



BSI Standards Publication

Steel structures — Execution of structural steelwork

Part 6: Bolting

National foreword

This British Standard is the UK implementation of [ISO 17607-6:2023](#).

The UK participation in its preparation was entrusted to Technical Committee CB/203, Design & execution of steel structures.

A list of organizations represented on this committee can be obtained on request to its committee manager.

Contractual and legal considerations

This publication has been prepared in good faith, however no representation, warranty, assurance or undertaking (express or implied) is or will be made, and no responsibility or liability is or will be accepted by BSI in relation to the adequacy, accuracy, completeness or reasonableness of this publication. All and any such responsibility and liability is expressly disclaimed to the full extent permitted by the law.

This publication is provided as is, and is to be used at the recipient's own risk.

The recipient is advised to consider seeking professional guidance with respect to its use of this publication.

This publication is not intended to constitute a contract. Users are responsible for its correct application.

© The British Standards Institution 2024
Published by BSI Standards Limited 2024

ISBN 978 0 539 04017 3

ICS 91.080.13

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 January 2024.

Amendments/corrigenda issued since publication

Date	Text affected
------	---------------

INTERNATIONAL STANDARD

ISO
17607-6

First edition
2023-12-08

Steel structures — Execution of structural steelwork —

Part 6: Bolting

*Structures en acier – Exécution des charpentes et
ossatures en acier —*

Partie 6: Boulonnage



Reference number
ISO 17607-6:2023(E)
Documents
Document Sharing Hub
© ISO 2023



COPYRIGHT PROTECTED DOCUMENT

© ISO 2023, Published in Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

Contents

Page

Foreword	vi
Introduction	vii
1 Scope	1
2 Normative references	1
3 Terms and definitions	2
4 Execution specification and quality requirements	2
4.1 General	2
4.2 Execution specification	2
5 Constituent products	3
5.1 General	3
5.1.1 Selection of constituent products	3
5.1.2 Verification of conformance	3
5.2 Structural bolting products	4
5.2.1 Property classes	4
5.2.2 Structural bolting assemblies for non-pretensioned applications	4
5.2.3 Structural bolting assemblies for pretensioned applications	4
5.2.4 Washers	4
5.2.5 Direct tension indicators	5
5.2.6 Alternative direct tension indicators	5
5.2.7 Coated structural bolting components	5
5.2.8 Atmospheric corrosion-resistant structural bolting components	6
5.2.9 Locking devices	6
5.2.10 Special structural fasteners	6
5.2.11 Packaging	6
5.2.12 Test reports	7
5.2.13 Delivery and identification	7
5.2.14 Storage of structural bolting components and assemblies	7
5.2.15 Reconditioning of structural bolting components and assemblies	7
5.3 Studs and shear connectors	8
5.4 Anchorages	8
5.4.1 Foundation bolts	8
5.4.2 Other anchorage systems	8
6 Preparation and assembly	8
6.1 General	8
6.2 Holes for structural bolting	8
6.2.1 General	8
6.2.2 Dimensions of holes	9
6.3 Faying surfaces for bearing-type joints	10
6.4 Preparation of friction surfaces in slip-resistant joints	10
6.4.1 General	10
6.4.2 Surface preparation	10
6.4.3 Precautions prior to assembly	10
6.5 Assembly	11
7 Structural bolting	12
7.1 General	12
7.2 Joint types and assembly	12
7.2.1 Joint type	12
7.2.2 Fit of joint and shims	12
7.2.3 Packing plates	12
7.2.4 Snugging of joint	13
7.2.5 Sequence of tightening	13
7.2.6 Structural bolts	13

7.2.7	Nuts	14
7.2.8	Washers	14
7.2.9	Locking methods	17
7.3	Tightening of non-pretensioned bolts	17
7.4	Tightening of pretensioned bolts	18
7.4.1	Bolting procedure for pretensioned bolts	18
7.4.2	Pretensioning tools	18
7.4.3	Minimum pretension	18
7.4.4	Bolting assembly k-class calibration	19
7.4.5	<i>k</i> -factor	19
7.4.6	Pre-installation verification testing	19
7.4.7	Torque method	20
7.4.8	Combined method	20
7.4.9	Spline-drive twist-off method	20
7.4.10	Direct tension indicator method	20
7.4.11	Turn-of-nut method	20
7.5	Fit bolts	20
7.6	Temporary bolts	21
7.7	Loss of pretension	21
7.8	Reuse of structural bolts	22
7.9	Use of special fasteners	22
7.10	Galling and seizure of stainless-steel structural bolts	23
8	Inspection, testing, and correction	23
8.1	General	23
8.2	Structural bolting inspection	23
8.2.1	Inspection prior to erection of steelwork	23
8.2.2	Inspection prior to installation of bolts	24
8.2.3	Inspection after installation of bolts	24
8.2.4	Inspection of pretensioned bolts	24
8.2.5	Inspection of special structural fasteners and special methods	27
8.3	Correction	28
8.3.1	Excessive coating thickness	28
8.3.2	Replacement of structural bolting components and assemblies	28
9	Documents required to claim conformity to this document	28
9.1	General	28
9.2	Declaration of conformity	28
	Bibliography	29
	Annex A (normative) Additional information, list of options and requirements related to the execution levels	33
	Annex B (normative) Bolting component, assembly and coating standards	38
	Annex C (normative) Nominal hole clearances for bolts	42
	Annex D (normative) Bolted friction surface slip factors	45
	Annex E (normative) Nominal minimum pretension	47
	Annex F (normative) Threads in grip, thread protrusion, and use of taper washers	49
	Annex G (normative) Pre-installation verification testing for pretensioned bolting assemblies	51
	Annex H (normative) Calibration test for the EN 14399 series pretensioned bolts under site conditions	52
	Annex I (normative) Pretensioning bolting assemblies — Torque method	57
	Annex J (normative) Pretensioning bolting assemblies — Combined method	59
	Annex K (normative) Pretensioning bolting assemblies — Spline-drive twist-off method	64

Annex L (normative) Pretensioning bolting assemblies — Direct tension indicator method	65
Annex M (normative) Pretensioning bolting assemblies — Turn-of-nut method	66
Annex O (normative) Method for structural bolting inspection	78
Annex P (normative) Test to determine slip factor	83
Annex Q (informative) Test to determine loss of pretension	90

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 167, *Steel and aluminium structures*.

This first edition cancels and replaces ISO 10721-2:1999, which has been technically revised.

A list of all parts in the ISO 17607 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Specific requirements for the achievement of structures that are optimal with respect to safety, the state of the economy, development and general values of a nation are given in the appropriate regional or national standards, if they exist.

Many nations do not have their own standards for structural steelwork. Some reference other national or regional standards. Some permit the project's standard to be selected by the owner, designer or constructor of the structure. Some do not require any standards to be followed.

The [ISO 17607](#) series of standards on the execution of structural steelwork was developed to serve as a means to provide a set of requirements and guidance for projects that are constructed without a governing regional or national standard. The [ISO 17607](#) series can also serve to reduce trade barriers.

Additional requirements to be addressed in the execution of structural steelwork, as structures or as fabricated components, can be found in the other parts of the series:

- [ISO 17607-1](#) (General requirements and terms and definitions);
- [ISO 17607-2](#) (Steels);
- [ISO 17607-3](#) (Fabrication);
- [ISO 17607-4](#) (Erection);
- [ISO 17607-5](#) (Welding).

This page deliberately left blank

Steel structures — Execution of structural steelwork —

Part 6: Bolting

1 Scope

This document defines the general requirements for structural bolting in the execution of structural steelwork as structures or as fabricated components, in conjunction with [ISO 17607-1](#).

Additional requirements to be addressed in the execution of structural steelwork, as structures or as fabricated components, can be found in other parts of [ISO 17607](#).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

[ISO 898-1](#), *Mechanical properties of fasteners made of carbon steel and alloy steel — Part 1: Bolts, screws and studs with specified property classes — Coarse thread and fine pitch thread*

[ISO 898-2](#), *Mechanical properties of fasteners made of carbon steel and alloy steel – Part 2: Nuts with specified property classes – Coarse thread and fine pitch thread*

[ISO 898-3](#), *Mechanical properties of fasteners made of carbon steel and alloy steel — Part 3: Flat washers with specified property classes*

ISO 2859-5, *Sampling procedures for inspection by attributes — Part 5: System of sequential sampling plans indexed by acceptance quality limit (AQL) for lot-by-lot inspection*

[ISO 3506-1](#), *Mechanical properties of corrosion-resistant stainless-steel fasteners — Part 1: Bolts, screws and studs*

[ISO 3506-2](#), *Mechanical properties of corrosion-resistant stainless-steel fasteners — Part 2: Nuts*

[ISO 4014](#), *Hexagon head bolts - Product grades A and B*

[ISO 4017](#), *Fasteners – Hexagon head screws – Product grades A and B*

[ISO 4032](#), *Hexagon nuts (style 1) - Product grades A and B*

[ISO 4033](#), *Hexagon nuts, (style 2) - Product grades A and B*

[ISO 4042](#), *Fasteners — Electroplated coating systems*

[ISO 6789-1](#), *Assembly tools for screws and nuts — Hand torque tools — Requirements and test methods for design conformance testing, quality conformance testing and recalibration procedure*

[ISO 7089](#), *Plain washers — Normal series — Product grade A*

[ISO 7090](#), *Plain washers, chamfered — Normal series — Product grade A*

[ISO 7091](#), *Plain washers — Normal series — Product grade C*

[ISO 7092](#), *Plain washers — Small series — Product grade A*

[ISO 7093-1](#), Plain washers — Large series — Part 1: Product grade A

[ISO 7093-2](#), Plain washers — Large series — Part 2: Product grade C

[ISO 7094](#), Plain washers — Extra large series — Product grade C

[ISO 10683](#), Fasteners — Non-electrolytically applied zinc flake coating systems

[ISO 10684](#), Fasteners — Hot dip galvanized coatings

[ISO 14713-3](#), Zinc coatings — Guidelines and recommendations for the protection against corrosion of iron and steel in structures — Part 3: Sherardizing

[ISO 16228](#), Fasteners — Types of inspection documents

[ISO 17607-1](#), Steel structures — Execution of structural steelwork — Part 1: General requirements and vocabulary

[ISO 17607-2](#), Steel structures — Execution of structural steelwork — Part 2: Steels

[ISO 17607-3](#), Steel structures — Execution of structural steelwork — Part 3: Fabrication

[ISO 17607-4](#), Steel structures — Execution of structural steelwork — Part 4: Erection

[ISO 17607-5](#), Steel structures — Execution of structural steelwork — Part 5: Welding

3 Terms and definitions

For the purposes of this document, the terms and definitions given in [ISO 17607-1](#) apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

4 Execution specification and quality requirements

4.1 General

See [ISO 17607-1](#) for execution levels, identification, traceability, and quality requirements.

4.2 Execution specification

National standards and documents that provide technically equivalent conditions may be used, in whole or in part, in place of referenced ISO standards or requirements of this document. In these cases, the technically equivalent national standards and documents, and deviations from the requirements of this document, shall be referenced in the execution specification.

The necessary information and technical requirements for execution of structural bolting shall be agreed on and complete before commencement.

The execution specification shall include the following items (see [Annex A](#)) as relevant:

- a) required additional information, see [A.1](#);
- b) options that may be specified, see [A.2](#);
- c) quality requirements related to execution levels, see [A.3](#).

There shall be procedures for making alterations to a previously agreed execution specification.

5 Constituent products

5.1 General

5.1.1 Selection of constituent products

See [ISO 17607-1](#) for selection of constituent products.

5.1.2 Verification of conformance

See [ISO 17607-1](#) for verification of conformance with the order and either relevant standards or specified requirements, or both.

Inspection documents shall be supplied in accordance with [ISO 16228](#), as listed in [Table 2](#), with the information in [Table 1](#) as required.

Table 1 — Inspection reporting for structural bolting products, by requirement

Type of requirement		Reported
Method of control	Required limit(s) expressed as:	
Chemical composition	Min and max, as applicable	Measured value
Mechanical properties (yield strength, tensile strength, hardness)	Min	Minimum value measured
	Max if applicable	Maximum value measured
	Min and max	Minimum and maximum value measured
Mechanical property (proof load)	Pass/Fail	Conform
Surface condition (carburization/decarburization)	Pass/Fail	Conform
Measurement (Geometry, tolerances)	Min	Minimum value measured
	Max	Maximum value measured
	Min & max	Minimum and maximum value measured
Dimensional attribute (gauge)	Go	Conform
	No-Go	
	Go/No-Go	
Bolting assemblies for preloading (k-value or COV, or both, if required)	k-class, if applicable	k-class
Inspection (VT, MT)	Pass/Fail	Conform

Table 2 — Inspection documents for structural bolting products according to ISO 16228

Constituent product	Inspection documents ^a
Structural bolting assemblies suitable for pretensioning	F3.1 ^b
Structural bolting assemblies	F2.1
^a If assemblies are marked with a manufacturing lot number and the manufacturer can trace the measured characteristic values from the internal (factory) production control records on the basis of this number, the F3.1 inspection certificate or F2.1 declaration of conformity may be omitted. ^b The inspection documents shall include the results of the suitability tests, if required. ^c Applicable if bolts, nuts or washers are supplied for use in non-pretensioned applications, or not as a component of a bolting assembly.	

Table 2 (continued)

Constituent product	Inspection documents ^a
Bolts ^c , nuts ^c , or washers ^c	F2.1
^a If assemblies are marked with a manufacturing lot number and the manufacturer can trace the measured characteristic values from the internal (factory) production control records on the basis of this number, the F3.1 inspection certificate or F2.1 declaration of conformity may be omitted.	
^b The inspection documents shall include the results of the suitability tests, if required.	
^c Applicable if bolts, nuts or washers are supplied for use in non-pretensioned applications, or not as a component of a bolting assembly.	

5.2 Structural bolting products

5.2.1 Property classes

Property classes of bolts and nuts and, if appropriate, coatings, shall be specified together with any required options within the product standard.

Structural bolting components and assemblies shall be selected from [Annex B](#).

The mechanical properties shall be specified for:

- a) carbon and alloy steel bolting assemblies with larger diameters than those specified in [ISO 898-1](#), [ISO 898-2](#) and [ISO 898-3](#);
- b) austenitic or austenitic-ferritic stainless-steel bolting assemblies with larger diameters than those specified in [ISO 3506-1](#) and [ISO 3506-2](#), or those specified in other relevant national standards;
- c) atmospheric corrosion-resistant bolting assemblies.

5.2.2 Structural bolting assemblies for non-pretensioned applications

Bolts, nuts, washers, and bolting assemblies that conform to the appropriate product standards as given in [Table B.1](#) through [Table B.5](#) may be used for non-pretensioned applications.

5.2.3 Structural bolting assemblies for pretensioned applications

High-strength structural bolts, nuts, washers and bolting assemblies that conform to the appropriate product standards as given in [Table B.1](#) through [Table B.3](#) may be used for pretensioned applications.

Unless specified in the execution specification, stainless-steel bolts shall not be used in pretensioned applications. If used in pretensioned applications, they shall be treated as special fasteners.

5.2.4 Washers

5.2.4.1 General

Washers that conform to the appropriate product standards as given in [Table B.3](#), or are included as a part of bolting assemblies as given in [Table B.1](#) or [Table B.2](#), may be used for pretensioned applications.

Washers that conform to the appropriate product standards as given in [Table B.3](#) or [Table B.5](#), or are included as a part of bolting assemblies as given in [Table B.1](#), [Table B.2](#), or [Table B.4](#), may be used for non-pretensioned applications.

5.2.4.2 Taper washers

Taper washers shall conform with the relevant product standard for flat washers, except for dimensions applicable to shape, which shall be specified.

NOTE Taper washers are also known as bevelled washers.

5.2.4.3 Plate washers

Plate washers shall be dimensioned with nominal clearances according to [Annex C](#) and have dimensions that ensure that the washer overlaps the connected component by at least as much as a standard plain washer would when used with standard round holes.

5.2.5 Direct tension indicators

Direct tension indicators and associated hardened nut face and bolt face washers that conform to the appropriate product standards as given in [Table B.6](#) may be used.

When direct tension indicators are used with bolts loaded in axial tension, the potential loss of pretension should be considered^[91].

Direct tension indicators shall not be used with stainless-steel bolts.

If direct tension indicators are used with atmospheric corrosion-resistant bolts, the direct tension indicators shall also be atmospheric corrosion resistant.

NOTE Type 3 direct tension indicators in accordance with ASTM F959/F959M can be suitable as atmospheric corrosion resistant.

5.2.6 Alternative direct tension indicators

Alternative direct tension indicators other than those listed in [Table B.6](#) may be used if permitted by the execution specification.

- a) Detailed installation instructions shall be available in a supplemental specification that shall provide, as a minimum, for the:
 - 1) required character and frequency of pre-installation verification;
 - 2) alignment of bolt holes to permit insertion of the bolt without undue damage to the threads;
 - 3) placement of bolting assemblies in all types and sizes of holes, including placement and orientation of the direct tension indicator and other washers;
 - 4) systematic assembly of the joint, progressing from the most rigid part of the joint until the connected plies are in firm contact;
 - 5) subsequent systematic pretensioning of all bolts in the joint, progressing from the most rigid part of the joint in a manner that will minimize relaxation of previously pretensioned bolts.
- b) Detailed inspection instructions shall be available in a supplemental specification that shall provide, as a minimum, for:
 - 1) observation of the required pre-installation verification testing;
 - 2) subsequent routine observation to ensure the proper use of alternative direct tension indicators.

5.2.7 Coated structural bolting components

The corrosion resistance of coated structural bolting components shall be comparable to that specified for the connected components.

Hot-dip galvanized coatings, non-electrolytically applied zinc flake coatings, electroplated coatings, or other coatings of structural bolting components appropriate with the product standards given in [Table B.9](#) may be used, or, in the absence thereof, with the bolting component manufacturer's recommendation.

Protective coatings of structural bolting components shall conform with the requirements of the relevant product standard or, in the absence thereof, with the manufacturer's recommendation.

For bolts of property class 10.9 or equivalent tensile strength or higher, electroplated coatings shall not be used.

NOTE Attention is drawn to the risk of hydrogen embrittlement of electroplated or hot dip galvanized bolts of property class 10.9 or equivalent tensile strength or higher.

5.2.8 Atmospheric corrosion-resistant structural bolting components

The chemical composition of the material of atmospheric corrosion-resistant structural bolting components shall be specified.

5.2.9 Locking devices

If required, devices shall be specified that effectively prevent loosening or loss of pretension of the assembly if subjected to impact, significant vibration, or cyclic loading.

NOTE 1 The use of wedge-locking washers, and the use of double-nutting with proper tightening techniques, have been shown to minimize loss of bolt pretension from self-loosening. Locking devices cannot prevent loss of pretension from relaxation or creep.

To prevent nuts from becoming disengaged from bolts, prevailing torque nuts from [ISO 7040](#), [ISO 7042](#), [ISO 7719](#), and [ISO 10511](#), and the performance requirements given in [ISO 2320](#), can be used unless otherwise specified.

NOTE 2 [ISO 2320](#) includes a test to determine either the performance properties or the torque/clamp force properties, or both, for prevailing torque type steel nuts.

5.2.10 Special structural fasteners

When permitted by the execution specification, special structural fasteners may be used:

- if the property class does not exceed grade 10.9 (or equivalent tensile strength);
- if the bolting component type is subjected to initial testing representative of the product type to demonstrate that its performance is suitable.

Initial testing parameters should include relevant testing requirements for comparable products listed in [Annex B](#).

Detailed installation instructions shall be available in a supplemental specification in accordance with [7.9](#).

NOTE 1 The use of special fasteners is addressed in [7.9](#).

NOTE 2 Resin injection bolts are classified as special fasteners and are addressed in [EN 1090-2](#).

5.2.11 Packaging

Structural bolting components shall be suitably packed for transportation and shall be identified in accordance with the relevant product standard. The contents of all packages shall be clearly displayed.

NOTE Consideration for packaging suitability can include needs for handling, durability, water resistance, puncture resistance, and related concerns.

5.2.12 Test reports

If required, the manufacturer or supplier test reports documenting conformance to the applicable specifications for all components used in structural bolting shall be available on delivery and before assembly or erection of structural steel.

5.2.13 Delivery and identification

Structural bolting components and bolting assemblies shall be delivered in unopened and complete packages.

Structural bolting components and bolting assemblies according to [5.2.2](#) to [5.2.5](#) shall be marked, delivered and identified in accordance with the requirements of the relevant product standard.

Atmospheric corrosion resistant bolting assemblies, foundation bolts, locking devices, plate washers, and special fasteners shall be marked in accordance with the product standard, if applicable, delivered in suitable packaging, and identified as follows:

- a) labelled such that the content is readily identifiable;
- b) labelled or documented in accordance with the relevant product standard with the following information in a legible and durable form:
 - manufacturer's identification and, if relevant, lot numbers;
 - type of structural bolting component and material and, if appropriate, its assembly;
 - protective coating, if applicable.

5.2.14 Storage of structural bolting components and assemblies

Structural bolting components and assemblies shall be divided by grade, size, length and lot number. They shall be protected from dirt and moisture in closed containers in a protected shelter at the site of installation.

The manufacturer's instructions shall be followed when stacking packages.

Only as many bolting components that are anticipated to be installed during the work shift shall be taken from protected storage. Components that are not incorporated into the work shall be returned to protected storage at the end of the work shift. Components shall not be cleaned or modified from the as-delivered condition.

High-strength bolts shall be handled carefully to prevent thread damage. In addition to thread damage, spline-drive assemblies shall be handled carefully to prevent spline damage.

5.2.15 Reconditioning of structural bolting components and assemblies

Bolting components to be installed using torque control methods, including spline-drive assemblies, that accumulate rust, dirt, or moisture, shall not be incorporated into the work unless they are requalified through testing.

Spline-drive assemblies and those bolting components to be installed using torque control methods that fail requalification testing, shall be returned to the manufacturer or supplier for reconditioning, including cleaning, relubrication, and retesting, unless these operations are permitted by the execution specification to be performed by others. Such reconditioning shall follow written procedures with requirements for lubrication products, batch control, process control, sampling, and a suitable test method to verify that the reconditioned assemblies provide the required pretension within the permitted range, if any.

5.3 Studs and shear connectors

Threaded studs for arc stud welding shall be in accordance with [ISO 17607-5](#).

Requirements for other types of shear connectors for bolted connections shall be classified as special fasteners.

5.4 Anchorages

5.4.1 Foundation bolts

The mechanical properties of rods used as foundation bolts shall be in accordance with [ISO 898-1](#), [ISO 3506-1](#) or fabricated from hot-rolled carbon, low-alloy, or stainless steel. The execution specification shall specify the required properties.

Unless otherwise specified in the execution specification, steel reinforcing bars shall not be used. When permitted in the execution specification, steel reinforcing bars shall be of a weldable grade, and the grade shall be specified in the execution specification.

5.4.2 Other anchorage systems

The execution specification shall specify if proprietary products shall be used.

6 Preparation and assembly

6.1 General

This clause applies to holes for connections with bolts, pins, and foundation bolts.

6.2 Holes for structural bolting

6.2.1 General

The nominal clearance shall be selected from [Annex C](#). Unless specified in the execution specification, the nominal clearance for bolt holes shall be as specified in [Table C.1](#).

The nominal clearances for bolts and for pins not intended to act in fitted conditions shall be specified in the execution specification. The nominal clearance is:

- for round holes, the difference between the nominal hole diameter and the nominal bolt diameter;
- for slotted holes, the difference between the length or the width of the hole and the nominal bolt diameter.

NOTE 1 [Annex C](#) provides information on nominal clearances as stated in several national standards.

NOTE 2 The nominal hole diameter combined with the nominal diameter of the bolt to be used in the hole, determines whether the hole is standard or oversized. The terms "short" and "long" applied to slotted holes refer to two types of holes used for the structural design of pretensioned bolts, and with limitation, non-pretensioned bolts. These terms are also used to designate clearances for non-pretensioned bolts.

The execution specification shall specify special dimensions for movement joints.

6.2.2 Dimensions of holes

6.2.2.1 General

Unless otherwise specified in the execution specification, the dimensions of holes shall provide the nominal clearance defined in [6.2.1](#).

6.2.2.2 Slotted holes

When permitted by the execution specification:

- short-slotted holes can be used in any or all plies of non-pretensioned joints and pretensioned bearing joints, provided the applied load is approximately perpendicular (between 80° and 100°) to the axis along the length of the slot;
- short-slotted holes can be used in any or all plies of slip-resistant joints without regard for the direction of the applied load;
- long-slotted holes can be used in only one ply at any individual faying surface of non-pretensioned joints and pretensioned bearing joints, provided the applied load is approximately perpendicular (between 80° and 100°) to the axis along the length of the slot;
- long-slotted holes can be used in one ply only at any individual faying surface of slip-resistant joints without regard for the direction of the applied load.

NOTE Fully inserted shims between the faying surfaces of load-transmitting elements of bolted joints are not considered a long-slotted element of a joint, nor are they considered to be a ply at any individual faying surface. See [6.3](#) and [6.4.2](#) for requirements for faying surfaces of shims and packing.

6.2.2.3 Holes for fit bolts

For fit bolts, the nominal hole diameter shall be equal to the shank diameter of the bolt.

NOTE For fit bolts conforming to [EN 14399-8](#), the nominal diameter of the shank is 1 mm larger than nominal diameter of the threaded portion.

6.2.2.4 Holes for countersunk bolts

For countersunk bolts, nominal dimensions of the countersinking and tolerances on those shall be such that, after installation, the bolt shall be flush with the outer face of the outer ply. The dimensions of the countersinking shall be specified accordingly.

If countersunk bolts are identified as being for use in tension or in pretensioned applications, the nominal depth of countersinking shall be at least 2 mm less than the nominal thickness of the outer ply.

NOTE The 2 mm is to allow for adverse tolerances.

6.2.2.5 Holes in base plates for foundation bolts

If the nominal clearance of the base plate hole is 3 mm or larger, but not more than 8 mm, a round or square plate washer of thickness not less than 4 mm shall be used under the nut.

In addition, for foundation bolts above 20 mm in diameter d with a minimum specified yield strength of 400 MPa or less:

- the maximum base plate hole diameter is $1,5 \times d$;
- the minimum outside diameter of the plate washer plate is $1,75 \times d + 20$ mm;
- the minimum plate washer thickness is $0,4 \times d$.

For foundation bolts with a minimum specified yield strength greater than 400 MPa, thicker plate washers can be required.

NOTE The above dimensions can be considered suitable for columns supporting gravity loads only, and for columns with low levels of moment at the column base.

6.3 Faying surfaces for bearing-type joints

The faying surfaces of bearing connections, whether with non-pretensioned or pretensioned bolts, shall be free of dirt and other foreign material, and are permitted to be uncoated, coated with protective coatings of any formulation, or galvanized, as specified in the execution specification. In addition, surfaces adjacent to the bolt head and nut, or washer(s), if used, shall be free of dirt and other foreign material.

Surface preparation and protective coating requirements also apply to packing plates and shims.

6.4 Preparation of friction surfaces in slip-resistant joints

6.4.1 General

This clause does not address corrosion protection of the structural steel.

6.4.2 Surface preparation

The slip factor for slip-resistant joints shall be specified in the execution specification.

Surface preparation and protective coatings that provide a designated minimum slip factor in accordance with specific national standards shall be selected from [Table D.1](#).

Uncoated faying surfaces, including parts of surfaces in contact with washers, shall be free of scale, except tight mill scale, and free of loose rust, dust, oil, welding spatter, paint, lacquer or other coatings, including overspray, other than those specified in the execution specification, in areas closer than one bolt diameter but not less than 25 mm from the edge of any hole and in all areas within the bolt pattern. If this condition cannot be achieved, the faying surface shall be blast cleaned. See [Figure 1](#).

Coated faying surfaces shall first be blast cleaned and subsequently coated with a coating that meets or exceeds the required slip resistance that is either qualified in accordance with the requirements in [Annex P](#) or listed in [Table D.1](#).

Packing plates and shims shall have a surface preparation that provides the same or better slip coefficient as the connected material. See [7.2.3](#).

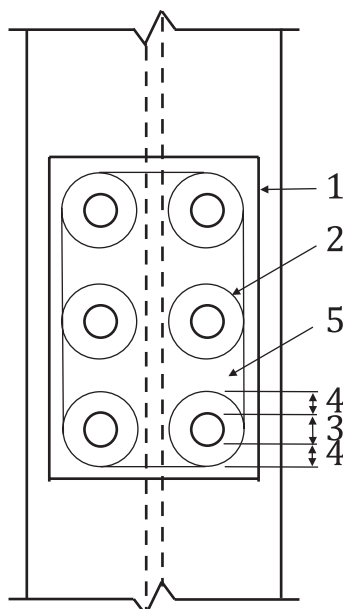
6.4.3 Precautions prior to assembly

The following precautions shall be taken prior to assembly:

- a) drilling of holes shall be completed prior to blasting;
- b) the friction surfaces shall be free from all contaminants, such as oil, dirt, or coatings other than those specified for the friction surface;
- c) uncoated surfaces shall be free from loose rust and other loose material;
- d) care shall be taken not to damage or smooth the roughened surface;
- e) when splice plates are temporarily fixed to a member, temporary bolts may be used;
- f) the plies of joints with coated faying surfaces shall not be assembled before the coating has cured.

When a grinder is used on the periphery of bolt holes for the removal of burrs after blasting, either:

- g) the ground area adjacent to the hole(s) shall be re-blasted, or
- h) the as-ground surface shall be exposed until red rust generation has occurred.



Key

- | | | | |
|---|--|---|--|
| 1 | perimeter of contact area of faying surfaces | 4 | bolt diameter or 25 mm, whichever is greater |
| 2 | circular area around bolt (typical) | 5 | area within the bolt pattern |
| 3 | bolt diameter | | |

Figure 1 — Coated faying surface for slip-resistant joints

6.5 Assembly

Loose material that would prevent solid seating of the connecting parts shall be removed before assembly.

For pretensioned and slip-resistant joints, excessive coating thickness that can cause substantial loss of bolt pretension shall be evaluated, unless otherwise approved in the execution specification.

Loss of pretension can be evaluated by testing as described in [Annex Q](#).

When assembled, connections shall be in close contact and shall not be separated by free spaces or compressible materials.

Assembly of components shall be carried out within the tolerances specified in [ISO 17607-3](#) or [ISO 17607-4](#), as applicable.

Precautions shall be taken to prevent galvanic corrosion produced by contact between different metallic materials.

Holes (e.g. for fit bolts) for which enlargement by reaming or cutting is not permitted shall be identified and not be used for alignment.

NOTE Additional holes specifically meant for alignment can be provided where connection holes cannot be used for alignment.

7 Structural bolting

7.1 General

This clause covers requirements for shop and site bolting of steel-to-steel connections using structural bolting components and assemblies.

7.2 Joint types and assembly

7.2.1 Joint type

The execution specification shall identify the joint type as a non-pretensioned joint, pretensioned joint, or slip-resistant joint.

7.2.2 Fit of joint and shims

The connected components shall be drawn together to achieve firm contact when assembled and shall not be separated by significant free spaces or compressible materials.

Shims may be used to adjust the fit in connections and the alignment of the structure. If the gap between the connected parts at the structural bolts is 1 mm or less, no shimming is required. If the gap between the connected parts at the structural bolts exceeds 1 mm, shims shall be used to reduce the gap to 1 mm or less.

For constituent products with $t > 4$ mm for plates and $t > 8$ mm for sections, unless full contact bearing is specified, residual gaps of up to 4 mm may be left at the edges when contact bearing is achieved at the central part of a connection.

Shims shall be made of flat steel unless otherwise permitted in the execution specification.

Shims shall have similar durability to that of the structure. If shims are used to align structures composed of coated material, the shims shall be protected in a similar manner to provide the specified durability, unless the shims are required to meet a specified friction slip factor.

Shims shall be secured where they are at risk of coming loose. For execution levels EXL3 and EXL4, if welding is used to secure shims, the welding shall be in accordance with [ISO 17607-5](#).

For slip-resistant joints, distortion, warping, or bending of the joint, splice plates or the connected members caused by welding, weld spatter, and burrs resulting from drilling, etc., shall be corrected and repaired with care not to damage the friction surfaces.

If lack-of-fit between erected components cannot be corrected by the use of shims, components of the structure shall be locally modified in accordance with the methods specified in [ISO 17607-4](#). The modifications shall not compromise the performance of the structure in the temporary or permanent state. This work may be executed on site. Care shall be taken with structures built of welded latticed components and space-frame structures to ensure that they are not subjected to excessive forces in an attempt to force a fit against their inherent rigidity.

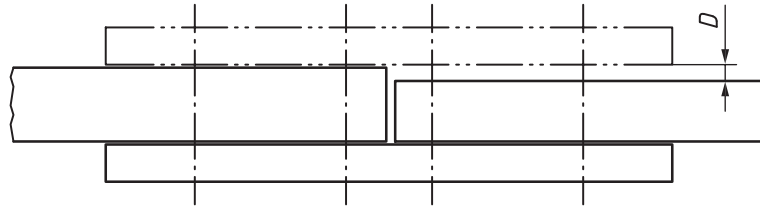
Permanent connections shall not be made between components until the structure has been aligned, levelled, plumbed and temporarily connected to ensure that components will not be displaced during subsequent erection or alignment of the remainder of the structure.

7.2.3 Packing plates

Packing plates shall be provided wherever necessary to ensure that the load-transmitting plies are in firm contact when the connection is tightened to the snug-tight condition. All packing plates shall be steel with a surface condition similar to that of the adjacent plies.

NOTE Packing plates are also referred to as filler plates when thick, or as shim plates when thin.

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



Key

D difference in thickness

Figure 2 — Difference in thickness between components of a common ply

In case of severe exposure, avoiding cavity corrosion can require closer contact.

Plate thickness shall be chosen to limit the number of packing plates to a maximum of three.

Packing plates shall have compatible corrosion behaviour and mechanical strength with the adjacent plate components of the connection. Full consideration shall be given to the risk and implication of galvanic corrosion resulting from dissimilar metals being in contact.

7.2.4 Snugging of joint

Each structural bolt assembly shall be brought at least to a snug-tight condition. Special care shall be given to avoid over-tightening, especially for short bolts and bolts of diameter M12 or smaller.

7.2.5 Sequence of tightening

The tightening process shall be carried out from structural bolt to structural bolt of the bolt group, starting from the most rigid part of the connection and moving progressively towards the least rigid part in a manner that will minimize relaxation of previously pretensioned bolts. To achieve a uniform snug-tight condition, more than one cycle of tightening can be necessary.

NOTE 1 The most rigid part of a cover plate connection of an H section is commonly in the middle of the connection bolt group. The most rigid parts of end plate connections of H sections are usually beside the beam or girder flanges.

For combined joints comprising both high-strength structural bolts and welding, in general, high-strength structural bolts shall be fastened first, followed by welding.

NOTE 2 In general, for combined connections such as beams where the webs are connected by high-strength structural bolts and the flanges connected by welding, the high-strength structural bolts are tightened first, followed by welding.

In combined connections, when the depth of a beam or the thickness of a beam flange is large, when bolt tightening is done first followed by welding, it should be considered that partial bolt tightening is done first, followed by welding, and then final bolt tightening.

NOTE 3 In combined connections as described above, there is a possibility that defects such as cracks of welds can occur.

7.2.6 Structural bolts

7.2.6.1 Bolt diameter

The nominal bolt diameter used for structural bolting shall be at least M12 unless specified in the execution specification together with the associated requirements.

7.2.6.2 Threads outside shear plane

If it is intended that a connection utilises the shear capacity of the unthreaded shank of structural bolts, then the dimensions of the structural bolts shall be specified to allow for the tolerances on the length of the bolt and the unthreaded portion. For connected parts of unequal thicknesses, if required, the orientation of the bolt shall also be specified.

7.2.6.3 Threads in grip

For non-pretensioned structural bolts, at least one full thread (in addition to the thread run-out) shall remain clear between the bearing surface of the nut and the unthreaded part of the shank, unless otherwise stated in the execution specification.

For pretensioned structural bolts, at least two threads shall be between the bearing surface of the nut and the unthreaded part of the shank, unless otherwise stated in the execution specification.

When regional or national standards are used, threads in the grip shall meet the requirements of [Annex F](#).

7.2.6.4 Thread protrusion

After tightening, at least one thread protrusion shall extend beyond the outer face of the nut when installed, unless otherwise stated in the execution specification.

When regional or national standards are used, thread protrusion shall meet the requirements of [Annex F](#).

7.2.7 Nuts

Nuts shall run freely on their partnering structural bolt, which is checked during hand assembly. Any uncoated bolting assembly where the nut does not run freely shall not be used. Coated assemblies shall not be used for pretensioned applications where the nut does not run with low resistance to rotation when using hand tools.

NOTE Hot dip galvanized bolts can have areas in the bolt or nut threads where excess zinc creates resistance to rotation of the nut.

If a power tool is used, either of the following two checks may be used:

- a) for each new batch of nuts or structural bolts, their compatibility may be checked by hand assembly before installation;
- b) for mounted bolt assemblies but prior to tightening, sample nuts may be checked for free-running by hand after initial loosening.

Nuts shall be installed so that their required identification markings are visible for inspection after installation.

7.2.8 Washers

7.2.8.1 General

If washers are required, it shall be specified whether washers are to be placed under the nut or under the bolt head, whichever is to be rotated, or both.

For lap (shingle) joints between thin plate or sheet with only one row of bolts perpendicular to the direction of stress, washers should be used under both bolt head and nut to reduce bending of the connected parts.

NOTE 1 In general, for non-pretensioned structural bolts, washers are not necessary with standard round holes.

NOTE 2 The use of washers can reduce local damage to protective coatings on steel, particularly where these are thick coatings.

7.2.8.2 Washer requirements for pretensioned bolts

For pretensioned structural bolts, unless otherwise specified, hardened washers (or if necessary, hardened taper washers) shall be used as follows:

- for grade 8.8 or equivalent tensile strength structural bolts, a washer shall be used under the bolt head or the nut, whichever is to be rotated;
- for grade 10.9 or equivalent tensile strength structural bolts installed in steel with yield strength of 300 MPa or lower, washers shall be used under both the bolt head and the nut;
- for grade 10.9 or equivalent tensile strength structural bolts installed in connected material of specified minimum yield strength above 300 MPa, a hardened flat washer shall be used under the bolt head or nut, whichever is to be rotated.

When an oversized or slotted hole occurs in an outer ply, the washer requirements shall be as prescribed in [Table 3](#). The washer used shall be of sufficient size to completely cover the hole.

Table 3 — Washer and plate washer requirements for oversized and slotted holes

Bolt grade	Nominal structural bolt diameter	Hole type in outer ply		
		Oversized	Short-slotted	Long-slotted
8.8 or equivalent strength	M12 to M36 1/2 inch to 1-1/2 inch (12,7 mm to 38,1 mm)	Standard thickness hardened washer ^a		8 mm thick plate washer or continuous bar ^{b, c}
10.9 or equivalent strength	M12 to M24 ½ inch to 1 inch (12,7 mm to 25,4 mm)			
	M27 to M36 1-1/8 inch to 1-1/2 inch (28,6 mm to 38,1 mm)	8 mm thick hardened washer ^{a, b, d}		Hardened standard thickness washer with either a 10 mm thick plate washer or continuous bar ^{b, c}
^a This requirement shall not apply to heads of round head spline-drive bolt assemblies that provide a bearing circle diameter that meets the requirements of the applicable assembly standard.				
^b Multiple washers with a combined thickness of 8 mm or larger do not satisfy this requirement.				
^c The plate washer or bar shall be of structural-grade steel material, but need not be hardened.				
^d Alternatively, a 10 mm thick plate washer and an ordinary thickness hardened washer may be used. The plate washer need not be hardened.				

When the torque control or combined method of pretensioning is used, the hardened washer as supplied or tested with the assembly shall be used under the turned element.

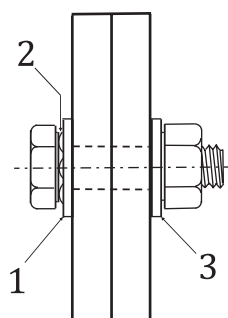
When the spline-drive twist-off bolt method of pretensioning is used, the hardened washer supplied with the assembly shall be used under the nut.

When the direct tension indicator method of pretensioning is used, a hardened washer shall be used as follows:

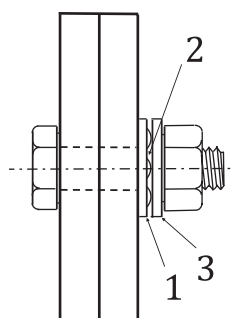
- when the nut is turned and the direct tension indicator is located under the nut, a hardened washer shall be used between the nut and the direct tension indicator - see [Figure 3b](#));
- when the bolt head is turned and the direct tension indicator is located under the bolt head, a hardened washer shall be used between the bolt head and the direct tension indicator - see [Figure 3c](#)).

When the direct tension indicator method of pretensioning is used, a hardened washer is not required where:

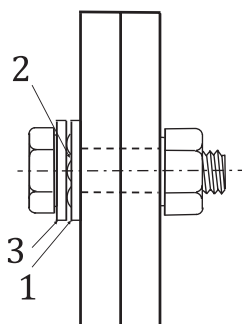
- the nut is turned and the DTI is under the bolt head - see [Figure 3a](#));
- the bolt head is turned and the DTI is under the nut - see [Figure 3d](#)).



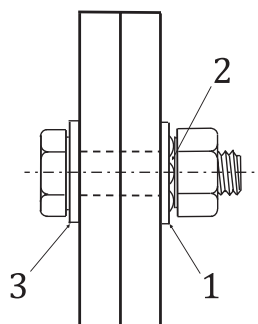
a) DTI under bolt head, nut turned



b) DTI under nut, nut turned



c) DTI under bolt head, bolt head turned



d) DTI under nut, bolt head turned

Key

- | | | | |
|---|---|---|-----------------------|
| 1 | direct tension indicator (DTI) | 3 | hardened steel washer |
| 2 | direct tension indicator gap measurement location | | |

Figure 3 — Washer placement with direct tension indicators

7.2.8.3 Chamfered washers

When required by the product specification, the washers used under heads of pretensioned structural bolts shall be chamfered and positioned with the chamfer towards the bolt head. Washers used under nuts may be non-chamfered or chamfered.

7.2.8.4 Plate washers

Plate washers shall be used for connections with slotted and oversized holes as prescribed in [Table 3](#).

For non-pretensioned structural bolting assemblies, the following may be used to adjust the grip length:

- One plate washer of any thickness; or
- Up to three plate washers, with a maximum combined thickness of 12 mm.

For pretensioned structural bolting assemblies, up to two plate washers may be used to adjust the grip length.

For non-pretensioned structural bolting assemblies, the plate washer or additional plate washers may be placed either on the side that is turned or on the side that is not turned.

For pretensioned structural bolting assemblies installed using any method except the torque control method, the plate washer or additional plate washers may be placed either on the side that is turned or on the side that is not turned.

For pretensioned structural bolt assemblies tightened by the torque control method, only one plate washer may be used on the side that is turned. Alternatively, the plate washer or additional plate washers may be placed on the side that is not turned.

Bolts detailed to have the threads excluded from the shear plane should be checked for conformance.

NOTE 1 Any use of additional washers or plate washers, or if plate washers of different thickness than specified are used, can result in the relocation of the shear plane.

Dimensions and steel grades of plate washers shall be specified in the execution specification. They shall not be thinner than 4 mm.

NOTE 2 For foundation bolts, see [6.2.2.4](#).

7.2.8.5 Taper washers

Taper washers shall be used if the surface of the constituent product is at an angle to a plane perpendicular to the bolt axis of more than that prescribed in [Table F.5](#).

Dimensions and steel grades of taper washers shall be specified in the execution specification.

When regional or national standards are used, the use of taper washers shall meet the requirements of [Table F.5](#).

7.2.9 Locking methods

Locking devices shall not be used with pretensioned assemblies unless required by the execution specification.

When locking devices are specified in addition to tightening, nuts shall be prevented from working loose by the use of locknuts, jam nuts, double nuts, thread burring, or other methods permitted by the execution specification.

Where a non-pretensioned joint is subject to impact or vibration, the effectiveness of the selected locking devices should be considered. See [5.2.9](#).

Welded joints should also be considered in lieu of bolted joints. Structural bolts and nuts shall not be welded.

The prohibition on welding of nuts does not apply to special weld nuts in accordance with, e.g. [ISO 21670](#) or to weld studs.

7.3 Tightening of non-pretensioned bolts

Non-pretensioned structural bolts shall be brought to the snug tight condition, as a minimum.

Tightening structural bolts beyond the snug-tight condition shall not be cause for rejection.

NOTE The snug-tight condition is defined in [ISO 17607-1](#).

7.4 Tightening of pretensioned bolts

7.4.1 Bolting procedure for pretensioned bolts

Prior to installation and tightening of pretensioned high-strength structural bolts, a bolting procedure for installation and tightening shall be prepared and shall indicate, as a minimum, the type of structural bolts and the tightening method.

Execution and supervision of bolt tightening work shall be carried out in accordance with the bolting procedure.

High-strength structural bolts for pretensioning shall be used without alteration to the as-delivered lubrication unless the direct tension indicator method, the turn-of-nut method, or a procedure developed using [Annex N](#) is adopted.

If the pretensioning process is delayed under uncontrolled exposure conditions such that the lubrication has degraded, and the direct tension indicator method or the turn-of-nut method is used, the performance of the lubrication should be checked and can be improved.

Before commencement of pretensioning, the connected components shall be fitted together and the structural bolts in a bolt group shall be tightened in accordance with [7.2](#), but the residual gap between connected components shall not exceed 1 mm with the necessary corrective action on steel components.

NOTE Generally, structural bolting assemblies used for achieving initial fit up need not be tightened to the minimum pretension or un-tightened and would therefore still be usable in the location in the final bolting up process. See [7.8](#).

Any of the pretensioning methods given in [7.4.7](#) through [7.4.11](#) may be used, unless restricted by the execution specification.

Tightening to the snug-tight condition and all steps of pretensioning shall be carried out progressively from the most rigid part of the joint to the least rigid part. To achieve uniform pretensioning, more than one cycle of tightening may be necessary.

7.4.2 Pretensioning tools

For the torque method, torque wrenches used in all steps of the method shall be capable of an accuracy of $\pm 4\%$ in accordance with [ISO 6789-1](#). Each wrench shall be maintained in accordance with [ISO 6789-1](#), and in case of pneumatic wrenches, checked every time the hose length is changed.

For the combined method, torque wrenches used in the first step of the method shall be capable of an accuracy of $\pm 10\%$ and checked yearly.

Other tightening equipment (e.g. hydraulic devices for axial pretensioning, ultrasonic control systems) shall be calibrated in accordance with the recommendations from the equipment manufacturer.

Pneumatic impact wrenches, if used, shall be of adequate capacity and supplied with sufficient air to perform the required pretensioning of each bolt within approximately 10 sec for bolts up to and including M30 diameter, and within approximately 15 sec for larger diameter bolts.

Checks shall be carried out after any incident affecting the wrench during use (e.g. significant impact, fall, overloading).

7.4.3 Minimum pretension

Unless specified in the execution specification, the nominal minimum pretension F_p is calculated in accordance with [Formula \(1\)](#):

$$F_p = 0,7 f_{ub} \times A_s \quad (1)$$

where

- f_{ub} is the nominal tensile strength of the bolt material;
 A_s is the tensile stress area of the bolt.

When regional or national standards are used, the minimum pretension shall meet the requirements of [Annex E](#).

This level of pretension shall be used for all slip-resistant joints and for all other pretensioned joints unless a lower level of pretension is specified in the execution specification. In the latter case, the structural bolt assemblies, the pretensioning method, the pretensioning parameters and the inspection requirements shall also be specified.

NOTE Pretension can be used for slip resistance, for seismic connections, for fatigue resistance, for execution purposes, or as a quality measure (e.g. for durability).

7.4.4 Bolting assembly k-class calibration

When specified, the *k*-class (as-delivered bolt calibration condition) of the structural bolting assembly shall be appropriate for the method used. As an alternative for all methods except the torque method, calibration to [Annex H](#) may be used. [Annex H](#) for bolt validation or evaluation for the torque method may be used if permitted by the execution specification.

The as-delivered calibration is valid for tightening by rotation of the nut. Tightening shall be performed by rotation of the nut except where the access to the nut side of the assembly is inadequate. If tightening is done by rotation of the bolt head, calibration shall be done in accordance with [Annex H](#), by supplementary testing from the matched bolting assembly manufacturer, or in accordance with an applicable standard. Special precautions, depending on the tightening method adopted, may be necessary when bolts are tightened by rotation of the structural bolt head.

NOTE [EN 14399-2](#) is an example of an applicable standard for calibration.

7.4.5 *k*-factor

The *k*-factor may be calculated in accordance with [Formula \(2\)](#):

$$k = \frac{M}{(F \times d)} \quad (2)$$

where

- M is the applied tightening torque;
 F is the achieved pretension;
 d is the nominal diameter of the bolting assembly.

NOTE The *k*-factor covers the friction in the bearing surface between the nut and the washer and the friction factor between the nut and bolt threads. Variability in the surface condition of the manufactured threads and the bearing surface between nut and washer will affect the *k*-factor, and limits can be set for this variability in terms of the as-delivered calibration condition or *k*-class. If there is deterioration of the surface condition of the threads before installation, this will also change the value of the *k*-factor.

7.4.6 Pre-installation verification testing

For structural bolting assemblies in EXL2, EXL3, or EXL4, with no known *k*-class or a *k*-class of K0, the pre-installation verification testing procedure shall be the method provided in [Annex G](#), unless otherwise restricted by the execution specification.

For [EN 14399-3](#), [EN 14399-4](#), and [EN 14399-10](#) structural bolting assemblies with a *k*-class of K1 or K2, pre-installation verification testing is not required, unless specified in the execution specification.

7.4.7 Torque method

For pretensioning using the torque method, the bolting procedure shall be selected from the methods provided in [Annex I](#), unless otherwise restricted by the execution specification.

7.4.8 Combined method

For pretensioning using the combined method, the bolting procedure shall be selected from the methods provided in [Annex J](#), unless otherwise restricted by the execution specification.

NOTE The combined method is also known as the part-turn method.

7.4.9 Spline-drive twist-off method

For pretensioning using the spline-drive twist-off method, the bolting procedure shall be as provided in [Annex K](#), unless otherwise restricted by the execution specification.

NOTE The spline-drive twist-off method is also known as the HRC method, Torshear method, and twist-off tension control bolt method.

7.4.10 Direct tension indicator method

For pretensioning using the direct tension indicator method, the bolting procedure shall be as provided in [Annex L](#), unless otherwise restricted by the execution specification.

7.4.11 Turn-of-nut method

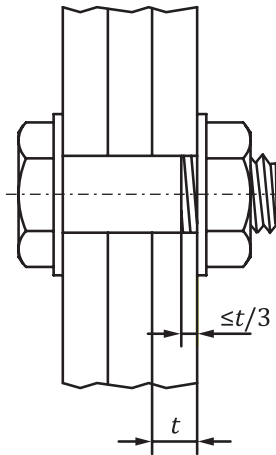
For pretensioning using the turn-of-nut method, the bolting procedure shall be selected from the methods provided in [Annex M](#), unless otherwise restricted by the execution specification.

7.5 Fit bolts

Fit bolts may be used in pretensioned or non-pretensioned applications, and [7.3](#) or [7.4](#) applies, as appropriate, in addition to the requirements below.

The length of the threaded portion of the shank of the fit bolt (including thread run out) included in the bearing length should not exceed 1/3 of the thickness of the plate adjacent to the nut unless specified in the execution specification, see [Figure 4](#).

Fit bolts shall be installed without applying excessive force, and in such a way that the thread is not damaged.

**Key** t plate thickness**Figure 4 — Threaded portion of the shank in the bearing length for fit bolts****7.6 Temporary bolts**

Temporary bolts are used for assembly of structural members during erection prior to full fastening or welding, to prevent deformation or collapse of the framework caused by external forces.

In typical high-strength structural bolted joints, temporary bolts shall be bolts or assemblies for either non-pretensioned applications (see [Table B.1](#) through [Table B.5](#)) or pretensioned applications (see [Table B.1](#) through [Table B.3](#)). The number of temporary bolts shall be approximately one third of the total number of bolts used in the final joint and shall not be less than two. Temporary bolts shall be located in a balanced distribution and shall be tightened as required for a non-pretensioned application.

Temporary bolts used for erection pieces for welded joints shall be high-strength bolts, and all bolts shall be tightened to at least the snug tight condition.

High-strength structural bolts used temporarily during erection to facilitate assembly may be used in the final connection, but if so used, they shall not be pretensioned until all bolts in the connection have been tightened to the snug-tight condition.

Temporary bolts that are to be removed shall be identified.

7.7 Loss of pretension

The potential loss of pretension from its initial value due to several factors, e.g. relaxation, creep of surface coatings (see [Annex P](#) and [Annex Q](#)), should be considered. In case of thick surface coatings, it shall be specified if measures shall be taken to offset possible subsequent loss of bolt pretension.

The higher levels of pretension normally achieved when using the combined method and the turn-of-nut method should be considered when evaluating the possible loss of pretension.

For the torque method, restoring the required pretension can be achieved by retightening after a delay of several days.

For the combined method and the turn-of-nut method, restoring the required pretension can be achieved by retightening, but caution is warranted to avoid excessive levels of pretension that would cause the bolting assembly to fail, and testing should be considered to verify that suitable pretension is achieved without undue damage to the bolt.

NOTE For significantly yielded bolts, there is no generally accepted procedure for retightening. Yielded bolts that require significant added nut rotation can cause the nut to engage and seize on the stretched bolt threads.