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Cranes — Design principles for loads and load combinations —

Part 5:
Overhead travelling and portal bridge cranes

Appareils de levage à charge suspendue — Principes de calcul des charges et des combinaisons de charges —

Partie 5: Ponts roulants et ponts portiques

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Contents

Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 96, *Cranes*, Subcommittee SC 9, *Bridge and gantry cranes*.

This second edition cancels and replaces the first edition (ISO 8686-5:1992), which has been technically revised. It has been adapted to technical progress and new requirements and changes in the International Standards referenced by it. The main changes are

— the normative references to ISO 8686-1, ISO 20332 and ISO 12488-1 have been updated, and

— a calculation method for loads caused by skewing for bridge and gantry cranes with rigid or flexible characteristics has been added.

A list of all parts in the ISO 8686 series can be found on the ISO website.

Cranes — Design principles for loads and load combinations —

Part 5:
Overhead travelling and portal bridge cranes

1 Scope

This document establishes the application of ISO 8686-1 to overhead travelling and portal bridge cranes as defined in ISO 4306-1 and gives specific values for the factors to be used.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

ISO 4301-1:2016, *Cranes — Classification — Part 1: General*

ISO 4302:2016, *Cranes — Wind load assessment*

ISO 4306-5:2005, *Cranes — Vocabulary — Part 5: Bridge and gantry cranes*

ISO 8686-1:2012, *Cranes — Design principles for loads and load combinations — Part 1: General*

ISO 12488-1:2012, *Cranes — Tolerances for wheels and travel and traversing tracks — Part 1: General*

ISO 20332:2016, *Cranes — Proof of competence of steel structures*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4306-5 and ISO 8686-1 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at http://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

4 Symbols

Table 1 — Symbols and abbreviated terms

Symbol	Description
a	acceleration or deceleration value
a	term used in determining the value of ϕ_1
b_j	distance in travel direction from wheel j
C_H	elasticity factor of crane structure and rope system at the load suspension point
d_j	distance in travel direction from the front guide means to wheel j
e	base of natural logarithms, 2,718

Table 1 *(continued)*

Symbol	Description
$F_{\mathrm{max,L}}$	maximum force
f_{uc}	ultimate strength of the chain steel
g	gravity constant
h_{M}	flexibility of the portal in angle per moment
l	span of crane
$l_{\mathrm{r}}, l_{\mathrm{c}}$	length of rope/chain fall
m	mass
m_{T}	total mass of the loaded crane
M	moment turning the floating end carriage by forces Y_j applied to the wheels of that carriage
M	moment between the portal and the unguided carriage
m_{H}	mass of the hoist load (gross load)
m_{RC}	mass of the rated hoist load
R_{r}	rope grade
$S_{\mathrm{(f)}}$	final load effect
$S_{\mathrm{(i)}}$	initial load effect
sgn	signum function
s_{j}	selection factor
t_{br}	reaction time of the braking
t_{IAL}	response-time of the indirect acting lifting force limiter
t_{st}	time to stop the mechanism in stall condition by effects of the braking and increasing rope force
v_{h}	maximum hoisting speed
$v_{\mathrm{h,max}}$	maximum steady hoisting speed
W	resulting wheel force
Y_{F}	lateral force at the guide means (F_{y} in ISO 8686-1:2012)
Y_{j}	lateral force at the contact point of wheel j (F_{yij} in ISO 8686-1:2012)
Z_{1i}	wheel load of the 1st wheel of shaft i
Z_{2i}	wheel load of the 2nd wheel of shaft i
Z_{a}	actual coefficient of utilization of the rope/chain
Z_{j}	vertical wheel force of wheel j
Z_{j}	wheel load of wheel j, ($Z_{\mathrm{j}} \geq 0$), ($j = 1, 2 \ldots n$ with n = number of wheels) The trolley carries maximum load. The trolley should be positioned on the crane's side, which has no guide means.
α	skewing angle in radian
α	triggering-factor [–]
α_{g}	skew component due to track clearance
α_{w}	component due to wear
α_{t}	component due to alignment tolerances of rail/wheel
$\Delta\alpha$	additional skewing angle due to flexible deformation
$(\dot{\alpha}/\dot{x})$	portal turning speed per travel speed
ϕ_{DAL}	force-limit factor for direct acting lifting force limiters
ϕ_{IAL}	force-limit factor for indirect acting lifting force limiters
ϕ_5	amplification factor for dynamic loads arising from acceleration of crane drives
ϕ_{p}	factor for effect of sequential positioning movements
μ_0	adhesion factor

Table 1 *(continued)*

Symbol	Description
$\mu_f\ (\sigma_j)$	friction coefficient of wheel *j* by lateral slip σ_j
μ_f	friction slip coefficient (*f* in ISO 8686-1:2012)
σ_j	lateral slip of wheel *j*
σ	slip factor

5 Loads and applicable factors

5.1 Regular loads

5.1.1 General

Regular loads, occurring during normal operation, shall be considered in proof of competence calculations against failure by yielding, elastic instability and, when applicable, against fatigue in accordance with ISO 8686-1:2012, 6.1 and the following amendments.

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

The gravitational force induced by the mass of the crane (dead weight) shall be multiplied by a factor ϕ_1, as shown in Formula (1):

$$\phi_1 = 1 + \alpha \qquad (1)$$

For masses with unfavourable gravitational load effect, the factors shall be taken as α = 0,10 and ϕ_1 = 1,10, and for masses with favourable gravitational load effect as α = −0,05 and ϕ_1 = 0,95, unless other values are obtained by measurements or calculations.

Where cranes work in atmospheres contaminated by process debris, such material accumulations deposited upon the upper surfaces of the crane shall be taken into account in the dead load computation.

5.1.3 Hoisting an unrestrained grounded load

5.1.3.1 General

The hoist load shall be multiplied by factor ϕ_2 that represents the additional dynamic force applied on the crane, when the weight of a grounded load is transferred on the hoisting medium (ropes or chains).

When assuming the most extreme conditions, the hoisting medium is slack while the hoist mechanism reaches its maximum hoisting speed. In this condition, the dynamic additional force is directly proportional to the hoisting speed, with a coefficient that depends upon the stiffness properties and mass distribution of the crane (β_2 in ISO 8686-1:2012, 6.1.2.1.1).

In physical crane operation, there are other factors that influence the actual dynamic effect, such as control systems, dampening and flexibility of other than main components (e.g. hoist slings, other lifting devices, load itself, crane foundation). These dependencies and determination of factor ϕ_2 are represented by hoisting classes in ISO 8686-1:2012, 6.1.2.1.2.

For determination of ϕ_2, the following principles shall be used:

- calculation by selection of a hoisting class;
- determination by alternative methods, see 5.1.3.5.

The hoisting class and the factor ϕ_2 shall be calculated either

— in accordance with ISO 8686-1:2012, 6.1.2.1.2, or

— in accordance with 5.1.3.2 to 5.1.3.4.

The hoisting speed used for the determination of the dynamic coefficient shall reflect the actual use and possible exceptional events of the crane in a realistic way. Two events shall be considered as follows:

— crane in normal use where hoisting commences at a mechanism controlled speed from a slack rope condition — load combination A and B as per ISO 8686-1:2012, Table 2b;

— exceptional case where hoisting commences at mechanism maximum speed from slack rope condition — load combination C as per ISO 8686-1:2012, Table 2b.

5.1.3.2 Determination of a dynamic factor, ϕ_{2t}

The determination of a hoisting class as defined in ISO 8686-1 shall be selected by the theoretical dynamic factor, ϕ_{2t}. It shall be estimated in one of the following ways.

— Make a complete dynamic simulation taking into account the elastic, inertial and dampening properties. The maximum force in the hoisting medium during time of the first 3 s represents the hoist load multiplied by factor ϕ_{2t}.

— Use one of the simplified Formulae (2) applicable to the hoist.

a) for a crane with a rope hoist b) for a crane with a chain hoist

$$\phi_{2t} = 1 + \frac{2{,}8 \times v_{\mathrm{h,max}}}{0{,}45 + \left(\dfrac{R_{\mathrm{r}} \times l_{\mathrm{r}}}{1\,500 \times Z_{\mathrm{a}}} \right)^{1/2}} \qquad \phi_{2t} = 1 + \frac{2{,}8 \times v_{\mathrm{h,max}}}{0{,}45 + \left(\dfrac{f_{\mathrm{uc}} \times l_{\mathrm{c}}}{150 \times Z_{\mathrm{a}}} \right)^{1/2}} \qquad (2)$$

where

$v_{\mathrm{h,max}}$	is the maximum steady hoisting speed in metres/second;
R_{r}	is the rope grade, in N/mm^2;
f_{uc}	is the ultimate strength of the chain steel, in N/mm^2;
l_{r}, l_{c}	is the length of rope/chain fall in metres;
Z_{a}	is the actual coefficient of utilization of the rope/chain (total breaking force of the rope/chain reeving system/hoist load).

The length, $l_{\mathrm{r}}/l_{\mathrm{c}}$, shall be taken as the typical distance between the upper and lower rope sheaves/chain sprockets, when hoisting a grounded load. Where a loaded part or all of the hoist media deviates from the vertical, the length of the rope/chain fall shall be adjusted to give the equivalent flexibility in vertical direction.

NOTE This simplified formula takes into account the rigidity and the masses of the crane parts and load.

The hoisting class shall be determined in accordance with Table 2.

Table 2 — Selection of hoisting class

Condition for calculation result			**Hoisting class of ISO 8686-1:2012**
	ϕ_{2t} ≤	$1{,}07 + 0{,}24 \times v_{h,max}$	HC1
$1{,}07 + 0{,}24 v_{h,max}$	< ϕ_{2t} ≤	$1{,}12 + 0{,}41 \times v_{h,max}$	HC2
$1{,}12 + 0{,}4 v_{h,max}$	< ϕ_{2t} ≤	$1{,}17 + 0{,}58 \times v_{h,max}$	HC3
$1{,}17 + 0{,}58 v_{h,max}$	< ϕ_{2t}		HC4

5.1.3.3 Selection of hoisting speed

The hoisting speed representing the normal use in load combinations A and B, and an exceptional occurrence in load combination C, shall be selected according to the hoist drive class, HD, provided by the system and ISO 8686-1:2012, Table 2b.

5.1.3.4 Calculation of factor, ϕ_2

The factor ϕ_2 shall be calculated in accordance with ISO 8686-1:2012, 6.1.2.1.2, using the selected hoisting class and speed determined in 5.1.3.2 and 5.1.3.3.

5.1.3.5 Determination of ϕ_2 by testing

The dynamic factor, ϕ_2, can also be determined by measurement from an equivalent crane. The values measured with different hoisting speeds shall be directly used in calculations, without reference to a hoisting class.

The dynamic increment of deflections found by measurement or dynamic simulation may include the dynamic effects from the mass of the crane including the trolley; see 5.1.2. The portion represented by the factor *a* could be removed from the evaluation of the final ϕ_2 to avoid it being considered twice in ϕ_1 and also in ϕ_2.

5.1.4 Loads caused by travelling on an uneven surfaces

The dynamic effects on the crane by travelling, with or without hoist load, on or off roadway or on rail tracks shall be considered by the specific factor, ϕ_4.

For continuous rail tracks or welded rail tracks with finished ground joints without notches (steps or gaps) the specific factor $\phi_4 = 1{,}0$.

For roadways or rail tracks with notches (steps or gaps), the specific factor, ϕ_4, shall be calculated according to ISO 8686-1. For rubber tyred cranes, the flexibility of the tyre shall be taken into account.

5.1.5 Loads caused by acceleration of drives

For crane drive motions, the change in load effect, ΔS, caused by acceleration or deceleration is presented by Formula (3):

$$\Delta S = S_{(f)} - S_{(i)} \qquad (3)$$

where

$S_{(f)}$ is the final load effect;

$S_{(i)}$ is the initial load effect.

NOTE The change in load effects, ΔS, is caused by the change of drive force, ΔF, given by the formula: $\Delta F = F_{(f)} - F_{(i)}$, where $F_{(f)}$ is the final drive force and $F_{(i)}$ is the initial drive force.

Loads induced in a crane by acceleration or deceleration caused by drive forces may be calculated using rigid body kinetic models. The load effect, S, shall be applied to the components exposed to the drive forces and where applicable to the crane and the hoist load as well. As a rigid body analysis does not directly reflect elastic effects, the load effect, S, shall be calculated by using an amplification factor, ϕ_5, in accordance with of ISO 8686-1:2012, 6.1.4 as in Formula (4):

$$S = S_{(\mathrm{i})} + \phi_\mathrm{p} \times \phi_5 \times a \times m \tag{4}$$

where

$S_{(\mathrm{i})}$ is the initial load effect caused by $F_{(\mathrm{i})}$;

ϕ_5 is the amplification factor for dynamic loads arising from acceleration of crane drives;

ϕ_p is the factor for effect of sequential positioning movements, see 5.1.6;

a is the acceleration or deceleration value;

m is the mass for which a applies.

The factor ϕ_5 shall be taken from Table 3 and Table 4 unless more accurate factors are available from elastic model calculations or measurements. The factor, ϕ_p, shall be taken from Table 6.

Where the force, S, is limited by friction or by the nature of the drive mechanism, this frictional force shall be used instead of calculated force, S.

Table 3 — Factor ϕ_5 for travel, traverse and slewing mechanism

Drive type	**Factor ϕ_5**	
	Typical backlash for gearbox	**Considerable backlash, e.g. open gears**
Stepless speed control	1,2	1,5
Multi-step speed control	1,6	2,0
Two-step speed control	1,8	2,2
Single-step speed control	2,0	2,4

Table 4 — Factor ϕ_5 for hoist mechanism

Drive type	**Factor ϕ_5 lifting**	**Factor ϕ_5 lowering**
Stepless speed control	1,05	1,10
Multi-step speed control	1,15	1,20
Two-step speed control	1,20	1,35
Single-step speed control	1,20	1,30

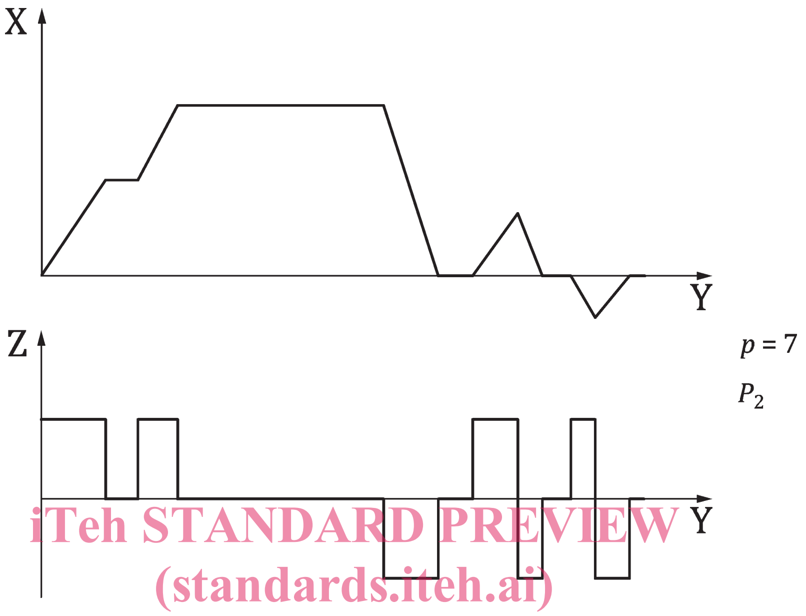
NOTE Factors in Tables 3 and 4 take account for switching on/off the speed and speed change.

5.1.6 Positioning of loads

The number of intended and additional accelerations of any drive to reach the intended position of the load shall be taken into account in the proof of competence. This shall be done by using average number of accelerations, P, in accordance with ISO 4301-1:2016, 7.6 classified in Table 5 and illustrated in Figure 1.

Table 5 — Average number of accelerations

Class	Average number of accelerations
P_0	$p = 2$
P_1	$2 < p \leq 4$
P_2	$4 < p \leq 8$
P_3	$8 < p$



Key

x	speed
y	time
z	acceleration

Figure 1 — Example for class *P*

Table 6 — Factor ϕ_p

Class of load positioning according to Table 5	ϕ_p
P_0 and P_1	1,0
P_2	1,15
P_3	1,3

Positioning movements may increase the total load effects, when made in non-optimal manner. This is taken into account by factor ϕ_p dependent upon the class *P*.

5.1.7 Loads induced by displacements

Account shall be taken of loads arising from displacements included in the design in accordance with ISO 8686-1:2012, 6.1.5.

Where displacements related to rail span variations or support deflections remain within the limit values specified in ISO 12488-1:2012, 6.2, their effect need not to be taken into account in the stress analysis.

5.2 Occasional loads

5.2.1 General

Occasional loads and effects which occur infrequently shall be considered in proof of competence calculations against failure by yielding elastic instability and may usually be neglected in fatigue evaluations in accordance with ISO 8686-1 and the following amendments.

5.2.2 Loads caused by skewing

5.2.2.1 General

In general, the skewing forces are usually taken as occasional loads and shall be addressed to load combination B, 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.

In cases where anti-skew devices are provided, the forces calculated without the effect of anti-skew devices shall be addressed to load combination C. If the crane can be used without anti-skew devices functioning, the forces shall be addressed to load combination B.

Skewing forces for top-running cranes and trolleys shall be calculated in accordance with 5.2.2.2 to 5.2.2.4 and Annex A, which provide simplified methods for calculating the forces generated when considering both RIGID and FLEXIBLE crane structures. Skewing forces for underhung cranes shall be calculated in accordance with 5.2.2.5.

NOTE 1 The method given in ISO 8686-1:2012, 6.2.2 is applicable to rigid structures. Bridge and gantry cranes can possess both RIGID and FLEXIBLE characteristics; therefore, a more general method is required as given here. With this method, in addition, flexible structures, uneven number of wheels, unequally distributed wheel loads, as well as different types of guide means and anti-skewing devices, can be considered.

NOTE 2 Forces arising from skewing are generated when the resultant direction of rolling movement of the travelling crane no longer coincides with the direction of the runway rail and when the front positive guiding means come into contact with the rail. This is caused by tolerances and inaccuracies, which arise in the manufacture of the crane (bores of track wheels) and that of the runway's rail (bends, kinks). The values and distribution of these forces depend chiefly upon the clearances between the runway rail and the wheel flanges or guide rollers and the latter's location, also on the number, arrangement, bearing arrangement and rotational speed synchronisation of the track wheels and structural flexibility.

NOTE 3 The use of anti-skew devices with travel motions reduces the guiding forces between the rail and guiding means. It also reduces the lateral slip forces of the wheels, but some lateral slip remains due to wheel alignment tolerances and lateral deformations of structures, which effect should be considered.

5.2.2.2 Skew angle

The skew angle shall be calculated as follows:

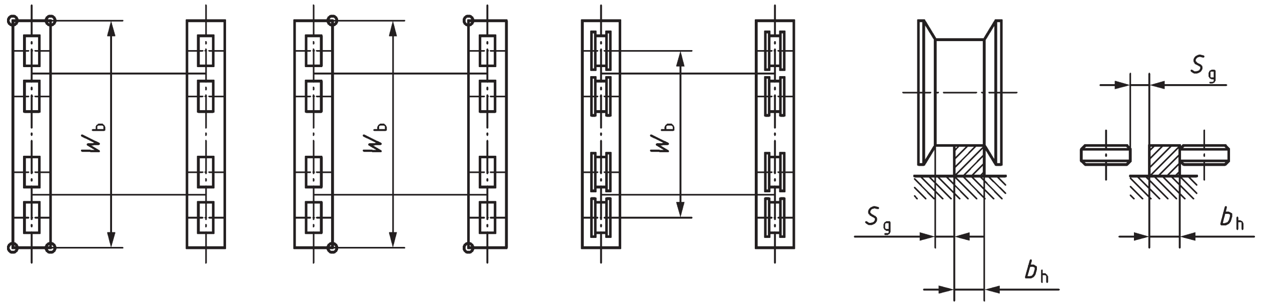


Figure 2 — Parameters of skew angle