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Cranes - General Design - Part 3-1: Limit States and proof competence of steel structure

Krane - Konstruktion allgemein - Teil 3-1: Grenzzustände und Sicherheitsnachweis von Stahltragwerken

Appareils de levage à charge suspendue - Conception générale - Partie 3-1: Etats limites et vérification d'aptitude des structures en acier

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English Version

Cranes - General Design - Part 3-1: Limit States and proof competence of steel structure

Appareils de levage à charge suspendue - Conception générale - Partie 3-1: Etats limites et vérification d'aptitude des charpentes en acier

Krane - Konstruktion allgemein - Teil 3-1: Grenzzustände und Sicherheitsnachweis von Stahltragwerken

This European Standard was approved by CEN on 11 February 2012.

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Contents

Page

Foreword

This document (EN 13001-3-1:2012) has been prepared by Technical Committee CEN/TC 147 "Cranes", the secretariat of which is held by BSI.

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of an identical text or by endorsement, at the latest by September 2012, and conflicting national standards shall be withdrawn at the latest by September 2012.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

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(s).

For relationship with EU Directive(s), see informative Annex ZA, which is an integral part of this document.

This European Standard is one Part of EN 13001, *Cranes – General design*. The other parts are as follows:

— *Part 1: General principles and requirements*;

— *Part 2: Load actions*;

— *Part 3-2: Limit states and proof of competence of wire ropes in reeving systems*;

— *Part 3-3: Limit states and proof of competence of wheel/rail contacts*;

— *Part 3-4: Limit states and proof of competence of machinery*;

— *Part 3-5: Limit states and proof of competence of forged hooks*.

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

Introduction

This European Standard has been prepared to be a harmonized 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 EN ISO 12100.

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

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.

1 Scope

This European Standard is to be used together with EN 13001-1 and EN 13001-2 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 cranes 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 intended use and reasonably foreseeable misuse. Clauses 4 to 8 of this standard are necessary to reduce or eliminate 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 not applicable to cranes which are manufactured before the date of its publication as EN and serves as reference base for the European Standards for particular crane types (see Annex I).

NOTE EN 13001-3-1 deals only with the limit state method in accordance with EN 13001-1.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

EN 1993-1-8:2005, *Eurocode 3: Design of steel structures — Part 1-8: Design of joints*

EN 10025-2:2004, *Hot rolled products of structural steels — Part 2: Technical delivery conditions for non-alloy structural steels*

EN 10025-3:2004, *Hot rolled products of structural steels — Part 3: Technical delivery conditions for normalized/normalized rolled weldable fine grain structural steels*

EN 10025-4:2004, *Hot rolled products of structural steels — Part 4: Technical delivery conditions for thermomechanical rolled weldable fine grain structural steels*

EN 10025-6:2004, *Hot rolled products of structural steels — Part 6: Technical delivery conditions for flat products of high yield strength structural steels in the quenched and tempered condition*

EN 10029:2010, *Hot rolled steel plates 3 mm thick or above — Tolerances on dimensions and shape*

EN 10045-1:1990, *Metallic materials — Charpy impact test — Part 1: Test method*

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 10160:1999, *Ultrasonic testing of steel flat product of thickness equal or greater than 6 mm (reflection method)*

EN 10163-1:2004, *Delivery requirements for surface conditions of hot-rolled steel plates, wide flats and sections — Part 1: General requirements*

EN 10163-2:2004, *Delivery requirements for surface conditions of hot-rolled steel plates, wide flats and sections — Part 2: Plate and wide flats*

EN 10163-3:2004, *Delivery requirements for surface conditions of hot-rolled steel plates, wide flats and sections – Part 3: Sections*

EN 10164:2004, *Steel products with improved deformation properties perpendicular to the surface of the product — Technical delivery conditions*

EN 13001-1, *Cranes — General design — Part 1: General principles and requirements*

EN 13001-2, *Crane safety — General design — Part 2: Load actions*

EN 20273:1991, *Fasteners — Clearance holes for bolts and screws (ISO 273:1979)*

EN ISO 286-2:2010, *Geometrical product specifications (GPS) — ISO code system for tolerances on linear sizes — Part 2: Tables of standard tolerance classes and limit deviations for holes and shafts (ISO 286-2:2010)*

EN ISO 898-1:2009, *Mechanical properties of fasteners made of carbon steel and alloy steel — Part 1: Bolts, screws and studs with specified property classes — Coarse thread and fine pitch thread (ISO 898-1:2009)*

EN ISO 5817:2007, *Welding — Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) — Quality levels for imperfections (ISO 5817:2003, corrected version:2005, including Technical Corrigendum 1:2006)*

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

EN ISO 12100:2010, *Safety of machinery — General principles for design — Risk assessment and risk reduction (ISO 12100:2010)*

EN ISO 17659:2004, *Welding — Multilingual terms for welded joints with illustrations (ISO 17659:2002)*

ISO 4306-1:2007, *Cranes — Vocabulary — Part 1: General*

3 Terms ,definitions, symbols and abbreviations

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in EN ISO 12100:2010 and the basic list of definitions as provided in EN 1990:2002 apply. For the definitions of loads, Clause 6 of ISO 4306-1:2007 applies.

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 (1 of 4)

Symbols, abbreviations	Description
A	cross section
A_n	net cross section
A_S	stress area of a bolt
A_S	shear area of the tear-out section (pinned connections)
a	length of plate in buckling
a	throat thickness of fillet welds
a_r	effective weld thickness
b	width of plate
c	edge stress ratio factor (buckling)
D_o, D_i	outer, inner diameter of hollow pin
d	diameter (shank of bolt, pin)
d_o	diameter of hole
E	modulus of elasticity
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_e	external force (on bolted connection)
$F_{b,\,Rd}$	limit design bearing force
$F_{b,\,Sd}$; $F_{bi,\,Sd}$	design bearing force
$F_{cs,\,Rd}$	limit design tensile force
$F_{p,\,d}$	design preloading force
F_{cr}	reduction in compression force due to external tension

Table 1 — Symbols and abbreviations (2 of 4)

Symbols, abbreviations	Description
$F_{t,\,Rd}$	limit design tensile force in bolt
$F_{t,Sd}$	external tensile force per bolt
$F_{v,\,Sd}$	design shear force per bolt and shear plane
$F_{vp,\,Rd}$	limit design shear force per pin and shear plane
$F_{vp,\,Sd}$	design shear force per pin and shear plane
$F_{s,Rd}$	limit design slip force per bolt and shear plane
$F_{vs,\,Rd}$	limit design shear force of the connected part
$F_{vd,\,Sd}$	design force in the connected part
$F_{vt,\,Rd}$	limit design tensile force of the connected part
$F_{\sigma,\tau}$	acting normal/shear force
f	maximum imperfection
f_d	limit stress
f_K	characteristic value (stress)
f_{Rd}	limit design stress
f_u	ultimate strength of material
f_{ub}	ultimate strength of bolts
$f_{w,\,Rd}$	limit design weld stress
f_y	yield stress of material
f_{yb}	yield stress of bolts
f_{yp}	yield stress of pins
h_d	distance between weld and contact area of acting load
I, I_i	moments of inertia of members
k	stress concentration factor (pinned connections)
K_b	stiffness of bolt
K_c	stiffness of connected parts
k^*	specific spectrum ratio factor
k_m	stress spectrum factor based on m of the detail under consideration
k_3	stress spectrum factor based on m = 3
$k_{\sigma x}, k_{\sigma y}, k_\tau$	buckling factors
L	element length (buckling)
l_m	gauge length
l_r	relevant weld length
l_W	weld length
M_{Rd}	limit design bending moment
M_{Sd}	design bending moment
m	slope constant of log Δσ/log N-curve
N	compressive force (buckling)

Table 1 — Symbols and abbreviations (3 of 4)

Symbols, abbreviations	Description
NC	notch class
N_k	critical buckling load
N_{ref}	reference number of cycles
$min\ \sigma$, $max\ \sigma$	extreme values of stresses
P_S	probability of survival
p	penetration of weld
Q	shear (evaluation of stress cycles)
q_i	impact toughness parameter
α	cross section parameter (lateral buckling)
α_b	characteristic factor for bearing connection
α_L	load introduction factor (bolted connection)
α_w	characteristic factor for limit weld stress
γ_m	general resistance factor
γ_{mf}	fatigue strength specific resistance factor
γ_p	partial safety factor
γ_R	resulting resistance factor
γ_S	specific resistance factor
γ_{Rb}	resulting resistance factor of bolt
γ_{sbb}, γ_{sbs}, γ_{sbt}	specific resistance factors of bolted connections
γ_{Rm}	resulting resistance factor of members
γ_{sm}	specific resistance factor of members
γ_{Rp}	resulting resistance factor of pins
γ_{spm}, γ_{sps}, γ_{spb}, γ_{spt}	specific resistance factors of pins
γ_{Rs}	resulting resistance factor of slip-resistance connection
γ_{ss}	specific resistance factor of slip-resistance connection
γ_{Rc}	resulting resistance factor for tension on section with holes
γ_{st}	specific resistance factor for tension on section with holes
γ_{Rw}	resulting resistance factor of welding connection
γ_{sw}	specific resistance factor of welding connection
δ_p	elongation from preloading
ϕ_2	dynamic factor
κ	dispersion angle (wheel pressure)
κ, κ_x, κ_y, κ_τ	reduction factors (buckling)
λ	width of contact area in weld direction

Table 1 — Symbols and abbreviations (4 of 4)

Symbols, abbreviations	Description
λ_x, λ_y, λ_τ	non-dimensional plate slenderness (buckling)
Ψ	edge stress ratio (buckling)
ΔF_b	additional force
$\Delta\delta_t$	additional elongation
μ	slip factor
ν	relative total number of stress cycles (normalized)
ν_D	ratio of diameters
$\Delta\sigma_c$	characteristic value of stress range (normal stress)
$\Delta\tau_c$	characteristic value of stress range (shear stress)
σ_e	reference stress (buckling)
σ_b	lower extreme value of stress range
σ_u	upper extreme value of stress range
σ_{Sd}	design stress (normal)
τ_{Sd}	design stress (shear)
$\sigma_{w, Sd}$	design weld stress (normal)
$\tau_{w, Sd}$	design weld stress (shear)
$\Delta\sigma_{Rd}$	limit design stress range (normal)
$\Delta\sigma_{Rd,1}$	limit design stress range for k* = 1
$\Delta\tau_{Rd}$	limit design stress range (shear)
$\Delta\sigma_{Sd}$	design stress range (normal)
$\Delta\tau_{Sd}$	design stress range (shear)

4 General

4.1 Documentation

The documentation of the proof of competence shall include:

— design assumptions including calculation models,

— applicable loads and load combinations,

— material grades and qualities,

— weld quality levels, in accordance with EN ISO 5817,

— materials of connecting elements,

— relevant limit states,

— results of the proof of competence calculation. and tests when applicable.

4.2 Materials for structural members

4.2.1 Grades and qualities

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:

a) Non-alloy structural steels EN 10025-2;

b) Weldable fine grain structural steels in conditions:

   1) normalized (N) EN 10025-3;

   2) thermomechanical (M) EN 10025-4;

c) High yield strength structural steels in the quenched and tempered condition EN 10025-6;

d) High yield strength steels for cold forming in conditions:

   1) thermomechanical (M) EN 10149-2;

   2) normalized (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). The values given are applicable for temperatures up to 150°C. For more information see the specific European Standard.

The actual material properties shall satisfy minimum ductility requirements as follows:

— the ratio $f_u / f_y \geq 1{,}05$ and

— the percentage elongation at fracture *A*≥7% on a gauge length $L_0 = 5{,}65 \times \sqrt{S_0}$ (where S_0 is the original cross-sectional area).

To allow the use of nominal values of plate thicknesses in the proof calculations, the minus tolerance of the plate shall be equal or better than that of class A of EN 10029:2010. Otherwise the actual minimum value of plate thickness shall be used. To allow the use of nominal dimensions for other steel products than plates, their minus tolerances shall be within those of the relevant European standards for those products.

Grades and qualities other than those mentioned in the above standards and in Table 2 may be used if the mechanical properties and the chemical composition are specified in a manner corresponding to relevant European standard, and if the material satisfies the following conditions:

— the ratio $f_u / f_y \geq 1{,}05$;

— the percentage elongation at fracture *A*≥7% on a gauge length $L_0 = 5{,}65 \times \sqrt{S_0}$ (where S_0 is the original cross-sectional area);

— weldability is demonstrated.

NOTE Where it is deemed necessary to check for internal defects, classes of EN 10160 should be specified.

Table 2 — Specific values of steels for structural members (1 of 2)

Steel	Standard	Thickness t mm	Nominal strength		Limit design stress (γ_{Rm}=1,1)	
			f_y yield N/mm^2	f_u ultimate N/mm^2	$f_{Rd\sigma}$, normal N/mm^2	$f_{Rd\tau}$, shear N/mm^2
S235	EN 10025-2	$t \le 16$	235	340	214	123
		$16 < t \le 40$	225		205	118
		$40 < t \le 100$	215		195	113
		$100 < t \le 150$	195		177	102
S275		$t \le 16$	275	430	250	144
		$16 < t \le 40$	265		241	139
		$40 < t \le 63$	255		232	134
		$63 < t \le 80$	245		223	129
		$80 < t \le 100$	235		214	123
		$100 < t \le 150$	225		205	118
S355		$t \le 16$	355	490	323	186
		$16 < t \le 40$	345		314	181
		$40 < t \le 63$	335		305	176
		$63 < t \le 80$	325		296	171
		$80 < t \le 100$	315		287	166
		$100 < t \le 150$	295		268	155
S355	EN 10025-3 (N) EN 10025-4 (M)	$t \le 16$	355	450	323	186
		$16 < t \le 40$	345		314	181
		$40 < t \le 63$	335		305	176
		$63 < t \le 80$ (N)	325		295	171
		$80 < t \le 100$ (N)	315		286	165
		$100 < t \le 150$ (N)	295		268	155
S420		$t \le 16$	420	500	382	220
		$16 < t \le 40$	400		364	210
		$40 < t \le 63$	390		355	205
		$63 < t \le 80$ (N)	370		336	194
		$80 < t \le 100$ (N)	360		327	189
		$100 < t \le 150$ (N)	340		309	178
S460		$t \le 16$	460	530	418	241
		$16 < t \le 40$	440		400	231
		$40 < t \le 63$	430		391	226
		$63 < t \le 80$ (N)	410		373	215
		$80 < t \le 100$ (N)	400		364	210
S460	EN 10025-6	$3 < t \le 50$	460	550	418	241
		$50 < t \le 100$	440		400	231
S500		$3 < t \le 50$	500	590	455	262
		$50 < t \le 100$	480		436	252
S550		$3 < t \le 50$	550	640	500	289
		$50 < t \le 100$	530		482	278
S620		$3 < t \le 50$	620	700	564	325
		$50 < t \le 100$	580		527	304
S690		$3 < t \le 50$	690	770	627	362
		$50 < t \le 100$	650	760	591	341
S890		$3 < t \le 50$	890	940	809	467
		$50 < t \le 100$	830	880	755	436