EUROPEAN STANDARD
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CEN/TC250/SC1/N379

Draft prEN 1991-3

English Version

Draft prEN 1991-3
EUROCODE 1 - Actions on structures

Part 3: Actions induced by cranes and machinery

Eurocode 1 – Actions sur les structures – Partie 3: Actions générales – Actions induites par les ponts roulans et machines

Eurocode 1 – Einwirkungen auf Tragwerke – Teil 3: Einwirkungen infolge von Kranen und Maschinen

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(including comments from Slovakia)

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CONTENTS

Foreword

This European Standard has been prepared by Technical Committee CEN/TC 250 « Structural Eurocodes », the secretariat of which is held by BSI.

CEN/TC 250 is responsible for all Structural Eurocodes.

This document is currently submitted to the Formal Vote.

This European Standard supersedes ENV 1991-5:1998.

The annexes A and B are informative.

Background of the Eurocode programme

In 1975, the Commission of the European Community decided on an action programme in the field of construction, based on article 95 of the Treaty. The objective of the programme was the elimination of technical obstacles to trade and the harmonisation of technical specifications.

Within this action programme, the Commission took the initiative to establish a set of harmonised technical rules for the design of construction works which, in a first stage, would serve as an alternative to the national rules in force in the Member States and, ultimately, would replace them.

For fifteen years, the Commission, with the help of a Steering Committee with Representatives of Member States, conducted the development of the Eurocodes programme, which led to the first generation of European codes in the 1980s.

In 1989, the Commission and the Member States of the EU and EFTA decided, on the basis of an agreement[1] between the Commission and CEN, to transfer the preparation and the publication of the Eurocodes to the CEN through a series of Mandates, in order to provide them with a future status of European Standard (EN). This links *de facto* the Eurocodes with the provisions of all the Council's Directives and/or Commission's Decisions dealing with European standards (e.g. the Council Directive 89/106/EEC on construction products - CPD - and Council Directives 93/37/EEC, 92/50/EEC and 89/440/EEC on public works and services and equivalent EFTA Directives initiated in pursuit of setting up the internal market).

The Structural Eurocode programme comprises the following standards generally consisting of a number of Parts:

EN 1990	Eurocode :	Basis of Structural Design
EN 1991	Eurocode 1:	Actions on structures
EN 1992	Eurocode 2:	Design of concrete structures
EN 1993	Eurocode 3:	Design of steel structures

[1] Agreement between the Commission of the European Communities and the European Committee for Standardisation (CEN) concerning the work on EUROCODES for the design of building and civil engineering works (BC/CEN/03/89).

EN 1994	Eurocode 4:	Design of composite steel and concrete structures
EN 1995	Eurocode 5:	Design of timber structures
EN 1996	Eurocode 6:	Design of masonry structures
EN 1997	Eurocode 7:	Geotechnical design
EN 1998	Eurocode 8:	Design of structures for earthquake resistance
EN 1999	Eurocode 9:	Design of aluminium structures

Eurocode standards recognise the responsibility of regulatory authorities in each Member State and have safeguarded their right to determine values related to regulatory safety matters at national level where these continue to vary from State to State.

Status and field of application of Eurocodes

The Member States of the EU and EFTA recognise that Eurocodes serve as reference documents for the following purposes:

as a means to prove compliance of building and civil engineering works with the essential requirements of Council Directive 89/106/EEC, particularly Essential Requirement N°1 – Mechanical resistance and stability – and Essential Requirement N°2 – Safety in case of fire ;

as a basis for specifying contracts for construction works and related engineering services ;

as a framework for drawing up harmonised technical specifications for construction products (ENs and ETAs)

The Eurocodes, as far as they concern the construction works themselves, have a direct relationship with the Interpretative Documents[2] referred to in Article 12 of the CPD, although they are of a different nature from harmonised product standards[3]. Therefore, technical aspects arising from the Eurocodes work need to be adequately considered by CEN Technical Committees and/or EOTA Working Groups working on product standards with a view to achieving full compatibility of these technical specifications with the Eurocodes.

The Eurocode standards provide common structural design rules for everyday use for the design of whole structures and component products of both a traditional and an innovative nature. Unusual forms of construction or design conditions are not specifically covered and additional expert consideration will be required by the designer in such cases.

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[2] According to Art. 3.3 of the CPD, the essential requirements (ERs) shall be given concrete form in interpretative documents for the creation of the necessary links between the essential requirements and the mandates for harmonised ENs and ETAGs/ETAs.

[3] According to Art. 12 of the CPD the interpretative documents shall :

a) give concrete form to the essential requirements by harmonising the terminology and the technical bases and indicating classes or levels for each requirement where necessary ;

b) indicate methods of correlating these classes or levels of requirement with the technical specifications, e.g. methods of calculation and of proof, technical rules for project design, etc. ;

c) serve as a reference for the establishment of harmonised standards and guidelines for European technical approvals.

The Eurocodes, *de facto*, play a similar role in the field of the ER 1 and a part of ER 2.

National Standards implementing Eurocodes

The National Standards implementing Eurocodes will comprise the full text of the Eurocode (including any annexes), as published by CEN, which may be preceded by a National title page and National foreword, and may be followed by a National annex.

The National annex may only contain information on those parameters which are left open in the Eurocode for national choice, known as Nationally Determined Parameters, to be used for the design of buildings and civil engineering works to be constructed in the country concerned, i.e. :
values and/or classes where alternatives are given in the Eurocode,
values to be used where a symbol only is given in the Eurocode,
country specific data (geographical, climatic, etc.), e.g. snow map,
the procedure to be used where alternative procedures are given in the Eurocode,
decisions on the application of informative annexes,
references to non-contradictory complementary information to assist the user to apply the Eurocode.

Links between Eurocodes and harmonised technical specifications (ENs and ETAs) for products

There is a need for consistency between the harmonised technical specifications for construction products and the technical rules for works[4]. Furthermore, all the information accompanying the CE Marking of the construction products which refer to Eurocodes should clearly mention which Nationally Determined Parameters have been taken into account.

Additional information specific for EN 1991-3

EN 1991-3 gives design guidance and actions for the structural design of buildings and civil engineering works, including the following aspects:
actions induced by cranes and
actions induced by machinery.

EN 1991-3 is intended for clients, designers, contractors and public authorities.

EN 1991-3 is intended to be used with EN 1990, the other Parts of EN 1991 and EN 1992 to EN 1999 for the design of structures.

National annex for EN 1991-3

This standard has been drafted on the assumption that it will be complemented by a National annex to enable it to be used for the design of buildings and civil engineering works to be constructed in the relevant country.

The National annex for EN 1991-3 should include:

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[4] see Art.3.3 and Art.12 of the CPD, as well as clauses 4.2, 4.3.1, 4.3.2 and 5.2 of ID 1.

National choice allowed by notes, in relation to reliability format and values of the particular actions only when a range is provided; National choice is allowed in this document through :

Selection of procedures from amongst the parallel procedures defined, when this is allowed by a note ;

Reference to non-contradicting complementary information provided by National Regulations and Requirements and additional publications which supplement the Eurocodes.

Section 1 General

1.1 Scope

(1) Part 3 of EN 1991 specifies imposed loads (models and representative values) associated with cranes on runway beams and stationary machines which include, when relevant, dynamic effects and braking, acceleration and accidental forces.

(2) Section 1 defines common definitions and notations.

(3) Section 2 specifies actions induced by cranes on runways.

(4) Section 3 specifies actions induced by stationary machines.

1.2 Normative References

This European Standard incorporates by dated or undated reference provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to, or revisions of, any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

ISO 3898 Basis of design of structures - Notations. General symbols

ISO 2394 General principles on reliability for structures

ISO 8930 General principles on reliability for structures. List of equivalent terms

NOTE 1 The Eurocodes were published as European Prestandards. The following European Standards which are published or in preparation are cited in normative clauses :

EN 1990	Eurocode : Basis of Structural Design
EN 13001-1	Crane safety –Part 1 General principles and requirements
EN 13001-2	Crane safety –Part 2 Load effects

1.3 Distinction between Principles and Application Rules

(1) Depending on the character of the individual clauses, distinction is made in this Part between Principles and Application Rules.

(2) The Principles comprise:

- general statements and definitions for which there is no alternative, as well as
- requirements and analytical models for which no alternative is permitted unless specifically stated.

(3) The Principles are identified by the letter P following the paragraph number.

(4) The Application Rules are generally recognised rules which comply with the Principles and satisfy their requirements.

(5) It is permissible to use alternative design rules different from the Application Rules given in EN 1991-3 for works, provided that it is shown that the alternative rules accord with the relevant Principles and are at least equivalent with regard to the structural safety, serviceability and durability which would be expected when using the Eurocodes.

> NOTE If an alternative design rule is substituted for an Application Rule, the resulting design cannot be claimed to be wholly in accordance with EN 1991-3 although the design will remain in accordance with the Principles of EN 1991-3. When EN 1991-3 is used in respect of a property listed in an Annex Z of a product standard or an ETAG, the use of an alternative design rule may not be acceptable for CE marking.

(6) In this Part the Application Rules are identified by a number in brackets, e.g. as this clause.

1.4 Terms and definitions

For the purposes of this European Standard, the terms and definitions given in ISO 2394, ISO 3898, ISO 8930 and the following apply. Additionally for the purposes of this standard a basic list of terms and definitions is provided in EN 1990, 1.5.

1.4.1 Terms and definitions specifically for hoists and cranes on runway beams

1.4.1.1 Dynamic factor: Factor that that represents the ratio of the dynamic response to the static one. ~~covers dynamic effects as from vibrational excitations, impact etc.~~

***1.4.1.2 Selfweight Q_C of the crane*:**Selfweight of all fixed and movable elements including the mechanical and electrical equipment of a crane structure, however without the lifting attachment and a portion of the suspended hoist ropes or chains moved by the crane structure, see 1.4.1.3.

1.4.1.3 Hoistload Q_H: It includes the masses of the payload, the lifting attachment and a portion of the suspended hoist ropes or chains moved by the crane structure, see Figure 1.1.

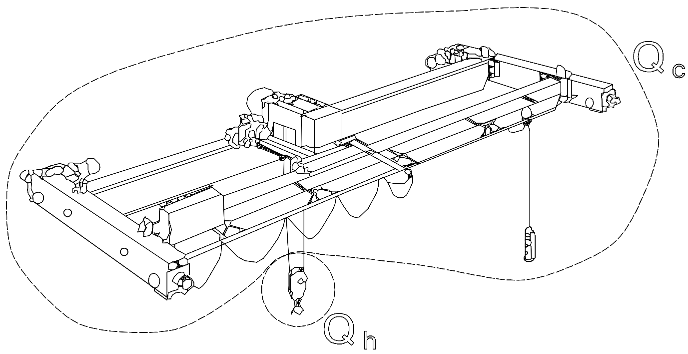


Figure 1.1: Definition of the hoistload and the selfweight of a crane

1.4.1.4 Crab: Part of an overhead travelling crane that incorporates a hoist and is able to travel on rails on the top of the crane bridge.

1.4.1.5 Crane bridge: Part of an overhead travelling crane that spans between the crane runway beams and supports the crab.

1.4.1.6 Guidance means: System used to keep a crane aligned on a runway, through horizontal reactions between the crane and the runway beams. The guidance means can consist of flanges on the crane wheels or a separate system of guide rollers operating on the side of the crane rails or the side of the runway beams.

1.4.1.7 Hoist: A machine for lifting loads.

1.4.1.8 Hoist block: An underslung trolley that incorporates a hoist and is able to travel on the bottom flange of a beam, either on a fixed runway (as shown in Figure 1.2) or under the bridge of an overhead travelling crane (as shown in Figures 1.3 and 1.4).

1.4.1.9 Overhead travelling crane: A machine for lifting and moving loads, that moves on wheels along overhead crane runway beams. It incorporates one or more hoists mounted on crabs or underslung trolleys.

1.4.1.10 Runway beam for hoist block: Crane runway beam provided to support a monorail hoist block that is able to travel on its bottom flange, see Figure 1.2.

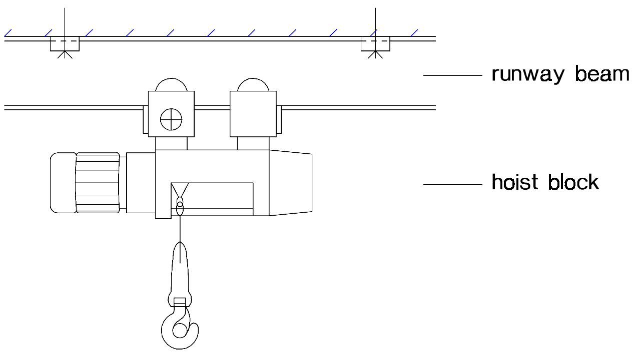


Figure 1.2: Runway beam with hoist block

1.4.1.11 Underslung crane: Overhead travelling crane that is supported on the bottom flanges of the crane runway beams, see Figure 1.3.

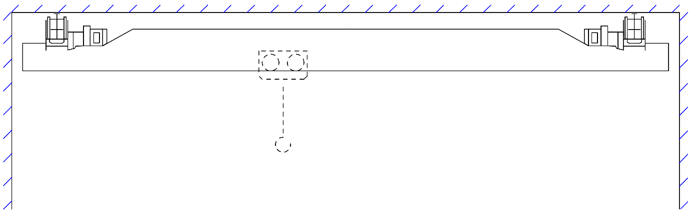


Figure 1.3: Underslung crane with hoist block

1.4.1.12 Top-mounted crane: Overhead travelling crane that is supported on the top of the crane runway beam. It usually travels on rails, but sometimes travels directly on the top of the beams, see Figure 1.4.

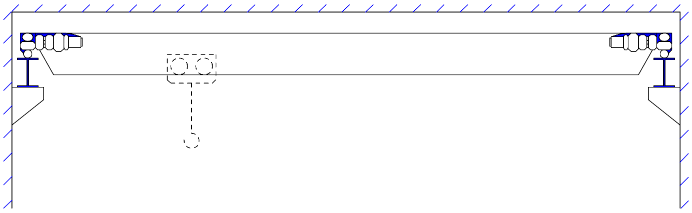


Figure 1.4: Top mounted crane with hoist block

1.4.2 Terms and definitions specifically for actions induced by machines

1.4.2.1 Natural frequency: The frequency of free vibration on a system. For a multiple degree-of-freedom system, the natural frequencies are the frequencies of the normal modes of vibrations. ~~The dynamic property of an elastic body or system by which it oscillates repeatedly from a fixed reference point when the external force is removed.~~

1.4.2.2 Free vibration: The vibration of a system that occurs in the absence of forced vibration. ~~Vibration process of a system excited initially, which may be in the form of initial displacement or velocity, but no more time-varying force acting on it.~~

1.4.2.3 Forced vibration: The vibration of a system if the response is imposed by the excitation.~~Vibration process of a system which is caused by external time-varying loads acting on it.~~

1.4.2.4 Damping: The dissipation of energy with time or distance. ~~Damping is dissipation of energy in a vibrating system.~~

1.4.2.5 Resonance: Resonance of a system in forced harmonic vibration exists when any change, however small, in the frequency of excitation causes a decrease in the response of the system.
~~Resonance of a system in forced vibration is a condition when any change, however small, in the frequency of excitation causes a decrease in the response of the system.~~

1.4.2.6 Mode of vibration: In a system undergoing vibration, a mode of vibration is a characteristic pattern assumed by the system in which the motion of every particle is simple harmonic with the same frequency. Two or more modes may exist concurrently in a multiple —degree of freedom system. A normal (natural) mode of vibration is a mode of vibration that is uncoupled from other modes of vibration of a system.

1.5 Symbols

(1) For the purposes of this European standard, the following symbols apply.

NOTE The notation used is based on ISO 3898: 1997.

(2) A basic list of symbols is provided in EN 1990 clause 1.6 and the additional notations below are specific to this part of EN 1991.

Latin upper case letters

F_k	characteristic value of a crane action
F_w	Forces caused by in service wind
H_B	buffer force
H_L	longitudinal loads caused by acceleration and deceleration
H_S	horizontal loads caused by skewing
H_T	transverse loads caused by acceleration and deceleration
H_{TA}	tilting force
K	drive force
Qc	selfweight of the crane
Q_h	hoistload
Q_T	test load

Latin lower case letters

h	distance between the instantaneous slide pole and means of guidance
kQ	load spectrum factor
P	span of the crane bridge
m_c	mass of the crane
m_w	number of single wheel drives
n	number of wheel pair
n_r	number of runway beams

Greek lower case letters

∀	skewing angle
8	damage equivalent factor
:	friction factor
v_i	dynamic factor
v_{fat}	damage equivalent dynamic impact factor

Section 2 Actions induced by hoists and cranes on runway beams

2.1 Field of application

(1) This section specifies actions (models and representative values) induced by:
– underslung trolleys on runways, see 2.5.1 and 2.5.2;
– overhead travelling cranes, see 2.5.3 and 2.5.4.

(2) The methods prescribed in this section are compatible with the provisions in EN 13001-1 and EN 13001-2, to facilitate the exchange of data with crane suppliers.

2.2 Classifications of actions

2.2.1 General

(1)P Actions induced by cranes are classified as variable and accidental actions which are represented by various models.

2.2.2 Variable actions

(1) For normal service conditions variable crane actions result from variation in time and location. They include gravity loads including hoistloads, inertial forces caused by acceleration/deceleration and by skewing and other dynamic effects.

(2) The variable crane actions should be separated in variable vertical crane actions caused by the selfweight of the crane and the hoist load and in variable horizontal crane actions caused by acceleration or deceleration or by skewing or other dynamic effects.

(3) The various representative values of variable crane actions are characteristic values composed of a static and a dynamic component.

(4) Dynamic components induced by vibration due to inertial and damping forces are in general accounted by dynamic factors φ to be applied to the static action values. ~~different loads due to masses and inertial forces are in general given in terms of dynamic factors φ_i to be applied to the static load values~~.

$$F_k = \varphi_i F \tag{2.1}$$

where:

F_k is the characteristic value of a crane action;
φ_i is the dynamic factor, see Table 2.1;
F is the static component of a crane action.

(5) The various dynamic factors and their application are listed in Table 2.1.

(6) The simultaneity of the crane load components may be taken into account by considering groups of loads as identified in Table 2.2. Each of these groups of loads

should be considered as defining one characteristic crane action for the combination with non-crane loads.

NOTE: The grouping provides that only one horizontal crane action is considered at a time.

2.2.3 Accidental actions

(1) Cranes may generate accidental actions due to collision with buffers (buffer forces) or collision of lifting attachments with obstacles (tilting forces). These actions should be considered for the structural design where appropriate protection is not provided.

(2) Accidental actions described in 2.11 refer to common situations. They are represented by various load models defining design values (i.e. to be used with $(_A = 1,0)$ in the form of equivalent static loads.

(3) The simultaneity of accidental crane load components may be taken into account by considering groups of loads as identified in Table 2.2. Each of these groups of loads defines one crane action for the combination of non-crane loads.

Table 2.1: Dynamic factors v_i

Dynamic factors	Effects to be considered	To be applied to
v_1	–~~vibrational~~ excitation of the crane structure due to lifting the hoist load off the ground	selfweight of the crane
v_2 or v_3	–dynamic effects of transferring the hoistload from the ground to the crane –dynamic effect of sudden release of the payload if for example grabs or magnets are used	hoistload
v_4	–dynamic effects induced when crane is travelling on rail tracks or runways	selfweight of the crane and hoistload
v_5	–dynamic effects caused by drive forces	drive forces
v_6	–when a test load is moved by the drives in the way the crane is used	test load
v_7	–considers the dynamic elastic effects of impact on buffers	buffer loads

Table 2.2: Groups of loads and dynamic factors to be considered as one characteristic crane action

		Symbol	Section	Groups of loads									
				ULS							SLS	Accidental	
				1	2	3	4	5	6	7	8	9	10
1	Selfweight of crane	Q_C	2.6	v_1	v_1	1	v_4	v_4	v_4	1	v_1	1	1
2	Hoist load	Q_H	2.6	v_2	v_3	-	v_4	v_4	v_4	$0^{1)}$	-	1	1
3	Acceleration of crane bridge	H_L, H_T	2.7	v_5	v_5	v_5	v_5	-	-	-	v_5	-	-
4	Skewing of crane bridge	H_S	2.7	-	-	-	-	1	-	-	-	-	-
5	Acceleration or braking of crab or hoist block	H_{T3}	2.7	-	-	-	-	-	1	-	-	-	-
6	In service wind	F_W^*	Annex A	1	1	1	1	1	-	-	1	-	-
7	Test load	Q_T	2.10	-	-	-	-	-	-	-	v_6	-	-
8	Buffer force	H_B	2.11	-	-	-	-	-	-	-	-	v_7	-
9	Tilting force	H_{TA}	2.11	-	-	-	-	-	-	-	-	-	1

1) *0* is the part of the hoist load that remains when the payload is removed, but is not included in the selfweight of the crane.

2.3 Design situations

(1)P The relevant actions induced by cranes shall be determined for each design situation identified in accordance with EN 1990.

(2)P Selected design situations shall be considered and critical load cases identified. For each critical load case the design values of the effects of actions in combination shall be determined.

(3) Multiple crane actions from several cranes are given in 2.5.5.

(4) Combination rules for crane actions with other actions are given in annex A.

(5) For the fatigue verification fatigue load models are given in 2.12.

(6) In case tests are performed with cranes on the supporting structures for the serviceability limit state verification, the test loading model of the crane is specified in 2.10.

2.4 Representation of crane actions

(1) The actions to be considered should be those exerted on the crane runway beams by the wheels of the cranes and possibly by guide rollers or other guidance means.

(2) Horizontal forces on crane supporting structures arising from horizontal movement of monorail hoist cranes and crane hoists should be determined from 2.5.2, 2.5.4 and 2.7.

2.5 Load arrangements

2.5.1 Vertical loads from monorail hoist blocks underslung from runway beams

(1) For normal service conditions, the vertical load should be taken as composed of the selfweight of the hoist block, the hoistload and the dynamic factor, see Table 2.1 and Table 2.2.

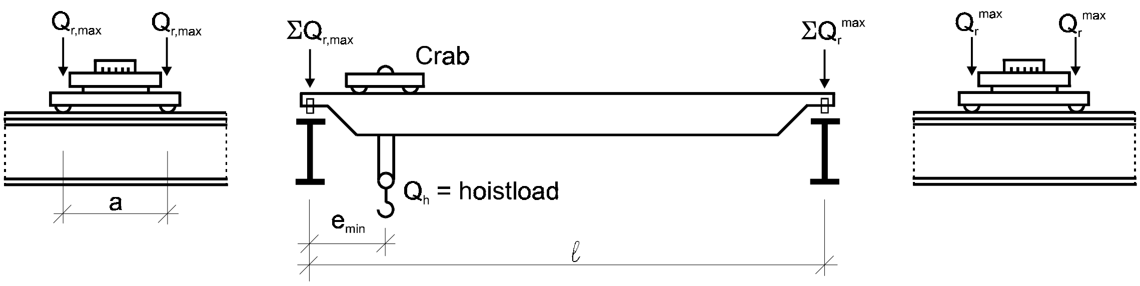
2.5.2 Horizontal loads from monorail hoist blocks underslung from runway beams

(1) In the case of fixed runway beams for monorail underslung trolleys, in the absence of a more accurate value, the horizontal loads should be taken as 5% of the maximum vertical wheel load, neglecting the dynamic factor.

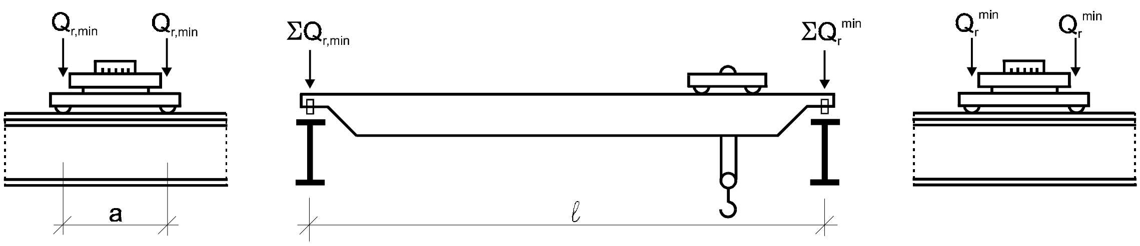
(2) This also applies to horizontal loads in the case of swinging suspended runway beams.

2.5.3 Vertical loads from overhead travelling cranes

(1) The relevant vertical wheel loads from a crane on a runway beam, should be determined by considering the load arrangements illustrated in Figure 2.5, using the characteristic values given in 2.6.



a) Load arrangement of the loaded crane to obtain the maximum loading on the runway beam



b) Load arrangement of the unloaded crane to obtain the minimum loading on the runway beam

Figure 2.5: Load arrangements to obtain the relevant vertical actions to the runway beams

where:

$Q_{r,max}$ is the maximum load per wheel of the loaded crane
Q_r^{max} is the accompanying load per wheel of the loaded crane
E$Q_{r,max}$ is the sum of the maximum loads $Q_{r,max}$ per runway of the loaded crane
EQ_r^{max} is the accompanying sum of the maximum loads Q_r^{max} per runway of the loaded crane
$Q_{r,min}$ is the minimum load per wheel of the unloaded crane
Q_r^{min} is the accompanying load per wheel of the unloaded crane
E$Q_{r,min}$ is the sum of the minimum loads $Q_{r,min}$ per runway of the unloaded crane
EQ_r^{min} is the accompanying sum of the minimum loads Q_r^{min} per runway of the unloaded crane
$Q_{r,nom}$ is the nominal hoistload

(2) The eccentricity of application *e* of a wheel load Q_r to a rail should be taken as equal to a quarter of the width of the rail head b_r, see Figure 2.6.

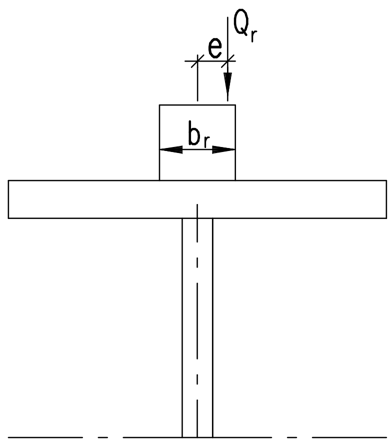


Figure 2.6: Eccentricity of the load introduction

2.5.4 Horizontal loads from overhead travelling cranes

(1) The following types of horizontal loads from overhead travelling cranes should be taken into account:

a) horizontal loads caused by acceleration or deceleration of the crane in relation to its movement along the runway beam, see 2.7.2;

b) horizontal loads caused by acceleration or deceleration of the crab or underslung trolley in relation to its movement along ~~across~~ the crane bridge, see 2.7.5;

c) horizontal loads caused by skewing of the crane in relation to its movement along the runway beam, see 2.7.4;

d) buffer forces related to crane movement, see 2.11.1;

e) buffer forces related to movement of the crab or underslung trolley, see 2.11.2.

(2) Unless otherwise specified, only one of the five types of horizontal load (a) to (e) listed in (1) should be included in the same group of simultaneous crane load components, see Table 2.2.

(3) For underslung cranes the horizontal loads at the wheel contact surface should be taken as at least 10% of the maximum vertical wheel load neglecting the dynamic component unless a more accurate value is justified.

(4) Unless otherwise specified, the longitudinal horizontal wheel forces $H_{L,i}$ and the transverse horizontal wheel forces $H_{T,i}$ caused by acceleration and deceleration of masses of the crane or the crab etc., should be applied as given in Figure 2.7. The characteristic values of these forces are given in 2.7.2.

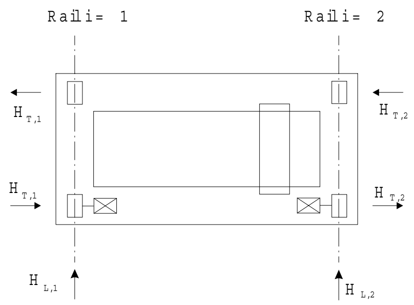
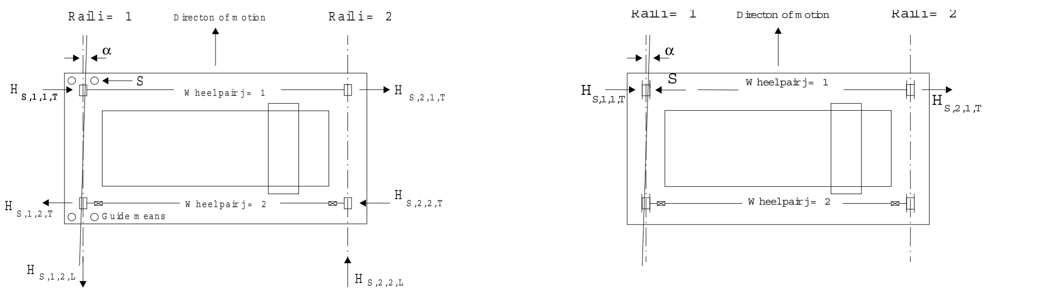


Figure 2.7: Load arrangement of longitudinal and transverse horizontal wheel forces caused by acceleration and deceleration

NOTE: These forces do not include the effects of oblique hoisting due to misalignment of load and crab because in general oblique hoisting is forbidden. Any effects of unavoidable small values of oblique hoisting are included in the inertial forces.

(5) The longitudinal and transverse horizontal wheel forces $H_{S,i,j,k}$ and the guide force S caused by skewing may occur at the guidance means of cranes or trolleys while they are travelling or traversing in steady state motion, see Figure 2.8. These loads are induced by guidance reactions which force the wheel to deviate from their free-rolling natural travelling or traverse direction. The characteristic values are given in 2.7.4.



a) with separate guidance means **b) with guidance by means of wheel flanges**

NOTE: The direction of the horizontal loads depends on the type of guidance means, the direction of motion and on the type of wheel drive.

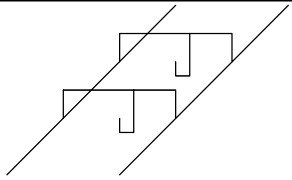
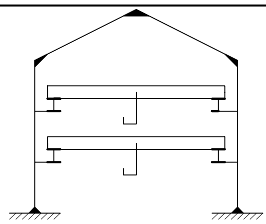
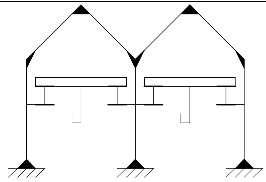
Figure 2.8: Load arrangement of longitudinal and transverse horizontal wheel forces caused by skewing

2.5.5 Multiple crane action

(1)P Cranes that are required to operate together shall be treated as a single crane action.

(2) If several cranes are operating independently, the maximum number of cranes taken into account as acting simultaneously should be as given in Table 2.3.

Table 2.3: Maximum number of cranes to be considered in the most unfavourable position

	Cranes to each runway	Cranes in each shop bay	Cranes in multi – bay buildings	
				
Vertical crane action	3	4	4	2
Horizontal crane action	2	2	2	2

2.6 Vertical crane loads - characteristic values

(1) The characteristic values of the vertical loads from cranes on crane supporting structures should be determined as indicated in Table 2.2.

(2)P For the selfweight of the crane and the hoistload, the nominal values specified by the crane supplier shall be taken as characteristic values of the vertical loads.

Table 2.4: Dynamic factors ν_i for vertical loads

ν_1	$0,9 < \nu_1 < 1,1$ The two values 1,1 and 0,9 reflect the upper and lower values of the vibrational pulses.
ν_2	$\nu_2 = \nu_{2,min} + 8_2 \nu_h$ ν_h - steady hoisting speed in [m/s] $\nu_{2,min}$ and 8_2 see table 2.5
ν_3	$\varphi_3 = 1 - \frac{\Delta_m}{m}(1 + \beta_3)$ where $)_m$ released or dropped part of the load m total hoisting load $8_3 = 0,5$ for cranes equipped with grabs or similar slow-release devices $8_3 = 1,0$ for cranes equipped with magnets or similar rapid-release devices
ν_4	$\nu_4 = 1,0$ provided that the tolerances for rail tracks as specified in EN~~V~~ 1993-6 are observed.

(3) If the dynamic factors ν_1, ν_2, ν_3 and ν_4 as specified in Table 2.1 are not included in the specifications of the crane supplier the indications in Table 2.4 may be used.

(4) For in-service wind reference should be made to annex A.

Table 2.5: Values of β_2 and $\nu_{2,min}$

Hoisting class of appliance	β_2	$\nu_{2,min}$
HC1	0,17	1,05
HC2	0,34	1,10
HC3	0,51	1,15
HC4	0,68	1,20
NOTE: Cranes are assigned to Hoisting Classes HC1 to HC4 to allow for the dynamic effects of transferring the load from the ground to the crane. The selection depends on the particular type of crane, see recommendation in annex B.		

2.7 Horizontal crane loads - characteristic values

2.7.1 General

(1)P For the acceleration and the skewing effects, the nominal values specified by the crane supplier shall be taken as characteristic values of the horizontal loads.

(2) The characteristic values of the horizontal loads may be specified by the crane supplier or be determined using 2.7.2 to 2.7.5.

2.7.2 Longitudinal loads $H_{L,i}$ and transverse loads $H_{T,i}$ caused by acceleration and deceleration of the crane

(1) The longitudinal loads $H_{L,i}$ caused by acceleration and deceleration of crane structures result from the drive force at the contact surface between the rail and the driven wheel, see Figure 2.9.

(2) The longitudinal loads $H_{L,i}$ applied to a runway beam may be calculated as follows:

$$H_{L,i} = \varphi_5 \, K \, \frac{1}{n_r} \qquad (2.2)$$

where:

- n_r is the number of runway beams;
- K is the drive force according to 2.7.3;
- v_5 is the dynamic factor, see Table 2.6;
- i is the integer to identify the runway beam (i = 1,2).

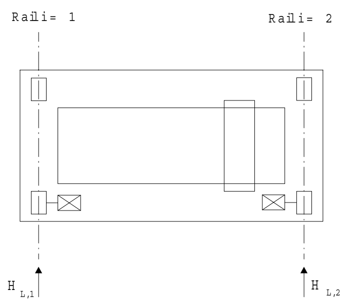


Figure 2.9: Longitudinal horizontal loads $H_{L,i}$

(3) The moment M resulting from the drive force which should be applied at the centre of mass is equilibrated by transverse horizontal loads $H_{T,1}$ and $H_{T,2}$, see Figure 2.10. The horizontal loads may be obtained as follows:

$$H_{T,1} = \varphi_5 \; \xi_2 \; \frac{M}{a} \qquad (2.3)$$

$$H_{T,2} = \varphi_5 \; \xi_1 \; \frac{M}{a} \qquad (2.4)$$

where:

$$\xi_1 = \frac{\Sigma\, Q_{r,max}}{\Sigma\, Q_r}$$

- $>_2$ = 1 - $>_1$;
- E Q_r = E $Q_{r,max}$ + E Q_r^{max};
- E $Q_{r,max}$ see Figure 2.1;
- E Q_r^{max} see Figure 2.1;
- a is the spacing of the guide roller or the wheel flanges;

M = $K\ P_s$;
P_s = ($>_1$ - 0,5) P;
P is the span length of the crane bridge;
v_5 is the dynamic factor, see Table 2.6;
K is the drive force, see 2.7.3.

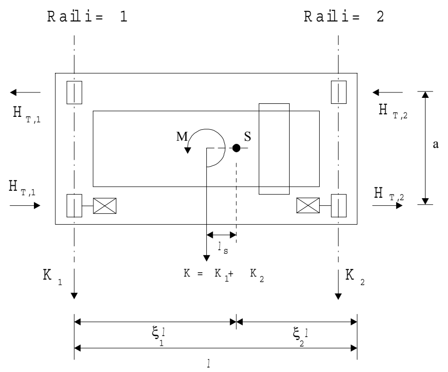


Figure 2.10: Definition of the transverse loads $H_{T,i}$

(4) For curved runway beams the resulting centrifugal force should be multiplied by the dynamic factor v_5.

(5) If the dynamic factor v_5 is not included in the specification documents of the crane supplier indications are given in Table 2.6.

Table 2.6: Dynamic factor v_5

v_5 = 1,0	for centrifugal forces
1 # v_5 # 1,5	correspond to systems in which forces change smoothly
1,5# v_5 # 2,0	when sudden changes occur
v_5 = 3,0	for drives with considerable backlash

2.7.3 Drive force K

(1) The drive force K on a driven wheel should be taken such that wheel spin is prevented.

(2) The drive force K may be calculated as follows:

$$K = K_1 + K_2 = :\ \mathrm{E}\ Q^*_{r,min} \quad (2.5)$$

where:

: is the friction factor, see (3);
– for single wheel drive: E $Q^*_{r,min} = m_w\ Q_{r,min}$, with m_w = number of single wheel drives;
– for central wheel drive: E $Q^*_{r,min} = Q_{r,min} + Q_r^{min}$;

NOTE: Modern cranes do not normally have central wheel drive.

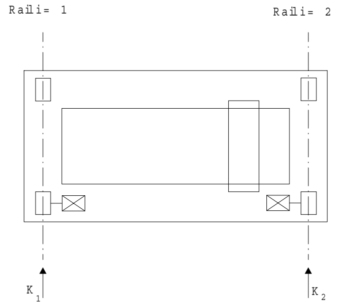


Figure 2.11: Definition of the drive force

(3) The friction factor *:* may be taken as:

– *:* = 0,2 for steel - steel;
– *:* = 0,5 for steel - rubber.

2.7.4 Horizontal loads $H_{S,i,j,k}$ *and the guide force* S *caused by skewing of the crane*

(1) The guide force *S* and the transverse forces $H_{S,i,j,k}$ caused by skewing may be obtained from:

$S = f\ 8_{S,j}\ \mathrm{E}\ Q_r$ (2.6)
$H_{S,1,j,L} = f\ 8_{S,1,j,L}\ \mathrm{E}\ Q_r$ (index j is the wheel pair with the wheel drive (2.7)
$H_{S,2,j,L} = f\ 8_{S,2,j,L}\ \mathrm{E}\ Q_r$ (index j is the wheel pair with the wheel drive) (2.8)
$H_{S,1,j,T} = f\ 8_{S,1,j,T}\ \mathrm{E}\ Q_r$ (2.9)
$H_{S,2,j,T} = f\ 8_{S,2,j,T}\ \mathrm{E}\ Q_r$ (2.10)

where:
f is the non-positive factor, see (2);
$8_{S,i,j,k}$ is the force factors, see (4);
i is the rail *i*;
j is the wheel pair *j*;
k is the direction of the force (L = longitudinal, T = transverse).

(2) The non-positive factor may be determined from:
f = 0,3 (1 - exp (-250 ∀)) # 0,3 (2.11)

where:
∀ is the skewing angle, see (3).

(3) The skewing angle ∀, see Figure 2.12, which should be equal to or less than 0,015 rad, should be chosen taking into account the space between the guidance means and the rail as well as reasonable dimensional variation and wear of the appliance wheels and the rails. It may be determined as follows:

$∀ = ∀_F + ∀_V + ∀_o$ # 0,015 rad (2.12)

where:

$∀_F$, $∀_V$ and $∀_o$ are defined in Table 2.7.

Table 2.7: Definition of $∀_F$, $∀_V$ and $∀_o$

Angles $∀_i$	Minimum values of $∀_i$
$∀_F = \frac{0,75x}{a}$	$0,75x$ ∃ 5 mm for guide rollers
	$0,75x$ ∃ 10 mm for wheel flanges
$∀_V = \frac{y}{a}$	y ∃ $0,03b$ in mm for guide rollers
	y ∃ $0,10b$ in mm for wheel flanges
$∀_o$	$∀_o = 0,001$
Where: *a* is the spacing of the guide rollers or extreme wheel flanges on the guiding rail; *b* is the width of the rail head; *x* is the track clearance between the rail and guide means (lateral slip); *y* is the wear of the rail and guide means; $∀_o$ is the tolerances of wheel and rail directions	

(4) The force factor $8_{S,i,j,k}$ depends on the combination of the wheel pairs and the distance *h* between the instantaneous centre of rotation and the relevant guidance means, which is the front guidance means in the direction of motion, see Figure 2.12. The value of the distance *h* may be taken from Table 2.8. The force factor $8_{S,i,j,k}$ may be determined from the expressions given in Table 2.9.

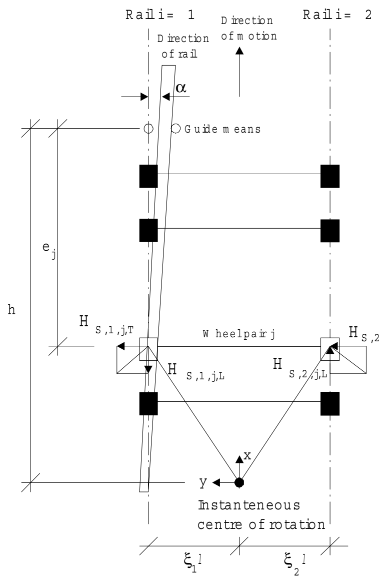
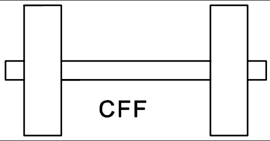
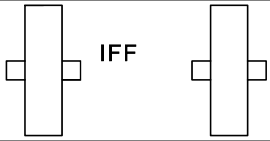
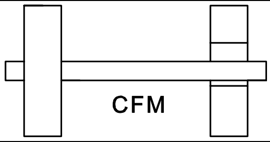
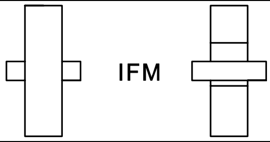


Figure 2.12: Definition of angle ∀ and the distance *h*

Table 2.8: Determination of the distance *h*

	Combination of wheel pairs		h
	coupled (c)	independent (i)	
Fixed/Fixed FF	 	 	$\frac{m\xi_1\xi_2\ell^2 + \Sigma e_j^2}{\Sigma e_j}$
Fixed/Movable FM	 	 	$\frac{m\xi_1\ell^2 + \Sigma e_j^2}{\Sigma e_j}$

Where:
h is the distance between the instantaneous centre of rotation and the relevant guidance means;
m is the number of pairs of coupled wheels (*m* = 0 for independent wheel pairs);
$>_1P$ is the distance of the instantaneous centre of rotation from rail 1;
$>_2P$ is the distance of the instantaneous centre of rotation from rail 2;
P is the span of the appliance;
e_j is the distance of the wheel pair *j* from the relevant guidance means.

Table 2.9: Definition of $8_{S,i,j,k}$ – values

System	$8_{S,j}$	$8_{S,1,j,L}$	$8_{S,1,j,T}$	$8_{S,2,j,L}$	$8_{S,2,j,T}$
CFF	$1 - \frac{\Sigma e_j}{nh}$	$\frac{\xi_1\xi_2}{n}\frac{\ell}{h}$	$\frac{\xi_2}{n}\left(1 - \frac{e_j}{h}\right)$	$\frac{\xi_1\xi_2}{n}\frac{\ell}{h}$	$\frac{\xi_1}{n}\left(1 - \frac{e_j}{h}\right)$
IFF		0	$\frac{\xi_2}{n}\left(1 - \frac{e_j}{h}\right)$	0	$\frac{\xi_1}{n}\left(1 - \frac{e_j}{h}\right)$
CFM	$\xi_2\left(1 - \frac{\Sigma e_j}{nh}\right)$	$\frac{\xi_1\xi_2}{n}\frac{\ell}{h}$	$\frac{\xi_2}{n}\left(1 - \frac{e_j}{h}\right)$	$\frac{\xi_1\xi_2}{n}\frac{\ell}{h}$	0
IFM		0	$\frac{\xi_2}{n}\left(1 - \frac{e_j}{h}\right)$	0	0

Where:
n is the number of wheel pairs;
$>_1P$ is the distance of the instantaneous centre of rotation from rail 1;
$>_2P$ is the distance of the instantaneous centre of rotation from rail 2;
P is the span of the appliance;
e_j is the distance of the wheel pair *j* from the relevant guidance means;
h is the distance between the instantaneous centre of rotation and the relevant guidance means.

2.7.5 Horizontal loads $H_{T,3}$ caused by acceleration or deceleration of the crab

(1) The horizontal load $H_{T,3}$ caused by acceleration or deceleration of the crab or trolley may be assumed to be covered by the horizontal load $H_{B,2}$ given in 2.11.2.

2.8 Temperature effects[5]

(1)P The action effects on runways due to temperature variations shall be taken into account where necessary. Non-uniform distributed temperature need not to be considered.

(2) The temperature difference for outdoor runways may be assumed to be ± 35 °K for a mean temperature of $+20$ °C.

2.9 Loads on access walkways, stairs, platforms and guard rails

2.9.1 Vertical loads

(1) Unless otherwise stated, the access walkways, stairs and platforms should be loaded by a vertical load Q spread over a square surface of 0,3m × 0,3m.

(2) Where materials can be deposited a vertical load $Q_k = 3$ kN should be applied.

(3) If the walkways, stairs and platforms are provided for access only the chracteristic value in (2) may be reduced to 1,5 kN.

(4) The vertical load Q_k may be disregarded if all structural members are subjected to crane actions.

2.9.2 Horizontal loads

(1) Unless otherwise stated, the guard rail should be loaded by a single horizontal load $H_k = 0{,}3$ kN.

(2) The horizontal load H_k may be disregarded in the case of all structural members are subjected to crane actions.

2.10 Test loads

(1) When tests are performed after erection of the cranes on the supporting structures, the supporting structure should be checked against the test loading conditions.

(2) If relevant, the crane supporting structure should be designed for these test loads.

(3)P The hoist test load shall be amplified by a dynamic factor v_6.

(4) When considering these test loads the following cases should be distinguished:
– Dynamic test load:
The test load is moved by the drives in the way the crane will be used. The test load should be at least 110% of the nominal hoist load.

$$\varphi_6 = 0{,}5\,(1 + v_2) \qquad (2.13)$$

[5] After coordination with Part 1.7 "Thermal actions" of EN 1991 these clauses will be substituted by a reference to Part 1.7.

– Static test load:

The load is increased for testing by loading the crane without the use of the drives. The test load should be at least 125% of the nominal hoist load.

$$\varphi_6 = 1{,}0 \qquad (2.14)$$

2.11 Accidental actions

2.11.1 Buffer forces $H_{B,1}$ related to crane movement

(1)P Where buffers are used, the forces on the crane supporting structure arising from collision with the buffers shall be calculated from the kinetic energy of all relevant parts of the crane moving at 0,7 to 1,0 times the nominal speed.

(2) The buffer forces multiplied by v_7 according to Table 2.10 to make allowance for dynamic effects may be calculated taking into account the distribution of relevant masses and the buffer characteristics, see Figure 2.13.

$$H_{B,1} = \varphi_7 \, v_1 \sqrt{m_c S_B} \qquad (2.15)$$

where:

v_7 see Table 2.10;

v_1 is70 % of the long travel velocity [m/s];

m_c is the mass of the crane and the hoist load [kg];

S_B is the spring constant of the buffer [~~k~~N/m].

Table 2.10: Dynamic factor v_7

v_7 = 1,25	if 0,0 # > # 0,5
v_7 = 1,25 + 0,7 (> - 0,5)	if 0,5 # > # 1
> may be approximately determined from Figure 2.14	

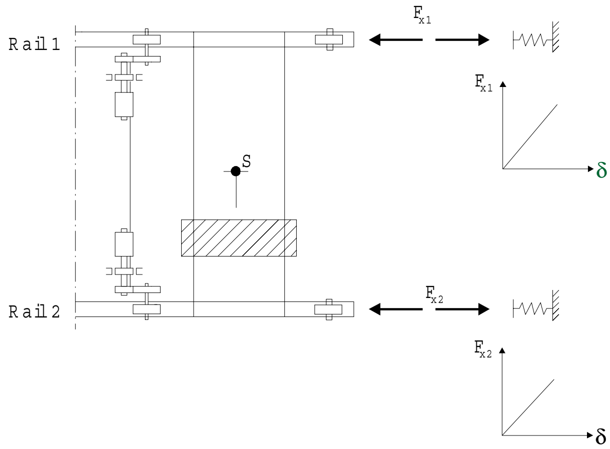


Figure 2.13: Buffer forces

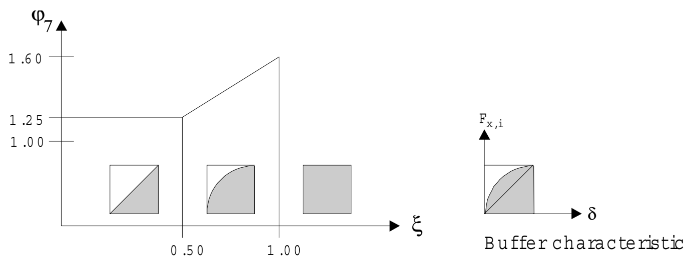


Figure 2.14: Definition of >

2.11.2 Buffer forces $H_{B,2}$ related to movements of the crab

(1) Provided that the payload is free to swing, the horizontal load $H_{B,2}$ representing the buffer forces related to movement of the crab or trolley may be taken as 10 % of the sum of the hoist load and the weight of the crab or trolley. In other cases the buffer force should be determined as for crane movement, see 2.11.1.

2.11.3 Tilting forces

(1)P If a crane with horizontally restrained loads can tilt when its load or lifting attachment collides with an obstacle, the resulting static forces shall be considered.

2.12 Fatigue loads

2.12.1 Single crane action

(1)P Fatigue loads shall be determined such, that the operational conditions of the distribution of hoistloads and the effects of the variation of crane positions to the fatigue details are duly considered.

(2) For normal service condition of the crane the fatigue loads may be expressed in terms of fatigue damage equivalent loads Q_e that may be taken as constant for all crane positions to determine fatigue load effects.

(3) The fatigue damage equivalent load Q_e may be determined such that it includes the effects of the stress histories arising from the specified service conditions and the ratio of the absolute number of load cycles during the expected design life of the structure to the reference value $N = 2,0H10^6$ cycles.

Table 2.11:Classification of the fatigue actions from cranes according to EN 13001-1

class of load spectrum		Q_0	Q_1	Q_2	Q_3	Q_4	Q_5
		kQ # 0,0313	0,0313 < kQ # 0,0625	0,0625 < kQ # 0,125	0,125 < kQ # 0,25	0,25 < kQ # 0,5	0,5 < kQ # 1,0
class of total number of cycles							
U_0	C # $1,6≅10^4$	S_0	S_0	S_0	S_0	S_0	S_0
U_1	$1,6≅10^4$ < C # $3,15≅10^4$	S_0	S_0	S_0	S_0	S_0	S_1
U_2	$3,15≅10^4$ < C # $6,30≅10^4$	S_0	S_0	S_0	S_0	S_1	S_2
U_3	$6,30≅10^4$ < C # $1,25≅10^5$	S_0	S_0	S_0	S_1	S_2	S_3
U_4	$1,25≅10^5$ < C # $2,50≅10^5$	S_0	S_0	S_1	S_2	S_3	S_4
U_5	$2,50≅10^5$ < C # $5,00≅10^5$	S_0	S_1	S_2	S_3	S_4	S_5
U_6	$5,00≅10^5$ < C # $1,00≅10^6$	S_1	S_2	S_3	S_4	S_5	S_6
U_7	$1,00≅10^6$ < C # $2,00≅10^6$	S_2	S_3	S_4	S_5	S_6	S_7
U_8	$2,00≅10^6$ < C # $4,00≅10^6$	S_3	S_4	S_5	S_6	S_7	S_8
U_9	$4,00≅10^6$ < C # $8,00≅10^6$	S_4	S_5	S_6	S_7	S_8	S_9

where:

kQ is a load spectrum factor for all tasks of the crane;

C is the total number of working cycles during the design life of the crane.

NOTE: The classes S_i are classified by the load effect history parameter s in EN 13001-1 which is defined as:

$s = < kQ$

where:

kQ is the load spectrum factor;

< is the number of load cycles C related to $2,0H10^6$ load cycles.

The classification is based on a total service life of 25 years.

(4) The fatigue load may be specified as:

$$Q_{e,i} = v_{fat}\ 8_i\ Q_{max,i} \tag{2.16}$$

where:

$Q_{max,i}$ is the maximum value of the characteristic vertical wheel load i;

$\lambda_i = \lambda_{1,i}\ \lambda_{2,i}$ is the damage equivalent factor to make allowance for the relevant standardized fatigue load spectrum and absolute number of load cycles in relation to $N = 2{,}0\text{H}10^6$ cycles;

$$\lambda_{1,i} = \sqrt[m]{kQ} = \left[\sum_j \left(\left(\frac{\Delta Q_{i,j}}{\max \Delta Q_i}\right)^m \frac{n_{i,j}}{\sum n_{i,j}}\right)\right]^{1/m} \tag{2.17}$$

$$\lambda_{2,i} = \sqrt[m]{\nu} = \left[\frac{\sum_j n_{i,j}}{N_i}\right]^{1/m} \tag{2.18}$$

where:

$)Q_{i,j}$ is the load amplitude of range j for wheel i: $)Q_{i,j}=Q_{i,j} - Q_{min,i}$;

$max)Q_i$ is the maximum load amplitude for wheel i:max$)Q_i=Q_{max,i} - Q_{min,i}$;

kQ, < is the damage equivalent factors;

m is theslope of the fatigue strength curve;

v_{fat} is the damage equivalent dynamic impact factor, see (7);

i is the number of the wheel

N_i *is* $2\text{H}10^6$.

(5) For determining the 8-value the use of cranes may be classified according to the load spectrum and the total number of load cycles as indicated in Table 2.11.

(6) 8-values may be taken from Table 2.12 according to the crane classification.

Table 2.12: 8_i-values according to the classification of cranes

classes S	S_0	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9
normal stresses	0,198	0,250	0,315	0,397	0,500	0,630	0,794	1,00	1,260	1,587
shear stresses	0,379	0,436	0,500	0,575	0,660	0,758	0,871	1,00	1,149	1,320

NOTE 1: In determining the 8-values standardized spectra with a gaussian distribution of the load effects, the Miner rule and fatigue strength S-N lines with a slope m = 3 for normal stresses and m = 5 for shear stress have been used.

NOTE 2: In case the crane classification is not included in the specification documents of the crane client indications are given in Annex B.

(7) The damage equivalent dynamic impact factor v_{fat} for normal conditions may be taken as:

$$\varphi_{fat,1} = \frac{1+\varphi_1}{2} \text{ and } \varphi_{fat,2} = \frac{1+\varphi_2}{2} \tag{2.19}$$

2.12.2 Stress range effects of multiple wheel or crane actions

(1) The stress range due to damage equivalent wheel loads Q_e may be determined from the evaluation of stress histories for the fatigue detail considered.

Section 3 Actions induced by machinery

3.1 Field of application

(1) This section applies to structures supporting rotating machines which induce dynamic effects in one or more planes.

(2) This section presents methods to determine the dynamic behaviour and action effects to verify the safety of the structure.

NOTE: Though a sharp bound cannot be set, in general it may be assumed that for minor machinery with only rotating parts and weighting less than 5 kN or having a power less than 50 kW, the action effects are included in the imposed loads and separate considerations are therefore not necessary. In these cases the use of so called vibration absorbers under the supporting frame is sufficient to protect the machine and the surroundings. Examples are washing machines and small ventilators.

3.2 Classification of actions

3.2.1 General

(1)P Actions from machinery are classified as permanent, variable and accidental actions which are represented by various models.

3.2.2 Permanent actions

(1) Permanent actions during service include the selfweight of all fixed and moveable parts and static actions from service such as:

– selfweight of rotors and the hull (vertical);
– selfweight of condensators, if relevant, taking account of the water infill (vertical);
– actions from vacuum for turbines, the condensators of which are connected to the hull by compensators. (vertical and horizontal);
– drive torques of the machine transmitted to the foundation by the hull (pairs of vertical forces);
– forces from friction at the bearings induced by thermal expansion of the hull (horizontal);
– actions from selfweight, forces and moments from pipes due to thermal expansion, actions from gas; flow and gas pressure (vertical and horizontal);
– temperature effects from the machine and pipes for instance temperature differences between machine and pipes and the foundation.

(2) Permanent actions during transient stages (erection, maintenance or repair) are those from selfweight only including those from hoisting equipments, scaffolding or other auxiliary devices.

3.2.3 Variable actions

(1) Variable actions from machinery during normal service are dynamic actions caused by accelerated masses such as:
– periodic frequency dependent bearing forces due to eccentricities of rotating masses in all directions, mainly perpendicular to the axis of the rotors;
– free mass forces or mass moments;
– periodic actions due to service depending on the type of machine that are transmitted by the hull or bearings to the foundations;
– forces or moments due to switching on or off or other transient procedures like for instance synchronisations.

3.2.4 Accidental actions

(1) Accidental actions may occur from:
– accidental magnification of the eccentricity of masses (for instance by fracture of blades or accidental deformation of moveable parts);
– short circuit or missynchronisation between generators and machines;
– impact effects from pipes by shutting down.

3.3 Design situations

(1)P The relevant actions induced by machinery shall be determined for each design situation identified in accordance with EN 1990.

(2)P Design situations shall in particular be selected for verifying that:
– the service conditions of the machinery are in compliance with the service requirements and no damage is induced to the structure supporting the machine and its foundation by accidental actions that would infringe the subsequent use of this structure for further service;
– the impact on the surroundings, for instance disturbance of sensitive equipment, is within acceptable limits;
– no ultimate limit state may occur in the structure;
– no fatigue limit state may occur in the structure.

NOTE: Unless specified otherwise, the serviceability requirements should be determined in contracts and/or in the design.

3.4 Representation of actions

3.4.1 Nature of the loads

(1)P In the determination of action effects a distinction shall be made between the static and the dynamic action effects.

(2)P In the static actions both those from machinery and those from the structure shall be included.

NOTE: The static actions from the machinery are the permanent actions defined in 3.2.2. They may be used for determining creeping effects or when limitations of static deformations are given.

(3)P The dynamic action effects shall be determined taking into account the interaction between the excitation from the machinery and the structure.

NOTE: The dynamic actions from the machinery are the variable actions defined in 3.2.3.

(4)P Dynamic action effects shall be determined by a dynamic calculation with an appropriate modelling of the vibration system and the dynamic action.

(5) Dynamic effects may be disregarded where not relevant.

3.4.2 Modelling of dynamic actions

(1) The dynamic actions of machines with only rotating parts, for instance rotating compressors, turbines, generators and ventilators, consist of periodically changing forces which may be defined by a sinusoidal function, see Figure 3.1.

(2) A short circuit $M_k(t)$ moment may be represented by a combination of sinusoidal moment-time diagrams acting between the rotor and the hull.

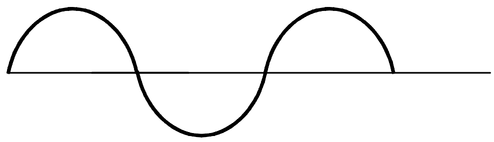


Figure 3.1: Harmonic force ~~Periodically changing forces~~

3.4.3 Modelling of the machinery-structure interaction

(1)P The vibration system composed of the machine and the structure shall be modelled such, that the excitations, the mass quantities, stiffness properties and the damping are sufficiently taken into account to determine the actual dynamic behaviour.

(2) The model may be linear elastic with concentrated or distributed masses connected with springs and supported by springs.

(3) The common centre of gravity of the system (for instance of the foundation and machine) should be located as near as possible to the same vertical line as the centroid of the foundation area in contact with the soil. In any case the eccentricity in the distribution of masses should not exceed 5% of the length of the side of the contact area. In addition, the centre of gravity of the machine and foundation system should if possible be below the top of the foundation block.

(4) In general the three possible degrees of freedom for translations and the three degrees of freedom for rotations should be considered; it is however in general not necessary to apply a three dimensional model.

(5) The properties of the supporting medium of the foundation structure should be converted in terms of the model (springs, damping constants etc.). The required properties are:

– for soils: dynamic G-modulus and damping constants;
– for piles: dynamic spring constants in vertical and horizontal directions ~~for vertical and horizontal motions;~~
– for springs: spring constants in horizontal and vertical directions and for rubber springs the damping data.

3.5 Characteristic values

(1) A complete survey of the static and dynamic forces for the various design situations should be supplied by the machine manufacturer together with all other machine data such as outline drawings, weights of static and moving parts, speeds, balancing etc.

(2) The following data should be made available to the designer by the machine manufacturer:
– loading diagram of the machine showing the location, magnitude and direction of all loads including dynamic loads;
– speed of the machine;
– critical speeds of the machine;
– outline dimensions of the foundation;
– mass moment of inertia of the machine components;
– details of inserts and embedments;
– layout of piping, ducting etc, and their supporting details;
– temperatures in various zones during operation;
– allowable displacements at the machine bearing points during normal operation.
(3) In simple cases, the dynamic forces (free forces) for rotating machine parts may be determined as follows:

$$F_s = m_R \; T_s^2 \; e = m_R \; T_s \, (T_s \; e) \tag{3.1}$$

where:

F_s	is the free force of the rotor;
m_R	is the mass of the rotor;
T_s	is the circular frequency of the rotor;
e	is the eccentricity of the rotor mass;
$T_s \; e$	is the accuracy of balancing of the rotor, expressed as a velocity amplitude.

(4) For the accuracy of balancing the following situations should be considered:

– persistent situation:

the machine is well balanced. However with time the balance of the machines decreases to a degree that is just acceptable for normal operation. A warning system on the machine achieves, that the operator is warned in case of exceeding a certain limit. Up to that state of balance no vibration hindrance may occur to the structure and the surroundings and the requirements concerning the vibration level must be fulfilled.

– accidental situation:

the balance is completely disturbed by an accidental event: the monitoring system achieves the switch off of the machine. The structure must be strong enough to withstand the dynamic forces.

(5) In simple cases the interaction effect from the excitation of a machine with a rotating mass and the dynamic behaviour of the structure may be expressed by a static equivalent force

$$F_{\mathrm{eq}} = F_{\mathrm{s}} < \tag{3.2}$$

where:

F_s is the free force of the rotor;

$<$ is the magnification factor which depends on the ratio of the natural frequency n_{e} (or T_{e}) of the structure to the frequency of the exciting force n_{s} (or T_{s}) and the damping ratio D.

(6) For harmonically varying forces (free forces of rotating equipment) the magnification factor may be taken in the following way:

a) for small damping or far from resonance

$$\nu = \frac{\omega_{\mathrm{e}}^2}{\omega_{\mathrm{e}}^2 - \omega_{\mathrm{s}}^2} \tag{3.3}$$

b) in case of resonance $T_e = T_s$ and a damping ratio D

$$\nu = \left[\left(1 - \frac{\omega_{\mathrm{s}}^2}{\omega_{\mathrm{e}}^2}\right)^2 + \left(2D\,\frac{\omega_{\mathrm{s}}}{\omega_{\mathrm{e}}}\right)^2\right]^{-\frac{1}{2}} \tag{3.4}$$

(7) If the time history of the short circuit moment $M_{\mathrm{k}}(t)$ is not indicated by the manufacturer, the following expression may be used:

$$M_{\mathrm{k}}(t) = 10\,M_{\mathrm{o}}\left(e^{-\frac{t}{0{,}4}}\sin \Omega_{\mathrm{N}} t - \frac{1}{2}e^{-\frac{t}{0{,}4}}\sin 2\,\Omega_{\mathrm{N}} t\right) - M_{\mathrm{o}}\left(1 - e^{-\frac{t}{0{,}15}}\right) \tag{3.5}$$

where:

M_{o} is the nominal moment resulting from the effective power;

Σ_N is the frequency of the electric net;

t is the time [s].

(8) For natural frequencies in the range $0{,}95\Sigma_N$ to $1{,}05\Sigma_N$ the calculative frequencies of the electric net should be identical with these natural frequencies.

(9) As a simplification, an equivalent static action may be considered for determine moments as below:

$$M_{\mathrm{k,eq}} = 1{,}7\, M_{\mathrm{k,max}} \tag{3.6}$$

where:

$M_{\mathrm{k,max}}$ is the peak value of $M_{\mathrm{k}}(t)$.

(10) In case no indication on $M_{\mathrm{k,max}}$ is given from the manufacturer the following value may be used:

$$M_{\mathrm{k,max}} = 12\, M_{\mathrm{o}}\,. \tag{3.7}$$

3.6 Serviceability criteria

(1) Serviceability criteria in general are related to vibration movements of:
a) the axis of the machine and its bearings;
b) extreme points of the structure and the machinery.

(2) Characteristics of the movements are:
– the path amplitude A;
– the velocity amplitude $T_s\, A$;
– the acceleration amplitude $T_s^2\, A$.

(3)P In calculating the amplitudes of the system, the translational vibrations as well as the rotational vibrations caused by the dynamic forces and moments shall be taken into account and also the spread in the stiffness properties of the foundation and the supporting medium (soil, piles).

(4) In the simple case of a one mass spring system, Figure 3.2, the path amplitudes may be calculated as follows:

$$A = \frac{F_{\mathrm{eq}}}{k} \tag{3.8}$$

where:

k is the spring constant of the system.

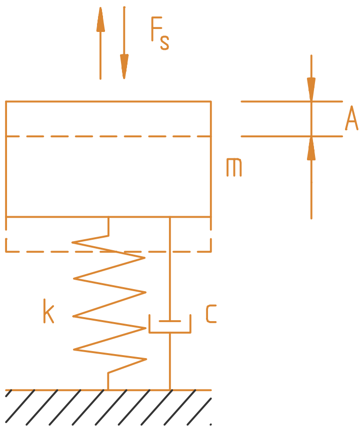


Figure 3.2: Mass spring system

Annex A (informative)
Basis of design – supplementary clauses to EN 1990 for runway beams loaded by cranes

A.1General

(1) This annex gives rules on partial factors for actions ((*(* factors), and on combinations of crane loads on runway beams with permanent actions, quasistatic wind, snow and temperature actions and on the relevant P factors.

(2) If other actions need to be considered (for instance mining subsidence) the combinations should be supplemented to take them into account. The combinations should also be supplemented and adapted for the erections phases.

(3) When combining a group of crane loads together with other actions, the group of crane loads should be considered as one action.

(4) When considering combinations of actions due to crane loads with other actions the following cases should be distinguished:

(a)runways outside buildings;

(b)runways inside buildings where climatic actions are resisted by the buildings and structural elements of the buildings may also be loaded directly or indirectly by crane loads.

(5) For runways outside buildings the characteristic wind action on the crane structure and the hoisting equipment may be assessed in ENV 1991-2-4 as characteristic force F_{wk}.

(6) When considering combinations of hoist loads with wind action, the maximum wind force compatible with crane operations should also be considered. This force F^*_w is associated with a wind speed equal to 20 m/s.The reference area $A_{ref,x}$ for the hoist load should be determined for each specific case.

(7) For runways inside buildings wind loads and snow loads on the crane structure may be neglected; however in structural parts of the building that are loaded by wind, snow and crane loads the appropriate load combinations should be carried out.

A.2 Ultimate limit states

A.2.1 Combinations of actions

(1) For each critical load case, the design values of the effects of actions should be determined by combining the values of actions which occur simultaneously in accordance with EN 1990.

(2) Where an accidental action is to be considered no other accidental action nor wind nor snow action need to be considered to occur simultaneously.

A.2.2Partial factors

(1) For verifications governed by the strength of structural material or of the ground, the partial factors on actions for ultimate limit states in the persistent, transient and accidental design situations are given in Table A.1.

NOTE: For the design of runway beams Table A1 and the following notes cover cases STR and GEO specified for buildings in 6.4.1(1) of EN 1990. For case EQU, see (2) below.

Table A.1: Partial factors

Action	Symbol	Situation	
		P/T	A
Permanent crane actions			
- unfavourable	$\gamma_{G,sup}$	1,35	1,00
- favourable	$\gamma_{G,inf}$	1,00	1,00
Variable crane actions			
- unfavourable	$\gamma_{Q,sup}$	1,35	1,00
- favourable	$\gamma_{Q,inf}$		
crane present		1,00	1,00
crane not present		0,00	0,00
Other variable actions	γ_Q		
- unfavourable		1,50	1,00
- favourable		0,00	0,00
Accidental actions	γ_A		1,00

P - Persistent situation T - Transient situation A - Accidental situation

(2) For verifications with regard to loss of static equilibrium and uplift of bearings, the favourable and unfavourable parts of variable crane actions should be considered as individual actions and unless otherwise specified (see in particular the relevant design Eurocodes) the unfavourable and favourable parts should be associated with $(_{Gsup}$ =1,05 and $(_{Ginf}$ = 0,95 respectively. The other partial factors on actions (especially on variable actions) are as in (1).

A.2.3 P *factors for crane loads*

(1) *P* factors for crane loads are as given in Table A.2.

Table A.2: *P* factors for crane loads

Action	Symbol	P_0	P_1	P_2
Single crane or groups of loads induced by cranes	Q_r	1,0	0,9	– [1)]
[1)] Ratio between the permanent crane action and the total crane action				

A.3 Serviceability limit states

A.3.1 Combinations of actions

(1) For verification of serviceability limit states the various combinations should be taken from EN 1990.

(2) When tests are performed, the test loading of the crane, see 2.10, should be considered as the crane action.

A.3.2 Partial factors

(1) In serviceability limit states the partial factor on actions on crane supporting structures should be taken as 1,0 unless otherwise specified.

A.3.3 P *factors for crane actions*

(1) Values of *P* factors are given in Table A.2.

A.4 Fatigue

(1) The verification rules for fatigue depend on the fatigue load model to be used and are specified in the design Eurocodes.

Annex B (informative)
Guidance for crane classification for fatigue

Table B.1: Recommendations for loading classes

Item	Type of crane	Hoisting class	*S-classes*
1	Hand-operated cranes	HC 1	S0, S1
2	Assembly cranes	HC1, HC2	S0, S1
3	Powerhouse cranes	HC1	S1, S2
4	Storage cranes - with intermittend operation	HC2	S4
5	Storage cranes, spreader bar cranes, scrap yard cranes -with continuous operation	HC3, HC4	S6 ,S7
6	Workshop cranes	HC2, HC3	S3,S4
7	Overhead travelling cranes, ram cranes - with grab or magnet operation	HC3, HC4	S6, S7
8	Casting cranes	HC2, HC3	S6, S7
9	Soaking pit cranes	HC3, HC4	S7, S8
10	Stripper cranes, charging cranes	HC4	S8, S9
11	Forging cranes	HC4	S6, S7
12	Transporter bridges, semi-portal cranes, portal cranes with trolley or slewing crane - with hook operation	HC2	S4, S5
13	Transporter bridges, semi-portal cranes, portal cranes with trolley or slewing crane - with grab or magnet operation	HC3, HC4	S6, S7
14	Travelling belt bridge with fixed or sliding belt(s)	HC1	S3, S4
15	Dockyard cranes, slipway cranes, fitting-out cranes - with hook operation	HC2	S3, S4
16	Wharf cranes, slewing, floating cranes, level luffing slewing - with hook operation	HC2	S4, S5
17	Wharf cranes, slewing, floating cranes, level luffing slewing - with grab or magnet operation	HC3, HC4	S6, S7
18	Heavy duty floating cranes, gantry cranes	HC1	S1, S2
19	Shipboard cargo cranes - with hook operation	HC2	S3, S4
20	Shipboard cargo cranes - with grab or magnet operation	HC3, HC4	S4, S5
21	Tower slewing cranes for the construction industry	HC1	S2, S3
22	Erection cranes, derrick cranes - with hook operation	HC1, HC2	S1, S2
23	Rail mounted slewing cranes - with hook operation	HC2	S3, S4
24	Rail mounted slewing cranes - with grab or magnet operation	HC3, HC4	S4, S5
25	Railway cranes authorised on trains	HC2	S4
26	Truck cranes, mobile cranes - with hook operation	HC2	S3, S4
27	Truck cranes, mobile cranes - with grab or magnet operation	HC3, HC4	S4, S5
28	Heavy duty truck cranes, heavy duty mobile cranes	HC1	S1, S2