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SIST EN 13001-2:2005

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ICS 53.020.20

English version

Crane safety - General design - Part 2: Load effects

Sécurité des appareils de levage à charge suspendue -
Conception générale - Partie 2: Effets de charge

Kransicherheit - Konstruktion allgemein - Teil 2:
Lasteinwirkungen

This European Standard was approved by CEN on 2 March 2004.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: rue de Stassart, 36 B-1050 Brussels

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Foreword

This document (EN 13001-2:2004) has been prepared by Technical Committee CEN/TC 147 “Cranes — Safety”, 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of an identical text or by endorsement, at the latest by *June 2005*, and conflicting national standards shall be withdrawn at the latest by *June 2005*.

According to the CEN/CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Cyprus, 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 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 EC Directive 98/37.

For relationship with EC Directives, see informative annex ZA, which is an integral part of this document.

Annex A is normative, annex B is informative.

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

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- Part 1: General principles and requirements SIST EN 13001-2:2005
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- Part 2: Load actions
- Part 3.1: Limit states and proof of competence of steel structures
- Part 3.2: Limit states and proof of competence of rope reeving components
- Part 3.3: Limit states and proof of competence of wheel/rail contacts
- Part 3.4: Limit states and proof of competence of machinery

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 the EN 1070.

The machinery concerned and the extent to which hazards 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 Part 1 and Part 3 and as such they specify general conditions, requirements and methods to prevent hazards of cranes by design and theoretical verification. Part 3 is only at pre-drafting stage; the use of Parts 1 and 2 is not conditional to the publication of Part 3.

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. Clause 4 of this standard is necessary to reduce or eliminate the risks associated with the following hazards:

- a) Rigid body instability of the crane or its parts (tilting and shifting).
- b) Exceeding the limits of strength (yield, ultimate, fatigue).
- c) Elastic instability of the crane or its parts (buckling, bulging).
- d) Exceeding temperature limits of material or components.
- e) Exceeding the deformation limits.

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.

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 editions of the publication referred to applies (including amendments).

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).*

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

EN 1990-1:2002, *Eurocode – Basic of structural design.*

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

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

3 Terms, definitions, symbols and abbreviations

3.1 Terms and definitions

For the purposes of this European Standard, the terms and definitions given in EN 1070:1998, ENV 1990-1:2002 and clause 6 of ISO 4306-1:1990 apply.

3.2 Symbols and abbreviations

For the purposes of this European Standard, the symbols and abbreviations given in Table 1 apply.

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Table 1 — Symbols and abbreviations

Symbols, abbreviations	Description
A1 to A4	Load combinations including regular loads
A	Characteristic area of a crane member
A_g	Projection of the gross load on a plane normal to the direction of the wind velocity
A_c	Area enclosed by the boundary of a lattice work member in the plane of its characteristic height d
A_j	Area of an individual crane member projected to the plane of the characteristic height d
b_h	Width of the rail head
b	Characteristic width of a crane member
B1 to B5	Load combinations including regular and occasional loads
c	Spring constant
C_a, C_{Oy}, C_{Oz}	Aerodynamic coefficients
C_o	Aerodynamic coefficient of a member of infinite length
C1 to C9	Load combinations including regular, occasional and exceptional loads
CFF, CFM	Coupled wheel pairs of system F/F or F/M
d	Characteristic dimension of a crane member

Table 1 (continued)

Symbols, abbreviations	Description
d_i, d_n	Distance between wheel pair i or n and the guide means
e_G	Width of the gap of a rail
f	Friction coefficient
f_i	Loads
f_q	natural frequency
f_{rec}	Term used in calculating $v(z)$
F	Force
F, F_y, F_z	Wind loads
F_b	Buffer force
\hat{F}	Maximum buffer force
F_i, F_f	Initial and final drive force
DF	Change of drive force
F_{x1i}, F_{x2i}	Tangential wheel forces
F_{y1i}, F_{y2i}	Guide force
F_y	Guide force
F_{z1i}, F_{z2i}	Vertical wheel forces
$F/F, F/M$	Abbreviations for Fixed/Fixed and Fixed/Moveable, characterizing the possibility of lateral movements of the crane wheels
g	Gravity constant
h	Distance between instantaneous slide pole and guide means of a skewing crane
$h(t)$	Time-dependent unevenness function
h_s	Height of the step of a rail
$H1, H2$	Lateral wheel forces induced by drive forces acting on a crane or trolley with asymmetrical mass distribution
HC1 to HC4	Hoisting classes
HD1 to HD5	Classes of the type of hoist drive and its operation method
i	Serial number
IFF, IFM	Independent wheel pairs of system F/F or F/M
j	Serial number
k	Serial number
K	Drag-coefficient of terrain
$K1, K2$	Roughness factors
l	Span of a crane
l_a	Aerodynamic length of a crane member
l_o	Geometric length of a crane member
m_H	Mass of the gross or hoist load

Table 1 (continued)

Symbols, abbreviations	Description
m	Mass of the crane and the hoist load
Δm_H	Released or dropped part of the hoist load
$MDC1, MDC2$	Mass distribution classes
n	Number of wheels at each side of the crane runway
n_r	Exponent used in calculating γ_n
n_m	Exponent used in calculating the shielding factor η
p	Number of pairs of coupled wheels
q	Equivalent static wind pressure
\bar{q}	Mean wind pressure
$q(z)$	Equivalent static storm wind pressure
$q(3)$	Wind pressure at $v(3)$
r	Wheel radius
R	Stormwind recurrence interval
Re	Reynold number
s_g	Slack of the guide
s_y	Lateral slip at the guide means
s_{yi}	Lateral slip at wheel pair i
S	Load effect
\hat{S}	Maximum load effect
$S1, S2$	Stability classes
S_i, S_f	Initial and final load effects
DS	Change of load effect
t	Time
u	Buffer stroke
\hat{u}	Maximum buffer stroke
v	Travelling speed of the crane
\bar{v}	Constant mean wind velocity
\bar{v}^*	Constant mean wind velocity if the wind direction is not normal to the longitudinal axis of the crane member under consideration
$v(z)$	Equivalent static storm wind velocity
$v(z)^*$	Equivalent static storm wind velocity if the wind direction is not normal to the longitudinal axis of the crane member under consideration
$v(3)$	Gust wind velocity averaged of a period of 3 seconds
v_g	Three seconds gust amplitude
v_h	Hoisting speed
$v_{h,max}$	Maximum steady hoisting speed
$v_{h,CS}$	Steady hoisting creep speed

Table 1 (continued)

Symbols, abbreviations	Description
$V_m(z)$	Ten minutes mean storm wind velocity in the height z
V_{ref}	Reference storm wind velocity
w_b	Distance between the guide means
z	Height above ground level
$z(t)$	Time-dependent coordinate of the mass centre
a_r	Relative aerodynamic length
a_w	Angle between the direction of the wind velocity \bar{v} or $v(z)$ and the longitudinal axis of the crane member under consideration
a	Skewing angle
a_g	Part of the skewing angle a due to the slack of the guide
a_G	Term used in calculating f_4
a_s	Term used in calculating f_4
a_t	Part of the skewing angle α due to tolerances
a_w	Part of the skewing angle α due to wear
b	Angle between horizontal plane and non-horizontal wind direction
b_2	Term used in calculating f_2
b_3	Term used in calculating f_3
g	Overall safety factor
g_m	Resistance coefficient
g_n	Risk coefficient
γ_p	Partial safety factor
d	Term used in calculating ϕ_1
e_S	Conventional start force factor
e_M	Conventional mean drive force factor
h	Shielding factor
h_W	Factor for remaining hoist load in out of service condition
l	Aerodynamic slenderness ratio
m, \dot{m}	Parts of the span l
F	Term used in calculating the guide force F_y
F_{1i}, F_{2i}	Terms used in calculating F_{y1i} and F_{y2i}
ξ	Term used in calculating ϕ_7
ξ_{1i}, ξ_{2i}	Term used in calculating F_{x1i} and F_{x2i}
$\xi_G(a_G), \xi_s(a_s)$	Curve factors
r	Density of the air
j	Solidity ratio
f_i	Dynamic factors

Table 1 (concluded)

Symbols, abbreviations	Description
f_1	Dynamic factor for hoisting and gravity effects acting on the mass of the crane
f_2	Dynamic factor for inertial and gravity effects by hoisting an unrestrained grounded load
f_{2min}	Term used in calculating f_2
f_3	Dynamic factor for inertial and gravity effects by sudden release of a part of the hoist load
f_4	Dynamic factor for loads caused by travelling on uneven surface
f_5	Dynamic factor for loads caused by acceleration of all crane drives
f_6	Dynamic factor for test loads
f_7	Dynamic factor for loads due to buffer forces
f_8	Gust response factor
y	Reduction factor used in calculating aerodynamic coefficients

4 Safety requirements and/or measures

4.1 General

Machinery shall conform to the safety requirements and/or measures of this clause. In addition, the machine shall be designed according to the principles of EN ISO 12100-1:2003 and EN ISO 12100-2:2003 for hazards relevant but not significant which are not dealt with by this document (e. g. sharp edges).

4.2 Loads

4.2.1 General

4.2.1.1 Introduction

The loads acting on a crane are divided into the categories of regular, occasional and exceptional as given in 4.2.1.2, 4.2.1.3 and 4.2.1.4. For the proof calculation of means of access loads only acting locally are given in 4.1.5.

These loads shall be considered in proof against failure by uncontrolled movement, yielding, elastic instability and, where applicable, against fatigue.

4.2.1.2 Regular loads

- a) hoisting and gravity effects acting on the mass of the crane;
- b) inertial and gravity effects acting vertically on the hoist load;
- c) loads caused by travelling on uneven surface;
- d) loads caused by acceleration of all crane drives;
- e) loads induced by displacements.

Regular loads occur frequently under normal operation.

4.2.1.3 Occasional loads

- a) loads due to in-service wind;
- b) snow and ice loads;
- c) loads due to temperature variation;
- d) loads caused by skewing.

NOTE Occasional loads occur infrequently. They are usually neglected in fatigue assessment.

4.2.1.4 Exceptional loads

- a) loads caused by hoisting a grounded load under exceptional circumstances;
- b) loads due to out-of-service wind;
- c) test loads;
- d) loads due to buffer forces;
- e) loads due to tilting forces;
- f) loads caused by emergency cut-out;
- g) loads caused by failure of mechanism or components;
- h) loads due to external excitation of crane foundation;
- i) loads caused by erection and dismantling.

NOTE Exceptional loads are also infrequent and are likewise usually excluded from fatigue assessment.

4.2.2 Regular loads

4.2.2.1 Hoisting and gravity effects acting on the mass of the crane

When lifting the load off the ground or when releasing the load or parts of the load vibrational excitation of the crane structure shall be taken into account. The gravitational force induced by the mass of the crane or crane parts shall be multiplied by the factor f_1 . The masses of cranes or crane parts in class MDC1 (see 4.3.3) shall be multiplied by

$$f_1 = 1 + \delta, \quad 0 \leq \delta \leq 0,1 \quad (1)$$

The value of δ depends on the crane structure and shall be specified.

The divisions of masses of crane parts in class MDC2 (see 4.3.3) shall be multiplied by

$$\phi_1 = 1 \pm \delta, \quad (2)$$

depending whether their gravitational acting is partly increasing (+ δ) or decreasing (- δ) the resulting load effects in the critical points selected for the proof calculation.

The mass of the crane includes those components, which are always in place during operation except for the net load itself. For some cranes or applications, it may be necessary to add mass to account for accumulation of debris.

4.2.2.2 Inertial and gravity effects acting vertically on the hoist load

4.2.2.2.1 Hoisting an unrestrained grounded load

In the case of hoisting an unrestrained grounded load, the hereby induced vibrational effects shall be taken into account by multiplying the gravitational force due to the mass of the hoist load by a factor f_2 (see Figure 1).

The mass of the hoist load includes the masses of the payload, lifting attachments and a portion of the suspended hoist ropes or chains etc.

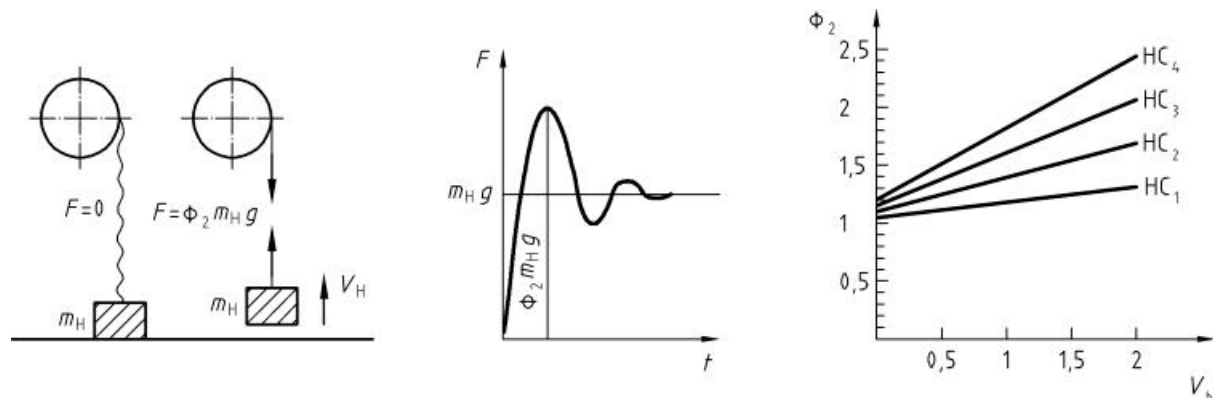


Figure 1 — Factor f_2
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The factor f_2 shall be taken as follows:

$$f_2 = \phi_{2,\min} + \beta_2 v_h \quad (3)$$

$\phi_{2,\min}$ and β_2 are given in Table 2 for the appropriate hoisting class. For the purposes of this standard, cranes are assigned to hoisting classes ranging from HC1 to HC4 according to their dynamic and elastic characteristics. HC1 requires a flexible structure and a drive system with smooth dynamic characteristics, whereas a rigid structure and a drive system with sudden speed changes imply HC4. The selection of hoisting classes depends on the particular type of cranes and is dealt with in the European Standards for specific crane types, see annex B. Equally, values of f_2 can be determined by experiments or analysis without reference to hoisting class.

v_h is the steady hoisting speed, in meters per second, related to the lifting attachment. Values of v_h are given in Table 3.

Table 2 — Values of β_2 and $\phi_{2,\min}$

Hoisting class of appliance	β_2	$\phi_{2,\min}$
HC1	0,17	1,05
HC2	0,34	1,10
HC3	0,51	1,15
HC4	0,68	1,20

Table 3 — Values of v_h for estimation of f_2

Load combination (see 4.3.6)	Type of hoist drive and its operation method				
	HD1	HD2	HD3	HD4	HD5
A1, B1	$v_{h,max}$	$v_{h,CS}$	$v_{h,CS}$	$0,5 \cdot v_{h,max}$	$v_h = 0$
C1	—	$v_{h,max}$	—	$v_{h,max}$	$0,5 \times v_{h,max}$

Where:

- HD1: hoist drive cannot be operated with creep speed;
- HD2: a steady creep speed of the hoist drive can be selected by the crane driver;
- HD3: hoist drive control ensures a steady creep speed until the load is lifted from the ground;
- HD4: a stepless variable speed control can be operated by the crane driver;
- HD5: after prestressing the hoist medium, the hoist drive control provides the reaching of a selected speed with an acceleration independent of the crane driver;

$v_{h,max}$ is the maximum steady hoisting speed;

$v_{h,CS}$ is the steady hoisting creep speed.

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4.2.2.2 Sudden release of a part of the hoist load

For cranes that release a part of the hoist load as a normal working procedure, the peak dynamic action on the crane can be taken into account by multiplying the hoist load by the factor f_3 (see Figure 2).

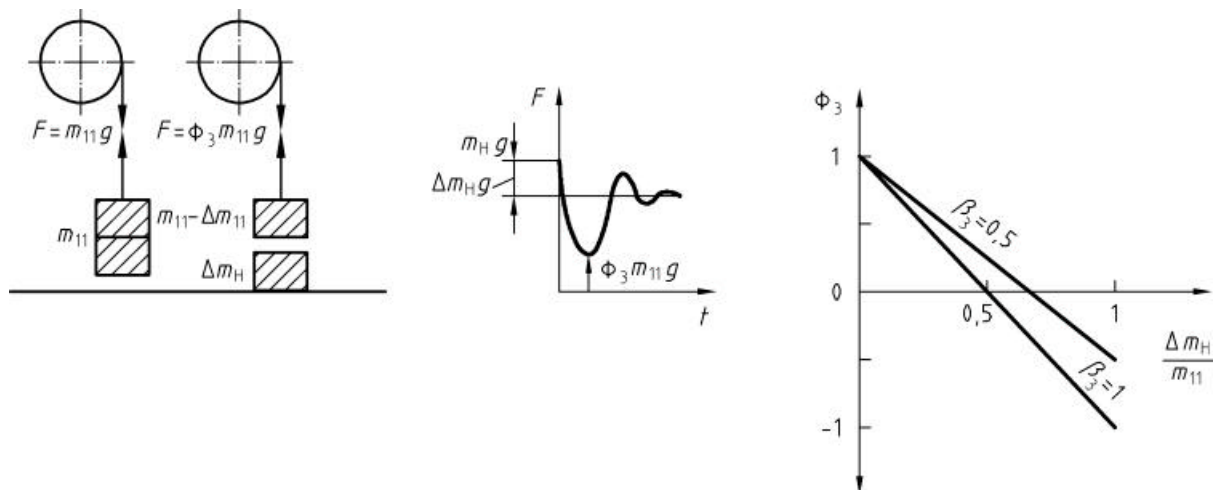


Figure 2 — Factor f_3

The factor f_3 shall be taken as follows:

$$f_3 = 1 - \frac{\Delta m_H}{m_H} (1 + \beta_3) \tag{4}$$

where:

Δm_H is the released part of the hoist load;

- m_H is the mass of the hoist load;
- $b_3 = 0,5$ for cranes equipped with grabs or similar slow-release devices;
- $b_3 = 1,0$ for cranes equipped with magnets or similar rapid-release devices.

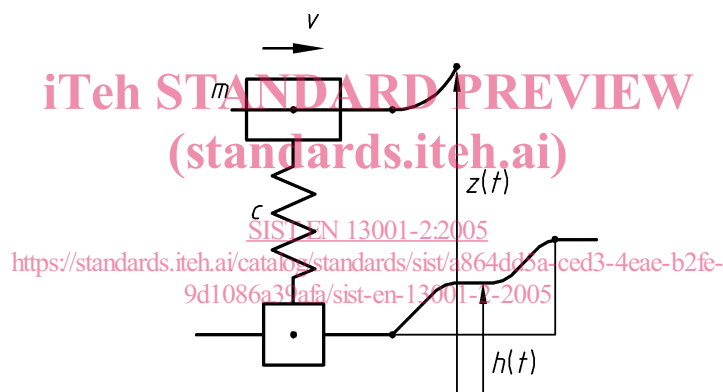
4.2.2.3 Loads caused by travelling on uneven surface

The dynamic actions on the crane by travelling, with or without load, on or off roadways or on rail tracks shall be estimated, by experiment or by calculation using an appropriate model for the crane or the trolley and the travel surface or the track, and shall be specified.

When calculating the dynamic actions on the crane by travelling, the induced accelerations shall be taken into account by multiplying the gravitational forces due to the masses of the crane and hoist load by a factor f_4 .

European Standards for specific crane types specify tolerances for rail tracks and ground conditions and give conventional values for f_4 .

Where there is no specific factor f_4 , it may be estimated by using a simple single mass - spring - model for the crane as shown in Figure 3.



Key

- m mass of the crane and the hoist load;
- v constant horizontal travelling speed of the crane;
- c spring constant;
- $z(t)$ coordinate of the mass centre;
- $h(t)$ unevenness function describing the step or gap of the rail;

Figure 3 — Single mass model of a crane for determining the factor f_4

f_4 may be calculated as follows:

$$f_4 = 1 + \left(\frac{p}{2}\right)^2 \frac{v^2}{g r} \mathbf{x}_s \quad (5) \quad \text{for travelling over a step (see Figure 4a);}$$

$$f_4 = 1 + \left(\frac{p}{2}\right)^2 \frac{v^2}{g r} \mathbf{x}_G \quad (6) \quad \text{for travelling over a gap (see Figure 4b);}$$

where:

- v is the constant horizontal travelling speed of the crane;
- r is the wheel radius;
- $g = 9,81 \text{ m/s}^2$ is the gravity constant;