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ISO 8686-2

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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 8686-2:2004(E)

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Foreword

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ISO 8686-2 was prepared by Technical Committee ISO/TC 96, *Cranes*, Subcommittee SC 6, *Mobiles cranes*.

ISO 8686 consists of the following parts, under the general title *Cranes — Design principles for loads and load combinations*:

— *Part 1: General*

— *Part 2: Mobile cranes*

— *Part 3: Tower cranes*

— *Part 4: Jib cranes*

— *Part 5: Overhead travelling and portal bridge cranes*

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Cranes — Design principles for loads and load combinations —

Part 2: **Mobile cranes**

1 Scope

This part of ISO 8686 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 part of ISO 8686 is applicable to mobile cranes used for normal service and to mobile cranes used for duty cycle service.

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

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.

ISO 4302:1981, *Cranes — Wind load assessment*

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

ISO 4310:1981, *Cranes — Test code and procedures*

ISO 8686-1:1989, *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*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4306-2 and the following apply.

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, including occasional use for duty cycle work if duty cycle rating is no more than 80 % of normal service rating

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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 unfavorable attitude and configuration, while the loads are assumed to act in magnitude, position and direction causing unfavorable 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 part of ISO 8686 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. However, no simultaneous accelerations shall be considered when specifically prohibited by the manufacturer for a particular configuration. No other accelerations are combined with travel unless specifically permitted in the manufacturer's instructions.

See Annex B 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 or Table 2 as given under Load combinations B.

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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 on row 11 of Table 1 or Table 2.

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 may possess excess power in some configurations, power that crane drivers in practice will not fully utilize (in accordance with the manufacturer's instructions). Therefore, in proof-of-competence calculations, the change in drive force (ΔF) inducing either acceleration or deceleration may have to be chosen on the basis of a simulation of driver actions 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 changes in drive forces ΔF causing slewing acceleration or deceleration which produce side loading can be taken as follows.

a) For cranes with stepped drive controls and for cranes wherein the driver does not have control over slewing acceleration or deceleration rates, ΔF shall be calculated from drive/brake characteristics.

b) For cranes with stepless continuously-variable drive controls, ΔF shall be calculated based either on

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

   2) a simulation of driver actions or tests, or

   3) drive/brake characteristics, but the resulting lateral force from slewing, referred to the boom tip, shall not be taken as less than 2 % of the rated load for latticed booms or 3 % for telescopic booms.

5.3 Hoisting effects

5.3.1 Inertial effects due to hoisting, except for hoisting an unrestrained grounded load (see ISO 8686-1:1989, 6.1.2.2), depend on the change in hoist drive force ΔF. The change in this force can be calculated from hoist drive or brake characteristics; or for hoist drives with stepless continuously-variable drive control, ΔF can be taken as follows:

$$\Delta F = \delta \times F$$

$$\delta = 0{,}167(v_\mathrm{h} - 0{,}2) \qquad \text{for } 0{,}2 \leqslant v_\mathrm{h} \leqslant 1{,}7$$

where

F is the rated load, in newtons;

v_h is the hoisting/lowering speed, in metres per second.

As given above, factor δ is for cranes in normal service. δ can also be determined from experience or by test.

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5.3.2 No increase in δ is taken for hoisting or lowering speeds, v_h, greater than 1,7 m/s. When speeds are equal to or less than 0,2 m/s, δ is taken as 0.

5.3.3 For cranes in duty cycle service, δ is taken as twice the value for normal service, or alternatively, δ can be determined from experience or by test.

5.4 Application of changes in drive force, ΔF

5.4.1 ΔF values for hoisting are amplified by an appropriate dynamic amplification factor value ϕ_5 taken from Table 3 to make up the load for use on row 5 of Table 1 or Table 2.

5.4.2 ΔF values for drives other than hoisting are amplified by an appropriate dynamic amplification factor value ϕ_5 taken from Table 3, and the resulting inertial force shall comprise the load for use on row 4 of Table 1 or Table 2.

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

6.1 General

For proof-of-competence calculations, the crane manufacturer shall choose either the allowable stress method or the limit state method. Calculations by the allowable stress method shall be carried out in accordance with 6.2. Calculations by the limit state method shall be carried out in accordance with 6.3.

6.2 Allowable stress method

6.2.1 Table 1 gives loads and load combinations for the allowable stress method, together with applicable allowable stress coefficients γ_f and dynamic amplification factors ϕ_n. Table 3 gives values for the factors ϕ_n and other pertinent load information.

6.2.2 For members under axial compression, the allowable stress coefficients γ_f given in Table 1 are applicable only when used in conjunction with a column formula selected in accordance with Annex A.

6.3 Limit state method

6.3.1 Table 2 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 3 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 be divided into the limit strength to reflect statistical variations in material strength and local imperfections.

6.3.2 For members under axial compression, the resistance coefficient γ_m and the partial load factors γ_p given in Table 2 are applicable only when used in conjunction with a column formula selected in accordance with Annex A.

7 Side-load deflection of latticed booms

7.1 Lateral deflection of wire-rope-supported 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 may be verified by calculation or by test. Deflection limitations apply only to mobile cranes with latticed booms and fly jibs mounted on latticed booms.

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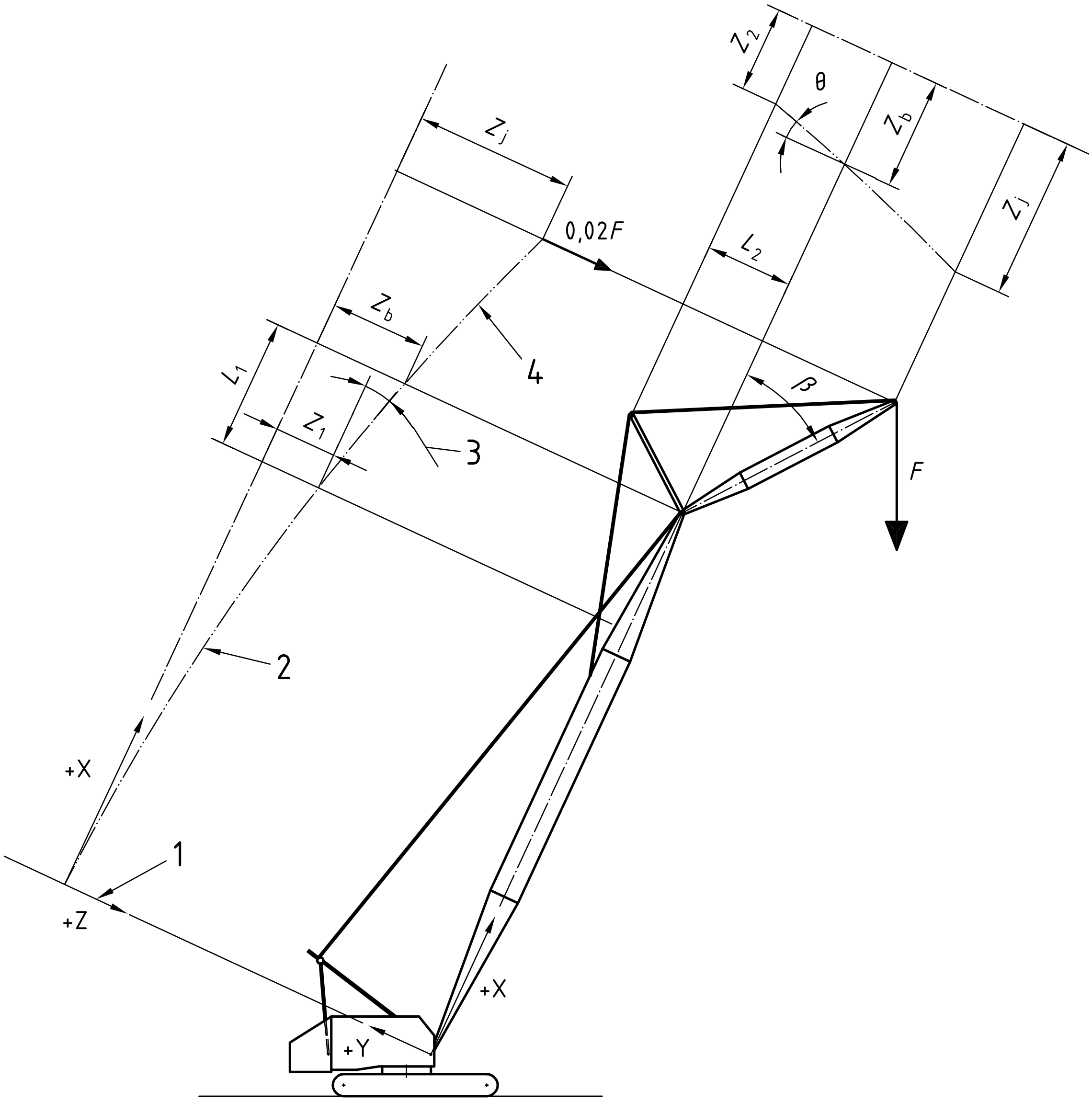

Key

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, the following relationship is given (Figure 1):

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

where the following values are calculated (or measured):

Z_j is the fly jib tip deflection;

Z_b is the latticed jib tip deflection;

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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 the equation for Z_j may be deleted.

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Table 1 — Loads and load combinations — Mobile cranes — Allowable stress method

Categories of loads	List of loads			Load combinations A: Allow. stress coef. γ_f	A1	A2	A3	A4	Load combinations B: Allow. stress coef. γ_f	B1	B2	B3	B4	Load combinations C: Allow. stress coef. γ_f	C1	C2	C3	C4	Row
Regular (6.1)	Gravity, acceleration and impacts	1. Mass of the crane		1,48	ϕ_1	ϕ_1	1	—	1,34	ϕ_1	ϕ_1	1	—	1,22	ϕ_1	1	ϕ_1	1	1
		2. Mass of the rated load			ϕ_2	ϕ_3	1	—		ϕ_2	ϕ_3	1	—		—	η	—	1	2
		3. Mass of the crane and rated load traveling on an uneven surface			—	—	—	ϕ_4		—	—	—	ϕ_4		—	—	—	—	3
	Acceleration from drives	4. Masses of the crane and rated load	Other than hoist drive		ϕ_5	ϕ_5	1	—		ϕ_5	ϕ_5	1	—		—	—	ϕ_5	—	4
			Hoist drive		—	—	ϕ_5	—		—	—	ϕ_5	—		—	—	—	—	5
Occasional (6.2)	Effects of climate	1. In-service wind			—	—	—	—		1	1	1	1		—	—	1	—	6
		2. Snow and ice			—	—	—	—		1	1	1	1		—	—	—	—	7
Exceptional (6.3)	1. Hoisting a grounded load				—	—	—	—		—	—	—	—		ϕ_2	—	—	—	8
	2. Out-of-service wind				—	—	—	—		—	—	—	—		—	1	—	—	9
	3. Test loads				—	—	—	—		—	—	—	—		—	—	ϕ_6	—	10
	4. Emergency cut-out				—	—	—	—		—	—	—	—		—	—	—	ϕ_5	11

NOTE 1 Under load combination C2, η allows for the mass of the hook block or overhaul ball remaining suspended when the crane is out of service. $\eta m = (m - \Delta m)$, see ISO 8686-1:1989, 6.3.1.

NOTE 2 The subclauses 6.1, 6.2 and 6.3 referenced in the first column, Categories of loads, are taken from ISO 8686-1:1989.

NOTE 3 See Table 3 for factors ϕ_n.

NOTE 4 See Table C.1 for descriptions of the load combinations.

NOTE 5 Additional load cases may need to be calculated. See 4.4.

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Table 2 — Loads and load combinations — Mobile cranes — Limit state method

Categories of loads	List of loads			Load combinations A: Partial load factor γ_p	A1	A2	A3	A4	Load combinations B: Partial load factor γ_p	B1	B2	B3	B4	Load combinations C: Partial load factor γ_p	C1	C2	C3	C4	Row
Regular (6.1)	Gravity, acceleration and impacts	1. Mass of the crane		1,22	ϕ_1	ϕ_1	1	—	1,16	ϕ_1	ϕ_1	1	—	1,1	ϕ_1	1	ϕ_1	1	**1**
		2. Mass of the rated load		1,34	ϕ_2	ϕ_3	1	—	1,22	ϕ_2	ϕ_3	1	—	1,1	—	η	—	1	**2**
		3. Mass of the crane and rated load traveling on an uneven surface		1,22	—	—	—	ϕ_4	1,16	—	—	—	ϕ_4	—	—	—	—	—	**3**
	Acceleration from drives	4. Masses of the crane and rated load	Other than hoist drive	1,34	ϕ_5	ϕ_5	1	—	1,22	ϕ_5	ϕ_5	1	—	1,1	—	—	ϕ_5	—	**4**
			Hoist drive	1,34	—	—	ϕ_5	—	1,22	—	—	ϕ_5	—	—	—	—	—	—	**5**
Occasional (6.2)	Effects of climate	1. In-service wind			—	—	—	—	1,16	1	1	1	1	1,1	—	—	1	—	**6**
		2. Snow and ice			—	—	—	—	1,22	1	1	1	1	1,1	—	—	1	—	**7**
Exceptional (6.3)	1. Hoisting a grounded load			—	—	—	—	—		—	—	—	—	1,1	ϕ_2	—	—	—	**8**
	2. Out-of-service wind				—	—	—	—		—	—	—	—	1,1	—	1	—	—	**9**
	3. Test loads				—	—	—	—		—	—	—	—	1,1	—	—	ϕ_6	—	**10**
	4. Emergency cut-out				—	—	—	—		—	—	—	—	1,1	—	—	—	ϕ_5	**11**

The resistance coefficient γ_m shall be taken as 1,1 for all load combinations.

NOTE 1 Under load combination C2, η allows for the mass of the hook block or overhaul ball remaining suspended when the crane is out of service. $\eta m = (m - \Delta m)$, see ISO 8686-1:1989, 6.3.1.

NOTE 2 The subclauses 6.1, 6.2 and 6.3 referenced in the first column, Categories of loads, are taken from ISO 8686-1:1989.

NOTE 3 See Table 3 for factors ϕ_n.

NOTE 4 See Table C.1 for descriptions of the load combinations.

NOTE 5 Additional load cases may need to be calculated. See 4.4.

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Table 3 — Requirements and values for factors ϕ_n

Tables 1 and 2: row Nos.	ϕ_n	References ISO 8686-1:1989	Values for factors ϕ_n Values for loads Relevant ISO standards
1	ϕ_1	6.1.1	$\phi_1 = 1 \pm a$ $a =$ 0 for normal service $a =$ 0,1 for duty cycle service such as grab, dragline or magnet work The value of ϕ_1 shall be taken as greater or less than 1,0, depending on whether the effect is favorable or unfavorable.
2	ϕ_2	6.1.2.1	Hoisting class is HC1 for normal service ϕ_2 = 1,0 (stepless continuously-variable drive control) Hoisting class is HC2 for occasional duty cycle service ϕ_2 = 1,3 (stepless continuously-variable drive control) For other situations, see ISO 8686-1
2	ϕ_3	6.1.2.3	Applicable for grab, dragline, magnet or similar service
3	ϕ_4	6.1.3.1	For wheeled mobile cranes: ϕ_4 = 1,1 for travel speed $\leqslant$ 0,4 m/s ϕ_4 = 1,3 for travel speed $>$ 0,4 m/s For track-mounted (crawler) mobile cranes: ϕ_4 = 1,0 for travel speed $\leqslant$ 0,4 m/s ϕ_4 = 1,1 for travel speed $>$ 0,4 m/s
4, 5, and 11	ϕ_5	6.1.4 and Annex E	For mobile cranes with stepless continuously-variable drive controls: ϕ_5 = 1,2 for normal service ϕ_5 = 1,5 for duty cycle service For mobile cranes with stepped drive controls: ϕ_5 = 1,6 for normal service ϕ_5 = 2,0 for duty cycle service
6		6.2.1.1	In accordance with ISO 4302 The in-service wind speed shall not be less than 9,0 m/s, corresponding to a static pressure of 50 N/m^2
7		6.2.1.3	Normally not considered. However, these effects are included when specifically agreed between purchaser and manufacturer.
8	ϕ_2	6.1.2.2.2	Applies only to mobile cranes rated for duty cycle service $\phi_{2,\max}$ = 1,6
9		6.3.1	The maximum out-of-service wind load and/or crane configuration shall be specified by the manufacturer.
10	ϕ_6	6.3.2	Test load in accordance with ISO 4310. $\phi_6 = 0{,}5(1 + \phi_2)$; ϕ_2 from 6.1.2.1 of ISO 8686-1:1989.

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Annex A
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Column strength

The column strength formulas (or curves) of ISO 10721-1 and ISO 10721-2 shall be used, together with the allowable stress coefficients γ_f of Table 1 or the resistance coefficient γ_m of Table 2. Alternatively, column strength formulas (or curves) from national standards may be used with the appropriate allowable stress or resistance coefficients.

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Annex B
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Simultaneous accelerations

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

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

— hoist (H) and slew (Sl);

— hoist and luff (Lu);

— slew and luff;

— travel (Tr) with load.

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

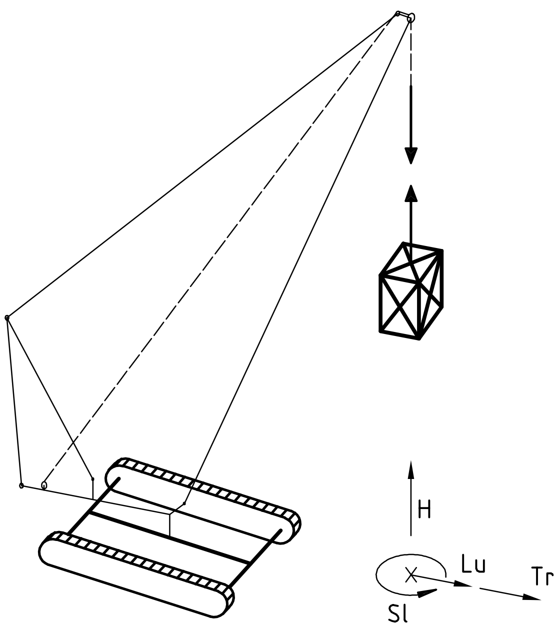

Figure B.1 — Track-mounted (crawler) latticed boom crane

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B.2 Wheeled mobile latticed boom crane

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

— hoist and slew;

— hoist and luff;

— slew and luff;

— travel with load.

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

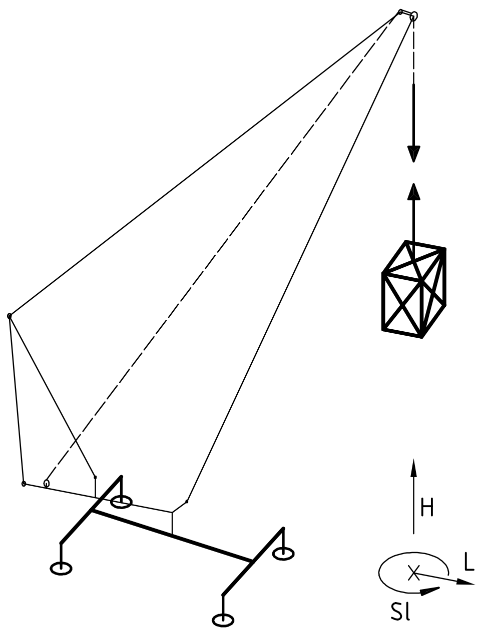

Figure B.2 — Wheeled mobile latticed boom crane

B.3 Wheeled mobile telescopic boom crane

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

— hoist and slew;

— hoist and luff;

— hoist and telescope (Te);

— slew and luff;

— slew and telescope;

— telescope and luff;

— travel with load.

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

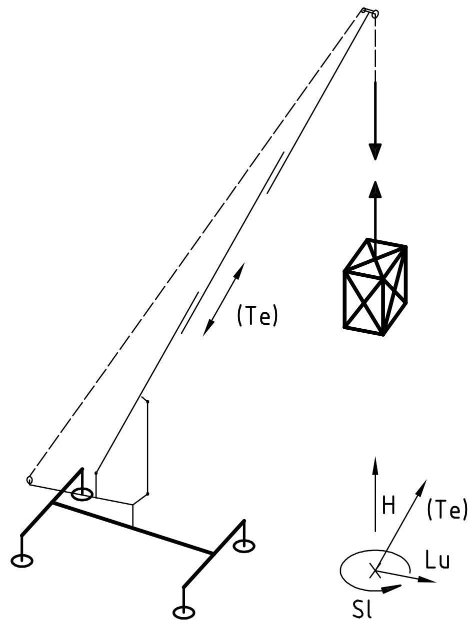

Figure B.3 — Wheeled mobile telescopic boom crane

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Annex C
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Application of load combinations given in Table 1 and Table 2

C.1 Description of load combinations

Table C.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 C.1 — Description of load combinations

Load combinations from Table 1 and Table 2	Description
A1 and B1	Mobile cranes supporting suspended loads while two motions other than hoisting are engaged, without in-service wind (A1), and with in-service wind (B1).
A2 and B2	Mobile cranes in duty cycle service suddenly releasing part of the suspended load while in motion, without in-service wind (A2), and with in-service wind (B2). See 4.2 and ISO 8686-1:1989, 6.1.2.3.
A3 and B3	Mobile cranes lifting or lowering loads while one other motion is engaged, without in-service wind (A3), and with in-service wind (B3). See 4.2.
A4 and B4	Mobile cranes travelling on an uneven surface, without in-service wind (A4), and with in-service wind (B4). See 4.2 and ISO 8686-1:1989, 6.1.3.1.
C1	Mobile cranes in duty cycle service hoisting a grounded load. (See ISO 8686-1:1989, 6.1.2.2.2)
C2	Mobile cranes in out-of-service wind conditions, as specified by the manufacturer.
C3	Mobile cranes under test conditions in accordance with ISO 4310.
C4	Mobile cranes under automatically initiated actions in accordance with 4.5.

C.2 Symbols

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

m_R is the mass of the rated load;

m_T is the mass of the test load;

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

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

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

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

F_W is the force resulting from wind and snow or ice;

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

ϕ is the dynamic amplification factor, as given in Table 3.

C.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.

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

C.4.1 In load combinations A1 and B1, two drive forces other than hoisting are combined. Therefore, only the combination including the pair of drive force loads producing maximum stress should be considered.

$$\text{Select the greatest of} \begin{Bmatrix} \Delta F_S + \Delta F_L \\ \Delta F_S + \Delta F_T \\ \Delta F_L + \Delta F_T \end{Bmatrix} = \text{max. comb.}$$

Then, for the Allowable Stress Method (ASM):

$$\sigma(\text{A1}) = \sigma(\phi_1 m_C + \phi_2 m_R + \phi_5 \times \text{max. comb.})$$

$$\sigma(\text{B1}) = \sigma(\text{A1} + F_W)$$

For the Limit State Method (LSM):

$$\sigma(\text{A1}) = \sigma(\gamma_p \phi_1 m_C + \gamma_p \phi_2 m_R + \gamma_p \phi_5 \times \text{max. comb.})$$

$$\sigma(\text{B1}) = \sigma(\gamma_p \phi_1 m_C + \gamma_p \phi_2 m_R + \gamma_p \phi_5 \times \text{max. comb.} + \gamma_p F_W)$$

C.4.2 In load combinations A2 and B2, two drive loads other than hoisting are also combined. Therefore

For ASM:

$$\sigma(\text{A2}) = \sigma(\phi_1 m_C + \phi_3 m_R + \phi_5 \times \text{max. comb.})$$

$$\sigma(\text{B2}) = \sigma(\text{A2} + F_W)$$

For LSM:

$$\sigma(\text{A2}) = \sigma(\gamma_p \phi_1 m_C + \gamma_p \phi_3 m_R + \gamma_p \phi_5 \times \text{max. comb.})$$

$$\sigma(\text{B2}) = \sigma(\gamma_p \phi_1 m_C + \gamma_p \phi_3 m_R + \gamma_p \phi_5 \times \text{max. comb.} + \gamma_p F_W)$$

C.4.3 In load combinations A3 and B3, 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 = max. drive force

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Then for ASM:

$\sigma(\text{A3}) = \sigma(m_\text{C} + m_\text{R} + \phi_5\Delta F_\text{H} + \text{max. drive force})$

$\sigma(\text{B3}) = \sigma(\text{A3} + F_\text{W})$

For LSM:

$\sigma(\text{A3}) = \sigma(\gamma_\text{p}m_\text{C} + \gamma_\text{p}m_\text{R} + \gamma_\text{p}\phi_5\Delta F_\text{H} + \gamma_\text{p}\ \text{max. drive force})$

$\sigma(\text{B3}) = \sigma(\gamma_\text{p}m_\text{C} + \gamma_\text{p}m_\text{R} + \gamma_\text{p}\phi_5\Delta F_\text{H} + \gamma_\text{p}\ \text{max. drive force} + \gamma_\text{p}F_\text{W})$

C.4.4 Load combinations A4 and B4 reflect effects on a crane driving over an uneven surface.

For ASM:

$\sigma(\text{A4}) = \sigma(\phi_4 m_\text{C} + \phi_4 m_\text{R})$

$\sigma(\text{B4}) = \sigma(\text{A4} + F_\text{W})$

For LSM:

$\sigma(\text{A4}) = \sigma(\gamma_\text{p}\phi_4 m_\text{C} + \gamma_\text{p}\phi_4 m_\text{R})$

$\sigma(\text{B4}) = \sigma(\gamma_\text{p}\phi_4 m_\text{C} + \gamma_\text{p}\phi_4 m_\text{R} + \gamma_\text{p}F_\text{W})$

C.4.5 Load combination C1 examines the effects of hoisting a grounded load.

For ASM:

$\sigma(\text{C1}) = \sigma(\phi_1 m_\text{C} + \phi_2\Delta m_\text{R})$

For LSM:

$\sigma(\text{C1}) = \sigma(\gamma_\text{p}\phi_1 m_\text{C} + \gamma_\text{p}\phi_2\Delta m_\text{R})$

C.4.6 Load combination C2 reflects out-of-service conditions.

For ASM:

$\sigma(\text{C2}) = \sigma(m_\text{c} + \eta m + F_\text{W})$

For LSM:

$\sigma(\text{C2}) = \sigma(\gamma_\text{p}m_\text{c} + \gamma_\text{p}\eta m + \gamma_\text{p}F_\text{W})$

C.4.7 Load combination C3 examines the effects of dynamic testing.

For ASM:

$\sigma(\text{C3}) = \sigma(\phi_1 m_\text{C} + \phi_6 m_\text{T} + \phi_5 \times \text{max. drive force} + F_\text{W})$

For LSM:

$\sigma(\text{C3}) = \sigma(\gamma_\text{p}\phi_1 m_\text{C} + \gamma_\text{p}\phi_6 m_\text{T} + \gamma_\text{p}\phi_5 \times \text{max. drive force} + \gamma_\text{p}F_\text{W})$

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C.4.8 Load combination C4 examines the effects of automatically initiated actions under 4.5.

For ASM:

$$\sigma(\text{C4}) = \sigma(m_\text{C} + m_\text{R} + \phi_5 \Delta F_\text{H} \text{ or } \phi_5 \times \text{max. drive force})$$

For LSM:

$$\sigma(\text{C4}) = \sigma(\gamma_\text{p} m_\text{C} + \gamma_\text{p} m_\text{R} + \gamma_\text{p} \phi_5 \Delta F_\text{H} \text{ or } \gamma_\text{p} \phi_5 \times \text{max. drive force})$$

using only drive forces subject to 4.5.

C.4.9 Other load cases may need to be considered in accordance with 4.4.

C.5 Examples of application of loads and load combinations

C.5.1 Allowable stress method: Load combination A3

Stress due to the action of the load effects on a particular element:

$$\sigma = 1{,}48\left[\sigma_\text{C} + \sigma_\text{R} + \sigma\left(\phi_5 \Delta F_\text{H}\right) + \max\left\{\sigma\left(\Delta F_\text{S}\right) \text{ or } \sigma\left(\Delta F_\text{L}\right) \text{ or } \sigma\left(\Delta F_\text{T}\right)\right\}\right]$$

C.5.2 Limit state method: Load combination A3

Stress due to the action of the load effects on a particular element:

$$\sigma = \sigma(1{,}22 m_\text{C}) + \sigma(1{,}34 m_\text{R}) + \sigma(1{,}34 \phi_5 \Delta F_\text{H}) + \max[\sigma(1{,}34 \Delta F_\text{S}) \text{ or } \sigma(1{,}34 \Delta F_\text{L}) \text{ or } \sigma(1{,}34 \Delta F_\text{T})]$$

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