INTERNATIONAL STANDARD

ISO 8686-2

Second edition
2018-06

Cranes — Design principles for loads and load combinations —

Part 2: **Mobile cranes**

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

Partie 2: Grues mobiles

Reference number
ISO 8686-2:2018(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on 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 the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 96, *Cranes*, Subcommittee SC 6, *Mobile cranes*.

This second edition cancels and replaces the first edition (ISO 8686-2:2004), which has been technically revised. The main changes compared to the previous edition are as follows:

— the document has been adapted to ISO 8686-1:2012;

— the Annexes have been renumbered after former Annex A has been deleted;

— Tables 1 and 2 have also been technically revised.

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 2:
Mobile cranes

1 Scope

This document applies the principles set forth in ISO 8686-1 to mobile cranes, as defined in ISO 4306-2, and presents loads and load combinations appropriate for use in proof-of-competence calculations for the steel structures of mobile cranes.

This document is applicable to mobile cranes used for normal and duty cycle service.

NOTE Means for proof-of-competence testing will be addressed in another document.

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 4302:2016, *Cranes — Wind load assessment*

ISO 4306-2, *Cranes — Vocabulary — Part 2: Mobile cranes*

ISO 4305, *Mobile cranes — Determination of stability*

ISO 4310, *Cranes — Test code and procedures*

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

ISO 10721-1, *Steel structures — Part 1: Materials and design*

ISO 10721-2, *Steel structures — Part 2: Fabrication and erection*

ISO 11662-2, *Mobile cranes — Experimental determination of crane performance — Part 2: Structural competence under static loading*

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 4306-2 and the following 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 http://www.electropedia.org/

3.1
rated capacity
rated load
hoist medium load which includes the mass of lifting attachments

3.2
normal service
hook duties for which fatigue analysis of the steel load-supporting structure is not required

3.3
duty cycle service
repetitive duties for which fatigue analysis of the steel load-supporting structure may be required

EXAMPLE Grab, dragline, magnet or comparable repetitive duty.

4 Choice of loads and load combinations

4.1 Basic considerations

Loads shall be combined with the intention of discovering maximum load effects on mobile crane components or members during operation, in accordance with the manufacturer's instructions, as simulated by elastostatic calculation. To achieve this, the following considerations govern preparation of proof-of-competence calculations.

a) The crane is taken in its most unfavourable position and configuration, while the loads are assumed to act in magnitude, position and direction causing unfavourable stresses at the critical points selected for evaluation on the basis of engineering considerations; and

b) conservatively, loads can be combined at the values defined in this document or, when appropriate, they can be combined with certain loads, adjusted by reduction factors for the probability of combined actions to more closely reflect loading conditions currently found in practice.

4.2 Simultaneous accelerations

The effect of one accelerating drive, e.g. slewing, luffing or telescoping, is assumed to act simultaneously with hoisting acceleration; only two drives are assumed to accelerate simultaneously in the absence of hoisting acceleration. See Annex A for further information on simultaneous accelerations.

4.3 Side loading

Certain design features may have the effect of inducing side loading on booms. When those features are present in a design, they shall be included with all applicable load combinations for which calculations are performed, combined so as to maximize side loading. In addition to slewing and wind effects, features affecting side loading may include:

a) reeving arrangements that cause the hoist line to deviate from the boom centreline, between the boom point sheave and the most extreme position on the hoisting drum; and

b) inclination of the boom foot due to deflection of the supporting crane structure.

4.4 Erection and dismantling

An evaluation shall be made for each step in the erection and dismantling processes, as appropriate to the crane type and configuration, and proof-of-competence calculations shall be carried out for each instance of significant member or component loading. Calculations shall utilize factors from Table 1 as given under load combinations B.

4.5 Automatically initiated actions

When mobile cranes are furnished with controls or devices that cut out drives and apply brakes without an initiating action by the driver, or are furnished with brakes that automatically engage on loss of power or control function, calculations reflecting those effects shall be carried out under Emergency cut-out, see column C4.

5 Loads from acceleration of crane drives

5.1 General

Mobile cranes are typically designed to accommodate a range of boom lengths and various extensions or front-end attachments. Therefore, some cranes can possess excess power in some configurations, power that crane drivers in practice do not fully utilize (in accordance with the manufacturer's instructions). Therefore, in proof-of-competence calculations, the effects acting on the mass of the crane, either acceleration or deceleration may need to be chosen on the basis of a simulation or tests rather than on drive or brake characteristics.

5.2 Slewing effects

In practice, slewing acceleration and deceleration rates can vary depending on the front-end attachment fitted, the operating radius, the control scheme employed, the crane driver's operating practices, and the characteristics of the slewing drive and braking mechanisms. For proof-of-competence calculations, the forces on the mass of the crane and the rated load by slewing acceleration or deceleration which produce side loading can be taken as follows.

a) For cranes with stepped drive controls and for cranes in which the driver does not have control over slewing acceleration or deceleration rates, the forces on the mass of the crane and the rated load shall be calculated from drive/brake characteristics.

b) For cranes with stepless continuously variable drive controls, the forces on the mass of the crane and the rated load shall be calculated based either on:

   1) the highest forces which occur during normal operation as described in the manufacturer's instructions; or

   2) a simulation or tests; or

   3) drive/brake characteristics.

But the resulting lateral force from slewing, applied to the boom tip, shall not be taken less than the maximum of:

— 1 % of the rated load plus 1 % of the mass of the main boom and jib reduced to the boom head or jib head (see ISO 4305, ISO 4310); and

— 2 % of the rated load for latticed booms or 3 % for telescopic booms.

5.3 Hoisting effects

5.3.1 Hoisting effects acting on the mass of the crane, except for the rated load itself, shall be calculated according to ISO 8686-1:2012, 6.1.1 (see also Table 2, line 1)

5.3.2 Hoisting effects acting on the mass of the rated load shall be calculated according to ISO 8686-1:2012, 6.1.2.

5.4 Driving effects

5.4.1 Driving acceleration

Loads caused by driving acceleration or deceleration, with or without load, shall be estimated from experience or experiment, or by calculation using an appropriate model for the crane.

5.4.2 Driving on uneven surface

Loads caused by travelling on uneven surface shall be calculated according to ISO 8686-1:2012, 6.1.3

5.5 Luffing and telescoping effects

Loads caused by luffing and telescoping, with or without load, shall be estimated from experience or experiment, or by calculation using an appropriate model for the crane.

5.6 Application of loads caused by acceleration

The forces on the mass of the crane caused by acceleration are amplified by an appropriate dynamic amplification factor value, ϕ_5, according ISO 8686-1:2012, 6.1.4.

6 Proof-of-competence calculations for load-supporting structures

6.1 General

Principally, a proof of fatigue according to ISO 20332 and proof of rigid body stability according to ISO 4305 shall be performed.

6.2 Allowable stress method

6.2.1 Table 1 gives loads and load combinations for the allowable stress method, together with an overall strength coefficient γ_f and dynamic amplification factors, ϕ_n. Table 2 gives values for the factors ϕ_n and other pertinent load information.

6.2.2 For members under axial compression, the overall strength coefficient, γ_f, given in Table 1 shall only be used in conjunction with a column formula (or curve) from ISO 10721-1 or ISO 10721-2.

6.3 Limit state method

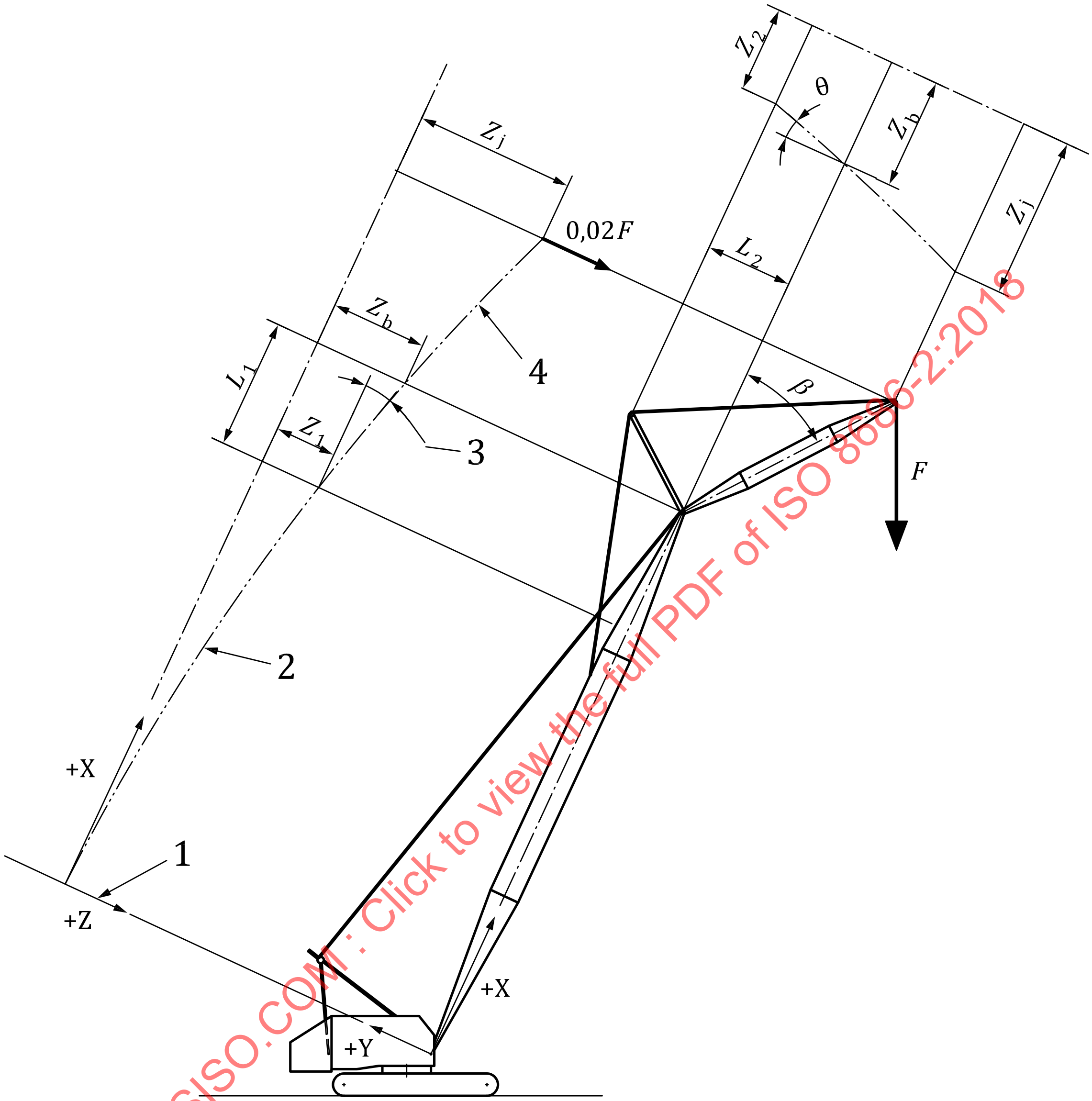
6.3.1 Table 1 gives loads and load combinations for the limit state method, together with applicable partial load factors, γ_p, and dynamic amplification factors, ϕ_n. Table 2 gives values for the factors ϕ_n and other pertinent load information. The resistance coefficient, γ_m, shall be taken as 1,1 for all load combinations. This coefficient shall reflect statistical variations in material strength.

6.3.2 For members under axial compression, the resistance coefficient, γ_m, and the partial load factors, γ_p, given in Table 1 shall only be used in conjunction with a column formula (or curve) from ISO 10721-1 or ISO 10721-2.

7 Side-load deflection of latticed booms

7.1 Lateral deflection of latticed booms and fly jibs are a measure of elastic stability, as these members are primarily loaded in compression. Excessive side deflections can induce elastic instability. Therefore, all wire-rope-supported latticed booms and fly jibs shall be limited to deflections not exceeding 2 % of their effective length when subjected to rated load together with side loading of 2 % of rated load.

Deflection limits shall be verified by calculation and by test according to ISO 11662-2. Deflection limitations apply only to mobile cranes with latticed booms and fly jibs mounted on latticed booms.



Key

1 boom foot centreline

2 boom centreline

3 slope Z'

4 jib centreline

F rated load

Figure 1 — Terms and symbols related to deflection measurement — Lattice jib with fly jib

7.2 For a single fly jib mounted on a jib, Formula (1) is given (Figure 1):

$$Z_j \leq 0{,}02\, L_j + Z_b + Z' (L_j \cos\beta) + \theta\, (L_j \sin\beta) \qquad (1)$$

where the following values are calculated (or measured):

- Z_j is the fly jib tip deflection;
- Z_b is the latticed jib tip deflection;
- Z_1 is the latticed jib deflection at a distance L_1 down from the jib tip;
- Z_2 is the fly jib strut deflection at the tip;

and the following values are calculated:

Z' (slope) = $(Z_b - Z_1) / L_1$

$\theta = (Z_b - Z_2) / L_2$

If slope Z' and torsion θ are not calculated, the last two terms of Formula (1) may be deleted.

Table 1 — Loads and load combinations — Mobile cranes — Limit state method

Categories of loads	Loads f_i		Row	Load combinations A					Load combinations B					Load combinations C						
				Factor γ_p	A1	A2	A3	A4	Factor γ_p	B1	B2	B3	B4	Factor γ_p	C1	C2	C3	C4	C5	C6
Regular	Gravity, acceleration and impacts	Mass of the crane	1	[a]	ϕ_1	ϕ_1	1	—	[a]	ϕ_1	ϕ_1	1	—	[a]	1	ϕ_1	1	1	1	1
		Mass of the rated load	2	1,34	ϕ_2	ϕ_3	1	—	1,22	ϕ_2	ϕ_3	1	—	1,1	1	—	—	1	1	−0,1
		Loads caused by travelling on an uneven surface	3	1,22	—	—	—	ϕ_4	1,16	—	—	—	ϕ_4	—	—	—	—	—	—	—
	Acceleration from drives	Masses of the crane and rated load	4	1,34	ϕ_5	ϕ_5	ϕ_5	ϕ_5	1,22	ϕ_5	ϕ_5	ϕ_5	ϕ_5	1,1	ϕ_5	—	—	ϕ_5	—	—
	Displacements[c]		5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Occasional	Effects of climate	In service wind	6	—	—	—	—	—	1,22	ω	ω	ω	ω	1,16	—	—	1	1		1
		Temperature	7	—	—	—	—	—	1,16	1	1	1	1	1,05	1	—	—	—	1	1
Exceptional		Erection and de-erection wind	8	—	—	—	—	—	—	—	—	—	—	1,16	1	—	—	—	—	—
		Out of service wind	9	—	—	—	—	—	—	—	—	—	—	1,16	—	—	—	—	1	—
	Hoisting a grounded load/ hoisting with max speed		10	—	—	—	—	—	—	—	—	—	—	1,1	—	ϕ_{2max}	—	—	—	—
	Test loads		11	—	—	—	—	—	—	—		—	—	1,1	—	—	ϕ_6	—	—	—
Resistance coefficient, γ_m			12	1,1	—				1,1		—			1,1	—					
Overall strength coefficient, γ_f, only for “Allowable stress method”			13	1,48	[b]				1,34		[b]			1,22	[b]					

[a] The partial safety factors shall be taken in accordance with ISO 8686-1:2012, Table 4, with due consideration to variable factors shown in the table.

[b] Load combinations and factors for dynamic effects see limit states method.

[c] See ISO 8686-1:2012, 6.1.5 “Loads induced by displacements”.

Table 2 — Requirements and values for factors, ϕ_n

Table 1: row Nos.	ϕ_n	References ISO 8686-1:2012	Comment
1	ϕ_1	6.1.1	See ISO 8686-1:2012, Annex B, for additional information. $\phi_1 = 1 \pm a$ $a = 0$ for normal service $a \le 0{,}1$ for duty cycle service such as grab, dragline or magnet work (unfavourable) or $a \le 0{,}05$ for duty cycle service such as grab, dragline or magnet work (favourable) The value of ϕ_1 shall be taken as greater or less than 1,0, depending on whether the effect is favourable or unfavourable.
2	ϕ_2	6.1.2.1	Depending on the characteristics/flexibility of the structure, the hoisting class HC shall be classified. For some kinds of mobile cranes (e.g. telescopic cranes) the hoisting class can be assumed as HC1 with φ2 min = 1,05. For other situations, see ISO 8686-1.
2	ϕ_3	6.1.2.2	Applicable for grab, dragline, magnet or similar service
3	ϕ_4	6.1.3.1	See ISO 8686-1:2012, Annex C, for detailed calculation. Alternatively use a simplified approach for: — wheeled mobile cranes: $\phi_4 = 1{,}1$ for travel speed ≤ 0,4 m/s; $\phi_4 = 1{,}3$ for travel speed > 0,4 m/s; — for track-mounted (crawler) mobile cranes: $\phi_4 = 1{,}0$ for travel speed ≤ 0,4 m/s; $\phi_4 = 1{,}1$ for travel speed > 0,4 m/s.
4	ϕ_5	6.1.4	See ISO 8686-1:2012, Annex D, for detailed calculation. Alternatively, use a simplified approach: — for mobile cranes with stepless continuously-variable drive controls: $\phi_5 = 1{,}2$ for normal service; $\phi_5 = 1{,}5$ for duty cycle service; — for mobile cranes with stepped drive controls: $\phi_5 = 1{,}6$ for normal service; $\phi_5 = 2{,}0$ for duty cycle service.
6		6.2.1.1	When lifting loads with a — on the load related — area exposed to wind greater than 1,2 m²/t, $\omega > 1$ accounts for the higher sensitivity of the crane system to wind influences. $\omega = 1 + \frac{\max\left(\frac{A \times C_f}{P};1{,}2\right) - 1{,}2}{14} \le 1{,}25$ A, C_f: ISO 4302:2016, Formula (4) shall be taken as reference P = mass of rated load [t].
7		6.2.1.3	Temperature
8			Erection and de-erection wind load and/or crane configuration shall be specified by the manufacturer.

Table 2 *(continued)*

Table 1: row Nos.	ϕ_n	References ISO 8686-1:2012	Comment
9		6.3.1	The maximum out-of-service wind load and/or crane configuration shall be specified by the manufacturer.
10	$\phi_{2,max}$	6.1.2.1	Hoisting with maximum speed
11	ϕ_6	6.3.2	≥1,25 (in accordance with ISO 4310:2009)

Annex A
(informative)

Simultaneous accelerations

A.1 Track-mounted (crawler) latticed boom crane

A.1.1 Possible acceleration combinations (see Figure A.1):

- — hoist (H) and slew (Sl);
- — hoist (H) and luff (Lu);
- — slew (Sl) and luff (Lu);
- — travel (Tr).

A.1.2 Additional accelerations may be combined with travel when specifically permitted by the manufacturer's instructions.

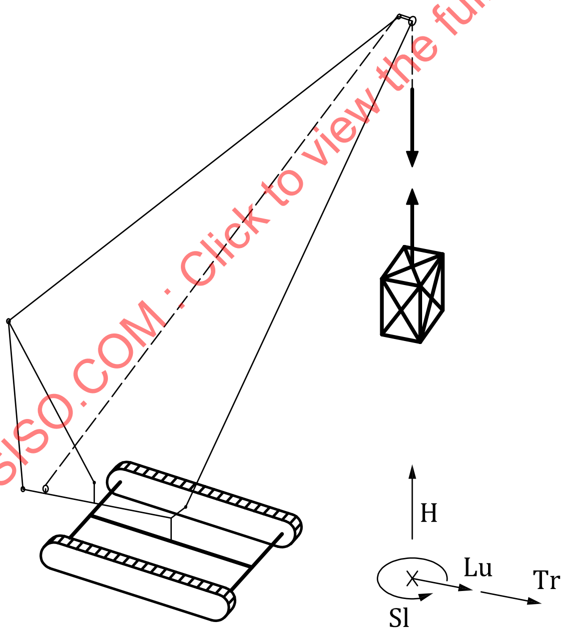


Figure A.1 — Track-mounted (crawler) latticed boom crane

A.2 Track mounted (crawler) telescopic boom crane

A.2.1 Possible acceleration combinations (see Figure A.2):

- — hoist (H) and slew (Sl);
- — hoist (H) and luff (Lu);
- — hoist (H) and telescope (Te);

— slew (Sl) and luff (Lu);

— slew (Sl) and telescope (Te);

— telescope (Te) and luff (Lu);

— travel (Tr).

A.2.2 Additional accelerations may be combined with travel when specifically permitted by the manufacturer's instructions.

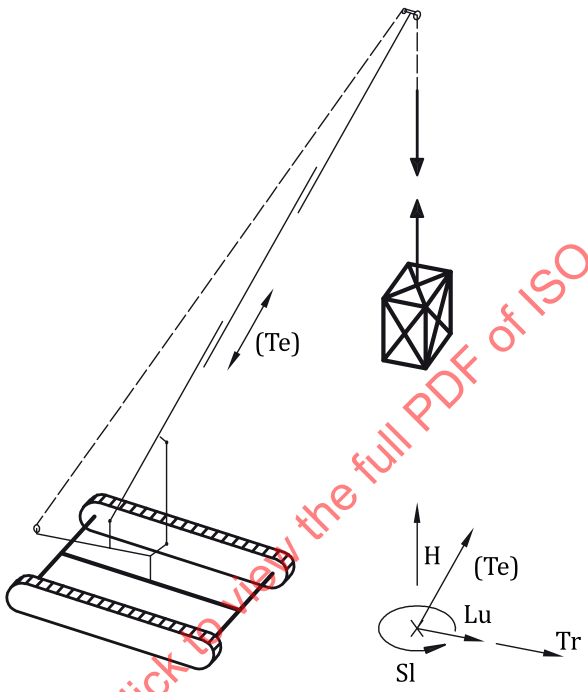


Figure A.2 — Track mounted (crawler) telescopic boom crane

A.3 Wheeled mobile latticed boom crane

A.3.1 Possible acceleration combinations (see Figure A.3):

— hoist (H) and slew (Sl);

— hoist (H) and luff (Lu);

— slew (Sl) and luff (Lu);

— travel (Tr).

A.3.2 Additional accelerations may be combined with travel when specifically permitted by the manufacturer's instructions.

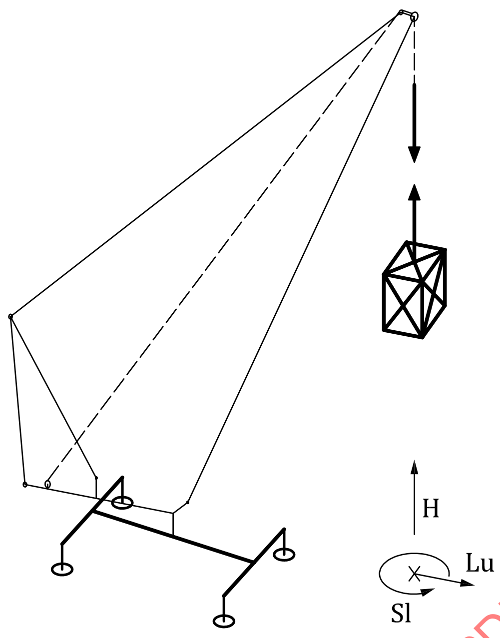


Figure A.3 — Wheeled mobile latticed boom crane (on outriggers)

A.4 Wheeled mobile telescopic boom crane

A.4.1 Possible acceleration combinations (see Figure A.4):

— hoist (H) and slew (Sl);

— hoist (H) and luff (Lu);

— hoist (H) and telescope (Te);

— slew (Sl) and luff (Lu);

— slew (Sl) and telescope (Te);

— telescope (Te) and luff (Lu);

— travel (Tr).

A.4.2 Additional accelerations may be combined with travel when specifically permitted by the manufacturer's instructions.

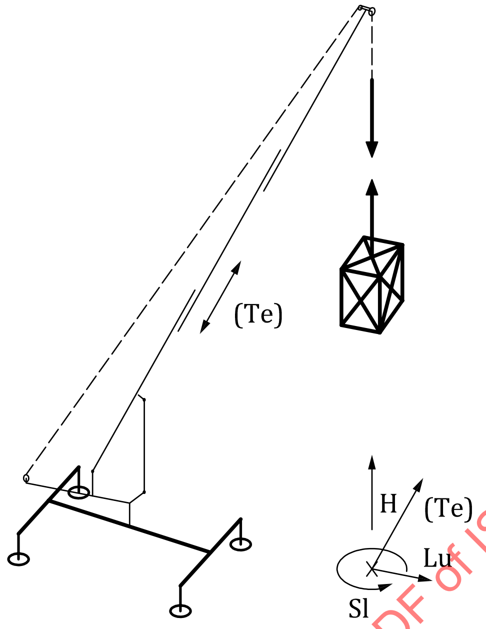


Figure A.4 — Wheeled mobile telescopic boom crane (on outriggers)

Annex B
(informative)

Application of load combinations given in Table 1

B.1 Description of load combinations

Table B.1 furnishes a general description of the loads that are to be included in each load combination and indicates which combinations apply only to cranes used in duty cycle service.

Table B.1 — Description of load combinations

Load combination from Table 1	Description
A1 (without in-service wind) and B1 (with in-service wind)	**Hoisting and moving 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 (without in-service wind) and B2 (with in-service wind)	Mobile cranes intentionally releasing a part of the suspended load while in motion. See 4.2 and ISO 8686-1:2012, 6.1.2.2.
A3 (without in-service wind) and B3 (with in-service wind)	Mobile cranes supporting suspended loads while two motions other than hoisting are engaged.
A4 (without in-service wind) and B4 (with in-service wind)	**Travelling on an uneven surface** 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, 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.
C1	Crane during erection, dismantling and transport. The manufacturer shall specify the maximum allowable wind-speed in the operations manual (minimum in-service wind-speed).
C2	Crane under in-service conditions, hoisting a grounded load at maximum hoisting speed, applying ϕ_2
C3	Crane under test conditions. See ISO 4310, minimum wind-speed to be applied in calculation: 8,3 m/s
C4	Emergency cut-out
C5	Crane out of service. The manufacturer shall specify the maximum allowable wind-speed in the operations manual
C6	Unexpected sudden release of load

B.2 Symbols

m_C mass of the crane or of an applicable component thereof;

m_R mass of the rated load;

m_T mass of the test load;

ΔF_S force resulting from the acceleration of the slewing drive which can be represented by a function, $f_S(m_C, m_R)$;

ΔF_L force resulting from the acceleration of the luffing drive which can be represented by a function, $f_L(m_C, m_R)$;

ΔF_T force resulting from the acceleration of the telescoping drive which can be represented by a function, $f_T(m_C, m_R)$;

ΔF_H force resulting from the acceleration of the load hoisting drive which can be represented by a function, $f_H(m_C, m_R)$;

ΔF_{Tr} force resulting from the acceleration of the travelling drive which can be represented by a function, $f_{Tr}(m_C, m_R)$;

σ stress resulting from the application of loads and their factors;

ϕ dynamic amplification factor, as given in Table 2 ;

F_D force resulting from a displacement;

F_ϑ load due to temperature variation;

F_W wind load due to in-service wind;

$F_{W\ out\text{-}of\text{-}service}$ wind load due to out-of-service wind;

$F_{W(E)}$ wind load during erection, dismantling and transport;

F_E load during erection, dismantling and transport;

Φ_{2max} dynamic factor resulting from the maximum hoisting speed.

B.3 Application of dynamic factors

The dynamic factors, ϕ, shall be applied to loads when the relationship between load and stress is non-linear. When the relationship is linear, the factors may be applied to either loads or stresses.

B.4 Selecting the appropriate loads in each applicable load combination

B.4.1 In load combinations A1 and B1, one drive force other than hoisting is combined. Therefore, only the combination including the drive force load producing maximum stress should be considered.

Select the greatest of ΔF_S or ΔF_L or ΔF_T = maximum drive force.

Then, for the Allowable Stress Method (ASM):

$$\sigma\ (A1) = \sigma\ (\phi_1 m_C + \phi_2 m_R + \phi_5 \times \text{maximum drive force} + F_D)$$

$$\sigma\ (B1) = \sigma\ (A1 + \omega F_W + F_\vartheta)$$

For the Limit State Method (LSM):

$$\sigma\ (A1) = \sigma\ (\gamma_p \phi_1 m_C + \gamma_p \phi_2 m_R + \gamma_p \phi_5 \times \text{maximum drive force} + \gamma_p F_D)$$

$$\sigma\ (B1) = \sigma\ (A1 + \gamma_P \omega F_W + \gamma_P F_\vartheta)$$