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

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Summary of pages

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

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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of an identical text or by endorsement, at the latest by September 2005, and conflicting national standards shall be withdrawn at the latest by September 2005.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.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.
1 Scope

This document specifies a tightening test to verify the suitability of high strength bolt/nut/washer assemblies for pre-loaded 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 pre-load 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 14399-3, 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.


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 $0.7f_{ub}A_s$, (kN)
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>
<thead>
<tr>
<th>Nominal bolt diameter</th>
<th>Hole diameter</th>
<th>Outside diameter</th>
<th>Thickness</th>
<th>Hardness for the outside shim</th>
<th>Parallelism</th>
</tr>
</thead>
<tbody>
<tr>
<td>d ≤ M14</td>
<td>d + 1</td>
<td>Not less than the outside assembly washer diameter and sufficient to distribute load adequately to the device</td>
<td>≥ 2</td>
<td>45 HRC to 50 HRC through hardened</td>
<td>≤ 1 %</td>
</tr>
<tr>
<td>M14 &lt; d ≤ M24</td>
<td>d + 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d &gt; M24</td>
<td>d + 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.

![Diagram of test set-up](image)

**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 $\Sigma t$

**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 $\theta_{pi}$ at which the bolt force first reaches the value of $F_p$: $\theta_{pi}$ is noted;
— the angle $\theta_{1i}$ at which the bolt force reaches its maximum value $F_{bi,max}$ is also noted;
— the angle $\theta_{2i}$ at which the test is stopped and at which the value of the bolt force $F_{bi}(\theta_{2i})$ is also noted.

When $\theta_{1i}$ 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 $\theta_{2i}$ 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 $\Delta \theta_{z min}$ 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 $(\theta_{1i} - \theta_{pi})$ 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 $(\theta_{2i} - \theta_{pi})$ and corresponds to the point at which the test has been stopped.

Key

- End of test
10.2 Torque/bolt force curve for the torque at the design preload

An individual value of \( k_i \) 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:

\[
s_k = \sqrt{\frac{\sum (k_i - k_m)^2}{n - 1}}
\]

with \( k_m = \frac{\sum k_i}{n} \).

![Figure 3 — Torque/bolt force curve](image)

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:

$$s_F = \sqrt{\frac{\sum (F_{bi} - F_{bm})^2}{n - 1}}$$

with

$$F_{bm} = \frac{\sum_{i=1}^{n} F_{bi}}{n}$$

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.
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