7091 (100HV)
8.8	BS 7419	BS EN ISO 4032 <sup>(2)</sup> (property class 8) <sup>(3)</sup>	BS EN ISO 7091 (100HV)
<ol style="list-style-type: none"> <li>1. Nuts of a higher property class may also be used.</li> <li>2. Nuts of property classes to BS EN ISO 4032 with dimensions and tolerances of BS EN ISO 4034 may also be used.</li> <li>3. Nuts for galvanised or sherardised bolts shall be tapped over-size to tolerance 6AZ to accommodate the thickness of galvanising/sherardising. This over-tapping reduces the strength of the nut and therefore a nut that has a proof load higher than the minimum ultimate tensile load of the assembly shall be used. Nuts for galvanised or sherardised 4.6 bolts shall be property class 8 and nuts for galvanised or sherardised 8.8 bolts shall be property class 10.</li> <li>4. As an alternative BS 4320 form G may be used.</li> </ol>			

<b>TABLE 4.8 CUP AND COUNTERSUNK NON-PRELOADED ASSEMBLIES <sup>(1)</sup></b>			
<b>Property class</b>	<b>Bolt</b>	<b>Nut <sup>(2)</sup></b>	<b>Washer</b>
4.6	BS 4933	BS EN ISO 4032 <sup>(3)</sup> (property class 5) <sup>(4)</sup>	BS EN ISO 7091 (100HV)
8.8	BS 4933	BS EN ISO 4032 <sup>(3)</sup> (property class 8) <sup>(4)</sup>	BS EN ISO 7091 (100HV)
<ol style="list-style-type: none"> <li>1. Countersunk bolts subject to tensile loads, e.g., direct tension or prying, should only be supplied with a screwdriver slot head unless the alternative can be demonstrated to not adversely affect the bolt load ability to BS EN ISO 898-1 or BS EN 15048-2.</li> <li>2. Nuts of a higher property class may also be used.</li> <li>3. Nuts of property classes to BS EN ISO 4032 with dimensions and tolerances of BS EN ISO 4034 may also be used.</li> <li>4. Nuts for galvanised or sherardised bolts shall be tapped over-size to tolerance 6AZ to accommodate the thickness of galvanising/sherardising. This over-tapping reduces the strength of the nut and therefore a nut that has a proof load higher than the minimum ultimate tensile load of the assembly shall be used. Nuts for galvanised or sherardised 4.6 bolts shall be property class 8 and nuts for galvanised or sherardised 8.8 bolts shall be property class 10.</li> <li>5. Any relevant international standards may also be used with approval from the S.O.</li> </ol>			

<b>TABLE 4.9: THE YIELD STRENGTH, TENSILE STRENGTH AND MINIMUM ELONGATION</b>			
<b>Class</b>	<b>Yield Strength (N/mm<sup>2</sup>)</b>	<b>Tensile Strength (N/mm<sup>2</sup>)</b>	<b>Minimum Elongation (mm)</b>
35	355	440 to 570	22
38	380	470 to 600	20
42	420	500 to 640	20
46	460	530 to 680	20
50	500	560 to 720	18

## **5.0 DRAWINGS**

### **5.1 General**

#### **5.1.1 Standards**

- 5.1.1.1 All design, fabrication and erection drawings shall be made in accordance with BS EN ISO 4157-1.
- 5.1.1.2 Where welding symbols are used, they shall conform to BS EN ISO 2553.

#### **5.1.2 Revisions**

- 5.1.2.1 Revised drawings shall have a suffix letter added to the number and a description of the notes stating the changes that have been made and the date.
- 5.1.2.2 The drawing office system shall ensure that the revised drawings are issued and the earlier copies withdrawn or clearly marked "superseded".

### **5.2 General Arrangement of Components**

#### **5.2.1 Marking System**

- 5.2.1.1 Every component which is to be individually assembled or erected shall have an erection mark.
- 5.2.1.2 Components which are identical in all respects may have the same erection mark.
- 5.2.1.3 Components shall be marked with their erection or fabrication orientation if this is not clear from their shape.

#### **5.2.2 General Arrangement Drawings (Marking Plans)**

- 5.2.2.1 Drawings shall be prepared by the Contractor showing plans and elevations at a scale such that the erection marks for all members can be shown on them. Preferred scales are 1:100 or larger.
- 5.2.2.2 The drawings shall show the grid locations as indicated on the design drawings, main dimensions, member levels and centre lines. Details at an enlarged scale should also be made if these are necessary to show the assembly of components.

### **5.3 Foundation and Steelwork Interface Connection Drawings**

- 5.3.1 Foundation Plan Drawings shall show the base location, column service loads, position and orientation of columns, the marks of all columns, any other members in direct contact with the foundations, their base location and level, and the datum level.
- 5.3.2 The drawings shall show complete details of fixing steel or bolts to the foundations, method of adjustment and packing space.
- 5.3.3 Connections information shall also be provided for steel structure components connecting to other structure surfaces.

### **5.4 Shop Drawings**

The Contractor shall prepare Shop Drawings consist of Fabrication and Erection Drawings endorsed by PEPC and submit to the S.O. for approval.

#### **5.4.1 Fabrication Drawings**

Fabrication Drawings shall show all necessary details and dimensions to enable fabrication of components to proceed.

#### **5.4.2 Erection Drawings**

- 5.4.2.1 Erection Drawings shall show all assembly and method of installation of components.
- 5.4.2.2 Details and arrangements of temporary steelwork for erection purposes shall be shown in the Erection Drawings.

#### **5.4.3 Drawing Register**

A drawing register shall be made and used for the control and issue of drawings. It shall incorporate a system so that erection marks of the components can be readily identified with each drawing.

#### **5.4.4 Attachments to Facilitate Erection**

- 5.4.4.1 Details of holes and fittings necessary for safety or to provide lifting and erection aids shall be included. All lifting holes/ holes/ fitting whether temporary or permanent use, shall be designed accordingly to relevant code of practice.
- 5.4.4.2 All temporary works for erection or installation on-site or off-site should comply to requirement by Department of Occupational Safety & Health Malaysia (DOSH).



- 5.4.4.3 Unless specified otherwise, such holes and fittings shall be remained on the permanent structure. Account shall be taken of clause 7.4.5 when detailing the welding of temporary attachments.

#### 5.4.5 Welding

- 5.4.5.1 Any requirements for edge preparations for welds shall be indicated on the Fabrication Drawings.

- 5.4.5.2 Welding inspection requirements which differ from those specified in clause 7.5 shall be indicated on the drawings.

#### 5.4.6 Packings, Clearances and Camber

- 5.4.6.1 When preparing Fabrication Drawings, the Contractor shall make provision for:

- i) Packings which may be necessary to ensure proper fit-up of joints (see clauses 8.2.1 and 8.4.1).
- ii) The need for clearances between the fabricated components so that the permitted deviations in fabrication and erection are not exceeded, (see Sections 9 and 11).
- iii) The specified requirements for pre-set or cambers to be provided in fabrication so that continuous frames and other steelwork can be erected to the required geometry.

#### 5.4.7 Hole Sizes

- 5.4.7.1 Holes shall be shown on the Fabrication Drawings to the following sizes:

- i) For ordinary bolts and preloaded bolts:

Not exceeding 14mm diameter - 1mm greater than the nominal bolt diameter

From 16mm to 24mm diameter - 2mm greater than the nominal bolt diameter

Greater than 24mm diameter - 3mm greater than the nominal bolt diameter

ii) For holding down bolts:

6mm greater than the bolt diameter, but with sufficient clearance to ensure that a bolt, whose adjustment may cause it to be out of perpendicular, can be accommodated through the base plate (see clause 11.5.3).

iii) For fitted bolts: in accordance with clause 8.1.8.

#### 5.4.8 Holding Down Bolt Cover Plates

Holding down bolt details shall include provision of loose cover plates or washers with holes 3mm greater than the holding down bolts.

#### 5.4.9 Connections to Allow Movement

Where the connection is designed to allow movement, the bolt assembly used shall remain secure without impeding the movement.

#### 5.4.10 Machining Note

Any machining requirements shall be clearly indicated.

#### 5.4.11 Drilling Note

5.4.11.1 The Shop Drawings shall indicate those locations where holes shall be drilled as indicated in the drawings (see also clause 6.6.4):

- i) in non-slip connections for preloaded bolts;
- ii) at locations where plastic hinges are assumed in the design analysis;
- iii) in elements of rigid connections where yield lines are assumed;
- iv) where repetition of loading makes fatigue critical to the member design;
- v) where the design code of practice does not permit punched holes.

#### 5.4.12 Faying Surfaces for Friction Grip Connections

Faying surfaces which are to receive special treatment shall be identified in the drawing.

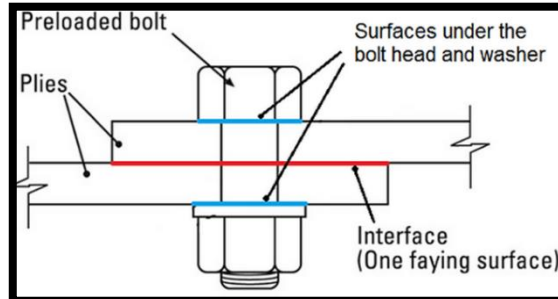


Figure 5.1: Faying surfaces for preloaded bolts

### 5.5 Drawing Approval or Information Review

#### 5.5.1 Approval by the S.O.

5.5.1.1 Drawings provided by the Contractor shall be submitted to the S.O. for approval in the period designated by the S.O.

5.5.1.2 S.O.'s approval does not relieve the Contractor of the responsibility for accuracy of his calculations, detail dimensions on the drawings, nor the general fit-up of parts to be assembled on site.

#### 5.5.2 Contractor's Drawings

Unless connections and other details are provided, the Contractor is required to design any structural member/ truss or temporary support system, the Contractor shall engage an approved structural steelwork fabricator to design such details and prepare fabrication drawings as mentioned in clause 4.5. The drawings shall be endorsed by PEPC.

#### 5.5.3 Contractor's Submission

5.5.3.1 Prior to fabrication, the Contractor shall submit the following documents and details for the S.O. approval:-

- (i) The design plan defining the allocation of design responsibilities, principal design activities in a logical sequence, target dates to meet the programme requirements, type of design output and a list of code of practice applied.

- (ii) Design documentation, production and checking procedures (verification).
- (iii) Fabricator's certification that the software used has been validated.
- (iv) Method Statement for handling and transportation requirements for unusually shaped or large components to ensure stability during movement.

#### 5.5.4 Acceptance of General Arrangement Drawings

The acceptance by the S.O. means the principle levels, dimensions, materials and typical details shown on the general arrangement drawings are a correct interpretation of design requirements when general arrangement drawings are issued for acceptance.

### 5.6 As-built Drawings

#### 5.6.1 General

On completion of the contract, the Contractor shall provide the S.O. with two (2) sets of paper prints and one (1) set of digital formats in CD or flash drive or external hard disk form as specified by the S.O. The as-built drawings which are endorsed by PEPC shall comprise:

- i) General Arrangement Drawings (.dwg and .pdf);
- ii) Other details drawings (.dwg and .pdf);
- iii) Shop Drawings (.pdf);

#### 5.6.2 Operation and Maintenance Manual

The Contractor shall provide operation and maintenance manual if required.

## 6.0 WORKMANSHIP – GENERAL

### 6.1 Identification

#### 6.1.1 Traceability of Steel Products

- 6.1.1.1 All constituent steel products to be used in The Works shall have a reference to a suitable material inspection certificate (test certificate) so that the properties are known and can be verified. Individual pieces do not need to be traceable to a particular inspection document, unless specified by the S.O.
- 6.1.1.2 If differing grades and/or sub-grades of constituent products are in circulation together, each item shall be designated with a mark that identifies its grade and its quality.
- 6.1.1.3 Partial traceability means nominally identical items do not need to be distinguished. Hence, backwards traceability is limited. This type of traceability can be achieved by carrying out a paper check of the order against the delivery note and a physical check of the steel sections and other products against the order when the steel sections and products are delivered.
- 6.1.1.4 Traceability through the workshop can then be achieved through a combination of shape and location within the workshop, i.e., serial size and weight can be obtained from the shape of the sections and the grade and job reference can be obtained by storing different grades in different locations. Alternatively, a colour coding or marking system can be used to distinguish between different grades, sub-grades, sections and projects/jobs.

#### 6.1.2 Material Grade Identification

The material grade and other relevant properties shall be identifiable within the manufacturing system.

#### 6.1.3 Marking Steelwork

- 6.1.3.1 Individual pieces shall be capable of positive identification at all stages of fabrication.

6.1.3.2 Completed components shall be marked with a durable and distinguishing erection mark in such a way as not to damage the material. Hard stamping may be used, except where otherwise specified by the PEPC.

6.1.3.3 Where areas of steelwork are indicated on the drawings as being unmarked, they shall be left free of all markings and hard stamping.

## 6.2 Handling

Steelwork shall be bundled, packed, handled and transported in a safe manner so that permanent distortion does not occur and surface damage is minimised. Particular care shall be taken to stiffen free ends and adequately protect any machined surfaces.

## 6.3 Cutting and Shaping

### 6.3.1 Cutting Operations

6.3.1.1 Cutting and shaping of steel may be carried out by sawing, shearing, cropping, thermal cutting, nibbling, planing, machining, disc cutting or water jetting. Hand-held cutting shall only be used if it is impractical to use machine thermal cutting.

*Note: Nibbling is a technique which involves punching out holes so the overlap. It is used to produce any kind of irregular contours or shapes.*

6.3.1.2 Any areas where thermal cutting is not permitted shall be indicated in the drawings.

*Note: Thermal cutting refers to plasma cutting, laser cutting or flame cutting.*

6.3.1.3 Specific requirements for quality of cut surfaces, hardness of free edge surfaces and tolerances on diameter, taper and burring of holes are given in BS EN 1090-2. It is recommended that the checking of process equipment capability is undertaken in liaison with the equipment manufacturer or supplier.

### 6.3.2 Thermally-cut Edges

6.3.2.1 The capability of the thermal cutting process used shall be checked according to BS EN 1090-2 for the quality and hardness of the cut surfaces that the process produces. This may be achieved by visually comparing the cut surface with that of the test sample described below.

- 6.3.2.2 A test sample shall be produced from the constituent product to be cut by the process and measurements taken to ensure that the quality of the cut surface of the test sample conforms with Range 5 as defined in BS EN ISO 9013 for perpendicular or angular tolerance,  $U$  and Range 4 as defined in BS EN ISO 9013 for mean height of the profile,  $Rz5$ .

*Note: Range 4 and Range 5 refer to perpendicularity tolerance of  $0.8 + 0.02a$  and  $1.2 + 0.035a$  respectively, where  $a$  is the sheet thickness in mm.*

- 6.3.2.3 Thermally-cut edges which are free from significant irregularities shall be accepted without further treatment except for the removal of dross; otherwise, cut edges that are not to be melted during subsequent welding shall have irregularities and the hardened surface material removed.
- 6.3.2.4 Thermally-cut re-entrant corners and notches, e.g., copes, shall be rounded off with a minimum radius of 5mm. Prior to galvanising, these locations shall be specifically inspected to verify conformity. Thermally cut edges for galvanising shall be in accordance with the requirements of BS EN ISO 14713-2.

### 6.3.3 Columns and Compression Members

- 6.3.3.1 Columns and compression members with ends not in direct bearing or intended to be erected on packs or shims shall be fabricated to the accuracy given in clause 9.2.2.
- 6.3.3.2 Columns and compression members intended to be in direct bearing shall be fabricated to the accuracy given in clause 9.2.3.
- 6.3.3.3 The butting surfaces of column sections which are one metre and over in width or depth and are to be in direct bearing, shall be specially prepared so that after erection both the deviation in plumb in 11.6.9 and the permitted gap in 11.6.10 are not exceeded.

## 6.4 Machining

### 6.4.1 Thickness of Machined Parts

The thickness of elements shown on the drawings as requiring machining shall be the minimum thickness after the machining operations.

## 6.5 Dressing

### 6.5.1 Removal of Burrs

Cut edges shall be dressed to remove dross, burrs and irregularities. Holes shall be dressed as required to remove burrs and protruding edges.

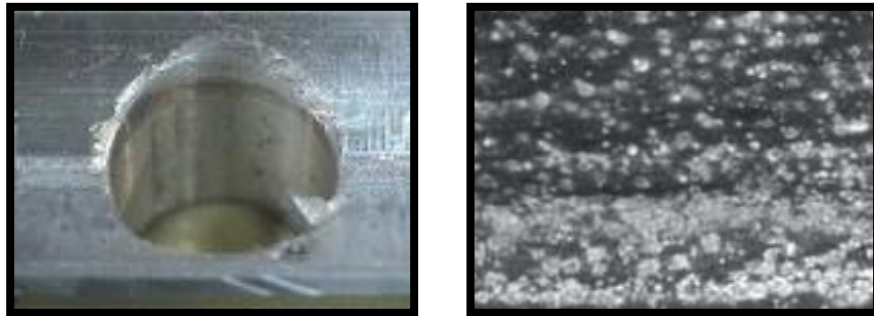


Figure 6.1: Burr and dross

### 6.5.2 Dressing of Edges

Sharp edges shall be dressed, but a 90° rolled, cut, sheared or machined edge is acceptable without further treatment.

## 6.6 Holing

### 6.6.1 Holes

- 6.6.1.1 Round holes for fasteners or pins shall be drilled, punched, plasma cut, laser cut or formed using other thermal cutting processes, see 6.6.5.

*Note: Pin is an unthreaded mechanical fastener which is designed to be inserted through preformed holes.*

- 6.6.1.2 Any areas on components where due to design requirements thermal cutting or full-size hole punching is not permitted shall be indicated in the drawings.
- 6.6.1.3 The capability of holing processes shall be checked annually in accordance with BS EN 1090-2.
- 6.6.1.4 Specific requirements for quality of cut surfaces, hardness of free edge surfaces and tolerances on diameter, taper and burring of holes are given in BS EN 1090-2. It is recommended that the checking of process equipment capability is undertaken in liaison with the equipment manufacturer or supplier.



### 6.6.2 Matching

All matching holes for fasteners or pins shall register with each other so that fasteners can be inserted without undue force through the assembled members in a direction at right angles to the faces in contact. Drifts may be used but holes shall not be distorted.

### 6.6.3 Drilling Through More Than One Thickness

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

### 6.6.4 Punching Full Size

6.6.4.1 Provided that the capability of the punching process used has been checked according to BS EN 1090-2, full size punching of holes shall be permitted unless otherwise specified in the drawings. The diameter of punched holes shall be limited to the nominal thickness of the component being punched or for a non-circular hole, its minimum dimension (see clause 9.3.5).

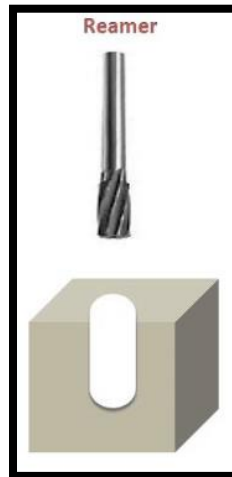
6.6.4.2 Any areas on components where holes are not to be punched full size shall be indicated in the drawings.

### 6.6.5 Punching and Reaming

6.6.5.1 Punching is permitted without the conditions in clause 6.6.4, provided that the holes are punched at least 2mm less in diameter than the required size, and the hole is reamed to the full diameter after punching.

6.6.5.2 Holes for fitted bolts or pins shall be punched at least 3mm less in diameter than the required size, and the hole reamed to the full diameter after punching.

*Note: Reaming is a cutting process in which a cutting tool produces a hole with very accurate size.*



*Figure 6.2: Reaming for finishing hole*

#### 6.6.6 Slotted Holes

6.6.6.1 Slotted holes shall be made by one of the following methods:

- (i) punched in one operation;
- (ii) formed by drilling two holes and completed by cutting;
- (iii) machine operated thermal cutting.

#### 6.6.7 Holes Details

Details of cut-outs, holes or fittings required for use must be indicated by the Contractor.

### 6.7 Assembly

6.7.1 Connected components shall be drawn together such that they achieve firm contact consistent with the requirements for fit-up or direct bearing, see 6.3.3, 7.4.1, 8.2.1 and 8.4.1.

6.7.2 Drifting of holes to align the components shall be permitted but must not cause damage or distortion to the final assembly (see clause 8.2.2).

### 6.8 Curving and Straightening

6.8.1 Curving or straightening components during fabrication shall be performed according to Clause 6.5 of BS EN 1090-2:2018 using one of the following methods:

- i) Mechanical means, taking care to minimise indentations, or change of cross- section;

- 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 if the procedure used includes careful temperature control and the procedure is validated beforehand in terms of its ability to retain suitable properties for the as-bent material.

6.8.2 The following restrictions shall be observed:

- i) For steel grades up to and including S355 hot forming shall take place in the heat range 600°C to 650°C and the temperature, timing and cooling shall be appropriate for the particular type of steel;
- ii) For steel grades up to and including S355 bending and forming in the heat range 250°C to 380°C is not permitted;
- iii) For steel grades S420 and S460 to BS EN 10025-3, the hot forming process shall take place in the temperature range 960°C to 750°C with subsequent cooling at air temperature;
- iv) Hot forming is not permitted for steels to BS EN 10025-4;
- v) Shaping by cold forming, produced either by roll forming, pressing or folding shall conform to the requirements for cold formability given in the relevant product standard;
- vi) Hammering shall not be used.

6.8.3 After curving or straightening, welds within the area of curving or straightening shall be visually inspected, see 7.5.3.4 Welds which are to be subject to NDT shall have these tests carried out before and after curving or straightening.

## 6.9 Inspection

All components shall be checked for dimensional accuracy and conformity to drawing to prove that the manufacturing process is working satisfactorily.

## 6.10 Storage

### 6.10.1 Stacking

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

### 6.10.2 Visible Markings

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

### 6.10.3 Accuracy

6.10.3.1 Deviations in an entire building frame and the members used to connect other building elements to the frame can be a combination of mill (source), fabrication and erection deviations.

6.10.3.2 The permitted deviations of source elements shall be in accordance with the appropriate material and dimension standards given in Table 4.1. Section 9 defines the permitted deviations during fabrication and Section 11 defines the permitted deviations during erection.

6.10.3.3 Permitted deviations are additive but with an overall requirement that the accumulated sum of the discrete deviations shall not be greater than the permitted deviations for the total structure defined in 11.6.4, 11.6.5, 11.6.6, 11.6.7, 11.6.8 and 11.6.14.

6.10.3.4 The procedure to calculate the accumulated sum of the discrete deviations ( $\Delta_{\text{sum}}$ ) arising from several independent sources of deviation is to calculate the 'Root-Sum-of-Squares' (RSS):

$$\Delta_{\text{sum}} = \sqrt{\Delta_{12}^2 + \Delta_{22}^2 + \Delta_{32}^2 + \text{etc.}}$$

where  $\Delta_{ij}$  are the permitted deviations.

- 6.10.3.5 The permitted deviations defined in 11.6.25 to 11.6.38 for crane rails are absolute deviations and the RSS method for accumulated deviations is not applicable. Suitable means of adjustment between crane rails and primary supports should be allowed for.

## 7.0 WORKMANSHIP – WELDING

### 7.1 General

- 7.1.1 Welding shall be metal arc process in accordance with the latest BS EN 1011 or AWS D1.1 or any equivalent ISO standards, together with other clauses contained in this section, unless otherwise specially permitted by the S.O.
- 7.1.2 “WPS register” shall be developed and maintained by the contractor throughout the duration of the project outlining the:
- i) WPS number;
  - ii) Supporting PQR;
  - iii) Qualification range;
  - iv) Base material;
  - v) Welding process and consumables (electrodes and gases), etc.
- 7.1.3 Any changes made shall be submitted with a copy of updated WPS register to the S.O for approval.
- 7.1.4 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.
- 7.1.5 Joints shall be prepared in accordance with BS EN ISO 9692 or AWS D1.1 or any equivalent standards. Precautions shall be taken to ensure cleanliness of the connection prior to welding.
- 7.1.6 The Contractor shall appoint an independent Certification Body (CIDB, SIRIM & etc.) accredited by Department of Standard Malaysia (DSM) to approve the welding procedures and test procedures.

### 7.2 Welder Qualification

#### 7.2.1 Testing

- 7.2.1.1 Welders shall be tested to meet the requirements of BS EN ISO 9606 or AWS D1.1 or other equivalent standards, and welding operators shall be tested to meet the requirements of BS EN ISO 14732 or AWS D1.1 or other equivalent standards.

*Note:*

*Welder – Performs a manual or semiautomatic welding operation.*

*Welding Operator – Operates adaptive control, automatic, mechanised or robotic welding equipment.*

7.2.1.2 Welders of reinforcement steel shall be tested to meet the requirements of BS EN ISO 17660-1 or BS EN ISO 17660-2 or AWS D1.4 or other equivalent standards.

7.2.1.3 Visual welding inspection and testing shall be carried out by an independent Visual Inspector who holds a valid certificate of competence from Certification Body under BS EN ISO 17024. Notwithstanding such inspection by the independent Visual Inspector, the S.O. may at his absolute discretion carry out any test to verify the integrity of the weld.

## 7.2.2 Certification

7.2.2.1 Welder testing shall be witnessed and certificates endorsed by a Certification Body which follows Amendment of Third Schedule of Act 520, CIDB.

7.2.2.2 The certification shall remain valid providing it complies with the conditions for re-approval of certification specified in the approval standard used to qualify (this may be BS EN ISO 9606-1, BS EN ISO 14732 or BS EN ISO 17660).

## 7.3 Welding Procedures Specification (WPS)

### 7.3.1 Preparation of WPS

7.3.1.1 Welding Procedure for steel shall be in compliance with BS EN ISO 15609-1 or AWS D1.1 or any equivalent standard.

7.3.1.2 Written WPS shall be available in accordance with BS EN ISO 15609-1 or AWS D1.1 or other equivalent standards. Each WPS shall be qualified by testing in accordance with BS EN ISO 15614-1 or BS EN ISO 15613 or AWS D1.1 for steel and BS EN ISO 17660-1 or BS EN ISO 17660-2 or AWS D1.4 for reinforcing steel. WPS shall comply with the guidance of Annex C of BS EN 1011- 2, Method A to avoid hydrogen cracking.

*Note: Whilst BS EN 1090-2 permits the use of welding procedures qualified according to BS EN ISO 15610, BS EN ISO 15611 and BS EN ISO 15612 for a restricted range of steel grades and welding processes, this Specification requires the Steelwork Contractor to qualify its own range of WPSs according to BS EN ISO 15614-1 or BS EN ISO 15613.*

7.3.1.3 If welding is to be undertaken on coated steel, the WPS shall be qualified on the maximum thickness of coating.

7.3.1.4 If specified in the drawings, WPS for fillet welds shall be supported by a Welding Procedure Qualification Records (WPQR) that includes a cruciform tensile test to BS EN ISO 9018.

*Note: This requirement may only be applied to qualification of procedures for fillet welds of throat thickness not above 8.5mm, which corresponds to a leg length of 12mm, joining S355 material with thickness not greater than 17mm.*

### 7.3.2 Approval of Procedures and Procedure Tests

7.3.2.1 WPQR in accordance with BS EN ISO 15614-1 or BS EN ISO 15613 or AWS D1.1 or other equivalent standards approved by the S.O. shall be verified by the Inspection Body accredited by DSM.

7.3.2.2 Mechanical properties testing shall be performed as specified in AWS D1.1 or any equivalent standard. The mechanical properties testing shall include the following (if required by the code).

- i) Tensile test
- ii) Bend test (root/face) or Side Bend test
- iii) Charpy v-notch
- iv) Macro examination
- v) Hardness test
- vi) Fracture test

7.3.2.3 The test shall be 100% examined for both surface and internal defects with relevant NDT methods. The sound of the weld shall comply with BS EN ISO 17635.

### 7.3.3 Use of WPS

Appropriate work instructions shall be produced from the WPQRs. The work instructions shall be either WPSs or contain all information required within a WPS in other formats suitable to the Contractor's system. They shall be provided for the welder prior to the commencement of the Works and shall be suitable for the joint configuration and material to be welded. These work instructions shall be made available to the S.O., PEPC or Certification Body on request.

*Note: The suitability of work instructions for the material to be welded includes consideration of the carbon equivalent of the actual material if this differs from the maximum value specified in the material product standard.*



### 7.3.4 Preheating Procedure

7.3.4.1 Preheating shall be carried out in accordance with BS EN ISO 13916, BS EN 1011-2 and/or BS EN 1011-3 or AWS D1.1 or any equivalent standard.

7.3.4.2 Where required, preheating shall be applied in accordance with the designated WPS. The required preheating temperature shall be applied prior to welding and maintained throughout the welding operation.

*Note: The application of preheating 'prior to welding' includes tack welding operations and the welding of temporary attachments.*

## 7.4 Assembly

### 7.4.1 Fit-up

Joints shall be fitted up to the dimensional accuracy required by the WPS, depending on the process to be used, to ensure that the quality in Table 7.3 or Table 7.4 is achieved.

### 7.4.2 Jigs

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

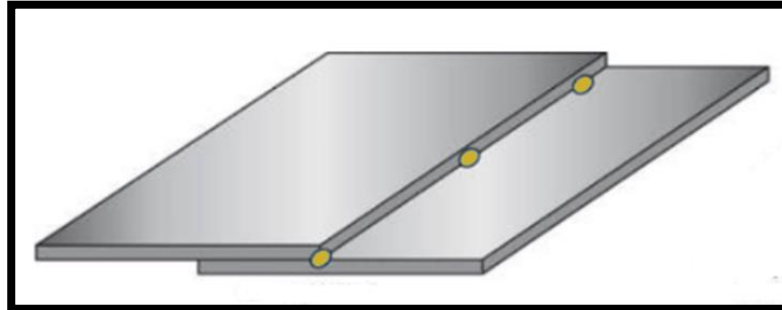
### 7.4.3 Tacks Welds

Tacks may be used provided:

- i) They are laid in an area to be welded and are thoroughly removed by grinding or gouging such that subsequent welding is unaffected;
- ii) They are undertaken by a welder qualified as in clause 7.2 as short length normal welds at least four times the thickness of the thicker part being joined and at least 50mm long, and the procedure for welding complies with clause 7.3;
- iii) They are undertaken by a welder qualified as in clause 7.2 to a welding procedure that complies with clause 7.3 and that demonstrates that the tack is fully re-melted during subsequent welding; or
- iv) They are located away from zones where subsequent welding is to take place and in a zone where only compressive forces are present in service.

*Note:*

1. Use of (iv) would be possible to secure column slab bases for transit.
2. Tack welds are small and temporary welds that hold part together ready for final welding.



*Figure 7.1: Tack welds on lap joint*

#### 7.4.4 Distortion Control

The sequence of welding a joint or a sequence of joints shall be such that distortion is minimised (see Section 9).

#### 7.4.5 Fabrication or Erection Attachments

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

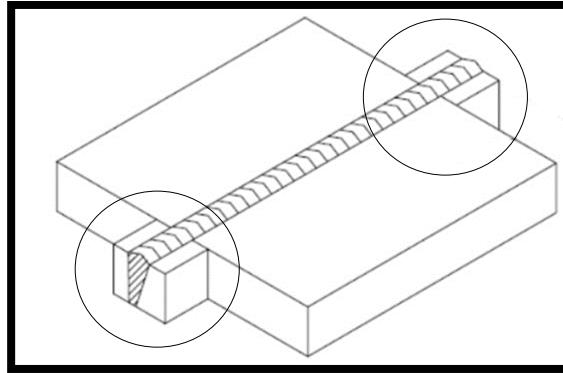
7.4.5.2 If removal is necessary, they shall be flame cut or gouged at a point not less than 3mm from the surface of the parent material. The residual material shall be ground flush and the affected area visually inspected. For steel grades equal to or higher than S355 the affected area shall also be subject to NDT i.e., Visual Inspection, Magnetic Testing (MT), or Penetrant Testing (PT) using the acceptance criteria given in clause 7.5.6. Attachments shall not be removed by hammering, see clause 5.4.4.

#### 7.4.6 Run-on/ run-off Pieces

7.4.6.1 If the profile of weld is maintained to the free end of a run by the use of run-on/ run-off pieces they shall be of material of a similar composition, but not necessarily the same grade, as the component.

7.4.6.2 They shall be arranged to provide continuity of preparation and if they are required to be removed after completion of the weld their removal shall comply with clause 7.4.5.

*Note: Run-on/ run-off pieces is piece of base metal which is tack welded onto the ends of the workpiece to allow the welder to start and end the weld without forming defect.*



*Figure 7.2: Run-on/ run-off pieces*

#### 7.4.7 Production Test Plates

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

### 7.5 Non-destructive Testing of Welds

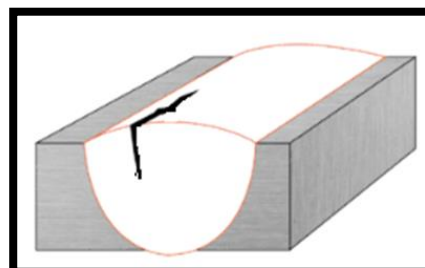
Non-destructive testing (NDT) methods shall be selected in accordance with BS EN ISO 17635 as the basis for the inspection and test plan required by the welding plan. The inspection and test plan shall include routine testing (see 7.5.2). The inspection and test plan shall identify joints for specific inspection of the fit-up that are likely to present difficulties in achieving the specified fit-up.

#### 7.5.1 Record of Testing

The test result shall be recorded and be available for inspection by the S.O. and PEPC.

#### 7.5.2 Routine Testing

- 7.5.2.1 All welds shall be visually inspected throughout their entire length. If surface breaking defects are detected, surface testing by penetrant testing or magnetic testing shall be carried out on the inspected weld.



*Figure 7.3: Surface breaking defects*

- 7.5.2.2 With the exception of visual inspection of welds, the NDT procedures shall be endorsed by NDT Level 3 Technician according to BS EN ISO 9712 from an Certification Body accredited by DSM.

### **Process Control**

Routine testing includes 100% visual inspection to 7.5.3 and a supplementary programme of NDT which shall be undertaken by the Contractor to ensure that the welding processes and welders/welding operators are producing work of a quality that is consistent with Execution Class 2. The benchmark for the quality of work required for Execution Class 2 is generally quality level C to BS EN ISO 5817 with the following exceptions:

Level D – Moderate (For normal structure)

Level C – Intermediate (For steel structure, columns with high loads)

Level B – Stringent (For crane, high load structure)

*Note:*

*Execution Class 2 – Buildings in general*

Incorrect toe (505) – not applicable;

Micro lack of fusion (401) – not applicable;

Overlap (506) – quality level D permitted;

Stray arc (601) – quality level D permitted;

End crater pipe (2025) – quality level D permitted;

Insufficient throat (5213) – quality level B required.

*Note:*

*505, 401, 506, 601, 2025, 5213 – Imperfection number according to BS EN ISO 5817*

The supplementary programme of NDT shall be in accordance with Table 7.1.

The joints for routine supplementary NDT shall be selected to ensure that sampling covers the following variables as widely as possible:

- i) The joint type (single-pass fillet, multi-pass fillet, partial penetration butt weld, full penetration butt weld);
- ii) The constituent steel material grade;
- iii) The welding equipment;
- iv) The work of the welders; and
- v) The location of the work in the shop or on site.

If routine testing discovers defects within an inspection length, further supplementary NDT shall be carried out over two inspection lengths, one each side of the length containing the defect. If this further testing identifies further defects, the RWC shall investigate the reason before agreeing the appropriate repair process. Supplementary NDT shall be in accordance with Table 7.1.

### **Fitness for Purpose Control**

If routine testing discovers imperfections outside the acceptance criteria given in Table 7.3 or Table 7.4 they shall be considered defects and shall be either repaired according to an appropriate WPS or referred to PEPC as appropriate.

Records of the most recent three months of routine testing applicable to each WPS shall be maintained and made available on request to the S.O., the PEPC and the Inspection Body.

*Note: The WPS used on the NDT request shall be included in the NDT report.*

### **Work where no supplementary NDT is required**

If a workshop is only producing work where no supplementary NDT is required according to Table 24: Extent of routine supplementary NDT in EN 1090-2, then a monthly programme of further NDT shall be instituted by the person appointed by the Contractor responsible for welding coordination such that a representative sample of each month's output is subjected to appropriate NDT.

## **7.5.3 Visual Inspection of Welds**

- 7.5.3.1 Certified Visual Inspector from an Inspection Body with SKKP certification shall performed visual inspection in accordance with guidance given in BS EN ISO 17637. 100% visual inspection shall be carried out before, during, and after welding to determine the production quality is being maintained. Visual inspection shall be carried out in accordance with the guidelines given in clause 7.5.3.4. Additional visual inspection shall be carried out as audit checking.

7.5.3.2 Any welds which will be rendered inaccessible by subsequent work shall be examined prior to the loss of access.

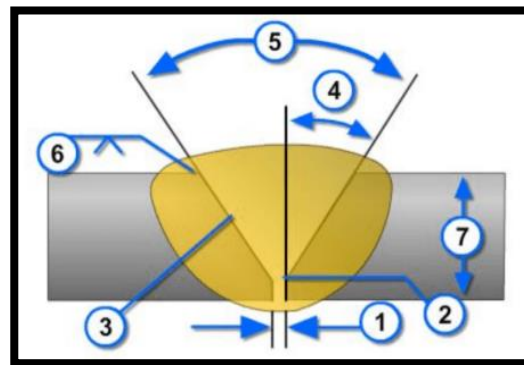
7.5.3.3 A suitably qualified person for visual inspection of welds shall be a visual inspector who can provide evidence of having been trained and assessed for competence in visual inspection of the relevant types of welds during and after welding. Additional visual inspection as audit checking shall be carried out by a Visual Inspector qualified to the requirements of BS EN ISO 17637.

*Note: The initial 100% visual inspection is often undertaken by the welder to verify that the weld has been completed satisfactorily. Defects visible at this stage can often be repaired immediately by the welder, see Table 7.3 or 7.4.*

7.5.3.4 Guidelines for Visual Inspection of Welds

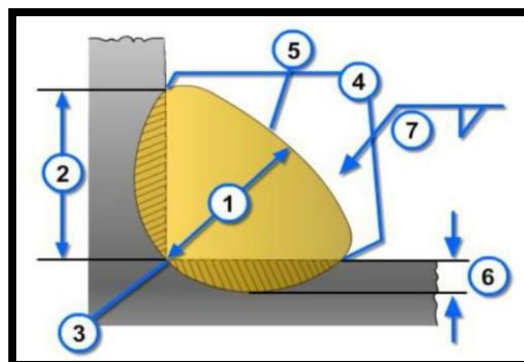
#### **Prior to Welding or Between Weld Passes**

- (i) Check the material is in accordance with drawing and/or WPS is identified and can be traced to a test certificate is in suitable condition (free from damage or contamination)
- (ii) Check the WPSs or work instruction are based on suitable WPQRs and are available to welders (and inspector)
- (iii) Check the welding equipment is in suitable condition and validated as appropriate
- (iv) Check the identification of welders qualified for each WPS to be used
- (v) Check the welding consumables to be used are as specified by the WPSs are being stored or controlled as specified by the quality procedure.
- (vi) Check that the weld preparation is correct in accordance with the welding work instruction. Items to be checked include preparation angles, root gap, root face condition, depth of preparation for part penetration welds, minimal gap for fillet welds;



Note:  
 1 – Root gap  
 2 – Root face  
 3 – Groove face  
 4 – Bevel angle  
 5 – Groove angle  
 6 – Size of weld  
 7 – Plate thickness

Figure 7.4: Butt weld



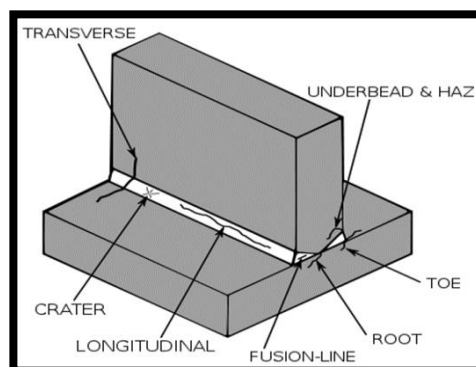
Note:  
 1 – Throat thickness  
 2 – Leg length  
 3 – Root  
 4 – Toe  
 5 – Weld face  
 6 – Fusion depth  
 7 – Size of weld

Figure 7.5: Fillet weld

- (vii) Check that the area to be welded is not contaminated with grease, oil, dirt, paint or moisture;
- (viii) Check that the relative position of parts to be joined is in accordance with the fabrication drawings and that the joint fit-up is satisfactory;
- (ix) Check that any tacks welds have been removed or are suitable for welding over as required by 7.4.3.
- (x) For multi-pass welds, check the suitability of the surface of previously deposited weld metal. In addition to checking any re-preparation to (i) and cleanliness to (ii), the area to be welded shall be de-slugged, free of weld spatter and be of a suitable profile for deposition of the subsequent pass;
- (xi) Check the shape and depth of any back gouging to ensure the complete removal of the second side back to sound metal. Also check whether supplementary NDT is needed at this stage before proceeding.

### After Deposition of Each Weld Pass or At Final Completion

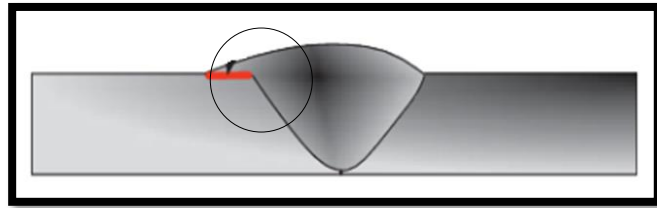
- (i) Check the weld size. Visual estimation may be used to assess acceptability, but, if in doubt, check by measurement. Confirm by measuring the weld size periodically;
- (ii) Check that welds are complete. Items to be checked include whether the weld extends fully to the end of the preparation or run-on/run-off plates if used for butt welds, and that return welds are completed;
- (iii) Check stray arcs and areas of weld spatter;
- (iv) Check that any craters have been filled and that no crater cracks are evident visually;



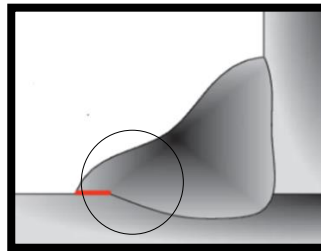
*Figure 7.6: Crater and other types of cracks*

- (v) Check for undercut, and measure for evaluation if identified;
- (vi) Check that the weld beads are of even appearance and that fillets present a mitre or slightly convex profile and butt welds are not under-flush with incomplete grooves. Measure any concave profiles to ensure that the specified throat thickness has not been compromised;
- (vii) Check for absence of any cracking or significant porosity;
- (viii) Check for absence of cold-lapping;





*Figure 7.7: Cold lapping in butt weld*



*Figure 7.8: Cold lapping in fillet weld*

- (ix) Check for absence of any mechanical damage from tool marks, e.g., chisels, hammers;
- (x) The inspection of the shape and surface of welds of welded branch joints using hollow sections shall pay careful attention to the following locations:
  - for circular sections: the mid-toe, mid-heel and two mid-flank positions;
  - for square or rectangular sections: the four corner positions.

### **Corrective Action**

Corrective action on minor defects capable of immediate rectification may be taken under the authority of the visual inspector. More significant defects shall be reported using a nonconformance procedure, and corrective action undertaken before further NDT including additional visual inspection. A record shall be kept that visual inspection has been carried out and any nonconformities identified.

#### **7.5.4 Surface Flaw Detection**

- 7.5.4.1 If examination of a weld surface is required magnetic particle testing shall be used in accordance with the recommendations given in BS EN ISO 17638 and this shall be preceded by visual inspection to BS EN ISO 17637 undertaken by the NDT technician or NDT inspector from an Inspection Body with SKKP certification.

7.5.4.2 If magnetic particle testing is impractical, penetrant testing may be used in accordance with the recommendations given in BS EN ISO 3452-1.

7.5.4.3 Final surface flaw detection of a welded joint shall be carried out after completion of the weld in accordance with the hold times given in Table 7.2.

*Note: If a welding procedure requires an inspection after initial weld runs, or back grinding/gouging before further welding is performed, such inspections may be carried out when the welded joint has cooled to ambient temperature.*

7.5.4.4 A suitably qualified person for surface flaw detection of welds may be an NDT technician or NDT inspector who holds a current Level 2 certificate of competence in surface flaw detection of the relevant types of work, from an Inspection Body under BS EN ISO 9712.

#### 7.5.5 Ultrasonic Examination

7.5.5.1 Where ultrasonic testing is required, it shall be carried out in accordance with BS EN ISO 17640 and BS EN ISO 23279 using either BS EN ISO 17640 Technique 1 (DAC from a 3mm diameter side drilled hole) or Technique 4 (tandem probes) as appropriate. Minimum testing levels are to be as specified for the required BS EN ISO 5817 Quality Level, see Table 5 of BS EN ISO 17640.

7.5.5.2 Final ultrasonic testing shall be carried out after any hold times required by Table 7.2.

7.5.5.3 Operators carrying out final ultrasonic testing of the weld shall hold a current certificate of competence to Level 2 according to BS EN ISO 9712 from Inspection Body.

#### 7.5.6 Acceptance Criteria and Corrective Action

7.5.6.1 Acceptance criteria, corrective action and re-testing shall be in accordance with Table 7.3 and Table 7.4 for components subject to static loading.

7.5.6.2 Acceptance criteria for Visual Inspection shall follow BS EN ISO 5817 (see Table 7.3) or AWS D1.1 (Table 7.4) whichever applicable. For other NDT methods:

- i) PT shall follow BS EN ISO 23277 or AWS D1.1 or any equivalent standard

- ii) MT shall follow BS EN ISO 23278 or AWS D1.1 or any equivalent standard
- iii) UT shall follow BS EN ISO 11666 or AWS D1.1 or any equivalent standard
- iv) RT shall follow BS EN ISO 10675-1 or BS EN ISO 10675-2 or AWS D1.1 or any equivalent standard.

## **7.6 Shear Stud Welding**

### **7.6.1 General**

7.6.1.1 The welding of shear studs shall be performed in accordance with the requirements and procedures of BS EN ISO 14555.

7.6.1.2 The general requirements for welding of steel shear studs to steel stipulated as follows:

- i) Mechanical properties and material of steel studs, and requirements for qualification of stud bases
- ii) Application qualification testing, operator qualification, preproduction testing, and workmanship
- iii) Stud welding during production, fabrication/ erection, and inspection
- iv) The stud manufacturer's certification of stud base weldability

7.6.1.3 Drawn-arc stud welding should be used. Where processes other than drawn-arc stud welding are proposed, the weld size shall be determined by the PEPC.

### **7.6.2 Method**

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

### **7.6.3 Trial Welding**

7.6.3.1 When specified by the S.O. 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 S.O.

- 7.6.3.2 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.

#### 7.6.4 Tests and Inspection

- 7.6.4.1 All studs are to be visually inspected. They shall show a full 360° collar.
- 7.6.4.2 At locations agreed with the S.O., a minimum of 5% studs which have satisfied the visual inspection shall have a bend test.
- 7.6.4.3 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.
- 7.6.4.4 The stud weld shall not show any signs of cracking or lack of fusion.
- 7.6.4.5 Studs subjected to the bend test shall not be straightened.

#### 7.6.5 Defective studs

Studs with defective welding shall be removed in the manner described in clause 7.4.5, and replaced and re-tested as in clause 7.6.4.

### 7.7 Welding of Reinforcement Steel to Structural Steel

The welding of reinforcing steel to structural steel shall be performed in accordance with the BS EN ISO 17660 or AWS D1.4 series or any equivalent standard.

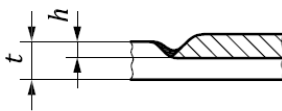
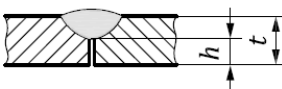
Table 7.1: Extent of routine supplementary NDT<sup>(5)</sup>

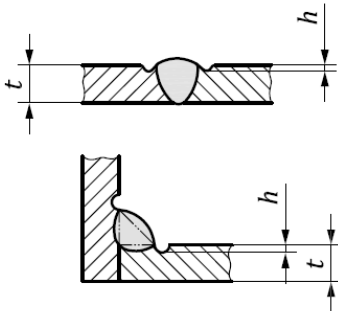
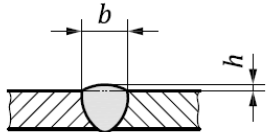
Weld Type <sup>(1)</sup>	Extent <sup>(2)</sup>
Full or partial penetration butt welds (other than welds to stiffeners or longitudinal welds)	10% Magnetic Testing (MT)
Full or partial penetration butt welds in material being joined with a maximum nominal thickness > 10mm	10% Ultrasonic Testing (UT)
Fillet welds ↓ with nominal throat thickness > 12mm (nominal leg length > 17mm), or ↓ in material being joined with a maximum nominal thickness > 20mm	10% MT and 5% UT <sup>(3)</sup>
Welds in cruciform joints (butt or fillet welds) in material with a maximum nominal 'through' plate thickness > 30mm	10% UT <sup>(4)</sup>
<ol style="list-style-type: none"> <li>1. Provided that site welding is under the control of a suitably competent on-site welding coordinator authorised by the RWC, these requirements make no distinction between shop and site welds. However, the extent of testing for the weld types above shall be 100% for site welds on a new project until the RWC is satisfied that suitable quality levels can be maintained.</li> <li>2. The percentages are subject to a minimum length of 900mm in any inspection lot and apply to the cumulative amount of weld length in joints welded according to the same WPS treated as a single continuing inspection lot. An inspection lot is a group of welds expected to show a uniform quality.</li> <li>3. Ultrasonic testing of fillet welds shall be carried out using 0° probes to determine the absence of defects in the parent material.</li> <li>4. For cruciform joints, the NDT operator, see 7.5.5, shall select the probes and scanning patterns used to test the welded joint. The purpose of this test is to detect lamellar tearing in the parent material.</li> <li>5. If a workshop is only producing work where no supplementary NDT is required, then a monthly programme of further NDT shall be instituted, see 7.5.2.</li> </ol>	

Table 7.2 Recommended minimum hold times in accordance with EN 1090-2

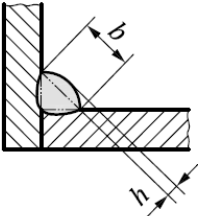
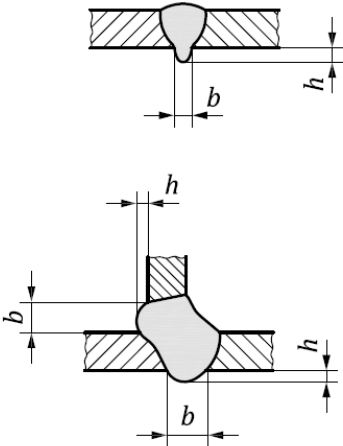
Hold Time (hours) <sup>(1)</sup>			
If preheat is applied in accordance with Method A of BS EN 1011-2, Annex C			
Weld Size (mm) <sup>(2)</sup>	Heat Input Q (kJ/mm)	S275 – S460	Above S460
$a$ or $s \leq 6$	All	Cooling period only	24
$6 < a$ or $s \leq 12$	$\leq 3$	8	24
	$> 3$	16	40
$a$ or $s > 12$	$\leq 3$	16	40
	$> 3$	24	48
<ol style="list-style-type: none"> <li>1. The time between weld completion and commencement of NDT shall be stated in the NDT report. In the case of 'cooling period only' this will last until the weld is cool enough for NDT to commence.</li> <li>2. Size applies to the nominal throat thickness, <math>a</math>, of a fillet weld, or the nominal material thickness, <math>s</math>, of a full penetration weld. For individual partial penetration butt welds the governing criterion is the nominal weld depth, <math>s</math>, but for pairs of partial penetration butt welds welded simultaneously it is the sum of the nominal weld throats, <math>a</math>.</li> </ol>			

Table 7.3: Visual Inspection Acceptance Criteria in accordance with ISO 5817

No.	Reference to ISO 6520-1	Imperfection designation	Remarks	t mm	Limits for imperfections for quality levels		
					D	C	B
1 Surface imperfections							
1.1	100	Crack		≥ 0,5	Not permitted	Not permitted	Not permitted
1.2	104	Crater crack		≥ 0,5	Not permitted	Not permitted	Not permitted
1.3	2017	Surface pore	Maximum dimension of a single pore for — butt welds — fillet welds	0,5 to 3	$d \leq 0,3 s$ $d \leq 0,3 a$	Not permitted	Not permitted
			Maximum dimension of a single pore for — butt welds — fillet welds	> 3	$d \leq 0,3 s$ , but max. 3 mm $d \leq 0,3 a$ , but max. 3 mm	$d \leq 0,2 s$ , but max. 2 mm $d \leq 0,2 a$ , but max. 2 mm	Not permitted
1.4	2025	End crater pipe		0,5 to 3	$h \leq 0,2 t$	Not permitted	Not permitted
				> 3	$h \leq 0,2 t$ , but max. 2 mm	$h \leq 0,1 t$ , but max. 1 mm	Not permitted
1.5	401	Lack of fusion (incomplete fusion)	—	≥ 0,5	Not permitted	Not permitted	Not permitted
		Micro lack of fusion	Only detectable by micro examination	≥ 0,5	Permitted	Permitted	Not permitted
1.6	4021	Incomplete root penetra- tion	Only for single side butt welds 	≥ 0,5	Short imperfections: $h \leq 0,2 t$ but max. 2 mm	Not permitted	Not permitted

No.	Reference to ISO 6520-1	Imperfection designation	Remarks	t mm	Limits for imperfections for quality levels		
					D	C	B
1.7	5011	Continuous undercut	Smooth transition is required. This is not regarded as a systematic imperfection.	0,5 to 3	Short imperfections: $h \leq 0,2 t$	Short imperfections: $h \leq 0,1 t$	Not permitted
	5012	Intermittent undercut		> 3	$h \leq 0,2 t$ , but max. 1 mm	$h \leq 0,1 t$ , but max. 0,5 mm	$h \leq 0,05 t$ , but max. 0,5 mm
1.8	5013	Shrinkage groove	Smooth transition is required.	0,5 to 3	Short imperfections: $h \leq 0,2 \text{ mm} + 0,1 t$	Short imperfections: $h \leq 0,1 t$	Not permitted
				> 3	Short imperfections: $h \leq 0,2 t$ , but max. 2 mm	Short imperfections: $h \leq 0,1 t$ , but max. 1 mm	Short imperfections: $h \leq 0,05 t$ , but max. 0,5 mm
1.9	502	Excess weld metal (butt weld)	Smooth transition is required. 	$\geq 0,5$	$h \leq 1 \text{ mm} + 0,25 b$ , but max. 10 mm	$h \leq 1 \text{ mm} + 0,15 b$ , but max. 7 mm	$h \leq 1 \text{ mm} + 0,1 b$ , but max. 5 mm



No.	Reference to ISO 6520-1	Imperfection designation	Remarks	t mm	Limits for imperfections for quality levels		
					D	C	B
1.10	503	Excessive convexity (fillet weld)		$\geq 0,5$	$h \leq 1 \text{ mm} + 0,25 b$ , but max. 5 mm	$h \leq 1 \text{ mm} + 0,15 b$ , but max. 4 mm	$h \leq 1 \text{ mm} + 0,1 b$ , but max. 3 mm
1.11	504	Excess penetration		0,5 to 3 > 3	$h \leq 1 \text{ mm} + 0,6 b$ $h \leq 1 \text{ mm} + 1,0 b$ , but max. 5 mm	$h \leq 1 \text{ mm} + 0,3 b$ $h \leq 1 \text{ mm} + 0,6 b$ , but max. 4 mm	$h \leq 1 \text{ mm} + 0,1 b$ $h \leq 1 \text{ mm} + 0,2 b$ , but max. 3 mm

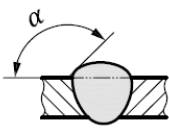
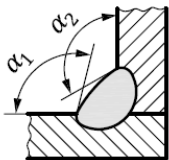
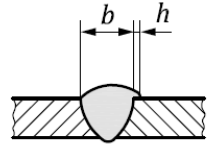
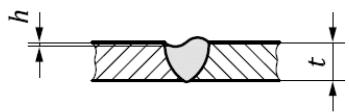
No.	Reference to ISO 6520-1	Imperfection designation	Remarks	t mm	Limits for imperfections for quality levels		
					D	C	B
1.12	505	Incorrect weld toe	— butt welds 	$\geq 0,5$	$\alpha \geq 90^\circ$	$\alpha \geq 110^\circ$	$\alpha \geq 150^\circ$
			— fillet welds  $\alpha_1 \geq \alpha$ and $\alpha_2 \geq \alpha$	$\geq 0,5$	$\alpha \geq 90^\circ$	$\alpha \geq 100^\circ$	$\alpha \geq 110^\circ$
1.13	506	Overlap		$\geq 0,5$	$h \leq 0,2 b$	Not permitted	Not permitted
1.14	509	Sagging	Smooth transition is required	0,5 to 3	Short imperfections: $h \leq 0,25 t$	Short imperfections: $h \leq 0,1 t$	Not permitted
	511	Incompletely filled groove		$> 3$	Short imperfections: $h \leq 0,25 t$ , but max. 2 mm	Short imperfections: $h \leq 0,1 t$ , but max. 1 mm	Short imperfections: $h \leq 0,05 t$ , but max. 0,5 mm

Table 7.4: Visual Inspection Acceptance Criteria in accordance with AWS D1.1

Discontinuity Category and Inspection Criteria	Statically Loaded Nontubular Connections	Cyclically Loaded Nontubular Connections
<b>(1) Crack Prohibition</b> Any crack shall be unacceptable, regardless of size or location.	X	X
<b>(2) Weld/Base Metal Fusion</b> Complete fusion shall exist between adjacent layers of weld metal and between weld metal and base metal.	X	X
<b>(3) Crater Cross Section</b> All craters shall be filled to provide the specified weld size, except for the ends of intermittent fillet welds outside of their effective length.	X	X
<b>(4) Weld Profiles</b> Weld profiles shall be in conformance with Clause 7.23 in AWS D1.1.	X	X
<b>(5) Time of Inspection</b> Visual inspection of welds in all steels may begin immediately after the completed welds have cooled to ambient temperature. (Refer Table 7.1)	X	X
<b>(6) Undersized Welds</b> The size of a fillet weld in any continuous weld may be less than the specified nominal size (L) without correction by the following amounts (U): <div style="display: flex; justify-content: space-around; margin-top: 10px;"> <div style="text-align: center;"> <b>L,</b>  specified nominal  weld size, in [mm]  <math>\leq 3/16</math> [5]  <math>1/4</math> [6]  <math>\geq 5/16</math> [8] </div> <div style="text-align: center;"> <b>U,</b>  allowable decrease from  L, in [mm]  <math>\leq 1/16</math> [2]  <math>\leq 3/32</math> [2.5]  <math>\leq 1/8</math> [3] </div> </div> <p style="margin-top: 10px;">In all cases, the undersize portion of the weld shall not exceed 10% of the weld length. On web-to-flange welds on girders, underrun shall be prohibited at the ends for a length equal to twice the width of the flange.</p>	X	X

Discontinuity Category and Inspection Criteria	Statically Loaded Nontubular Connections	Cyclically Loaded Nontubular Connections
<b>(7) Undercut</b> <b>(A)</b> For material less than 1 in [25 mm] thick, undercut shall not exceed 1/32 in [1 mm], with the following exception: undercut shall not exceed 1/16 in [2 mm] for any accumulated length up to 2 in [50 mm] in any 12 in [300 mm]. For material equal to or greater than 1 in [25 mm] thick, undercut shall not exceed 1/16 in [2 mm] for any length of weld.	X	
<b>(B)</b> In primary members, undercut shall be no more than 0.01 in [0.25 mm] deep when the weld is transverse to tensile stress under any design loading condition. Undercut shall be no more than 1/32 in [1 mm] deep for all other cases.		X
<b>(8) Porosity</b> <b>(A)</b> CJP groove welds in butt joints transverse to the direction of computed tensile stress shall have no visible piping porosity. For all other groove welds and for fillet welds, the sum of the visible piping porosity 1/32 in [1 mm] or greater in diameter shall not exceed 3/8 in [10 mm] in any linear inch of weld and shall not exceed 3/4 in [20 mm] in any 12 in [300 mm] length of weld.	X	
<b>(B)</b> The frequency of piping porosity in fillet welds shall not exceed one in each 4 in [100 mm] of weld length and the maximum diameter shall not exceed 3/32 in [2.5 mm].  Exception: for fillet welds connecting stiffeners to web, the sum of the diameters of piping porosity shall not exceed 3/8 in [10 mm] in any linear inch of weld and shall not exceed 3/4 in [20 mm] in any 12 in [300 mm] length of weld.		X
<b>(C)</b> CJP groove welds in butt joints transverse to the direction of computed tensile stress shall have no piping porosity. For all other groove welds, the frequency of piping porosity shall not exceed one in 4 in [100 mm] of length and the maximum diameter shall not exceed 3/32 in [2.5 mm].		X

*Note: An "X" indicates applicability for the connection type; a shaded area indicates non-applicability.*

## 8.0 WORKMANSHIP – BOLTING

### 8.1 Ordinary (non-preloaded) Bolt Assemblies

#### 8.1.1 Bolt/Nut Combinations

8.1.1.1 The combinations of hexagon bolts and nuts which may be used are as tabulated in Table 4.3.

8.1.1.2 The combinations of cup and countersunk head bolts and nuts which may be used are as tabulated in Table 4.8.

8.1.1.3 Any bolt assemblies which seize when being tightened shall be replaced.

#### 8.1.2 Different Bolt Grades

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

#### 8.1.3 Bolt Length

8.1.3.1 The bolt length shall be chosen such that, after tightening, at least one thread plus the thread run-out will be clear between the nut and the unthreaded shank of the bolt and the length of protrusion shall be at least the length of one thread pitch measured from the outer face of the nut to the end of the bolt.

8.1.3.2 Due to the thread run-out permitted by the bolt product standards, this does not mean that a full thread form will necessarily be shown beyond the nut.

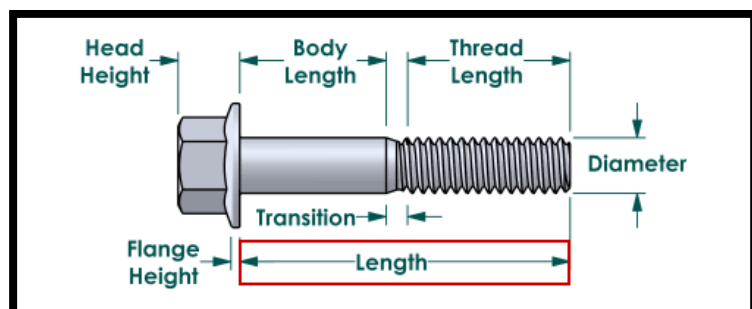


Figure 8.1: Bolt length

#### 8.1.4 Washers

8.1.4.1 Washers are not required for use with non-preloaded bolts in normal round holes. If required, it shall be specified whether washers are to be placed under the nut or the bolt head, whichever is rotated, or both.

8.1.4.2 For single lap connections with only one bolt row, washers are required under both bolt head and the nut.

8.1.4.3 To achieve the full bearing capacity when connecting two or more thin-gauge sections of 4mm, or less, washers shall be used under both the bolt head and the nut.

Requirements 8.1.4.1 – 8.1.4.3 does not apply when connecting thin-gauge sections to another steel component that is not thin-gauge.

8.1.4.4 If the components 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.

8.1.4.5 Chamfered washers (positioned with chamfer towards the bolt head) shall be used under the bolt head.

8.1.4.6 Plate washers shall be used under the head and nut if bolts are used to assemble components with oversize or slotted holes.

8.1.4.7 Plate washers shall be dimensioned with nominal clearance in accordance with 5.4.7 and with dimensions that ensure that the washer overlaps the connected components by at least as much as a standard plain washer would when used with nominal round holes. Plate washers shall be at least 4mm thick and the steel grade should be specified.

8.1.4.8 For ordinary bolt assemblies, in addition to the minimum specified washer(s), up to:

- a) two additional washers, or
- b) one plate washer, or
- c) one washer and one plate washer may be used.

The combined thickness of the additional washers shall not exceed 12mm.

### 8.1.5 Taper Washers

A taper washer shall be used to achieve satisfactory bearing where the bolt head or nut is in contact with a surface which is inclined more than:

- i)  $3^\circ$  for bolts not exceeding 20mm diameter; or
- ii)  $2^\circ$  for bolts greater than 20mm diameter

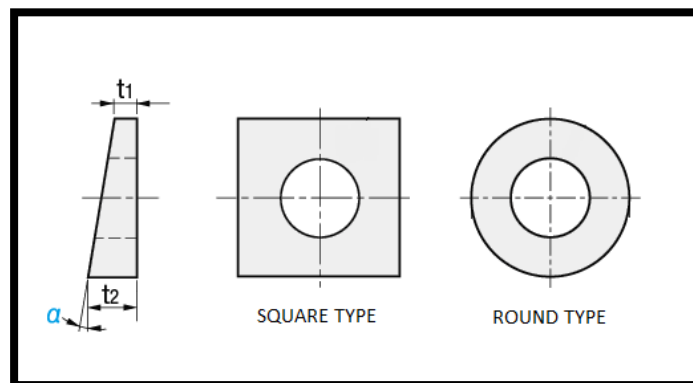


Figure 8.2: Taper washers

### 8.1.6 Galvanised Nuts

Nut blanks (unthreaded nuts) shall be tapped after being galvanised. Galvanising and re-tapping of nuts is not permitted.

### 8.1.7 Bolt Tightening

Bolts may be assembled using power tools or shall be fully tightened by hand using appropriate spanners in accordance with BS 2583.

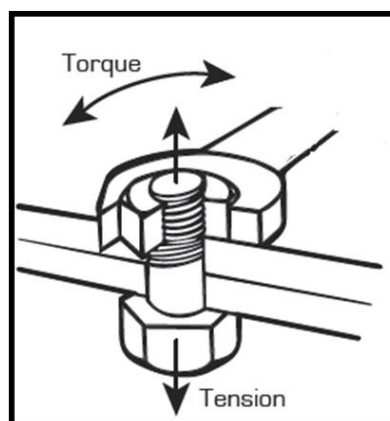


Figure 8.3: Bolt tightening

### 8.1.8 Fitted Bolts

Precision bolts to BS EN ISO 4014 may be used as fitted bolts if holes are drilled or reamed after assembly so that the clearance in the hole is not more than 0.3mm.

## **8.2 Fit-up If Using Non-Preloaded Bolt Assemblies**

### **8.2.1 Fit-up**

- 8.2.1.1 Connected parts shall be firmly drawn together.
- 8.2.1.2 If there is an unacceptable residual gap it shall be taken apart and a pack of not less than 2mm thickness inserted.
- 8.2.1.3 Residual gaps are unacceptable in general if they exceed 2mm, but in connecting parts thicker than 8mm, residual gaps of up to 4mm may be left at the edges, provided that contact bearing is achieved at the central part of the connection, unless otherwise specified in the drawings.
- 8.2.1.4 If plies of different nominal thickness are being joined, no more than three packing plates shall be used. The maximum limit on the total thickness of packs should be limited to 1/3 of the bolt diameter unless otherwise specified in the drawings and approved by the S.O.

### **8.2.2 Reaming**

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

## **8.3 Preloaded Bolt Assemblies**

### **8.3.1 Bolt/Nut/Washer Combinations**

- 8.3.1.1 The combination of bolt, nut, and washers may be used as specified in Table 4.4.
- 8.3.1.2 Washers shall be used under both the nut and the bolt head except that for 8.8 bolts only a single washer is necessary under the part to be rotated.
- 8.3.1.3 If the bolt head or nut is in contact with a surface which is inclined at more than 2° from the plane at right angles to the bolt axis, a taper washer to BS 4395 shall be placed to achieve satisfactory bearing.



- 8.3.1.4 Plain washers to BS EN 14399-5 may only be used under the nut. Otherwise, plain chamfered washers to BS EN 14399-6 shall be used. The chamfer shall be placed towards the bolt head when fitted under the bolt head and towards the nut when fitted under the nut.
- 8.3.1.5 For 10.9 bolts a washer shall be placed under the bolt head or the nut whichever is rotated, unless the use of washers under both the bolt head and the nuts is specified.
- 8.3.1.6 For 10.9 bolts used with steel grade S235, washer shall be used under both the bolt head and the nut.
- 8.3.1.7 Bolt lengths shall comply with the recommendation given in BS EN 14399.

Additional washers may be necessary to achieve requirements 8.3.1.1 – 8.3.1.7, see 8.1.4. Due to the thread run-out permitted by the bolt product standards, see BS EN 14399, this does not mean that a full thread form will necessarily be shown beyond the nut.

- 8.3.1.8 For preloaded bolt assemblies, additional washer(s) may be used up to:
  - a) three additional washers; or
  - b) two washers and one plate washer; or
  - c) a plate washer.

The combined thickness of the additional washers shall not exceed 12mm.

The additional washers in preloaded and non-preloaded applications may be placed on the side that is turned or on the side that is not turned.

- 8.3.1.9 For preloaded bolt assemblies tightened by the torque control method, including system HRC, only one washer may be used on the side that is turned.



*Figure 8.4: Bolt, nut and washer.*

### 8.3.2 Tightening

- 8.3.2.1 The use of preloaded fasteners in friction grip applications shall comply with BS EN 1090-2.
- 8.3.2.2 Tightening which complies with BS EN 1090-2 and the relevant product standards may be by any of the torque control, combined, Direct Tension Indicator (DTI), or HRC tightening methods.
- 8.3.2.3 The combined method specified in BS EN 1090-2 may be modified to be implemented with a lower initial torque and a larger subsequent part-turn provided that the values are calibrated in accordance with Annex H of BS EN 1090-2. Provided that the total nominal thickness of the parts to be connected (including all packs and washers) does not exceed 160mm, the following values may be used for fastener assemblies of classes K0, K1 or K2 to BS EN 14399-1, see Table 8.1.

### 8.3.3 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.

### 8.3.4 Inspection During and After Tightening

- 8.3.4.1 Unless otherwise specified in the drawings, inspection shall comply with the requirements specified in BS EN 1090-2.
- 8.3.4.2 Unless prohibited in the drawings, the tightening of direct tension indicators to apparent full compression in more than 10% of cases shall not be a cause for rejection if the manufacturer's certificate of conformity confirms that this is acceptable in terms of the specified suitability tests.

### 8.3.5 Discarded Bolt Assemblies

The whole bolt assembly shall be scrapped if a bolt or nut shall be slackened off after the complete tightening.

*Note: Slackening leads to loss of preload which leads to bolt loosening.*

## 8.4 Fit-Up If Using Preloaded Bolts Assemblies

### 8.4.1 Fit-up

8.4.1.1 Connected parts intended to transfer force in friction shall be firmly drawn together with all bolts partially tightened to a snug-tight condition.

8.4.1.2 The joints shall then be examined and if there is any residual gap that exceeds 1mm it shall be taken apart and a pack of not less than 2mm thickness inserted before recommencing the tightening procedure.

8.4.1.3 If plies of differing nominal thickness are being joined, no more than three packing plates shall be used.

*Note: The term 'snug-tight' can generally be taken as that achievable by the effort of one person using a normal sized spanner without an extension arm and can be set as the point at which a percussion wrench starts hammering.*

### 8.4.2 Reaming

8.4.2.1 If parts cannot be brought together by drifting without distorting the steelwork, rectification can be made by reaming if the design of the connection allows for the use of larger diameter bolts.

8.4.2.2 Calculations shall be made to demonstrate that the connection remains adequate to resist the design forces.

Table 8.1 Modified combined method

Bolt size	Torque for first tightening step <sup>(1)</sup>	Part-turn for final tightening step
M24	270 Nm	180 degrees, or 1/2 turn
M30	460 Nm	
1. Accuracy ±10%.		

## 9.0 WORKMANSHIP – ACCURACY OF FABRICATION

### 9.1 Permitted Deviations

- 9.1.1 Permitted deviations for manufacture of structural components are classified as essential tolerances from BS EN 1090-2.
- 9.1.2 Components are warranted by the Contractor as conforming with the essential tolerance requirements.
- 9.1.3 Functional tolerances are defined for two classes in BS EN 1090-2, of which the less onerous tolerance class 1 is the default specification for routine execution.
- 9.1.4 The permitted deviations, indicated by  $\Delta$ , do not include elastic deformations induced by the self-weight by the components. The deviations shall be measured with respect to any specified camber or pre-set.
- 9.1.5 Methods and instruments used for dimensional measurement shall be selected, as appropriate, from those listed in ISO 7976-1 and ISO 7976-2 (BS 7307-1 and BS 7307-2).
- 9.1.6 Accuracy shall be assessed in accordance with the relevant part of ISO 17123.

*Note: ISO 17123 is not issued as BS but is supersedes ISO 8322 which was issued as BS 7334.*

- 9.1.7 Constituent products used in the manufacture of structural components shall conform to the relevant product standard. The permitted deviations of those product standards continue to apply to components manufactured from such products, unless superseded by more stringent criteria specified within this Specification.
- 9.1.8 For braked cold formed profiles refer to Table B.2: Manufacturing Tolerances - Welded Profiles of BS EN 1090-2.
- 9.1.9 For stiffened plating refer to Table B.7: Manufacturing Tolerances – Stiffened Plating of BS EN 1090-2.

### 9.2 Permitted Deviations in Rolled Components after Fabrication (Including Structural Hollow Sections)

#### 9.2.1 Cross Section after Fabrication

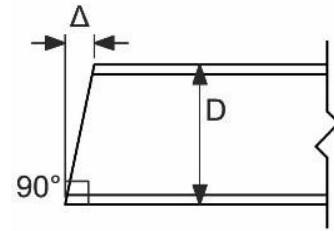
In accordance with the tolerances specified in Table 4.1 as appropriate.

### 9.2.2 Squareness of Ends Not Prepared for Bearing

Plan or elevation of end.

See also clause 6.3.3 (i).

$$\Delta = \pm D/100$$



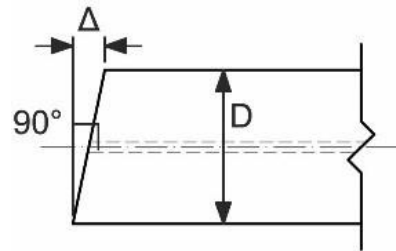
### 9.2.3 Squareness of Ends Prepared for Bearing

Prepare ends with respect to the longitudinal axis of the member.

Plan or elevation of end.

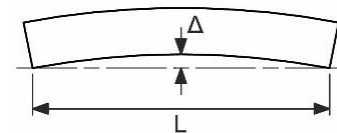
See also clause 6.3.3 (ii) and (iii).

$$\Delta = \pm D/1000$$



### 9.2.4 Straightness on Both Axes

$$\Delta = \pm L/1000$$



### 9.2.5 Length

Length  $L$  after cutting, measured on the centreline of the section or on the corner of angles.

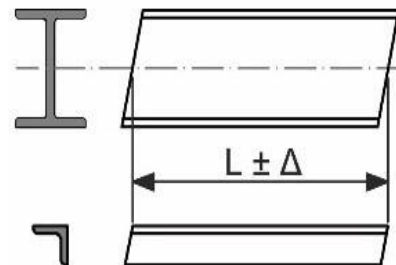
- General case:

$$\Delta = (L/5000 + 2) \text{ mm}$$

- End ready for full contact in bearing:

$$\Delta = 1 \text{ mm}$$

*Note: Length  $L$  measured including welded end plates as applicable.*

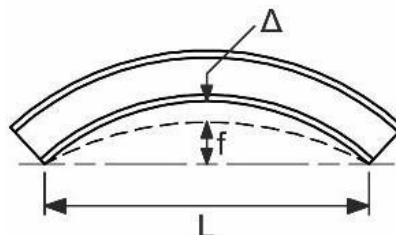


### 9.2.6 Curved or Cambered

Deviation from intended curve or camber at mid-length of curved portion when measured with web horizontal.

$$-\Delta = 0$$

$$+\Delta = L/500 \text{ mm or } 6 \text{ mm whichever is greater}$$



### 9.3 Permitted Deviations for Elements of Fabricated Members ( $\Delta$ )

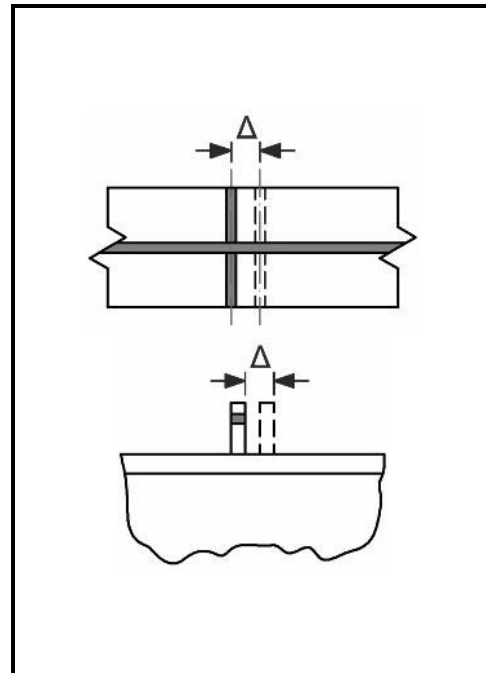
#### 9.3.1 Position of Fittings E

Deviation  $\Delta$  from the intended position, generally, relative to the setting-out point on the primary component.

$$\Delta = \pm 3\text{mm}$$

Fittings and attachments whose location is not critical to the force path (including non-bearing stiffeners):

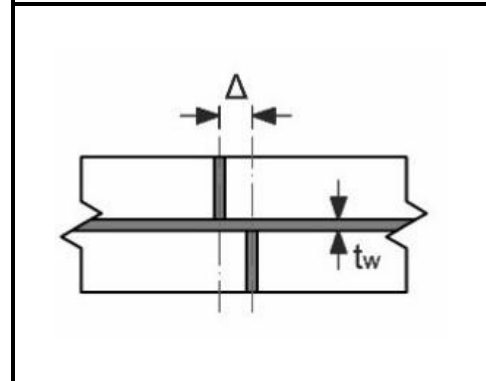
$$\Delta = \pm 5\text{mm}$$



#### 9.3.2 Position of Stiffeners E

Misalignment  $\Delta$  between a pair of bearing stiffeners fixed to a web of thickness  $t_w$ .

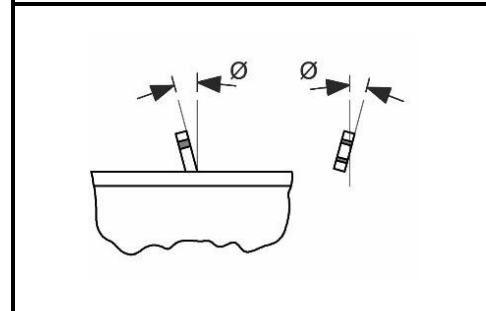
$\Delta = \pm t_w/2$  generally but restricted to  $\pm t_w/3$  at support positions.



#### 9.3.3 Alignment of fittings

Angular deviation  $\emptyset$  relative to intended local orientation (assumed square in figure).

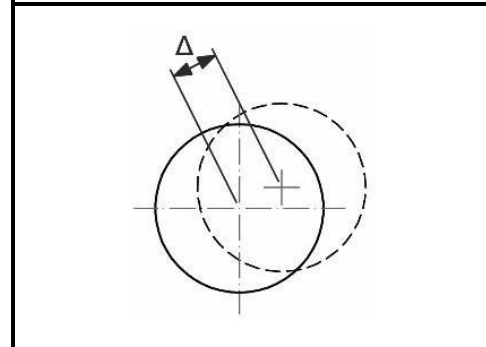
$$\emptyset = 1 \text{ in } 60$$



#### 9.3.4 Position of Holes E

Deviation from the intended position of an individual hole within a group hole.

$$\Delta = \pm 2\text{mm}$$



### 9.3.5 Punched Holes

Distortion caused by a punched hole shall not exceed  $\Delta$ .

(See clause 6.6.4)

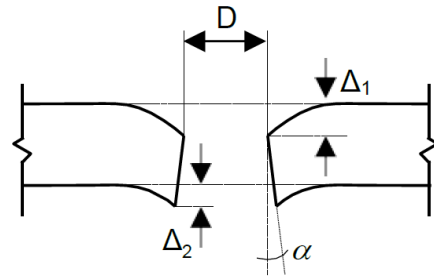
$$\max (\Delta_1 \text{ or } \Delta_2) \leq \max (D/10; 2\text{mm})$$

where:

$$D = (d_{\max} + d_{\min})/2$$

And the taper angle  $\alpha$  shall not exceed:

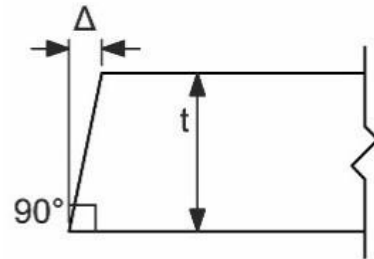
$$\alpha \leq 4^\circ \text{ (i.e., 7\%)}$$



### 9.3.6 Sheared or Cropped Edges of Plates or Angles

Deviation from a 90° edge.

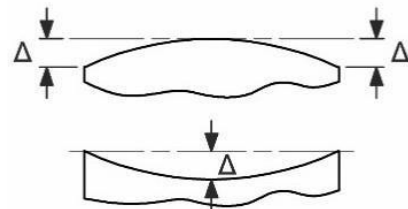
$$\Delta = \pm t/10 \text{ up to maximum of } 3\text{mm}$$



### 9.3.7 Flatness

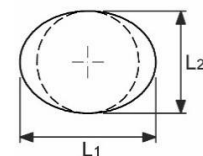
Maximum gap  $\Delta$  between the surface and a straight edge laid in any direction for surfaces specified for full contact bearing.

Generally,  $\Delta = 0.5\text{mm}$  with local high spots shall not be protruded by more than 0.5mm.



### 9.3.8 Ovaliation of Holes

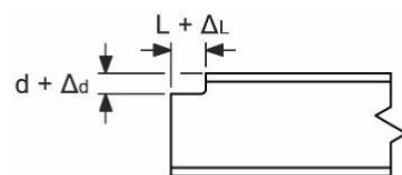
$$\Delta = L_1 - L_2 = \pm 1\text{mm}$$



### 9.3.9 Notches

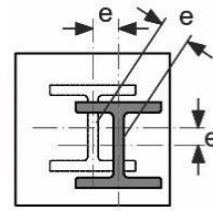
$$\Delta = -0\text{mm} / +3\text{mm on depth } d, \Delta_d, \text{ or length } L, \Delta_L.$$

Note: See also 6.3.2.



## 9.3.10 Base Plates

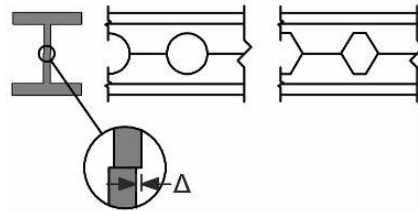
Non-intended eccentricity  $e$  in any direction.  
 $e \leq 5\text{mm}$



## 9.3.11 Castellated and Cellular Beams

Fabricated either from plate or from hot rolled sections with openings of inscribed nominal diameter  $D$ .

- Misalignment of web-post across thickness, as shown:  
 $\Delta = 2\text{mm}$
- Misalignment of web-post overlap for openings radius,  $r$ :



For  $r = D/2 < 200\text{mm}$ ;  
 $\Delta = 2\text{mm}$

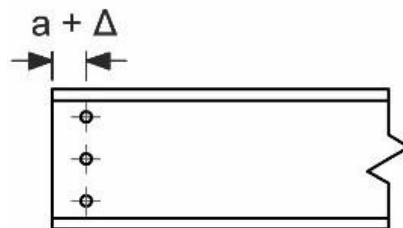
For  $r = D/2 \geq 200\text{mm}$ ;  
 $\Delta = r/100$  and  $\Delta \leq 5\text{mm}$

## 9.3.12 Position of Holes for Fasteners E

Deviation  $\Delta$  in distance  $a$ , between an individual hole of diameter  $d_o$  and a cut end.

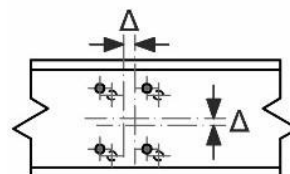
If  $a < 3d_o$ ;  $-\Delta = 0\text{mm}$  (note negative sign) and  
 $+\Delta = 3\text{mm}$

If  $a \geq 3d_o$ ;  $\Delta = \pm 3\text{mm}$



## 9.3.13 Position of Hole Group E

Deviation of a hole group from its intended position.  
 $\Delta = \pm 2\text{mm}$

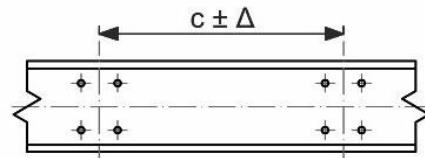




### 9.3.14 Spacing of Hole Groups

Deviation in spacing  $c$  between centres of hole groups.

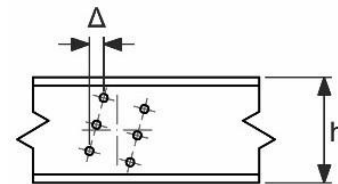
- General case:  
 $\Delta = 5\text{mm}$
- If a single component is connected to another single component by two groups of fasteners:  
 $\Delta = 2\text{mm}$



### 9.3.15 Twist of A Hole Group

$\Delta = \pm 2\text{mm}$  if  $h \leq 1000\text{mm}$

$\Delta = \pm 4\text{mm}$  if  $h > 1000\text{mm}$



## 9.4 Permitted Deviations in Plate Girder Sections ( $\Delta$ )

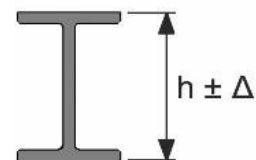
### 9.4.1 Depth E

Depth on centreline.

$\Delta = 3\text{mm}$  if  $h \leq 900\text{mm}$

$\Delta = h/300$  if  $900\text{mm} < h < 1800\text{mm}$

$\Delta = 6\text{mm}$  if  $h \geq 1800\text{mm}$

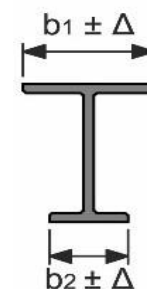


### 9.4.2 Flange Width E

Width  $b_1$  or  $b_2$ .

$-\Delta = b/100$  (note negative sign)

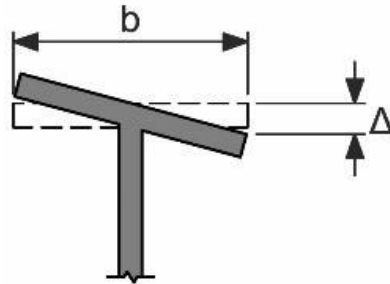
$+\Delta = b/100$  or  $3\text{mm}$   
whichever is greater



#### 9.4.3 Squareness of Section

Out of squareness of flange width  $b$ .

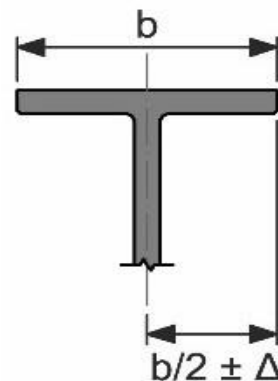
Generally,  $\Delta = \pm b/100$  or 5mm whichever is greater but limited to  $\pm b/400$  in locations identified in the drawings, as in contact with structural bearings.



#### 9.4.4 Web Eccentricity

Position of web from one edge to flange width  $b$  relative to intended position.

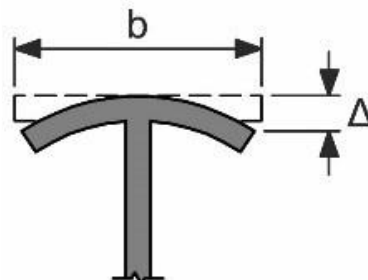
Generally,  $\Delta = 5\text{mm}$ , but limited to 3mm in locations identified in the drawings, as in contact with structural bearings.



#### 9.4.5 Flanges

Out of flatness of flange with  $b$ .

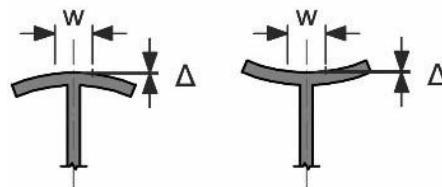
Generally,  $\Delta = \pm b/100$  or 5mm whichever is greater but limited to  $\pm b/400$  in locations identified in the drawings, as in contact with structural bearings.



#### 9.4.6 Top Flange of Crane Girder

Out of flatness where the rail seats in zone  $w$  equal to rail width plus 10mm either side of rail in nominal position.

$\Delta = \pm 1\text{mm}$

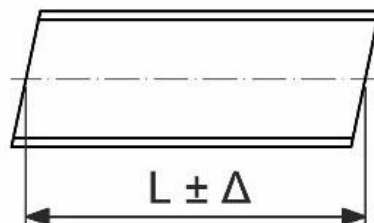


#### 9.4.7 Length

Length on centre line.

$\Delta = (L/5000 + 2) \text{ mm}$

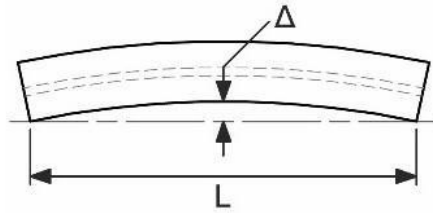
*Note: This may be increased up to a maximum of 50mm if sufficient clearance compensation with next adjacent component is possible.*



#### 9.4.8 Flange Straightness E

Straightness of individual flanges.  $\Delta = \pm L/1000$

*Note: At least 3mm allowable on beams shorter than 3000mm if specified as restrained in the drawings.*

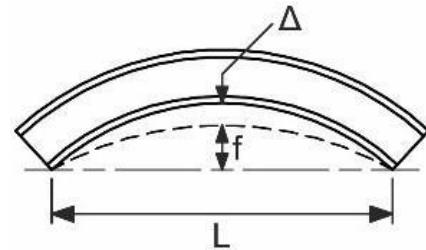


#### 9.4.9 Curve or Camber

Deviation from intended curve or camber at middle length  $L$  of curved portion, when measured with the web horizontal.

-  $\Delta = 0$

+  $\Delta = L/500$  or 6mm  
whichever is greater



#### 9.4.10 Plate curvature, web distortion and web undulation E

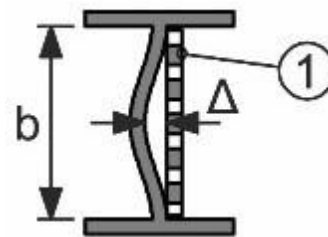
**Plate curvature  $\Delta$  over plate height  $b$**

$\Delta = \pm b/200$  if  $b/t \leq 80$

$\Delta = \pm b^2/(16000t)$  if  $80 < b/t \leq 200$ ;

$\Delta = \pm b/80$  or  $t$  whichever is greater if  $b/t > 200$

where  $t$  is the plate thickness



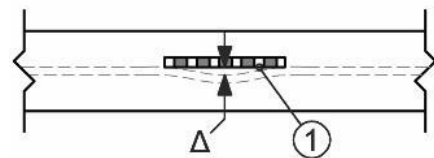
#### **Web Distortion**

Distortion on web depth or gauge.

Deviation  $\Delta$  on gauge length  $L$  equal to web height  $b$ .

$\Delta = \pm b/100$  or  $t$  whichever is greater

where  $t$  is the plate thickness

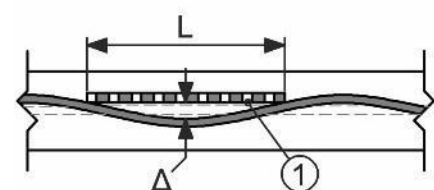


#### **Web Undulation**

Deviation  $\Delta$  on gauge length  $L$  equal to web height  $b$ .

$\Delta = \pm b/100$  or  $t$  whichever is greater

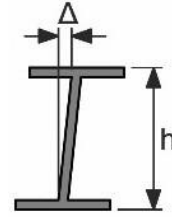
where  $t$  is the plate thickness



## 9.4.11 Cross Section at Bearings E

Squareness of flanges to web.

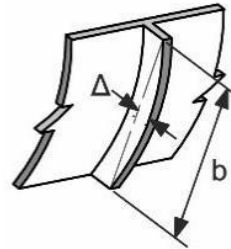
$$\Delta = \pm h/300 \text{ or } 3\text{mm} \text{ whichever is greater}$$



## 9.4.12 Web Stiffeners E

Straightness of stiffener out of plane with web after welding.

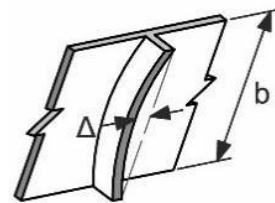
$$\Delta = \pm b/500 \text{ or } 4\text{mm} \text{ whichever is greater}$$



## 9.4.13 Web Stiffeners E

Straightness of stiffener in plane with web after welding.

$$\Delta = \pm b/250 \text{ or } 4\text{mm} \text{ whichever is greater}$$

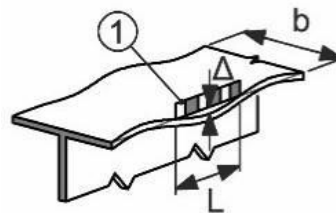
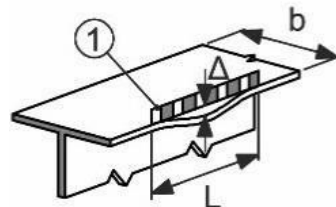


## 9.4.14 Flange distortion or undulation E

Distortion  $\Delta$  or undulation over gauge ① of length  $L$  equal to flange width  $b$  of thickness  $t$ .

$$\Delta = \pm b/150 \text{ if } b/t \leq 20$$

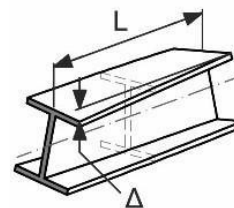
$$\Delta = \pm b^2/(3000t) \text{ if } b/t > 20$$



## 9.4.15 Twist

Overall twist in a component of length  $L$ .

$$\Delta = \pm L/700 \text{ or } 4\text{mm} \text{ whichever is greater, up to a maximum of } 20\text{mm}$$

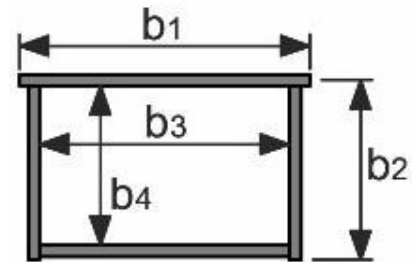


## 9.5 Permitted Deviation in Box Sections ( $\Delta$ )

### 9.5.1 Plate Widths E

Deviation  $\Delta$  in internal or external dimension  $b = b_1, b_2, b_3$  or  $b_4$ .

$$\begin{aligned}\Delta &= -(b/100) / +3\text{mm if } b \leq 300\text{mm} \\ \Delta &= \pm 3\text{mm if } 300\text{mm} < b \leq 900\text{mm} \\ \Delta &= \pm b/300 \text{ if } 900\text{mm} < b < 1800\text{mm} \\ \Delta &= \pm 6\text{mm if } b \geq 1800\text{mm}\end{aligned}$$



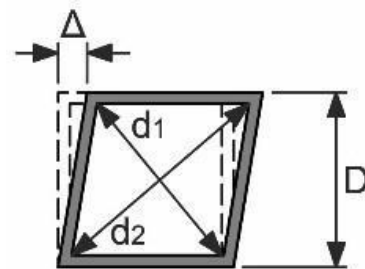
### 9.5.2 Squareness

Difference  $\Delta$  between diagonal dimensions (nom = nominal and act = actual) at diaphragm positions.

$\Delta$  is  $(d_1 + d_2)_{\text{nom}}/400$  or 6mm whichever is greater,

where:

$$\Delta = [(d_1 - d_2)_{\text{act}} - (d_1 - d_2)_{\text{nom}}]$$



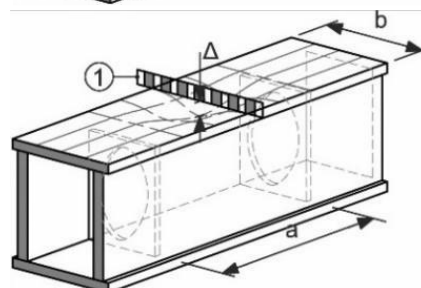
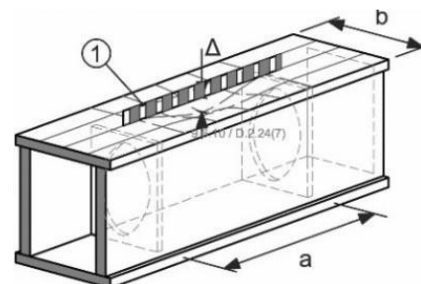
### 9.5.3 Plate Distortion E

For a panel of width  $b$  with distance  $a$  between stiffener diaphragms.

Distortion perpendicular to the plane of the plate transversely over whole width relative to straight edge ① or longitudinally with respect to a gauge ① of length  $b$ .

- General case:  
 $\Delta = \pm b/125$  unless  $a \leq 2b$   
in which case  $\Delta = \pm a/250$
- Special case:  
 $\Delta = \pm a/125$  unless  $a \geq b/2$   
in which case  $\Delta = \pm b/250$
- 

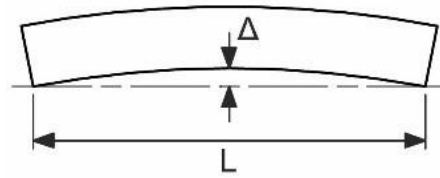
*Note: The special case only applies for compression of the box section in the transverse direction if specified in the drawings.*



#### 9.5.4 Web or Flange Straightness E

Straightness of individual web or flanges.

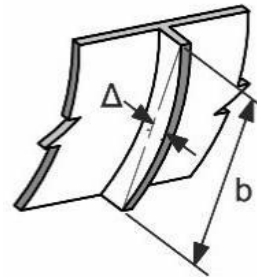
$\Delta = \pm L/1000$  or 3mm whichever is greater



#### 9.5.5 Web Stiffeners E

Straightness of stiffener of length  $b$  out of plane with web after welding.

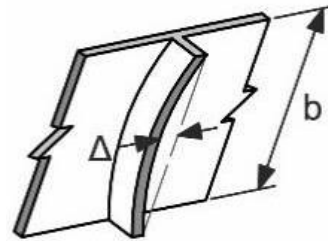
$\Delta = \pm b/500$  or 4mm whichever is greater



#### 9.5.6 Web Stiffeners E

Straightness of stiffener of length  $b$  in plane with web after welding.

$\Delta = \pm b/500$  or 4mm whichever is greater

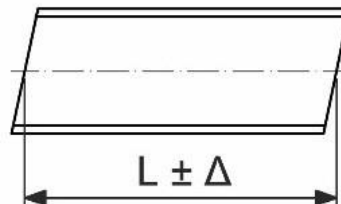


#### 9.5.7 Length

Length  $L$  on centre line.

$\Delta = (L/5000 + 2)$  mm

*Note: This may be increased up to a maximum of 50mm if sufficient clearance compensation with next adjacent component is possible.*

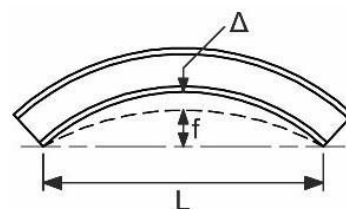
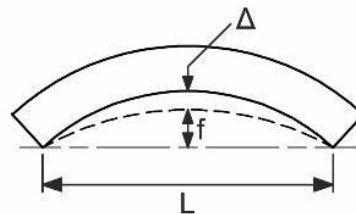


#### 9.5.8 Curve or Camber

Deviation  $\Delta$  from intended curve or camber  $f$  at middle of length  $L$  of curved portion when measured with the uncambered side horizontal.

$-\Delta = 0$

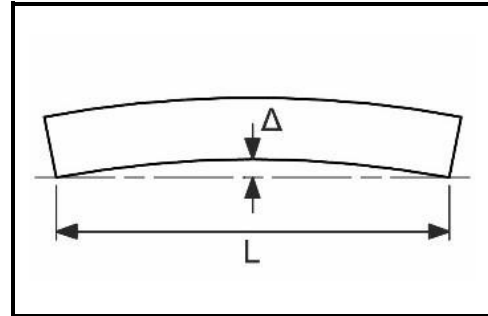
$+\Delta = L/500$  or 6mm whichever is greater



### 9.5.9 Twist

Overall twist in a component of length  $L$ .

$\Delta = \pm L/700$  or 4mm whichever is greater, up to a maximum of 10mm

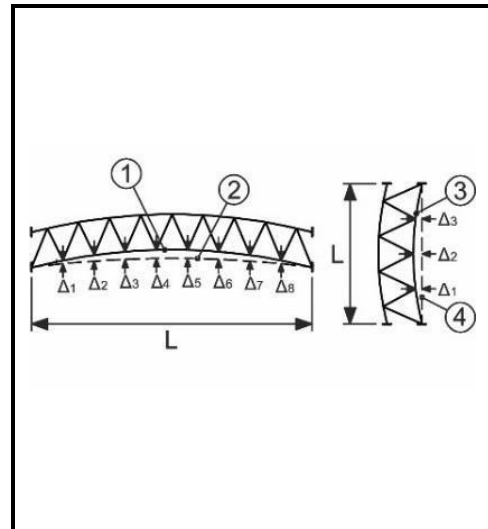


## 9.6 Permitted Deviations for Lattice Components ( $\Delta$ )

### 9.6.1 Straightness and Camber E

Deviations  $\Delta_i$  of the actual positions ③ or ① at each panel point relative to a straight line ④ or to the intended camber ② when measured after welding with the component lying flat on its side.

$\Delta = \pm L/500$  or 12mm whichever is greater.



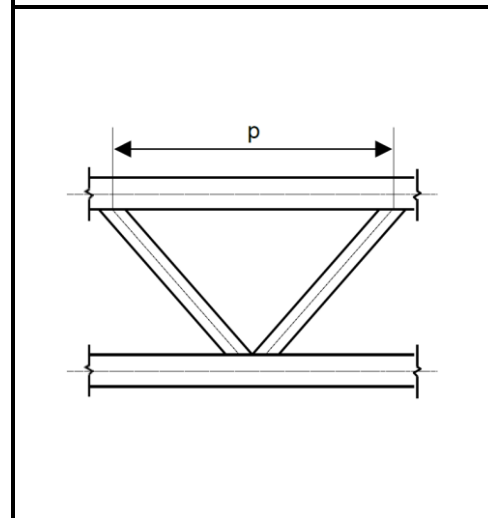
### 9.6.2 Panel Dimensions

Deviation of individual distances  $p$  between intersections of centrelines of panel points.

$\Delta = \pm 5\text{mm}$

Cumulative deviation  $\Sigma p$  of panel point position.

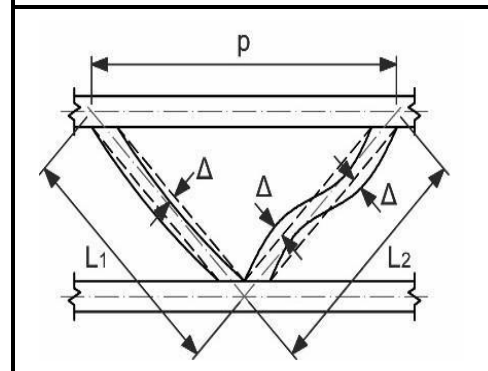
$\Delta = \pm 10\text{mm}$



### 9.6.3 Straightness of bracings E

Deviation  $\Delta$  of individual bracing lengths  $L_i$  ( $L_1$  or  $L_2$ ) from straightness:

$\Delta = \pm L_i/1000$  or 4mm whichever is greater



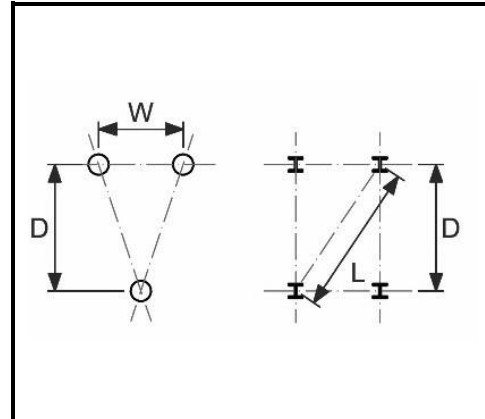
#### 9.6.4 Cross-sectional dimensions

Deviation  $\Delta$  of distance  $s = D$ ,  $W$  or  $L$ , as appropriate.

$$\Delta = \pm 3\text{mm if } s \leq 300\text{mm}$$

$$\Delta = \pm 5\text{mm if } 300\text{mm} < s < 1000\text{mm}$$

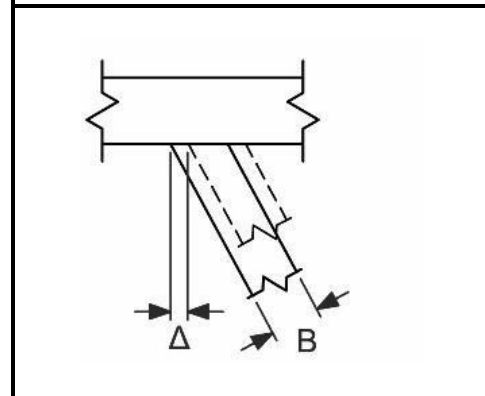
$$\Delta = \pm 10\text{mm if } s \geq 1000\text{mm}$$



#### 9.6.5 Intersecting joints

Eccentricity of bracing of dimension  $B$  relative to intended eccentricity.

$$\Delta = \pm (B/20 + 5\text{mm})$$

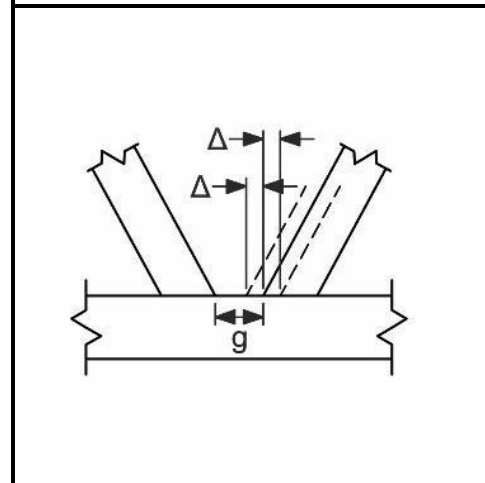


#### 9.6.6 Gap joints

Deviation  $\Delta$  of the gap  $g$  between bracings components.

$$g \geq (t_1 + t_2) \text{ and } \Delta = \pm 5\text{mm}$$

where  $t_1$  and  $t_2$  are the wall thicknesses of the braces





## 10.0 WORKMANSHIP – ERECTION

### 10.1 General

#### 10.1.1 Erection Method Statement

10.1.1.1 The Contractor shall prepare and submit the method statement to the S.O. for approval at least two weeks before erection commences.

10.1.1.2 The Erection Method Statement which among others shall include the following, but not limited to:

- i) Pre-erection survey correctly positioned foundation as per as-built drawing approved by the S.O.;
- ii) Phases of component delivery;
- iii) Shop drawings inclusive of temporary restraints (propping, back propping, access and bracing)
- iv) Risk management (Safety and environmental controls);
- v) Operative certification;
- vi) Plant and equipment certification;
- vii) Inspection of each phase of construction.

10.1.1.3 The Contractor shall also provide documents/information as required on design, erection and programme. See Appendix 1.1, 1.3 and 1.5.

#### 10.1.2 Approval by the S.O.

Erection shall not commence before the method statement has been approved by the S.O.

#### 10.1.3 Provision of Setting Out Lines

The Contractor shall provide and maintain setting out lines and datum levels within or immediately adjacent to the Works until the steelwork is approved.

#### 10.1.4 Handling and Storage

10.1.4.1 Components shall be handled and safely stacked in such a manner as to minimise the risk of surface abrasion and damage.

10.1.4.2 Fasteners and small fittings shall be stored under cover in dry conditions.

### 10.1.5 Damaged Steelwork

Any steelwork damaged during off-loading, transportation, storage or erection shall be restored to conform to the standards of manufacture as given in this Specification. The procedure for repairing damaged steelwork shall be certified by PEPC and approved by the S.O.

### 10.1.6 Column Base Plates and Slabs

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

10.1.6.2 Base packs shall be placed so that they do not prevent subsequent grouting to completely fill all spaces directly under the base plates.

10.1.6.3 Base packs may be left permanently in place.

### 10.1.7 Grouting

10.1.7.1 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.

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

## 10.2 Site Conditions

### 10.2.1 Contractor's Responsibilities

The Contractor shall be responsible for the followings:

- i) Prepare plan showing width and level of access, level of the prepared working area for site traffic and cranes, and areas available for storage;
- ii) Maintain the working surfaces of the Site free from standing water and remove water from foundations;
- iii) Provide a firm, properly graded, working area and storage area; also maintain adequate access roads, into and through the site, for the safe delivery of plant and materials on normal road vehicles;

- iv) Be aware of the position of any underground services which may be considered liable to damage by their plant;
- v) Be responsible for removing overhead obstructions;
- vi) Ensure that the load spread under cranes and lifting plant is commensurate with the strength of firm standing provided by the Contractor.

### **10.3 Safety**

#### **10.3.1 Contractor's Responsibilities**

- 10.3.1.1 The initial planning, design, site management and procedures adopted for safe erection of the structure shall be submitted for approval by the S.O.
- 10.3.1.2 Ensure that appropriate safe systems of work are provided, installed and properly maintained to discharge the duties under current safety legislation
- 10.3.1.3 Ensure projects involving Sub Contractor(s), coordinate their activities with information provided by the Contractor.

### **10.4 Stability**

#### **10.4.1 Temporary Restraints until Permanent Features are Built**

- 10.4.1.1 The Contractor shall design and provide the temporary bracing or restraints and ensure stability at all times and shall conform to CIS 22 and CIS 23 published by CIDB or any relevant standards with the approval from the S.O. The design should be validated by PEPC and submitted for approval by the S.O.
- 10.4.1.2 The Contractor shall indicate positions on the structure where temporary bracing or restraints are necessary until walls, floors or other non-steel structures are built. The Contractor shall also provide details of the forces and moments in these elements.

#### 10.4.2 Other Temporary Restraints used by Contractor

If the Contractor uses temporary restraints during erection which do not substitute for permanent features, they may be removed after the structure has been lined, levelled and plumbed provided that sufficient and/or permanent bracing has been erected to ensure the stability of the structure under the worst expected conditions of dead, imposed and wind loading.

### 10.5 Erection Loads

10.5.1 The Contractor shall ensure that no part of the structure is permanently distorted by stacking of materials or temporary erection loads during the erection process.

10.5.2 The Contractor shall ensure that no other Sub Contractor shall place loads on the partly erected structure without his permission.

### 10.6 Lining and Levelling

#### 10.6.1 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 components members until the structure has been aligned, levelled, plumbed and temporarily connected to ensure that components members will not be displaced during subsequent erection or alignment of the remainder of the structure.

#### 10.6.2 Temperature Effect

Due account shall be taken of the effects of temperature on the structure, tapes and instrument when measurements are made for setting out, during erection and for subsequent dimensional checks. The reference temperature shall be 30°C.

### 10.7 Site Welding

10.7.1 Site welding shall be carried out in accordance with Section 7 and with the regulatory requirements of DOSH (if required).

10.7.2 Welding shall not be permitted during inclement weather.

### 10.8 Site Bolting

Bolting shall be carried out in accordance with Section 8.

### **10.9 Certification of Completion**

When the steelwork, or portion of the steelwork, has been completed, the Contractor shall submit a signed certificate to the S.O. The completion of the certificate means the following:

- i) The PEPC's signature signifies that an inspection has been made to ensure that all connections are completed and that the steelwork is erected and installed in accordance with the Drawings, Specification and contract requirements.
- ii) The PEPC's signature signifies acceptance that the steelwork has been built in accordance with the Drawings, Specification and the contract requirements.

## **11.0 WORKMANSHIP – ACCURACY OF ERECTED STEELWORK**

### **11.1 Inspection of Foundation and Holding Down Bolt**

- 11.1.1 The Contractor shall inspect the prepared foundations and holding down bolts for position and level not less than seven (7) days before erection of steelwork starts.
- 11.1.2 The Contractor shall then inform the S.O. if the Contractor finds any discrepancies which are outside the deviations specified in clause 11.5 requesting that remedial work be carried out before erection commences.
- 11.1.3 The compliance survey used to check the position of the foundation supports shall be documented by the Contractor and endorsed by licensed Surveyor and approved by the S.O.

### **11.2 Steelwork**

- 11.2.1 Methods and instruments used for dimensional measurement shall be selected as appropriate from those listed in ISO 7976-1 and ISO 7976-2 (BS 7307-1 and BS 7307-2) or other equivalent standards.
- 11.2.2 Point cloud surveys may be used alternatively. Accuracy and precision of instruments shall be assessed in accordance with the relevant part of ISO 17123 or other equivalent standards.  
  
*Note: Point cloud survey uses a laser to produce an internal and external scan of a building.*
- 11.2.3 A survey of the completed structure shall be made by licensed Surveyor. This survey shall be related to the system for setting out the building established in accordance with ISO 4463-1 (BS 5964-1) or other equivalent standards.
- 11.2.4 Measurement will only be taken of the position of components adjacent to site interconnection nodes as set out below, unless otherwise specified in the drawings. The location and frequency of measurements shall be specified in the Contractor's erection Method Statement.
- 11.2.5 The positional accuracy of the erected steelwork shall be measured under self-weight of steelwork only unless otherwise specified in the drawings.

11.2.6 Permitted maximum deviations in erected steelwork shall be as specified in clause 11.6 taking account of the following:

- i) The deviations shown for I-sections apply also to box and tubular sections.
- ii) Where deviations are shown relative to nominal centre lines of the section, the permitted deviation on cross-section, straightness, length, flatness, cutting, holing and position of fittings, given in Section 9, may be added.

### 11.3 Deviations

11.3.1 The Contractor shall as soon as possible inform the PEPC. of any deviation position of erected steelwork which exceed the permitted deviation in 11.6 so that the effect can be evaluated by the PEPC and decide whether remedial work is required.

11.3.2 Assessment of whether a nonconformity exists shall take into account the unavoidable variability in methods of measurement. Accuracy of construction, see 6.10.3, shall be interpreted in relation to the expected deflections, cambers, pre-sets, elastic movement and the thermal expansion of components.

11.3.3 BS 6954-1 to BS 6954-3 give guidance on tolerances for buildings and the implications of variabilities (including manufacturing, setting-out and erection deviations) on the fit between components.

11.3.4 For the permitted deviations in 11.6.27, 11.6.31, 11.6.32, 11.6.34, 11.6.35 and 11.6.36 closer tolerances, such as those defined in BS 466, may be required for more exacting crane condition and should be defined in the drawings.

### 11.4 Information for Other Contractors

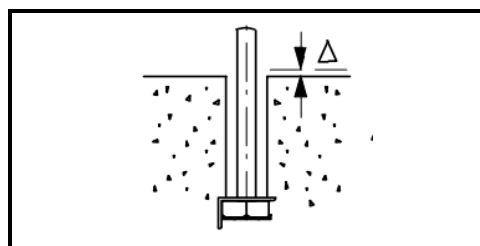
The Contractor shall inform other Sub Contractors engaged in operations following steel erection of the deviations acceptable in this document in fabrication and erection, so that they can provide the necessary clearances and adjustments.

### 11.5 Permitted Deviations for Foundations, Walls and Foundation Bolts

#### 11.5.1 Foundation Level

Deviation,  $\Delta$  from specified level.

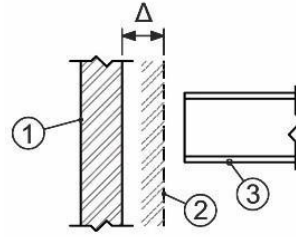
$\Delta = -15\text{mm}$  below /  $+5\text{mm}$  above.



### 11.5.2 Vertical wall

Deviation,  $\Delta$  of actual position  
① from specified position ②  
at steelwork ③ support point.

$$\Delta = \pm 25\text{mm}.$$



### 11.5.3 Pre-set Foundation Bolt or Bolt Groups if Prepared for Adjustment

Deviation ( $\Delta_p$ ) of bolt protrusion relative to intended position.

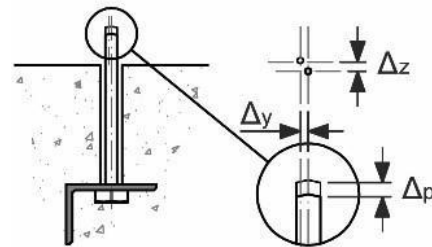
$$\Delta_p = -5\text{mm (low)} / +25\text{mm (high)}.$$

Deviation ( $\Delta_y$  or  $\Delta_z$ ) from specified position at top of concrete.

$$\Delta_y \text{ or } \Delta_z = \pm 10\text{mm}.$$

A minimum clearance of 25mm around the bolt is required for adjustment.

*Note: The permitted deviation for the location of the centre of the foundation bolt group is 6mm.*



### 11.5.4 Pre-set Foundation Bolt or Bolt Groups if Not Prepared for Adjustment

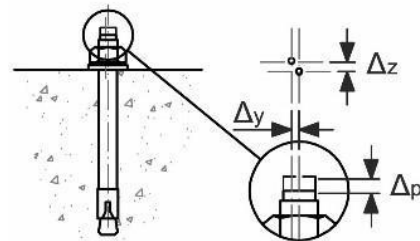
Deviation ( $\Delta_p$ ) of bolt protrusion relative to intended position.

$$(\Delta_p) = -5\text{mm (low)} / +45\text{mm (high)}$$

Deviation ( $\Delta_y$  or  $\Delta_z$ ) from specified position at top of concrete.

$$\Delta_y \text{ or } \Delta_z = \pm 3\text{mm}.$$

*Note: The permitted deviation for the location of the centre of the foundation bolt group is also  $\pm 3\text{mm}$ .*





### 11.5.5 Pre-set Wall Bolt or Bolt Groups if Not Prepared for Adjustment

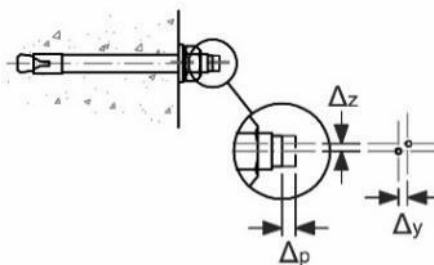
Deviation ( $\Delta_p$ ) of bolt protrusion relative to intended position.

( $\Delta_p$ ) = - 5mm (inwards) / + 45mm (outwards).

Deviation ( $\Delta_y$  or  $\Delta_z$ ) from specified position at face of concrete.

$\Delta_y$  or  $\Delta_z = \pm 3\text{mm}$ .

*Note: The permitted deviation for the location of the centre of the wall bolt group is also  $\pm 3\text{mm}$ . These measurements are measured locally relative to the achieved vertically of the wall as specified in 11.5.5.*

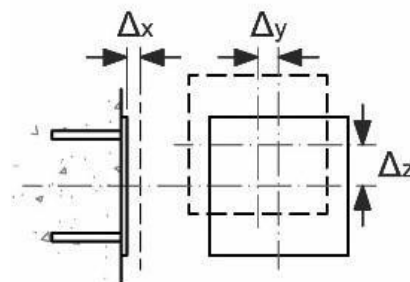


### 11.5.6 Embedded Cast-in Fixing Plates

Deviation ( $\Delta_x$ ,  $\Delta_y$  or  $\Delta_z$ ) of centre lines of the plate relative to the specified positions.

$\Delta_x$ ,  $\Delta_y$  or  $\Delta_z = \pm 10\text{mm}$ .

*Note: These measurements are measured locally relative to the achieved vertically of the wall as specified in 11.5.5.*

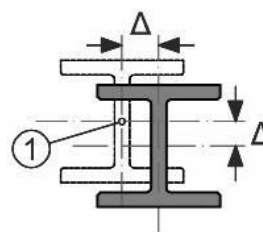


## 11.6 Permitted Deviations of Erected Components

### 11.6.1 Position at Base of First Column Erected

Deviation of section centre line from the specified position.

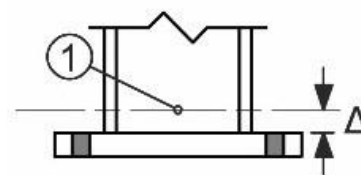
$\Delta = \pm 10\text{mm}$



### 11.6.2 Level of Column at Base

Deviation  $\Delta$  of the top of the base plate from the specified level ①.

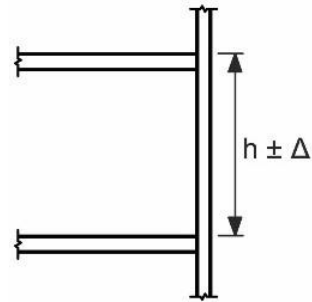
$\Delta = \pm 5\text{mm}$



### 11.6.3 Storey Height

Deviation  $\Delta$  of storey  $h$  measured relative to adjacent levels.

$$\Delta = \pm 10\text{mm}$$



### 11.6.4 Overall Height

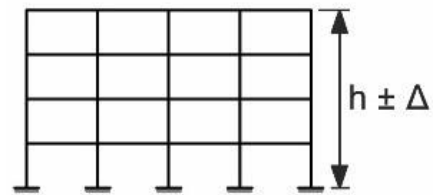
Deviation,  $\Delta$  of overall height,  $h$ .

$$\Delta = 20\text{mm if } h \leq 20\text{m}$$

$$\Delta = 0.5 (h+20) \text{ if } 20\text{m} < h < 100\text{m}$$

$$\Delta = 0.2 (h+200) \text{ if } h \geq 250\text{m}$$

*Note: Value in meters for  $h$  in formulae*

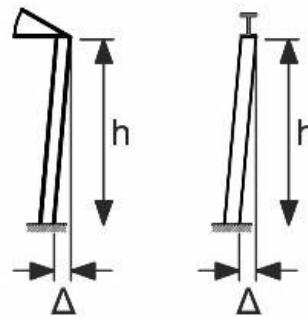


### 11.6.5 Inclination of Single Storey Columns

Deviation,  $\Delta$  of top relative to base, on main axes.

$$\Delta = \pm h/300$$

*Note: Excluding portal frame, see 11.6.6 and 11.6.7, and column supporting crane gantries, see 11.6.25.*

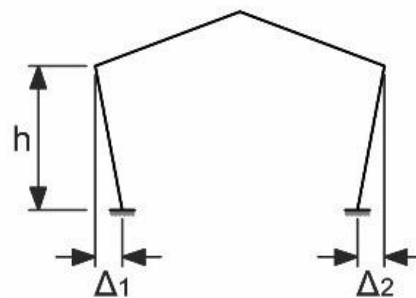


### 11.6.6 Inclination of Individual Columns in Single Storey Portal Frames

Deviation,  $\Delta_i$  of each column.

$$\Delta_1 \text{ or } \Delta_2 = \pm h/150$$

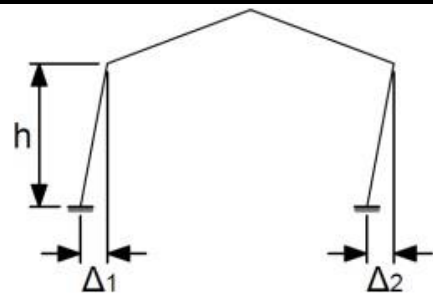
*Note: See clause 5.4.5(iii) regarding pre-setting portal frames.*



### 11.6.7 Inclination of Single Storey Portal Frames

Mean deviation,  $\Delta$  of all the columns in the same frame.

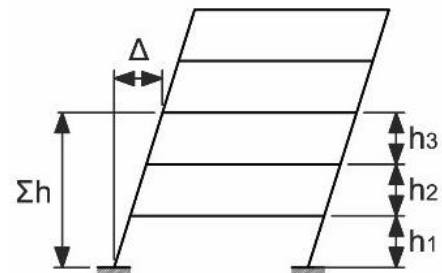
$\Delta = \pm h/500$  (e.g.,  $\Delta = (\Delta_1 + \Delta_2)/2$  for two columns)



### 11.6.8 Overall Inclination of Multi-storey Columns

Deviation,  $\Delta$  of a column centreline in plan at each storey  $n$  relative to a vertical line through column centre at its base.

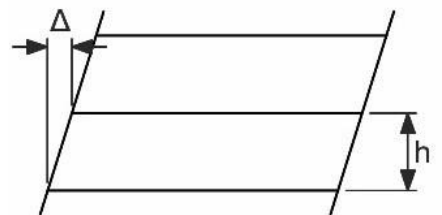
$\Delta = \pm \frac{\Sigma h}{300\sqrt{n}}$  and  $\Sigma h = h_1 + h_2 + h_3 + \text{etc.}$



### 11.6.9 Inclination of Multi-storey Columns over Storey

Deviation in each storey,  $\Delta$  of a column centreline in plan relative to a vertical line through its centre at the next lower level.

$\Delta = \pm h/300$



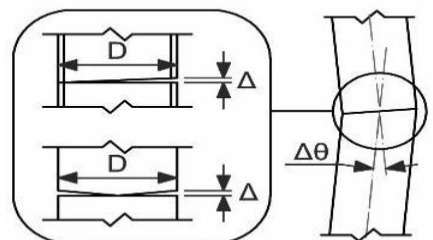
### 11.6.10 Column Splice Alignment and Gap Between Bearing Surfaces

Local angular misalignment  $\Delta\theta$  occurring at same time as gap  $\Delta$ .

$\Delta\theta = \pm 1/500$  radians

$\Delta = 0.5\text{mm}$  over at least two thirds of the area with maximum of  $1.0\text{mm}$  locally.

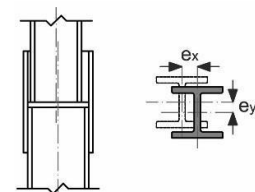
Note: (See clauses 6.3.3, 9.2.3 and 11.6.12)



### 11.6.11 Eccentricity at Column Splice

Non-intended eccentricity  $e = e_x$  or  $e_y$  about either axis.

$e \leq 5\text{mm}$

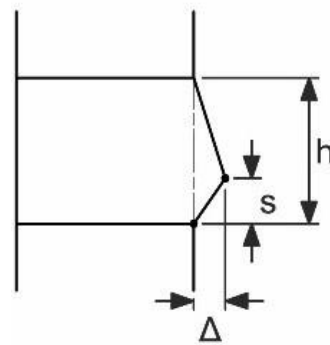


#### 11.6.12 Straightness of A Spliced Column Between Adjacent Storey Levels

Deviation,  $\Delta$  of the column in plan relative to a straight line between position points at adjacent storey levels

$$\Delta = \pm s/1000$$

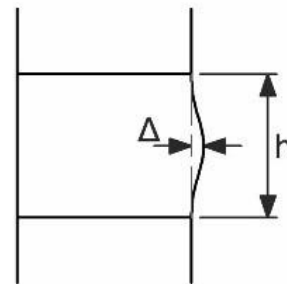
Where  $s$  is the position of the column splice and  $s \leq h/2$



#### 11.6.13 Location of a continuous Column Between Adjacent Storey Levels

Deviation,  $\Delta$  of the column in plan relative to a straight line between position points at adjacent storey levels

$$\Delta = \pm h/1000$$



#### 11.6.14 Overall Plan (Length and Width) Dimensions of Building

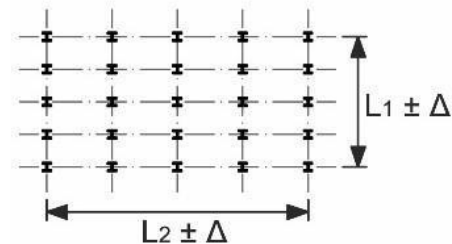
Deviation,  $\Delta$  in distance  $L = L_1$  or  $L_2$ , between end columns in each line at base level.

$$\Delta = 20\text{mm if } L \leq 30\text{m}$$

$$\Delta = 0.25 (L+50) \text{ if } 30\text{m} < L < 250\text{m}$$

$$\Delta = 0.1 (L+500) \text{ if } L \geq 250\text{m}$$

Note: Value in meters for  $L$  in formulae



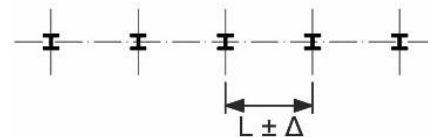
#### 11.6.15 Column Spacing

Deviation,  $\Delta$  in distance  $L$  between centres of columns at base level

$$\Delta = 10\text{mm if } L \leq 5\text{m}$$

$$\Delta = 0.2 (L+45) \text{ if } L > 5\text{m}$$

Note: Value in metres for  $L$  in formulae.



#### 11.6.16 Column Alignment Generally

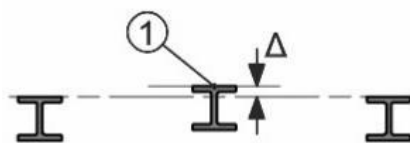
Deviation,  $\Delta$  of the centre of the column at base level relative to the established column line.

$$\Delta = \pm 10\text{mm}$$



#### 11.6.17 Alignment of Adjacent Perimeter Columns

Deviation,  $\Delta$  of the outer face ① of a Perimeter column at base level relative to the line joining the faces of adjacent columns.  $\Delta = \pm 10\text{mm}$

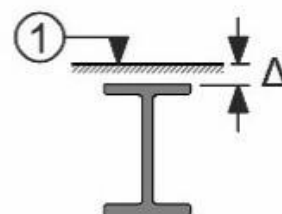


#### 11.6.18 Floor Beams Level

Level of beam  $\Delta$  at beam to column connection measured relative to the established floor level ①

$$\Delta = \pm 10\text{mm}$$

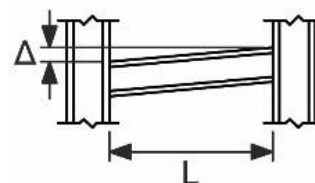
*Note: The established floor level is the level representing a series of beams at one storey level.*



#### 11.6.19 Floor Beams Slope

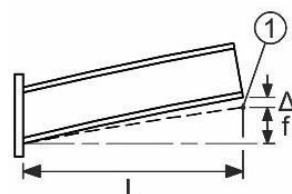
Height  $\Delta$  relative to the other end of A beam of length L.

$$\Delta = \pm L/500 \text{ but not greater than } 10\text{mm}$$



#### 11.6.20 Pre-set of Cantilever

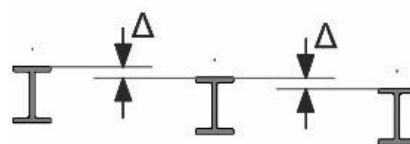
Deviation,  $\Delta$  from intended pre-set  $f$  at end of an erected cantilever of length L.  $\Delta = \pm L/200$



#### 11.6.21 Relative Beam Level

Deviation,  $\Delta$  from relative levels (measured on centreline, of top flange).

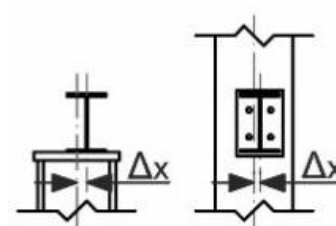
$$\Delta = \pm 10\text{mm}$$



#### 11.6.22 Beam Location

Deviation in line,  $\Delta$  from intended location at a beam-to-column connection measured relative to the column

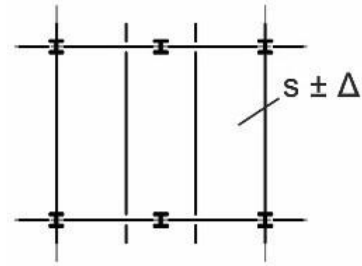
$$\Delta = \pm 5\text{mm}$$



## 11.6.23 Beam Spacing

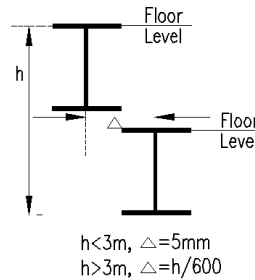
Deviation,  $\Delta$  from intended distance,  $s$  between adjacent erected beams measured at corresponding ends.

$$\Delta = 10\text{mm}$$



## 11.6.24 Beams Alignment

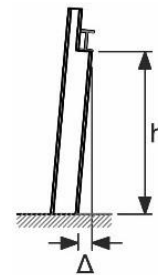
Horizontal deviation relative to an adjacent beam above or below.



## 11.6.25 Inclination of a Crane Gantry Columns

Deviation  $\Delta$  from floor level to the bearing of crane beam.

$$\Delta = \pm h/1000 \text{ up to a maximum of } 25\text{mm}$$



## 11.6.26 Eccentricity of Rail Relative to Web

Eccentricity  $\Delta$  of rail relative to web of thickness,  $t_w$ .

$$\Delta = 5\text{mm if } t_w \leq 10\text{mm}$$

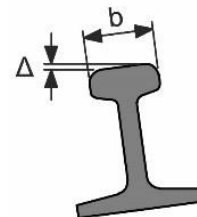
$$\Delta = t_w/2 \text{ if } t_w > 10\text{mm}$$



## 11.6.27 Slope of Rail Surface

Slope  $\Delta$  of top surface of cross-section of crane rail of width  $b$ .

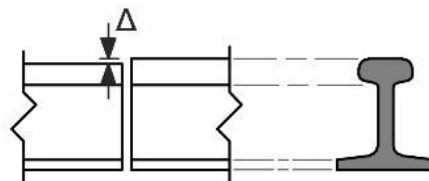
$$\Delta = \pm b/100$$



## 11.6.28 Level of rail

Deviation, Step  $\Delta$  in top of rail at joint.

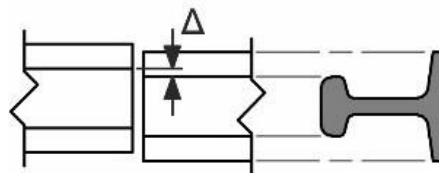
$$\Delta = \pm 1\text{mm}$$



## 11.6.29 Edge of rail

Deviation,  $\Delta$  in edge of rail at joint.

$$\Delta = \pm 1\text{mm}$$

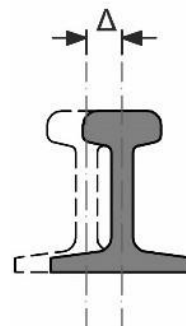


## 11.6.30 Relative location of rail in plan

Deviation,  $\Delta$  in location of rail in plan relative to the intended location.

$$\Delta = \pm 10\text{mm}$$

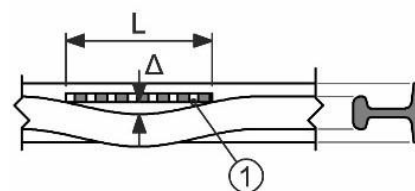
*Note: Location is relative to supporting Steelwork.*



## 11.6.31 Local alignment of rail

Misalignment in plan of rail over gauge of length L equal to 2m.

$$\Delta = \pm 1.5\text{mm}$$

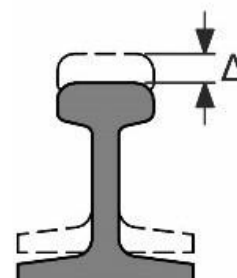


## 11.6.32 Relative level of rail

Deviation,  $\Delta$  in level of rail relative to the intended level.

$$\Delta = \pm 15\text{mm}$$

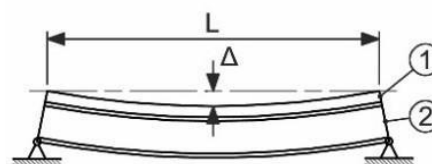
*Note: Location is relative to supporting Steelwork.*



## 11.6.33 Level of rail over crane beam

Variation on level of rail over crane beam of span L.

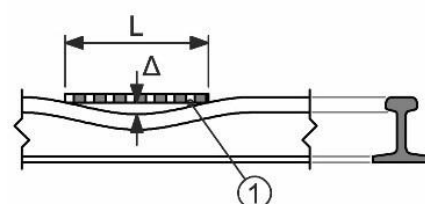
$$\Delta = \pm L/500 \text{ or } 10\text{mm} \text{ whichever is greater}$$



## 11.6.34 Local level of rail

Misalignment in elevation of rail over gauge ① of length L equal to 2m.

$$\Delta = \pm 3\text{mm}$$

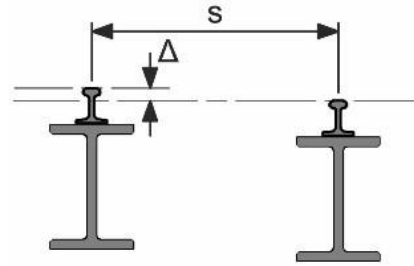


## 11.6.35 Relative level of two rails

Deviation  $\Delta$  in levels of two rails on the two sides of a crane gantry of span  $s$ .

$$\Delta = \pm 20\text{mm if } S \leq 10\text{m}$$

$$\Delta = \pm s/500 \text{ if } S > 10\text{m}$$



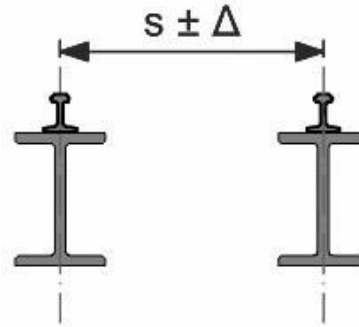
## 11.6.36 Crane gantries gauge of rail tracks

Deviation  $\Delta$  in spacing from nominal gauge,  $s$ .

$$\Delta = 10\text{mm if } s \leq 16\text{m}$$

$$\Delta = 10 + (s/16)/3 \text{ if } s > 16\text{m}$$

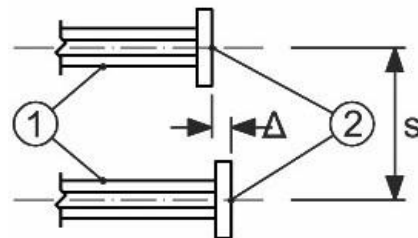
*Note: Value in metres for  $s$  in formula.*



## 11.6.37 Structural end stops

Relative location  $\Delta$  of the end stops ② at the same end measured in the direction of travel on the gantry ①.

$$\Delta = \pm s/1000 \text{ but limited to a maximum of } 10\text{mm}$$



## 11.6.38 Inclination of opposite rails

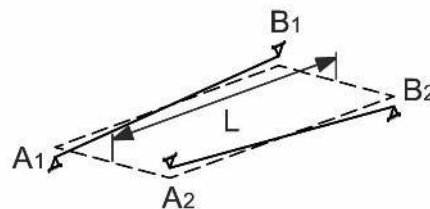
Relative inclination  $\Delta$  of rails opposite sides of a gantry of length  $L$  between adjacent supports.

Inclination of rail  $A_1B_1$  is  $N_1$ .

Inclination of rail  $A_2B_2$  is  $N_2$ .

Relative inclination  $\Delta$  is  $(N_1 - N_2)$  and is limited to  $\pm L/500$ .

*Note: In example  $N_2$  will be a negative slope*



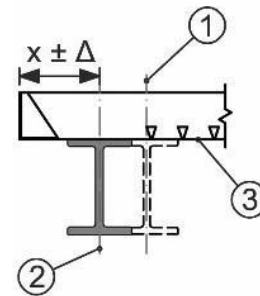


## 11.6.39 Profiled steel floor decking

Deviation  $\Delta$  from nominal dimension  $x$  between decking edge trim prior to concrete placement and actual position of perimeter beam.

$$\Delta = 10\text{mm}$$

*Note: Profile metal floor decking is fixed to beams, and it is relative to those supporting beams that the edge position of the decking is controlled. The deviation, as shown, between actual beam centreline ② and intended beam centreline ① relative to local grid arises from other permitted tolerances, e.g., 11.6.22. Decking ③ is a generic profile and may span in either direction.*



## **12.0 PROTECTIVE TREATMENT (CORROSION AND FIRE)**

### **12.1 General**

12.1.1 The Contractor shall follow the coatings and associated surface preparation required for structural steelwork as specified in the drawings.

12.1.2 The requirements for the following types of protective treatment are given in this Specification:

#### **A. Corrosion protection**

- i) Paint systems, see clause 12.3;
- ii) Hot-dip galvanising, see clause 12.8;
- iii) Metal spraying, see clause 12.9.

#### **B. Fire protection**

- i) Reactive; Intumescent systems, see clause 12.4;
- ii) Non-reactive; Cementitious systems/ Panel, see BCSA Steel Construction Fire Protection.

12.1.3 This Specification only covers Corrosivity Categories C1 to C4. Corrosivity Categories C5 and CX are outside the scope of this Specification and are considered project-specific.

12.1.4 The Contractor shall obtain and submit to the S.O. product and performance warranty certificates for both corrosion and fire protection systems.

12.1.5 The Contractor shall propose the fire protection system which at least contain the required information listed in Appendix 2 for S.O. approval.

12.1.6 The Contractor shall consult paint manufacturer for the coating procedure and test procedure. The procedures shall be approved by the S.O.

### **12.2 Method Statement**

12.2.1 Before any work commences for the application or reapplication of protective coating, the Contractor shall prepare a detailed method statement and submit to the S.O. for acceptance. The method statement shall identify the inspection to be undertaken.

- 12.2.2 A copy of the approved method statement shall be available where the work is being carried out.

## **12.3 Paint Systems**

### **12.3.1 General**

- 12.3.1.1 The protective coating system shall be chosen using one of the specifications described in clause 12.3.2. Surface preparation shall be in accordance with the recommendations given in clause 12.5.
- 12.3.1.2 The products procured shall have been performance tested by the paint manufacturer to demonstrate they conform with the requirements of BS EN ISO 12944-6. The results of the performance tests shall be declared in an assessment report.
- 12.3.1.3 The Contractor shall have access to the assessment reports provided by the paint manufacturer and, if requested, the Contractor shall make the assessment reports available to the S.O.
- 12.3.1.4 A single source of protective coating system supply shall be used for applications off-site, repairs and subsequent maintenance on-site, unless otherwise approved by the S.O.

### **12.3.2 Specification**

The Contractor shall follow the corrosion protection requirements as specified in the drawings which to be read together with the following performance requirements and generic protection coating specifications.

#### **12.3.2.1 Performance Requirements for Protective Coatings**

12.3.2.1.1 The performance requirements for protective coatings are given below:

- i) The Corrosivity Category C1 to C4 in accordance with BS EN ISO 12944-2 or Table 12.7 for the finished structure; and
- ii) The required durability of the corrosion protection in accordance with BS EN ISO 12944-1.

12.3.2.1.2 The Contractor shall review the performance specification and confirm the environmental assumptions for the execution and construction stages (including storage of the protected steelwork prior to erection).

#### 12.3.2.2 Generic Protective Coating Specifications

12.3.2.2.1 The generic protective coating specifications are given in Table 12.1. When choosing this specification, allowance should be made for the environmental conditions during execution and construction stages.

12.3.2.2.2 The nominal DFT's in Table 12.1 satisfy the requirements of Table B2 of BS EN ISO 12944-5. The nominal DFT may need to be increased where high or very high durability is required.

### 12.4 Intumescent Systems

#### 12.4.1 General

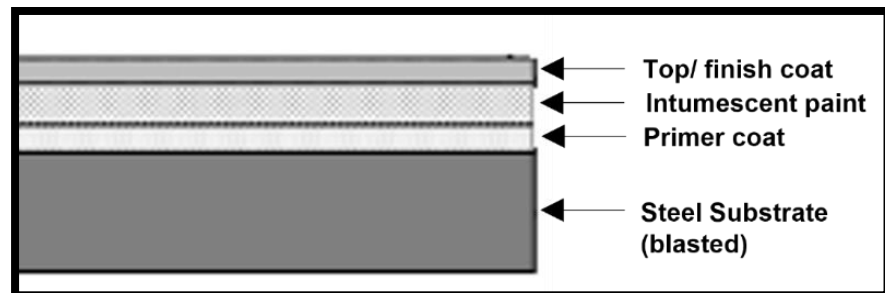
12.4.1.1 These clauses give the requirements for intumescent systems that are applied off-site.

12.4.1.2 The intumescent system shall comprise an epoxy primer, an intumescent coating and an acrylic or acrylic urethane sealer coat for fire protection. The intumescent system shall be chosen using one of the specifications described in clause 12.4.2. Surface preparation shall be in accordance with the recommendations given in clause 12.5.

12.4.1.3 All intumescent systems shall be fire tested to BS EN 13381-8 or BS 476-20, as appropriate and certified by *Jabatan Bomba dan Penyelamat Malaysia* (JBPM). Additionally, intumescent systems shall have passed the appropriate durability and exposure tests in BS EN 16623. The results of the fire tests shall be declared on a test certificate and the results of the durability and exposure tests shall be declared on an assessment report.

12.4.1.4 The Contractor shall have access to the test certificates and assessment report and, if requested, the Contractor, shall make the certificates and assessment reports available to the S.O., PEPC and Inspection Body.

12.4.1.5 A single source of intumescent system supply shall be used for application in the workshop, repairs and subsequent maintenance on-site unless otherwise agreed with the S.O.



*Figure 12.1: Intumescent systems*

## 12.4.2 Specification

The Contractor shall follow the fire protective coating system as specified in the drawings which to be read together with the following performance requirements and generic specifications for intumescent systems.

### 12.4.2.1 Performance Requirements for Intumescent Systems

12.4.2.1.1 The performance requirements for intumescent systems are given below:

- i) The Corrosivity Category C1 to C4 in accordance with BS EN ISO 12944-2 for the finished structure; and
- ii) The required durability of the corrosion protection in accordance with BS EN ISO 12944-1; and
- iii) The associated durability & classification for the intumescent coating in accordance with BS EN 16623; and
- iv) The critical temperatures of structural steel elements; and
- v) The required fire resistance period.

12.4.2.1.2 The performance requirements shall also consider the execution (including storage of the protected steelwork prior to erection), construction and the in-service environmental conditions when assessing the corrosivity category, and durability classification.

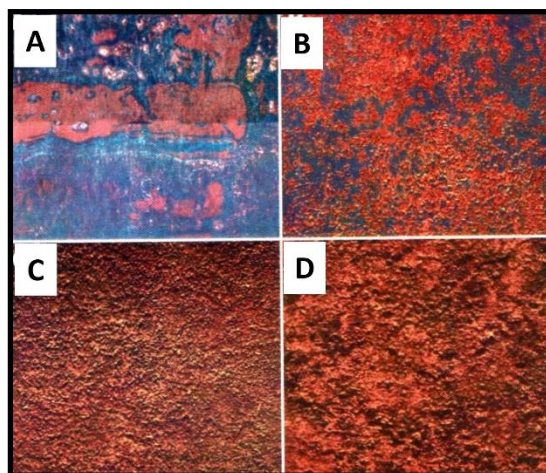
#### 12.4.2.2 Generic Specification for Intumescent Systems

The generic intumescent system specifications are given in Table 12.2. When choosing this specification, allowance should be made for the environmental conditions during execution and construction stages.

### 12.5 Surface Preparation

#### 12.5.1 Surface Condition

The surface condition of the steelwork to be coated shall be in accordance with either rust grades A or B to BS EN ISO 8501-1, prior to the start of surface preparation. Rust grade C to BS EN ISO 8501-1 may be used for buildings exposed to corrosivity categories C1 and C2 with the approval of the S.O. Rust grade D to BS EN ISO 8501-1 shall not be used.



*Figure 12.2: Visual comparison of rust grades*

*Note:*

*Rust Grade A – The steel surface is covered completely with adherent mill scale and with little rust.*

*Rust Grade B – The steel surface has begun to rust and mill scale has begun to flake from the surface.*

*Rust Grade C – The steel surface on which the mill scale has rusted away or from which it can be scrapped, shows little pitting visible to the naked eyes.*

*Rust Grade D – The steel surface on which mill scale has rusted away, shows considerable pitting visible to the naked eyes.*

#### 12.5.2 Surface Preparation

Centrifugal shot blasting or compressed air grit blasting shall be used, in accordance with BS EN ISO 8501-1.



*Figure 12.3: Steel Shot and Steel Grit*

### 12.5.3 Blast, Fabricate and Prime

12.5.3.1 Centrifugal shot blasting before welding and fabrication shall be permitted where MIG, MAG, and submerged arc welding is used. The steel is blast cleaned to ISO 8501-1 Sa2½, but the welds are not blast cleaned.

12.5.3.2 Where MMA welding is used, such welds shall be blasted cleaned to Sa2½ in accordance with BS EN ISO 8501-1 after fabrication. A working mix of typically SS230 – SS280 steel shot may be used to produce a Medium profile in accordance with BS EN ISO 8503-1.

12.5.3.3 Blast cleaning visual standards conforming to BS EN ISO 8501-1 can usually be maintained for several days provided the shot blasted steelwork is kept in heated workshops with a relative humidity typically less than 60%. Steelwork that on visual inspection is found to have tarnished so has cleanliness less than Sa2½ should be re-blast cleaned to achieve the specified cleanliness of Sa2½ in accordance with BS EN ISO 8501-1.

12.5.3.4 Manual grit blasting may be used on steelwork that is too large to fit through a centrifugal shot blasting machine. All steelwork to be coated should be blast cleaned to Sa2½ in accordance with BS EN ISO 8501-1. Typically, G17 – G24 abrasive using either chilled iron or steel grit should be used to produce a surface cleanliness of Sa2½ and medium profile. All steelworks should be coated within 4hrs of blasting. Steelwork that on visual inspection is found to have cleanliness less than Sa2½ in accordance with BS EN ISO 8501-1 or exhibits tarnishing or flash rusting should be blast cleaned to achieve the specified cleanliness of Sa2½ in accordance with BS EN ISO 8501-1.

#### 12.5.4 Surface Cleanliness

12.5.4.1 All steelwork surfaces to be coated shall be blast cleaned to Sa2½ in accordance with BS EN ISO 8501-1.

*Note: Sa2½ surface cleanliness standard – very thorough blast cleaning.*



*Figure 12.4: Blast cleaned steel surface to Sa 2½ standard*

12.5.4.2 The surface cleanliness of the steelwork to be coated after surface preparation shall be clean and free from shot or grit, dust, dirt or overspray, any dye penetrant residues and cutting oils or grease.

12.5.4.3 A dust test using pressure sensitive tape in accordance with BS EN ISO 8502-3 shall be carried out once per day on the steelwork to be coated. Steelwork that is found to have a dust class level of 3 and above in accordance with BS EN ISO 8502-3 shall be cleaned, e.g., vacuum cleaning, sweeping, and re-tested.

	<b>1</b>
	<b>2</b>
	<b>3</b>
	<b>4</b>
	<b>5</b>

*Figure 12.5: Dust class level*

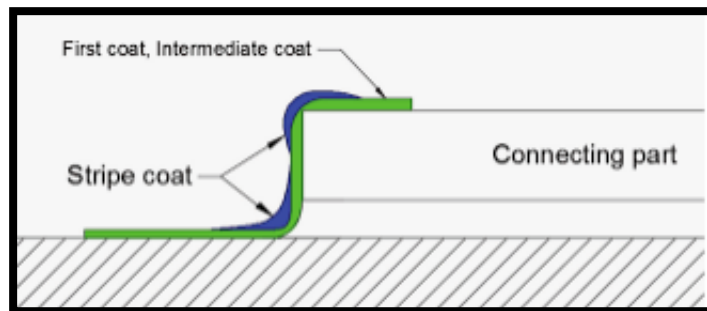
#### 12.5.5 Sharp Edges and Stripe Coats

There are no additional preparation requirements for structures with a Corrosivity Category C1 or C2. Structures with a Corrosivity Category C3 and above shall have the following additional preparation and protection.



#### 12.5.5.1 Plate Cut Edges

Plate cut edges that are exposed shall be blast cleaned and shall have additional edge protection by a brush applied stripe coat, extending across approximately 25mm on both side of the edge and applied to a nominal thickness appropriate for the specified coating system.



*Figure 12.6: Plate cut edge protection by stripe coating  
(Elevation view)*

#### 12.5.5.2 Welds – Generally

MIG, MAG and submerged arc welds that are exposed shall have additional protection, by a brush applied stripe coat, extending across approximately 25mm on both sides of the weld and applied to a nominal thickness appropriate for the specified coating system.

#### 12.5.5.3 Welds – MMA

MMA welds that are exposed shall be bristle blasted, or equivalent, and shall have additional protection, by a brush applied stripe coat, extending across approximately 25mm on both sides of the weld and applied to a nominal thickness appropriate for the specified coating system.

#### 12.5.6 Measurement of Surface Profile

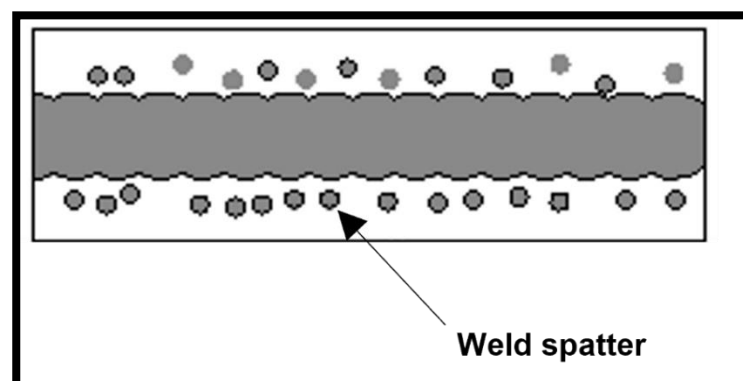
Measurement of the surface profile of steelwork to be coated shall be made using the methods given in BS EN ISO 8503-1, namely using an ISO comparator, and shall be “Medium” grade: equal to Segment 2 (medium grade profile) and not exceeding Segment 3 (coarse grade profile).



*Figure 12.7: ISO comparator*

### 12.5.7 Surface Defects

Surface defect, e.g., surface shells or laminations, including weld spatter, revealed during surface preparation shall be dealt with in accordance with clause 4.6 (surface condition) prior to coating.



*Figure 12.8: Weld spatter (Plan view)*

## 12.6 Application and Inspection of Coatings

### 12.6.1 General

The coating shall be applied in accordance with the coating manufacturer's instructions as approved by the S.O.

## 12.6.2 Storage

12.6.2.1 All paint shall be stored in a suitable ventilated paint store conforming to the requirements of DOSH Guidelines on Storage of Hazardous Chemicals, DOSH Guidelines for The Formulation of Chemical Safety Data Sheet, FMA and OSHA. A bund shall be used when more than 500 litres of paint and solvent is to be stored.

12.6.2.2 Paint shall be stored at temperatures above 5°C and below 35°C or as per manufacturers' instructions.

12.6.2.3 All paint shall be used within the manufacturer's recommended shelf life. Contents shall be in good, undamaged condition and the lid seals shall be unbroken prior to use.

## 12.6.3 Mixing

12.6.3.1 All paint and two pack products like epoxy or acrylic urethane shall be mixed thoroughly prior to application in accordance with the manufacturers' instructions.

12.6.3.2 Where small amounts of paint are required a full unit of paint (base and additive) should be mixed and distributed into several painter's kettles or small tins. Mixing ratios shall always be carefully measured.

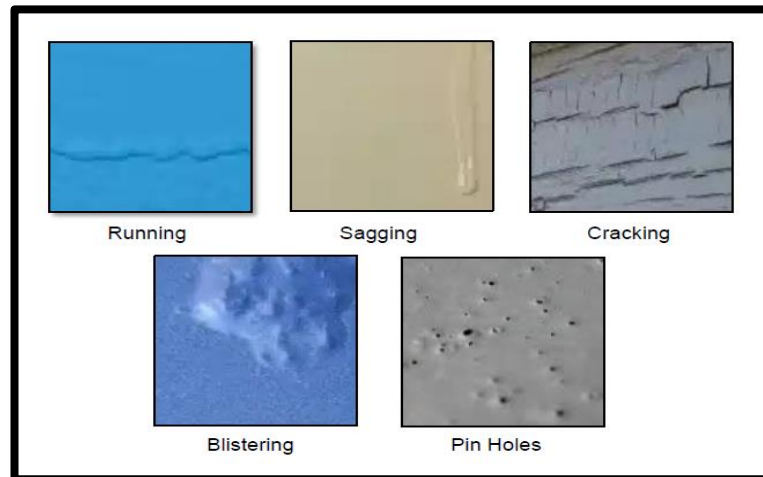
12.6.3.3 Pneumatic or spark free, intrinsically safe electric power drills shall be used with an appropriate twist paddle mixer fitted. Mixer speeds of around 500 rpm should be used.

## 12.6.4 Application

12.6.4.1 All paint shall be applied using airless spray or brush in the case of stripe coats. Each coat shall be applied in multiple passes to achieve a uniform DFT. If thinners are necessary, the amount used should be that recommended in the paint manufacturer's Technical Data Sheet and the maximum amount of solvent shall not exceed 5%. The use of reclaimed solvent (recsol) or gun wash for thinning is forbidden.

12.6.4.2 Painters shall use wet film gauges to regularly check paint thickness. Only stainless- steel wet film gauges in good condition shall be used. Plastic or aluminium wet film gauges shall not be used.

- 12.6.4.3 In the case of protective coatings, they shall be of good visual appearance and free from significant defects, such as low DFTs, missed areas, runs, sags, cracking, pinholes, blistering and shall be free from inclusions and foreign particles, such as grit or shot.



*Figure 12.9: Defects in Protective Coatings*

- 12.6.4.4 Cosmetic finish for intumescent systems is covered in clause 12.6.7.
- 12.6.4.5 The minimum acceptable air temperature for painting shall be 10°C unless a different temperature is recommended by the paint manufacturer. The relative humidity during painting and curing shall not exceed 85%.
- 12.6.4.6 The surface to be painted shall always be clean and dry and the steel temperature shall be at least 3°C above the dew point when painting and curing is in progress.
- 12.6.4.7 Steel trestles or bogies shall be used for painting all structural steel. Trestles should lift the steel to be painted at least 500mm from the floor to prevent airless spray turbulence blowing dry spray and dirt from the floor on to the wet paint. There should be good access to the work piece between the trestles and bogies to enable ease of movement for the painters. Steel laid on timber at floor level shall not be permitted.

## 12.6.5 Painting of Site Weld Areas and Fasteners

12.6.5.1 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.

12.6.5.2 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.

## 12.6.6 Inspection

### 12.6.6.1 General

12.6.6.1.1 The DFT shall be measured in accordance with ISO 19840. DFT measurement instruments, shall be calibrated before taking the first series of readings and once per shift thereafter.

12.6.6.1.2 Plastic shims (foils) used for calibrating shall be in good condition, appropriate for the film thickness to be measured and as close as possible to the specified DFT. Worn shims shall be discarded.

12.6.6.1.3 Calibration of the DFT measurement instruments shall be carried out with the selected shim placed on an uncoated, smooth, flat and visually clean steel test plate. The steel test plate shall be free from mill scale and at least 3mm thick with an area greater than 100mm<sup>2</sup>.

12.6.6.1.4 Adhesion of a single coating or a multi-coat system of paint, varnish or related products can be assessed by measuring the minimum tensile stress required to detach or rupture the coating in a direction perpendicular to the substrate according to the international EN ISO 4624 or ASTM D4541-17; or The cross-cut test (ASTM D3359 – 09 or ISO 2409:2013) as an alternative method.

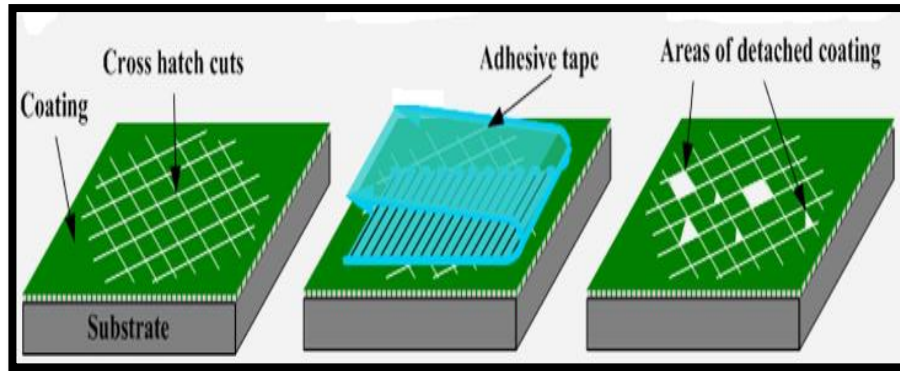


Figure 12.10: Cross-Cut Test

#### 12.6.6.2 Measurement Frequency

DFT measurements shall be taken according to the sampling plan given in Table 12.3. Areas of difficult configuration with regards to paint application shall have an increased number of readings at the Painting Inspector's discretion, with attention paid to stiffeners, the inside of flanges and brackets and boxes. Measurements shall not be taken on surfaces less than 25mm from an edge.

#### 12.6.6.3 Correction Factor for Surface Profile

A correction value of 25 $\mu$ m shall be made to compensate for the BS EN ISO 8501-3 medium blast profile. This value shall be subtracted from every measurement and the corrected DFT shall be recorded and used for inspection assessment and in the quality records.

#### 12.6.6.4 Acceptance/Rejection Criteria

12.6.6.4.1 The following procedure shall be used to accept or reject the DFTs in an inspection area for each layer of paint.

- i) The arithmetic mean of all individual corrected DFTs shall be equal to or greater than the nominal DFT specified;
- ii) All individual corrected DFTs shall be equal to or above 80% of the nominal DFT specified;

- iii) Individual corrected DFTs between 80% of the nominal DFT specified and the nominal DFT specified are acceptable provided that the number of these measurements is less than 20% of the total number of individual measurements taken;
- iv) All individual corrected DFTs shall be less than or equal to the specified maximum DFT for the paint system.

12.6.6.4.2 If the maximum DFT is not given in the paint manufacturer's Technical Data Sheet, it shall be taken as double the nominal DFT given in Table 12.2.

12.6.6.4.3 If the acceptance criteria above are not met, the inspection area shall be rejected pending corrective action.

12.6.6.4.4 The Contractor shall provide the inspection reports to the S.O. Where DFTs are rejected, this shall be treated as a non-conformity. An approved corrective action shall be documented, re-inspected and recorded when completed.

#### 12.6.7 Standard of Cosmetic Finish for Intumescent Coatings

The standard of cosmetic finish for intumescent systems shall achieve the required fire performance and corrosion protection performance but is not required to achieve any requirement for standard of finish.

#### 12.6.8 Supervision and Operatives

The Contractor shall appoint supervisors, inspectors, blasting, painting operatives and other skilled construction workers with SKKP certification as per Amendment of Third Schedule of Act 520, CIDB.

#### 12.6.9 Repair Specification and Maintenance

12.6.9.1 Areas to be repaired and repainted should be first washed down with detergent and water solution to remove any dirt and then rinsed clean with fresh water.

- 12.6.9.2 Areas of spot corrosion should be abraded to St3 in accordance with BS EN ISO 8501-1 using either an orbital (DA) sander or bristle blaster. Disc grinders shall not be used. Cutting discs may be used to break out the coating.

*Note: St3 preparation of steel surface by very thorough hand and power tool cleaning.*

- 12.6.9.3 Areas of exposed steel corrosion larger than typically 75mm X 75mm shall be manually prepared to St3 in accordance with BS EN ISO 8501-1.

- 12.6.9.4 Loose paint shall be taken back to a sound edge, feathering and abrading at least 50mm past the edge to provide a key onto the sound coating.

- 12.6.9.5 Feathering and abrading can be done typically with an orbital sander and an 80-grit self-adhesive aluminium oxide abrasive pad.

- 12.6.9.6 Where bare steel is exposed, an approved compatible surface tolerant anti-corrosive epoxy primer shall be applied by brush, overlapping the edges by at least 25mm. Additional brush coats shall be applied to build up the coating to the original specified DFT.

- 12.6.9.7 Where a cosmetic or decorative coat is required, two or more brush coats may be needed to fully cover the base coat.

- 12.6.9.8 For intumescent systems, the primer shall be suitable for use under the intumescent coating. An approved intumescent mastic or the same intumescent product used in the shop shall be applied to build-up the intumescent and match the required thickness specified in the drawings.

- 12.6.9.9 Once the intumescent is dry the specified sealer coat(s) shall be applied by brush to achieve the specified sealer coat thickness.

- 12.6.9.10 The application and environmental conditions specified in clause 12.6.4 shall be used for site application.

#### 12.6.10 On-site Cleaning

- 12.6.10.1 On-site cleaning of the coating system shall not be carried out unless otherwise approved by the S.O.



12.6.10.2 Where on-site cleaning is carried out, a wash down with a standard household detergent then thorough rinse with either hot or cold water is recommended. Steam cleaners or high-pressure water jetting and chemical cleaners shall not be used.

#### 12.6.11 Transportation, Handling, And Storage of Coated Steelwork

12.6.11.1 The paint systems shall be allowed sufficient time to dry, cure and sufficiently harden before the steelwork is handled. The paint manufacturer's recommendations for over-coating and handling times shall be followed.

12.6.11.2 Wet or partly dried paint should not be exposed to weather conditions such as rain and condensation as these can reduce its protective performance and in the case of intumescent coatings reduced its fire performance.

12.6.11.3 The procedures for transportation, handling and storage of coated steelwork shall be arranged to minimise the risk of damage to the coating. It is good practice to use handling rigs and temporary lifting lugs for large, heavy components.

### 12.7 Coating of Surfaces to Be Encased in Concrete

Structural steel surfaces to be encased in concrete may be left unpainted and need not be blast cleaned unless specified in the drawings.

### 12.8 Hot Dip Galvanising

#### 12.8.1 Specification

12.8.1.1 Galvanising shall be carried out in accordance with ISO 1461. The minimum galvanised coating thickness and mass on samples that are not centrifuged and the minimum galvanised coating thickness and mass that are centrifuged are in Table 12.5 and Table 12.6 respectively.

12.8.1.2 Where a thicker galvanised coating is required, this may be achieved by grit blasting steelwork to Sa2½ with G24 angular iron grit prior to hot dip galvanising.

12.8.1.3 Generally, the steel should meet the requirements of Class B material in Table 1 of BS EN ISO 14713-2.

*Note: Class B – 0.14% ≤ Silicon ≤ 0.25%*

## 12.8.2 Surface Condition

Prior to hot dip galvanising, steelwork shall be free from welding slag, oil or grease, paint, lacquers or other surface contaminants.

## 12.8.3 Inspection

12.8.3.1 Steelwork shall be visual inspected to ensure that it meets the surface finish requirements of ISO 1461.

12.8.3.2 All galvanised components shall be subjected to post-galvanising inspection in accordance with reference PGI-1 in Table 12.4.

12.8.3.3 Where a level of post galvanising inspection other than reference PGI-1 is required, the conditions shall be specified as follows:

- i) Any components for which post-galvanising inspection is not required (PGI-0);
- ii) Any components that shall be subjected to reference PGI-2A in addition;
- iii) Any specific locations that shall be subjected to reference PGI-2B in addition.

12.8.3.4 The results of post-galvanising inspection shall be recorded. These records shall be made available to the S.O., PEPC and Inspection Body.

12.8.3.5 If evidence of cracking is identified, then the component and all similarly shaped components fabricated with similar materials and weld details shall be identified and quarantined as non-conforming products. A photographic record of the cracking shall be made and procedure PGI-3 shall then be used to establish the scope and origin of the problem. The results shall be submitted to the S.O. Quarantined components may only be repaired for use in the Works with the approval of the S.O.

#### 12.8.4 Vent Holes

12.8.4.1 The Contractor shall propose the position of vent and drainage holes in hollow components as laid down in BS EN ISO 14713 and to be approved by the S.O. This includes any requirements for subsequent sealing of components. Vent and drain holes shall be located as close as possible to the high and low points of the hollow section when hung to prevent air locks. Entrapment of pre-treatment solution and zinc pooling as well as being oriented in the same plane as the fabrication.

12.8.4.2 Holes must not be located in the centre of end plates and connections. This will cause cleaning fluids to be trapped and result in uncoated surface inside the plate or connection as well as potential “blowouts” where the cleaning fluids are expelled from the hole under pressure creating bare spots on the finished article. On withdrawal from the galvanizing bath, centre located holes will trap zinc.

12.8.4.3 Hollow sections connected together require external vent and drain holes as close to the connection as possible. Internal venting may also be used to ensure pre-treatment solution and zinc can flow freely through the sections and steam generated from any liquids remaining inside the sections can be efficiently vented.



*Figure 12.11: Vent Holes*

*Note: Vent holes help the steel to be coated evenly throughout the inside and outside of the steel*

#### 12.8.5 Repairs After Cutting or Welding

12.8.5.1 If galvanising has been removed or damaged by welding, the surfaces shall be cleaned (to ensure adhesion), prepared and coated with either:

- i) A suitable zinc-containing paint with zinc dust pigment/ lamellar zinc pigment;
- ii) A suitable paste product or zinc alloy stick;

- iii) Thermal zinc spraying (see ISO 2063-2) within the practical limits of such system.

12.8.5.2 The repair coating thickness on the repair areas shall have a minimum average thickness of 100 micrometre in accordance with ISO 1461

#### 12.8.6 Fire Protection: Intumescent Systems on Hot Dip Galvanised Steel

12.8.6.1 The type and thickness of the intumescent system to be used shall be based on the level of fire protection required, and it shall be suitable for use over zinc.

12.8.6.2 The galvanised surface shall be treated by either a chemical pre-treatment or mechanical pre-treatment procedure, e.g., sweep blasting, to ensure adhesion of the intumescent coating system.

12.8.6.3 The specification of intumescent systems in accordance with BS EN 16623 may be applied on a hot dip galvanised steel substrate after sweep blasting of the galvanised substrate to produce a profile that enhances adhesion between the intumescent coating and the galvanised steel. Alternatively, the galvanised steel surface shall receive an adhesion promoter primer such as aqueous component primer based on synthetic resins, or equivalent. The intumescent system shall be compatible with a surface preparation as recommended by the manufacturer such that good adhesion and its fire protection functionality is achievable. The intumescent system shall have been fire tested and approved by the paint manufacturer for use with the surface preparation as recommended by the manufacturer so that good adhesion and its fire protection functionality over galvanising is assured.

#### 12.8.7 Painting and Powder Coating Galvanised Steel

12.8.7.1 Paint systems in accordance with BS EN ISO 12944-5 may be applied to galvanised steel.

12.8.7.2 Powder coatings of hot dip galvanised steel may be specified in accordance with BS EN 13438 with additional guidance available in BS EN 15773.

12.8.7.3 Galvanised surfaces shall be pre-treated prior to the application of powder coating. Chemical or mechanical pre-treatments shall be used, in accordance with Annex B of BS EN 13438.

## 12.9 Metal Spraying

### 12.9.1 Procedures

Zinc or aluminium sprayed coatings for corrosion protection shall be applied to the surface as required by BS EN ISO 2063 to a thickness as specified in the drawings.

### 12.9.2 Reinstatement of Damaged Coating

All reinstatement of damaged coatings shall be made good to the standard of the original work.

### 12.9.3 Sealing Before Painting

If a sprayed metal coating is to be overcoated subsequently, it shall be sealed before the application of the overcoating. This sealer shall be compatible with the overcoating paint and shall be applied immediately after the metal spraying has cooled, so as to avoid oxidation or moisture trapping.

Table 12.1 Generic protection coating specifications

Type	Corrosivity Category (BS EN ISO 12944)	Functional		Decorative	
		Coating	Nom. DFT <sup>(1)</sup> (µm)	Coating	Nom. DFT <sup>(1)</sup> (µm)
1	C1 Very low	Epoxy Zinc Phosphate	75	Epoxy Zinc Phosphate Acrylic Urethane	75 50
2	C2 Low	Epoxy Zinc Phosphate	100	Epoxy Zinc Phosphate Acrylic Urethane	75 50
3	C3 Medium	Epoxy Zinc Phosphate	125	Epoxy Zinc Phosphate Acrylic Urethane	100 50
4	C4 High	Epoxy Zinc Phosphate Epoxy MIO	100 100	Epoxy Zinc Phosphate Epoxy MIO Acrylic Urethane	75 100 50
5	C4 High Alternative	Zinc Rich Epoxy Epoxy MIO	75 150	Zinc Rich Epoxy Epoxy MIO Acrylic Urethane	75 125 50
1. Nominal Dry Film Thickness (DFT).					

Table 12.2: Generic specification for intumescent systems

Type	Corrosivity Category (BS EN ISO 12944)	Durability classification (BS EN 16623)	Primer <sup>(3)</sup>		Intumescent coating <sup>(1)</sup>	Sealer system <sup>(2)</sup>
			Coating	Nom. DFT (µm)		
1	C1	W/Z2 <sup>(4)</sup>	Epoxy Zinc Phosphate	75	Solvent / Water based acrylic	1 sealer coat
2	C2	W/Z1 <sup>(4)</sup>	Epoxy Zinc Phosphate	75	Solvent / Water based acrylic	1 sealer coat
3	C2	W/Y <sup>(4)</sup>	Epoxy Zinc Phosphate	100	Solvent / Water based acrylic	1 sealer coat
4	C3	W/Y <sup>(4)</sup>	Epoxy Zinc Phosphate	100	Solvent / Water based acrylic	1 sealer coat
5	C3	X <sup>(4)</sup>	Epoxy Zinc Phosphate	125	Solvent / Water based acrylic	2 sealer coats
6	C4	X <sup>(4)</sup>	Epoxy Zinc Phosphate	125	Solvent / Water based acrylic	2 sealer coats
7	C4	X <sup>(4)</sup>	Epoxy Zinc Phosphate	125	Epoxy / Water intumescent	1 sealer coat
1. DFT to be advised by the paint manufacturer. 2. Sealer coat type and DFT to be advised by the paint manufacturer. 3. Where application of the whole intumescent system is carried out in the workshop the DFT can be reduced to 25µm of epoxy blast primer. 4. Definition: W - Reactive coating system intended for temporary external exposure prior to final exposure conditions X - Reactive coating system intended for all conditions internal or external Y - Reactive coating system intended for semi external conditions Z1 - Reactive coating system intended for internal conditions with high humidity Z2 - Reactive coating system intended for internal conditions with controlled environment						

Table 12.3 Sampling plan

Area/length of inspection area (m <sup>2</sup> or m)	Minimum number of measurements	Maximum number of measurements allowed to be repeated
Up to 1	5	1
Above 1 to 3	10	2
Above 3 to 10	15	3
Above 10 to 30	20	4
Above 30 to 100	30	6
Above 100 <sup>(1)</sup>	Add 10 for every additional 100m <sup>2</sup> or 100m or part thereof	20% of the minimum number of requirements
1. Areas above 1000m <sup>2</sup> or 1000m should be divided into smaller inspection areas/lengths.		

Table 12.4 Post-galvanising inspection

Inspection	Visual Inspection	Magnetic Testing
PGI-0	Not required	Not required
PGI-1	100% of all surfaces with special attention to areas around copes, welded connections and joints	Not required
PGI-2A	As required by PGI-1	On 10% of welded connections or node points of welded joints
PGI-2B	As required by PGI-1	On specified areas
PGI-3	Already undertaken	Sufficient to establish the scope and origin of the problem <sup>(1)</sup>
Personnel	Inspection to be undertaken by a suitably trained person <sup>(2)</sup>	NDT to be undertaken by a person suitably qualified on the technique to be used
1. Eddy current and alternating current field measurement tests may be used to assist diagnosis.		

**Table 12.5** Minimum galvanized coating thickness and mass on sample that are not centrifuged

Article and its thickness	Local galvanized coating thickness (minimum) $\mu\text{m}$	Local galvanized coating mass <sup>(1)</sup> (minimum) $\text{g/m}^2$	Mean galvanized coating thickness (minimum) $\mu\text{m}$	Mean galvanized coating mass <sup>(1)</sup> (minimum) $\text{g/m}^2$
Steel: > 6 mm	70	505	85	610
Steel: > 3 mm to $\leq$ 6 mm	55	395	70	505
Steel: $\geq$ 1.5 mm to $\leq$ 3 mm	45	325	55	395
Steel: < 1.5 mm	35	250	45	325
Casting: > 6 mm	70	505	80	575
Casting: $\leq$ 6 mm	60	430	70	505
Note: This table is general use: Individual product standards can include different requirements including different categories of thickness. Local and mean galvanized coating mass requirements are set out in this table for reference in such cases of dispute.				
<sup>(1)</sup> Equivalent galvanized coating mass using a nominal density of $7.2 \text{ g/cm}^3$				

**Table 12.6** Minimum galvanized coating thickness and mass on sample that are centrifuged

Article and its thickness	Local galvanized coating thickness (minimum) $\mu\text{m}$	Local galvanized coating mass <sup>(1)</sup> (minimum) $\text{g/m}^2$	Mean galvanized coating thickness (minimum) $\mu\text{m}$	Mean galvanized coating mass <sup>(1)</sup> (minimum) $\text{g/m}^2$
Articles with threads: > 6 mm diameter $\leq$ 6 mm diameter	40 20	285 145	50 25	360 180
Other articles (including casting): $\geq$ 3 mm < 3 mm	45 35	325 250	55 45	395 325
Note: This table is general use: standards for galvanized fasteners and individual product standards can have difference requirement. Local and mean galvanized coating mass requirements are set out in this table for reference in such cases of dispute.				
<sup>(1)</sup> Equivalent galvanized coating mass using a nominal coating density of $7.2 \text{ g/cm}^3$				



Table 12.7 Atmospheric-corrosivity categories and examples of typical environments

Corrosivity category	Mass loss per unit surface/ thickness loss (after first year of exposure)				Examples of typical environments (informative only)	
	Low-carbon steel		Zinc		Exterior	Interior
	Mass loss g/m <sup>2</sup>	Thickness loss µm	Mass loss g/m <sup>2</sup>	Thickness loss µm		
C1 Very low	≤ 10	≤ 1.3	≤ 0.7	≤ 0.1	-	Heated buildings with clean atmospheres, e.g. offices, shops, schools, hotels
C2 Low	> 10 to 200	> 1.3 to 25	> 0.7 to 5	> 0.1 to 0.7	Atmospheres with low level of pollution: mostly rural areas	Unheated buildings where condensation can occur, e.g. depots, sports halls
C3 Medium	> 200 to 400	> 25 to 50	> 5 to 15	> 0.7 to 2.1	Urban and industrial atmospheres, moderate sulfur dioxide pollution; coastal areas with low salinity	Production rooms with high humidity and some air pollution, e.g. food processing plants, laundries, breweries, dairies
C4 High	> 400 to 650	> 50 to 80	> 15 to 30	> 2.1 to 4.2	Industrial areas and coastal areas with moderate salinity	Chemical plants, swimming pools, coastal ship and boatyards
C5 Very High	> 650 to 1500	> 80 to 200	> 30 to 60	> 4.2 to 8.4	Industrial areas with high humidity and aggressive atmosphere and coastal areas with high salinity	Building or areas with almost permanent condensation and with high pollution

Corrosivity category	Mass loss per unit surface/ thickness loss (after first year of exposure)				Examples of typical environments (informative only)	
	Low-carbon steel		Zinc		Exterior	Interior
	Mass loss g/m <sup>2</sup>	Thickness loss µm	Mass loss g/m <sup>2</sup>	Thickness loss µm		
CX Extreme	> 1500 to 5500	> 200 to 700	> 60 to 180	> 8.4 to 25	Offshore areas with high salinity and industrial areas with extreme humidity and aggressive atmosphere and subtropical and tropical atmospheres	Industrial areas with extreme humidity and aggressive atmosphere
Note: The loss value used for the corrosivity categories are identical to those given in ISO 9223						

**APPENDIX 1****Appendix 1.1: List of Design Requirements**

When the Contractor carries out:

- (i) design and detailing of the steelwork including connections

The Contractor shall comply to the followings:

- (i) The design and detailing shall in accordance with General Notes of the construction drawings;
- (ii) The design and detailing, such as bolts, nuts, and washer, plates, welds and bedding material shall be based on ultimate forces at each joints and structural member sizes given in the construction drawings;
- (iii) To specify the design standard or code of practise to be used;
- (iv) Design parameters;
- (v) Analysis and design – pinned or fixed connection;
- (vi) Lateral stabilising element
- (vii) To specify the protective treatment (corrosion protection and fire protection/fire engineering);
- (viii) Particulars of any aesthetic, structural or clearance limits to be observed, or environmental conditions which may affect detailing or protective treatment;
- (ix) To specify details and locations of any temporary works specified by the PEPC in the design;
- (x) A schedule of drawings, design report, calculations and other information which the Contractor shall submit for S.O. approval;
- (xi) To submit the calculations, design report, detail drawings and shop drawings certified by PEPC for S.O. approval.

*Note: This checklist is also applicable for the design and detailing of any minor or secondary elements within the Contractor's scope of work*

## Appendix 1.2: List of Workmanship Requirements

The Contractor shall provide the followings for the S.O. approval:

- (i) Areas on steelwork where hard stamping or other permanent forms of identification may not be used, see 6.1.3;
- (ii) Any special welding procedures, such as for non-standard joint types, or for restricted access situations, which have to be approved prior to the work commencing;  
*Note: Standard welding procedure requirements are given in 7.3;*
- (iii) Any special requirements regarding fabrication or erection attachments, see 5.4.4 and 7.4.5;
- (iv) Any production test plates which are required, see 7.4.7;
- (v) Any project-specific weld inspection, see 7.5;
- (vi) The weld size for stud welding where processes other than drawn-arc stud welding are proposed, see 7.6.1;
- (vii) Short plate girders that are to be considered restrained for the purposes of 9.4.8.

## Appendix 1.3: List of Erection Requirements

*Note: Information for some of these erection items may be provided separately by the Contractor, or subject to negotiation.*

The Contractor shall provide the Method Statements that consist of the following items for the S.O. approval:

- (i) To specify the working area, for access of Site traffic and cranes, and areas available for storage, see 10.2;
- (ii) To specify list of responsibility and integration with other trades;
- (iii) To identify any limitation on dimensions or weights of components to be delivered to the Site or ground capacity limits for heavy loads;
- (iv) To specify any design features which would affect the construction sequence, or which may create an unusual hazard during construction;
- (v) To identify details of any underground services, overhead cables or Site obstructions;
- (vi) To specify the sequence for erecting the structure taking into account any phasing of The Works, including positions on the structure where temporary bracing, metal decking or other restraints are needed to provide stability to individual members or the structure until walls, floors or other non-steel structures are in position, in accordance with 10.4.1;
- (vii) A description of any temporary works and any special requirements for temporary bracing required by the PEPC to comply with (vi) above; the stage when it is no longer necessary, or whether it is to be left in position after completion of the steelwork;

**Appendix 1.4: List of Protective Treatment Requirements**

The Contractor shall provide the Method Statement that consist of the following items for the S.O.'s approval:

- (i) Surface preparation as per 12.5.
- (ii) Any requirements for paint treatment, see 12.2, 12.3, and 12.5;
- (iii) Any requirements for galvanising including post-galvanising inspection, see 12.8;
- (iv) Thickness and composition of any sprayed metal coatings, see 12.9;
- (v) Responsibility for touch-up of damaged areas and cleaning of surface treatments on Site, and the specification for this work;
- (vi) The fire resistance performance and any requirement for fire protective coating.

**Appendix 1.5: List of Construction Work Programme Requirements**

*Note: Programme dates may be those suggested by the Contractor and approved by the S.O.*

The Contractor shall provide the followings for the S.O.'s approval.

- (i) The proposed starting and completion dates for erection of steelwork and the dates when other contractors' activities are expected to interface with the steelwork

**APPENDIX 2****Technical Data Sheet of Proposed Fire Protection Material**

PRODUCT NAME	
1. Product Description	
2. Name of Manufacturer	
3. Name of Supplier	
4. Protection Technique	
5. Application Technique	
6. Steel Surface Preparation Requirements	
7. Additional Mechanical Fixing or Reinforcement	
8. Physical Characteristics (colour, texture, specific gravity, adhesion, abrasion, etc.)	
9. Number of Coats	
10. Dry Film Thickness Range	
11. Fire Resistance Range	
12. Constraints for Fire Resistance	
13. Appearance	
14. On Site Use	
15. Durability	

## NORMATIVE REFERENCES

- [1] **ASTM D3359-2:** Standard test method for measuring adhesion by type
- [2] **ASTM D4541-17:** Standard test method for pull off strength
- [3] **AWS D1.1:** Structural welding code: steel
- [4] **AWS D1.4:** Structural welding code: steel reinforcement bars
- [5] **BS 2583:** Specification for podger spanners
- [6] **BS 3643-2:** ISO metric screw threads Specification for selected limits of size
- [7] **BS 6954-1:** Tolerances for building Recommendations for basic principles for evaluation and specification
- [8] **BS 6954-3:** Tolerances for building Recommendations for selecting target size and predicting fit
- [9] **BS 7371-1:** Coatings on metal fasteners Specification for general requirements and selection guidelines
- [10] **BS 7371-8:** Coatings on metal fasteners Specification for sherardized coatings
- [11] **BS 7668:** Weldable structural steels. Hot finished structural hollow sections in weather resistant steels. Specification
- [12] **BS EN 1090-2:** Execution of steel structures and aluminium structures technical requirements for steel structures
- [13] **BS EN 1090-4:** Execution of steel structures and aluminium structures technical requirements for cold-formed structural steel elements and cold-formed structures for roof, ceiling, floor and wall applications
- [14] **BS EN 1011-1:** Welding. Recommendations for welding of metallic materials General guidance for arc welding
- [15] **BS EN 10160:** Ultrasonic testing of steel flat product of thickness equal or greater than 6 mm (reflection method)
- [16] **BS EN 10163-1:** Delivery requirements for surface condition of hot-rolled steel plates, wide flats and sections General requirements
- [17] **BS EN 10163-2:** Delivery requirements for surface condition of hot-rolled steel plates, wide flats and sections Plate and wide flats

- [18] **BS EN 10163-3:** Delivery requirements for surface condition of hot-rolled steel plates, wide flats and sections
- [19] **BS EN 15048-1:** Non-preloaded structural bolting assemblies General requirements
- [20] **BS EN 14399-3:** High-strength structural bolting assemblies for preloading System HR. Hexagon bolt and nut assemblies
- [21] **BS EN 14399-4:** High-strength structural bolting assemblies for preloading System HV. Hexagon bolt and nut assemblies
- [22] **BS EN 14399-5:** High-strength structural bolting assemblies for preloading Plain washers
- [23] **BS EN 14399-6:** High-strength structural bolting assemblies for preloading Plain chamfered washers
- [24] **BS EN 14399-8:** High-strength structural bolting assemblies for preloading System HV. Hexagon fit bolt and nut assemblies
- [25] **BS EN 10365:** Hot rolled steel channels, I and H sections. Dimensions and masses
- [26] **BS EN 1003:** Structural steel I and H sections. Tolerances on shape and dimensions
- [27] **BS EN 10024:** Hot rolled taper flange I sections. Tolerances on shape and dimensions
- [28] **BS EN 10279:** Hot rolled steel channels. Tolerances on shape, dimension and mass
- [29] **BS EN 10056-1:** Structural steel equal and unequal leg angles Dimensions
- [30] **BS EN 10056-2:** Specification for structural steel equal and unequal angles Tolerances on shape and dimensions
- [31] **BS EN 10029:** Hot-rolled steel plates 3 mm thick or above. Tolerances on dimensions and shape
- [32] **BS EN 10051:** Continuously hot-rolled strip and plate/sheet cut from wide strip of non-alloy and alloy steels. Tolerances on dimensions and shape
- [33] **BS EN 14399-7:** High-strength structural bolting assemblies for preloading System HR. Countersunk head bolt and nut assemblies



- [34] **BS EN 14399-10:** High-strength structural bolting assemblies for preloading System HRC. Bolt and nut assemblies with calibrated preload
- [35] **BS EN 14399-9:** High-strength structural bolting assemblies for preloading System HR or HV. Direct tension indicators for bolt and nut assemblies
- [36] **BS EN 3643-1:** ISO metric screw threads. Principles and basic data
- [37] **BS EN 3643-2:** ISO metric screw threads
- [38] **BS EN 10346:** Continuously hot-dip coated steel flat products for cold forming. Technical delivery conditions
- [39] **BS EN 10143:** Continuously hot-dip coated steel sheet and strip. Tolerances on dimensions and shape
- [40] **BS EN 15773:** Industrial application of powder organic coatings to hot dip galvanized or sherardized steel articles [duplex systems]. Specifications, recommendations and guidelines
- [41] **BS EN 13438:** Paints and varnishes. Powder organic coatings for hot dip galvanized or sherardized steel products for construction purposes
- [42] **BS EN 10204:** Metallic products. Types of inspection documents
- [43] **BS EN ISO 8501-1:** Preparation of steel substrates before application of paints and related products. Visual assessment of surface cleanliness Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings
- [44] **BS EN ISO 2560:** Welding consumables. Covered electrodes for manual metal arc welding of non-alloy and fine grain steels. Classification
- [45] **BS EN ISO 14341:** Welding consumables. Wire electrodes and weld deposits for gas shielded metal arc welding of non-alloy and fine grain steels. Classification
- [46] **BS EN ISO 14174:** Welding consumables. Fluxes for submerged arc welding and electroslag welding. Classification
- [47] **BS EN ISO 17632:** Welding consumables. Tubular cored electrodes for gas shielded and non-gas shielded metal arc welding of non-alloy and fine grain steels. Classification
- [48] **BS EN ISO 4035:** Hexagon thin nuts chamfered (style 0). Product grades A and B

- [49] **BS EN ISO 4036:** Hexagon thin nuts unchamfered (style 0). Product grade B
- [50] **BS EN ISO 4042:** Fasteners. Electroplated coating systems
- [51] **BS EN ISO 10684:** Fasteners. Hot dip galvanized coatings
- [52] **BS EN ISO 13918:** Welding. Studs and ceramic ferrules for arc stud welding
- [53] **BS EN ISO 14713-2:** Zinc coatings. Guidelines and recommendations for the protection against corrosion of iron and steel in structures Hot dip galvanizing
- [54] **BS EN ISO 4014:** Fasteners. Hexagon head bolts. Product grades A and B
- [55] **BS EN ISO 4016:** Fasteners. Hexagon head bolts. Product grade C
- [56] **BS EN ISO 4017:** Fasteners. Hexagon head screws. Product grades A and B
- [57] **BS EN ISO 4018:** Fasteners. Hexagon head screws. Product grade C
- [58] **BS EN ISO 4043:** Simultaneous interpreting. Mobile booths. Requirements
- [59] **BS EN ISO 7091:** Plain washers. Normal series. Product grade C
- [60] **BS EN ISO 4032:** Hexagon regular nuts (style 1). Product grades A and B
- [61] **BS EN ISO 4033:** Hexagon high nuts (style 2). Product grades A and B
- [62] **BS EN ISO 898-1:** Mechanical properties of fasteners made of carbon steel and alloy steel Bolts, screws and studs with specified property classes. Coarse thread and fine pitch thread
- [63] **BS EN ISO 965-5:** ISO General Purpose Metric Screw Threads
- [64] **BS EN ISO 4157-1:** Construction drawings. Designation systems Buildings and parts of buildings
- [65] **BS EN ISO 2553:** Welding and allied processes. Symbolic representation on drawings. Welded joints
- [66] **BS EN ISO 9013:** Thermal cutting. Classification of thermal cuts. Geometrical product specification and quality tolerances
- [67] **BS EN ISO 9692:** Welding and allied processes
- [68] **BS EN ISO 9606-1:** Qualification testing of welders. Fusion welding Steels

- [69] **BS EN ISO 9606-2:** Qualification test of welders. Fusion welding Aluminium and aluminium alloys
- [70] **BS EN ISO 14732:** Welding personnel. Qualification testing of welding operators and weld setters for mechanized and automatic welding of metallic materials
- [71] **BS EN ISO 17660-1:** Welding. Welding of reinforcing steel Load-bearing welded joints
- [72] **BS EN ISO 17660-2:** Welding. Welding of reinforcing steel Non load-bearing welded joints
- [73] **BS EN ISO 17024:** Conformity assessment. General requirements for bodies operating certification of persons
- [74] **BS EN ISO 15614-1:** Specification and qualification of welding procedures for metallic materials. Welding procedure test Arc and gas welding of steels and arc welding of nickel and nickel alloys
- [75] **BS EN ISO 15613:** Specification and qualification of welding procedures for metallic materials. Qualification based on pre-production welding test
- [76] **BS EN ISO 9018:** Destructive tests on welds in metallic materials. Tensile test on cruciform and lapped joints
- [77] **BS EN ISO 17635:** Non-destructive testing of welds. General rules for metallic materials
- [78] **BS EN ISO 13916:** Welding. Measurement of preheating temperature, interpass temperature and preheat maintenance temperature
- [79] **BS EN ISO 9712:** Qualification and certification of NDT personnel
- [80] **BS EN ISO 17637:** Non-destructive testing of welds. Visual testing of fusion-welded joints
- [81] **BS EN ISO 17638:** Non-destructive testing of welds. Magnetic particle testing
- [82] **BS EN ISO 3452-1:** Non-destructive testing. Penetrant testing General principles
- [83] **BS EN ISO 14555:** Welding. Arc stud welding of metallic materials
- [84] **BS EN ISO 17640:** Non-destructive testing of welds. Ultrasonic testing. Techniques, testing levels, and assessment

- [85] **BS EN ISO 23279:** Non-destructive testing of welds. Ultrasonic testing. Characterization of discontinuities in welds
- [86] **BS EN ISO 5817:** Welding. Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded). Quality levels for imperfections
- [87] **BS EN ISO 23277:** Non-destructive testing of welds. Penetrant testing. Acceptance levels
- [88] **BS EN ISO 23278:** Non-destructive testing of welds. Magnetic particle testing. Acceptance levels
- [89] **BS EN ISO 11666:** Non-destructive testing of welds. Ultrasonic testing. Acceptance levels
- [90] **BS EN ISO 10675-1:** Non-destructive testing of welds. Acceptance levels for radiographic testing Steel, nickel, titanium and their alloy
- [91] **BS EN ISO 7976-1:** Tolerances for building — Methods of measurement of buildings and building products— Part 1: Methods and instruments
- [92] **BS EN ISO 7976-2:** Tolerances for building — Methods of measurement of buildings and building products — Part 2: Position of measuring points
- [93] **BS EN ISO 17123:** Optics and optical instruments — Field procedures for testing geodetic and surveying instruments
- [94] **BS EN ISO 4463-1:** Measurement methods for building — Setting-out and measurement — Part 1: Planning and organization, measuring procedures, acceptance criteria
- [95] **BS EN ISO 12944-1:** Paints and varnishes. Corrosion protection of steel structures by protective paint systems General introduction
- [96] **BS EN ISO 12944-2:** Paints and varnishes. Corrosion protection of steel structures by protective paint systems Classification of environments
- [97] **BS EN ISO 12944-5:** Paints and varnishes. Corrosion protection of steel structures by protective paint systems Protective paint systems
- [98] **BS EN ISO 12944-6:** Paints and varnishes. Corrosion protection of steel structures by protective paint systems Laboratory performance test methods
- [99] **BS EN 13381-8:** Test methods for determining the contribution to the fire resistance of structural members Applied reactive protection to steel members

- [100] **BS 476-20:** Fire tests on building materials and structures Method for determination of the fire resistance of elements of construction (general principles)
- [101] **BS EN 16623:** Paints and varnishes. Reactive coatings for fire protection of metallic substrates. Definitions, requirements, characteristics and marking
- [102] **BS EN ISO 8503-1:** Preparation of steel substrates before application of paints and related products. Surface roughness characteristics of blast-cleaned steel substrates Specifications and definitions for ISO surface profile comparators for the assessment of abrasive blast-cleaned surfaces
- [103] **BS EN ISO 19840:** Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Measurement of, and acceptance criteria for, the thickness of dry films on rough surfaces
- [104] **BS EN ISO 4624:** Paints and varnishes. Pull-off test for adhesion
- [105] **BS EN ISO 2063:** Thermal spraying. Zinc, aluminium and their alloys Design considerations and quality requirements for corrosion protection systems
- [106] **CIS 22:** Safe use of scaffolding in construction
- [107] **CIS 23:** Safe use of falsework in construction
- [108] **ISO 1461:** Hot dip galvanized coatings on fabricated iron and steel articles. Specifications and test methods
- [109] **ISO 9000:** Quality management and Quality assurance
- [110] **ISO 9034:** Hot-rolled structural steel wide flats — Tolerances on dimensions and shape
- [111] **MS EN 10080:** Steel for the reinforcement of concrete - Weldable reinforcing steel – General
- [112] **MS EN 10210-1:** Hot finished structural hollow sections of non-alloy and fine grain steels - Part 1: Technical delivery conditions
- [113] **MS EN 10210-2:** Hot finished structural hollow sections of non-alloy and fine grain steels - Part 2: Tolerances, dimensions and sectional properties
- [114] **MS EN 10219-1:** Cold formed welded structural hollow sections of non-alloy and fine grain steels - Part 1: Technical delivery conditions

- [115] **MS EN 10219-2:** Cold formed welded structural hollow sections of non-alloy and fine grain steels - Part 2: Tolerances, dimensions and sectional properties
- [116] **MS EN 10025-2:** Hot rolled products of structural steels - Part 2: Technical delivery conditions for non-alloy structural steels (Second revision)
- [117] **MS EN 10025-3:** Hot rolled products of structural steels - Part 3: Technical delivery conditions for normalized/ normalized rolled weldable fine grain structural steels
- [118] **MS EN 10025-4:** Hot rolled products of structural steels - Part 4: Technical delivery conditions for thermomechanical rolled weldable fine grain structural steels
- [119] **MS EN 10025-5:** Hot rolled products of structural steels - Part 5: Technical delivery conditions for structural steels with improved atmospheric corrosion resistance
- [120] **MS ISO 14171:** Welding consumables - wire electrodes and wire-flux combinations for submerged arc welding of non-alloy and fine grain steels - classifications

## ACKNOWLEDGEMENTS

### Committee Members

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