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IS 4000 (1992): Code of practice for high strength bolts in steel structures [CED 7: Structural Engineering and structural sections]



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“Knowledge is such a treasure which cannot be stolen”

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भारतीय मानक

इस्पात संरचना में उच्च ताकतवर बोल्ट की रीति संहिता

(पहला पुनरीक्षण)

Indian Standard

**HIGH STRENGTH BOLTS IN STEEL
STRUCTURES — CODE OF PRACTICE**

(First Revision)

UDC 631-882.2 : 624-014.2-078.2

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BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Structural Engineering Sectional Committee had been approved by the Civil Engineering Division Council.

Use of high strength bolts in structural connections is fast gaining popularity over the conventional bolted connections. These structural connections which could be either bearing type or friction type have rigidity or continuity comparable with what is achievable in welded construction. The strength of the joint fabricated by means of these bolts is obtained by bearing or friction (grip) developed as a result of very high initial tension in the bolts produced by tightening the nuts to the specified bolt tension.

This standard was first published in 1967. In this revision following important modifications have been effected:

- i) Bolts of property class 8·8 and 19·9 as covered in IS 3757 : 1958 'High strength structural bolts (*second revision*)' have been specified.
- ii) In addition to friction type joints, joints subjected to tensile force only in the direction of the bolt axis and bearing type joints have been covered.
- iii) In the method of tightening of bolts, the 'torque control method' has been replaced by use of 'direct tension indication device'.
- iv) Fabrication and assembling provisions have been elaborated.
- v) A method for the determination of slip factor for the different surface conditions has been included.

In the preparation of this code, considerable assistance has been derived from AS 1511-1984 'SAA High Strength Structural Bolting Code', issued by Standards Association of Australia (SAA).

Indian Standard

HIGH STRENGTH BOLTS IN STEEL STRUCTURES — CODE OF PRACTICE

(*First Revision*)

1 SCOPE

1.1 This standard covers the requirements for the design, fabrication, assembly and inspection in all types of steel structures, of structural joints using high strength bolts conforming to IS 3757 : 1985 'High strength structural bolts (*second revision*)' tensioned to the minimum bolts tension specified in this code.

1.2 This standard applies to high strength bolts used in both friction type and bearing type shear joints and for tension joints.

1.3 This standard is complementary to IS 800 : 1984 'Code of practice for general construction on steel (*second revision*)'. Provisions not covered in this standard shall be conforming to IS 800 : 1984.

2 REFERENCES

The Indian Standards listed in Annex A are necessary adjuncts to this standard.

3 TERMINOLOGY AND SYMBOLS

3.1 Terminology

For the purpose of this standard the definitions given in 3.1.1 to 3.1.8 shall apply in addition to the nomenclature and terminology covered in IS 8537 : 1977.

3.1.1 Bearing Type Joints — A joint connected with fully tensioned high strength bolts where joint slip may occur so that the applied force is transferred by shear in the bolts and bearing on the connected parts.

3.1.2 Effective Interface — A common contact surface between two load-transmitting plies, excluding packing pieces, through which the bolt passes.

3.1.3 Factor of Safety — The numerical value by which the load that would cause slip in a joint is divided to give the maximum permissible working load on the joint.

3.1.4 Friction Type Joints — A joint connected with high-strength bolts tensioned to such a bolt tension that the resultant clamping action transfers all the applied forces acting in the plane of the common contact surfaces by the friction developed between the contact surfaces.

3.1.5 Grip — The total thickness of steel sections to be held together, including packing but excluding washers.

3.1.6 Length of Bolt — The distance from the underside of the bolt head to the extreme end of the shank including any camber or radius.

3.1.7 Ply — A single thickness of steel forming part of a structural joint.

3.1.8 Proof Load — Proof stress $R_{F0.2}$ multiplied by the stress area of the bolt.

3.1.9 Slip Factor — The ratio of the shear force required to produce slip between two plies to the force (shank tension) clamping the two plies together.

3.1.10 Snug Tight — The level of tightness attained by a few impacts of an impact wrench or by the full efforts of a man using a Standard/podger spanner or a spud wrench.

3.2 Symbols

Symbols used in this code shall have the following meaning:

d = nominal dia of bolt, in mm;

e = minimum distance from edge of a hole to the edge of a ply, in mm, measured in the direction of a component of a force, plus half the bolt diameter. The edge of a ply shall be deemed to include the edge of an adjacent bolt hole;

f_y = yield stress of the ply, in MPa;

P_t = tensile force on the bolt, in kN;

P_{t0} = maximum permissible tensile force in the bolt, in kN;

- t = thickness of the ply, in mm;
- V = shear force on the bolt, in kN; and
- V_{ob} = maximum permissible shear force on the bolt, in kN.

4 BOLT, NUTS AND WASHERS

4.1 Dimensions and Properties

Bolts, nuts and washers shall conform to IS 3757 : 1985, IS 6623 : 1985 and IS 6649 : 1985 respectively.

4.1.1 The length of the bolt shall be calculated by adding the allowance given in Table 1 to the total calculated maximum grip length covering maximum limits of ply thickness. The total length shall be rounded off to the next higher nominal length given in IS 3757 : 1985. It is desirable that the designer checks in each case whether with the final bolt length so obtained, it is possible to tighten the nuts when all the plates are of minimum permissible thickness.

4.2 Storage

Care shall be taken that bolts, nuts and washers are stored in such a way that they do not deteriorate. They are normally supplied by the manufacturer with a light coating of rust preventing oil which is not detrimental and should not be removed. In this condition they are ready for use and any further treatment at works or site is not recommended.

Table 1 Allowance for Bolt Length

(Clause 4.1.1)

| Nominal Size of Bolt | Nominal Bolt Dia in mm | Allowance for Grip in mm |
|----------------------|------------------------|--------------------------|
| M 16 | 16 | 26 |
| M 20 | 20 | 31 |
| M 24 | 24 | 36 |
| M 30 | 30 | 42 |
| M 36 | 36 | 48 |

NOTES

1 Allowance specified includes thickness of one nut and one standard washer, to provide a safe protrusion of bolt end beyond the nut after tightening. Thickness of additional washers if used should be included in calculating the maximum total grip length.

2 The allowance specified applies to friction type joints or bearing type joints where threads are permitted in the shear plane. Higher allowance may be required for bearing type joints where threads are excluded from the shear plane. A minimum number of two free threads shall project beyond the inside bearing face of the nut in all joints.

5 DESIGN

5.1 General

All connections, the rigidity of which is essential to the continuity assumed as the basis of the design analysis, shall be capable of resisting the moments, shears and axial loads to which they would be subjected by the design loading.

5.2 Joints subject to an Applied Tensile Force Only in the Direction of the Bolt Axis.

For joints in which the only force is an applied tensile force in the direction of bolt axis, the tensile force on any bolt shall not exceed the values specified in col 4 and 5 of Table 2.

NOTES

1 The tabulated value for tension P to correspond to 0.6 times the minimum bolt tension (see Table 3) taken equal to the proof load values as stipulated in Table 7 of IS 1367 (Part 3) : 1979.

2 The tabulated values for shear in bearing type joints V_{ob} correspond to 0.25 times the appropriate minimum tensile strength R_m as given in Table 3 of IS 1367 (Part 3) : 1979 multiplied by the relevant stress area of the shank or threaded portion of the bolt.

5.2.1 Where fatigue conditions are involved, the tensile force on any bolt shall not exceed 0.5 times the minimum bolt tension specified in Table 3.

5.3 Bearing Type Joints

5.3.1 Limitations on Bearing Type Joints

Shear and moment connection where slip is not acceptable shall be designed as friction-type joints.

5.3.2 Joints Subject to Shear Force Only

Bearing type joints subject to shear force only, and which are less than 500 mm long in the direction of the applied shear force, shall be proportioned so that the shear force on any bolt does not exceed the maximum permissible shear force V_{ob} specified in col 6 to 9 of Table 2.

For joints greater than 500 mm long in the direction of the applied shear force, the shear force on any bolt shall not exceed the values established on tests. However in the absence of the above, the following values, as appropriate may be used:

- a) 500 mm to 1 200 mm long $6/7 V_{ob}$
- b) Over 1 200 mm long $4/7 V_{ob}$

Table 2 Maximum Permissible Applied Forces for Joints

(Clauses 5.2 and 3.2)

| Nominal Size of Bolt | Stress Area of Bolt, in mm ² | | Maximum Permissible Applied Forces in Bolts in kN | | | | | |
|----------------------|---|-----|---|--------|---|--------|-------|--------|
| | | | Tension (P_{t0}) in Bolts of Property Class | | Shear in Bearing Type Joints V_{ob} for Bolts of Property Class | | | |
| | | | Shank | Thread | 8.8 | 10.9 | 8.8 | |
| (1) | (2) | (3) | (4) | (5) | Shank | Thread | Shank | Thread |
| M 16 | 201 | 157 | 56.7 | 78 | 40.2 | 31.4 | 52.3 | 40.8 |
| M 20 | 314 | 245 | 88.2 | 122 | 65.2 | 50.8 | 81.6 | 63.7 |
| M 24 | 452 | 353 | 127 | 176 | 93.8 | 73.2 | 117 | 91.8 |
| M 30 | 706 | 561 | 202 | 280 | 146 | 116 | 148 | 146 |
| M 36 | 1 017 | 817 | 294 | 407 | 211 | 169 | 264 | 212 |

5.3.3 Joints Subject to Shear and Tensile Forces

Bearing-type joints subject to shear and tensile forces shall be proportioned so that:

$$(P_t/P_{t0})^2 + (V/V_{ob})^2 \leq 1.0$$

5.3.4 Limitations of Transmitted Forces

For bolts of all diameters, bearing force in Newtons transmitted between any bolt and any ply shall not exceed $1.2 \times f_y \times d \times t$. In addition, the component of a force in newtons on a ply acting on the edge of a bolt hole in the direction of the minimum distance toward the edge of a ply shall not exceed $e f_y \cdot t/1.4$.

5.4 Friction Type Joints

5.4.1 General

Where the surfaces in contact comply with the requirements of 6.2 and the surfaces are clean 'as rolled', slip factor shall be assumed as 0.35. If any applied finish, or other surface conditions including a machined surface is desired, slip factor used shall be based upon tests performed in accordance with the procedure given in Annex B.

NOTE — In the absence of test results, the slip factor given in Annex C for different surface conditions generally adopted may be used at the discretion of the designer.

5.4.1.1 Joints shall be identified in accordance with 5.6 and the fabrication drawings shall indicate the surface treatment required at each joint and whether masking of the joint is required during painting shall also be indicated.

5.4.2 Joints Subject to Shear Force Only

In friction-type joints subject to shear force only in the Plane of the effective interfaces, the number and dispositions of high-strength bolts shall be proportioned so that the resulting force at any bolt positions does not exceed the value:

$$\frac{\text{Slip factor} \times \text{Number of effective interfaces} \times \text{Minimum bolt tension}}{\text{Factor of safety}}$$

In the above expression, the factor of safety shall be taken as 1.4 for structures and materials within the scope of IS 800 : 1984 and for the load combination specified therein. No additional factor is required to take account of fatigue conditions. Where the effect of wind forces on the structures has to be taken into consideration, this factor of safety may be reduced to 1.2 provided the connections are adequate when (i) wind forced are not considered, (ii) wind is not the primary loading for the purpose of design. For structures not covered by IS 800 : 1984, the factor of safety/load factor given in the appropriate design standard shall be used.

5.4.3 Joints Subject to Shear and Tensile Force

An externally applied tension in the direction of the bolt axis reduces the effective clamping action of a bolt which has been tightened to induce shank tension. To allow for this effect the bolt shall be proportioned to satisfy the

expression:

$$\frac{\text{Calculated Shear}}{\text{Slip factor} \times \text{Number of effective interface}} \leq \frac{(\text{Proof load} - \text{Calculated tension} \times F)}{\text{Factor of Safety}}$$

The value of factor F shall be taken as 2.0 if the external tension is repetitive and 1.7 if non-repetitive.

5.4.4 Limitation of Transmitted Forces

The shear force between the bolt and ply shall be limited to the value determined in accordance with 5.3.4.

5.5 Packing

5.5.1 Friction Type Joints

For friction type joints no additional factor is required to take account of packings within a joint.

5.5.2 Bearing Type Joints

In bearing-type joints where high-strength bolts through a packing plate are required to carry calculated shear, the number of bolts required, determined by calculation, shall be increased above the numbers required by normal calculation by 2.5 percent for each 2 mm thickness of packing in excess of 6 mm. For double shear connection with packing on both sides of a member, the increase in number of bolts shall be determined by the thickness of the thicker packing provided.

5.6 Identification

The designer shall indicate on drawings the position of all high-strength structural bolts and shall state the type of joint that is, friction type joint or bearing-type joint. In the absence of such designation, the fabricator shall assume such joints to be bearing-type joints.

6 FABRICATION

6.1 Holes in Members

Unless specified otherwise, the diameter of a hole shall be 1.5 mm and 2.00 mm more than the nominal bolt diameter for bearing type joints and friction type joints respectively.

6.2 The edge distance for any hole and the distance between holes (pitch) shall conform to the requirements of IS 800 : 1984.

6.3 Holes shall be provided by drilling only for all dynamically loaded connections and also friction type joints and by any of the following methods (a), (b) or (c) for other type of joints:

- a) *Drilling* — Holes drilled full size.
- b) *Sub punching* — Holes sub-punched 3 mm undersize and reamed to size.
- c) *Punching full size* — Holes punched full size provided:
 - i) The joint is not located at a plastic hinge,
 - ii) The material shall not have a yield stress (f_y) in excess of 360 MPa, and
 - iii) Thickness of individual members does not exceed 12 mm.

6.3.1 Oversize and Slotted Holes

- a) Oversize holes shall not exceed $1.25 d$ or $d + 8$ mm,
- b) Short slotted holes shall not exceed $d+2$ mm in width and $1.33 d$ or $d+10$ mm in length, and
- c) Long slotted holes shall not exceed $d + 2$ mm in width and $2.5 d$ in length.

6.3.2 Limitation on Use

- a) *Oversize holes* — Oversize holes may be used in any or all plies of bearing-type and friction-type connections provided hardened washers are installed over the oversize holes.
- b) *Short slotted holes* — Short slotted holes may be used in shear-type connections in any or all plies of friction-type and bearing-type joints provided hardened washers are installed over the exposed holes.

In friction-type joints the slots may be used without regard to direction of loading but in bearing-type joints slotted holes may be used only where the joint is not eccentrically loaded, where the bolts can bear uniformly and where the slots are normal to the direction of the load.

- c) *Long slotted holes* — Long slotted holes may be used in shear-type connections only in alternate plies of either friction-type or bearing-type joints provided a special washer or coverplate, not less than 8 mm thick, is used to completely cover all exposed long slotted holes.

In friction-type joints, long slotted holes may be used without regard to direction of loading provided an additional 33 percent more bolts are used than needed to satisfy the provisions covered under 5.4 but in bearing-type joints, long slotted holes may be used only where the joint is not eccentrically loaded, where the bolts can bear uniformly and where the slots are normal to the direction of the load.

6.4 Preparation of Surfaces in Contact

6.4.1 General

All oil, dirt, loose scale, loose rust, burrs and any other defects on the surfaces of contact which will prevent solid seating of the parts shall be removed.

6.4.2 Friction-type Joints

For friction-type joints the contact surfaces shall be clean 'as-rolled' surfaces or equivalent and in addition to meeting the provisions covered under 6.4.1 shall be free from paint, lacquer, galvanizing or other applied finish, unless otherwise specified or approved by the competent authority.

6.4.3 Bearing-type Joints

For bearing-type joints, an applied finish on the contact surfaces shall be permitted.

7 ASSEMBLY

7.0 General

No joint shall be assembled for bolting until the contact surfaces have been inspected and approved by the competent authority.

7.1 Procedure

7.1.1 Number of Washers

Each bolt and nut shall be assembled with at least one washer. A washer shall be placed under the rotating component.

7.1.2 Tapered Washers

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

7.1.3 Placement of Nuts

The nut should be placed so that the mark specified in IS 6623 : 1985 to identify a high-strength nut is visible after tightening.

7.1.4 Packing

Packing shall be provided wherever necessary to ensure that the load-transmitting plies are in effective contact when the joint is tightened to the 'snug-tight' condition as defined in 7.2.2 (a). All packings shall be of steel with a surface condition similar to that of the adjacent plies.

7.1.5 Alignment of Parts

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

7.1.6 Tightening Pattern

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

High strength bolts may be used temporarily during erection to facilitate assembly, but if so used they shall not be finally tensioned until all bolts in the joint are snug-tight in their correct sequence.

7.1.7 Retensioning

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

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

7.2 Method of Tensioning

7.2.1 General

The method of tensioning shall be in accordance with 7.2.2 or 7.2.3.

In the completed connection all bolts shall have at least the minimum tension specified in Table 3.

Table 3 Minimum Bolt Tension
(Clauses 7.2.1, B-1.2 and D-2.2)

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

7.2.2 Part-turn Method of Tensioning

Tensioning of bolts and nuts by the part-turn method shall be in accordance with the following procedure:

- On assembly, all bolts and nuts in the joint shall be first tightened to a 'snug-tight' condition to ensure that the load-transmitting plies are brought into effective contact.
- After completing this preliminary tightening to 'snug-tight' location marks shall be established to mark the relative position of bolt and nut and to control the final nut rotation specified in Table 4. Observation of the final nut rotation may be achieved by using marked wrench sockets, but location marks shall be permanent when required for inspection [(see B-2 (a))].
- Bolts shall be finally tensioned by the amount specified in Table 4. During the final tensioning the component not turned by the wrench shall not rotate.

7.2.3 Tensioning by Use of Direct-tension Indication

Tensioning of bolts and nuts using a direct-tension indication device shall be in accordance with the manufacturer's instructions and the following procedure:

- On assembly, all bolts and nuts in the joint shall be first tightened to a 'snug-tight' condition as described in 7.2.2(a).
- After completing this preliminary tightening to 'snug-tight' the bolt and nut shall be tensioned to provide the minimum bolt tension specified in Table 3. This shall be indicated by the tension indication device.

Table 4 Nut Rotation from the 'Snug-Tight' Condition
(Clause 7.2.2)

| Nominal Size of Bolt | Length of Bolt, mm | |
|----------------------|---|---|
| | Nut Rotation ¹ $\frac{1}{2}$ turn | Nut Rotation ¹ $\frac{3}{4}$ turn |
| M 16 | < 120 | > 120 < 240 |
| M 20 | < 120 | > 120 < 240 |
| M 24 | < 160 | > 160 < 350 |
| M 30 | < 160 | > 160 < 350 |
| M 36 | < 160 | > 160 < 350 |

¹ Nut rotation is rotation relative to the bolt, regardless of the component turned.

NOTES

1 Tolerance on rotation: one-sixth of a turn (60 degrees) over : no under tolerance.

2 The bolt tension achieved with the amount of nut rotation specified in Table 4 will be at least equal to the minimum bolt tension.

8 INSPECTION

8.1 Visual Inspection

Bolts and nuts which on visual inspection show any evidence of physical defects shall be removed and replaced by new one.

8.2 Tensioning Procedures

Inspection shall ensure that the selected tensioning procedure has been correctly applied and that all bolts are fully tensioned. This will require inspection both at the 'snug-tight' stage and when bolts are fully tensioned. The following methods shall be used to check that all bolts are fully tensioned:

- In Part-turn Tensioning* —by ensuring that the correct part-turn from the 'snug-tight' position can be measured or observed.

When the subsequent use of an inspection wrench is not required by the supervising engineer, the bolts and nuts shall carry permanent location marks.

- In Direct-Tension Indication Tensioning* — by ensuring that the manufacturer's specified tensioning procedure has been followed and that the development of minimum bolt tension is indicated by the tension indication device.

NOTE — The use of a torque wrench for inspection is considered suitable only to detect gross under-tensioning. A procedure for such use is detailed in Annex D.

ANNEX A

(Item 2)

LIST OF INDIAN STANDARDS REFERRED

| IS No. | Title | IS No. | Title |
|---------------------------|--|-------------|---|
| 1367 (Part 3) : 1979 | Technical supply conditions for threaded steel fasteners: Part 3 Mechanical properties and test methods for bolts, screws and studs with full loadability | 6623 : 1985 | Specification for high strength structural nuts (<i>first revision</i>) |
| 3757 : 1985 | Specification for high strength structural bolts (<i>second revision</i>) | 6649 : 1985 | Specification for hardening and tempering washers for high strength structural bolts and nuts (<i>first revision</i>) |
| | | 8537 : 1977 | Nomenclature and terminology of fasteners |

ANNEX B

(Clause 5.4.1)

STANDARD TEST FOR EVALUATION OF SLIP FACTOR

B-1 TEST SPECIMENS

B-1.1 Form

The standard test specimen is a symmetrical double coverplated butt joint as shown in Fig. 1. It is suggested that use of M 20 bolts will prove to be most convenient, with use of 25 mm inner plates and 12 mm outer plates. It is essential that both inner plates are identical in thickness which can be controlled by cutting adjacent pieces from one plate.

B-1.2 Assembly and Measurement

Care must be taken in assembling the specimen to ensure that neither bolt is in bearing in the direction of loading, and that the surface conditions of the friction in the faces is maintained in the condition to be achieved in the field. For example, if it is necessary to machine the ends of the inner plates to fit into the loading machine grip, machining oil should not be allowed to contaminate the surfaces. Preferably, bolts shall be tensioned in the same manner as that to be used in practice and shall develop at least the minimum bolt tension specified in Table 3.

Between 'snug-tightening' and final tensioning the bolt extension shall be measured using a

displacement transducer with a resolution of 0.003 mm or finer. Bolt tension shall be ascertained from a calibration curve determined from load cell tests of at least three bolts of the test batch. In establishing the calibration curve, the bolt grip through the load cell shall be as close as practicable to that used in the specimens, the same method of extension measurement and tensioning employed, and the calibration based on the mean result. For the purposes only of these tests, the initial 'snug-tight' condition shall be finger tight.

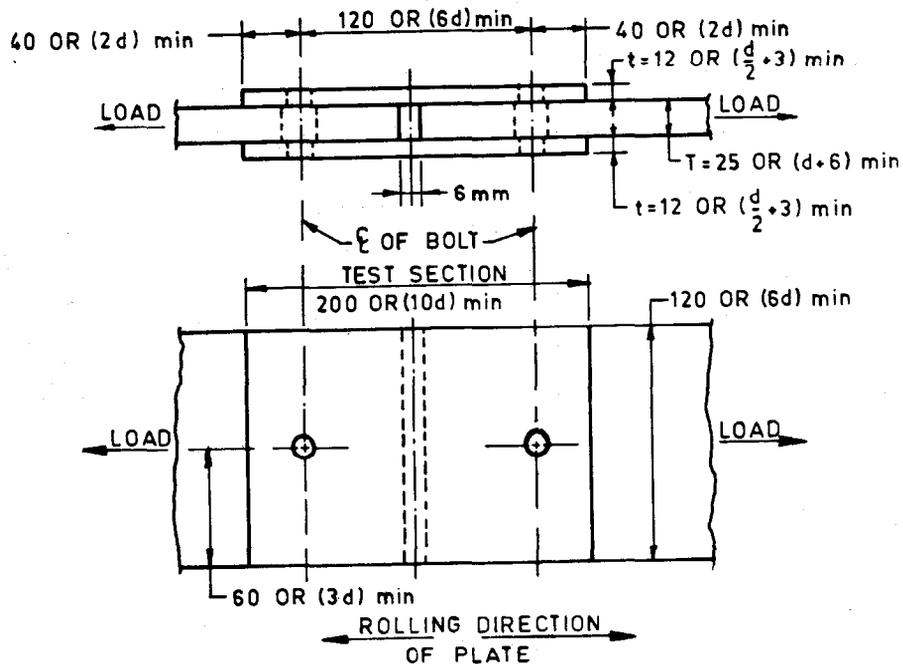
Alternatively, when a bolt tension load cell is not available, the bolts shall be tensioned to at least 80 percent and not more than 100 percent of their specified proof loads, and the tension induced in the bolts calculated from the formula:

$$R = \frac{E \times \Delta \times 10^{-3}}{\frac{a}{A} + \frac{b + c/2}{A_s}} \dots (i)$$

where

R = tension induced in the bolt, in kN

E = young's modulus = 200 000 MPa



NOTES

- 1 Holes in plates:
 Cover plates.....22 mm or $(d+2)$ mm
 Inter plates.....23 mm or $(d+3)$ mm
- 2 Length and width of inner plates outside of test section may be raised to suit the laboratory's testing facilities.
- 3 Dimensions are shown for the (suggested) use of M 20 bolts. Dimensions in parentheses are for use of bolts with nominal diameter d in mm, which should be not less than 16 mm.
- 4 All dimensions are in millimetres.

FIG. 1 STANDARD TEST SPECIMEN

- a = length of the unthreaded portion of the bolt shank contained within the grip¹ before tensioning, in mm
- A = cross-sectional area of the unthreaded portion of the bolt, in mm²
- b = length of the threaded portion of the bolt contained within the grip¹ before tensioning, in mm
- c = thickness of the nut, in millimetres
- A_s = tensile stress area of the bolt as tabulated in Table 2, in mm²
- Δ = the measured total extension of the bolt when tightened from a finger-tight condition to final tensioned condition,

¹In this context, the grip includes the washer thickness.

in millimetres. The final measurement shall be made immediately prior to testing. A micrometer or other transducer with resolution achieving 0.003 mm or finer is required.

NOTE — It is not necessary for both bolts in the one specimen to have identical tension.

B-1.3 Number of Specimens

Test on at least three specimens shall be undertaken, but five is preferred as a practical minimum number.

B-2 INSTRUMENTATION

Two pairs of dial gauges or other displacement transducers having an effective resolution achieving 0.003 mm or finer shall be symmetrically disposed over gauge lengths of 60 mm

(3d) on each edge of the specimen so as to measure the deformation between the inner plates from the bolt positions to the centre of the cover plates. The deformation of each half of the joint shall be taken as the mean of the deformation at each edge. The deformation so measured is therefore the sum of the elastic extension of the cover plates and any slip at the bolt positions. It is essential that transducers are securely mounted since they may be shock loaded as slip occurs.

B-3 METHOD OF TESTING

- a) **Type of Loading** — Specimens may be tested only by tensile loading.
- b) **Loading Rate** — Up to the slip load, force shall be applied in increments exceeding neither 25 kN nor 25 percent of the slip load of the joint assuming a slip factor of 0.35 and calculated bolt tension. The loading rate should be approximately uniform at not more than 50 kN/min within each load increment. Slower loading rates are preferred. Each load increment should be applied after creep at constant load due to the preceding load increment having effectively ceased.

Since slip will in all probability occur at one bolt position before the other, it is clear that the first bolt may slip into bearing before the slip load at the other bolt position is attained.

After attainment of the slip load at one bolt position, the loading rate and increment size may be adjusted at the discretion of the operator.

B-4 SLIP LOAD P_s

Slip is usually well defined and easily detected by the operator when a sudden increase in deformation occurs. One or more sharp clearly audible reports may also be heard. However, with some types of surface, and occasionally

with normal surfaces, the incidence of slip is not so well defined. In these cases the load corresponding to a slip of 0.13 mm shall be used to define the slip load.

B-5 SLIP FACTOR

The slip factor μ to be used in design is given by:

$$\mu = k (\mu_m - 1.64 s) \dots\dots\dots (2)$$

where

$$k = 0.85 \text{ when 3 specimens are tested}$$

$$= 0.90 \text{ when 5 or more specimens are tested}$$

μ_m = mean value of slip factors for all tests, and is

$$= \frac{1}{2N} \times \sum_{i=1}^{2N} \mu_i \dots\dots\dots (3)$$

s = standard deviation of slip factors for all tests, and is

$$= \sqrt{\left[\frac{1}{2N-1} \sum_{i=1}^{2N} (\mu_i - \mu_m)^2 \right]} \dots\dots\dots (4)$$

$$\mu_i = \frac{1}{2} \times \left(\frac{P_{si}}{R_i} \right) \dots\dots\dots (5)$$

N = number of specimens tested, each providing two estimates of μ , say μ_i and μ_{i+1}

P_{si} = measured slip load at the position of the i^{th} bolt

R_i = tension induced in the i^{th} bolt by the tensioning as calculated from formula (1)

However, if the value of μ calculated from formula (2) above is less than the lowest of all values of μ_i , then μ may be taken as equal to be lowest value of μ_i .

ANNEX C

(Clause 5.4.1)

RECOMMENDED SLIP FACTORS

| <i>Treatment of Surface</i> | <i>Slip Factor, μ</i> | <i>Treatment of Surface</i> | <i>Slip Factor, μ</i> |
|--|--------------------------------------|--|--------------------------------------|
| Surface not treated | 0.20 | Surfaces blasted with shot or grit and painted with ethyl-zinc silicate coat (thickness 60-80 μ_m) | 0.30 |
| Surface blasted with shot or grit with any loose rust removed, no pitting | 0.50 | Surfaces blasted with shot or grit and painted with ethyl-zinc silicate coat (thickness 60-80 μ_m) | 0.30 |
| Surfaces blasted with shot or grit and hot-dip galvanized | 0.10 | Surfaces blasted with shot or grit and spraymetallized with zinc (thickness 50-70 μ_m) | 0.50 |
| Surfaces blasted with shot or grit and spray-metallized with zinc (thickness 50-70 μ_m) | 0.25 | Surfaces blasted with shot or grit and painted with ethyl-zinc silicate coat (thickness 30-60 μ_m) | |
| Surfaces blasted with shot or grit and painted with ethyl-zinc silicate coat (thickness 30-60 μ_m) | 0.30 | | |

NOTE — The contact surfaces shall not be sand blasted.

ANNEX D

(Clause 8.2, Note)

INSPECTION OF BOLT TENSION USING A TORQUE WRENCH

D-1 GENERAL

The correlation between the torque determined to fully tension a calibration specimen and that which will be required on a bolt nut assembly installed in a structural joint, will be materially effected by such factors as:

- the exact equivalence of thread and bearing surface condition and lubrication;
- the occurrence of galling during tensioning; and
- the time lapse between tensioning and inspection.

Within these limitations, the procedure given herein may be considered the most practical method for an independent assessment of whether the specified bolt tension has been achieved.

D-2 CALIBRATION

D-2.1 Inspection Wrench

The inspection wrench may be either a hand-operated or adjustable-torque power-operated wrench. It shall be calibrated at least once per shift or more frequently if the need to closely simulate the conditions of the bolt in the structure so demands.

The torque value determined during calibration may not be transferred to another wrench.

D-2.2 Samples

At least three bolts, desirably of the same size (minimum length may have to be selected to suit the calibrating device) and condition as those under inspection shall be placed individually in a calibrating device capable of indicating bolt tension. A hardened washer shall be placed under the part turned.

Each calibration specimen shall be tensioned in the calibrating device by any convenient means to the minimum tension shown for that diameter in Table 3. The inspection wrench then shall be applied to the tensioned bolt and the torque necessary to turn the nut or bolt head 5 degrees (approximately 25 mm at 300 mm radius) in the tensioning direction shall be determined. The average torque measured in the tests of at least three bolts shall be taken as the job inspection torque.

D-3 INSPECTION

Bolts represented by the sample prescribed in D-2.2 which have been tensioned in the structure shall be inspected by applying, in the tensioning direction, the inspection wrench and its job inspection torque to such proportion of the bolts in the structure as the supervising engineer shall prescribe.

NOTE — For guidance it is suggested that a suitable sample size would be 10 percent of the bolt, but not less than two bolts in each connection are to be inspected.

D-4 ACTION

Where no nut or bolt head is turned by the job-inspection torque, the connection shall be accepted as properly tensioned.

Where any nut or bolt head is turned by the application of the job-inspection this torque shall then be applied to all other bolts in the connection and all bolts whose nut or head is turned, by the job inspection torque shall be tensioned and re-inspected. Alternatively, the fabricator or erector at his option may retension all of the bolts in the connection and then resubmit the connection for inspection.

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