INTERNATIONAL STANDARD

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Second edition
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Cranes — Design principles for loads and load combinations —

Part 3: Tower cranes

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

Partie 3: Grues à tour

Reference number
ISO 8686-3:2018(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 96, *Cranes*, SC 7, *Tower cranes*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

This second edition cancels and replaces the first edition (ISO 8686-3:1998) and ISO 12485:1998 which have been technically revised.

The main changes compared to the previous edition are as follows:

— integration and rules for application of ISO 8686-1;

— integration of special rules regarding the calculation of wind loads on tower cranes in the out-of-service state;

— integration of rules regarding the calculation of rigid body stability in this document;

— integration of rules regarding the calculation of loads on crane support structure;

— integration of rules for the calculation of climbing systems;

— integration of rules for the calculation of mobile self-erecting tower cranes.

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 3: Tower cranes

1 Scope

This document establishes the application of ISO 8686-1 to tower cranes for construction work as defined in ISO 4306-3, and gives specific requirements and values for factors to be used at the structural calculation.

Tower cranes for construction work are exclusively equipped with a hook as the load-handling device.

For tower cranes intended to be used for other purposes and/or with other load-handling devices, other values can be necessary according to the tower crane usage specification.

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 4302, *Cranes — Wind load assessment*

ISO 4306-3, *Cranes — Vocabulary — Part 3: Tower cranes*

ISO 4310, *Cranes — Test code and procedures*

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 4306-3 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 https://www.iso.org/obp

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

3.1
balancing moment
moment at which the balance of the lifted components of the crane is achieved before starting the climbing operation

3.2
deviation moment
amount by which the *balancing moment* (3.1) may deviate during a climbing sequence

4 Symbols and abbreviated terms

The symbols given in ISO 8686-1 and ISO 4302 shall apply.

5 General

The proof calculation — proof of strength and proof of stability — shall be performed in accordance with ISO 8686-1 and ISO 20332, together with the following provisions.

General principles of calculation are presented in ISO 8686-1:2012, Clause 5. Due to the general properties and usual design of tower cranes all calculations shall base on the assumption of a deformed system in a state of equilibrium (second order theory). Structural deformations may be neglected only if they result in a insignificant increase of the load effect.

Several of the following assumptions presuppose specific boundary conditions, which shall be adhered to or controlled by the user. It is therefore necessary that these boundary conditions are described along with the necessary measures in the operating instructions of the crane.

6 Loads

6.1 General

Design loads shall take into consideration the most unfavourable effects that can be expected during the life of the crane while it is operated and out of service, as well as during assembly, disassembly and transportation. In-service loads shall reflect unfavourable but realistic operating conditions and sequences of actions by the crane operator.

Loads, load combinations and parameters used in this document are considered to be deterministic.

These loads shall be defined and classified as regular loads (for load combinations A), occasional loads (for load combinations B) and exceptional loads (for load combinations C) according to ISO 8686-1:2012, Clause 6.

6.2 Loads and values for dynamic factors, ϕ_i

Table 1 indicates loads that are generally relevant for tower cranes, and gives guidance on values for appropriate dynamic factors.

Alternatively, other values for dynamic factors may be used when determined by recognized theoretical analysis or a practical test.

In the case of a tower crane designed for a special use and/or with dedicated requirements, additional loads and relevant values of dynamic factors shall be considered and defined according to ISO 8686-1:2012, Clause 6.

Table 1 — Loads and guidance on values for dynamic factors, ϕ_i, for tower cranes

Line number i	Loads	Dyn. factors ϕ_i	Definitions and guidance on values for dynamic factors, ϕ_i, and load determination
Regular loads			
1	Hoisting and gravity effects acting on the mass of the crane	ϕ_1	ϕ_1 shall be considered according to ISO 8686-1. The value a defined for tower cranes is: a = 0,05.
2	Inertial and gravity effects by hoisting an unrestrained grounded load	ϕ_2	ϕ_2 shall be considered according to ISO 8686-1. Hoisting class HC1 is defined for tower cranes. For load combinations A1 and B1: $\phi_{2,max}$ = 1,3. For load combination C1: ϕ_2 without limitation. Due to the nature of tower cranes, only the hoist drive classes HD1 or HD4 shall be used. The classes HD2, HD3 and HD5 are not allowed to be used.
3	Inertial and gravity effects by sudden release of a part of the hoist load	ϕ_3	Not applicable for tower cranes.
4	Loads caused by travelling on uneven surface	ϕ_4	The railway tolerances for a tower crane rail track shall be specified according to ISO 12488-1:2012, Class 2. With this condition, this load action does not need to be considered. In case of different condition, the load action shall be considered according to ISO 8686-1.
5	Loads caused by acceleration of drives	ϕ_5	ϕ_5 shall be considered according to ISO 8686-1. Usual values of the dynamic coefficient ϕ_5 for tower cranes are: — ϕ_5 = 1,0 for centrifugal forces; — ϕ_5 = 1,5 for drive forces for all typical drives of tower cranes (with no backlash or in case where existing backlash does not affect the dynamic forces and with smooth change of forces).
6	Loads determined by displacements (or rotations)	—	The erection tolerances for the supporting structure for a tower crane shall comply with the requirements given in 7.6, item (i). Under this condition, this load action does not need to be considered. In case of different condition, the load action shall be considered according to ISO 8686-1.
Occasional loads			
7	Loads due to in-service wind	—	The minimum in-service wind pressure that shall be considered is $q_{(3)}$ = 250 Pa (wind speed $v_{(3)}$ = 20 m/s). In case a special load chart is additionally provided for the tower crane, the minimum in-service wind pressure that shall be considered for this special load chart is $q_{(3)}$ = 125 Pa (wind speed $v_{(3)}$ = 14,1 m/s).
8	Loads due to snow and ice	—	This load shall be considered only on special request from a user.
9	Loads due to temperature variation	—	Not applicable for tower cranes.

Table 1 *(continued)*

Line number i	Loads	Dyn. factors ϕ_i	Definitions and guidance on values for dynamic factors, ϕ_i, and load determination
10	Loads caused by skewing	—	Skewing forces are insignificant and do not need to be considered when the ratio of the wheel base divided by the track width of the undercarriage is 1 or greater. In case of different conditions, the load action shall be considered according to ISO 8686-1.
Exceptional loads			
11	Loads caused by hoisting a grounded load at maximum hoisting speed	ϕ_2	Refer to line 2 of Table 1.
12	Loads due to out-of-service wind	—	Refer to 6.3.
13	Test loads	ϕ_6	The values of test loads shall be in accordance with ISO 4310. The minimum wind pressure that shall be considered for test loads is $q_{(3)}$ = 40 Pa (wind speed $v_{(3)}$ = 8 m/s).
14	Loads due to buffer forces	ϕ_7	A verification of the energy absorption capacity of the buffers and the effect of the buffer forces on the tower crane structure may be disregarded, on condition that the crane travelling speed does not exceed 40 m/min and at least 2 limit switches are installed in each driving direction in addition to buffer stops. In case of different conditions, the load action shall be considered according to ISO 8686-1.
15	Loads due to tilting forces	—	Not applicable to tower cranes.
16	Loads due to unintentional loss of hoist load	ϕ_9	According to ISO 8686-1. For tower cranes, this load case refers to hoist rope rupture or accidental drop of hoist load. ϕ_9 = −0,3 shall be used for the proof of strength and the proof of rigid body stability. Alternatively, this load may be evaluated by calculation on a dynamic model analysis or by a practical test.
17	Loads caused by Emergency Off	—	This load can be determined by calculation on a dynamic model analysis or by a practical test.
18	Loads caused by anticipated failure of mechanism or components	—	This load can be determined by calculation on a dynamic model analysis or by a practical test.
19	Loads due to external excitation of the crane foundation	—	To be considered only on special request from a third party.
20	Loads caused by erection, dismantling and transport	—	Refer to 6.4.
21	Loads on means provided for access	—	Refer to 6.5

6.3 Loads due to out-of-service wind

6.3.1 General

Loads due to out-of-service wind shall be considered according to ISO 8686-1 and ISO 4302.

Tower cranes are typically designed to slew freely in the out-of-service state and to show a good weathervaning behaviour thereby.

Nevertheless, in order to cover a delayed slewing of the cranes in the prevailing wind direction or generally to take into account particularly turbulent construction sites, additional safety load cases in the out-of-service state shall be considered. These additional empirical load cases relate primarily to an extension of the proof of rigid body stability. However, in order not to create a gap in the proof verification, at least the substructure and the crane tower shall be verified by a proof of strength regarding these load actions.

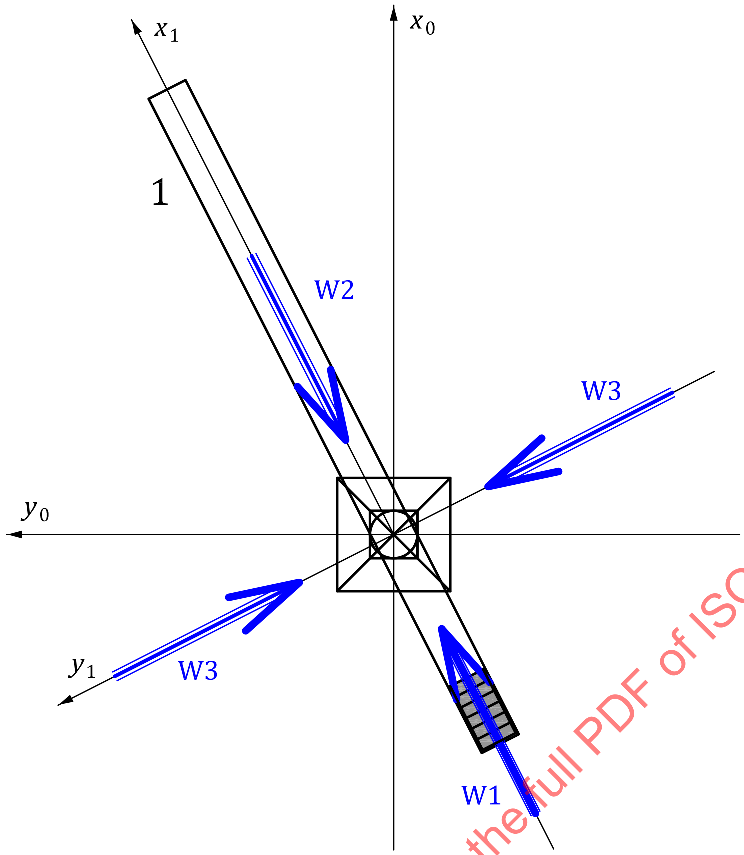
Hence, wind loads due to out-of-service wind for tower cranes are split-up in three different wind load assumptions, depending on the wind direction acting on the crane (see Figure 1), with the requirement of a free slewing upper works. These loads are converted into three load combinations: C2.1, C2.2 and C2.3 according to Tables 4 and 5.

The proof of stability and the proof of strength shall be made with the following load combinations:

— C2.1: crane in out-of-service conditions, considering out-of-service wind from rear;

— C2.2: crane in out-of-service conditions, considering out-of-service wind from front; and

— C2.3: crane in out-of-service conditions, considering out-of-service wind from side.



Key

(x_0, y_0)	coordinate system defined in a horizontal plane at ground level, linked to the stationary crane part of the crane, x_0 is conventionally defined parallel to the most unfavourable tilting axis (index 0)
(x_1, y_1)	coordinate system defined in a horizontal plane at the level of the slewing ring, linked to the slewing part of the crane, x_1 is conventionally defined parallel to the jib axis of the crane (index 1)
1	jib direction
W1	wind from rear
W2	wind from front
W3	wind from side

Figure 1 — Figure illustrating the wind directions "wind from rear", "wind from front" and "wind from side"

If the tower crane is not slewing freely out-of-service, the wind load action "wind from rear" according to 6.3.2 shall be applied from all sides. The additional wind loads given in 6.3.3 and 6.3.4 may be ignored in that case.

For a crane that possesses innate means to be readily removed from exposure to storm winds (e.g. a mobile self-erecting tower crane), loads due to out-of-service wind may be disregarded or reduced, as appropriate.

6.3.2 Loads due to out-of-service wind from rear

The out-of-service wind loads from rear are assumed to act on a member of a tower crane or on the hoist load remaining suspended at the crane and are calculated using Formula (1):

$$F = K_s * q(z) * C_f * A \qquad (1)$$

where

F is the wind load as defined in ISO 4302:2016, 6.2;

K_S is the structural factor, where, due to the size and structure of tower cranes, the structural factor K_S takes into account the effect on wind actions from the non-simultaneous occurrence of peak wind pressures on the surface, such that

K_S is set to 0,95 for tower cranes,

K_S is only allowed to be used at load combination C2.1;

$q(z)$ is the wind pressure as defined in ISO 4302:2016, 6.2;

C_f is the aerodynamic coefficient as defined in ISO 4302:2016, 6.2;

A is the characteristic area as defined in ISO 4302:2016, 6.2.

The reference wind speed and recurrence period shall conform to the following minimum requirements:

— reference wind speed, v_{ref} = 28 m/s;

— recurrence period, R = 25 years.

Higher reference wind speeds and recurrence periods shall be applied when required by the local wind conditions and duration of exposure.

For specific applications or jobsite conditions (special cranes such as very high cranes, cranes tied to a building, jobsites with special wind effects, etc.), parameters different from those listed above based on more accurate wind load evaluation methods may be used.

6.3.3 Loads due to out-of-service wind from front

The wind load action for out-of-service wind from front as described in 6.3.1 shall be considered according to Formula (2):

$$F = q_{(3)} * C_f * A \tag{2}$$

where

F is the calculated wind load;

$q_{(3)}$ is an empirically defined uniform wind pressure with 710 Pa; This wind pressure shall be applied constant over the height of the crane;

$C_f * A$ is the effective aerodynamic area ($C_f * A$) for an approaching flow from front. Simplified, the effective wind area for a flow from rear, as calculated in 6.3.2, can be used for this load action also.

6.3.4 Loads due to out-of-service wind from side

The wind load action for out-of-service wind from side as described in 6.3.1 shall be considered according Formula (3):

$$F = q_{(3)} * C_f * A \tag{3}$$

where

F is the calculated wind load;

$q_{(3)}$ is an empirically defined uniform wind pressure with 425 Pa; This wind pressure shall be applied constant over the height of the crane;

$C_f * A$ is the effective aerodynamic area ($C_f * A$) for an approaching flow attacking the rotating upper crane perpendicular (to the jib axis) from side, calculated according to ISO 4302:2016, 6.2.

6.4 Loads caused by erection, dismantling and transport

Loads caused by erection, dismantling and transport shall be considered in accordance with ISO 8686-1:2012, 6.4.1. For tower cranes, these loads are classified as exceptional load (load combination type C) as a basic statement.

In instances where the frequency of exposure is occasional or regular, the corresponding partial safety factors shall be taken for these design and stability load cases.

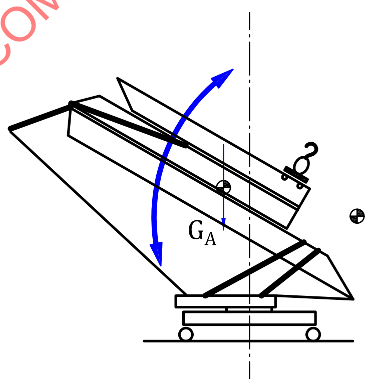
At the erection, dismantling and transportation of tower cranes several different types of loads shall be considered.

— Weight forces: Weight forces shall be calculated using the dynamic amplification from Table 1, line 1, as applicable.

— Mass forces from impact of a hoist load: In case of hoisting an unrestrained grounded load, the mass of the hoist load shall be multiplied by the coefficient ϕ_2 according to Table 1, line 2, as applicable. The characteristic of the hoist drive shall be considered.

— Mass forces due to accelerations from drives: For loads induced in a crane by accelerations or decelerations caused by drive, the coefficient ϕ_5 according to Table 1, load line 5 shall be considered, as applicable. The load effect of these mass forces shall not be less than 10 % of the weight force in the direction of the actual motion.

For a typical self-erecting tower crane, loading conditions through the whole process of folding and unfolding shall be considered (see Figure 2).



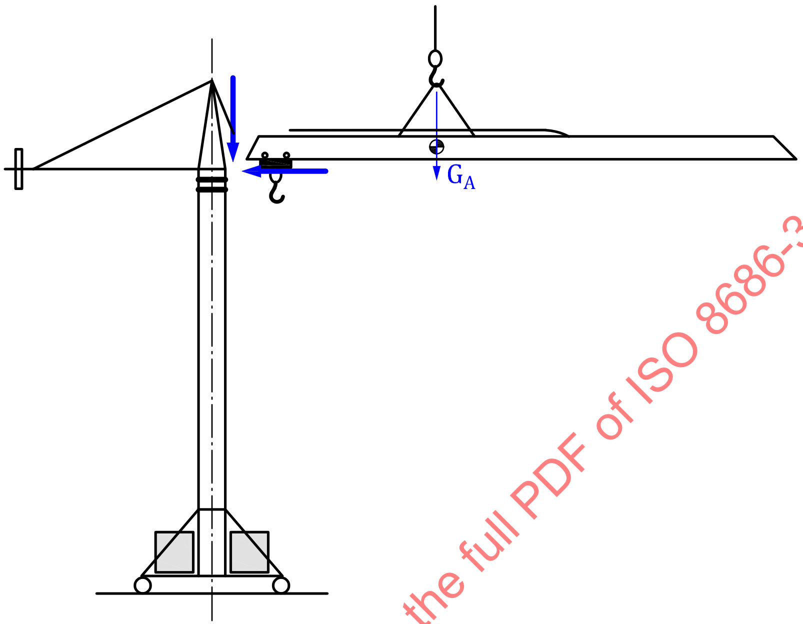
Key

G_A mass of a part of a crane creating mass forces caused by accelerations or decelerations of the assembly drive

Figure 2 — Mass forces due to accelerations from drives

— Mass forces from impact of assembled or disassembled parts: For loads induced in a crane by impact of assembled parts a vertical or horizontal force of 10 % of the weight of the assembled or disassembled part shall be applied in a manner that induces the most unfavourable load effect.

For a typical top slewing tower crane, a vertical load shall be considered, for example, while installing the counter ballast. A horizontal load shall be considered, for example, while installing the jib (see Figure 3).



Key

G_A mass of a part of a crane at assembly or disassembly creating a horizontal or vertical impact force

Figure 3 — Mass forces from impact of assembled or disassembled parts

— Wind forces: The minimum wind pressure that shall be considered during erection, dismantling and transport is $q_{(3)}$ = 125 Pa.

Additional requirements regarding erection load cases for climbing systems are given in Annex A.

6.5 Loads on means provided for access

Loads on means for access shall conform to ISO 8686-1:2012, 6.4.2 and the requirements given in Table 2.

Loads on means for access shall be regarded as local loads only affecting the components themselves and their direct support structure.

Table 2 — Loads on means provided for access

Component	Description	q_k	Q_k
Working platforms	Where parts or objects can be temporarily placed.	2,0 kN/m^2	3,0 kN
Rest platforms and walkways	For the exclusive use of persons.	1,0 kN/m^2	1,5 kN
Stairs		1,3 kN/m^2	2,0 kN
Ladders		0,6 kN/m	1,5 kN
Hoop guards	Load applied as a vertical load on each ring with the ladder in installation position. (safety load case).	—	1,0 kN

Table 2 *(continued)*

Component	Description	q_k	Q_k
Guardrail	Load applied as a horizontal load at the height of the handrail.	0,3 kN/m	0,5 kN
Cabin	Typical size with a capacity up to 3 persons staying inside the cabin.	2,0 kN/m^2	3,0 kN
Trolley basket	Typical size with a capacity of 1 person staying in the basket.	—	1,5 kN
Anchor points	Load applied in the direction in which the force, due to dynamic loading with a person, can act.	—	8,0 kN
Fixing element (anchor device)	Load on fixing element of a guide rope when dynamically loaded with a person.	—	12,0 kN

All loads, with the exception of loads on guardrails, anchor points and fixing elements, shall be applied vertically. Loads on guardrails shall be applied horizontally at the height of the handrail. Loads on anchor points or fixing elements shall be applied in the direction in which the force due to dynamic loading with a person can act.

If a proof of the local minimum load bearing capacity is required, e.g. for components without a sufficient load distribution capacity, then the proof of strength using the characteristic values of the single load, Q_k, according to the table above has to be carried out without a superposition of the surface or line load, q_k,. The contact area for Q_k comprises a square with a side length of 20 cm.

If an excess of concentrated loads is to be expected during assembly or service works, the single load shall be determined separately in this case and taken into account together with the evenly distributed rated surface loads at the proof of strength.

The loads stated above shall be regarded as regular loads. The safety coefficients of load combination A as well as load combinations according to the model given there have to be used. Wind loads do not need to be considered usually.

These values are minimum values. In cases where higher loads are to be expected, the higher loads have to be applied.

7 Load combinations

7.1 General

The proof calculation of tower cranes shall be based on the *limit state method* according to ISO 8686-1, which requires that the selected loads of a load combination are multiplied by the partial safety factor, γ_p.

For parts of a tower crane with a linear relationship between loads and load effects (sectional loads), the allowable stress method may be used alternatively with the given overall safety factor, γ_f.

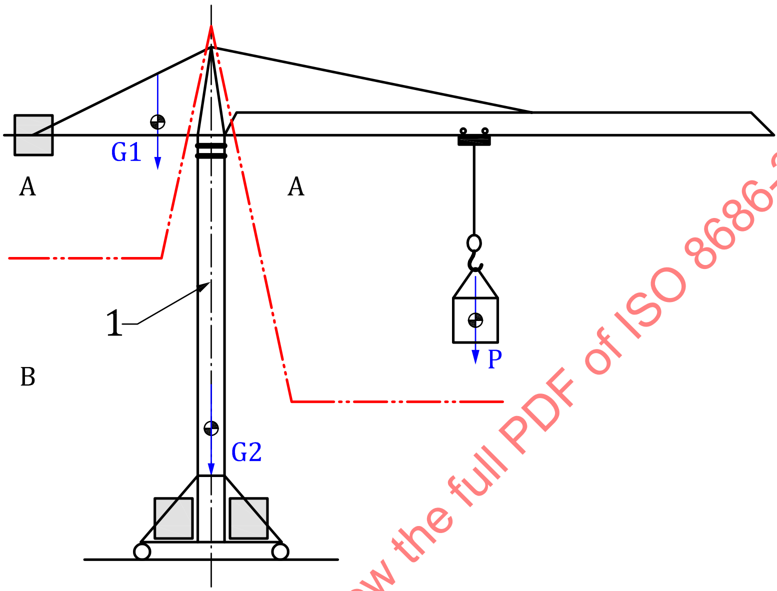
To determine the maximum load effect for a detail under consideration, it can be necessary to permute the magnitudes and orientations of load actions involved in a load combination. In doing so, some loads may be set to their minimum value or zero.

7.2 Favourable and unfavourable masses

When calculating gravitational loads for a given crane configuration and load combination, the masses of parts of the crane can either increase ("unfavourable") or decrease the resulting load effect ("favourable") at the detail under review. Considering the different load combinations according to 7.5 and 7.7, the same mass can be favourable in some configurations and unfavourable in other configurations.

For tower cranes, the slewing axis can be defined as reference axis to determine the effect of the mass load action at the proof of strength. The evaluation takes place under non-deformed condition with unfactored loads. Components with a centre of gravity (COG) lying on the reference axis (e.g. tower section of top-slewing tower cranes) shall be considered as unfavourable.

Figures 4, 5, and 6 show the reference axis and the assignment of the different parts of the crane regarding the behaviour of their masses. All parts above the dash-dotted line are assumed to have always an unfavourable influence on the loading and all parts below have either an unfavourable or a favourable influence on the loading at the point under consideration.



Key

A crane components or parts which always have an unfavourable influence on the loading at the point under consideration in all load combinations

B crane components or parts which can have either an unfavourable or a favourable influence on the loading at the point under consideration depending on the load combination

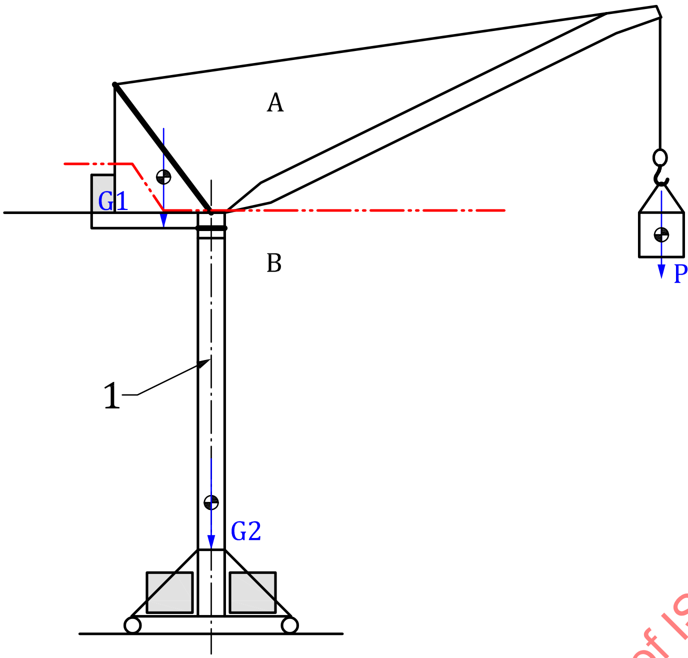
G1 mass and centre of gravity of the rotating upper works

G2 mass and centre of gravity of the stationary lower works

P mass of hoist load

1 reference axis for determining load effects of masses for the proof of strength

Figure 4 — Favourable and unfavourable masses of a trolley jib tower crane (top slewing trolley jib tower crane with articulated connected counter-jib and rigidly connected tower top)



Key

A crane components or parts which always have an unfavourable influence on the loading at the point under consideration in all load combinations

B crane components or parts which can have either an unfavourable or a favourable influence on the loading at the point under consideration depending on the load combination

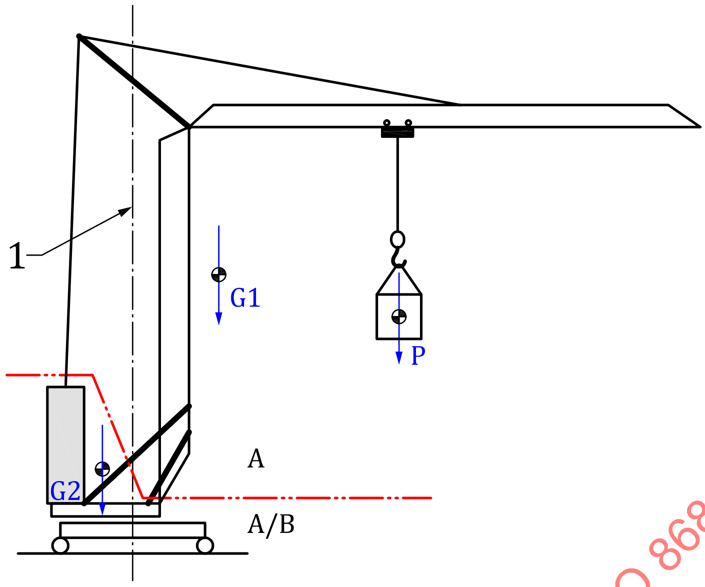
G1 mass and centre of gravity of the rotating upper works

G2 mass and centre of gravity of the stationary lower works

P mass of hoist load

1 reference axis for determining load effects of masses for the proof of strength

Figure 5 — Favourable and unfavourable masses of a luffing jib tower crane (top slewing luffing tower crane with rigidly connected counter-jib and articulated connected A-frame)



Key

A crane components or parts which always have an unfavourable influence on the loading at the point under consideration in all load combinations

B crane components or parts which can have either an unfavourable or a favourable influence on the loading at the point under consideration depending on the load combination

G1 mass and centre of gravity of jib and tower incl. suspension system

G2 mass and centre of gravity of slewing table incl. counter ballast and undercarriage

P mass of hoist load

1 reference axis for determining load effects of masses for the proof of strength

Figure 6 — Favourable and unfavourable masses of a self-erecting tower crane (bottom slewing self-erecting tower crane)

The slewing table and the undercarriage of self-erecting tower cranes (see Figure 6) shall be considered as components, which are subject to unfavourable and favourable load effects, in case the combined centre of gravity (COG) of all parts above the slewing ring is shifted behind the slewing axis.

The classification of a part of the crane to have only unfavourable mass load effects do not automatically imply a linear relationship between loads and load effects (sectional loads). In many cases, some parts (e.g. the jib of a luffing jib crane or the tower of a self-erecting tower crane) shall be calculated using the "limit state method" considering the deformed system in a state of equilibrium (second order theory).

7.3 Partial safety factors for the mass of the crane

The partial safety factors γ_p shall be chosen from Table 3 depending on the method of determining the masses of the crane parts and whether they have an unfavourable or favourable influence on the load effect at the point under consideration, according to 7.2.

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

The partial safety factors given in Table 3 may only be applied if the ratio between the sum load effect due to favourable masses of crane parts and the sum load effect of unfavourable masses of crane parts together with the load effect of the hoist load is less than 0,6 — see Formula (4). These load effects shall be calculated without application of an amplification factor (partial safety factor or dynamic coefficient).

$$f_L = \left| \frac{L_f}{L_{unf} + L_h} \right| < 0{,}6 \quad (4)$$

where

f_L is the ratio of load effects;

L_f is the load effect of favourable masses of crane parts;

L_{unf} is the load effect of unfavourable masses of crane parts;

L_h is the load effect of the hoist load.

In case above condition is not fulfilled, partial safety factors according to ISO 8686-1:2012, Table 4 shall be used.

Table 3 — Values of partial safety factors, γ_p

Method of determining masses of crane parts and their centres of gravity	Load combinations according 7.5					
	A		B		C	
	Un-favourable	Favourable	Un-favourable	Favourable	Un-favourable	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

7.4 High risk applications

For usual applications of tower cranes, the risk coefficient, γ_n, is not required. This coefficient may only be applied for special application on special request from a user and according to ISO 8686-1:2012, 7.3.6.

7.5 Load combinations for the proof of strength

Load combinations to consider for tower cranes are given in Table 4 using the loads defined in Clause 6.

Table 4 — Loads, load combinations and partial safety factors for proof of strength

Categories of loads	Loads			Load combinations A			Load combinations B			Load combinations C													
				Partial safety factor γ_p	A1	A3	Partial safety factor γ_p	B1	B3	Partial safety factor γ_p	C1	C2.1[c]	C2.2[c]	C2.3[c]	C3	C6	C7	C8	C9	C10.1[d]	C10.2[d]	C10.3[d]	...
Regular	Gravitation, acceleration, impact	Mass of the crane		[a]	ϕ_1	ϕ_1	[a]	ϕ_1	ϕ_1	[a]	ϕ_1	1	1	1	ϕ_1	ϕ_1	ϕ_1	1	ϕ_1	ϕ_1	ϕ_1	ϕ_1	
		Mass of the hoist load		1,34	ϕ_2	1	1,22	ϕ_2	1	1,1	ϕ_2	η_w [e]	η_w [e]	η_w [e]	ϕ_6	1	1	1	ϕ_9	ϕ_2	1	1	
	Acceleration from drives[b]	Masses of the crane and the hoist load	Hoist drives excluded	1,34	ϕ_5	—	1,22	ϕ_5	—	1,1	ϕ_5	—	—	—	ϕ_5	—	—	—	ϕ_5	ϕ_5	—	—	
			Hoist drives included		—	ϕ_5		—	ϕ_5		—	—	—	—	—	ϕ_5	ϕ_5	—	—	—	ϕ_5	—	
Occasional	Environmental actions	In—service wind loads		—	—	—	1,22	1	1	1,1	—	—	—	—	—	—	—	—	—	—	—	—	
Exceptional	Out-of-service wind loads			—	—	—	—	—	—	1,1	—	1	—	—	—	—	—	—	—	—	—	—	
	Out-of-service wind loads from front			—	—	—	—	—	—	1,0	—	—	1	—	—	—	—	—	—	—	—	—	
	Out-of-service wind loads from side			—	—	—	—	—	—	1,0	—	—	—	1	—	—	—	—	—	—	—	—	
	Test loads			—	—	—	—	—	—	1,1	—	—	—	—	1	—	—	—	—	—	—	—	
	Emergency Off			—	—	—	—	—	—	1,1	—	—	—	—	—	1	—	—	—	—	—	—	
	Failure of mechanisms			—	—	—	—	—	—	1,1	—	—	—	—	—	—	1	—	—	—	—	—	
	Excitation of the crane foundation[f]			—	—	—	—	—	—	1,0	—	—	—	—	—	—	—	1		—	—	—	
	Unintentional loss of hoist load			—	—	—	—	—	—	1,1	—	—	—	—	—	—	—	—	1	—	—	—	
	Erection, dismantling and transport — impact load			—	—	—	—	—	—	1,1	—	—	—	—	—	—	—	—	—	—	—	1	
	Erection, dismantling and transport — wind loads			—	—	—	—	—	—	1,1	—	—	—	—	—	—	—	—	—	1	1	1	
	...																						
Resistance coefficient, γ_m				1,1	—		1,1	—		1,1	—												
Overall safety factor, γ_f				1,48			1,34			1,22													

[a] For values of the partial safety factor to be applied. See 7.3, Table 3.

[b] Additionally to the hoist load, only two further mass forces need to be considered. For load combinations type C, only one further mass force needs to be considered.

[c] For loads due to out-of-service wind, see 6.3.

[d] For loads caused by erection, dismantling and transport to be considered, see 6.4.

[e] η_w: Factor for remaining hoist load in out-of-service condition.

[f] For load combination C8, considering excitation of the crane foundation (e.g. earthquake), a partial safety factor γ_p = 1,0 and a resistance coefficient γ_m = 1,0 can be accepted.

Table 4 *(continued)*

Categories of loads	Loads	Load combinations A			Load combinations B			Load combinations C													
		Partial safety factor γ_p	A1	A3	Partial safety factor γ_p	B1	B3	Partial safety factor γ_p	C1	C2.1[c]	C2.2[c]	C2.3[c]	C3	C6	C7	C8	C9	C10.1[d]	C10.2[d]	C10.3[d]	…
Load combination definitions: Load combinations A cover regular loads for a crane under normal operation: A1: Hoisting an unrestrained grounded load in combination with other mass loads created by crane drives. A3: Hoisting or lowering a lifted load in combination with other mass loads created by crane drives.																					
Load combinations B cover regular loads combined with occasional loads: B1 & B3: Load combinations are equivalent to load combinations A1 and A3 but additionally in-service wind.																					
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. C2.1: Crane under out-of-service conditions, including out-of-service wind from rear. C2.2: Crane under out-of-service conditions, including out-of-service wind from front. C2.3: Crane under out-of-service conditions, including out-of-service wind from side. C3: Crane under test conditions. C6: Crane with hoist load in combination with loads caused by “Emergency Off”. 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 in emergency situation with unintentional loss of hoist load. C10.1: Crane during erection, dismantling considering hoisting an unrestrained grounded load including erection wind loads. C10.2: Crane during erection, dismantling considering a hoist load with any combination of accelerating or decelerating forces caused by any of the drives, including the hoist drive, or of their sequence during positioning movements, including erection wind load. C10.3: Crane during erection, dismantling considering an impact of assembled or disassembled parts, including erection wind load.																					

7.6 Load combinations for the proof of fatigue

The effects of fatigue shall be considered. The method of verification shall conform to ISO 20332:2016, Clause 6.

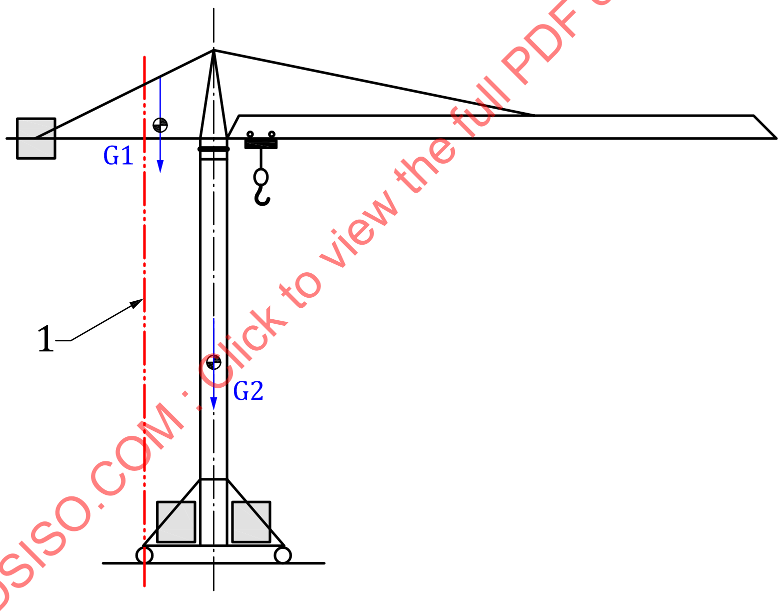
In general, regular loads (load combinations A) shall be taken into account at the proof of fatigue.

For tower cranes, crane travelling may be excluded from the fatigue analysis. However, for some types of crane, it can be necessary to also consider loads which are classified as occasional or exceptional loads by this document.

7.7 Load combinations for the proof of stability

A tower crane is considered to be stable if the resulting moment — considering the partial safety factors for all participating loads (according to Table 5) — is greater than or equal to zero regarding the most unfavourable tilting edge. The tilting edge is a line passing through two adjacent support points of the crane. Moments having a tilting effect receive a negative sign.

Masses of structural parts shall receive the appropriate partial safety factors following the principle given in 7.2 for the proof of strength, except that the reference axis shall be the tipping axis for the proof of stability (see Figure 7 and 8). These masses can have a favourable or an unfavourable load effect.



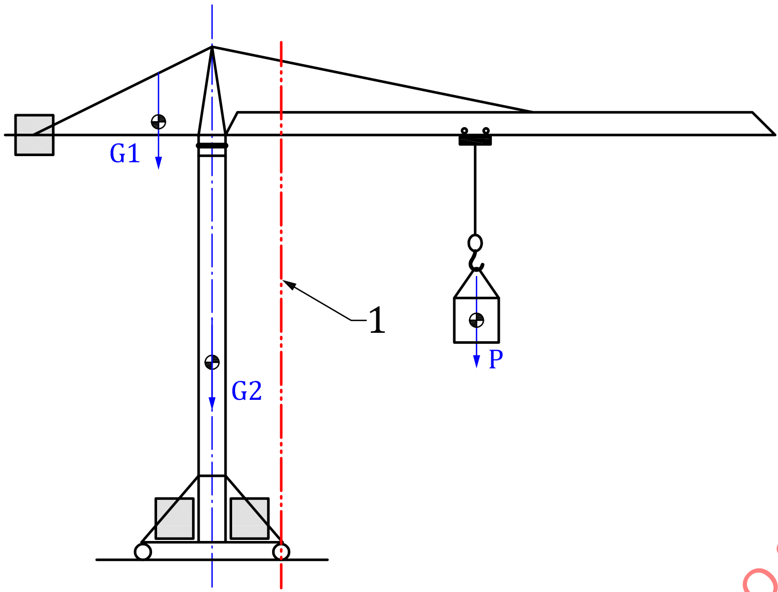
Key

G1 mass and centre of gravity of the rotating upper works

G2 mass and centre of gravity of the stationary lower works

1 reference axis for determining load effects of masses for proof of stability

Figure 7 — Example for reference axis for top slewing tower cranes without load



Key

G1 mass and centre of gravity of the rotating upper works

G2 mass and centre of gravity of the stationary lower works

P mass of hoist load

1 reference axis for determining load effects of masses for proof of stability

Figure 8 — Example for the reference axis for top slewing tower cranes with load

Load combinations to consider for tower cranes are given in Table 5.

At all these load combinations the dynamic factors, ϕ_i, shall be set to $\phi_i = 1{,}0$.

The following requirements shall be met in order that tower cranes are able to use the partial safety factors for the proof of stability.

— Proof exists that the ground to support the crane can reliably withstand the supporting forces, without significant unintended displacements (see Clause 8) or taking into account their effect on stability. A resulting slope of the crane supporting structure lower than 0,2 % is seen as not significant and does not need to be considered.

— Reliable load indicating and limiting system exists, that pre-warns the crane driver and finally cuts out any movements that decrease the stability.

— Relevant masses (e.g. slewing part of the tower crane) and their centres of gravity shall be evaluated with an accuracy of ±3 %.

