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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

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

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*

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

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.

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:

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

$$\delta = 0,167(v_h - 0,2) \quad \text{for } 0,2 \leq v_h \leq 1,7$$

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.

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.

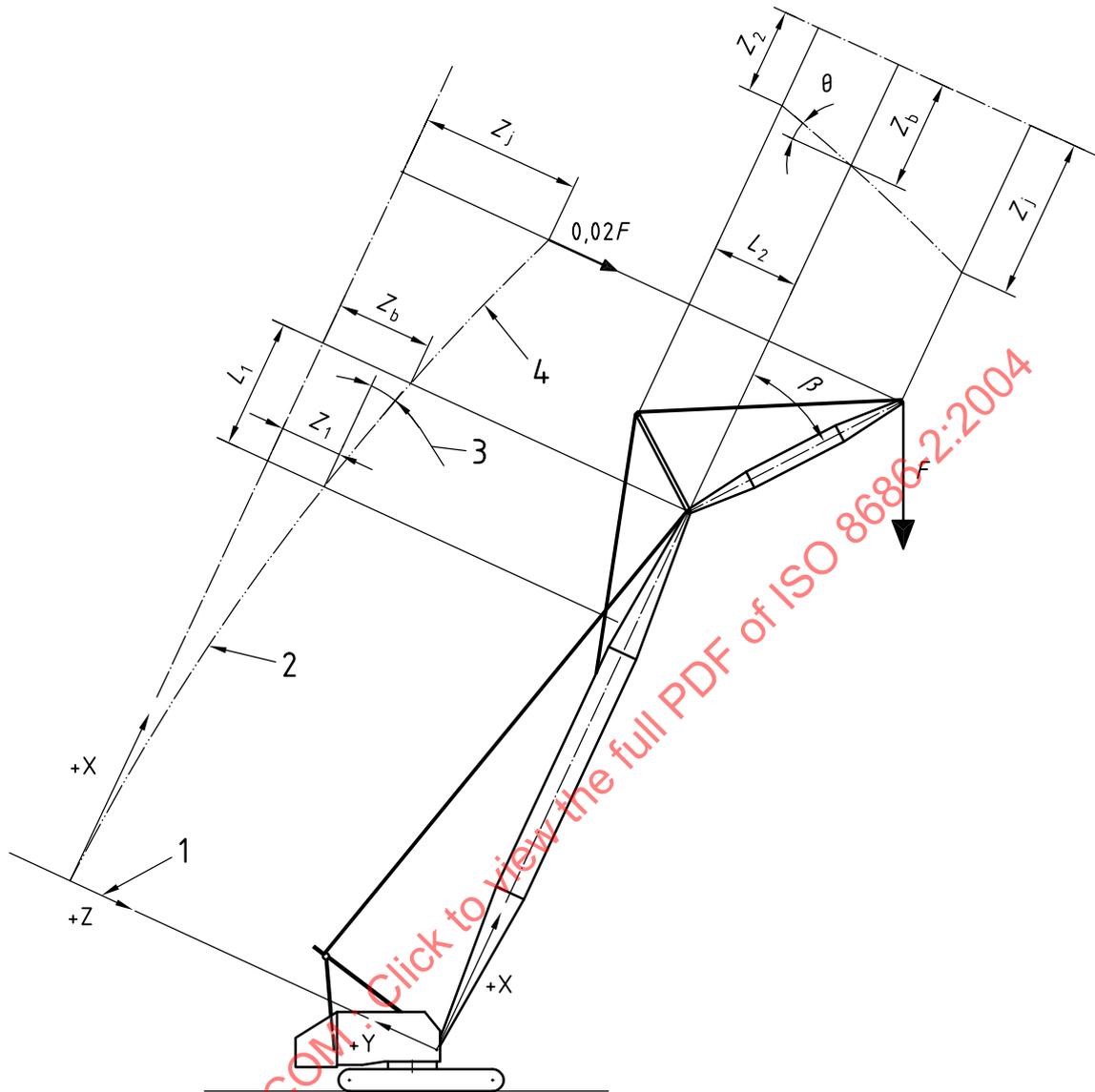
6.3 Limit state method

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.



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):

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

where the following values are calculated (or measured):

Z_j is the fly jib tip deflection;

Z_b is the latticed jib tip deflection;

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:

$$Z' \text{ (slope)} = (Z_b - Z_1) / L_1$$

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

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

NOTE 1 Under load combination C2, γ_f allows for the mass of the hook block or overhead ball remaining suspended when the crane is out of service. $\gamma_{pm} = (m - \Delta m)$, 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_r .

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.

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

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

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 $\phi_2 = 1,0$ (stepless continuously-variable drive control) Hoisting class is HC2 for occasional duty cycle service $\phi_2 = 1,3$ (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: $\phi_4 = 1,1$ for travel speed $\leq 0,4$ 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 $\leq 0,4$ m/s $\phi_4 = 1,1$ 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: $\phi_5 = 1,2$ 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	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.

Annex A
(normative)

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 (informative)

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.

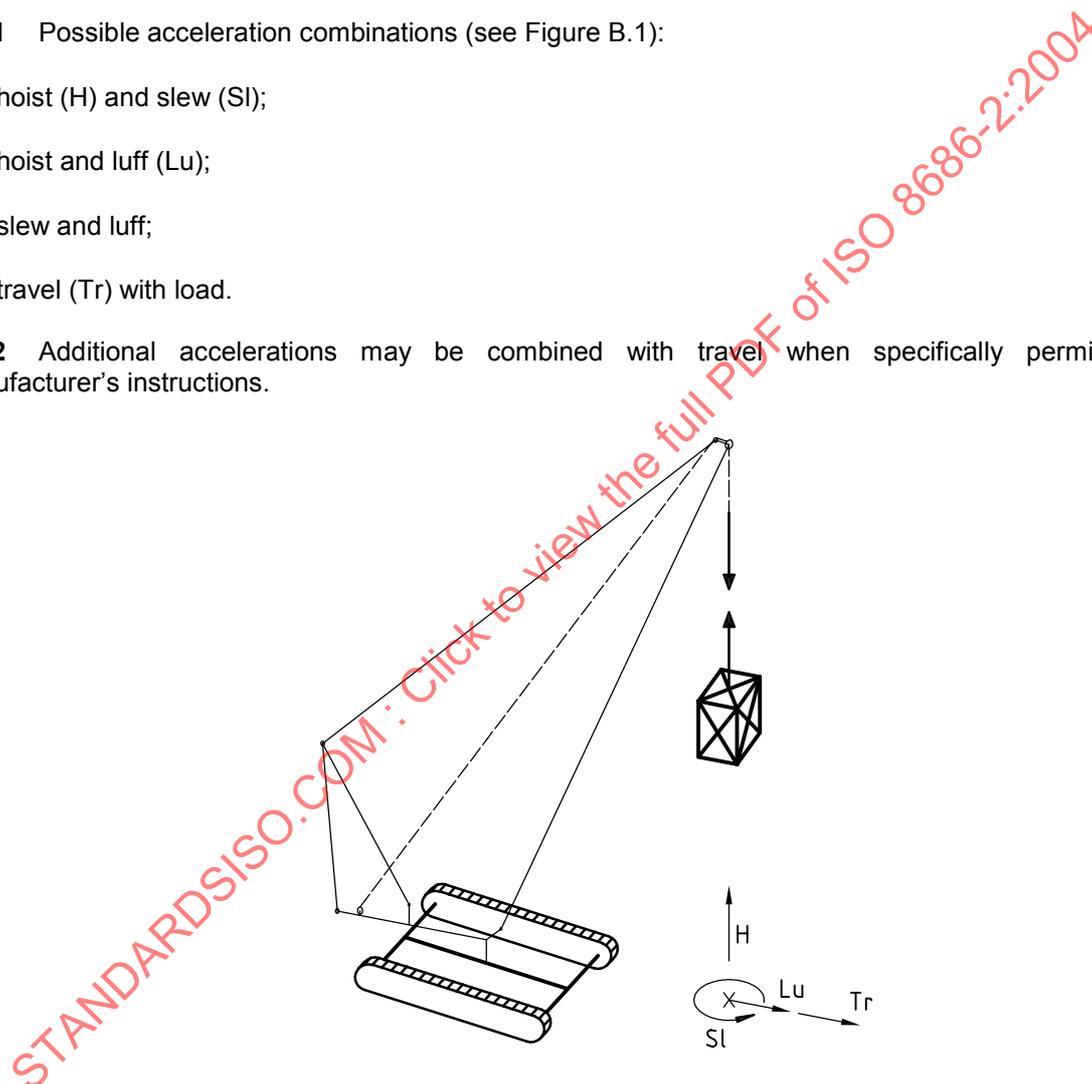


Figure B.1 — Track-mounted (crawler) latticed boom crane

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.

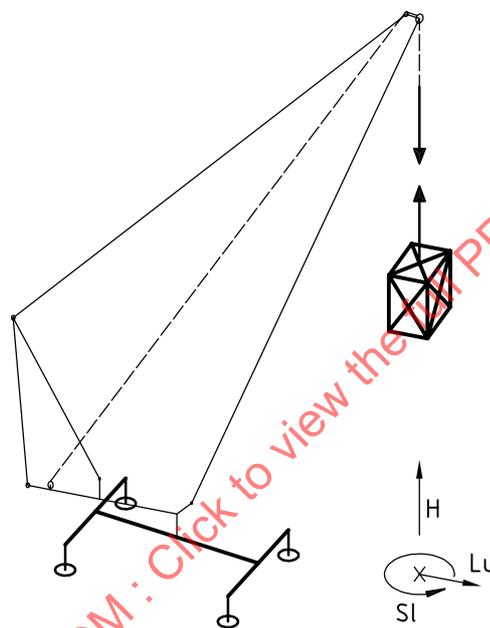


Figure B.2 — Wheeled mobile latticed boom crane

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.

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

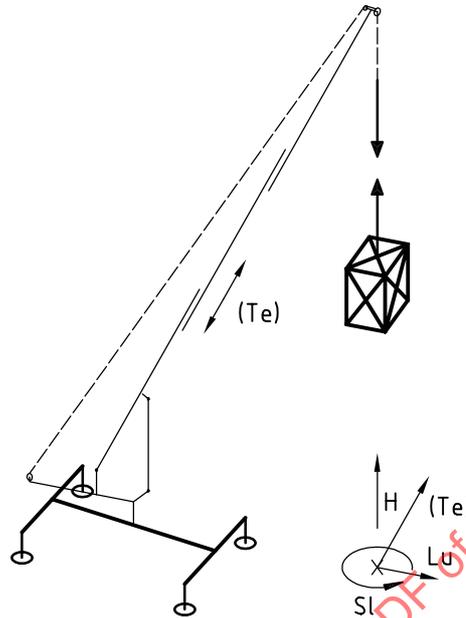


Figure B.3 — Wheeled mobile telescopic boom crane