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Studiedag EN 1090
Edegem 10/11 juni 2010

Mechanische bevestigingsmiddelen
ir. Rik DEBRUYCKERE (SECO)



Mechanical fasteners according to EN 1090-2



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5.6.3 Bolting assemblies for non preloaded applications

- EN 15048-1 : Non preloaded structural bolting assemblies - Part 1: General requirements
- EN 15048-2 : Non preloaded structural bolting assemblies - Part 2: Suitability test
- EN ISO 898-1: Mechanical properties of fasteners made of carbon steel and alloy steel - Part 1: Bolts, screws and studs - Coarse thread and fine pitch thread
- EN ISO 898-2: Mechanical properties of fasteners made of carbon steel and alloy steel - Part 2: Nuts with specified proof load values - Coarse thread



5.6.3 Stainless steel

- EN ISO 3506-1 : Mechanical properties of corrosion-resistant stainless steel fasteners - Part 1: Bolts, screws and studs
- EN ISO 3506-2 : Mechanical properties of corrosion-resistant stainless steel fasteners - Part 2: Nuts



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5.6.3 Bolting assemblies for non preloaded applications

- EN 15048-1 : Non preloaded structural bolting assemblies - Part 1: General requirements

4.7.2009 NL Publicatieblad van de Europese Unie C 152/9

INFORMATIE AFKOMSTIG VAN DE LIDSTATEN

Mededeling van de Commissie in het kader van de uitvoering van Richtlijn 89/106/EEG van de Raad betreffende de onderlinge aanpassing van de wettelijke en bestuursrechtelijke bepalingen der Lid-Staten inzake voor de bouw bestemde produkten
(Voor de EER relevante tekst)
(Bekendmaking van titels en referentienummers van geharmoniseerde normen in het kader van de richtlijn)
(2009/C 152/05)

CEN	EN 15048-1:2007 Niet-voorgespannen boutverbinding voor staalconstructies — Deel 1: Algemene eisen		1.1.2008	1.10.2009
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Datum inwerkingtreding geharmoniseerde norm Einddatum coëxistentieperiode

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5.6.3 Bolting assemblies for non preloaded applications


- EN 15048-1 : Non preloaded structural bolting assemblies - Part 1: General requirements

Table 6 — Appropriate combinations of bolts, nuts and washers with regard to property classes

Assemblies made of steel			
Bolts	Nuts	Washers	
Property class	Property class	Hardness class	
4.6	4, 5, 6 or 8	100 HV or 200 HV	
4.8			
5.6	5, 6 or 8		
5.8			
6.8	6 or 8		
8.8	8 or 10		
10.9	10 or 12		
Assemblies made of stainless steel			
Grade	Bolts	Nuts	Washers
	Property class	Property class	Hardness class
A2	50	50, 70 or 80	100 HV or 200 HV
A3	70	70 or 80	
A4	80	80	
A5			

Table from prEN

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 **5.6.3 Bolting assemblies for non preloaded applications**


- EN 15048-1 : Non preloaded structural bolting assemblies - Part 1: General requirements

The standard applies to thread sizes from M12 to M36 and to the associated washers but does not preclude the use of other sizes.


Bolted connections with components according to this European standard are able to be shear and/or tensile loaded.


Bolts, nuts and washers according to this European Standard are not normally intended for welding.

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 **5.6.3 Bolting assemblies for non preloaded applications**

- EN 15048-1 : Non preloaded structural bolting assemblies - Part 1: General requirements
 - M12=>M36

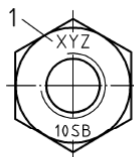
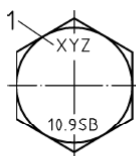


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5.6.3 Bolting assemblies for non preloaded applications

- EN 15048-1 : Non preloaded structural bolting assemblies - Part 1: General requirements




5.6.3 Bolting assemblies for non preloaded applications

- EN 15048-1 : Non preloaded structural bolting assemblies - Part 1: General requirements

Table 1 — General mechanical characteristics of bolts

Mechanical characteristic	Relevant standard for property class	
	carbon steel and alloy steel 4.6, 4.8, 5.6, 5.8, 6.8, 8.8, 10.9	stainless steel 50, 70, 80
Elongation after fracture	EN ISO 898-1	EN ISO 3506-1
Minimum tensile strength	EN ISO 898-1	EN ISO 3506-1
Lower yield strength or Stress at 0,2 % non-proportional elongation	EN ISO 898-1	EN ISO 3506-1
Stress under proof load	EN ISO 898-1	not applicable
Strength under wedge loading	EN ISO 898-1	not applicable
Hardness	EN ISO 898-1	not applicable




 **5.6.3 Bolting assemblies for non preloaded applications**


- EN 15048-1 : Non preloaded structural bolting assemblies - Part 1: General requirements

Table 3 — Nuts


Mechanical characteristic	Relevant standard for property class	
	carbon steel and alloy steel 4, 5, 6, 8, 10, 12	stainless steel 50, 70, 80
Stress under proof load	EN 20898-2	EN ISO 3506-2
Hardness	EN 20898-2	not applicable


↓
EN ISO 898-2

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 **5.6.3 Bolting assemblies for non preloaded applications**

- Assembly = bolt + nut (+ washer if necessary)
- Assemblies according to EN 14399-1 may also be used for non preloaded applications
- Fasteners acc. to EN ISO 898-1 shall not be used to join stainless steel


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5.6.4 HS Structural bolting assemblies for preloading

- EN 14399-1 : General requirements
- EN 14399-2 : Suitability test for preloading
- EN 14399-3 : Hexagon bolt and nut assemblies (system HR)
- EN 14399-4 : Hexagon bolt and nut assemblies (system HV)
- EN 14399-5 : Plain washers
- EN 14399-6 : Plain chamfered washers
- EN 14399-7 : Countersunk head bolts and nut assemblies
- EN 14399-8 : Hexagon fit bolt and nut assemblies
- EN 14399-9 : Direct tension indicators (system HR or HV)
- EN 14399-10 : Bolt and nut assemblies with calibrated preload (system HRC)

Bolts and nuts Washers



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5.6.4 HS Structural bolting assemblies for preloading

EN 14399-1 : General requirements

4.7.2009 SL Publicatieblad van de Europese Unie C 152/9


INFORMATIE AFKOMSTIG VAN DE LIDSTATEN

Mededeling van de Commissie in het kader van de uitvoering van Richtlijn 89/106/EEG van de Raad betreffende de onderlinge aanpassing van de wettelijke en bestuursrechtelijke bepalingen der Lid-Staten inzake voor de bouw bestemde producten
(Voor de EER relevante tekst)


(Bekendmaking van titels en referentienummers van geharmoniseerde normen in het kader van de richtlijn)
(2009/C 152/05)

CEN	EN 14399-1:2005 Verbindingen met hoge voorspanning in staalconstructies — Deel 1: Algemene eisen	1.1.2006	1.10.2007
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Datum inwerkingtreding geharmoniseerde norm Einddatum coëxistentieperiode

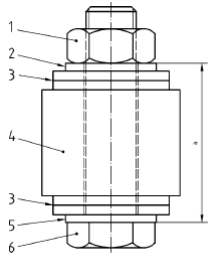


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5.6.4 HS Structural bolting assemblies for preloading

EN 14399-2 : Suitability test for preloading




Three curves:

- la relation angle de rotation/précontrainte dans la vis ;
- la relation couple/précontrainte dans la vis, si demandé ;
- la relation allongement/précontrainte dans la vis, si demandé.



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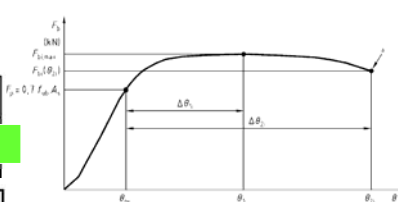


5.6.4 HS Structural bolting assemblies for preloading

EN 14399-2 : Suitability test for preloading


Courbe angle de rotation/ précontrainte

Longueur de serrage Σr	β_{R1} min.
$\Sigma r < 2d$	90°
$2d \leq \Sigma r < 6d$	120°
$6d \leq \Sigma r \leq 10d$	150°



Longueur de serrage Σr	β_{R2} min.
$\Sigma r < 2d$	210°
$2d \leq \Sigma r < 6d$	240°
$6d \leq \Sigma r \leq 10d$	270°

Longueur de serrage Σr	β_{R2} min.
$\Sigma r < 2d$	180°
$2d \leq \Sigma r < 6d$	210°
$6d \leq \Sigma r \leq 10d$	240°



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5.6.4 HS Structural bolting assemblies for preloading

EN 14399-2 : Suitability test for preloading
Courbe couple/ précontrainte

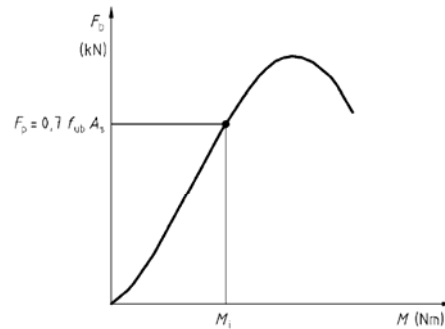
K1-bolts

$$0,10 \leq k_i \leq 0,16$$

K2-bolts

$$0,10 \leq k_m \leq 0,23$$

$$V_k \leq 0,10$$



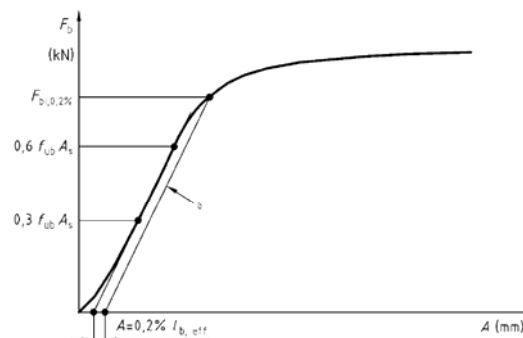
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5.6.4 HS Structural bolting assemblies for preloading

EN 14399-2 : Suitability test for preloading
Courbe allongement/ précontrainte



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5.6.4 HS Structural bolting assemblies for preloading

EN 14399-3 : Hexagon bolt and nut assemblies (system HR)


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

5.6.4 HS Structural bolting assemblies for preloading



EN 14399-4 : Hexagon bolt and nut assemblies (system HV)


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 **5.6.4 HS Structural bolting assemblies for preloading**

- EN 14399-3 : HR
 - M12=>M36
 - 8.8/8 & 10.9/10
 - Ductility by plastic elongation of bolt
 - Nut height EN ISO 4032
 - Thread length ISO 888
- EN 14399-4 :HV
 - M12=>M36
 - 10.9/10
 - Ductility by plastic deformation of threads
 - Nut height $\approx 0,8d$
 - Short thread length










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 **5.6.4 HS Structural bolting assemblies for preloading**

- EN 14399-3 : HR
 - $b=78\text{à}97\text{mm}$ M36
 - $l_g=116\text{mm}$ M36/200mm
 - $m=29,4\text{à}31\text{mm}$ M36/200mm
- EN 14399-4 : HV
 - $b=52\text{mm}$ M36
 - $l_g=148\text{mm}$ M36/200mm
 - $m=27,7\text{à}29\text{mm}$ M36/200mm







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5.6.4 HS Structural bolting assemblies for preloading

- EN 14399-5
 - Plain washer
- EN 14399-6
 - Plain chamfered

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5.6.4 HS Structural bolting assemblies for preloading

EN 14399-7 : Countersunk head bolts and nut assemblies

	Bolt/nut/washer(s) assembly System HR	Bolt/nut/washer(s) assembly System HV
General requirements	EN 14399-1	
Bolt/nut assemblies	EN 14399-3, EN 14399-7	EN 14399-4, EN 14399-8
Marking	HR	HV
Property classes	8.8/8 or 8.8/10	10.9/10
Washer(s)	EN 14399-5 or EN 14399-6	
Marking	H	H
Suitability test for preloading	EN 14399-2	EN 14399-2

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5.6.4 HS Structural bolting assemblies for preloading

EN 14399-7 : Countersunk head bolts and nut assemblies

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5.6.4 HS Structural bolting assemblies for preloading

EN 14399-8 : Hexagon fit bolt and nut assemblies

	Bolt/nut/washer(s) assembly System HR		Bolt/nut/washer(s) assembly System HV
General requirements	EN 14399-1		
Bolt/nut assemblies	EN 14399-3, EN 14399-7		EN 14399-4, EN 14399-8
Marking	HR		HV
Property classes	8.8/8 or 8.8/10	10.9/10	10.9/10
Washer(s)	EN 14399-5 or EN 14399-6		EN 14399-5 or EN 14399-6
Marking	H		H
Suitability test for preloading	EN 14399-2		EN 14399-2

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5.6.4 HS Structural bolting assemblies for preloading

EN 14399-8 : Hexagon fit bolt and nut assemblies

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5.6.4 HS Structural bolting assemblies for preloading

EN 14399-9 : Direct tension indicators (system HR or HV)

Figure 7 Load indicating washers

Before tensioning After tensioning

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5.6.4 HS Structural bolting assemblies for preloading

EN 14399-10 : Bolt and nut assemblies with calibrated preload (system HRC)



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5.6.11 Screws

- EN ISO 1479 : Hexagon head tapping screws
- EN ISO 1481 : Slotted pan head tapping screws
- EN ISO 7049 : Cross recessed pan head tapping screws
- EN ISO 15480 : Hexagon washer head drilling screws with tapping screw thread
- ISO 10509 : Hexagon flange head tapping screws

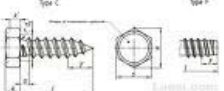


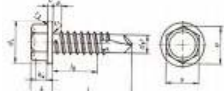
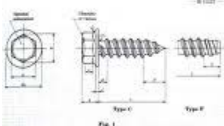


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5.6.11 Screws

- EN ISO 1479 : 
- EN ISO 1481 : 
- EN ISO 7049 : 
- EN ISO 15480 : 
- ISO 10509 : 


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5.6.11 Rivets


- EN ISO 15976 : Closed end blind rivets with break pull mandrel and protruding head
- EN ISO 15979 : Open end blind rivets with break pull mandrel and protruding head
- EN ISO 15980 : Open end blind rivets with break pull mandrel and countersunk head
- EN ISO 15983 : Open end blind rivets with break pull mandrel and protruding head - A2/A2
- EN ISO 15984 : Open end blind rivets with break pull mandrel and countersunk head - A2/A2

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 **5.6.11 Rivets**

- EN ISO 15976 : 
- EN ISO 15979 : 
- EN ISO 15980 : 
- EN ISO 15983 : 
- EN ISO 15984 : 

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 **5.6.1 Coating**

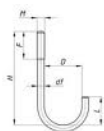
- EN ISO 10684 : Fasteners - Hot dip galvanized coatings

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5.6.7 Foundation bolts

- EN ISO 898-1
- Fabricated from steel acc to EN 10025-2 to EN 10025-4
- Reinforcing steel acc to EN 10080



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5.6.8 Locking devices

- EN ISO 2320 : Prevailing torque type steel nuts - Mechanical and performance properties
- EN ISO 7040 : Prevailing torque type hexagon nuts (with non-metallic insert), style 1 - Property classes 5, 8 and 10
 - EN ISO 7042 : Prevailing torque type all-metal hexagon nuts - Property classes 5, 8, 10 and 12
 - EN ISO 7719 : Prevailing torque type all-metal hexagon nuts, style 1 - Property classes 5, 8 and 10
 - EN ISO 10511 : Prevailing torque type hexagon thin nuts (with non-metallic insert)
 - EN ISO 10512 : Prevailing torque type hexagon nuts (with non-metallic insert), style 1, with metric fine pitch thread - Property classes 6, 8 and 10
 - EN ISO 10513 : Prevailing torque type all-metal hexagon nuts, style 2, with metric fine pitch thread - Property classes 8, 10 and 12

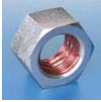


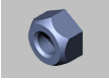





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5.6.8 Locking devices


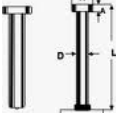


- EN ISO 2320 : 
- EN ISO 7040 : 
- EN ISO 7042 : 
- EN ISO 7719 : 
- EN ISO 10511 : 
- EN ISO 10512 : 
- EN ISO 10513 : 

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5.7 Stud and shear connectors

- EN ISO 13918

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5.2 Inspection documents

Table 1 — Inspection documents for metallic products

Constituent product	Inspection documents
Structural steels (Tables 2 and 3)	according to Table B.1 of EN 10025-1:2004 ^{a b}
Stainless steels (Table 4)	3.1
Steel castings	according to Table B.1 of EN 10340:2007
Welding consumables (Table 5)	2.2
Structural bolting assemblies	2.1 ^c
Hot rivets	2.1 ^c
Self-tapping and self-drilling screws and blind rivets	2.1
Studs for arc studs welding	2.1 ^c
Expansion joints for bridges	3.1
High strength cables	3.1
Structural bearings	3.1



6.6 Holing

Table 11 — Nominal clearances for bolts and pins (mm)

Nominal bolt or pin diameter d (mm)	12	14	16	18	20	22	24	27 and over
Normal round holes ^a	1 ^{b c}		2				3	
Oversize round holes	3		4			6		8
Short slotted holes (on the length) ^d	4		6			8		10
Long slotted holes (on the length) ^d	1,5 d							


^a For applications such as towers and masts the nominal clearance for normal round holes shall be reduced by 0,5 mm unless otherwise specified.

^b For coated fasteners, 1 mm nominal clearance can be increased by the coating thickness of the fastener.

^c Bolts with nominal diameter 12 and 14 mm, or countersunk bolts may also be used in 2 mm clearance holes under conditions given in EN 1993-1-8.


^d For bolts in slotted holes the nominal clearances across the width shall be the same as the clearances on diameter specified for normal round holes.






6.6.2 Holing : tolerances on hole diameter

- Holes for fit bolts and fitted pins: class H11 acc to ISO 286-2
- Other holes : $\pm 0,5\text{mm}$




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6.6.2 Holing : tolerances on hole diameter

- Holes for fit bolts and fitted pins: class H11 acc to ISO 286-2

Nominal hole sizes (mm)																				
over	3	6	10	18	30	40	50	65	80	100	120	140	160	180	200	225	250	280	315	355
inc.	6	10	18	30	40	50	65	80	100	120	140	160	180	200	225	250	280	315	355	400
micrometres																				
E6	+28 +20	+34 +25	+43 +32	+53 +40	+66 +50	+79 +60	+94 +72	+110 +85	+129 +100	+142 +110	+161 +125									
E7	+32 +20	+40 +25	+50 +32	+61 +40	+75 +50	+90 +60	+107 +72	+125 +85	+146 +100	+162 +110	+185 +125									
E11	+95 +20	+115 +25	+142 +32	+170 +40	+210 +50	+250 +60	+292 +72	+335 +85	+390 +100	+430 +110	+485 +125									
H11	+75 0	+90 0	+110 0	+130 0	+160 0	+190 0	+220 0	+250 0	+290 0	+320 0	+360 0									




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6.6.3 Holing : execution of holing

- Holes may be formed by any process (drilling, punching, laser cutting, plasma cutting, other thermal cutting)
 - Cutting requirements (local hardness and quality cut surface acc to 6.4 are fulfilled)
 - All matching holes register with each other so that fasteners can be inserted freely




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6.6.3 Holing : execution of holing

- EXC1 and EXC2 : punching without reaming is allowed
- EXC3 and EXC4 : punching without reaming is not allowed
- Punching is allowed if thickness \leq diameter hole



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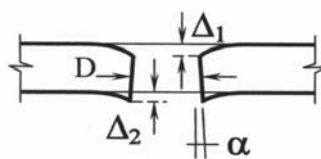
6.6.3 Holing : execution of holing

- Capability of holing processes shall be checked periodically
 - 8 samples shall be produced on constituent product encompassing the range of hole diameters, constituent product thickness and grades processed
 - Hole sizes shall be checked at both ends of each hole using go/no go gauges



6.6.3 Holing : execution of holing

- Holes shall also conform to the following:




$$D = \frac{(d_{\max} + d_{\min})}{2}$$

$$\max(\Delta_1 \text{ or } \Delta_2) \leq \max(D/10 ; 1 \text{ mm})$$

$$\alpha \leq 4^\circ \text{ (i.e. 7 \%);}$$

Figure 1 — Permitted distortions of punched holes and plasma cuts



 **8 Mechanical fastening: General**

- $D \leq 2$ mm (generally) or 1 mm (preload)
- Steel packing plates ≥ 2 mm
- Number of packing plates limited to 3

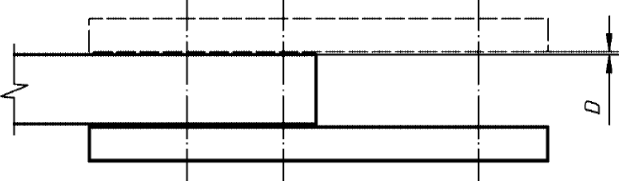





Figure 3 — Différence d'épaisseur entre éléments d'un même assemblage

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 **8 Mechanical fastening: General**

- It shall be specified if other measures or means are to be used to secure the nuts
- Preloaded assemblies do not need additional locking devices
- Bolts and nuts shall not be welded (exception weld nuts acc to EN ISO 21670, DIN 928, DIN 929, weld studs,...)

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8.2.2 Mechanical fastening: Bolts

- The nominal fastener diameter shall be at least M12
- Length of protrusion shall be at least length of 1 thread pitch
- If connection utilises the shear capacity of the unthreaded shank of bolts, then the dimension of the bolts shall be specified to allow for the tolerances on the length of the unthreaded portion



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8.2.2 Bolts

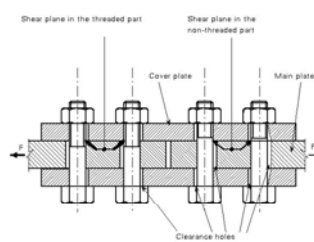
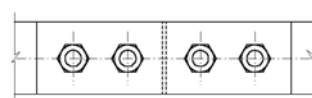


Figure 1 Typical bolted connection with cover plates.



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8.2.2 Bolts

- For non-preloaded bolts, at least 1 full thread shall remain clear between the bearing surface of the nut and the unthreaded part of the shank
- For *preloaded bolts acc to EN 14399-3 and EN 14399-7* at least 4 full threads shall remain clear between the bearing surface of the nut and the unthreaded part of the shank
- For preloaded bolts acc to EN 14399-4 and EN 14399-8: see Table A.1 of EN 14399-4



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8.2.3 Nuts

- Nuts shall run freely on their partnering bolt, which is easily checked during hand assembly
- Nuts shall be assembled so that their designation markings are visible for inspection after assembly



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8.2.4 Washers

- Generally, washers are not required for use with non-preloaded round holes
- The use of washers can reduce local damage to metal coatings (washer to be placed under nut or bolt head, whichever is rotated)
- Washers used under heads of preloaded bolts shall be chamfered acc to EN 14399-6 and positioned with the chamfer towards the bolt head
- Washers acc to EN 14399-5 shall only be used under nuts



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8.2.4 Washers

- For preloaded 8.8 bolts a plain washer (or hardened taper washers) shall be used under the bolt head or the nut, whichever is to be rotated
- For preloaded 10.9 bolts plain washers (or hardened taper washers) shall be used under both the bolt head and the nut
- Plate washers shall be used for connections with long slotted and oversized holes. They shall not be thinner than 4 mm.
- Taper washers shall be used if the surface is at an angle to a plane perpendicular to the bolt axis of more than 1/20 ($d \leq 20\text{mm}$) or 1/30 ($d > 20\text{mm}$)



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8.3 Tightening of non-preloaded bolts

- Components shall be drawn together such that they achieve firm contact. Shims may be used.
- For plates $t \geq 4\text{mm}$ & for sections $t \geq 8\text{mm}$, residual gaps up to 4 mm may be left at te edges on condition that contact bearing is achieved at the central part of the connection
- Avoid overtightening, especially for short bolts and M12
- The bolt shall protude from the face of the nut after tightening not less than one full thread pitch



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8.4 Preparation of contact surfaces in slip resistant connections

- Contact surfaces shall be prepared to produce the required slip factor (test acc to Annex G).
- The contact surfaces shall be free from all contaminants, such as oil, dirt or paint. Burrs that would prevent solid seating of the connecting parts shall be removed.
- Uncoated surfaces shall be freed from all films of rust and other loose material. Care shall be taken not to damage or smooth the roughened surface.



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8.4 Preparation of contact surfaces in slip resistant connections

- Surface treatment, assumed to provide the minimum slip factor acc to the specified class of friction surface

Table 18 — Classifications that may be assumed for friction surfaces

Surface treatment	Class	Slip factor μ
Surfaces blasted with shot or grit with loose rust removed, not pitted.	A	0,50
Surfaces blasted with shot or grit:	B	0,40
a) spray-metallized with a aluminium or zinc based product;		
b) with alkali-zinc silicate paint with a thickness of 50 μm to 80 μm		
Surfaces cleaned by wire-brushing or flame cleaning, with loose rust removed	C	0,30
Surfaces as rolled	D	0,20



8.5 Tightening of preloaded bolts

- Preload may be used for slip resistance, for seismic connections, for fatigue resistance, for execution purposes or as a quality measure
- Nominal min preloading force $F_{p,C} = 0,7 f_{ub} A_s$

Table 19 — Values of $F_{p,C}$ in [kN]

Property class	Bolt diameter in mm							
	12	16	20	22	24	27	30	36
8.8	47	88	137	170	198	257	314	458
10.9	59	110	172	212	247	321	393	572





8.5 Tightening of preloaded bolts

- Four tightening methods : the k-class of the bolting assembly shall be in accordance with Table 20

Table 20 — κ-classes for tightening methods

Tightening method	k-classes
Torque method	K2
Combined method	K2 or K1
HRC tightening method	K0 with HRD nut only or K2
Direct tension indicator (DTI) method	K2, K1 or K0



8.5 Tightening of preloaded bolts

- The as-delivered calibration is valid for tightening by rotation of the nut. If tightening is done by rotation of the bolt head, new calibration shall be done (annex H or suppl testing from the manufacturer)





8.5 Tightening of preloaded bolts

- Torque wrenches in torque method: accuracy of 4%, accuracy checked weekly, accuracy pneumatic wrenches checked every time the hose length is changed
- Torque wrenches in 1st step combined method: accuracy of 10%, accuracy checked yearly



8.5 Tightening of preloaded bolts

▪ 8.5.2 Torque reference values

- a) values based on *k*-class declared by the fastener manufacturer in accordance with the relevant parts of EN 14399:
- 1) $M_{r,2} = k_m d F_{p,C}$ with k_m for *k*-class K2.
 - 2) $M_{r,1} = k_m d F_{p,C}$ with k_m for *k*-class K1.
- b) values determined according to Annex H:
- 1) $M_{r,test} = M_m$ with M_m determined according to the procedure relevant to the tightening method to be used.





8.5 Tightening of preloaded bolts

- 8.5.3 Torque method
 - Hand or power operated wrenches may be used
 - Impact wrenches may be used for the 1st step
 - 1st step : torque value of about $0,75 M_{r,i}$
 - $M_{r,i} = M_{r,2}$ or $M_{r,test}$
 - 2nd step : torque value of $1,10 M_{r,i}$



8.5 Tightening of preloaded bolts

- 8.5.4 Combined method
 - 1st step : torque value of about $0,75 M_{r,i}$ (this step shall be completed for all bolts before 2nd step)
 - $M_{r,i} = M_{r,2}$ or $M_{r,1}$ or $M_{r,test}$
 - For simplification $M_{r,1} = 0,13.d.F_{p,C}$ may be used
 - 2nd step : a specified part turn is applied to the turned part of the assembly (acc to Table 21)





8.5 Tightening of preloaded bolts

8.5.4 Combined method

Table 21 — Combined method: additional rotation
(8.8 and 10.9 bolts)

Total nominal thickness "t" of parts to be connected (including all packs and washers) <i>d</i> = bolt diameter	Further rotation to be applied, during the second step of tightening	
	Degrees	Part turn
$t < 2d$	60	1/6
$2d \leq t < 6d$	90	1/4
$6d \leq t \leq 10d$	120	1/3

NOTE Where the surface under the bolt head or nut (allowing for taper washers, if used) is not perpendicular to the bolt axis, the required angle of rotation should be determined by testing



8.5 Tightening of preloaded bolts

8.5.5 HRC method

- HRC bolts shall be tightened using a specific shear wrench
 - The 1st tightening step is achieved at the latest when the shear wrench outer socket stops turning. The first step shall be completed for all bolts in 1 connection prior to commencement of the 2nd step.
 - The 2nd tightening step is achieved when the spline end of the bolt shears off at the break-neck.





8.5 Tightening of preloaded bolts

- 8.5.6 Direct tension indicator method
 - Applies to compressible washers
 - Fitting and checking of compressible washer-type direct tension indicators acc to Annex J
 - 2 steps of tightening



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8.6 Fit bolts

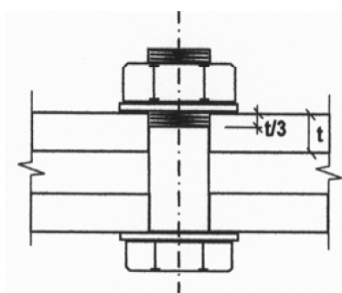


Figure 4 — Threaded portion of the shank in the bearing length for fit bolts



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8.7 Hot riveting

- Rivets: shall be of sufficient length
- Installation of rivets:
 - Connected components shall be drawn together
 - Max eccentricity between common holes $\leq 1\text{mm}$
- Acceptance criteria
 - Rivet heads shall be centred
 - Rivet heads shall be well formed and shall not show cracks or pits
 - Rivets shall be in satisfactory contact with the assembled parts



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8.8.1 Fastening of thin gauge components: General

- Applies to thin gauge up to 4 mm
- Procedure tests may be used to demonstrate that the required connections can be performed under site conditions
 - Ability to produce correct hole size for self-tapping screws and rivets
 - Ability to correctly adjust power screwdrivers with the correct tightening torque/depth location
 - Ability to drive a self-drilling screw perpendicular to the connected surface and set sealing washers to correct compression
 - Ability to select and use cartridge fired pins
 - Ability to form an adequate structural connection and to recognize an inadequate one



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8.8.3 Use of self-tapping and self-drilling screws

- Length and thread form of screws shall suit the thickness of the product to be fastened.
- Fasteners shall be located in the valley of the corrugation, unless otherwise specified.
- If screws are fastened in the crown of a roofing profile, care shall be taken to avoid dents in the sh

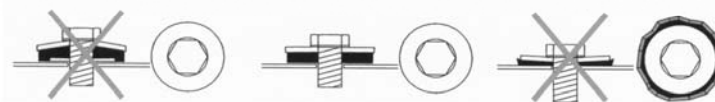


Figure 5 — Guide for compression of sealing washers



8.8.2 Use of blind rivets

- The choice of the length of the blind rivet shall be acc to the total thickness to be fastened.
- After installation work, the ejected broken mandel stems shall be collected and removed form exterior work surfaces to prevent subsequent corrosion.





8.10 Galling and seizure of stainless steels


- The following methods may be used to avoid galling:
 - Dissimilar standard grades of stainless steel which vary in composition, work hardening rate and hardness
 - A proprietary high work-hardening stainless steel alloy may be used for 1 component
 - Anti-galling agents such as PTFE dry film spray



12.5.2 Inspection and testing of preloaded bolted connections


- 12.5.2.1 Inspection of friction surfaces
- 12.5.2.2 Inspection before tightening
- 12.5.2.3 Inspection during and after tightening
- 12.5.2.4 Torque method
- 12.5.2.5 Combined method
- 12.5.2.6 HRC method
- 12.5.2.7 Direct tension indicator method






12.5.2 Inspection and testing of preloaded bolted connections

- 12.5.2.1 Inspection of friction surfaces
 - The surfaces shall be visually checked immediately before assembly




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12.5.2 Inspection and testing of preloaded bolted connections

- 12.5.2.2 Inspection before tightening
 - All connections shall be visually checked immediately before assembly
 - The chamfered washers shall be visually checked
 - For EXC2, EXC3 and EXC4, the tightening procedure shall be checked.
 - The torque wrench certificates shall be checked to verify the accuracy (torque method or combined method)



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12.5.2 Inspection and testing of preloaded bolted connections

- 12.5.2.3 Inspection during and after tightening
 - Number of bolt assemblies inspected
 - EXC2: 5% for the 2nd step of the torque or the combined method
 - EXC3 and EXC4: 5% for the 1st step and 10% for the 2nd step of the combined method
 - EXC3 and EXC4: 10% for the 2nd step of the torque method
 - Inspection using a sequential sampling plan according to Annex M
 - EXC2 and EXC3: sequential type A
 - EXC4: sequential type B



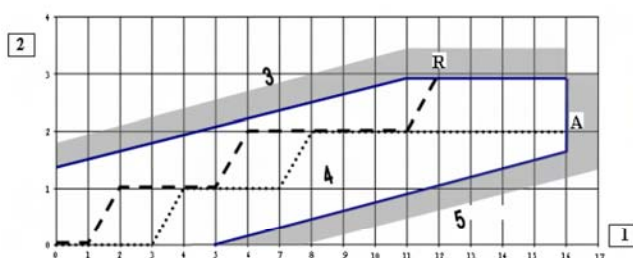
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12.5.2 Inspection and testing of preloaded bolted connections

- 12.5.2.3 Inspection during and after tightening



Key

- 1 number of fasteners inspected
- 2 number of defective fasteners
- 3 rejection zone
- 4 indecision zone
- 5 acceptance zone



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12.5.2 Inspection and testing of preloaded bolted connections

- 12.5.2.4 Torque method
 - Torque necessary to initiate rotation is at least 1,1 times $M_{r,i}$
 - Accuracy torque wrench $\pm 4\%$
 - Inspection between 12 h and 72 h after final completion
 - A bolting assembly for which the nut turns by more than 15° is considered to be undertightened



12.5.2 Inspection and testing of preloaded bolted connections

- 12.5.2.5 Combined method
 - Check the 1st step (75%) for EXC3 and EXC4: a bolt which turns by more than 15° is considered defective
 - Before the 2nd step, the marking of the nuts relative to the bolt threads shall be visually inspected
 - After the 2nd step, the marks shall be inspected
 - If rotation angle is more than 15° below the specified value: this angle shall be corrected
 - If rotation angle is more than 30° over the specified angle: bolt assembly shall be replaced





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