BS EN 13001-2:2011

Incorporating corrigenda March 2012 and November 2012

BSI Standards Publication

Crane safety — General design

Part 2: Load actions

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National foreword

This British Standard is the UK implementation of EN 13001-2:2011 incorporating corrigendum March 2012. Together with BS EN 13001-3-1:2012, BS EN 13001-1:2004+A1:2009, BS EN 13001-3-2, BS EN 13001-3-3, BS EN 13001-3-4 and DD CEN/TS 13001-3-5:2010, it supersedes BS 2573-1:1983 and BS 2573-2:1980, which will be withdrawn on publication of all parts of the BS EN 13001 series. It also supersedes BS EN 13001-2:2004+A3:2009, which is withdrawn.

Users' attention is drawn to the fact that neither BS 2573-1 nor BS 2573-2 should be used in conjunction with the EN 13001 series as they are not complementary. The BS 2573 series will remain current until all parts of the BS EN 13001 series cited above have been published to ensure that a coherent package of standards remains available in the UK during the transition to European standards.

The start and finish of text introduced or altered by corrigendum is indicated in the text by tags. Text altered by CEN corrigendum March 2012 is indicated in the text by [AC1⟩ ⟨AC1].

The UK participation in its preparation was entrusted by Technical Committee MHE/3, Cranes and derricks, to Subcommittee MHE/3/1, Crane design.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

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EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 13001-2

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English Version

Crane safety - General design - Part 2: Load actions

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 27 February 2011.

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EUROPÄISCHES KOMITEE FÜR NORMUNG

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Foreword

This document (EN 13001-2:2011) 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of an identical text or by endorsement, at the latest by October 2011, and conflicting national standards shall be withdrawn at the latest by October 2011.

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 supersedes EN 13001-2:2004+A3:2009.

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 integral part of this document.

CEN/TC 147 / WG 2 "Cranes – Design General" has developed a revision of this document to give added value, which differ from EN 13001-2:2004+A3:2009 as follows:

— Table 3 - Definition of HD 1 … HD 5 are modified and

— Annex B – illustration added to clarify HD 1…HD 5 classes.

NOTE This document does not change the previous content.

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

— *Part 1: General principles and requirements*

— *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*

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 and the United Kingdom.

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 ISO 12100.

The machinery concerned and the extent to which hazards are covered are indicated in the scope of this European 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 series of Part 3 and as such they specify general conditions, requirements and methods to prevent 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. Clause 4 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

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

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

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

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

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 1990:2002 and ISO 4306-1:2007, Clause 6 apply.

3.2 Symbols and abbreviations

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

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
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
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
ΔF	Change of drive force
F_{x1i}, F_{x2i}	Tangential wheel forces
F_{y1i}, F_{y2i}	
F_y	Guide force
F_{z1i}, F_{z2i}	Vertical wheel forces

Table 1 *(continued)*

Symbols, abbreviations	Description
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
H_1, H_2	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
K_1, K_2	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
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

Table 1 *(continued)*

Symbols, abbreviations	Description
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
ΔS	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
$v_m(z)$	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
α_r	Relative aerodynamic length
α_w	Angle between the direction of the wind velocity $\bar{v}$ or $v(z)$ and the longitudinal axis of the crane member under consideration
α	Skewing angle
α_g	Part of the skewing angle α due to the slack of the guide

Table 1 *(continued)*

Symbols, abbreviations	Description
α_G	Term used in calculating ϕ_4
α_s	Term used in calculating ϕ_4
α_t	Part of the skewing angle α due to tolerances
α_w	Part of the skewing angle α due to wear
β	Angle between horizontal plane and non-horizontal wind direction
β_2	Term used in calculating ϕ_2
β_3	Term used in calculating ϕ_3
γ_f	Overall safety factor
γ_m	Resistance coefficient
γ_n	Risk coefficient
γ_p	Partial safety factor
δ	Term used in calculating ϕ_1
ε_S	Conventional start force factor
ε_M	Conventional mean drive force factor
η	Shielding factor
η_W	Factor for remaining hoist load in out of service condition
λ	Aerodynamic slenderness ratio
μ, μ'	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}
$\xi_G(\alpha_G)$, $\xi_s(\alpha_s)$	Curve factors
ρ	Density of the air
φ	Solidity ratio
ϕ_i	Dynamic factors
ϕ_1	Dynamic factor for hoisting and gravity effects acting on the mass of the crane
ϕ_2	Dynamic factor for inertial and gravity effects by hoisting an unrestrained grounded load
$\phi_{2,min}$	Term used in calculating ϕ_2

Table 1 *(continued)*

Symbols, abbreviations	Description
ϕ_3	Dynamic factor for inertial and gravity effects by sudden release of a part of the hoist load
ϕ_4	Dynamic factor for loads caused by travelling on uneven surface
ϕ_5	Dynamic factor for loads caused by acceleration of all crane drives
ϕ_6	Dynamic factor for test loads
ϕ_7	Dynamic factor for loads due to buffer forces
ϕ_8	Gust response factor
ψ	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 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 4.2.5.

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 ϕ_1. The masses of cranes or crane parts in class MDC1 (see 4.3.3) shall be multiplied by

$$\phi_1 = 1 + \delta, \quad 0 \le \delta \le 0{,}1 \qquad (1)$$

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

$$\phi_1 = 1 \pm \delta, \quad 0 \le \delta \le 0{,}05 \qquad (2)$$

depending on whether their gravitational acting is partly increasing ($+\delta$) or decreasing ($-\delta$) 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 ϕ_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.

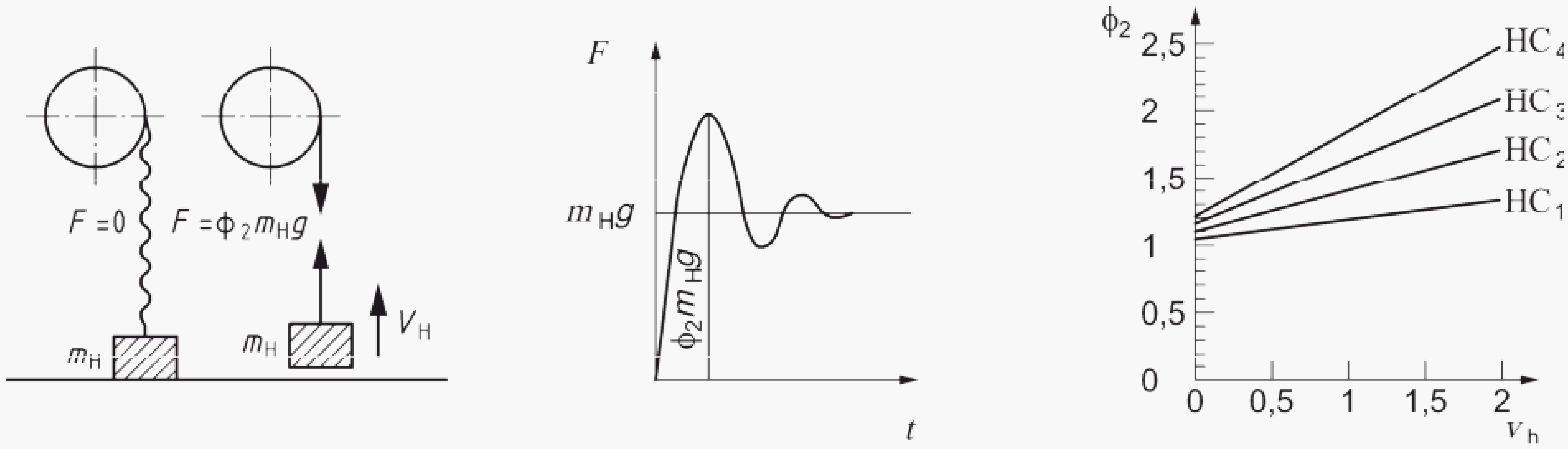


Figure 1 — Factor ϕ_2

The factor ϕ_2 shall be taken as follows:

$$\phi_2 = \phi_{2,\text{min}} + \beta_2\, v_h \tag{3}$$

$\phi_{2,\text{min}}$ and β_2 are given in Table 2 for the appropriate hoisting class. For the purposes of this European 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 ϕ_2 can be determined by experiments or analysis without reference to hoisting class.

v_h is the characteristic hoisting speed, in meters per second, related to the lifting attachment. Values of v_h in relation to steady hoisting speeds and hoist drive classes are given in Table 3.

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

Hoisting class of appliance	β_2	$\phi_{2,\text{min}}$
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 ϕ_2

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

where

HD1 is the creep speed is not available or the start of the drive without creep speed is possible;

HD2 is the hoist drive can only start at creep speed of at least a preset duration;

HD3 is the hoist drive control maintains creep speed until the load is lifted off the ground;

HD4 is the step-less hoist drive control, which performs with continuously increasing speed;

HD5 is the step-less hoist drive control automatically ensures that the dynamic factor φ_2 does not exceed $\varphi_{2,min}$;

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

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

See Annex B for illustration of the types of hoist drives.

4.2.2.2.2 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 ϕ_3 (see Figure 2).

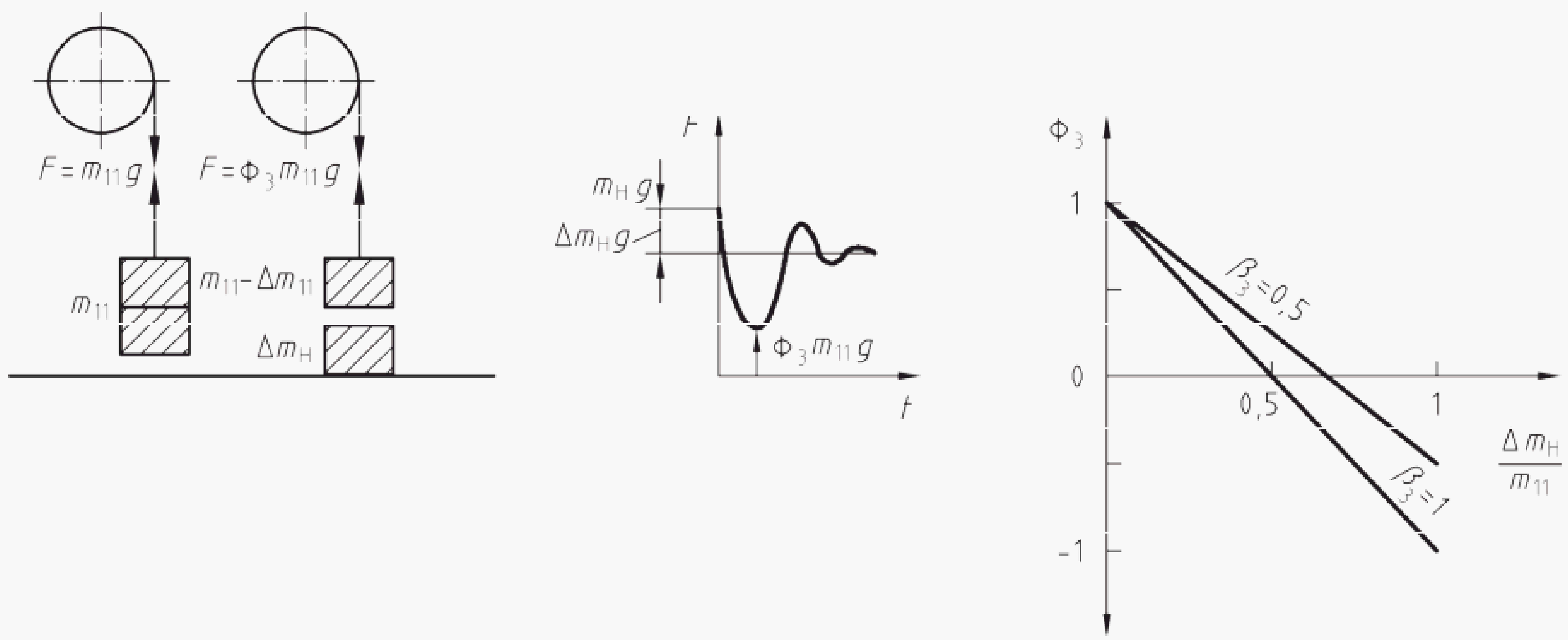


Figure 2 — Factor ϕ_3

The factor ϕ_3 shall be taken as follows:

$$\phi_3 = 1 - \frac{\Delta m_H}{m_H}(1 + \beta_3) \tag{4}$$

where

Δm_H is the released part of the hoist load;

m_H is the mass of the hoist load;

$\beta_3 = 0{,}5$ for cranes equipped with grabs or similar slow-release devices;

$\beta_3 = 1{,}0$ for cranes equipped with magnets or similar rapid-release devices.

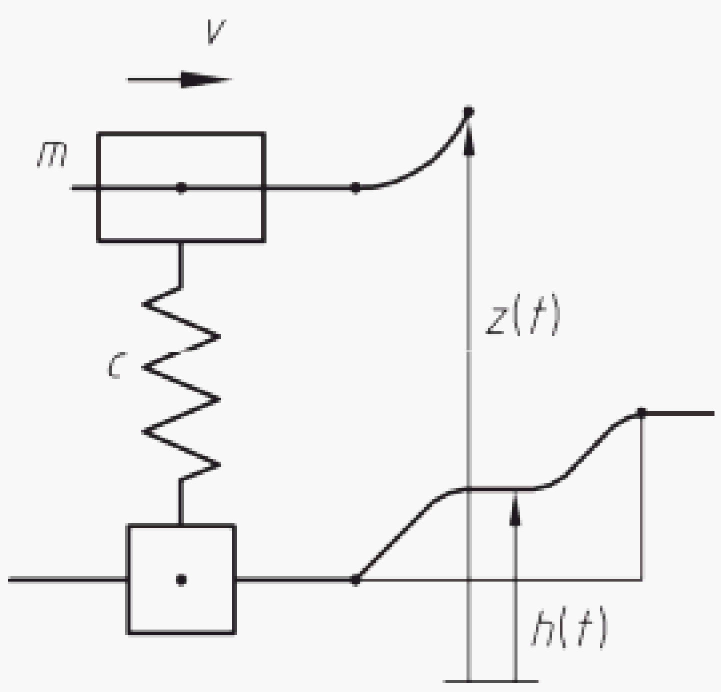
4.2.2.3 Loads caused by travelling on uneven surface

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 ϕ_4.

European Standards for specific crane types specify tolerances for rail tracks and ground conditions and give conventional values for ϕ_4.

Where there is no specific factor ϕ_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 ϕ_4

ϕ_4 may be calculated as follows:

$$\phi_4 = 1 + \left(\frac{\pi}{2}\right)^2 \frac{v^2}{g\,r}\xi_S \tag{5}$$

for travelling over a step (see Figure 4 a));

$$\phi_4 = 1 + \left(\frac{\pi}{2}\right)^2 \frac{v^2}{g\,r} \xi_G \qquad (6)$$ for travelling over a gap (see Figure 4 b));

where

v is the constant horizontal travelling speed of the crane;

r is the wheel radius;

$g =$ 9,81 m/s^2 is the gravity constant.

$\xi_s(\alpha_s)$, $\xi_G(\alpha_G)$ are curve factors that become maximum for the time period after the wheel has passed the unevenness; they can be determined for $\alpha_s < 1{,}3$ and $\alpha_G < 1{,}3$ by the diagrams given in Figure 5.

where

$\alpha_s = \frac{2 f_q h_s}{v} \sqrt{\frac{2r}{h_s}}$ (see Figure 5 a));

$\alpha_G = \frac{f_q e_G}{v}$ (see Figure 5 b));

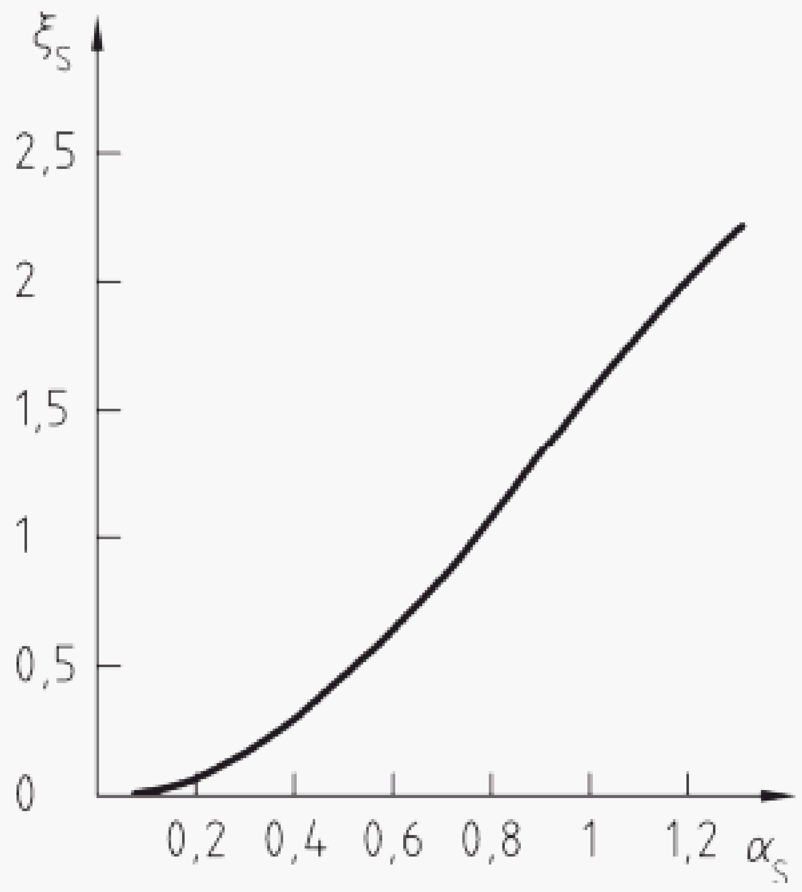
h_s is the height of the step (see Figure 4);

e_G is the width of the gap (see Figure 4);

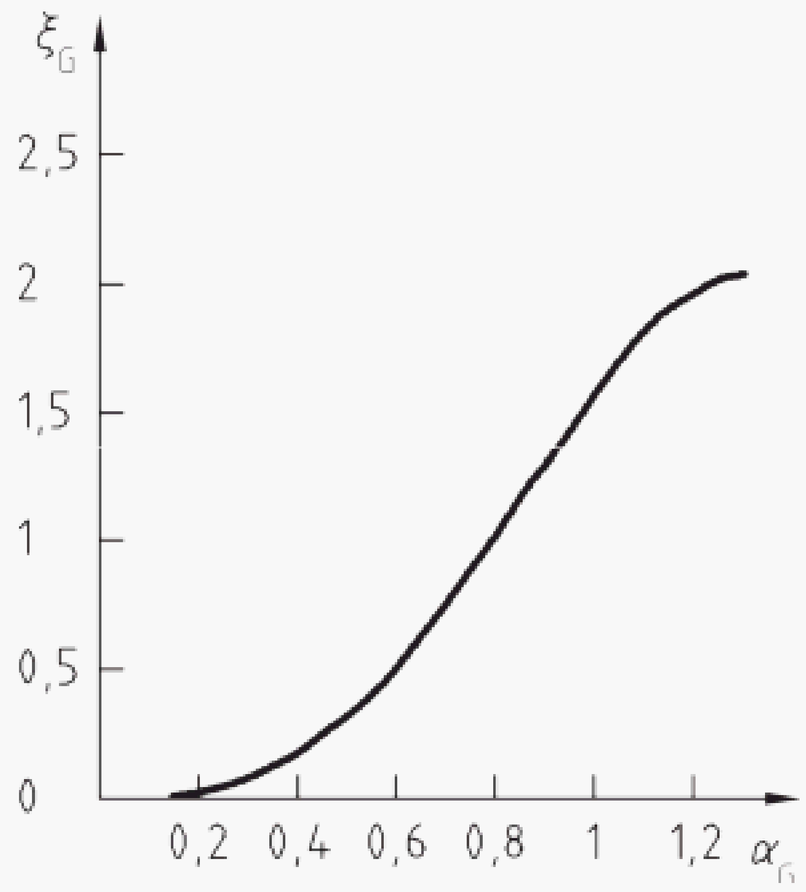
$f_q = \frac{\sqrt{c/m}}{2\pi}$ is the natural frequency of a single mass model of the crane (see Figure 3). If unknown, to be taken as 10 Hz.

a) Travelling over a step **b) Travelling over a gap**

Figure 4 — Movement of the wheel centre



a) **Travelling over a step**



b) **Travelling over a gap**

Figure 5 — Curve factors $\xi_s(\alpha_s)$ and $\xi_G(\alpha_G)$

NOTE The use of this simple model is restricted to cranes whose actual dynamic behaviour corresponds to that of the model. If more than one natural mode contributes a significant response and/or rotation occurs, the designer should estimate the dynamic loads using an appropriate model for the circumstances.

4.2.2.4 Loads caused by acceleration of drives

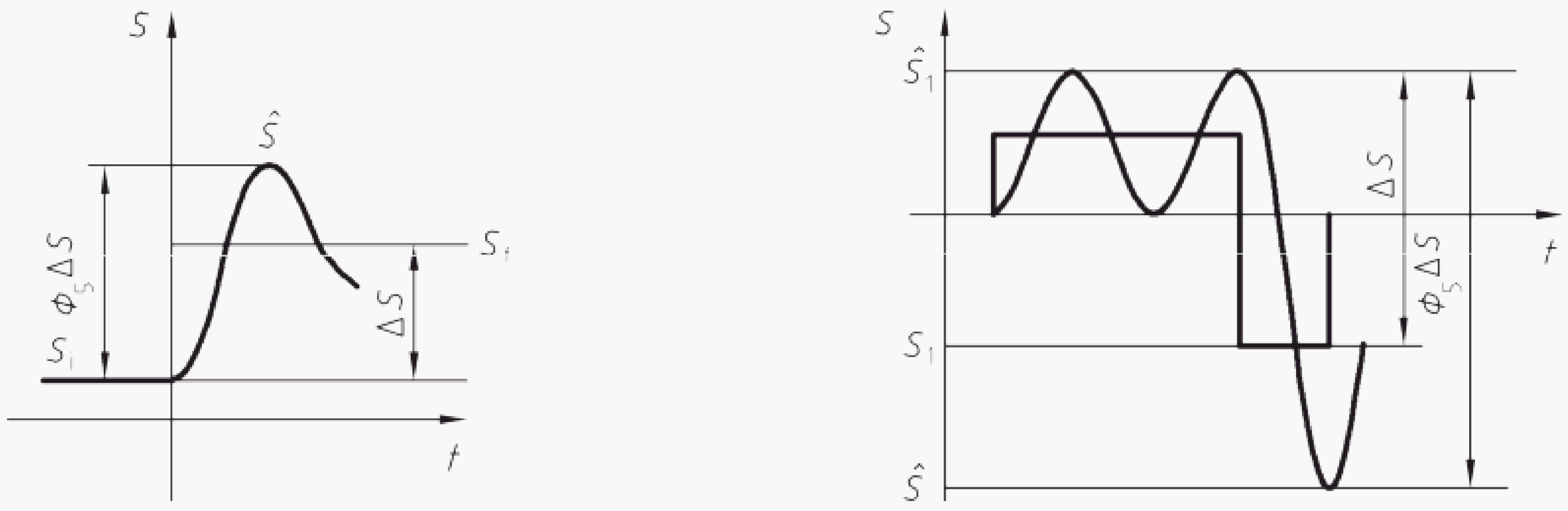
Loads induced in a crane by acceleration or decelerations caused by drive forces may be calculated using rigid body kinetic models. For this purpose, the gross load is taken to be fixed at the top of the jib or immediately below the crab.

The load effect $\hat{S}$ shall be applied to the components exposed to the drive forces and where applicable to the crane and the gross load as well. As a rigid body analysis does not directly reflect elastic effects, the load effect $\hat{S}$ shall be calculated by using a factor ϕ_5 as follows (see Figure 6):

$$\hat{S} = S_i + \phi_5 \Delta S \qquad (7)$$

where

$\Delta S = S_f - S_i$	is the change of the load effect due to the change of the drive force $\Delta F = F_f - F_i$;
S_i, S_f	are the initial (i) and final (f) load effects caused by F_i and F_f;
F_i, F_f	are the initial (i) and final (f) drive forces.



a) for the change of drive forces from steady state

b) for the positioning case

Figure 6 — Factor ϕ_5

Following values of ϕ_5 shall be applied:

$\phi_5 = 1$	for centrifugal forces;
$1 \leq \phi_5 \leq 1{,}5$	for drives with no backlash or in cases where existing backlash does not affect the dynamic forces and with smooth change of forces;
$1{,}5 \leq \phi_5 \leq 2$	for drives with no backlash or in cases where existing backlash does not affect the dynamic forces and with sudden change of forces;
$\phi_5 = 3$	for drives with considerable backlash, if not estimated more accurate by using a spring-mass-model.

Where a force that can be transmitted is limited by friction or by the nature of the drive mechanism, the limited force and a factor ϕ_5 appropriate to that system shall be used.

4.2.2.5 Loads induced by displacements

Account shall be taken of loads arising from displacements included in the design such as those within the limits necessary to initiate response from compensating systems (e.g. skewing) or those resulting from prestressing.

Other loads to be considered include those that can arise from displacements that are within defined limits such as those set for the variations in the height or the gauge between rails or uneven settlement of supports.

4.2.3 Occasional loads

4.2.3.1 Loads due to in-service wind

The wind loads assumed to act perpendicularly to the longitudinal axis of a crane member are calculated by

$F = q(3) \times c \times A$ (8) regarding the structure of the crane;

$F = \varepsilon_S \times q(3) \times c \times A$ (9) regarding the required starting drive forces;

$F = \varepsilon_M \times q(3) \times c \times A$ (10) regarding the drive forces during controlled movement;

where

F is the wind load acting perpendicularly to the longitudinal axis of the member under consideration;

c is the aerodynamic coefficient of the member under consideration; it shall be used in combination with the characteristic area A; values of c shall be as given in Annex A;

A is the characteristic area of the member under consideration (see Annex A);

where

$q(3) = 0{,}5 \times \rho \times v(3)^2$	is the wind pressure at $v(3)$;
$\rho = 1{,}25$ kg/m^3	is the density of the air;
$\varepsilon_S = 0{,}7$	is the conventional start force factor;
$\varepsilon_M = 0{,}37$	is the conventional mean drive force factor;
$v(3) = 1{,}5 \times \bar{v}$	is the gust wind velocity averaged over a period of 3 s;
$\bar{v}$	is the mean wind velocity, which is related to the Beaufort scale, averaged over 10 min in 10 m height above flat ground or sea level.

For the calculation of loads due to in-service wind it is assumed that the wind blows horizontally at a constant mean velocity $\bar{v}$ at all heights.

Considering a crane member, the component $\bar{v}^*$ of the wind velocity acting perpendicularly to the longitudinal axis of the crane member shall be applied; it is calculated by $\bar{v}^* = \bar{v} \times \sin \alpha_w$, where α_w is the angle between the direction of the wind velocity $\bar{v}$ and the longitudinal axis of the member under consideration.

The wind load assumed to act on the gross load in direction of the wind velocity is determined by analogy to the wind loads assumed to act on a crane member, whereas a substitution of $\bar{v}$ by $\bar{v}^*$ shall not be applied. The factors in the given equations for F (see above) are as follows:

F is the wind load acting on the gross load in direction of the wind velocity;

c is the aerodynamic coefficient of the gross load in direction of the wind velocity;

A_g is the projection of the gross load on a plane normal to the direction of the wind velocity, in square metres.

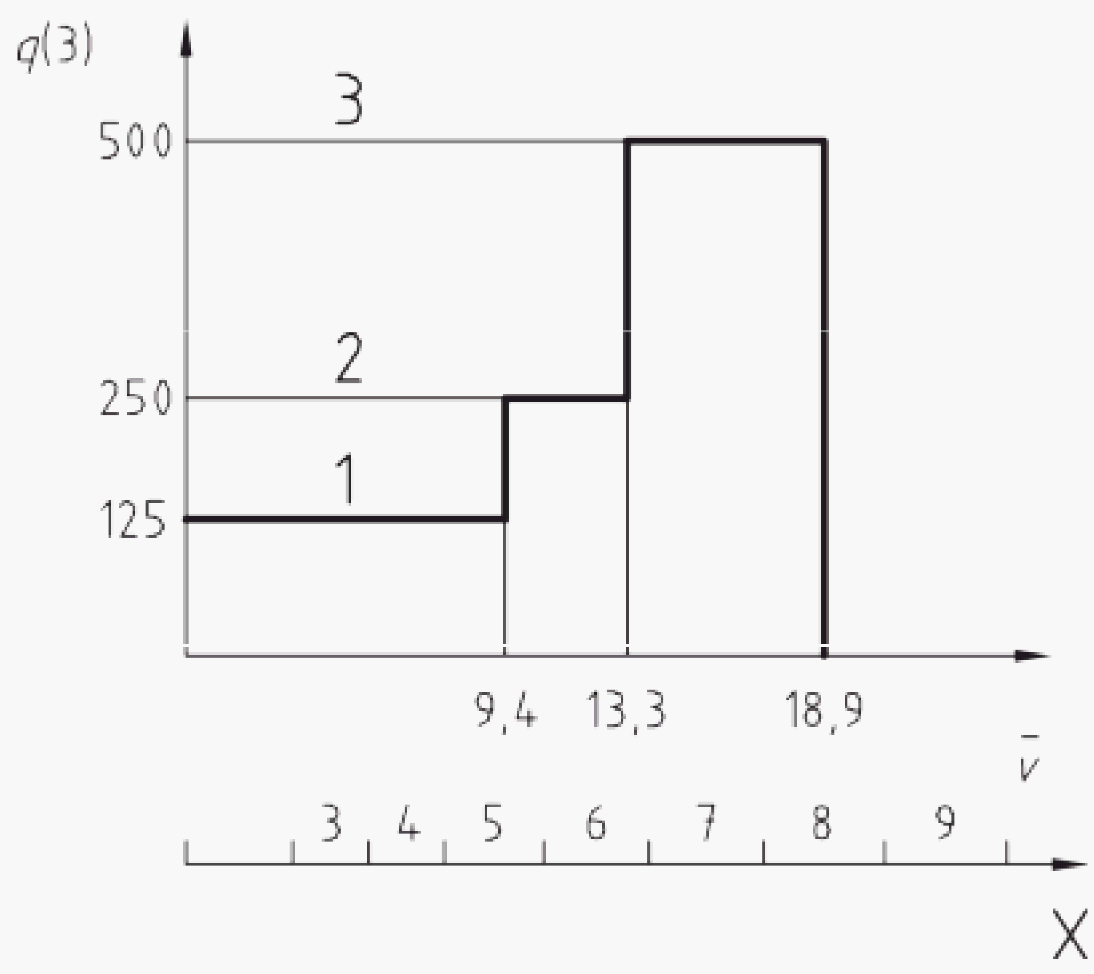
In absence of detailed information of the load it should be assumed $c = 2{,}4$ and $A_g = 0{,}000\,5 \times m_H$, where m_H is the mass of the gross load in kilograms. A_g shall not be less than 0,8 m^2.

Depending upon the type of crane, its configuration, operation and service conditions and the agreed/specified number of out-of-service-days per year, a mean wind velocity $\bar{v}$ shall be specified. Table 4 gives values of the mean velocity $\bar{v}$ for standardized wind states.

Table 4 — In-service wind states

Wind State	$\bar{v}$ [m/s]	$v(3)$ [m/s]	$q(3)$ [N/m²]	$\varepsilon_S \cdot q(3)$ [N/m²]	$\varepsilon_M \cdot q(3)$ [N/m²]
1 light	9,4	14	125	88	46
2 normal	13,3	20	250	176	92
3 heavy	18,9	28	500	353	184

The correlation of the mean wind velocity $\bar{v}$, the Beaufort scale and the in-service wind states is shown in Figure 7.



Key

X Beaufort
1 wind states 1
2 wind states 2
3 wind states 3

Figure 7 — Correlation of the mean wind velocity $\bar{v}$, the Beaufort scale and the in-service wind states

The design is based on the following requirement for the operation of the crane: If the wind velocity, measured at the highest point of the crane, increases and tends to reach $v(3)$, the crane shall be secured or its configuration shall be transformed into a safe configuration. As the methods and/or means for this securing are different and need different time (locking devices at special locations of the crane runway, hand-operated or automatic rail clamps) a lower level of mean wind velocity shall be chosen to start the securing.

NOTE Any slender structural member, when placed in a windstream with its longitudinal axis perpendicular to this stream, may become aeroelastically unstable. Means to prevent these effects (e.g. galloping or formation of eddies) by design should be considered both for in-service and out-of-service wind conditions.

4.2.3.2 Snow and ice loads

Where relevant, snow and ice loads shall be specified and taken into account. The increased wind exposure surfaces shall be considered.

4.2.3.3 Loads due to temperature variation

Where relevant, local temperature variation shall be specified and taken into account.

4.2.3.4 Loads caused by skewing

Skewing loads occur at the guidance means of guided wheel-mounted cranes or trolleys while they are travelling or traversing at constant speed. These loads are induced by guidance reactions which force the wheels to deviate from their free-rolling, natural travelling or traversing direction.

Skewing loads as described above are usually taken as occasional loads but their frequency of occurrence varies with the type, configuration, accuracies of wheel axle parallelism and service of the crane or trolley. In individual cases, the frequency of occurrence will determine whether they are taken as occasional or regular loads. Guidance for estimating the magnitude of skewing loads and the category into which they are placed is given in the European Standards for specific crane types.

The lateral and tangential forces between wheels and rails as well as between guide means and guidance caused by skewing of the crane, can be calculated by a simplified mechanical model. The crane is considered to be travelling at a constant speed without anti-skewing control.

The model consists of n pairs of wheels transversally in line, of which p pairs are coupled. A coupled pair of wheels (C) is coupled mechanically or electrically. Independently supported non-driven or also — in approximation — single-driven wheels are considered as independent wheel pair (I). The latter condition is also valid in the case of independent single drives.

The wheels are arranged in ideal geometric positions in a rigid crane structure which is travelling on a rigid track. Differences in wheel diameters are neglected in this model. They are either fixed (F) or movable (M) in respect of lateral movement.

The different combinations of transversally in-line wheel pairs that are possible are shown in Figure 8.

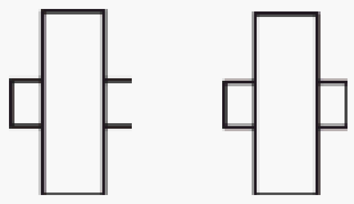
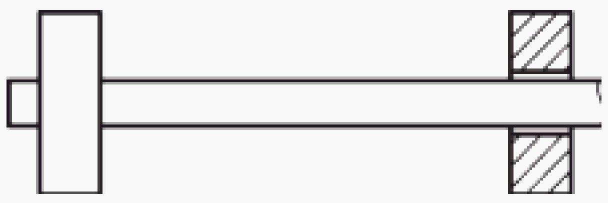
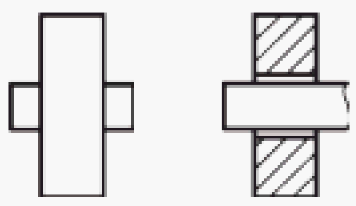
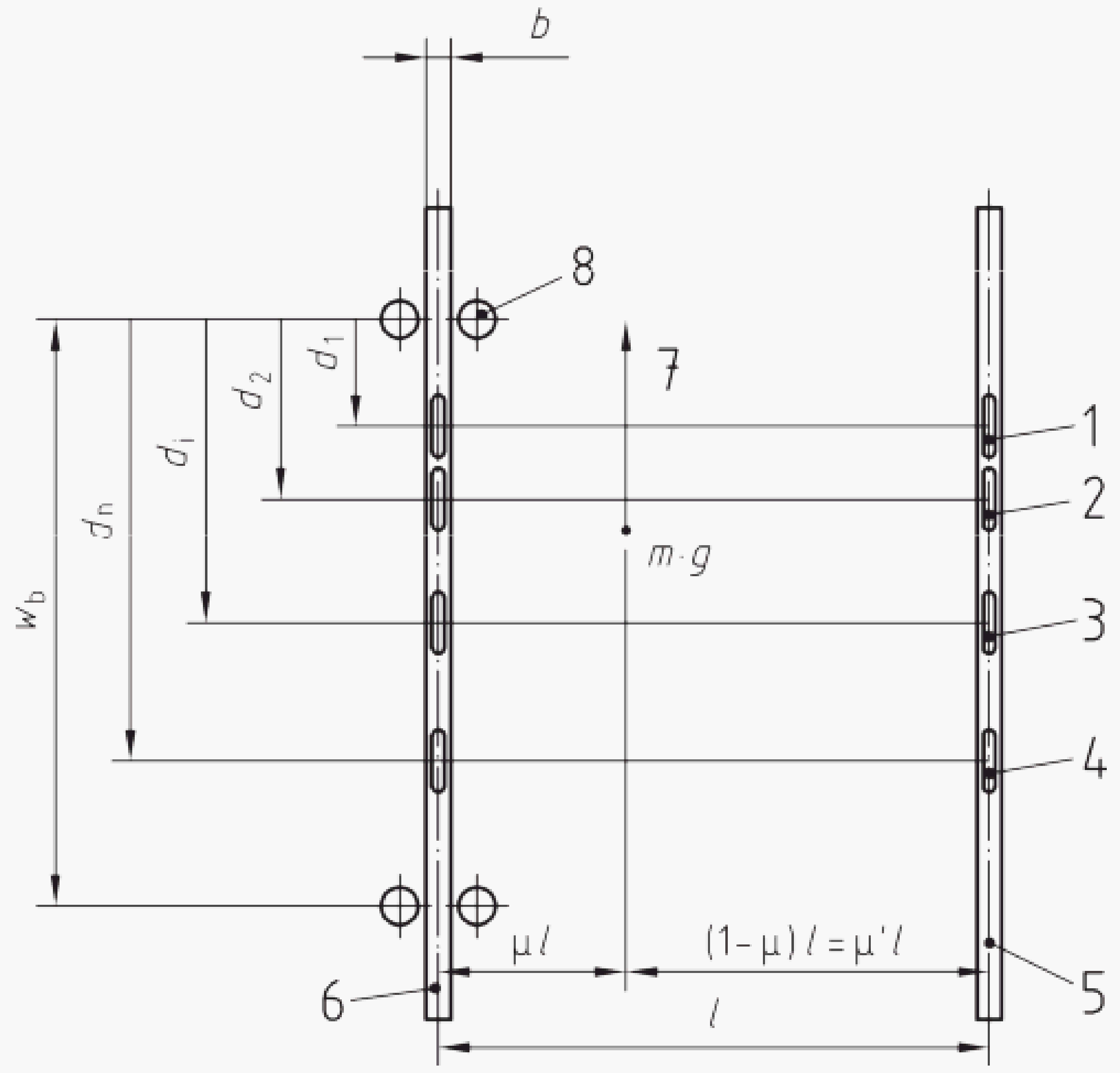
	Coupled (C)	**Independent (I)**
Fixed/Fixed (F/F)	 **CFF**	 **IFF**
Fixed/Movable (F/M)	 **CFM**	 **IFM**

Figure 8 — Different combinations of wheel pairs

The positions of the wheel pairs relative to the position of the guide means in front of the travelling crane are given by the distance d_i as shown in Figure 9.

NOTE 1 Where flanged wheels are used instead of an external guide means, $d_1 = 0$.

NOTE 2 It is assumed that the gravitational forces due to the masses of the loaded appliance $(m \cdot g)$ are acting at a distance μl from rail 1 and are distributed equally to the n wheels at each side of the crane runway.

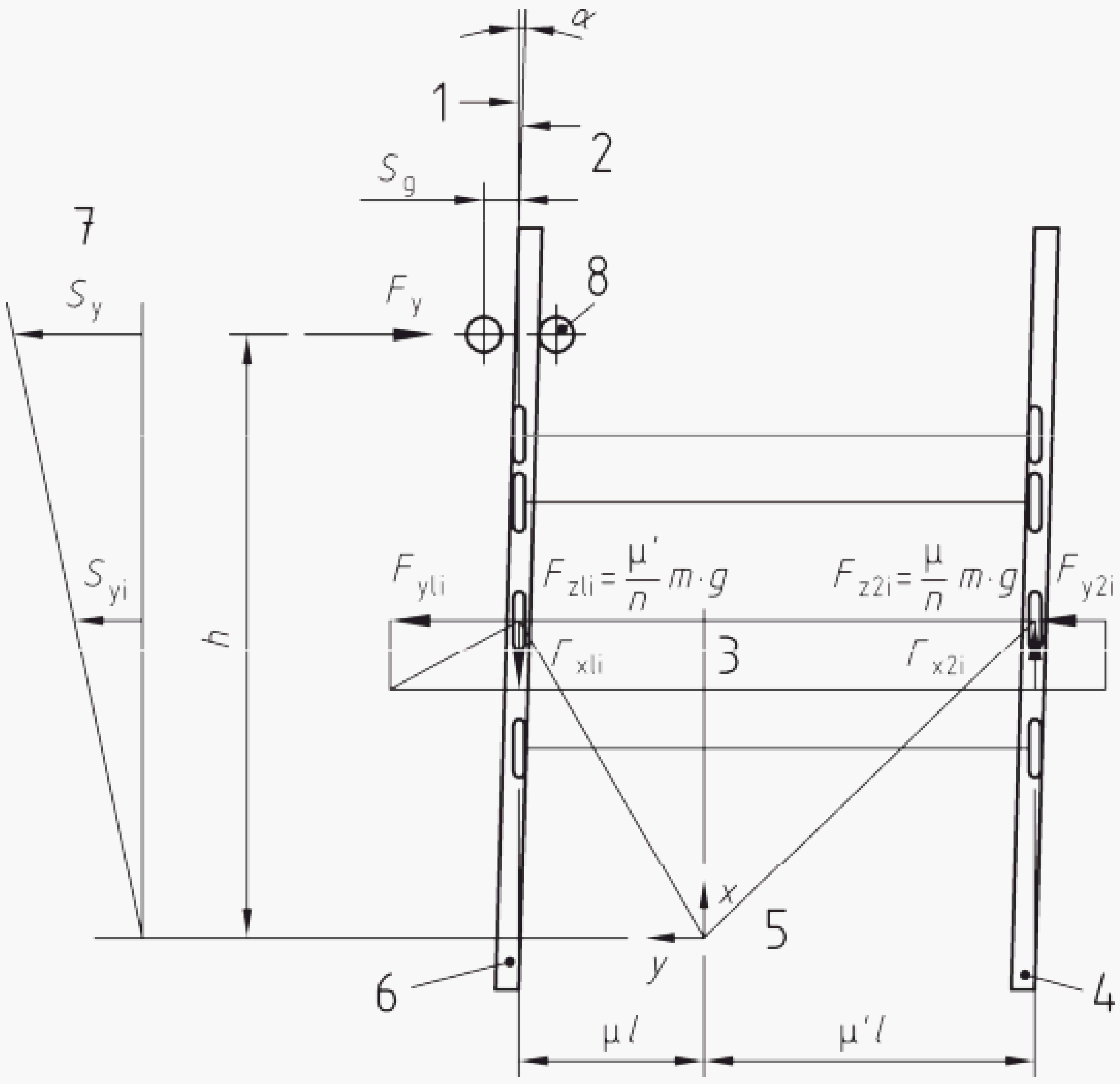


Key

1 wheel pair 1
2 wheel pair 2
3 wheel pair I
4 wheel pair *n*
5 rail 2
6 rail 1
7 travelling direction
8 guide means

Figure 9 — Positions of wheel pairs

The crane model is assumed to be travelling at constant speed and to have skewed to an angle α, as shown in Figure 10. The crane may be guided horizontally by external means or by wheel flanges.



Key

1 direction of motion
2 direction of rail
3 wheel pair *i*
4 rail 2
5 instantaneous slide pole
6 rail 1
7 slip
8 guide means

Figure 10 — Loads acting on crane in skewed position

A guide force F_y is in balance with the wheel forces F_{x1i}, F_{y1i}, F_{x2i}, F_{y2i}, which are caused by rotation of the crane about the instantaneous slide pole. With the maximum lateral slip $s_y = \alpha$ at the guide means and a linear distribution of the lateral slip s_{yi} between guide means and instantaneous slide pole, the corresponding skewing forces may be calculated as follows:

The guide force F_y may be calculated by

$$F_y = \nu \cdot f \cdot m \cdot g \qquad (11)$$

where

$m \cdot g$ is the gravitational force due to the mass of the loaded crane;

[AC1) $f = 0{,}3 \cdot \left[1 - e^{(250\alpha)} \right]$ (AC1] is the friction coefficient of the rolling wheel;

where

α is the skewing angle (see Figure 10), in radians.

The skewing angle α, which should not exceed 0,015 radians, shall be chosen taking into account the space between the guide means and the rail as well as reasonable dimensional variation and wear of the appliance wheels and the rails as follows:

$$\alpha = \alpha_g + \alpha_w + \alpha_t$$

where

$\alpha_g = s_g / w_b$	is the part of the skewing angle due to the slack of the guide;
s_g	is the slack of the guide (see Figure 10);
w_b	is the distance between the guide means;
$\alpha_w = 0{,}1\ (b_h / w_b)$	is the part of the skewing angle due to wear;
b_h	is the width of the rail head (see Figure 9);
$\alpha_t = 0{,}001$ rad	is the part of the skewing angle due to tolerances;
$\nu = 1 - \sum d_i / nh$	for systems F/F (see Figure 8);
$\nu = \mu'\left(1 - \sum d_i / nh\right)$	for systems F/M (see Figure 8);

where

h	is the distance between the instantaneous slide pole and the guide means;
$h = (p\mu\mu' l^2 + \sum d_i^2) / \sum d_i$	for systems F/F;
$h = (p\mu l^2 + \sum d_i^2) / \sum d_i$	for systems F/M;
n	is the number of wheels at each side of the crane runway;
p	is the number of pairs of coupled wheels;
l	is the span of the crane (see Figure 9);
μ, μ'	are parts of the span l (see Figure 9);
d_i	is the distance of wheel pair i from the guide means (see Figure 9).

The forces F_{x1i}, F_{x2i}, F_{y1i} and F_{y2i} may be calculated by

$$
\begin{aligned}
F_{x1i} &= \xi_{1i} \times f \times m \times g \\
F_{x2i} &= \xi_{2i} \times f \times m \times g \\
F_{y1i} &= \nu_{1i} \times f \times m \times g \\
F_{y2i} &= \nu_{2i} \times f \times m \times g
\end{aligned}
\qquad (12)
$$

where ξ_{1i}, ξ_{2i}, ν_{1i} and ν_{2i} are as given in Table 5.

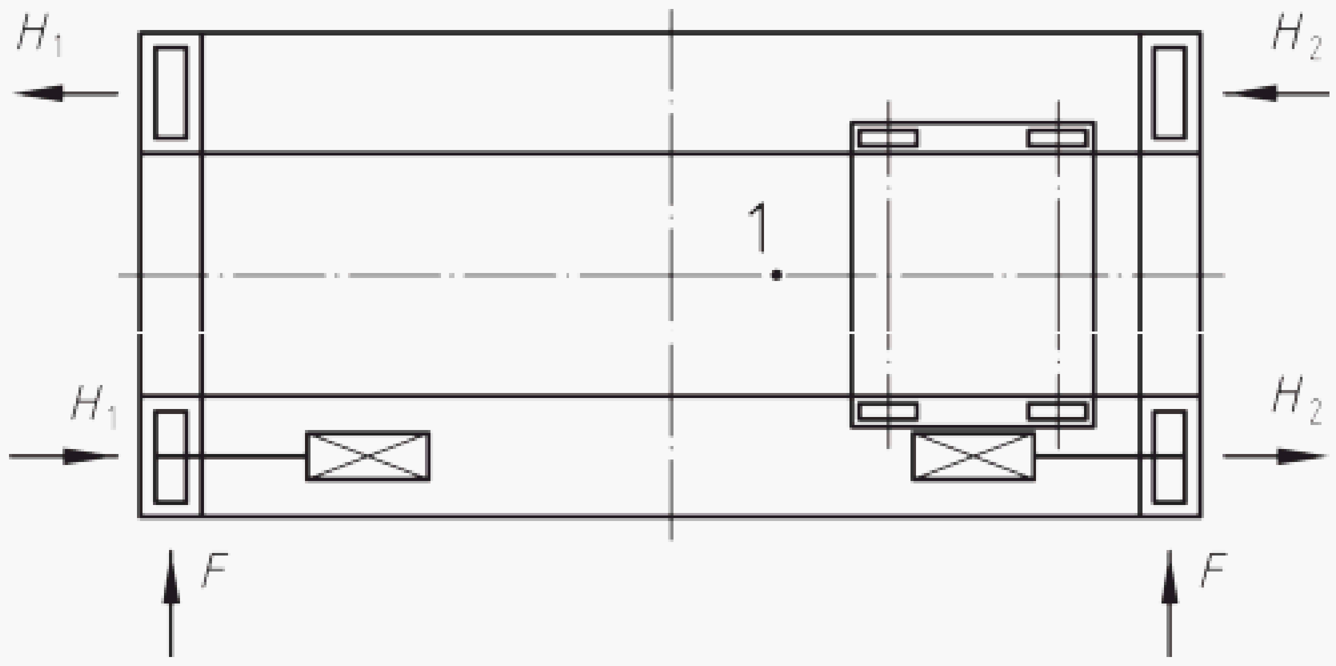
Table 5 — Values of ξ_{1i}, ξ_{2i}, ν_{1i} and ν_{2i}

AC1⟩

Combinations of wheel pairs (see figure 8)	$\xi_{1i} = \xi_{2i}$	ν_{1i}	ν_{2i}
CFF	μμ′ l/nh	$\frac{\mu'}{n}\left(1-\frac{d_i}{h}\right)$	$\frac{\mu}{n}\left(1-\frac{d_i}{h}\right)$
IFF	0		
CFM	μμ′ l/nh		0
IFM	0		

⟨AC1

NOTE The drive forces F acting on a crane or a trolley with asymmetrical mass distribution induce the forces H_1 and H_2, as shown in Figure 11. They are taken into account as regular loads in accordance with 4.2.2.4.



Key

1 gravity centre

Figure 11 — Forces acting on a bridge crane with asymmetrical mass distribution, that are induced by acceleration of the travelling drives

4.2.4 Exceptional loads

4.2.4.1 Loads caused by hoisting a grounded load at maximum hoisting speed

With reference to 4.2.2.2.1 and Table 10 loads caused by dynamic effects on the crane by transferring an unrestrained grounded load from the ground to the crane are considered as exceptional loads in load combination C1. For this case the estimation of the dynamic factor ϕ_2 is shown in Table 3.

4.2.4.2 Loads due to out-of-service wind

The out-of-service wind loads assumed to act on a member of a crane or on the hoist load remaining suspended from the crane are calculated by

$$F = q(z) \times c \times A \tag{13}$$

where

in case of considering a member of the crane:

- F is the wind load acting perpendicularly to the longitudinal axis of the crane member;
- c is the aerodynamic coefficient of the member under consideration; it has to be used in combination with the characteristic area A; values of c are given in Annex A;
- A is the characteristic area of the member under consideration (see Annex A);

in case of considering the gross load remaining suspended from the crane:

- F is the wind load, acting on the remaining hoist load in direction of the wind velocity;
- c is the aerodynamic coefficient of the remaining hoist load in direction of the wind velocity;

A is the projection of the remaining hoist load on a plane normal to the direction of the wind velocity.

In absence of detailed information of the load it should be assumed

$$c = 2{,}4$$
$$A = 0{,}000\,5 \times \eta_w \times m_H$$

where

A is the assumed area of the load and shall not be less than 0,8 m^2;

η_w is the factor for the remaining hoist load in out of service condition;

m_H is the mass of the hoist load in kilograms.

The equivalent static out-of-service wind pressure is calculated by

$$q(z) = 0{,}5 \times \rho \times v(z)^2$$

where

$\rho = 1{,}25\ \text{kg/m}^3$ is the density of the air;

$v(z) = f_{rec}\left[\frac{v_m(z)}{v_{ref}} + \phi_8 \frac{v_g}{v_{ref}}\right] v_{ref}$ is the equivalent static out-of-service wind velocity;

$$v(z) = f_{rec}\left[(z/10)^{0{,}14} + 0{,}4\right] v_{ref}$$

For the calculation of loads acting on a crane due to out-of-service wind, it is assumed that the wind blows horizontally at a velocity increasing with the height above the surrounding ground level.

Considering a crane member, the component $v(z)^*$ of the wind velocity acting perpendicularly to the longitudinal axis of the crane member shall be applied; it is calculated by $v(z)^* = v(z) \times \sin \alpha_w$, where α_w is the angle between the direction of the wind velocity $v(z)$ and the longitudinal axis of the member under consideration. Considering the hoist load remaining suspended from the crane the substitution of $v(z)$ by $v(z)^*$ shall not be applied.

z is the height above the surrounding ground level, in metres;

f_{rec} is a factor depending on the recurrence interval R; for crane design in general an out-of-service wind, which may recur once in intervals of 5 years to 50 years ($R = 5$ to $R = 50$) may be selected:

$f_{rec} = 0{,}815\,5$ for $R = 5$;

$f_{rec} = 0{,}873\,3$ for $R = 10$;

$f_{rec} = 0{,}946\,3$ for $R = 25$;

$f_{rec} = 1{,}0$ for $R = 50$;

$v_m(z)$ is the 10 min mean storm wind velocity in the height z, in metres per second;

v_{ref}	is the reference storm wind velocity, in metres per second, in dependence on the different geographical regions in Europe. It is defined as the mean storm wind velocity with a recurrence interval of once in 50 years, measured at 10 m above flat open country, averaged over a period of 10 min.
$v_m(z)/v_{ref} = (z/10)^{0,14}$	is a simplified roughness coefficient;
$\phi_8 = 1{,}1$	is the gust response factor;
$V_g = v_{ref} \times 2 \times \sqrt{6 \times K}$	is a 3 s gust amplitude beyond the 10 min mean storm wind;
$K = 0{,}005\,5$	is the drag-coefficient of the terrain.

In Figure 12 a storm wind map of Europe is given, roughly indicating the regions where the same reference storm wind velocities are applicable.

The reference storm wind velocities for these regions are given in Table 6.

More detailed (national) wind maps or local meteorological data can be used as sources for the reference storm wind velocities v_{ref} (e.g. EN 1991-1-4).

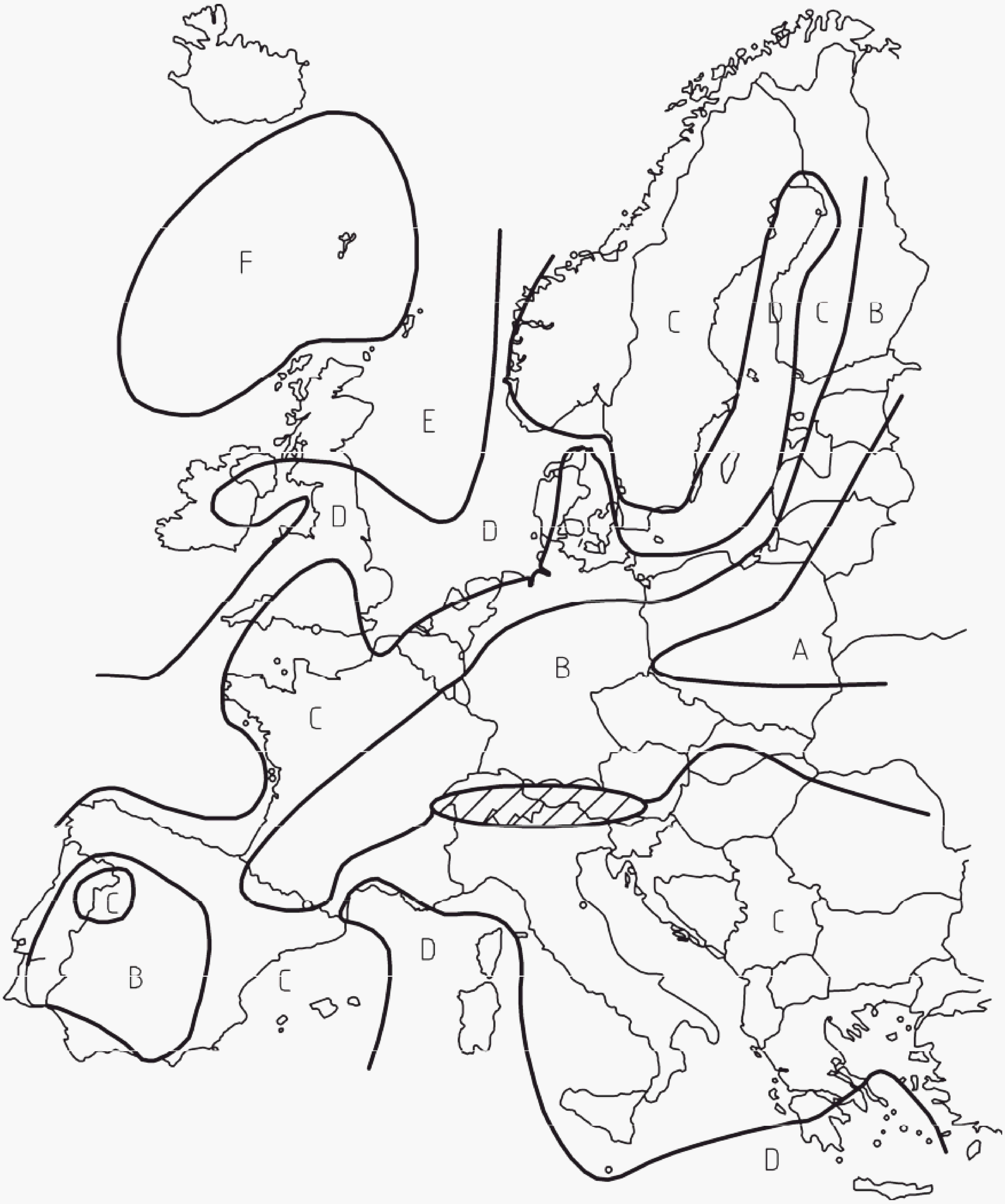


Figure 12 — Map of Europe indicating regions where the same reference storm wind velocities are applicable

Table 6 — Reference storm wind velocities v_{ref} in dependence on regions in Europe as shown in Figure 12

Region	A/B	C	D	E
v_{ref} [m/s]	24	28	32	36

Special conditions shall be agreed upon for cranes used in region F, where $v_{ref} \geq 36$ m/s. Cranes likely to be used in different regions shall be designed for the conditions applicable in those different regions.

Where cranes are installed or used for extended periods in areas where due to the local topographical configurations the out-of-service wind is expected to be more severe, the equivalent static out-of-service wind velocities and pressures, calculated by the equations given above, shall be modified in the light of meteorological data and/or aerodynamical considerations.

4.2.4.3 Test loads

The test loads shall be applied to the crane in its service configuration. The crane system shall not be altered, e.g. by applying enlarged counterweights.

The test load shall be multiplied by a factor ϕ_6. The factor ϕ_6 shall be taken as follows:

a) Dynamic test load:

The test load is moved by the drives in the way the crane will be used. The test load shall be at least 110 % of the maximum hoist load.

$$\phi_6 = 0{,}5\ (1 + \phi_2) \qquad (14)$$

where

ϕ_2 is calculated in accordance with 4.2.2.2.

b) Static test load:

The load is increased for testing by loading the crane without the use of the drives. The test load shall be at least 125 % of the maximum hoist load.

$\phi_6 = 1$

Other values of ϕ_6 are given in the European Standards for specific crane types.

In the proof calculation for test load situations a minimum level of wind of $\bar{v}$ = 5,42 m/s shall be taken into account.

4.2.4.4 Loads due to buffer forces

Where buffers are used, the forces arising from collision calculated by rigid body analysis shall be multiplied by a factor ϕ_7 to account for elastic effects.

The factor ϕ_7 shall be taken as follows:

$\phi_7 = 1{,}25$ using buffers with linear characteristics;

$\phi_7 = 1{,}6$ using buffers with rectangular characteristics.

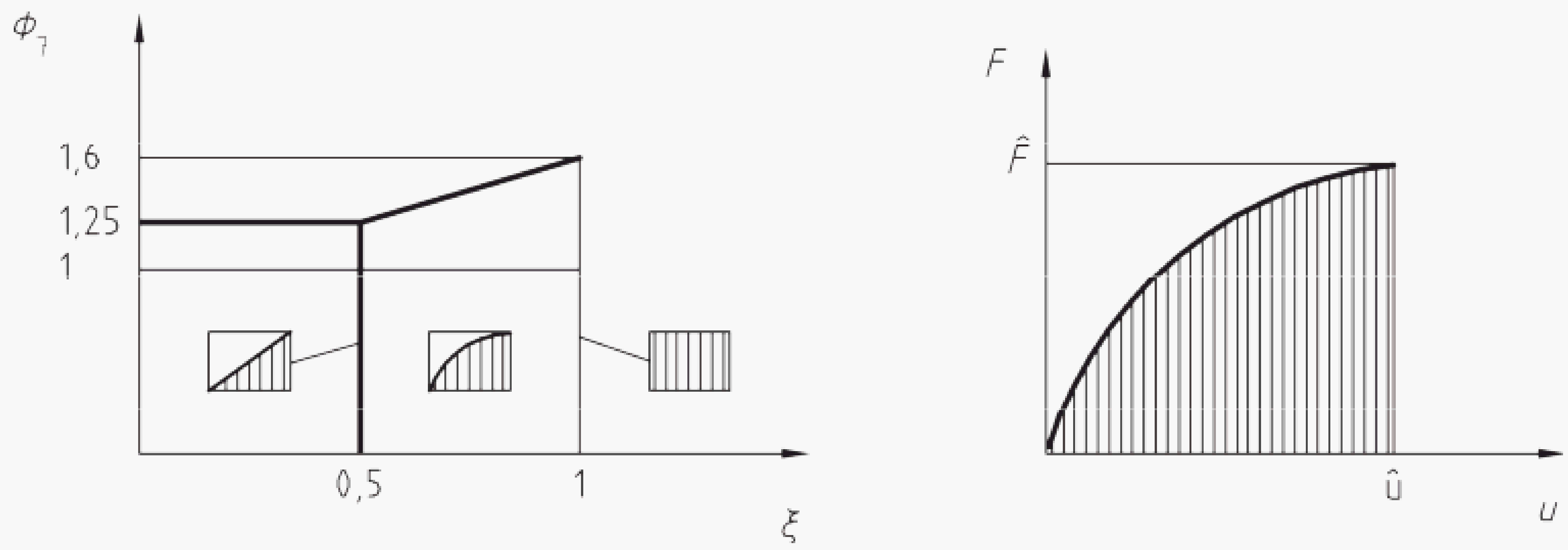
For buffers with other characteristics other values justified by calculation or by test shall be used (see Figure 13).

Intermediate values of ϕ_7 can be estimated as follows:

$\phi_7 = 1{,}25$ for $0 \leq \xi \leq 0{,}5$;

$\phi_7 = 1{,}25 + 0{,}7\ (\xi - 0{,}5)$ for $0{,}5 \le \xi \le 1$; (15)

with ξ as shown in Figure 13.



Key

$\xi = \frac{1}{\hat{F}\hat{u}} \int_{o}^{\hat{u}} F_b \, d u$ relative buffer energy

F_b buffer force

u buffer stroke

$\hat{F}, \hat{u}$ maximum values

Figure 13 — Factor ϕ_7

The buffer forces should be calculated from the kinetic energy of all relevant parts of the crane moving at 0,7 to 1 times the nominal speed. Lower values than 0,7 may be used where they are justified by special measures such as the existence of a redundant control system for retarding the motion.

Where the crane or the trolley is restrained against rotation on the vertical axis and its structure is stiff, the buffer deformations shall be assumed to be equal; in that case, if the buffer characteristics are similar, the buffer forces will be equal.

Where the crane or the trolley is not restrained against rotation on the vertical axis or its structure is flexible, the buffer forces shall be calculated taking into account the distribution of relevant masses and the buffer characteristics.

In calculating buffer forces, the effects of suspended loads that are unrestrained horizontally (free to swing) need not be taken into account. However when the travel speed is reduced before collision with the buffers, it is possible that the load sway forward is near its maximum amplitude simultaneously with compression of the buffers. In this case the hoisted mass multiplied by the deceleration used before reaching the buffers should be added as a horizontal load.

4.2.4.5 Loads due to tilting forces

If a crane with horizontally restrained load can tilt when it, its load or lifting attachment collides with an obstacle, the resulting static forces shall be determined.

If a tilted crane can fall back into its normal position uncontrolled, the resulting impact on the supporting structure shall be taken into account.

4.2.4.6 Loads caused by emergency cut-out

Loads caused by emergency cut-out shall be calculated in accordance with 4.2.2.4 taking into account the most unfavourable state of drive (i.e. the most unfavourable combination of acceleration and loading) at the time of cut-out.

4.2.4.7 Loads caused by anticipated failure of mechanism or components

Where protection is provided by emergency brakes in addition to service brakes, failure and emergency brake activation shall be assumed to occur under the most unfavourable condition.

Where mechanisms or components are duplicated or secured by other means for safety reasons, failure shall be assumed to occur in any part of either system.

Resulting loads shall be calculated in accordance with 4.2.2.4, taking into account any resulting impacts.

4.2.4.8 Loads due to external excitation of the crane foundation

Examples of crane foundation excitation are seismic or wave-induced movements. Where relevant, loads caused by such excitations shall be specified and taken into account.

4.2.4.9 Loads caused by erection, dismantling and transport

Depending on the crane type it may be necessary to take into account the loads caused by erection, dismantling and transport, including specified wind loads during these processes.

In some cases these loads could be occasional.

4.2.4.10 Loads on means provided for access

Loads acting on means provided for access are considered to be local, acting only on the facilities themselves and on their immediate supporting members. The following perpendicular loads shall be taken into account:

3 000 N where materials can be deposited;

1 500 N on means provided for access only;

300 N horizontally on railings at least, depending on location and use.

4.3 Load combinations

4.3.1 General

The proof calculation based on the “Limit state method” requires to multiply the selected loads of a load combination with partial safety factors (see Tables 10 and 11).

For specific crane systems, the “Allowable stress method” with global safety factors may be used (see EN 13001-1).

Safety factors given in this European Standard have been determined by experience and by taking into account the deviations of the particular loads or the loading in general. They are only valid in connection with the limit state method according to EN 13001-1.

4.3.2 High risk applications

In some instances where the human or economic consequences of failure are exceptionally severe (for example ladle cranes or cranes of nuclear applications), increased reliability is obtained by applying a specified risk coefficient

$$\gamma_n = 1{,}05^{n_r} \tag{16}$$

where values $1 \leq n_r \leq 14$ shall be selected according to the requirements of the particular application.

γ_n shall be applied in the proof calculation to verify that yielding or elastic instability or rigid body instability does not occur.

4.3.3 Mass distribution classes MDC1 and MDC2

Concerning the application of partial safety factors on gravitational loads there are two mass distribution classes the cranes can be attached to:

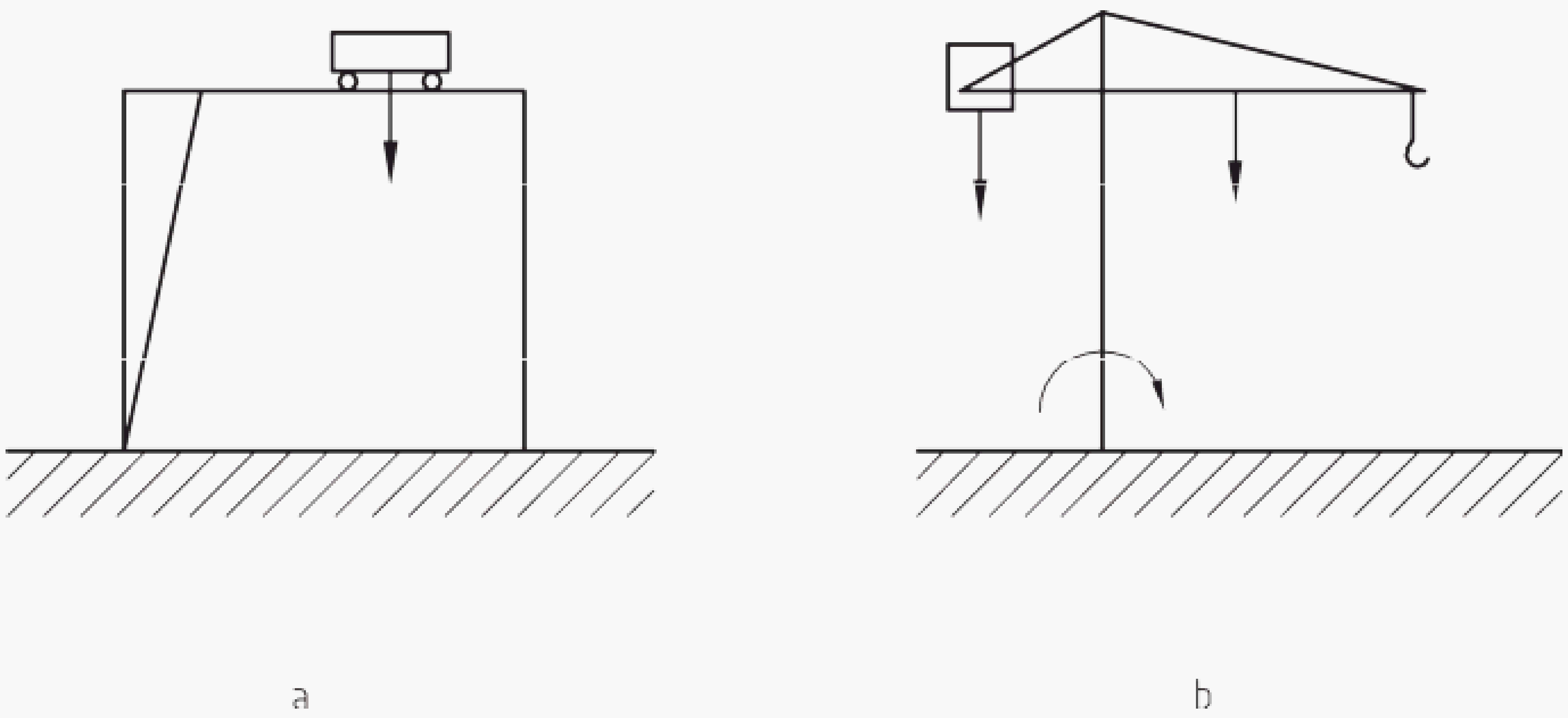
a) Cranes of mass distribution class MDC1

Cranes or crane parts, where in all critical points selected for the proof calculation all loads from gravitation acting on the masses of the different parts of the crane increase the resulting load effects ("unfavourable") and which are not affected by intended displacement ("prestressing"), are considered as cranes or crane parts of mass distribution class MDC1 (see Figure 14).

In this case the given values of the partial safety factors γ_p shall be applied (see Table 7).

b) Cranes of mass distribution class MDC2

A crane or a part of a crane is assigned to the class MDC2 (see Figure 14), if it contains at least one element, in which gravitational load effect from some partial mass of the crane is decreasing the resulting load effect or in which load effects are affected by intended displacements (pre-stressing). In this case the total mass has to be divided into those whose gravitational actions increase the resulting load effects ("unfavourable mass") and into those that decrease the resulting load effects ("favourable mass").



Key

a cranes of mass distribution MDC1
b crane of mass distribution class MDC2

Figure 14 — Illustration of the two different mass distribution classes

4.3.4 Partial safety factors for the mass of the crane

For the mass of the crane partial safety factors γ_p shall be chosen from Table 7 depending on the method of determining the masses of the crane parts and depending on the type of the load effect. This choice shall be made separately for each relevant load combination and it may result in one mass having different partial safety factors in different load combinations.

For a crane of mass distribution class MDC2, a mass may be considered “favourable” with respect to a certain load effect that is evaluated in a certain element of the crane. The same mass may be “unfavourable” with respect to another load effect, another element of the crane or another load combination. The mass is deemed “favourable” if its action decreases the resulting load effect under consideration.

A part of a crane, (e.g. total length of girder of an unloader, slewing upper structure of a tower crane) having both favourable and unfavourable masses, may be assigned only one partial safety factor in each load combination, related to the centre of gravity of this part.

Table 7 — Values of factor γ_p

Method of determining the masses of crane parts and their centres of gravity	Load combinations according 4.3.6					
	A		B		C	
	MDC1/MDC2 unfavourable	MDC2 favourable	MDC1/MDC2 unfavourable	MDC2 favourable	MDC1/MDC2 unfavourable	MDC2 favourable
by calculation	1,22	1,00	1,16	1,00	1,10	1,00
by weighing	1,16	1,10	1,10	1,05	1,05	1,00

4.3.5 Partial safety factors to be applied to loads caused by displacements

For those parts of a crane, where intended displacements are induced to affect resulting load effects, upper and lower values of partial safety factors as given in Table 8 shall be taken into account to reflect deviations of the displacements due to the inaccuracies of the prestressing process and its parameters.

In cases where intended displacements are applied locally to create compression forces in connections to avoid gaping or to cause friction forces, such as the prestressing of high tensile bolts, the same upper and lower limits of the partial safety factor shall be applied.

Table 8 — Values of the partial safety factor γ_p to be applied to loads due to intended displacements

Values of partial safety factor γ_p	Load combinations according 4.3.6		
	A	B	C
upper value	1,10	1,05	1,00
lower value	0,90	0,95	1,00

Any unintended, but reasonably foreseeable elastic or rigid body displacement acting in any direction, which affect significantly the resulting load effects in a crane shall be considered as load and shall be amplified with the partial safety factors given in Table 9.

In general the direction of an unintended displacement can vary and therefore all directions should be considered.

Table 9 — Values of the partial safety factor γ_p to be applied to loads due to unintended displacements

	Load combinations according 4.3.6		
	A	B	C
γ_p	1,10	1,05	1,00

4.3.6 Survey of load combinations

Basic load combinations for the calculation to prove that mechanical hazards from yielding and elastic instability from extreme values are prevented are given in Table 10.

For the proof of fatigue strength load combinations A, with all partial safety factors γ_p set to 1,00, shall be considered. In some cases load combination B and/or C can contribute significantly to fatigue and shall be considered.

Table 10 — Loads, load combinations and partial safety factors

Categories of loads	Loads f_i			i	Ref.	Load combinations A					Load combinations B						Load combinations C									
						Partial safety factors γ_p	A1	A2	A3	A4	Partial safety factors γ_p	B1	B2	B3	B4	B5	Partial safety factors γ_p	C1	C2	C3	C4	C5	C6	C7	C8	C9
Regular	Gravitation acceleration, Impacts	Mass of the crane		1	4.2.2.1	*)	ϕ_1	ϕ_1	1	–	*)	ϕ_1	ϕ_1	1	–	–	*)	ϕ_1	1	ϕ_1	1	1	1	1	1	1
Regular	Gravitation acceleration, Impacts	Mass of the hoist load		2	4.2.2.2	1.34	ϕ_2	ϕ_3	1	–	1,22	ϕ_2	ϕ_3	1	–	–	1,1	–	η_W	–	1	1	1	1	1	–
Regular	Gravitation acceleration, Impacts	Masses of the crane and the hoist load, travelling on uneven surface		3	4.2.2.3	1,22	–	–	–	ϕ_4	1,16	–	–	–	ϕ_4	ϕ_4	–	–	–	–	–	–	–	–	–	–
Regular	Acceleration from drives	Masses of the crane and the hoist load	Hoist drives excluded	4	4.2.2.4	1,34	ϕ_5	ϕ_5	–	ϕ_5	1,22	ϕ_5	ϕ_5	–	ϕ_5	–	1,1	–	–	ϕ_5	–	–	–	–	–	–
Regular	Acceleration from drives	Masses of the crane and the hoist load	Hoist drives included	5	4.2.2.4	1,34	–	–	ϕ_5	–	1,22	–	–	ϕ_5	–	–	1,1	–	–	–	–	–	–	–	–	–
Regular	Displacements			6	4.2.2.5	**)	1	1	1	1	**)	1	1	1	1	1	**)	1	1	1	1	1	1	1	1	1
Occasional	Environmental actions	In-service wind loads		7	4.2.3.1	–	–	–	–	–	1,22	1	1	1	1	1	1,16	–	–	1	–	–	–	–	–	–
Occasional	Environmental actions	Snow and ice loads		8	4.2.3.2	–	–	–	–	–	1,22	1	1	1	1	1	1,1	–	1	–	–	–	–	–	–	–
Occasional	Environmental actions	Temperature variations		9	4.2.3.3	–	–	–	–	–	1,16	1	1	1	1	1	1,05	–	1	–	–	–	–	–	–	–
Occasional	Skewing			10	4.2.3.4	–	–	–	–	–	1,16	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–

Table 10 *(continued)*

Categories of loads	Loads f_i	i	Ref.	Load combinations A					Load combinations B						Load combinations C									
				Partial safety factors γ_p	A1	A2	A3	A4	Partial safety factors γ_p	B1	B2	B3	B4	B5	Partial safety factors γ_p	C1	C2	C3	C4	C5	C6	C7	C8	C9
Exceptional	Hoisting a grounded load	11	4.2.4.1	–	–	–	–	–	–	–	–	–	–	–	1,1	ϕ_2	–	–	–	–	–	–	–	–
	Out-of-service wind loads	12	4.2.4.2	–	–	–	–	–	–	–	–	–	–	–	1,16	–	1	–	–	–	–	–	–	–
	Test loads	13	4.2.4.3	–	–	–	–	–	–	–	–	–	–	–	1,1	–	–	ϕ_6	–	–	–	–	–	–
	Buffer forces	14	4.2.4.4	–	–	–	–	–	–	–	–	–	–	–	1,1	–	–	–	ϕ_7	–	–	–	–	–
	Tilting forces	15	4.2.4.5	–	–	–	–	–	–	–	–	–	–	–	1,1	–	–	–	–	1	–	–	–	–
	Emergency cut-out	16	4.2.4.6	–	–	–	–	–	–	–	–	–	–	–	1,1	–	–	–	–	–	ϕ_5	–	–	–
	Failure of mechanism	17	4.2.4.7	–	–	–	–	–	–	–	–	–	–	–	1,1	–	–	–	–	–	–	ϕ_5	–	–
	Excitation of the crane foundation	18	4.2.4.8	–	–	–	–	–	–	–	–	–	–	–	1,1	–	–	–	–	–	–	–	1	–
	Erection, dismantling and transport	19	4.2.4.9	–	–	–	–	–	–	–	–	–	–	–	1,1	–	–	–	–	–	–	–	–	1
Overall safety factor γ_f				–	1,48				–	1,34					–	1,22								
Resistance coefficient γ_m				1,1	–				1,1	–					1,1	–								

Table 10 *(continued)*

*)	For values of the partial safety factor to be applied see Table 7
**)	For values of the partial safety factor to be applied to loads due to displacements see 4.3.5
Load combinations A, B, C:	
Load combinations A cover regular loads for a crane under normal operation:	
A1:	Hoisting and depositing loads;
	In general, the loads shall be combined to reflect the events during the acceleration, deceleration and positioning of the loaded or unloaded crane, moving in both directions.
	During the hoisting of a grounded load or a grounded lifting attachment, only a combination of accelerating drive forces caused by other drives (excluding the hoist drive) shall be taken into account in accordance with the intended normal operation as well as the control of the drives.
A2:	Sudden release of part of the hoist load;
	Drive forces shall be combined as in A1.
A3:	Load or lifting attachment suspended;
	With a suspended load or lifting attachment, any combination of accelerating or decelerating forces caused by any of the drives, including the hoist drive, or of their sequence during positioning movements, shall be taken into account in accordance with the intended normal operation as well as the control of the drives.
A4:	Travelling on an uneven surface or track;
	Drive forces shall be combined as in A1.
Load combinations B cover regular loads combined with occasional loads:	
B1 to B4:	Load combinations are equivalent to load combinations A1 to A4 but additionally in-service wind and loads from other environmental actions shall be taken into account;
B5:	Crane under normal operation, travelling on an uneven surface at constant speed and skewing, with in-service wind and loads from other environmental actions.

Table 10 *(continued)*

Load combinations C cover regular loads combined with occasional and exceptional loads:	
C1:	Crane under in-service conditions, hoisting a grounded load at max. hoisting speed, applying ϕ_2, see 4.2.2.2.1.
C2:	Crane under out-of-service conditions, including out-of-service wind and loads from other environmental actions.
C3:	Crane under test conditions;
	Drive forces shall be combined as in A1.
C4:	Crane with hoist load in combination with loads due to buffer forces.
C5:	Crane with hoist load in combination with loads due to tilting forces.
C6:	Crane with hoist load in combination with loads caused by emergency cut-out.
C7:	Crane with hoist load in combination with loads caused by failure of mechanism.
C8:	Crane with hoist load in combination with loads due to external excitation of the crane foundation.
C9:	Crane during erection, dismantling and transport.

NOTE CEN/TC 147 WG 2 is currently working out an amendment referring to application of partial safety factors in connection with MDC2 crane systems.

4.3.7 Partial safety factors for the proof of rigid body stability

The partial safety factors to proof that a crane is stable as a rigid body are given in Table 11 for the relevant load combinations A1, A2, B1, C2, C3, C4, C6 and C9 as given in 4.3.6.

In all these load combinations the dynamic factors ϕ_i except ϕ_3 shall be set to $\phi_i = 1,0$.

ϕ_3 shall be calculated according to 4.2.2.2.2 and shall be set to –0,1, when greater.

Table 11 — Partial safety factors for the proof of rigid body stability

Categories of loads	Loads f_i		i*)	Load combinations A				L. comb. B		Load combinations C									
				A1		A2		B1		C2		C3		C4		C6		C9	
				S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
Regular	Gravitation, Acceleration	Mass of the crane, unfavourable effects	1.1	1,1	1,05	1,1	1,05	1,1	1,05	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
		Mass of the crane, favourable effects	1.2	0,95	1,0	0,95	1,0	0,95	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
		Mass of the hoist load	2	1,34	1,22	1,0	1,0	1,22	1,1	1,0	1,0	–	–	1,0 **)	1,0 **)	1,1	1,05	–	–
	Acceleration From drives	Masses of the crane and the hoist load, hoist drives included	5	1,34	1,22	1,34	1,22	1,22	1,1	–	–	1,1	1,0	–	–	–	–	–	–
	Displacements		6	1,1	1,1	1,1	1,1	1,05	1,05	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Occasional	Environmental actions	In-service wind loads	7	–	–	–	–	1,22	1,16	–	–	1,0	1,0	–	–	–	–	1,16	1,1
		Snow and ice loads	8	–	–	–	–	1,22	1,22	–	–	–	–	–	–	–	–	–	–
Exceptional	Out-of-service wind loads		12	–	–	–	–	–	–	1,16	1,1	–	–	–	–	–	–	–	–
	Test loads		13	–	–	–	–	–	–	–	–	1,16	1,1	–	–	–	–	–	–
	Buffer forces		14	–	–	–	–	–	–	–	–	–	–	1,1	1,1	–	–	–	–
	Emergency cut-out		16	–	–	–	–	–	–	–	–	–	–	–	–	1,1	1,1	–	–
	Erection, dismantling and transport		19	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1,1	1,1

Table 11 *(continued)*

*) according to numbering in Table 10

**) only to be applied if unfavourable

S1, S2 are the stability classes (see explanations below)

Partial safety factors given in the columns of stability class S1 are applicable to all types of cranes.

Partial safety factors given in the columns of stability class S2 may only be applied to cranes which fulfil the following conditions:

a) proof exists that the ground to support the crane can reliably withstand the supporting forces, without significant unintended displacements or taking into account their affect on stability. This shall also be shown in the case, if supports (those not causing rigid body movement) become unloaded and thus cause maximum forces at other supports;

b) reliable load indicating and limiting system exists, that prewarns the crane driver and finally cuts out any movement if approaching a situation of rigid body instability in any configuration, position and state of loading;

c) relevant masses and their centres of gravity shall be evaluated by weighing with an accuracy of ± 2,5 %;

d) the crane being driven by competent crane drivers, who are familiar with the crane and its indicating and limiting devices.

Annex A
(normative)

Aerodynamic coefficients

A.1 General

According to EN 13001-1, alternatively advanced and recognised values for aerodynamic coefficients derived from theoretical or experimental methods may be used.

The aerodynamic coefficient c_a of a member is given by:

$$c_a = c_o \times \psi \tag{1}$$

where

- c_o is the aerodynamic coefficient of a member of infinite length, where the member is a straight and prismatic element; such a member with one or more solid sections or one hollow section is called an individual member; plane or spatial lattice structure members may be assembled by those individual members;
- ψ is a reduction factor, which reduces c_o for members with a finite length; it depends on the aerodynamic slenderness ratio λ of an individual member and if the member is a lattice structure it also depends on the solidity ratio φ.

The correlation between ψ, λ and φ is given by Figure A.1.

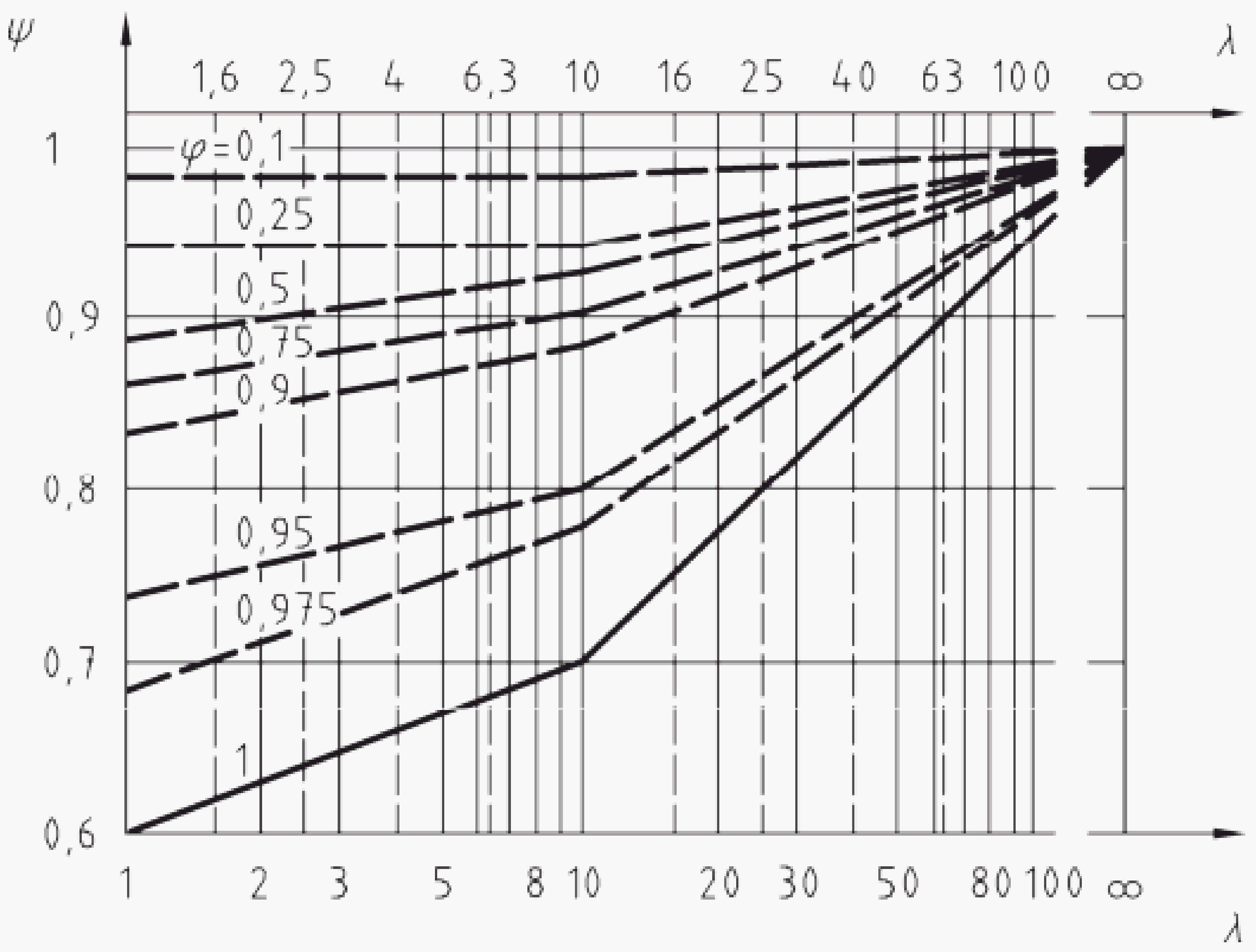


Figure A.1 — Reduction factor ψ related to the aerodynamic slenderness ratio λ and the solidity ratio φ

The aerodynamic slenderness ratio λ is defined as follows:

$$\lambda = l_a / d \tag{2}$$

where

d is the characteristic dimension of a member as shown in the respective tables of members in this annex;

$l_a = \alpha_r \times l_o$ is the aerodynamic length of a member;

where

l_o is the length of the member;

i.e. the distance between the free ends of the member or, in case the member is connected to other members, the distance between the centres of their joints;

α_r is the relative aerodynamic length, which in relation to the position of the member and a possibly adjacent obstacle is given in Table A.1.

The solidity ratio φ of a plane lattice structure member is established as follows:

$$\varphi = \sum_j A_j / A_c \tag{3}$$

where

$\sum_j A_j$ is the sum of the areas of the individual members with gusset plates projected to the plane of the characteristic height d of the lattice structure member (see Figure A.2);

A_c is the area enclosed by the boundary of the lattice structure member in the plane of its characteristic height d (see Figure A.2).

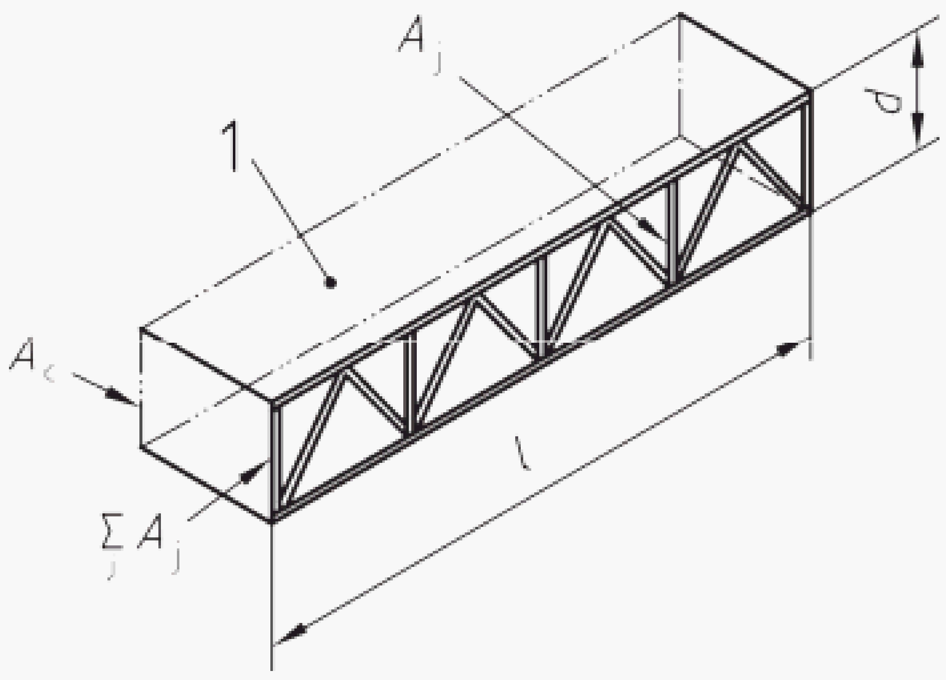
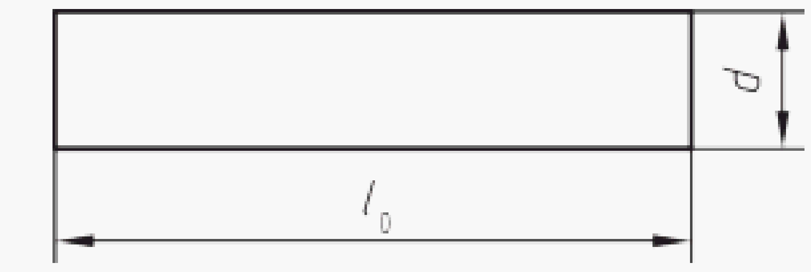
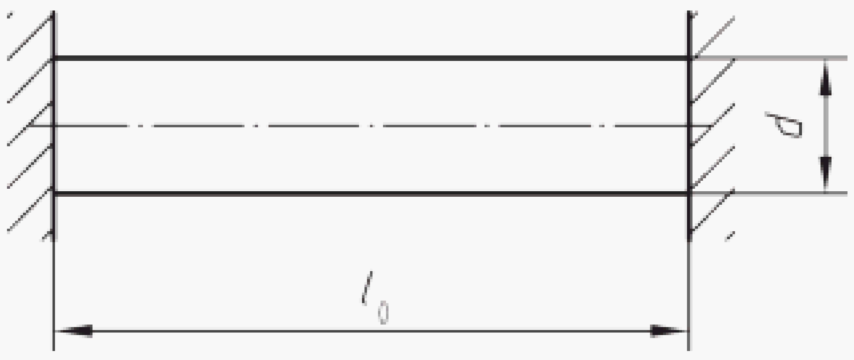
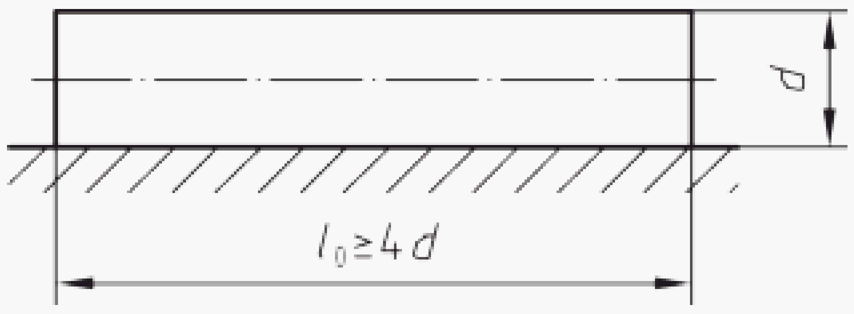
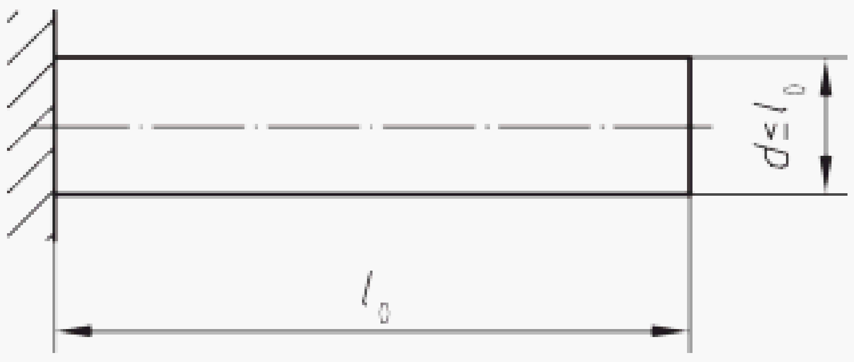
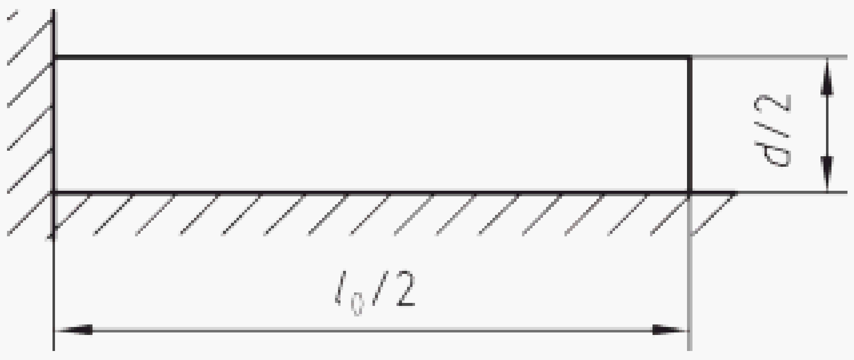
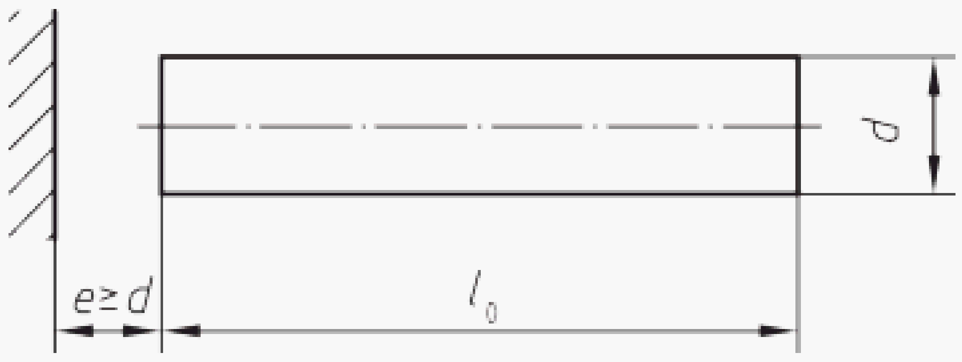
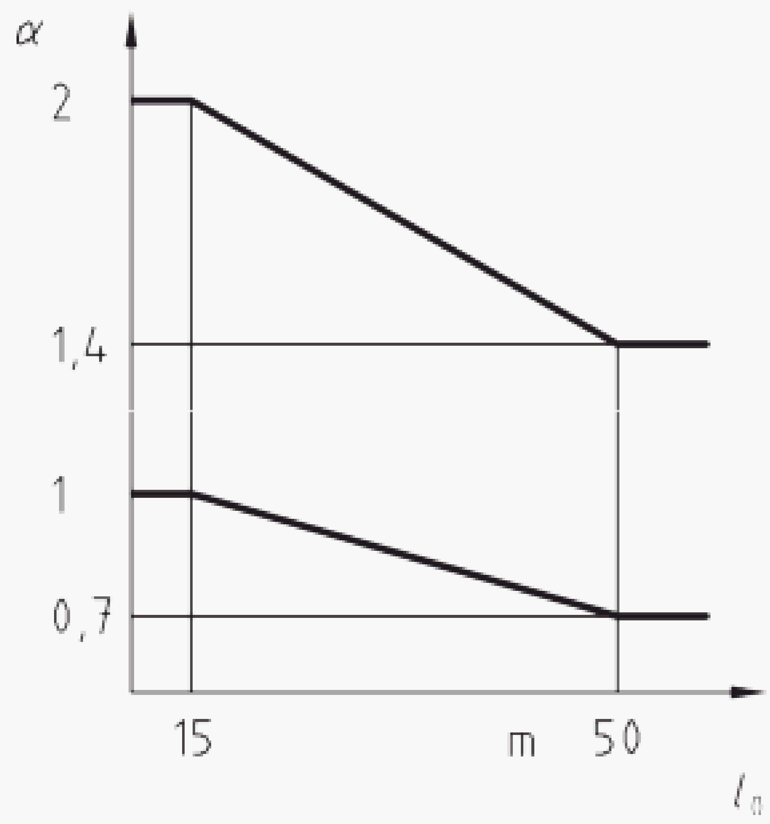
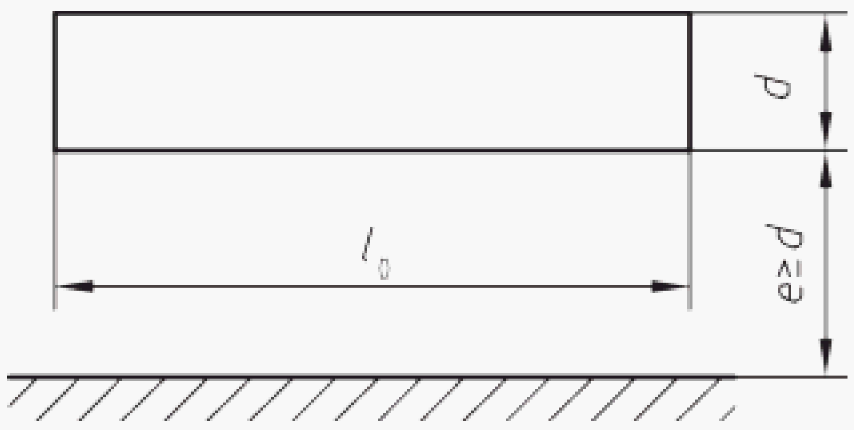


Figure A.2 — Example of a lattice structure member

Table A.1 — Relative aerodynamic length α_r

Position of member and obstacle in-wind direction		α_r
1		1
2		∞
3		1
4		a) Non-circular members: $\alpha_r = 2{,}0$, $l_0 \leq 15$ m $\alpha_r = 1{,}4$, $l_0 \geq 50$ m } $\lambda \leq 70$
5		b) Circular members: $\alpha_r = 1{,}0$, $l_0 \leq 15$ m $\alpha_r = 0{,}7$, $l_0 \geq 50$ m } $\lambda \leq 70$ (α_r for 15 m $\leq l_0 \leq$ 50 m by linear interpolation)
6		
7		

Some aerodynamic coefficients of individual members and of lattice structure members are given in dependence on the Reynolds number Re which is established as follows:

$$\text{Re} = 0{,}667 \times 10^5 \times v \times d \qquad (4)$$

where

d is the characteristic dimension of a member in meter;

v is the wind velocity in meter per second; considering loads due to in-service wind v shall be substituted by $\bar{v}$ or $v(3)$ (see 4.2.3.1); considering loads due to out-of-service wind v shall be substituted by $v(z)$, see 4.2.4.2.

A.2 Individual members

In this clause the following tables and figures are given

Table A.2: Aerodynamic coefficients c_{o} for individual members of circular sections;

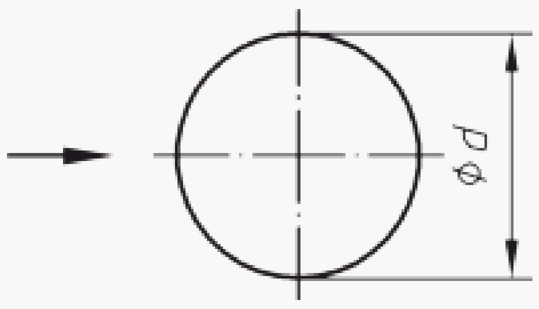
Figure A.3: More exactly aerodynamic coefficients c_{o} for individual members of circular sections related to Re;

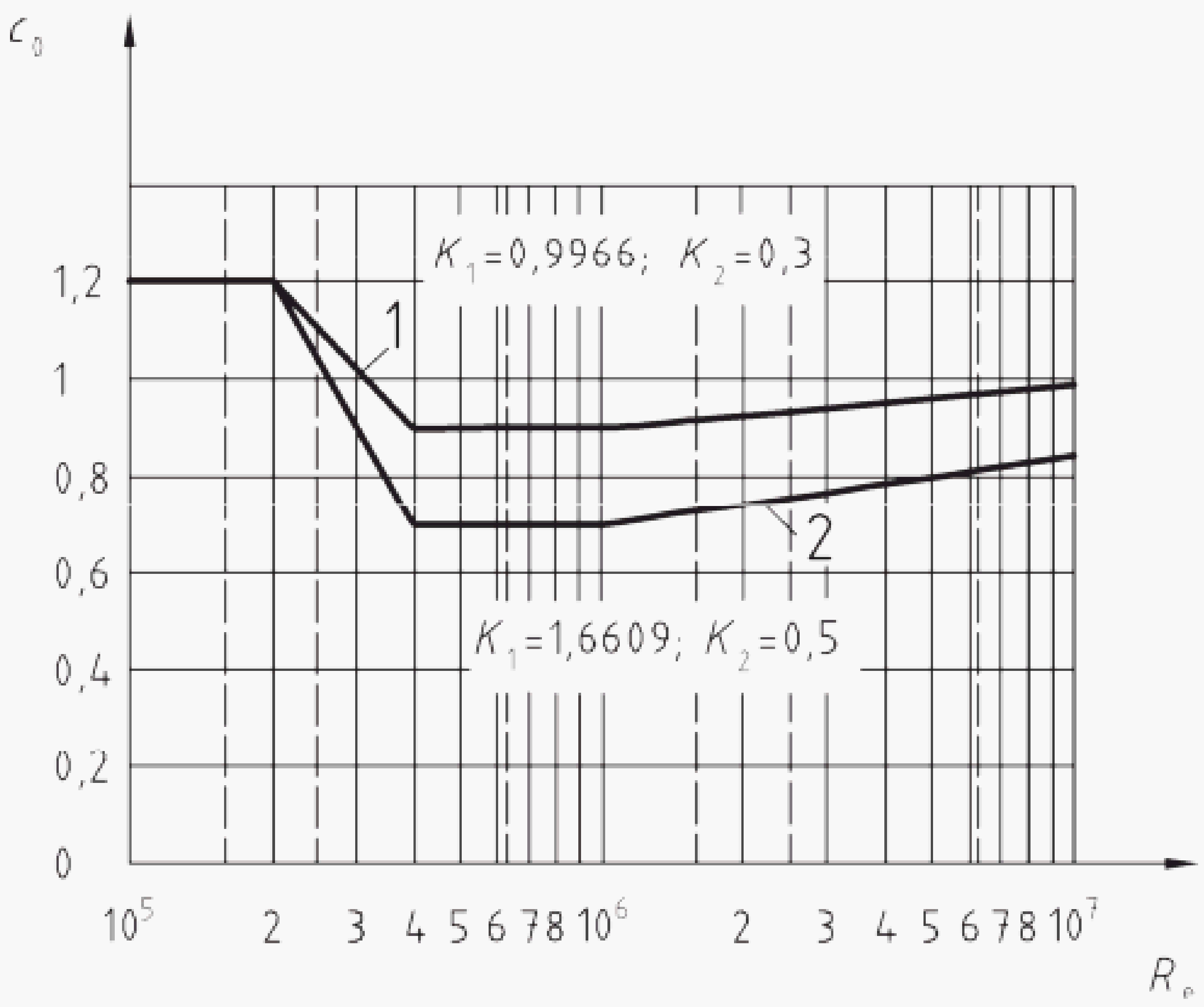
Figure A.4: Definition of the angle β of the wind direction and corresponding wind forces;

Table A.3: Aerodynamic coefficients c_{oy}, c_{oz} for individual flat sided structural member;

Table A.4: Aerodynamic coefficients c_{o} for individual structural members of triangular and rectangular hollow sections.

Table A.2 — Aerodynamic coefficients c_o for individual members of circular sections

No.	Shape and position of the member: Member	Shape and position of the member: Aerodynamic slenderness ratio	Shape and position of the member: Wind direction β	Characte-ristic area A	c_o
1	Cylinders 	$l/d \leq \infty$	Perpendicular to axis of member	$d \cdot l$	$c_o = 1{,}20$ more accurately: c_o is according to Figure A.3
2	Pipes, rods	$l/d > 100$	Perpendicular to axis of member	$d \cdot l$	$\text{Re} \leq 2 \times 10^5$ $c_o = 1{,}20$
					$4 \times 10^5 \leq \text{Re} \leq 10^6$ $c_o = 0{,}70$
					$\text{Re} > 10^6$ $2 \times 10^5 \leq \text{Re} \leq 4 \times 10^5$ c_o is according to Figure A.3
3	Ropes	$l/d > 100$	Perpendicular to axis of member	$d \cdot l$	$\text{Re} \leq 2 \times 10^5$ $c_o = 1{,}20$
					$4 \times 10^5 \leq \text{Re} \leq 10^6$ $c_o = 0{,}90$
					$\text{Re} > 10^6$ $2 \times 10^5 \leq \text{Re} \leq 4 \times 10^5$ c_o is according to Figure A.3



for $2 \times 10^5 \leq \text{Re} \leq 4 \times 10^5$:

$c_o = 1{,}2 - K_1 \log[\text{Re}/(2 \times 10^5)]$

where the roughness is given by

$K_1 = 0{,}996\,6$ for ropes;

$K_1 = 1{,}660\,9$ for pipes and rods;

for $\text{Re} \geq 10^6$:

$$c_o = 1{,}2 - \frac{K_2}{1 + 0{,}4 \log(\text{Re}/10^6)}$$

where the roughness is given by

$K_2 = 0{,}3$ for ropes;

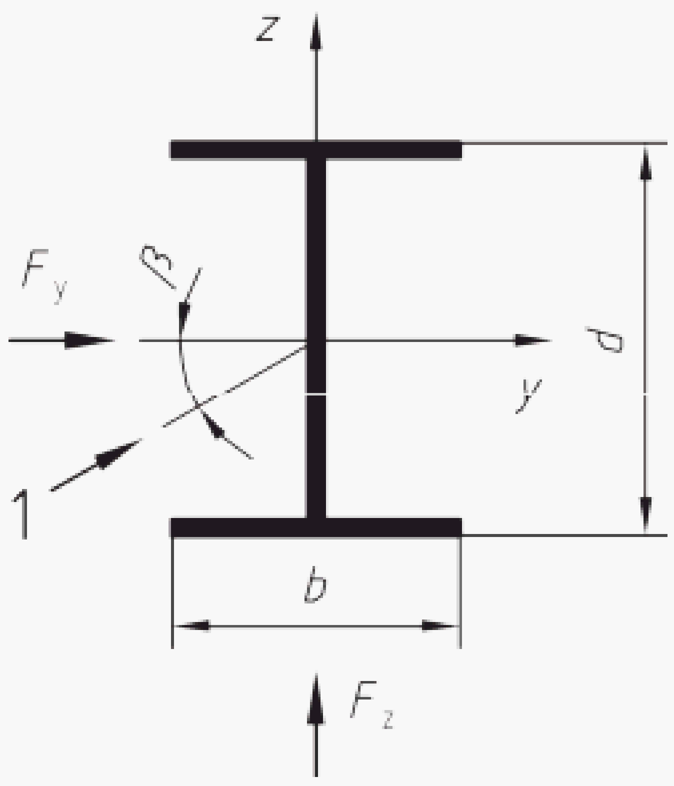
$K_2 = 0{,}5$ for pipes and rods.

Key

[AC1) **1** ropes

2 pipes, rods (AC1]

Figure A.3 — More detailed aerodynamic coefficients c_o for individual members of circular sections related to Re



Key

1 wind direction

Figure A.4 — Definition of the angle β of the wind direction and corresponding wind forces

NOTE The force coefficients c_{oy} and c_{oz} given in Table A.3 are related to the y and z axis of the section of the structural member and depend on the wind direction given by the angle β. The wind loads F_y and F_z are calculated separately for the y and z direction according to the equations given for F in 4.2.3.1 and 4.2.4.2.

Table A.3 — Aerodynamic coefficients c_{oy}, c_{oz} for individual flat sided structural members

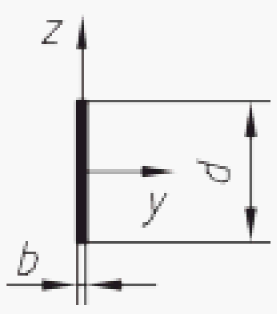
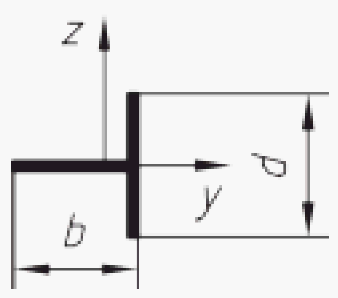
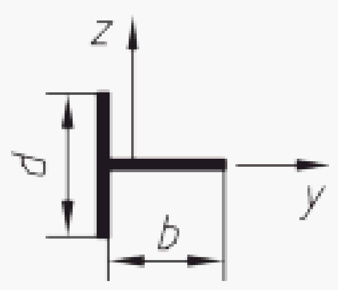
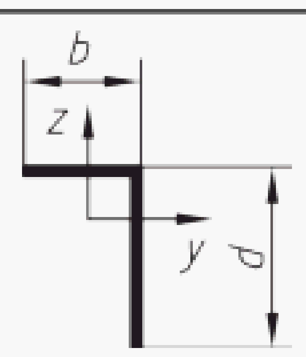
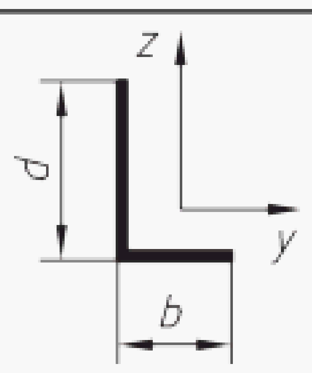
No.	Shape and position of the member			Characteristic area A	c_{oy}	c_{oz}
	Member	Section ratio	Wind direction β			
1		$b/d \leq 0{,}1$	0°	$d \cdot l$	2,0	0
			± 45°		1,3	± 0,13
			90°		0	0,1
2		$b/d = 1$	0°	$d \cdot l$	1,65	0
			± 45°		2,2	± 1,0
			± 90°		1,3	2,1
3		$b/d = 1$	0°	$d \cdot l$	2,0	0
			± 45°		1,15	± 0,8
			± 90°		–1,3	2,1
4		$b/d = 0{,}5$	0°	$d \cdot l$	2,0	1,0
			+45°		1,8	0,8
			–45°		1,3	–0,2
			90°		1,75	1,25
5		$b/d = 0{,}5$	0°	$d \cdot l$	2,0	–0,1
			+45°		1,55	0,7
			–45°		1,55	–0,8
			90°		–0,25	0,8

Table A.3 *(continued)*

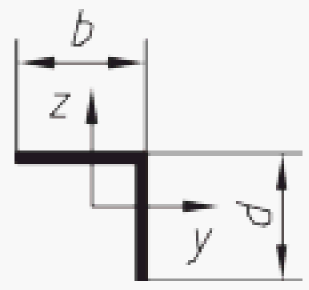
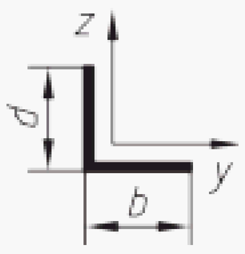
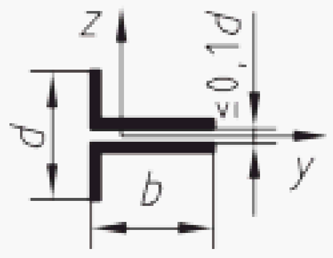
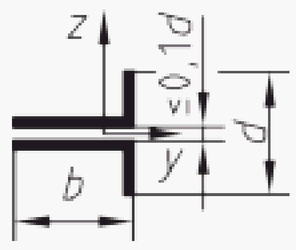
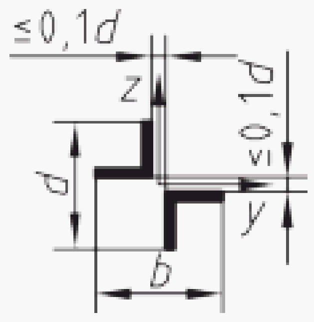
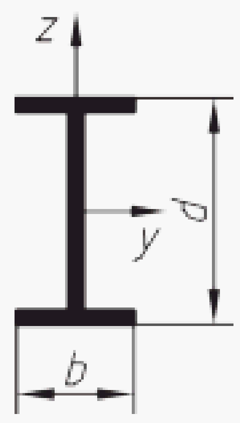
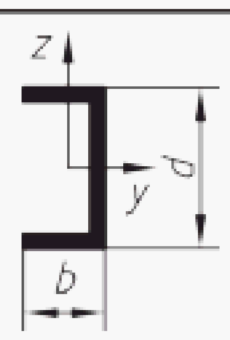
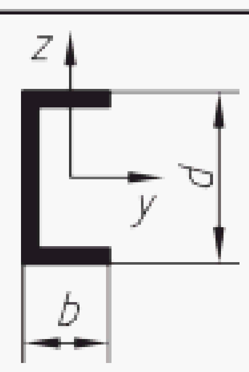
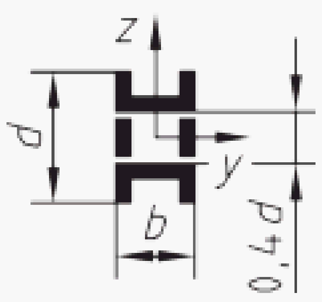
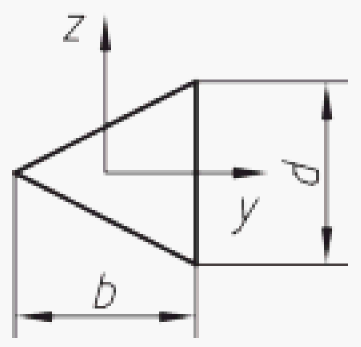
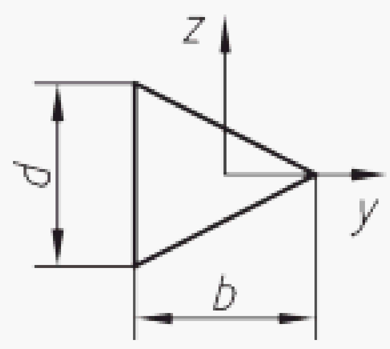
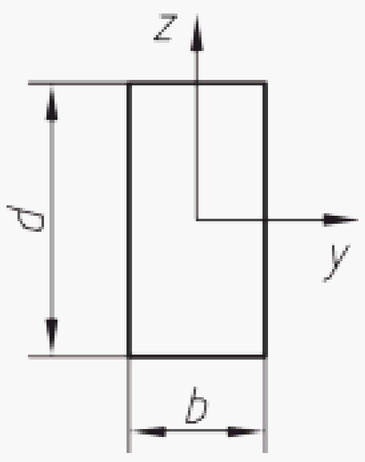
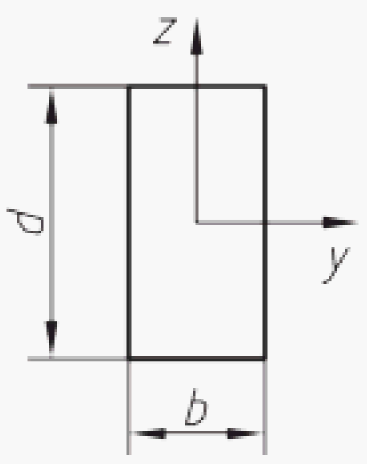
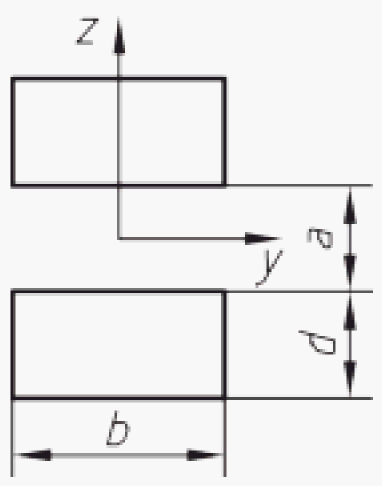
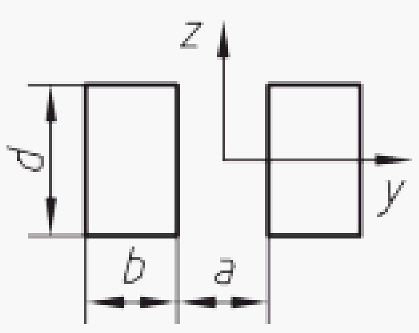
No.	Shape and position of the member: Member	Section ratio	Wind direction β	Characteristic area A	c_{oy}	c_{oz}
6		$b/d = 1$	0°	$d \cdot l$	1,8	2,0
			+45°		1,8	1,8
			90°		2,0	1,8
7		$b/d = 1$	0°	$d \cdot l$	1,9	–0,2
			+45°		1,4	1,4
			–45°		0,7	–1,8
			90°		–0,2	1,9
8		$b/d = 0{,}9$	0°	$d \cdot l$	1,6	0
			± 45°		1,4	0
			± 90°		–0,9	0,7
9		$b/d = 0{,}9$	0°	$d \cdot l$	1,4	0
			± 45°		0,4	± 1,0
			± 90°		0,9	0,7
10		$b/d = 1$	0°	$d \cdot l$	1,7	0
			± 45°		0,85	± 0,85
			90°		0	1,7
11		$b/d = 0{,}5$	0°	$d \cdot l$	2,0	0
			± 45°		1,8	± 0,6
			± 90°		0	0,8
		$b/d = 0{,}66$	0°		1,85	0
			± 45°		1,7	± 1,0
			± 90°		0	1,2
		$b/d = 1$	0°		1,7	0
			± 45°		1,5	± 1,5
			± 90°		0	1,7
12		$b/d = 0{,}5$	0°	$d \cdot l$	2,1	0
			± 45°		1,8	± 0,6
			± 90°		0	0,7
13		$b/d = 0{,}5$	0°	$d \cdot l$	1,8	0
			± 45°		1,8	± 0,5
			± 90°		0	0,7
14		$b/d = 0{,}6$	0°	$d \cdot l$	2,1	0
			± 45°		1,6	± 1,2
			± 90°		0	1,2

Table A.4 — Aerodynamic coefficients c_o for individual structural members of triangular and rectangular hollow sections

No.	Shape and position of the member			Characteristic area A	c_o
	Member	Section ratio	Wind direction β		
1		$1 \le b/d \le 1{,}4$	0°	$d \cdot l$	1,2
2		$1 \le b/d \le 1{,}4$	0°	$d \cdot l$	2
3		$b/d = 0{,}5$	0°	$d \cdot l$	2,2
		$b/d = 1$	0°	$d \cdot l$	2,0
		$b/d = 2$	0°	$d \cdot l$	1,5
		$b/d = 3$	0°	$d \cdot l$	1,3
		$b/d = 4$	0°	$d \cdot l$	1,0
4	 Rounded corners with r/d = 1/24	$b/d = 0{,}5$	0°	$d \cdot l$	2,1
		$b/d = 1{,}0$	0°	$d \cdot l$	1,5
		$b/d = 2{,}0$	0°	$d \cdot l$	1,1
5		$a/d = 0{,}5;\ b/d = 2$	0°	$2\,d \cdot l$	1,6
		$a/d = 1;\ b/d = 2$	0°	$2\,d \cdot l$	1,5
		$a/d = 2;\ b/d = 2$	0°	$2\,d \cdot l$	1,4
6		$a/d = 0{,}5;\ b/d = 0{,}5$	0°	$d \cdot l$	1,25
		$a/d = 1;\ b/d = 0{,}5$	0°	$d \cdot l$	1,30
		$a/d = 2;\ b/d = 0{,}5$	0°	$d \cdot l$	1,40

A.3 Plane and spatial lattice structure members

In this clause the following Tables and Figures are given

Table A.5: Characteristic areas A and aerodynamic coefficients c_o for plane and spatial lattice structure members;

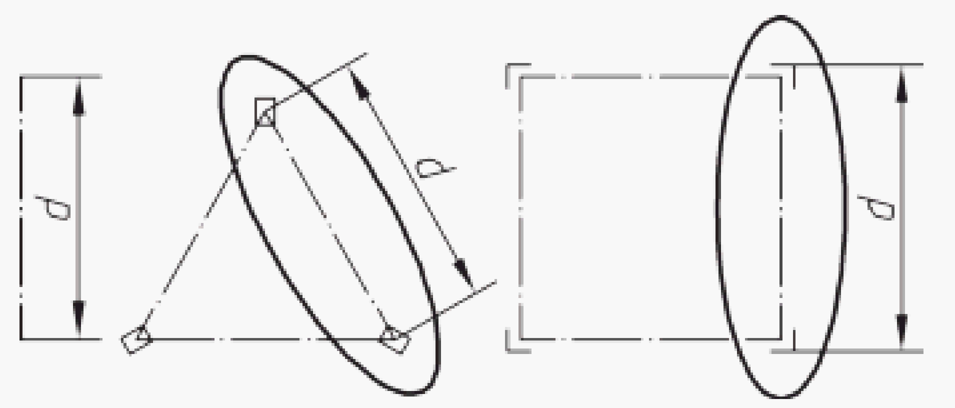
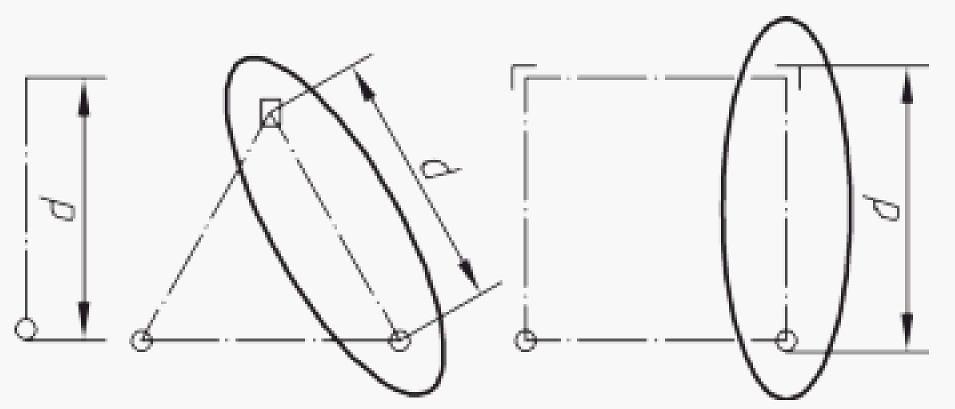
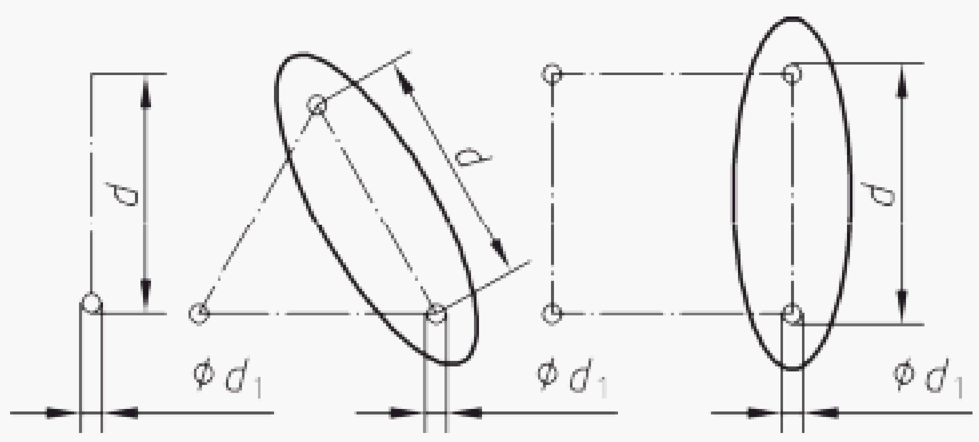
Figure A.5: Aerodynamic coefficients c_o of plane lattice structure members in dependence on φ, circular and non-circular individual members;

Figure A.6: Aerodynamic coefficients c_o of spatial lattice structure members in dependence on φ, circular and non-circular individual members;

Figure A.7: Aerodynamic coefficients c_o of plane lattice structure members in dependence on Re and φ, circular individual members;

Figure A.8: Aerodynamic coefficients c_o of spatial lattice structure members with triangular and square cross section in dependence on Re and φ, circular individual members.

Table A.5 — Characteristic areas A and aerodynamic coefficients c_o for plane and spatial lattice structure members

No.	Shape and position of the member	Characteristic area A		c_o
1	Individual members: non-circular 	$A=\sum_j A_j\ ,\ \varphi=\frac{A}{d\cdot\ell}$		For plane member see Figure A.5 For spatial member see Figure A.6
		$\sum_j A_j$	is the sum of the projected areas of all individual members and gusset plates of one wall (d) onto its plane	
2	Individual members: circular and non-circular 	$A=\sum_j A_{1j}+0{,}75\sum_k A_{2k}\quad \varphi=\frac{A}{d\cdot\ell}$		For plane member see Figure A.5 For spatial member see Figure A.6
		$\sum_j A_{1j}$	is the sum of areas as in No. 1	
		$\sum_k A_{2k}$	is the sum of areas as in No. 3	
3	Individual members: circular (without gusset plate) 	$A=\sum_j A_j\ ;\ \varphi=\frac{A}{d\cdot\ell}$		For plane member see Figure A.7 For spatial ∇-member see Figure A.8a For spatial □-member see Figure A.8b
		$\sum_j A_j$	is the sum of the projected areas of all individual members of one wall (d) onto its plane	
		$\mathrm{Re}=0{,}667\times10^5\times v\times d_1$ (see A.1)		

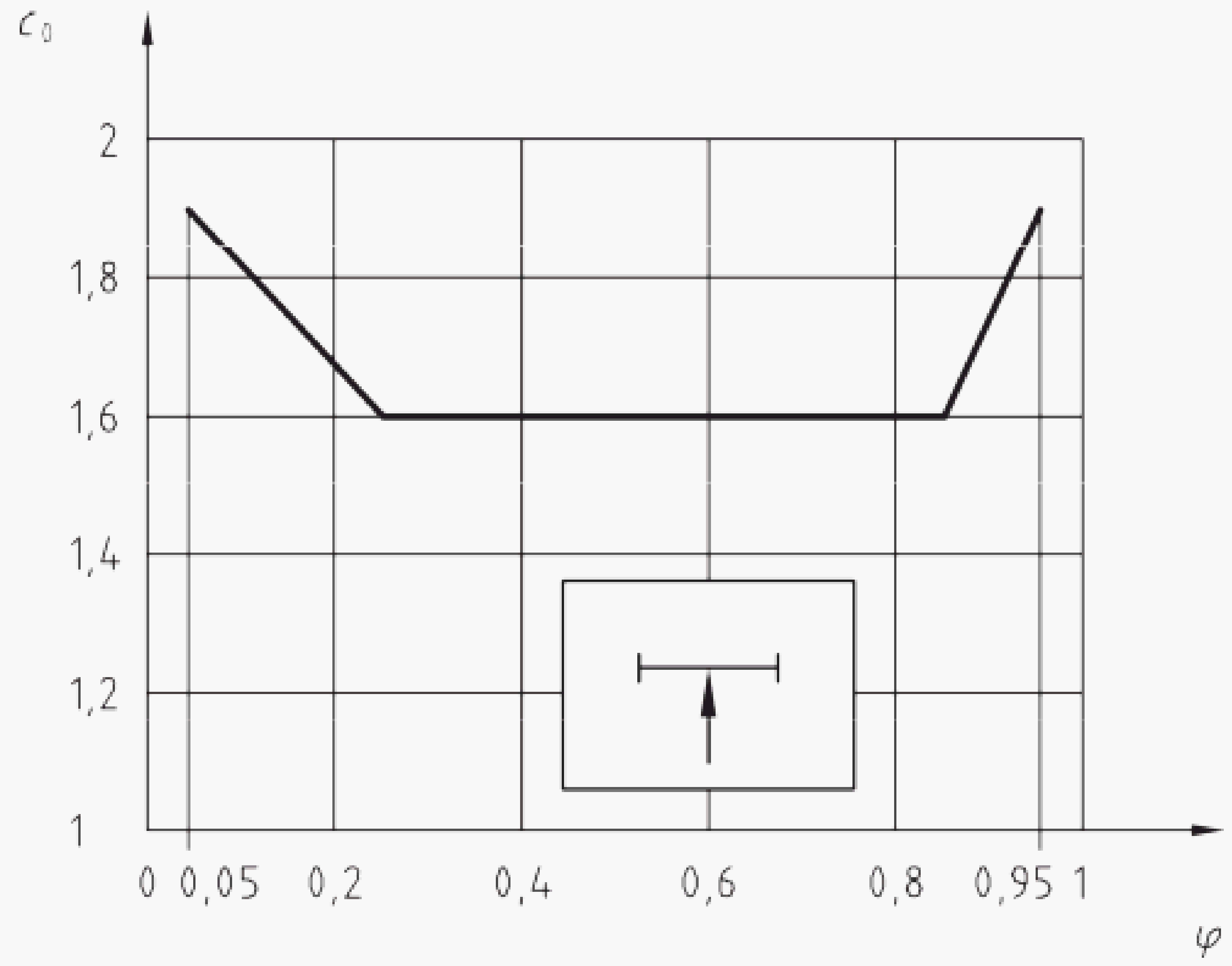


Figure A.5 — Aerodynamic coefficients c_o of plane lattice structure members in dependence on φ, having circular and non-circular individual members

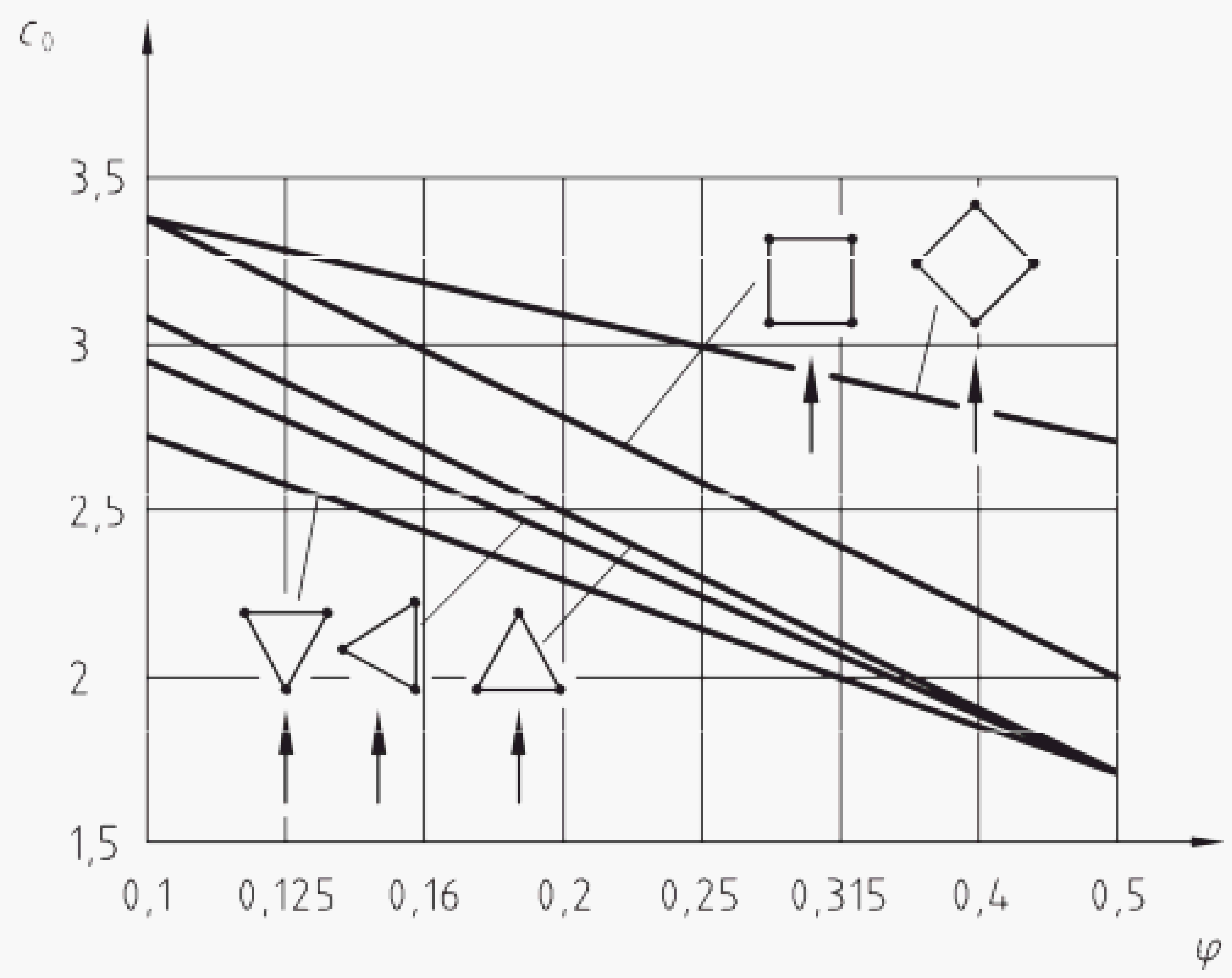


Figure A.6 — Aerodynamic coefficients c_o of spatial lattice structure members in dependence on φ, having circular and non-circular individual members

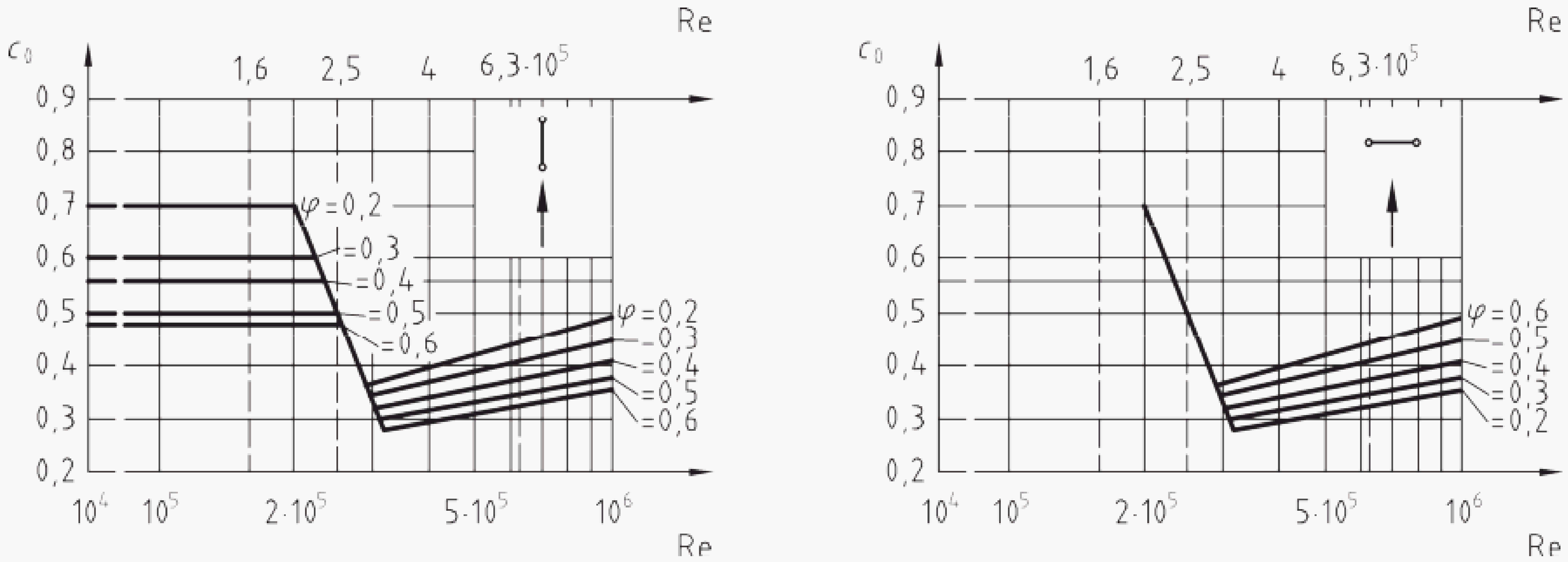
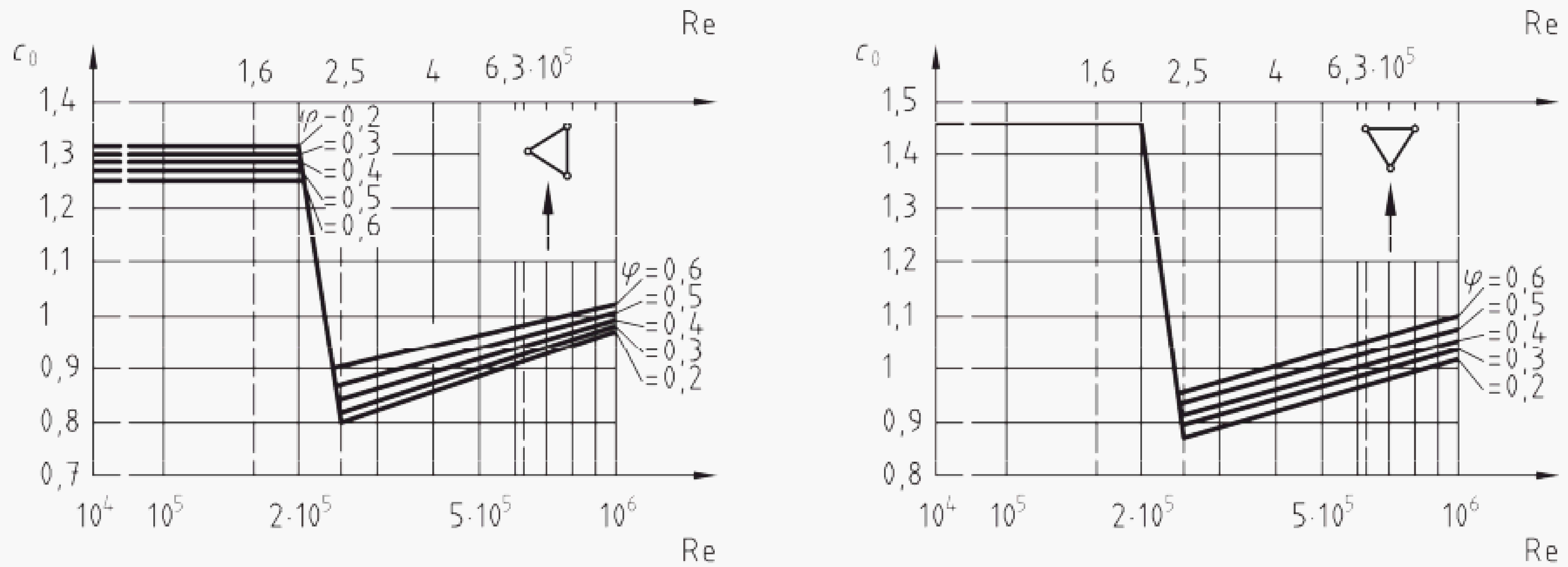
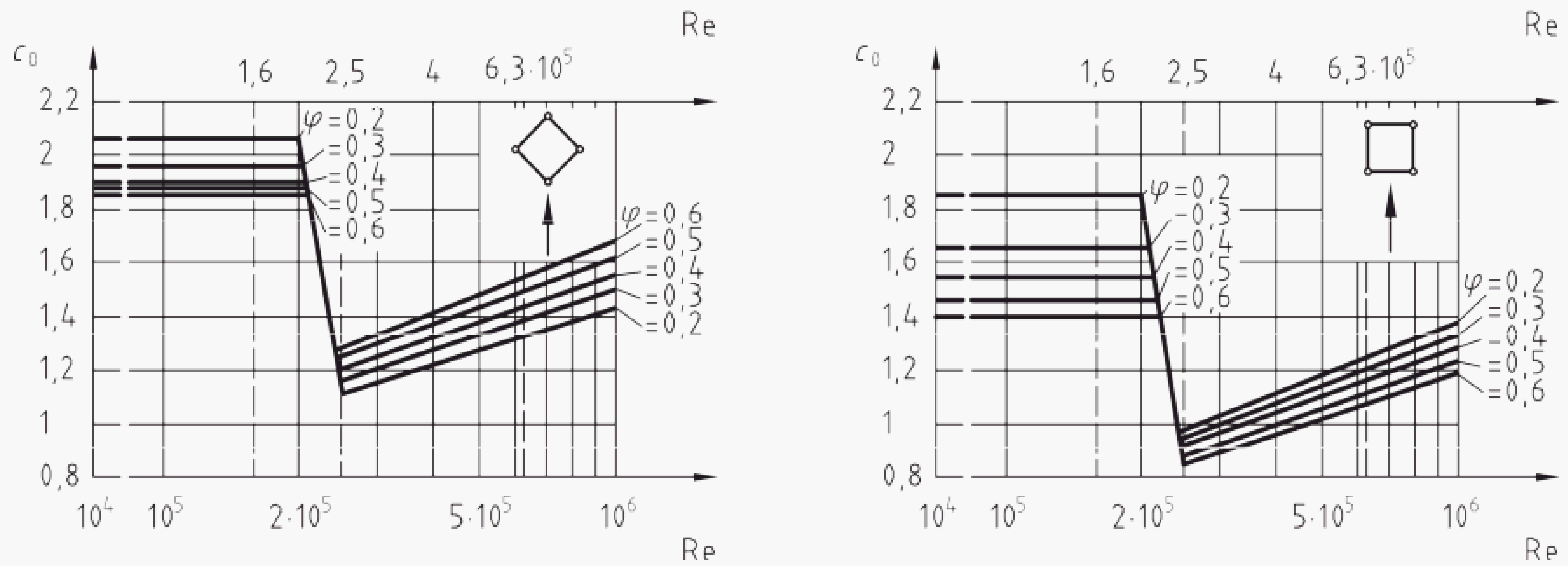


Figure A.7 — Aerodynamic coefficients c_0 of plane lattice structure members in dependence on Re and φ, having circular individual members



a



b

Figure A.8 — Aerodynamic coefficients c_0 of spatial lattice structure members with triangular (a) and square cross section (b) in dependence on Re and φ, having circular individual members

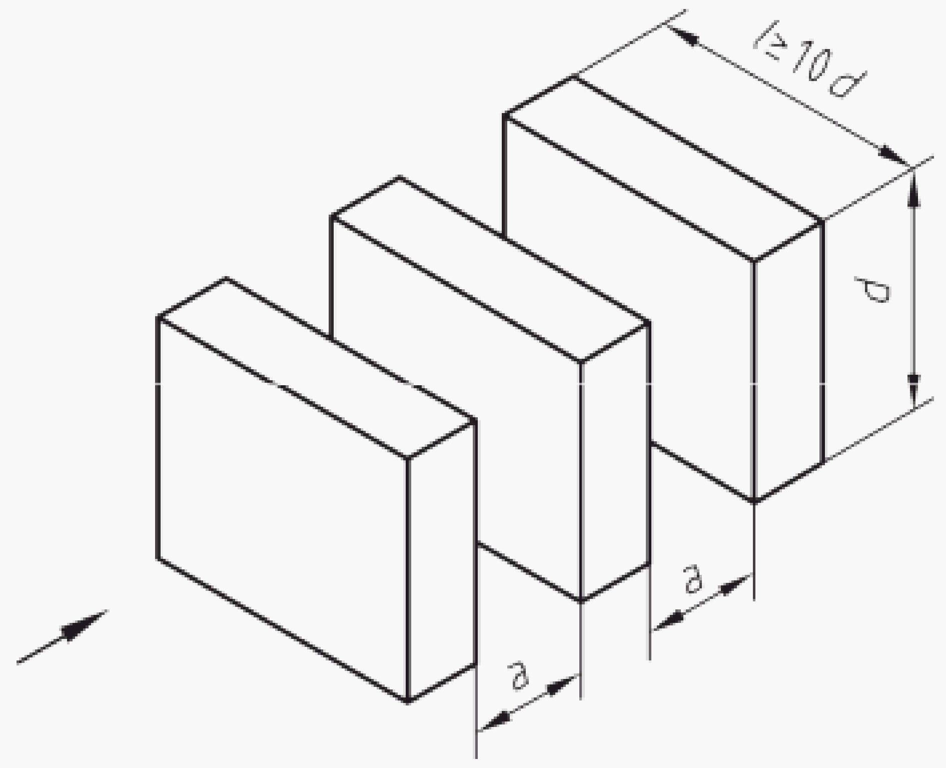
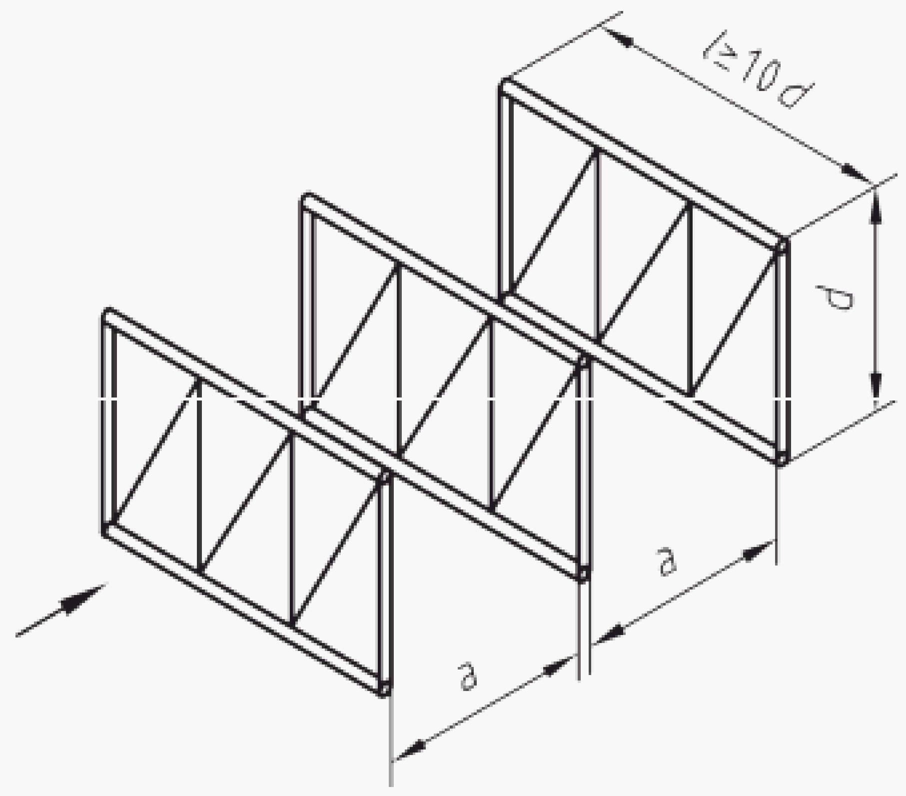
A.4 Structural members in multiple arrangement

In this clause the following is given

Table A.6: Characteristic areas A and aerodynamic coefficients c_o of structural members in multiple arrangement;

Figure A.9: Shielding factor η for structural members in multiple arrangement.

Table A.6 — Characteristic areas A and aerodynamic coefficients c_o of structural members in multiple arrangement

<table>
<tr><th>Shape and positions of the members</th><th>Characteristic area A</th><th>c_o</th></tr>
<tr><td>
</td>
<td rowspan="2">n_m parallel and identical members
if $1 \le n_m \le 9$:
$A = \frac{1-\eta^{n_m}}{1-\eta} \times A_1$
if $n > 9$:
$A = \left[\frac{1-\eta^9}{1-\eta} + (n_m - 9)\,\eta^8\right] A_1$
with $\eta \ge 0{,}10$
where
A_1 is the characteristic area of one member
η is the shielding factor dependent on the solidity ratio φ and the relation a/d between space and height of the members, according to Figure A.9</td>
<td rowspan="2">Aerodynamic coefficient of one member</td></tr>
<tr><td>
</td></tr>
<tr><td colspan="3">NOTE This formula may also be used if
a) the direction of the wind velocity deviates up to $\beta = 5°$ from the direction perpendicular to the surface of the members;
b) the members are not identical and the greatest characteristic area $A_{1,max}$ is taken into account and
c) the distance of the members is not equal and the greatest distance a_{max} is taken into account.</td></tr>
</table>

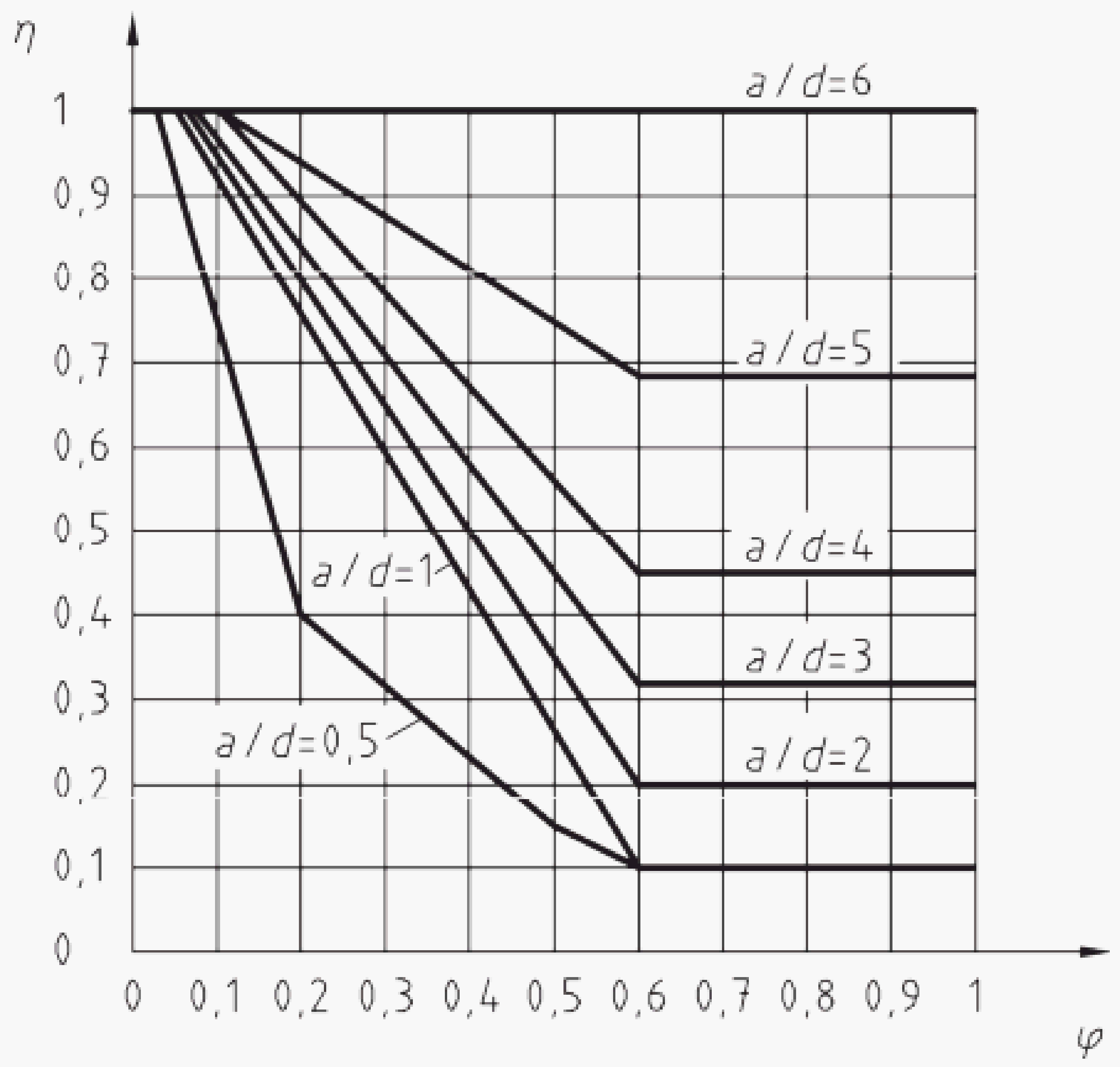


Figure A.9 — Shielding factor η for structural members in multiple arrangement

Annex B
(informative)

Illustration of the types of hoist drives

Table B.1 illustrates the five hoist drive types used in Table 3 of 4.2.2.2.1 by means of their time histories of actual rotational or linear hoist drive speed ω and resulting hoist force F.

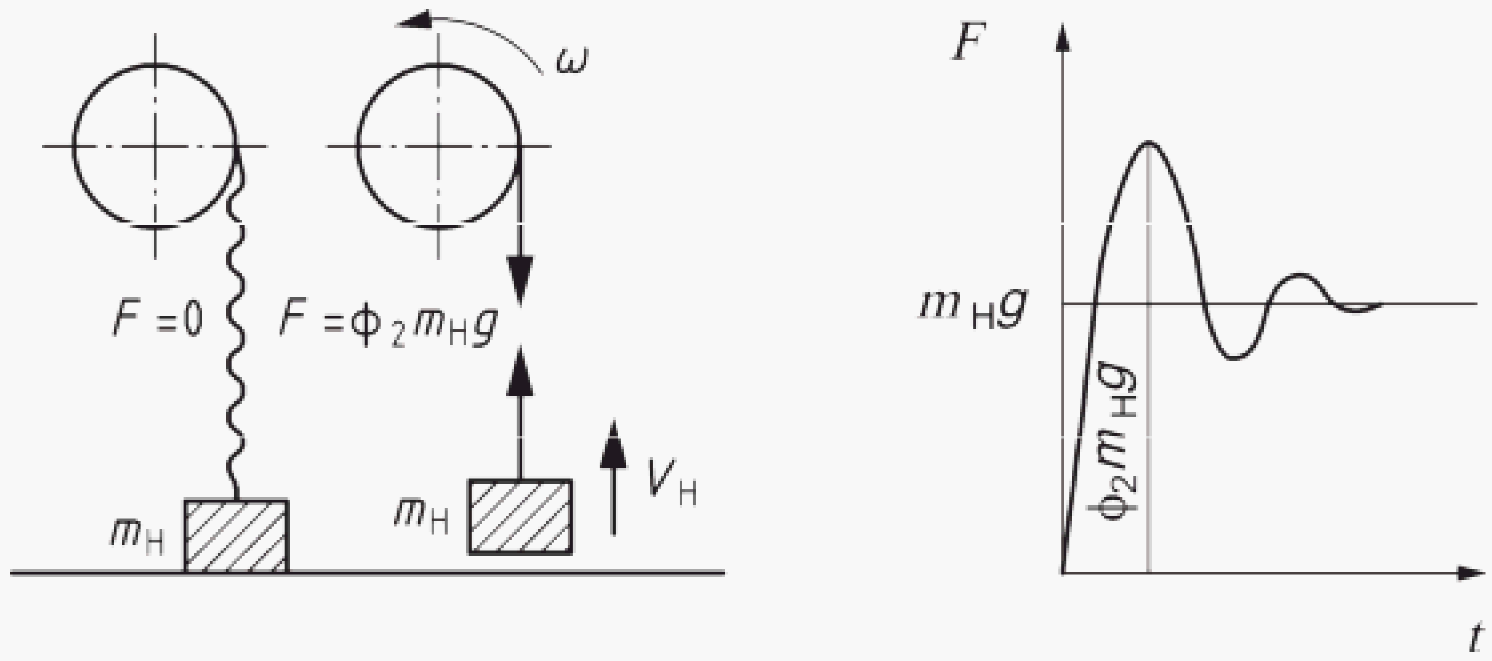


Figure B.1 — ω and F

Table B.1 — Hoist drive types

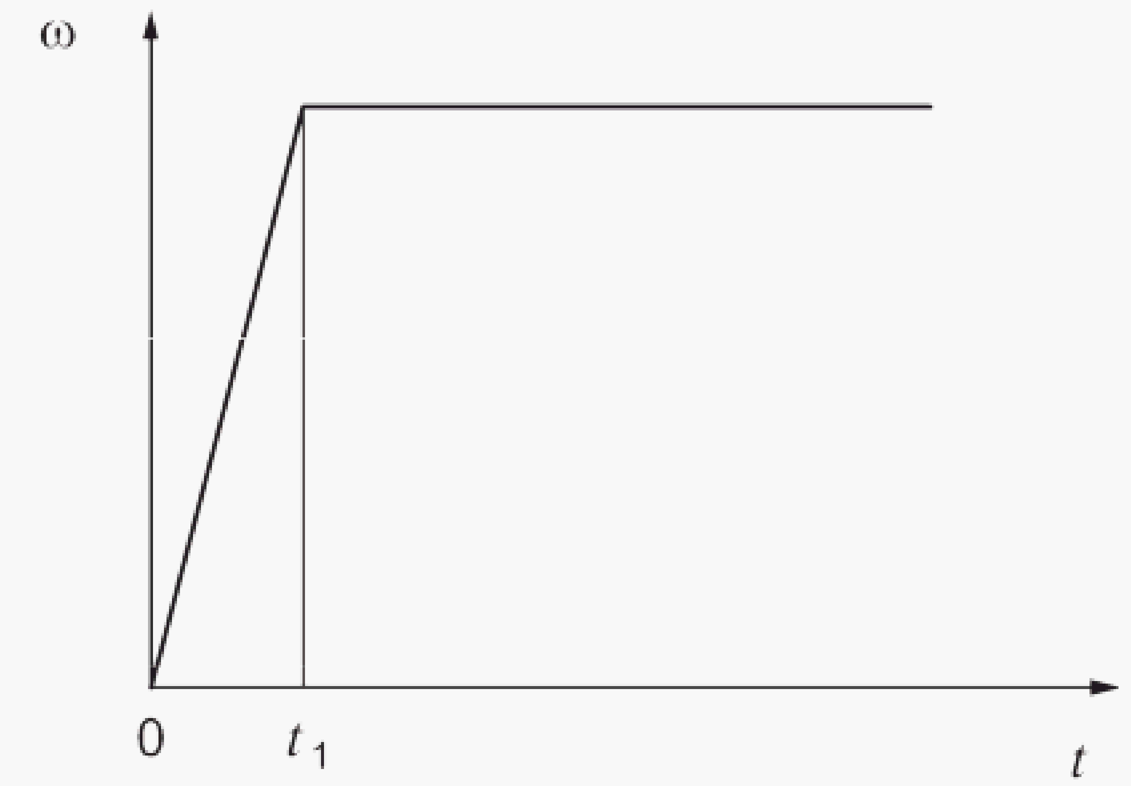
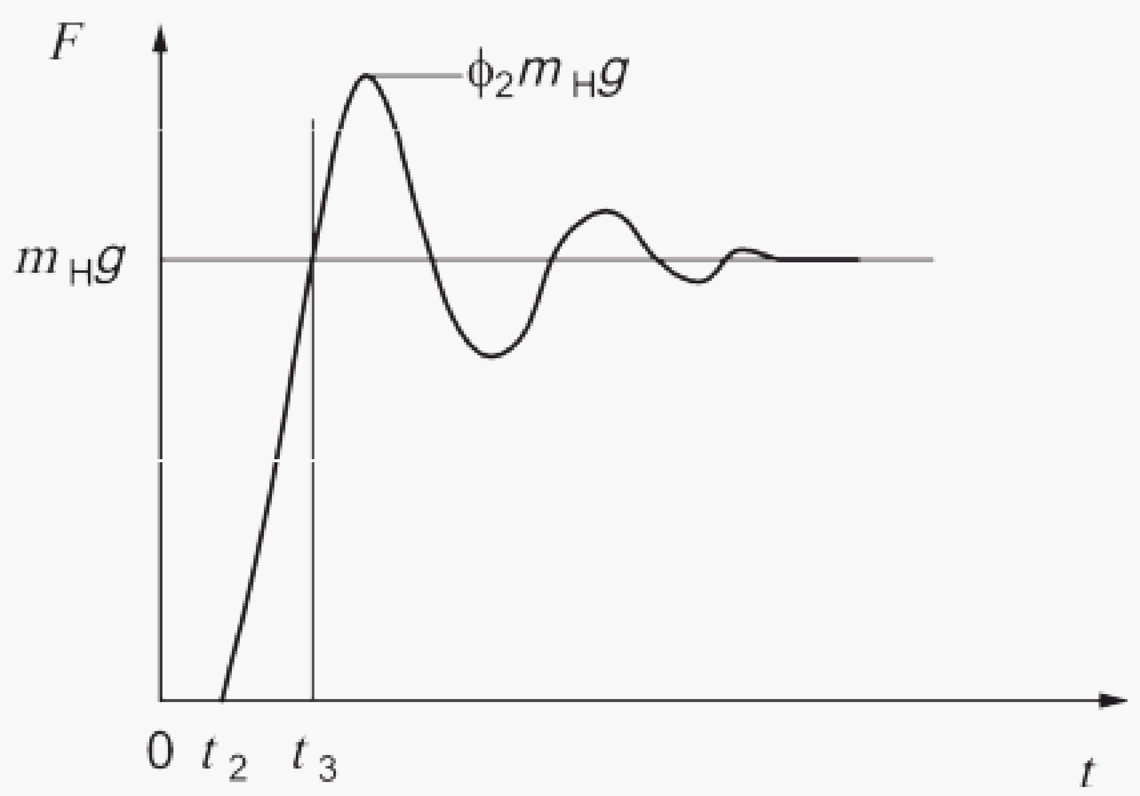
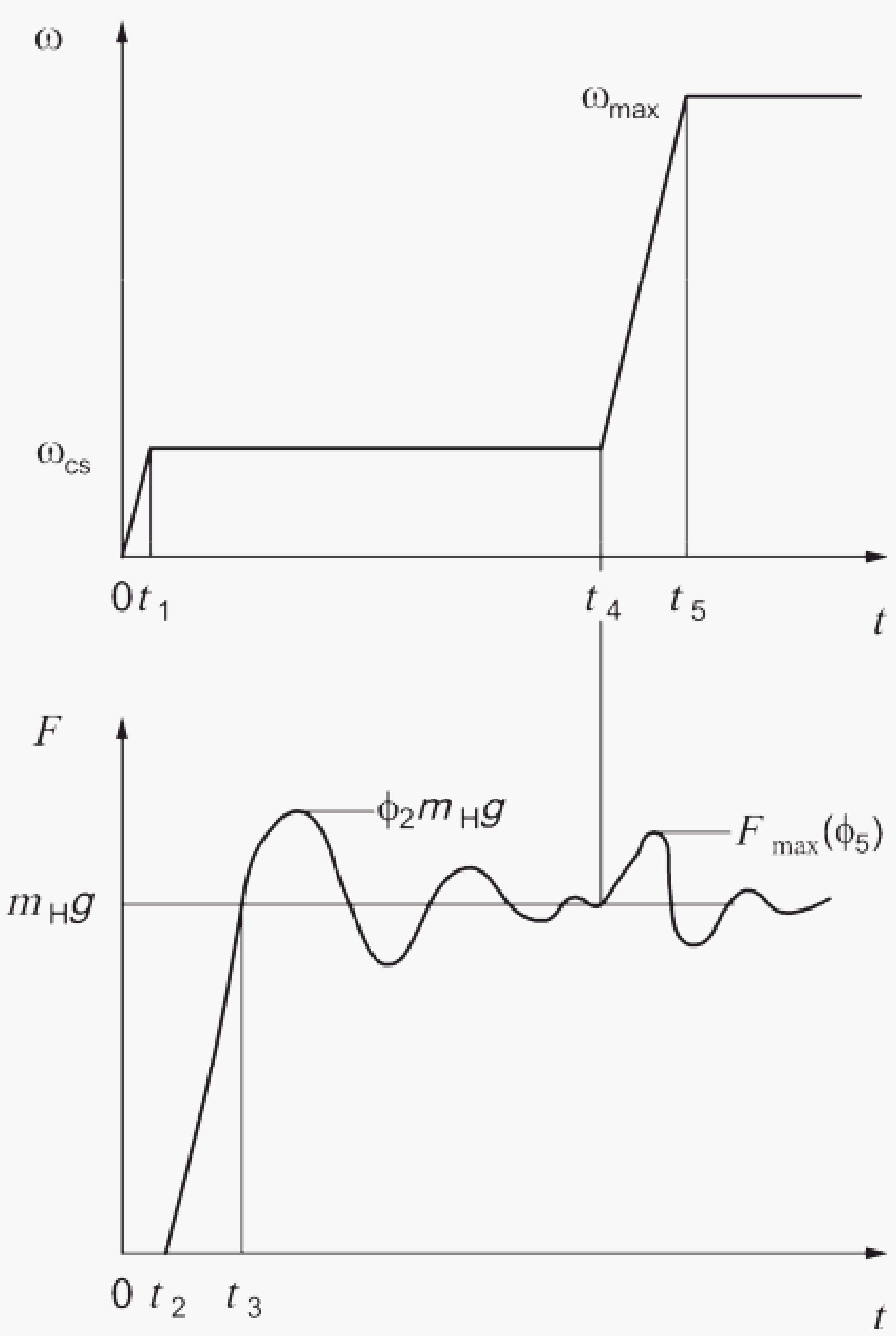
HD1	**Creep speed is not available or the start of the drive without creep speed is possible**	
	  	Time history: $t = 0$ Start of drive $t = t_1$ $\omega = \omega_{max}$ $t = t_2$ Start of rope tightening ($t_2 \rightarrow 0$) $t = t_3$ Start of load lifting Regular load (Combinations A, B): $\phi_2 = \phi_{2,min} + \beta_2 \, v_{h,max}$ Example: Squirrel cage motor with or without creep speed

Table B.1 *(continued)*

<table>
<tr><td>HD2</td><td colspan="2">Hoist drive can only start at creep speed of at least a preset duration</td></tr>
<tr><td></td><td>
</td><td>Time history:
$t = 0$ Start of drive
$t = t_1$ $\omega = \omega_{cs}$
$t = t_4$ Start of acceleration to ω_{max} ($t_4 > t_{4min}$)
$t = t_5$ $\omega = \omega_{max}$
$t = t_2$ Start of rope tightening ($t_2 \to 0$)
$t = t_3$ Start of load lifting

Regular loads (Combinations A, B):
$\phi_2 = \phi_{2,min} + \beta_2\ v_{h,CS}$

$F_{max}(\Phi_5) = m_H\,g + \Phi_5 \cdot (F_f - m_H\,g)$

Exceptional load (Combination C1):
$\phi_2 = \phi_{2,min} + \beta_2\ v_{h,max}$

EXAMPLE Pole changeable squirrel cage motor with creep speed. Time delay t_{4min} ensured by any means like time relay or special push button.</td></tr>
<tr><td>HD3</td><td colspan="2">Hoist drive control maintains creep speed until the load is lifted off the ground</td></tr>
<tr><td></td><td colspan="2">The time histories of F and ω in HD3 are the same as those shown for hoist drive types HD2. However, whilst HD3 type hoist drives ensure that $t_3 < t_4$. HD2 type drives do not prevent the application of full speed whilst the load is still grounded (i.e. foreseeable misuse of slack rope).

Therefore in HD3 only regular loads with $\phi_2 = \phi_{2,min} + \beta_2\ v_{h,CS}$ shall be considered in load combinations A and B.

EXAMPLE Any drive with creep speed and load measuring devices. The maximum speed can only be activated (either automatically or manually) when F stays constant and > 0 for a certain time, thus ensuring that the load is lifted from the ground.</td></tr>
</table>

Table B.1 *(continued)*

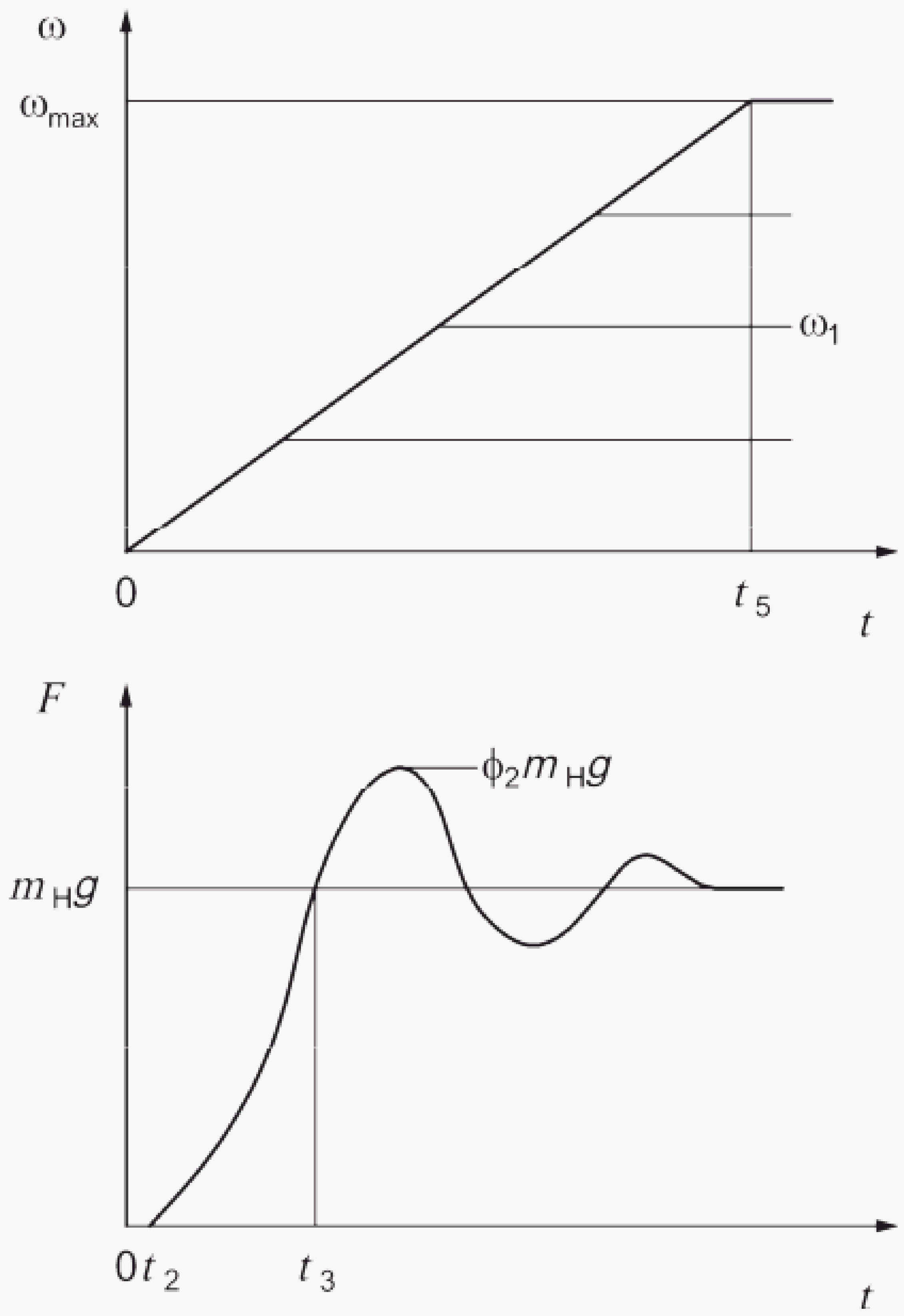
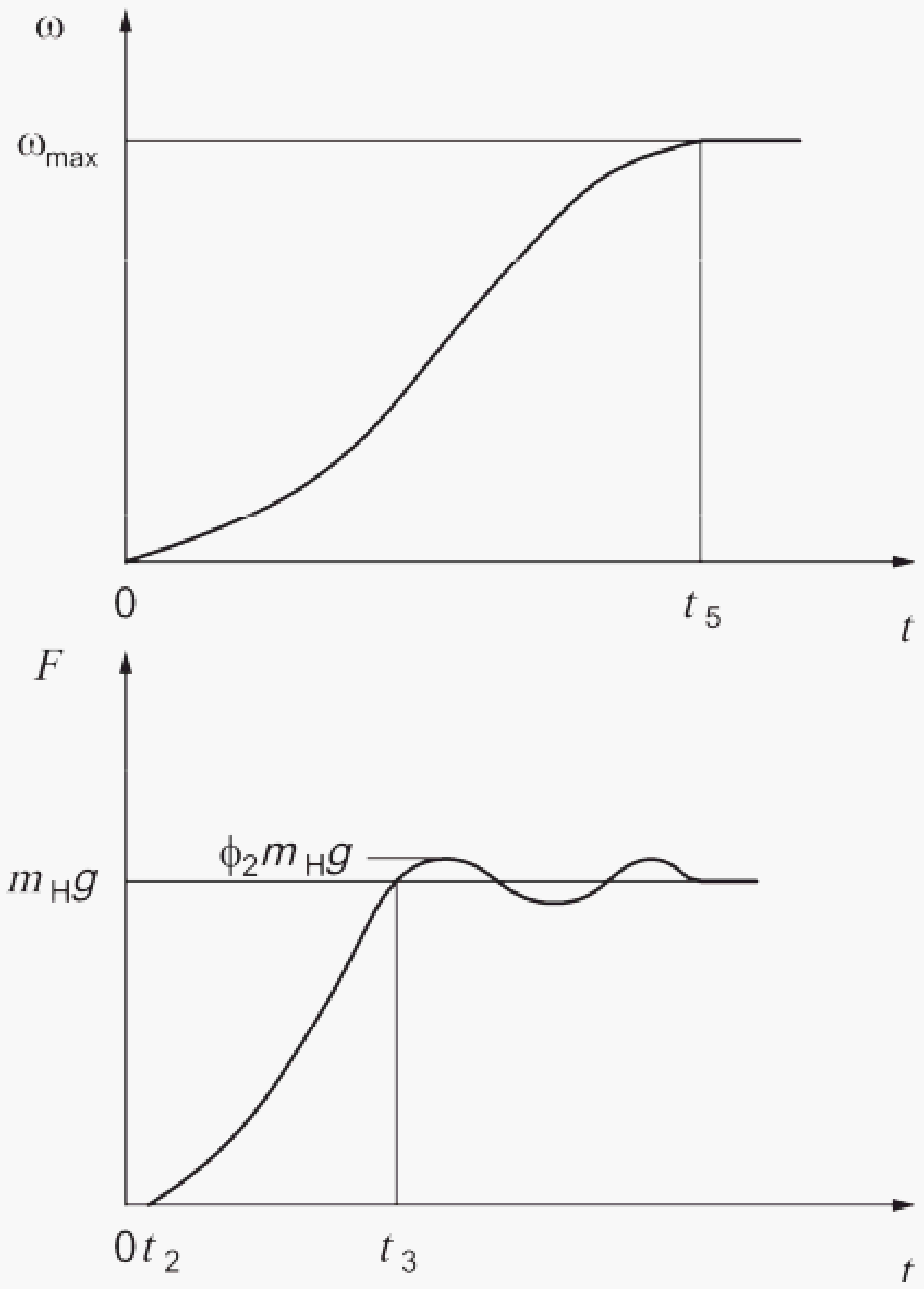
HD4	**Step-less hoist drive control, which performs with continuously increasing speed**	
		Time history: $t = 0$ Start of drive $t = t_5$ $\omega = \omega_{max}$ $t = t_2$ Start of rope tightening $t = t_3$ Start of load lifting Regular load (Combinations A, B): $\phi_2 = \phi_{2,min} + \beta_2 \frac{v_{h,max}}{2}$ Exceptional load (Combination C1): $\phi_2 = \phi_{2,min} + \beta_2 v_{h,max}$ EXAMPLE Any drive that accelerates smoothly (e.g. ramp), e.g. by means of frequency control or DC-motor or hydraulic spool valve. As foreseeable misuse ($t_2 \rightarrow t_5$) is not prevented, load combination C1 shall be considered.

Table B.1 *(continued)*

HD5	**Step-less hoist drive control automatically ensures that the dynamic factor φ_2 does not exceed $\varphi_{2,min}$**	
		Time history: $t = 0$ Start of drive $t = t_5$ $\omega = \omega_{max}$ $t = t_2$ Start of rope tightening $t = t_3$ Start of load lifting Regular load (Combinations A, B): $\phi_2 = \phi_{2,min}$ Exceptional load (Combination C1): $\phi_2 = \phi_{2,min} + \beta_2 \frac{v_{h,max}}{2}$ EXAMPLE Frequency control, DC-motor or hydraulic LS-valve plus load measuring devices. Automatic control for smooth rope tightening and cosine shaped acceleration or direct load control. For additional safety load combination C1 shall be considered.

Annex C
(informative)

Selection of a suitable set of crane standards for a given application

Is there a product standard in the following list that suits the application?

EN 13000	Cranes — Mobile cranes
EN 14439:2006	Cranes — Safety — Tower cranes
EN 14985	Cranes — Slewing jib cranes
prEN 15011	Cranes — Bridge and gantry cranes
EN 13852-1	Cranes — Offshore cranes — Part 1: General purpose offshore cranes
EN 13852-2	Cranes — Offshore cranes — Part 2: Floating cranes
EN 14492-1	Cranes — Power driven winches and hoists — Part 1: Power driven winches
EN 14492-2	Cranes — Power driven winches and hoists — Part 2: Power driven hoists
FprEN 12999	Cranes — Loader cranes
EN 13157	Cranes — Safety —Hand powered cranes
EN 13155:2003	Cranes — Safety — Non-fixed load lifting attachments
EN 14238:2004	Cranes — Manually controlled load manipulating devices

YES

Use it directly, plus the standards that are referred to

NO

Use the following:

EN 13001-1	Cranes — General design — Part 1: General principles and requirements
EN 13001-2:2004	Cranes — General design — Part 2: Load actions
CEN/TS 13001-3-1	Cranes — General design — Part 3.1: Limit states and proof of competence of steel structures
CEN/TS 13001-3-2	Cranes — General design — Part 3.2: Limit states and proof of competence of wire ropes in reeving systems
CEN/TS 13001-3-3	Cranes — General design — Part 3.3: Limit states and proof of competence of wheel/rail contacts
EN 13135-1	Cranes — Safety — Design — Requirements for the equipment — Part 1: Electrotechnical equipment
EN 13135-2	Cranes — Equipment — Part 2: Non-electrotechnical equipment
EN 13557	Cranes — Controls and control stations
EN 12077-2	Cranes safety — Requirements for health and safety — Part 2: Limiting and indicating devices
EN 13586	Cranes — Access
EN 14205-1	Cranes — Equipment for the lifting of persons — Part 1: Suspended
EN 14502-2	Cranes — Equipment for the lifting of persons — Part 2: Moveable
EN 12644-1	Cranes — Information for use and testing — Part 1: Instructions
EN 12644-2	Cranes — Information for use and testing — Part 2: Marking

Annex ZA
(informative)

Relationship between this European Standard and the Essential Requirements of EU Directive 2006/42/EC

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association to provide a means of conforming to Essential Requirements of the New Approach Directive 2006/42/EC.

Once this standard is cited in the Official Journal of the European Union under that Directive and has been implemented as a national standard in at least one Member State, compliance with the normative clauses of this standard confers, within the limits of the scope of this standard, a presumption of conformity with the relevant Essential Requirements of that Directive and associated EFTA regulations.

WARNING — Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard.

Bibliography

[1] EN 1991-1-4:2005, *Eurocode 1: Actions on structures — Part 1-4: General actions — Wind actions*

[2] CEN/TS 13001-3-1, *Cranes — General design — Part 3-1: Limit states and proof of competence of steel structures*

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