

Cranes — General design —

Part 3.1: Limit states and proof of competence of steel structures

ICS 53.020.20

National foreword

This Draft for Development was published by BSI. It is the UK implementation of CEN/TS 13001-3.1:2004, incorporating Corrigendum July 2006.

When Parts 1, 2, 3.1, 3.2 and 3.3 of this Standard are published, BS 2573 Parts 1 and 2 will be withdrawn.

The start and finish of text introduced or altered by corrigendum is indicated in the text by tags AC AC. Tags indicating changes to CEN text carry the number of the CEN amendment. For example, text altered by CEN Corrigendum 1 is indicated in the text by AC1 AC1.

This publication is not to be regarded as a British Standard.

It is being issued in the Draft for Development series of publications and is of a provisional nature because CEN/TS 13001-3.1:2004 is itself a provisional standard.

NOTE A CEN/TS is a “Technical Specification” issued by CEN for an evolving technology, with a view to it being developed to full EN status within three years.

It should be applied on this provisional basis, so that information and experience of its practical application may be obtained.

Comments arising from the use of this Draft for Development are requested so that UK experience can be reported to the European organization responsible for its conversion to a European standard. A review of this publication will be initiated 2 years after its publication by the European organization so that a decision can be taken on its status at the end of its 3-year life. Notification of the start of the review period will be made in an announcement in the appropriate issue of *Update Standards*.

According to the replies received by the end of the review period, the responsible BSI Committee will decide whether to support the conversion into a European standard, to extend the life of the Technical Specification or to withdraw it. Comments should be sent in writing to the Secretary of BSI Subcommittee MHE/3/1, Crane design, at British Standards House, 389 Chiswick High Road, London W4 4AL, giving the document reference and clause number and proposing, where possible, an appropriate revision of the text.

A list of organizations represented on MHE/3/1 can be obtained on request to its secretary.

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Amd. No.	Date	Comments
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English version

Cranes - General design - Part 3.1: Limit states and proof of competence of steel structures

Appareils de levage à charge suspendue - Conception générale - Partie 3.1: Etats limites et vérification d'aptitude des structures métalliques

Krane - Konstruktion allgemein - Teil 3.1: Grenzzustände und Sicherheitsnachweis von Stahltragwerken

This Technical Specification (CEN/TS) was approved by CEN on 25 November 2003 for provisional application.

The period of validity of this CEN/TS is limited initially to three years. After two years the members of CEN will be requested to submit their comments, particularly on the question whether the CEN/TS can be converted into a European Standard.

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Foreword

This document (CEN/TS 13000-3.1:2004) has been prepared by Technical Committee CEN/TC 147 “Cranes — Safety”, the secretariat of which is held by BSI.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive 98/37/EC, amended by 98/79/EC.

According to the CEN/CENELEC Internal Regulations, the national standards organisations of the following countries are bound to announce this Technical Specification: 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 the United Kingdom.

This European Standard is one Part of EN 13001. The other parts are as follows:

Part 1: General principles and requirements

Part 2: Load actions

The annexes A, C and D are normative. The annexes B, E and F are informative.

Introduction

This European Standard has been prepared to be a harmonised standard to provide one means for the mechanical design and theoretical verification of cranes to conform with the essential health and safety requirements of the Machinery Directive, as amended. This standard also establishes interfaces between the user (purchaser) and the designer, as well as between the designer and the component manufacturer, in order to form a basis for selecting cranes and components.

This European Standard is a type C standard as stated in AC1 EN ISO 12100-1 AC1.

The machinery concerned and the extent to which hazards, hazardous situations and events are covered are indicated in the scope of this document.

When provisions of this type C standard are different from those which are stated in type A or B standards, the provisions of this type C standard take precedence over the provisions of the other standards, for machines that have been designed and built according to the provisions of this type C standard.

The machinery concerned and the extent to which hazards are covered are indicated in the scope of this standard.

1 Scope

This European Standard is to be used together with Part 1 and Part 2 and as such they specify general conditions, requirements and methods to prevent mechanical hazards of cranes by design and theoretical verification.

NOTE Specific requirements for particular types of crane are given in the appropriate European Standard for the particular crane type.

The following is a list of significant hazardous situations and hazardous events that could result in risks to persons during normal use and foreseeable misuse. Clauses 4 to 8 of this standard are necessary to reduce or eliminate the risks associated with the following hazards:

- a) Exceeding the limits of strength (yield, ultimate, fatigue);
- b) Exceeding temperature limits of material or components;
- c) Elastic instability of the crane or its parts (buckling, bulging).

This European Standard is applicable to cranes which are manufactured after the date of approval by CEN of this standard and serves as reference base for the European Standards for particular crane types.

NOTE CEN/TS 13001-3.1 deals only with limit state method according to EN 13001-1.

As an alternative to the herein presented limit state method using partial safety factors, the allowable stress method using a global safety factor according to Part 1 and Part 2 may also be applied for special crane systems with linear behaviour.

As crane structures are basically dynamically loaded only the linear theory of elasticity is applicable and only limited local plasticity is allowed. The use of the theory of plasticity for calculation of ultimate load bearing capacity is not allowed.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These

normative references are cited at the appropriate places in the text, and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of, any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 1070:1998, *Safety of machinery — Terminology*.

AC1 EN 1990:2002, *Eurocode — Basis of structural design* **AC1**

EN 1993-1-1:1992, *Eurocode 3: Design of steel structures — Part 1-1: General rules and rules for buildings*.

EN 10025:1990/A1:1993, *Hot rolled products of non-alloy structural steels — Technical delivery conditions (includes amendment A1:1993)*.

EN 10045-1:1989, *Charpy impact test on metallic material — Part 1: Test method*.

EN 10113-1:1993, *Hot-rolled products in weldable fine grain structural steels — Part 1: General delivery conditions*.

EN 10113-2:1993, *Hot-rolled products in weldable fine grain structural steels — Part 2: Delivery conditions for normalized/normalized rolled steels*.

EN 10113-3:1993, *Hot-rolled products in weldable fine grain structural steels — Part 3: Delivery conditions for thermomechanical rolled steels*.

EN 10137-2:1995, *Plates and wide flats made of high yield strength structural steels in the quenched and tempered or precipitation hardened conditions — Part 2: Delivery conditions for quenched and tempered steels*.

EN 10149-1:1995, *Hot-rolled flat products made of high yield strength steels for cold forming — Part 1: General delivery conditions*.

EN 10149-2:1995, *Hot-rolled flat products made of high yield strength steels for cold forming — Part 2: Delivery conditions for thermomechanically rolled steels*.

EN 10149-3:1995, *Hot-rolled flat products made of high yield strength steels for cold forming — Part 3: Delivery conditions for normalized or normalized rolled steels*.

EN 10164:1993, *Steel products with improved deformation properties perpendicular to the surface of the product — Technical delivery conditions*.

EN 12345:1996, *Welding — Multilingual terms for welding joints with illustrations (trilingual version)*.

EN 13001-1:2004, *Cranes — General Design — Part 1: General principles and requirements*.

EN 13001-2:2004, *Cranes — General Design — Part 2: Load actions*.

EN 22553:1994, *Welded, brazed and soldered joints — Symbolic representation on drawings (ISO 2553:1992)*.

EN 25817:1992, *Arc-welded joints in steel — Guidance on quality levels for imperfections (ISO 5817:1992)*.

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

EN ISO 9013:2002, *Thermal cutting — Classification of thermal cuts — Geometrical specification and quality tolerances (ISO 9013:2002)*.

EN ISO 12100-1:2003, *Safety of machinery — Basic concepts, general principles for design — Part 1: Basic terminology, methodology (ISO 12100-1:2003)*.

EN ISO 12100-2:2003, *Safety of machinery — Basic concepts, general principles for design — Part 2: Technical principles and specifications (ISO 12100-2:2003)*.

ISO 286-2:1990, *ISO system of limits and fits — Part 2: Tables of standard tolerance grades and limit deviations for holes and shafts*.

ISO 4306-1:1990, *Cranes — Vocabulary — Part 1: General*.

3 Terms and definitions

3.1

Terms and definitions

AC1 For the purposes of this European Standard, the terms and definitions given in EN ISO 12100-1 and EN ISO 12100-2 and the basic list of definitions as provided in EN 1990 apply. For the definitions of loads, clause 6 of ISO 4306-1:1990 applies. AC1

3.2

Symbols and abbreviations

The symbols and abbreviations used in this Part of the EN 13001 are given in Table 1.

Table 1 — Symbols and abbreviations

Symbols, abbreviations	Description
A	cross section
A_S	stress area of a bolt
a_r	relevant weld thickness
D_o, D_i	outer, inner diameter of hollow pin
d	diameter (shank of bolt, pin)
d_o	diameter of hole
e_1, e_2	distances
F_b	tensile force in bolt
F_d	limit force
F_K	characteristic value (force)
F_p	preloading force in bolt
F_{Rd}	limit design force
F_t	external force (on bolted connection)
$F_{b, Rd}$	limit design bearing force
$F_{b, Sd}; F_{bi, Sd}$	design bearing force
$F_{p, d}$	design preloading force
$F_{s, Rd}$	limit design slip force per bolt and friction interface
$F_{t, Rd}$	limit design tensile force in bolt
$F_{v, Rd}$	limit design shear force per bolt/pin and shear plane
$F_{v, Sd}$	design shear force per bolt/pin and shear plane
$F_{s, t}$	acting normal/shear force
f_d	limit stress
f_K	characteristic value (stress)
f_{Rd}	limit design stress

Table 1 (continued)

Symbols, abbreviations	Description
f_u	ultimate strength of material
f_{ub}	ultimate strength of bolts
$f_{w, Rd}$	limit design weld stress
f_y	yield point of material
f_{yb}	yield point of bolts
f_{yk}	yield point (nominal value) of material or member
f_{yp}	yield point of pins
G_i	mass of the moving crane parts during a representative working cycle
h	distance between weld and contact area of acting load
K_b	stiffness (slope) of bolt
K_c	stiffness (slope) of flanges
k^*	specific spectrum ratio factor
$k_{(m)}$	stress spectrum factor based on m of the detail under consideration
$k_{(m=3)}$	stress spectrum factor based on m = 3
l_r	relevant weld length
l_w	weld length
M_{Rd}	limit design bending moment
M_{Sd}	design bending moment
m	inverse slope of σ/N -curve
NC	notch class
$\min s, \max s$	extreme values of stresses
P_s	probability of survival
p_1, p_2	distances
Q	mass of the maximum hoist load
q	impact toughness parameter
R_d	design resistance
r	radius of wheel
S_d	design strain
$s(m)$	stress history parameter
T	temperature
t	thickness
W_{el}	elastic section modulus
a	characteristic factor for bearing connection
a_w	characteristic factor for limit weld stress
g_m	general resistance coefficient
g_{Mf}	fatigue strength specific resistance factor

Table 1 (concluded)

Symbols, abbreviations	Description
g_p	partial safety factor
g_R	resulting resistance coefficient
g_S	specific resistance factor
g_{Rb}	resulting resistance coefficient of bolt
g_{sb}	specific resistance factor of bolt
g_{Rm}	resulting resistance coefficient of members
g_{sm}	specific resistance factor of members
g_{Rp}	resulting resistance coefficient of pins
g_{sp}	specific resistance factor of pins
g_{Rs}	resulting resistance coefficient of slip-resistance connection
g_{ss}	specific resistance factor of slip-resistance connection
g_{Rw}	resulting resistance coefficient of welding connection
g_{sw}	specific resistance factor of welding connection
f_2	dynamic factor
k	spread angle
l	width of contact area in weld direction
d_p	elongation from preloading
DF_b	additional force
Dd	additional elongation
μ	slip factor
Ds_c	characteristic value of stress range (normal stress)
Dt_c	characteristic value of stress range (shear stress)
s_{Sd}	design stress (normal)
t_{Sd}	design stress (shear)
$s_{w, Sd}$	design weld stress (normal)
$t_{w, Sd}$	design weld stress (shear)
DS_{Rd}	permissible (limit) stress range (normal)
$DS_{Rd,1}$	permissible stress range for $k^* = 1$
Dt_{Rd}	permissible (limit) stress range (shear)
DS_{Sd}	design stress range (normal)
Dt_{Sd}	design stress range (shear)

4 General

4.1 Materials

4.1.1 Structural members

European Standards specify materials and specific values. This standard gives a preferred selection.

For structural members, steel according to following European Standards should be used:

- Non-alloy structural steels EN 10025.
- Weldable fine grain structural steels in conditions:
 - normalised (N) EN 10113-2;
 - thermomechanical (M) EN 10113-3.
- High yield strength structural steels in the quenched and tempered condition EN 10137-2.
- High yield strength steels for cold forming in conditions:
 - thermomechanical (M) EN 10149-2;
 - normalised (N) EN 10149-3.

Table 2 shows specific values for the nominal value of strength f_u , f_y and limit design stress f_{Rd} (see 5.2). For more information see the specific European Standard.

Grades and qualities other than those mentioned in the above standards and in Table 2 can be used if the mechanical properties and the chemical composition are guaranteed by the manufacturer and conform to the relevant European Standard. If necessary, the weldability shall be demonstrated by the steel manufacturer.

When selecting grade and quality of the steel for tensile members, the sum of impact toughness parameters q shall be taken into account. Table 3 gives the impact toughness parameters q for various influences. Table 4 gives the required steel quality and impact energy/test temperature in dependence of Σq_i . Grades and qualities of steel other than mentioned in Table 4 may be used, if the steel manufacturer guarantees and certifies an impact energy/test temperature, tested according to EN 10045-1.

Table 2 — Specific values of steels for structural members

Steel	Standard	Thickness t (mm)	Nominal strength		Limit design stress for $\gamma_{Rm}=1,1$		
			f_y yield (N/mm ²)	f_u ultimate (N/mm ²)	f_{Rd} , normal (N/mm ²)	f_{Rd} , shear (N/mm ²)	
S235	EN 10025	t≤16	235	340	214	123	
		16<t≤40	225		205	118	
		40<t≤100	215		195	113	
		100<t≤150	195		177	102	
S275		t≤16	275	430	250	144	
		16<t≤40	265		241	139	
		40<t≤63	255		232	134	
		63<t≤80	245		223	129	
		80<t≤100	235		214	123	
		100<t≤150	225		205	118	
S355		t≤16	355	490	323	186	
		16<t≤40	345		314	181	
		40<t≤63	335		305	176	
		63<t≤80	325		296	171	
		80<t≤100	315		287	166	
		100<t≤150	295		268	155	
S355		t<16	355	450	323	186	
		16<t≤40	345		314	181	
		40<t≤63	335		305	176	
		63<t≤80 (N)	325		295	171	
		80<t≤100 (N)	315		286	165	
		100<t≤150 (N)	295		268	155	
S420		EN 10113-2 (N)	t<16	420	500	382	220
			16<t≤40	400		364	210
	40<t≤63		390	355		205	
	63<t≤80 (N)		370	336		194	
	80<t≤100 (N)		360	327		189	
	100<t≤150 (N)		340	309		178	
S460	EN 10113-3 (M)	t<16	460	530	418	241	
		16<t≤40	440		400	231	
		40<t≤63	430		391	226	
		63<t≤80 (N)	410		373	215	
		80<t≤100 (N)	400		364	210	
S460	EN 10137-2	3<t≤50	460	550	418	241	
50<t≤100		440	400		231		
S500		3<t≤50	500	590	455	262	
50<t≤100		480	436		252		
S550		3<t≤50	550	640	500	289	
50<t≤100		530	482		278		
S620		3<t≤50	620	700	564	325	
50<t≤100		580	527		304		
S690	3<t≤50	690	770	627	362		
50<t≤100	650	591		341			
S890	3<t≤50	890	940	809	467		
50<t≤100	830	755		436			
S960	3<t≤50	960	980	873	504		

Table 2 (concluded)

Steel	Standard	Thickness t (mm)	Nominal strength		Limit design stress for $\gamma_{Rm}=1,1$	
			f_y yield (N/mm ²)	f_u ultimate (N/mm ²)	f_{Rd} , normal (N/mm ²)	f_{Rd} , shear (N/mm ²)
S315	EN 10149–2 (M)	all t	315	390	286	165
S355			355	430	323	186
S420			420	480	382	220
S460 (M)			460	520	418	241
S500 (M)			500	550	455	262
S550 (M)			550	600	500	289
S600 (M)			600	650	545	315
S650 (M)		t≤8	650	700	591	341
		t>8	630		573	331
S700 (M)		EN 10149-3 (N)	t≤8	700	750	636
	t>8		680		618	357

Table 3 — Impact toughness parameters q_i

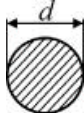
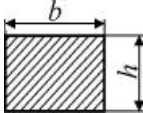
i	Influence		q_i
1	Temperature T (°C)	$0 \leq T$	0
		$-20 \leq T < 0$	1
		$-40 \leq T < -20$	2
		$-50 \leq T < -40$	4
2	Yield point f_y (N/mm ²)	$f_y \leq 300$	0
		$300 < f_y \leq 460$	1
		$460 < f_y \leq 700$	2
		$700 < f_y \leq 1\ 000$	3
		$1\ 000 < f_y$	4
3	Material thickness t (mm) Equivalent thickness t for solid bars:   $t = \frac{d}{1,8}$ for $\frac{b}{h} < 1,8$; $t = \frac{b}{1,8}$	$t \leq 10$	0
		$10 < t \leq 20$	1
		$20 < t \leq 50$	2
		$50 < t \leq 100$	3
		$t > 100$	4
4	Stress concentration and notch class $\Delta\sigma_c$ (N/mm ²) (see annex A and annex E)	$\Delta\sigma_c > 125$	0
		$80 < \Delta\sigma_c \leq 125$	1
		$56 < \Delta\sigma_c \leq 80$	2
		$\Delta\sigma_c \leq 56$	3

Table 4 — Impact toughness requirement and corresponding steel quality for $\hat{a} q_i$

	$\hat{a} q_i \leq 3$	$4 \leq \hat{a} q_i \leq 6$	$7 \leq \hat{a} q_i \leq 9$	$\hat{a} q_i \geq 10$
Impact energy/ test temperature requirement	27 J / +20°C	27 J / 0°C	27 J / -20°C	27 J / -40°C
EN 10025	JR	J0	J2	a)
EN 10113	N, M	N, M	N, M	NL, ML
EN 10137-2	Q	Q	Q	QL
EN 10149	NC, MC	NC, MC	NC, MC	a)
a) May be used if the steel manufacturer guarantees and certifies an impact energy/test temperature of at least 27 J at -40 °C, tested according to EN 10045-1.				

4.1.2 Connecting devices

For bolt connections bolts of the property classes 4.6, 5.6, 8.8, 10.9 or 12.9 according to EN ISO 898-1 shall be used. Nominal values of the strengths:

Table 5 — Property classes

Property class	4.6	5.6	8.8	10.9	12.9
f_{yb} (N/mm ²)	240	300	640	900	1 080
f_{ub} (N/mm ²)	400	500	800	1 000	1 200

4.2 Bolt connections

4.2.1 General

For the purpose of this standard bolt connections are specified as connections, where

- bolts are tightened and thus compress the joint surfaces together;
- the joint surfaces are secured against rotation (e. g. by using multiple bolts).

4.2.2 Shear and bearing connections

Connections with fitted bolts, where

- the loads act perpendicular to the bolt axis and cause shear and bearing stresses in the bolts;
- clearance between bolt and hole shall be according to ISO 286-2 tolerances h13 and H11;
- at maximum 10 % of the clamping length may be covered by the threaded part of the bolt;
- special surface treatment of the contact surfaces is not required.

4.2.3 Slip resistant connections

Connections with high strength bolts of property classes 8.8, 10.9 or 12.9, where

- the loads are transmitted by friction between the joint surfaces;
- bolts are tightened by a controlled method to the full preloading state;
- the surface condition of the contact surfaces shall be specified and taken into account accordingly.

4.2.4 Connections loaded in tension

Connections with high strength bolts of property classes 8.8, 10.9 or 12.9, where

- the loads act in the direction of the bolt axis and cause axial stresses in the bolts;
- bolts are tightened by a controlled method to the full preloading state;
- fatigue assessment of the bolts shall be done considering the structural features of the joint, e.g. stiffness of the connected parts and the leverage action caused by the joint geometry;
- an even contact over the whole intended contact area of the joint shall be ensured.

4.3 Pin connections

Pin connections are regarded as connections that allow turning of the connected parts.

4.4 Welded connections

Terms for welded joints shall be as given in EN 12345. Symbolic representation on drawings shall be according to EN 22553.

4.5 Proofs of structural members and connections

It has to be proven that the strains S_d do not exceed the resistances R_d :

$$S_d \leq R_d \quad (1)$$

The strains S_d shall be determined by applying the loads, load combinations and partial safety factors according to Table 10 of EN 13001-2.

In the following clauses, the resistances R_d are presented as limit stresses f_d or limit forces F_d .

For the ultimate limit state, the following proofs shall be delivered:

- proof of strength of structural members and connections under quasi-static stress according to 5;
- proof of fatigue strength according to 6;
- proof of strength of hollow section girder joints under quasi-static stress according to 7;
- proof of elastic stability of structural members and special elements according to 8.

5 Proof of static strength

5.1 General

The proof of strength under quasi-static stress protects against excessive deformations due to yielding of the material or sliding of friction-grip connections as well as against static rupture of structural members or connections.

The proof shall be delivered for structural members and connections taking into account the most unfavourable load effects from the load combinations A, B or C according to Table 10 of EN 13001-2: and applying the resistances according to 5.2.

5.2 Limit design stresses and forces

5.2.1 General

The limit design stresses and forces shall be calculated by:

Limit design stresses $f_{Rd} = \text{function} (f_k, g_R)$ or

Limit design forces $F_{Rd} = \text{function} (F_k, g_R)$

(2)

where

f_k or F_k are characteristic values (or nominal values)

g_R is the resulting resistance coefficient $g_R = g_m \cdot g_s$

g_m is the resistance coefficient $g_m = 1,1$ (see Table 10 of EN 13001-2)

g_s is the general specific resistance coefficient for special parts of this standard

NOTE f_{Rd} and F_{Rd} are equivalent to R/g_m in Figure 2 of EN 13001-1.

5.2.2 Limit design stress in structural members

The limit design stress f_{Rd} , used for the design of structural members, shall be calculated by:

$$f_{Rd} = \frac{f_{yk}}{g_{Rm}} \quad \text{for normal stresses} \quad (3)$$

$$f_{Rd} = \frac{f_{yk}}{g_{Rm} \sqrt{3}} \quad \text{for shear stresses} \quad (4)$$

with $\gamma_{Rm} = \gamma_m \cdot \gamma_{sm}$

where

f_{yk} is the nominal value of the yield point of the material (see Table 2)

γ_{sm} is the specific resistance coefficient for material as follows:

For non-rolled material

$$g_{sm} = 1,0$$

For rolled materials (e. g. plates and profiles):

$g_{sm} = 1,0$ for stresses in the plane of rolling

$g_{sm} = 1,0$ for compressive and shear stresses

For tensile stresses perpendicular to the plane of rolling (see Figure 1):

$g_{sm} = 1,0$ for material in quality classes Z25 or Z35 according to EN 10164

$g_{sm} = 1,16$ for material in quality class Z15 according to EN 10164

$g_{sm} = 1,34$ without quality classification

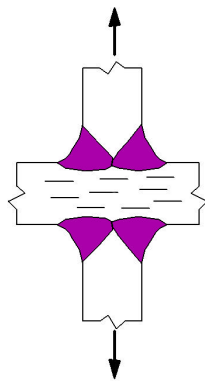


Figure 1 — Tensile load perpendicular to plane of rolling

Hence follow the limit design stresses, which are dependent on the material and the kind of stressing which are given in Table 2.

5.2.3 Limit design forces in bolt connections

5.2.3.1 Shear and bearing connections

The resistance of a connection shall be determined by applying the limit forces of the individual connecting devices.

The limit design shear force $F_{v,Rd}$ per bolt and per shear plane shall be calculated by:

$$F_{v,Rd} = \frac{f_{yb} \cdot A}{g_{Rb} \cdot \sqrt{3}} \quad (5)$$

with $g_{Rb} = g_m \cdot g_{sb}$

where

f_{yb} is the yield point (nominal value) of the bolt material

A is the cross-section of the bolt shank at the shear plane

g_{sb} is the specific resistance factor for bolt connections

$g_{sb} = 1,0$ for multiple shear plane connections

$$g_{sb} = 1,3 \quad \text{for single shear plane connections}$$

See Table 6 for limit design shear forces as an example.

Table 6 — Limit design shear force $F_{v,Rd}$ per fitted bolt and per shear plane for multiple shear plane connections

Fitted bolt	Hole diameter (mm)	Shank resp. hole section (mm ²)	$F_{v,Rd}$ (kN)				
			Fitted bolt material				
			for $g_{Rb} = 1,1$				
			4.6	5.6	8.8	10.9	12.9
M12	13	133	16,7	20,9	44,6	62,8	75,4
M16	17	227	28,6	35,7	76,2	107,2	128,6
M20	21	346	43,5	54,4	116,2	163,2	196,1
M22	23	415	52,2	65,3	139,4	196,0	235,2
M24	25	491	61,8	77,3	164,9	231,9	278,3
M27	28	616	77,6	97,0	206,9	291,0	349,2
M30	31	755	95,1	111,8	253,6	356,6	428,0

The limit design bearing force $F_{b,Rd}$ per bolt may be calculated by:

$$F_{b,Rd} = \frac{a \cdot f_y \cdot d \cdot t}{g_{Rb}} \quad (6)$$

with $g_{Rb} = g_m \cdot g_{sb}$

where

$$a = \text{Min} \left\{ \begin{array}{ll} \frac{e_1}{3 \cdot d_0} & e_1 \geq 2,0 d_0 \\ \frac{p_1}{3 \cdot d_0} - \frac{1}{4} & e_2 \geq 1,5 d_0 \\ \frac{f_{ub}}{f_u} & p_1 \geq 3,0 d_0 \\ 1,0 & p_2 \geq 3,0 d_0 \end{array} \right. \quad (7)$$

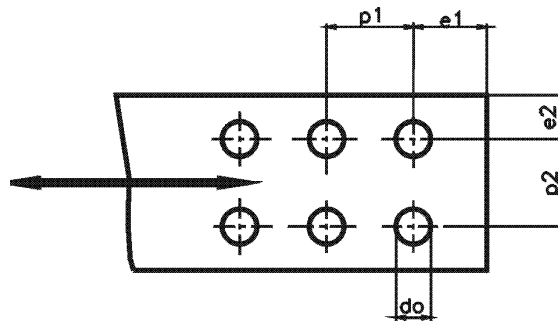


Figure 2 — Illustration for formula (7)

f_{ub} is the ultimate strength (nominal value) of the bolt (Table 5)

f_u is the ultimate strength (nominal value) of the basic material (Table 2)

f_y is the yield point (nominal value) of the basic material (Table 2)

d is the shank diameter of the bolt

t is the minimum of thicknesses of the basic material

g_{sb} is the specific resistance factor for bolt connections

$g_{sb} = 0,7$ for multiple shear plane connections

$g_{sb} = 0,9$ for single shear plane connections

5.2.3.2 Slip-resistant connections

The resistance of a connection shall be determined by applying the limit forces of the individual connecting devices.

For slip-resistant connections the limit design slip force $F_{s,Rd}$ per bolt and per friction interface shall be calculated by:

$$F_{s,Rd} = \frac{m \cdot (F_{p,d} - F_t)}{g_{Rs}} \quad (8)$$

with $g_{Rs} = g_m \cdot g_{ss}$

where:

m is the slip factor

$m = 0,50$ for surfaces

- blasted metallic bright with steel grit or sand, no unevennesses;
- blasted with steel grit or sand and aluminised;
- blasted with steel grit or sand and metallised with a product basing on zinc that causes a friction coefficient of min. 0,5

$m = 0,40$ for surfaces

- blasted with steel grit or sand and alkali-zinc-silicate coating of 50 µm to 80 µm thickness

$m = 0,30$ for surfaces

- cleaned metallic bright with wire brush or scarfing

$m = 0,20$ for surfaces

- cleaned of loose rust, oil and dirt

$F_{p,d}$ is the design preloading force.

F_t is an external tensile force in direction of the axis of the bolt (see Figure 3)

It shall be ensured that the used preloading force is greater than or equal to the design preloading force.

g_{ss} is the specific resistance factor for slip-resistant connections;

$$g_{ss} = 1,14$$

See Table 7 for limit design slip forces using for example a design preloading force of

$$F_{p,d} = 0,7 \cdot f_{yb} \cdot A_s,$$

where

f_{yb} is the yield point (nominal value) of the bolt material (Table 5)

A_s is the stress area of the bolt.

Table 7 — Limit design slip force $F_{S,Rd}$ per bolt and per friction interface using a design preloading force $F_{p,d} = 0.7 \cdot f_{yb} \cdot A_s$

Bolt	stress area A_s (mm ²)	Design preloading force $F_{p,d}$ (kN) Bolt material			Limit design slip force $F_{S,Rd}$ (kN)											
					Bolt material											
					8.8				10.9				12.9			
					Slip factor :				Slip factor :				Slip factor :			
		8.8	10.9	12.9	0.50	0.40	0.30	0.20	0.50	0.40	0.30	0.20	0.50	0.40	0.30	0.20
M12	84,3	37,8	53,1	63,7	15,1	12,1	9,1	6,0	21,2	17,0	12,7	8,5	25,5	20,4	15,3	10,2
M16	157,0	70,3	98,9	119,0	28,1	22,5	16,9	11,2	39,6	31,6	23,7	15,8	47,6	38,1	28,6	19,0
M20	245,0	110,0	154,0	185,0	44,0	35,2	26,4	17,6	61,6	49,3	37,0	24,6	74,0	59,2	44,4	29,6
M22	303,0	136,0	191,0	229,0	54,4	43,5	32,6	21,8	76,4	61,1	45,8	30,6	91,6	73,3	55,0	36,6
M24	353,0	158,0	222,0	267,0	63,2	50,6	37,9	25,3	88,8	71,0	53,3	35,5	107,0	85,4	64,1	42,7
M27	459,0	206,0	289,0	347,0	82,4	65,9	49,4	33,0	116,0	92,5	69,4	46,2	139,0	111,0	83,3	55,5
M30	561,0	251,0	353,0	424,0	100,0	80,3	60,2	40,2	141,0	113,0	84,7	56,5	170,0	136,0	102,0	67,8
M36	817,0	366,0	515,0	618,0	146,0	117,0	87,8	58,6	206,0	165,0	124,0	82,4	247,0	198,0	148,0	98,9

5.2.3.3 Connections loaded in tension

The resistance of a connection shall be determined by applying the limit forces of the individual connecting devices.

In principle the proof of competence has to take into account the stiffnesses of the bolt and the flanges to be connected (see Figure 3).

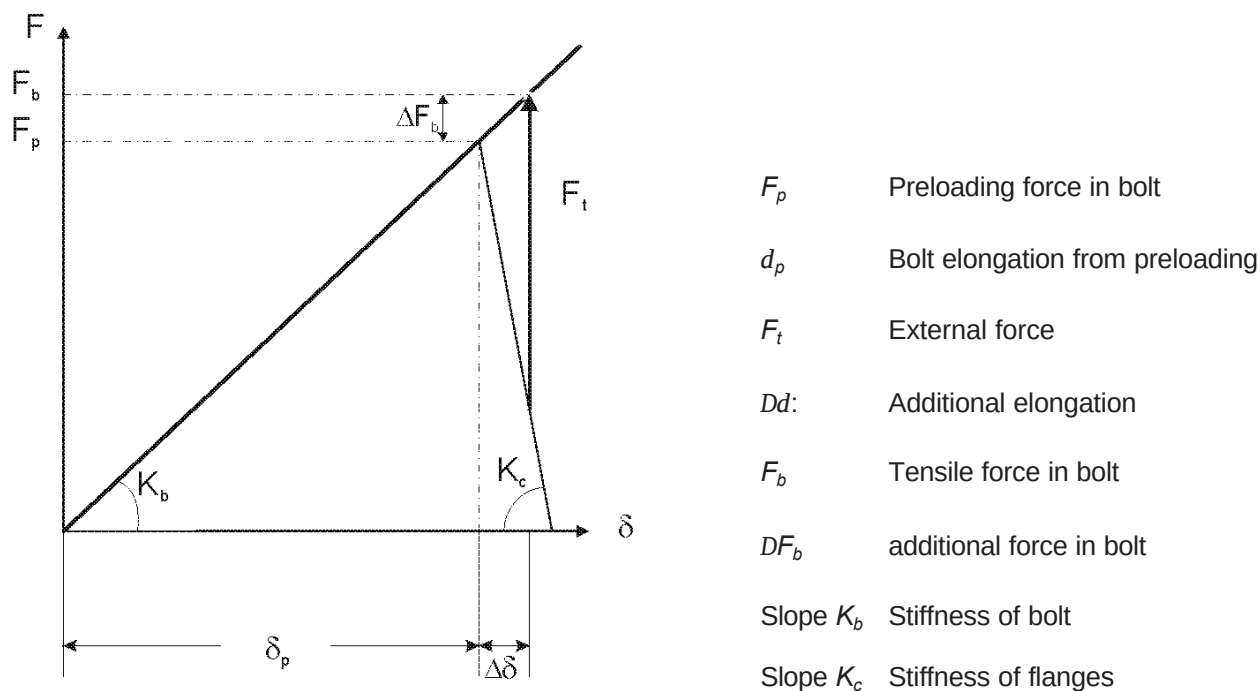


Figure 3 — Force-elongation-diagram

For simplification the limit design tensile force per bolt $F_{t,Rd}$ may be calculated by:

$$F_{t,Rd} = \frac{F_{p,d}}{g_{Rb}} \quad (9)$$

with $\gamma_{Rb} = \gamma_m \cdot \gamma_{sb}$

where

$F_{p,d}$ is the design preloading force. It shall be ensured that the used preloading force is greater than or equal to the design preloading force

g_{sb} is the specific resistance factor for connections loaded in tension

$$g_{sb} = 1,0$$

See Table 8 for limit design tensile forces according to formula (9) using for example a design preloading force of

$$F_{p,d} = 0,7 \cdot f_{yb} \cdot A_s$$

where