

CHAPTER EIGHT

Specification of Iron and Steelwork

THIS chapter is primarily concerned with the drafting of specification clauses covering structural steelwork with riveted and welded connections. Incidental items of metalwork such as ladders, handrailing and open steel flooring, and some of the more common forms of wall and roof sheeting are also included.

Probable main headings in a structural steelwork specification are as follows

- (1) Structural steel
- (2) Fabrication
- (3) Inspection and marking
- (4) Erection
- (5) Bolting
- (6) Riveting
- (7) Welding
- (8) Measurement
- (9) Testing
- (10) Painting

Structural steelwork is normally supplied and erected by a steel fabricator, who may also carry out the painting of the steelwork. On very large structural steelwork contracts the steel fabricator, as main contractor under the steelwork contract, may also be responsible for incidental work such as roof decking, ventilators and patent glazed lanterns, which are to be provided by nominated sub-contractors. The steelwork contractor is usually required to prepare working drawings of the permanent steelwork and to submit them to the Engineer for approval before any work is put in hand. He also furnishes corrected or amended drawings as necessary.

STRUCTURAL STEELWORK

Structural steel

Structural steel shall be to the approval of the Engineer or his representative and shall comply with the requirements of B.S. 15: Mild Steel for General Structural Purposes. Steelwork for bridges shall comply with B.S. 153: Steel Girder Bridges, Part I.

Steel castings shall comply with the requirements of B.S. 3100: Steel Castings for General Purposes.

High tensile steel for riveted work shall comply with the requirements of B.S. 548: High-tensile Structural Steel for Bridges, etc., and General Building Construction, and for welded work it shall comply with B.S. 968: High Yield Stress (Welding Quality) Structural Steel.

Numerous references are made to British Standards which lay down stringent standards and tests to be performed on the steel. For instance, B.S. 15 specifies the process of manufacture, with maximum limits of sulphur and phosphorous contents, and describes the tests to be carried out on plates, sections, bars and rivets. The standard also covers marking, certificates and testing procedures.

Fabrication

Workmanship and general fabrication procedure shall be in accordance with B.S. 153, Part 2, where appropriate, and with the best modern practice for structural steelwork.

The edges of universal plates or flats need not be machined except for accurate fitting against adjacent parts. All butting members shall have their ends machined after fabrication.

Where turned bolts are to be used, the holes shall be reamed through the full thickness while the members are held in their correct relative positions. With the approval of the Engineer turned bolts may be used as an alternative to rivets for site connections.

Most of the normal fabrication workmanship requirements are contained in B.S. 153, Part 2. Any additional requirements should be inserted in the specification.

Members can be connected in several different ways: bolting, riveting, welding and, more recently, by the use of high strength friction grip bolts (B.S. 3139 and 3294).

In connection with girder work, it is sometimes specified that plates and bars shall be accurately assembled, and shall be of uniform thickness

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All stiffeners shall bear tightly against the compression flange and against the loaded flange at points of concentrated load. At other points the ends of riveted stiffeners shall, unless tightly fitted, provide a clearance of at least 10 mm ($\frac{3}{8}$ in.) between their ends and the tension flange, with the outstanding leg bevelled. The ends of welded stiffeners shall be sawn square or to the correct bevel and shall fit tightly against both flanges.

All members shall be to the dimensions shown on the Drawings, cut to exact lengths and finished true and square.

All holes shall be accurately marked from templates and shall be drilled to give smooth edges. The diameters of holes shall not exceed those of the bolts or rivets by more than 1.5 mm ($\frac{1}{16}$ in.).

The Engineer may require the Contractor to erect each part of the steel structure temporarily in the shop, to check the accuracy of the work.

Inspection and marking

The Contractor shall notify the Engineer when materials are ready for inspection at the maker's works and fabricated material at the fabricator's works.

After checking or testing at the fabricator's works all members and fittings shall, for the purpose of identification during erection, have a distinguishing number and letter (corresponding to the distinguishing number and letter on an approved drawing) painted and where possible also stamped on in two positions.

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and free from winding, with the surface of adjoining plates and bars in close contact.

Another requirement might be that plates shall be of sufficient size to permit 3 mm ($\frac{1}{8}$ in.) to be planed off all edges.

With regard to bolt and rivet holes, it will be noted that punching of holes and drifting will not be permitted.

The Contractor must provide adequate facilities for inspection of materials by the Engineer at fabricating and manufacturer's shops. It is good practice to have all structural members and fittings suitably marked for ease of working on the job.

Erection

Ordinary steelwork may have a tolerance not exceeding 1 in 500 and steelwork around lift shafts shall not be greater than 1 in 1000 from plumb. Girders shall have a camber of uniform curvature of 5 mm for every metre of span ($\frac{1}{8}$ in. for every foot of span).

All columns and bases shall be set accurately to the required lines and levels, and all holding-down bolts shall be strictly in accordance with the detailed drawings. Concrete bases shall be laid not less than one month before the steelwork is placed in position.

Grillages shall be set truly level by careful levelling at each corner. Girders shall be lowered slowly onto their seating cleats, with each end secured initially by at least one bolt and nut.

No member of the structure shall be finally bolted, riveted or welded until the whole or a major section is approved by the Engineer for line, levels and verticality. Connections shall be completed as soon as possible after receipt of the Engineer's written approval, with care being taken not to interfere with existing steelwork in any way.

Bolting

All bolts, nuts, rods, straps and the like shall comply with the latest appropriate British Standard. Unless otherwise stated all bolts shall have washers 5 mm ($\frac{3}{16}$ in.) thick, and heads and nuts shall be well forged hexagonal Whitworth screws. All bolts shall be screwed tight with at least one clear thread projecting beyond the nut when tightened

It is essential that all the structural members should be accurately fixed in the correct positions, and if any tolerances are permitted, then these must be detailed in the specification.

It is advisable to fix individual members temporarily in the first instance and to carry out the final connections when each structure or section thereof has been inspected and approved by the Engineer.

General requirements as to bolts and washers should be supplied where bolting is permitted. It is imperative that all bolts should be screwed up tight and have a projecting thread beyond the nut. This is subsequently riveted down or welded.

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up, and the projecting thread shall be riveted down or welded.

Tapered washers shall be provided to bolts which pass through the flanges of rolled joists, etc. The external diameter of washers shall be $2\frac{1}{2}$ times the diameter of the bolt.

Riveting

Rivets shall be of the size and to the pitch shown on the Drawings, and shall be of best quality mild steel and be set up by hydraulic power to fill the holes completely when closed up. They shall have hemispherical heads with a projection in all directions of not less than $\frac{1}{4}$ times the diameter of the rivet.

Any rivets which are away from adjoining surfaces, badly formed, cracked or in any way defective, shall be cut out and replaced. No riveting shall be carried out until the work has been approved by the Engineer and the members shall be bolted together in advance of the riveting.

Welding

Welding shall be performed by an electric arc process conforming to best British practice and complying with the requirements of B.S. 1856: General Requirements for the Metal-Arc Welding of Mild Steel. All welding shall be carried out by fully trained and experienced welders.

The welding procedure for making each joint shall be approved by the Engineer before work is commenced and the Contractor shall make such trial

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B.S. 3139 deals with dimensions, mechanical properties and tests of high strength friction grip bolts.

It is important that rivets should be provided of the sizes and in the positions required, and that they should be properly formed with well shaped and adequately sized heads.

The specification requirements for welding need to be given in considerable detail to ensure a good class, sound job. As on previous occasions the use of British Standards can help considerably in this respect.

It is usual to require all welding to be performed by the electric arc process, although it can be carried out

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welds as may be required to demonstrate the soundness of the proposed method and the competence of his workmen.

Electrodes shall be grade A, of the best heavy-coated type, and shall be kept in a dry store in unbroken packets. They shall comply with the requirements of B.S. 639: Covered Electrodes for Metal-arc Welding of Mild Steel. Fillet welds shall be made with electrodes not less than 6 mm ($\frac{1}{4}$ in.) in diameter.

The welding plant shall be of modern design and of adequate capacity to produce the required current to each welding point without appreciable fluctuations.

All parts to be welded shall be accurately prepared so that they will fit closely together. After assembly and before the general welding is commenced, the parts shall be tack welded with small fillet welds about 50 mm (2 in.) long made with a 5 mm ($\frac{3}{16}$ in.) diameter electrode and a high current. The tack welds shall be of the same quality and size as the first run of the main weld. When the latter is deposited it shall fuse completely with the ends of the tack welds to form a final profile free from irregularities.

Measurement

Prices for steelwork shall include for the supply, fabrication, delivery and erection of the steelwork as shown on the Drawings and to the satisfaction of the Engineer. Steelwork rates shall include the cost of all necessary staging,

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either manually with coated electrodes or by a suitable automatic process. When welding high tensile steel it is often necessary to use electrodes of the basic-coated or hydrogen-free variety.

It is necessary to make suitable allowance in the lengths of steel parts for contraction during welding, in order that the finished lengths will be within the normally accepted limits.

Steelwork rates are to include everything required in the supply, manufacture and erection of the steelwork complete. The actual weights of steel sections may vary

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plant, equipment and materials required in the erection of the steelwork.

Payment shall be made on the basis of the calculated weights as determined from the dimensions given on the Drawings. Where the weight of any rolled steel is short of the calculated weight by more than $2\frac{1}{2}$ per cent, but the material is nevertheless accepted, then payment shall be made only for the actual weight of steel supplied.

In the case of mild steel plates, the calculated weight shall be based on 185 kg/m^2 , 25 mm thick (40.8 lb/ft^2 , 1 in. thick), and with mild steel standard sections the calculated weight shall be based on the weight per linear metre (foot) specified in the relevant British Standard Specification. No additional weight for weld metal deposited will be included in the measurements.

Testing

The Contractor shall test all welds in main plates and such other welds as the Engineer may direct, with X-ray or gamma-ray apparatus.

No part of the steelwork shall at any time be loaded in excess of the designed working load. On completion of steel-framed bridges, the Contractor shall provide, position and move from place to place, such rollers and loaded trailers as the Engineer may require for testing purposes. The Contractor shall also supply and fix, as directed by the Engineer, sufficient instruments for the measurement of deflection and stresses. Any work shown to be defective by these tests shall be removed and replaced at the Contractor's expense.

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from the calculated weights due to wear and tear on the manufacturer's plant. The permissible allowance for rolling margin is usually $2\frac{1}{2}$ per cent up or down from the calculated weights. Where a deficiency in excess of $2\frac{1}{2}$ per cent occurs it is customary to pay only on the basis of the actual weights supplied, otherwise the basis of payment is that of calculated weights.

Adequate testing of structural frameworks to design loadings is most desirable. The responsibility for failure may not always lie with the Contractor, as for instance where the failure results from errors in a design prepared by the Engineer. It was a common practice in some quarters in years gone by to require the Engineer responsible for the design of a structure to remain beneath it while test loads were applied.

MISCELLANEOUS ITEMS

Ladders

All ladders shall be 375 mm (15 in.) wide overall, fabricated of 65 mm × 15 mm (2½ in. × ½ in.) steel strings and stays, with 20 mm (¾ in.) diameter rungs at 225 mm (9 in.) centres shouldered and riveted to the strings. The bottom ends of strings shall be bent 90° and built into concrete, and the top ends shall be turned over to 150 mm (6 in.) radius, returned 450 mm (18 in.) and bolted to precast concrete copings. Prices shall include for rustproof bolt fixings and mortices or drilling in concrete and grouting in. Ladders shall be heavily galvanised after erection.

This clause gives essential details such as materials, dimensions of members, spacing of rungs and finish to top and bottom ends of strings.

Prices should include for fixing and for all protective treatment.

Widths of ladders are sometimes increased to 450 mm (18 in.), and they may be constructed of wrought iron. Alternative protective treatments include applications of epoxy resin or bituminous paints.

Guardrails

Guardrails shall be supported on galvanised steel double ball pattern forged steel standards, spaced at no more than 1.5 m (5 ft) centres, drilled to receive two 30 mm (1¼ in.) bore tubular handrails with the top handrail at a height of 1 m (3 ft) above base. The standards shall be supplied with extensions and rectangular plates for bolting to sides of concrete walls or have flanged bases with ragged shanks for building into concrete. Plates shall be fixed to concrete walls with two 15 mm × 100 mm (½ in. × 4 in.) galvanised rawl-bolts. Prices shall also include for forming mortices in concrete to receive ragged shanks to standards and for grouting them in.

The majority of guardrails are formed of galvanised steel standards and tubular handrails, to a total height of 1 m (3 ft or 3 ft 6 in.). The handrail tubing can be conveniently provided in accordance with B.S. 1387: Steel Tubes and Tubulars suitable for screwing to B.S. 21 Pipe Threads.

The finish to the bases of standards will vary according to whether they are to be connected to the tops or sides of walls.

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Handrails shall be made of 30 mm ($1\frac{1}{4}$ in.) nominal bore, galvanised steel tubes to B.S. 1387, heavy grade, with screwed and socketed joints, in lengths as required. Made bends and capped ends shall be provided as necessary.

Open steel flooring

The Contractor shall supply and place in position in prepared rebates Messrs X, type B, or other equal and approved 25 mm (1 in.) deep open steel floor panels with a heavily galvanised finish. Steel angle curbs 50 mm \times 50 mm \times 5 mm (2 in. \times 2 in. \times $\frac{1}{4}$ in.) shall be cast into the concrete at the tops of walls, where shown on the Drawings, with angles formed of welded mitres.

The Engineer often has a particular type of flooring in mind, although even then the Contractor should be given the opportunity to offer an alternative for consideration. Chequer plating is usually galvanised with a thickness of 10 mm ($\frac{3}{8}$ in.).

SURFACE PROTECTION

Painting

(a) *General requirements.* All work required to be painted shall be properly cleaned and rubbed down between each coat. No coat of paint shall be applied until the Engineer has passed the previous coat as dry, hard and entirely satisfactory.

No paint shall be applied on wet surfaces, or in damp or frosty weather. All paintwork shall be undertaken by skilled tradesmen experienced in this class of work.

Welds and adjacent parent metal shall not be painted prior to inspection and approval.

It is essential that all steel surfaces which will be in contact after assembly should be thoroughly cleaned and given one or two coats of suitable priming paint. One of the best primers for steelwork is red lead paint, although sprayed metal coatings complying with B.S. 2569 can be most effective.

Steps must be taken to ensure that suitable paints are applied under satisfactory conditions to properly

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(b) *Works painting.* Before leaving the Manufacturer's works, all surfaces which will, after erection on the site, be in contact with steel or concrete or be otherwise inaccessible, shall be thoroughly cleaned, scraped, wire-brushed and freed from dirt, rust and scale and shall be given two substantial coats of genuine red lead paint of approved quality and composition. All other surfaces shall be left bare. Red lead shall comply with B.S. 217.

(c) *Site painting.* All exposed surfaces of steelwork shall be thoroughly cleaned, as previously specified, and shall as soon as practicable thereafter be given one good coat of suitable red lead priming paint. The cleaning and application of priming paint shall be carried out after the erection of the steelwork on the site and in such sections as the Engineer may approve or consider necessary to arrest or prevent undue corrosion of the steelwork.

The steelwork shall then be painted with two coats of an approved ready-mixed oil undercoat and one finishing coat of approved ready-mixed oil gloss paint. All paint shall be delivered to the site in the manufacturers' sealed containers. The colours of the undercoats and finishing coat shall be to the approval of the Engineer. The total thickness of paint film shall not be less than 0.15 mm ($\frac{6}{1000}$ in.)

Galvanising

Steel and iron work required to be galvanised shall be pickled in dilute muriatic acid, and then stored and

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prepared surfaces. British Standards 2521-2532 cover ready-mixed oil-based paints. It is sometimes advocated that steel surfaces which will become encased in concrete should have a cement wash applied to them and that steelwork which is to be in permanent contact with soil, brickwork or masonry should be protected by bituminous paint.

Site painting may be undertaken by the steel fabricator or by the main civil engineering contractor. Where the paint is applied by the steel fabricator the cost is included in the steelwork rates; otherwise the main contractor will be paid in accordance with the normal rules for the measurement of painting work.

Galvanised work is specified, particularly for hand-rails and standards. Specifi-

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dipped in a bath of pure virgin spelter, the quality of which shall comply with the requirements of B.S. 221: Special Zinc. All items shall be passed rapidly through the bath, which shall be of sufficient size to take the articles without need for bending. The galvanised articles shall then be washed and brushed.

Galvanising shall be undertaken after corrugating, chipping, trimming, filing and fitting are completed. All galvanised articles shall be covered evenly on all sides and the additional weight after galvanising shall be not less than 0.35 kg/m^2 ($1\frac{1}{4} \text{ oz/ft}^2$) of surface galvanised. All galvanised surfaces shall have a bright face with a crystalline structure and all edges shall be clean and free from drops of spelter.

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Galvanising requirements such as those listed are necessary to ensure that a sound galvanising process is adopted to produce a first-class finish.

WALL AND ROOF SHEET COVERINGS

Asbestos cement

Wall cladding shall be of coloured asbestos cement panels, 5 mm ($\frac{1}{4}$ in.) thick with an overall depth of about 55 mm ($2\frac{1}{4}$ in.), fixed with end laps of 150 mm (6 in.) and side laps of 75 mm (3 in.) to steel angles at 2 m (6 ft) centres, with 10 mm ($\frac{3}{8}$ in.) diameter galvanised hook bolts and bituminous washers.

Colours available include grey, blue, red, russet, browns and greens. Various types of sheets with varying profiles are available for wall and roof coverings: roof sheets are fixed in a similar manner to purlins.

The desirable characteristics of asbestos cement decking are detailed in B.S. 3717.

Aluminium

Wall cladding shall be of 22 gauge corrugated aluminium sheets, with an

There are many proprietary forms of aluminium

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average depth of 20 mm ($\frac{3}{4}$ in.) and corrugations to a nominal pitch of 75 mm (3 in.), fixed as for asbestos cement sheets with side laps of $1\frac{1}{2}$ corrugations and end laps not less than 150 mm (6 in.).

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sheeting available, and many types of roof decking, of which aluminium troughing covered with insulation board or wood wool slabs, finished with built-up bitumen roofing, is very popular.

Corrugated steel

Wall cladding shall be of corrugated galvanised mild steel sheeting of 22 s.w.g. with laps and method of fixing as for aluminium sheeting.

This is a less popular alternative which needs painting at regular intervals. It is advisable to apply a coating of oxide of zinc where the sheeting will be exposed to sea air or acid vapour.

Newer materials for roof decking include glass-fibre polyester resin.