BRITISH STANDARD

BS EN
14399-2:2005

High-strength structural bolting assemblies for preloading —

Part 2: Suitability test for preloading

The European Standard EN 14399-2:2005 has the status of a British Standard

ICS 21.060.01

BSI
British Standards

National foreword

This British Standard is the official English language version of EN 14399-2:2005. Together with BS EN 14399-1:2005, BS EN 14399-3:2005, BS EN 14399-4:2005, BS EN 14399-5:2005 and BS EN 14399-6:2005, it supersedes BS 4395-1:1969 and BS 4395-2:1969, which are planned to be declared obsolescent in September 2007[1], and then, together with BS 449 and BS 5950, will be withdrawn upon publication of Eurocode 3. (BS 4395-1:1969 and BS 4395-2:1969 currently support BS 449 and BS 5950.)

The UK participation in the preparation of EN 14399-2 was entrusted by Technical Committee FME/9, Nuts, bolts and accessories/Steering Committee, to its Subcommittee, FME/9/1, Materials, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

Additional information

This part of BS EN 14399 is one of several parts that comprise the BS EN 14399 series of standards. BS EN 14399-1 provides the general requirements to which the other parts, which provide specific requirements regarding manufacture, materials and testing, relate.

Cross-references

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[1] CEN/TC 185/WG 6 has applied for a two-year extended co-existence period, to "September 2007", and for a corrigendum to amend the second "September 2005" date in the Foreword to EN 14399-2:2005 to "September 2007".

Summary of pages

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EUROPEAN STANDARD

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English version

High-strength structural bolting assemblies for preloading - Part 2: Suitability test for preloading

Boulonnerie de construction métallique à haute résistance apte à la précontrainte - Partie 2 : Essai d'aptitude à l'emploi pour la mise en précontrainte

Hochfeste planmäßig vorspannbare Schraubenverbindungen für den Metallbau - Teil 2: Prüfung der Eignung zum Vorspannen

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Foreword

This document (EN 14399-2:2005) has been prepared by Technical Committee CEN/TC 185, "Threaded and non-threaded mechanical fasteners and accessories", the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2005, and conflicting national standards shall be withdrawn at the latest by September 2005.

Rules for design and execution of bolted connections with preloaded high-strength structural bolts are respectively defined in ENV 1993-1-1 (Eurocode 3) and ENV 1090-1 for general rules and rules for buildings.

This test, which determines the functional characteristics identified in the relevant product standards, has been developed to confirm the suitability of a high strength bolt/nut/washer assembly for preloaded bolted connections in civil engineering structures.

This document includes a Bibliography.

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1 Scope

This document specifies a tightening test to verify the suitability of high strength bolt/nut/washer assemblies for preloaded bolted connection in metallic structures.

The purpose of this test is to check the behaviour of the fastener assembly so as to ensure that the required preload can be reliably obtained by the tightening methods specified in ENV 1090-1 with sufficient margins against over tightening and against failure.

2 Normative references

The following referenced documents are indispensable for the application 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.

EN 14399-1:2005, *High-strength structural bolting assemblies for preloading — Part 1: General requirements.*

EN 14399-3*, High-strength structural bolting assemblies for preloading — Part 3: System HR — Hexagon bolt and nut assemblies.*

EN 14399-4 *High-strength structural bolting assemblies for preloading — Part 4: System HV — Hexagon bolt and nut assemblies.*

EN 14399-5, *High-strength structural bolting assemblies for preloading — Part 5: Plain washers.*

EN 14399-6, *High-strength structural bolting assemblies for preloading — Part 6: Plain chamfered washers.*

EN ISO 898-1, *Mechanical properties of fasteners made of carbon steel and alloy steel — Part 1: Bolts, screws and studs (ISO 898-1:1999).*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 14399-1:2005 apply.

4 Symbols and units

A elongation, (mm)

A_s nominal stress area of the bolt, (mm^2) (see EN ISO 898-1)

d nominal thread diameter, (mm)

F_b bolt force during the test, (kN)

F_{bi} individual value of the bolt force related to a given nut rotation, torque or bolt elongation, (kN)

F_{bm} mean value of F_{bi} values, (kN)

$F_{bi,max}$ individual value of the maximum bolt force reached during the test, (kN)

F_p specified preload of $0{,}7\, f_{ub}\, A_s$, (kN)

f_{ub} nominal tensile strength ($R_{m,nom}$), (MPa)

k k-factor

k_i individual value of the k-factor

k_m mean value of the k-factor

$l_{b,eff}$ effective preloaded bolt length given as the clamp length (Σt) plus half the nominal nut height, (mm)

M torque applied during the test, (Nm)

M_i individual value of the torque applied during the test, (Nm)

M_{spec} specified value of the torque to be applied to the bolt, (Nm)

n number of test results

s_F estimated standard deviation of the F_{bi} values

s_k estimated standard deviation of the k_i -values

t thickness of a clamped part, (mm)

V_F coefficient of variation of the F_{bi} values

V_k coefficient of variation of the k_i-values

θ angle of rotation of the nut relative to the bolt, (°)

θ_{pi} individual value of the angle θ at which the bolt force has first reached the value of F_p, (°)

θ_{1i} individual value of the angle θ at which the bolt force has reached its maximum value $F_{bi,\,max}$, (°)

θ_{2i} individual value of the angle θ at which the test is stopped, (°)

$\Delta\theta_{1i}$ individual angle difference (θ_{1i} - θ_{pi}), (°)

$\Delta\theta_{2i}$ individual angle difference (θ_{2i} - θ_{pi}), (°)

$\Delta\theta_{2\,min}$ minimum required value of the angle difference $\Delta\theta_{2i}$ as specified in the relevant product standard (°)

Σt clamp length given as the total thickness of the clamped parts between the nut bearing face and the bolt head bearing face, (mm)

5 Principle of the test

The principle of the test is to tighten the assembly and to measure, during tightening, the following parameters:

— the bolt force;
— the relative rotation between the nut and the bolt;
— the torque, if required;
— the bolt elongation, if required.

6 Test apparatus

The test apparatus shall be made of steel.

The block on which the assembly is mounted shall be sufficiently rigid.

NOTE Hydraulic measuring devices do not normally meet this requirement.

It is recommended that the stiffness of the test set-up be as high as practicable.

The length of the bolt between the head and the nut shall be adjusted by the use of shims as specified in Table 1. The number of shims shall not exceed four.

Table 1 — Characteristics of shims

Dimensions in millimetres

Nominal bolt diameter	Hole diameter	Outside diameter	Thickness	Hardness for the outside shim	Parallelism
$d \leq$ M14	d + 1	Not less than the outside assembly washer diameter and sufficient to distribute load adequately to the device	≥ 2	45 HRC to 50 HRC through hardened	≤ 1 %
M14 < $d \leq$ M24	d + 2				
$d >$ M24	d + 3				

The bolt force shall be measured by a calibrated device (e.g. dynamometer) with uncertainty of ± 2 % of the actual value and a repeatability error of ± 1 %.

The rotation shall be measured to an uncertainty of ± 1°.

The torque shall be measured by a calibrated torque measuring device with an uncertainty of the value and a repeatability error of ± 1 %.

The bolt elongation shall be measured to an uncertainty of ± 1/100 mm. Ball bearings may be fitted at the ends of the bolt to facilitate these measurements.

7 Test assemblies

The test shall be carried out on assemblies that include at least a washer under the nut.

Test assemblies shall be taken from a single assembly lot or extended assembly lot (see EN 14399-1). Associated bolts, nuts and washers shall be in accordance with one of the following:

— EN 14399-3 for the HR bolt and nut system associated with washers either according to EN 14399-5 or to EN 14399-6;

— EN 14399-4 for the HV bolt and nut system associated with washers either according to EN 14399-5 or to EN 14399-6.

Each component of a test assembly shall be used once only.

Unless otherwise agreed between the supplier and the purchaser (see Annex A), the tests shall be carried out on test assemblies in the condition of delivery without alteration of the lubrication of the various components.

8 Test set-up

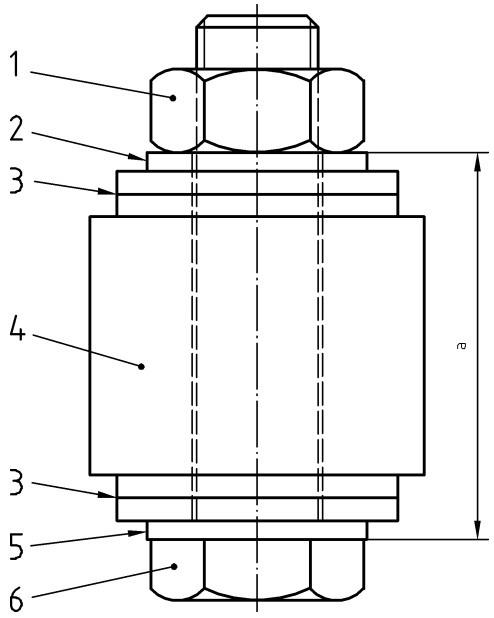
The test set-up (see Figure 1) may include shims (see Table 1) needed to suit the measuring device.

The test assemblies and shims shall be positioned such that:

— a washer of the assembly is placed under the nut;

— a chamfered washer or a chamfered shim is placed under the bolt head;

— the clamp length including shims and washer(s) is the minimum allowed in the relevant product standard.



Key
1 Nut: turned during tightening
2 Washer of the assembly: prevented from rotating
3 Shim(s)
4 Calibrated bolt force measuring device
5 Chamfered washer of the assembly or chamfered shim
6 Bolt head: prevented from rotating

a Clamp length Σt

Figure 1 — Test set-up

9 Test procedure

The test shall be carried out at an ambient temperature range of 10 °C to 35 °C.

The tightening shall be carried out by rotation of the nut in a continuous manner and measurements shall be recorded throughout the test.

The speed of rotation of the test shall be between 1 min^{-1} and 10 min^{-1}.

Neither the bolt nor the washer under the nut shall rotate during the test. If either of them rotates during tightening, the phenomena shall be noted and a new test shall be carried out to replace the test in question.

The test shall be stopped when any one of the following conditions is first satisfied:

— the angle of nut rotation exceeds ($\theta_{pi} + \Delta\theta_{2\,min}$);
— the bolt force drops to F_p;

— bolt failure by fracture occurs.

For each of the test assemblies the following curves shall be determined:

— the rotation/bolt force relationship;

— the torque/bolt force relationship, if required;

— the elongation/bolt force relationship, if required.

The data of these relationships shall be such as to permit accurate interpretation of the results and be consistent with the accuracy of the test apparatus (see examples of curves in Figures 2 to 5).

10 Evaluation of the test results

10.1 Rotation/bolt force curve

The following shall be obtained from each curve in accordance with Figure 2:

— the angle θ_{pi} at which the bolt force first reaches the value of F_p; θ_{pi} is noted;

— the angle θ_{1i} at which the bolt force reaches its maximum value $F_{bi,\,max}$ is also noted;

— the angle θ_{2i} at which the test is stopped and at which the value of the bolt force F_{bi} (θ_{2i}) is also noted.

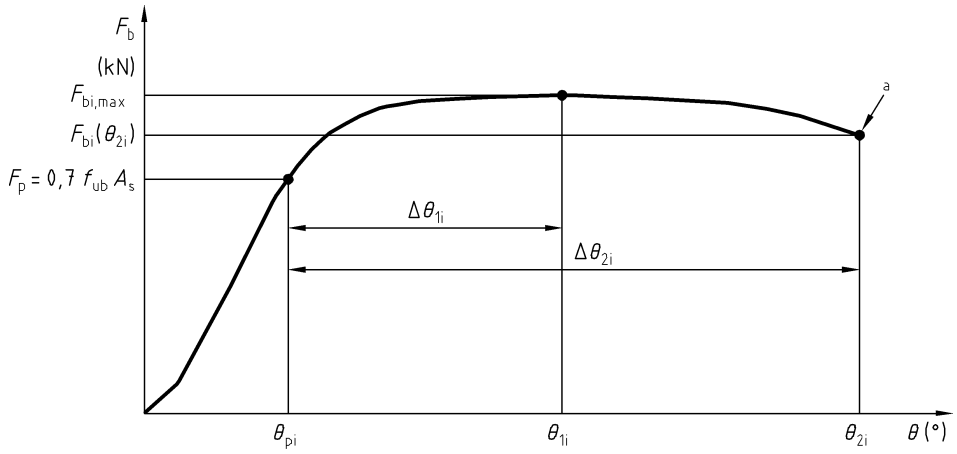
When θ_{1i} cannot be precisely determined from the measurement data, it shall be calculated as the mean value of two angles corresponding to the two intersections of the curve with a horizontal line at 1 % below the maximum bolt force value $F_{bi,\,max}$ noted during the test.

Although the purpose of measuring the angle θ_{2i} is to obtain an indication of the nut rotation at which the bolt force drops back to the value F_p, in practice the test may be stopped when the angle difference $\Delta\theta_{2i}$ reaches the specified required minimum value $\Delta\theta_{2\,min}$ according to the relevant product standard (see Clause 9).

From the above angle measurements the following values are determined:

— the angle difference $\Delta\theta_{1i}$, which is defined as (θ_{1i} - θ_{pi}) and corresponds to the point at which the maximum bolt force $F_{bi,\,max}$ has been reached;

— the angle difference $\Delta\theta_{2i}$, which is defined as (θ_{2i} - θ_{pi}) and corresponds to the point at which the test has been stopped.



Key

a End of test

Figure 2 — Rotation/bolt force curve

10.2 Torque/bolt force curve for the torque at the design preload

An individual value of k (k_i) shall be obtained from each curve in accordance with Figure 3 for the torque (M_i) corresponding to the bolt force (F_p). The value of k_i is calculated as follows:

$$k_i = \frac{M_i}{d\ F_p}$$

The coefficient of variation (V_k) of the thus obtained k_i values is given by the ratio of their estimated standard deviation and their mean value (k_m).

The estimated standard deviation (s_k) and the mean value (k_m) are calculated as follows:

$$s_k = \sqrt{\frac{\sum (k_i - k_m)^2}{n-1}} \qquad \text{with} \qquad k_m = \frac{\sum_{i=1}^{n} k_i}{n}$$

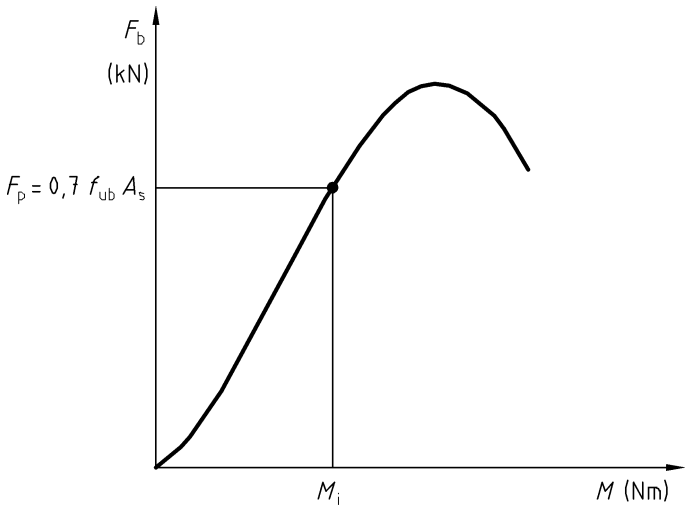
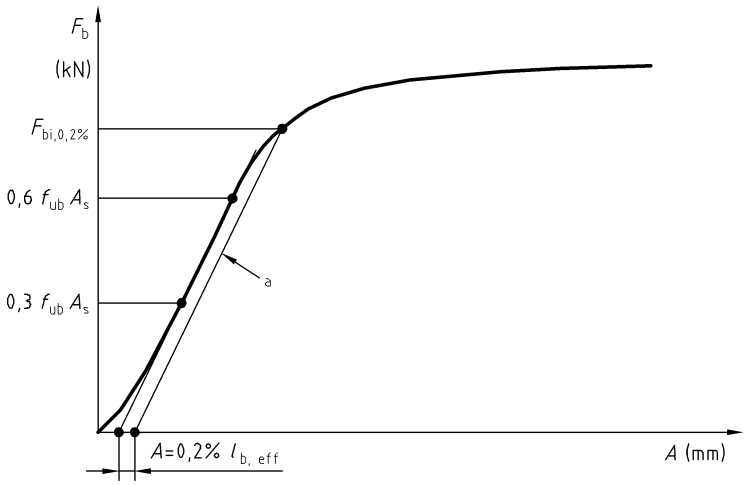


Figure 3 — Torque/bolt force curve

10.3 Elongation/bolt force curve

The individual bolt force value $F_{bi,\ 0,2\%}$ corresponding to a permanent bolt elongation of 0,2 % $l_{b,eff}$, where $l_{b,eff}$ is the effective preloaded bolt length, shall be obtained from each curve in accordance with Figure 4.

The 0,2 % permanent elongation line is drawn parallel to the straight line between the two points on the curve at which the bolt force values are $0,3\ f_{ub}\ A_s$ and $0,6\ f_{ub}\ A_s$ respectively.



Key

a Line of 0,2 % permanent elongation

Figure 4 — Elongation/bolt force curve

10.4 Torque/bolt force curve for the individual values of the bolt force at a specified value of the applied torque

When a specified torque value is required:

The individual bolt force value F_{bi} at a specified torque value of M_{spec} shall be obtained from each curve in accordance with Figure 5:

$$F_{bi} = F_{bi}\,(M_{spec})$$

The coefficient of variation (V_F) of the thus obtained F_{bi} values is given by the ratio of their estimated standard deviation (s_F) and their mean value (F_{bm}).

The estimated standard deviation (s_F) and the mean value (F_{bm}) are calculated as follows:

$$s_F = \sqrt{\frac{\sum (F_{bi} - F_{bm})^2}{n-1}} \qquad \text{with} \qquad F_{bm} = \frac{\sum_{i=1}^{n} F_{bi}}{n}$$

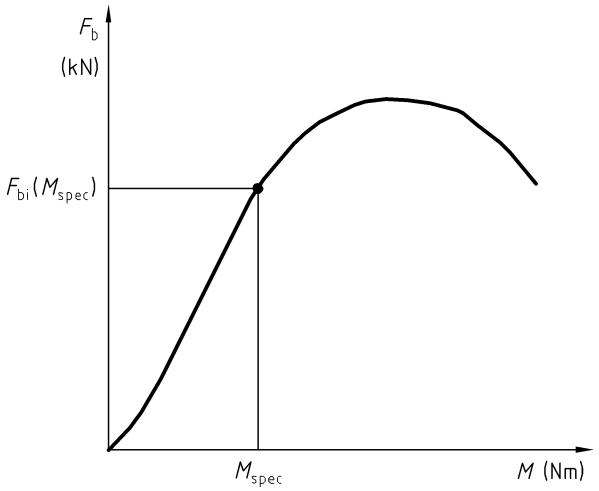


Figure 5 — Torque/bolt force curve

11 Test report

The following minimum information shall be included in the test documentation.

— Identification of the laboratory.

— Identification of the organization ordering the test.

— Date of reception of the assemblies.

— Date of testing.

— Identification number of the assembly lot or the extended assembly lot (provided by the client).

— Number of assemblies tested.

— Designation of the fasteners.

— Marking of bolts, nuts and washers.

— Coating or surface finish.

— Lubrication.

— Test clamp length.

— Details of the test set-up including rigidity.

— Tightening conditions (speed of tightening, number of shims).

— Remarks concerning the execution of tests (including, if any, those on special testing conditions and procedures, see Annex A).

— Tests results according to this standard.

— Evaluation of the functional characteristics of the assembly lot or the extended assembly lot in relation to the requirements of the relevant product standard.

— Conclusions.

Annex A
(informative)

Special testing conditions and procedures

By agreement between the supplier and the purchaser, the following special conditions can be applied. However, the test results obtained are not comparable with those for the standard test conditions:

a) Long bolts:

For the evaluation of bolts of a length greater than 10 d, the procedure in 10.2 for obtaining values of k is valid, but special evaluation criteria for rotation or deformation should be agreed.

b) Short bolts:

When the bolts are too short to meet the testing conditions defined in Clause 8, one of the following possibilities can be considered:

1) The bolts can be tested provided that one thread length exists after tightening between the end of the bolt and the unloaded face of the nut.

2) Longer bolts from an otherwise similar lot can be tested using the standard test conditions. The difference in length should be as small as practicable.

c) Lubrication:

The as-delivered lubrication can be altered.

d) Tightening:

1) The speed of rotation can be altered.

2) Tightening by rotation of the head of the bolt can be carried out.

In this case, an assembly washer is required to be placed under the bolt head and both the nut and the washer under the bolt head shall be prevented from rotating. If they rotate during the test, the phenomena shall be noted and a new test should be carried out to replace the test in question.

3) Discontinuous tightening can be carried out.

Bibliography

[1] ENV 1090-1, *Execution of steel structures — Part 1: General rules and rules for buildings.*

[2] ENV 1993-1-1, *Eurocode 3 - Design of steel structures — Part 1-1: General rules and rules for buildings.*

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