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RULES FOR THE DESIGN OF HOISTING APPLIANCES

BOOKLET 1

OBJECT AND SCOPE

The total 3rd Edition comprises booklets 1 to 8

Also available in French and German

This booklet is part of the "Rules for the design of hoisting appliances" consisting of 8 booklets :

Booklet 1 - Object and scope
Booklet 2 - Classification and loading on structures and mechanisms
Booklet 3 - Calculating the stresses in structures
Booklet 4 - Checking for fatigue and choice of mechanism components
Booklet 5 - Electrical equipment
Booklet 6 - Stability and safety against movement by the wind
Booklet 7 - Safety rules
Booklet 8 - Test loads and tolerances

and must not be used separately.

BOOKLET 1

OBJECT AND SCOPE

CONTENTS

1.1. PREFACE

The Rules for the Design of Hoisting Appliances set up by the Technical Committee of the Section I of the F.E.M., which have been published so far in two Editions, the first one in 1962 and the second in 1970, have been increasingly widely used in many countries all over the world.

Taking account of this enlarged audience, Section I of the FEM decided to change the format of these Design Rules and to facilite updating by abandoning the single volume form and dividing the work into a number of separate booklets as follows :

Booklet 1 - Object and Scope

Booklet 2 - Classification and loading on structures and mechanisms

Booklet 3 - Calculating the stresses in the structure

Booklet 4 - Checking for fatigue and choice of mechanism components

Booklet 5 - Electrical equipment

Booklet 6 - Stability and safety against movement by the wind

Booklet 7 - Safety rules

Booklet 8 - Test loads and tolerances

Although not directly a part of these Design Rules, the opportunity is taken to draw attention to the new Terminology of Section I.

1.2. INTRODUCTION

To facilitate the use of these Rules by the purchasers, manufacturers and safety organizations concerned, it is necessary to give some explanation in regard to the two following questions.

1. How should these Rules be applied in practice to the different types of appliance whose construction they cover ?

2. How should a purchaser use these Rules to define his requirements in relation to an appliance which he desires to order and what conditions should he specify in his enquiry to ensure that the manufacturers can submit a proposal in accordance with his requirements ?

1. It is necessary first to recognize the great variety of appliances covered by the Design Rules. It is obvious that a crane having very high speeds and a rapid working cycle ist not designed in the same manner as a small overhead crane for infrequent duty. For such a machine there can be no question of making all the verifications which would appear to be required, from reading through the Rules, because one would clearly finish with a volume of calculations which would be totally out of proportion to the objective in view. The manufacturer must therefore decide in each particular case which parts of the machine, which he is designing, should be analysed and those for which calculation is unnecessary, not because he must accept that the results for the latter would not be in accordance with the requirements of the Rules, but because on the contrary he is certain in advance that the calculations for the latter would only confirm a favourable outcome. This may be because a standard component is being used which has been verified once and for all or because it has been established that some of the verifications imposed by the Rules cannot in certain cases have an unfavourable result and therefore serve no purpose.

   If one takes, for example, the fatigue calculations, it is very easy to see that certain verifications are unnecessary for appliances of light or moderate duty because they always lead to the conclusions that the most unfavourable cases are those resulting from checking safety in relation to the elastic limit.

   These considerations show that calculations made in accordance with the Rules can take a very different form according to the type of appliance which is being considered, and may in the case of a simple machine or a machine embodying standard components be in the form of a brief summary without prejudicing the compliance of the machine with the principles set out by the Design Rules.

2. As far as the second question is concerned, some explanation is first desirable for the purchaser, who may be somewhat bewildered by the extent of the document and confused when faced with the variety of choice which it presents, a variety which is, however, necessary if one wishes to take account of the great diversity of problems to be resolved.

In fact, the only important matter for the purchaser is to define the duty which he expects from his appliance and if possible to give some indication of the duty of the various motions.

As regards the service to be performed by the appliance, two factors must be specified, i.e. :

- the class of utilization, as defined in 2.1.2.2 ;

- the load spectrum, as defined in 2.1.2.3.

In order to arrive at the number of hoisting cycles determining the class of utilization, the purchaser may, for instance, find the product of :

- the number of hoisting cycles which the appliance will have to average each day on which it is used ;

- the average number of days of use per year ;

- the number of years after which the appliance may be considered as having to be replaced.

Similarly, the load spectrum may be calculated by means of the simplified formula set out in the above mentioned paragraph.

In neither case do the calculations call for a high degree of accuracy, being more in the nature of estimates than of precise calculations. Moreover, the numbers of hoisting cycles determining the classes of utilization do not constitute guaranteed values : they are merely guide values, serving as a basis for the fatigue calculations and corresponding to an average life which can be expected with a reasonable degree of safety, provided the appliance, designed in accordance with the present design rules, is used under the conditions specified by the customer in his call for tender and also that it is operated and maintained regularly in compliance with the manufacturer's instructions.

If he is unable to determine the class of utilization and the load spectrum, the purchaser may confine himself to stating the group in which the appliance is to be classified. A guide as to the choice of group is provided by Table 2.1.2.5., which is not binding but gives simple examples which, by way of comparison, may facilitate selection.

In the case of mechanisms, the following should also be specified :

- the class of utilization, as defined in 2.1.3.2 ;

- the load spectrum, as defined in 2.1.3.3. ;

the same observations apply as were made concerning the appliance as a whole.

The tables in Appendix A.2.1.1. may be used to facilitate determination of the class of utilization. On the basis of the class of utilization of the appliance, they make it possible to determine a total number of working hours for the mechanism, according to the average duration of a working cycle and the ratio between the operating time of the mechanism and the duration of the complete cycle.

Table T.2.1.3.5. may be used as a guide by a purchaser wishing simply to choose a group for each of the mechanisms with which the appliance he wants to order is to be fitted.

As a general rule, the purchaser has no other information to supply in connection with the design of the appliance, except in certain cases :

- the area of hoisted loads presented to the wind, if this area is larger than those defined in 2.2.4.1.2. ;
- the value of the out-of-service wind, where local conditions are considered to necessitate design for an out-of-service wind greater than that defined in 2.2.4.1.2.

1.3. OBJECT OF THE RULES

The purpose of these rules is to determine the loads and combinations of loads which must be taken into account when designing hoisting appliances, and also to establish the strength and stability conditions to be observed for the various load combinations.

1.4 SCOPE

The Rules apply to the design of lifting appliances or parts of lifting appliances which appear in the illustrated terminology for cranes and heavy lifting appliances of Section I of the FEM.

<u>Appliances not covered by Section I</u>

1) Lifting appliances included in Section V, for example :

   - mobile jib cranes on pneumatic or solid rubber tyres, crawler tracks, lorries, trailers and brackets.

2) Lifting equipment which according to the internal regulations of FEM, are included in Section IX, that is to say :

- various items of series lifting equipment,
- electric hoists,
- pneumatic hoists,
- accessories for lifting,
- hand operated chain blocks,
- elevating platforms, work platforms, dock levellers,
- winches,
- jacks, tripods, combined apparatus for pulling and lifting,
- stacker cranes.

For series lifting equipment, those chapters of the Design Rules of Section I which have been accepted by Section IX should be used.

These rules comprise eight booklets. In addition some booklets contain appendices which give further information on the method of application.

LIST OF SYMBOLS AND NOTATIONS

Symbol	Dimension	Designation – First mention page (...)
A	m^2	Area exposed to wind (2-23)
A	-	Combined influence of residual tensile stresses with dead weight stresses (3-4)
A1 to A8	-	Crane groups (2-3)
Ae	m^2	Enveloped area of lattice (2-27)
a	mm	Wheelbase of crane (2-20); Dimension of lattice in wind load calculation (2-27); Length of strip of plate in buckling calculation (3-3 Size of fillet weld in notch case 2.33 (3-62)
a	m/s^2	Acceleration (5-22)
B	-	Influence of thickness of structural member (3-6)
B	mm	Width of lattice in wind load calculation (2-27)
B0 to B10	-	Classes of utilisation of structural members (2-11)
b	mm	Breadth of section across wind front (2-27); Largest dimension of rectangular steel section (3-6); Length of plate in buckling calculation (3-39); Useful width of rail in wheel calculation (4-21)
C	-	Influence of cold (3-7); Coefficient used to calculate the tightening torque of bolts (3-28); Selection coefficient for choice of running steel wire ropes (4-15)
Cf	-	Shape coefficient in wind load calculation (2-24)
c	-	Starting class (5-20)
c, c'	-	Factors characterising the slope of Wöhler curves (4-9)
c_1, c_{1max}	-	Rotation speed coefficients for wheel calculation (4-21)
c_2, c_{2max}	-	Group coefficient for wheel calculation (4-21)
cos φ	-	Power factor (5-8)
D	-	Symbol used in plate inspection for lamination defects (3-57)
D	m	Section diameter in shape factor determination (2-25)
D	mm	Rope winding diameter (4-19); Wheel diameter (4-21); Shaft diameter in fatigue verification of mechanism parts (4-26).

D_t	mm	Diameter of bolt holes (3-15)
d	mm	Depth of section parallel to wind direction in wind load calculation (2-27); Nominal diameter of bolt (3-28); Nominal diameter of rope (4-18); Shaft diameter in fatigue verification of mechanism parts (4-26)
d_2	mm	Bolt diameter at thread root (3-14)
d_c	-	Number of completed starts per hour (5-20)
d_i	-	Number of impulses or incomplete starts per hour (5-20)
d_{min}	mm	Minimum rope diameter (4-33)
d_t	mm	Nominal bolt diameter (3-14)
E	N/mm^2	Elastic modulus of steel (3-39)
E1 to E8	-	Groups of components (2-14)
ED	%	Duty factor (5-19)
e	mm	Thickness of strip of plate in buckling calculation (3-39); Thickness of plate in welded joints (3-62)
e_1, e_2	mm	Plate thicknesses in welded joints (3-64)
F	N	Wind force (2-23); Horizontal force during acceleration (2-45); Tensile load in bolts (3-19); Compressive force on member in crippling calculation (3-34)
F_0	N	Minimum breaking load of rope (4-17)
F_1	N	Permissible working load on bolts (3-15)
F_c	N	Projection of rope load on the x axis during travelling (2-49)
F_{cm}	N	Inertia force due to the load during travelling (2-46)
F_{cmax}	N	Maximum value of F_c (2-51)
f	-	Fill factor of rope (4-18); Number of electrical brakings (5-20)
fiT	s	Running time of motor (5-24)
f_s	-	Coefficient for relative times of deceleration and acceleration (5-25)
g	m/s^2	Acceleration due to gravity, according to ISO 9.80665 m/s^2 (2-46)
H	-	Coefficient depending on group for choice of rope drums and pulleys (4-19)
I	kgm^2	Moment of inertia of mass in slewing motion (2-56)
I_1, I_2	mm^4	Moment of inertia of stiffeners (3-45)

I_D	A	Starting current of motor (5-7)
I_N	A	Nominal current of motor (5-6)
I_{tot}	A	Sum of currents I_A and I_N (5-8)
I_Z	mm^4	Moment of inertia of stiffeners (3-44)
I_i	kgm^2	Moment of inertia of mass of a part in rotation (2-45)
I_m	kgm^2	Moment of inertia of mass of all parts in rotation (2-49)
J_M	kgm^2	Moment of inertia of mass of motor and brake (5-22)
j	-	Group number in component groups E1 to E8 (4-10)
J_0	m/s^2	Acceleration in horizontal motions (2-50)
j_m	m/s^2	Average acceleration/deceleration in horizontal motions (2-46)
K	-	Cubic mean factor for choice of bearings (4-13)
K'	-	Empirical coefficient for determining minimum breaking strength of rope (4-18)
K0 to K4	-	Stress concentration classes for welded parts (3-48)
K_2	-	Coefficient for calculating force in the direction of the wind for lattice girders and towers (2-29)
K_L	N/mm^2	Pressure of wheel on rail (4-25)
K_m	-	$\frac{Mn\ med}{M\ max}$ (5-24)
k	-	Spinning loss coefficient (4-18)
k_c	-	Corrosion coefficient in fatigue verification of mechanism parts (4-26)
k_d	-	Size coefficient in fatigue verification of mechanism parts (4-26)
k_H	-	Correction coefficient for abnormal location (5-19)
k_m	-	Spectrum coefficient for mechanisms (2-8)
k_p	-	Spectrum coefficient for cranes (2-4)
k_s	-	Shape coefficient in fatigue verification of mechanism parts (4-26)
k_{sp}	-	Spectrum coefficient for components (2-12)
k'_{sp}	-	Spectrum coefficient for mechanism parts (4-10)
k_u	-	Surface finish (machining) coefficient in fatigue verification of mechanism parts (4-26)
k_σ , k_τ	-	Buckling coefficients used in buckling calculations (3-33)

L	N	Maximum permissible lifting force (5-17)
L1 to L4		Spectrum classes for mechanisms (2-9)
ℓ	m	Length of suspension/length of load pendulum (2-46)
ℓ	m	Equivalent length of line (5-8)
ℓ	mm	Length of members in wind force calculations (2-27); Overall width or rail head (4-22)
ℓ_k	mm	Length of parts tightened in bolted joints (3-15)
M	Nm	External moment in bolted joints (3-19)
M1 to M8	-	Mechanism groups (2-6) (5-20)
M1, M2 and M3	Nm	Motor torques required during a cycle of operations (5-18)
M_A	Nm	Accelerating torque (5-21)
M_F	Nm	Braking torque of motor (5-18)
M_f	Nm	Torque required to lift the safe working load (5-25)
M_{fmed}	Nm	Resistance to travelling with load (5-25)
M_{Nmax}	Nm	Maximum running torque required to lift the load (5-18)
M_a	Nm	Torque required to tighten bolts (3-28)
M_F	Nm	Bending moment in member in crippling calculation (3-34)
M_{max}	Nm	Maximum value of motor torque (5-24)
M_{med}	Nm	Mean value of torque $\overline{M}$ during motor running time fiT (5-24)
M_{min}	Nm	Minimum motor torque during starting (5-18)
M_{nmed}	Nm	Mean nominal torque required (5-24)
M_x	Nm	Mean of absolute values of motor torques during acceleration or deceleration (5-25)
m	-	Number of friction surfaces in bolted joints (3-19)
m	kg	Equivalent mass for calculating loads due to horizontal motions (2-45); Total mass of crane (2-47)
m_o	kg	Mass of crane without load (2-45)
m_l	kg	Mass of the load (2-46)
m_H	kg	Sum of masses set in motion, excluding hook load (5-22)
m_L	kg	Mass of the hook load (5-22)

m_e	kg	Equivalent mass in calculation of loads due to horizontal motion (2-49)
m	kg	Load (2-4)
m_{max}	kg	Safe working load (2-4)
N	-	Number of hoisting cycles (2-39)
N	N	Force perpendicular to joint plane in bolted joints (3-19)
N_G	-	Ordinary quality in welding (3-57)
N_M	N	Tensile force due to external moment in bolted joints (3-19)
n	-	Number of hoisting cycles (2-4); Number of stress cycles (4-9)
n	min^{-1}	Nominal rotation speed of motors in rpm (5-22)
n_{max}	-	Number of hoisting cycles determining the total duration of use (2-4)
P	N	Load on wheel (4-25)
P1 to P4	-	Spectrum classes for components (2-12)
P10, P100	-	Symbols indicating welding tests (3-57)
P_L	N/mm^2	Limiting pressure in wheel calculation (4-21)
P_N	W	Nominal power of motor (5-26)
P_{Nmax}	W	Maximum power requirement of motor (5-17)
P_{Nmed}	W	Mean power requirement of motor (5-26)
$P_{mean\ I,\ II}$	N	Mean load on wheel in loading cases I and II (4-21)
$P_{mean\ III}$	N	Mean load on wheel in loading case III (4-21)
$P_{min\ I,II,III}$	N	Minimum load on wheel in loading cases I, II and III (4-21)
$P_{max\ I,II,III}$	N	Maximum load on wheel in loading cases I, II and III (4-21)
P_{med}	kW	Equivalent mean power (5-19)
p	mm	Span of crane (2-20)
p_a	mm	Pitch of thread (3-14)
Q1 to Q4	-	Spectrum classes for cranes (2-5)
q	-	Correction factor for shape coefficient k_s (4-27)
q	N/mm^2	Dynamic pressure of the wind (2-22)
q	-	Coefficient for type of electric braking, etc (5-20)
R_0	N/mm^2	Minimum ultimate tensile strength of the wire of a rope (4-18)

R_E	N/mm^2	Apparent elastic limit σ_E according to ISO 3800/1 (3-16)
r	-	Number of levels of loading (2-8): Ratio of stresses for large deformations (3-23)
r	mm	Radius of cylindrical shells in buckling calculations (3-44): Radius of rope groove (4-20): Radius of rail head (4-22): Blending radius (4-26)
r	-	Coefficient for type of electric braking (5-20)
r	Ω /km	Ohmic resistance per unit length (5-9)
S	N	Stress (2-8): Maximum tensile force in rope (4-16)
S	m^2	Area of all members of lattice girders and towers (2-29)
S	mm^2	Cross sectional area of conductor (5-8)
S_1	mm	Bearing diameter under bolt head (3-15)
S_G	-	Special quality of welding (3-57)
S_G	N	Load due to dead weight, constant load (2-15), (3-23)
S_H	N	Load due to horizontal motions (2-19)
S_L	N	Load due to working load (2-15)
S_M	N	Load due to torques (2-33)
S_{Mmean}	N	Mean type M load in bearing calculation (4-13)
S_{Mmin}	N	Minimum type M load in bearing calculation (4-13)
$S_{Mmax\ I}$	N	Maximum type M load in load case I (2-34)
$S_{Mmax\ II}$	N	Maximum type M load in load case II (2-35)
$S_{Mmax\ III}$	N	Maximum type M load in load case III (3-35)
S_{MA}	N	Load due to acceleration or braking (2-33)
S_{MCmax}	N	Load due to maximum motor torque (2-37)
S_{MF}	N	Load due to frictional forces (2-33)
S_{MG}	N	Load due to vertical displacement of moveable parts of a lifting appliance, excluding the working load (2-33)
S_{ML}	N	Load due to vertical displacement of the working load (2-33)
S_{MW}	N	Load due to the effect of limiting wind for appliance in service (2-33)
$S_{MW\ 8}$	N	Load due to wind effect for q = 80 N/mm^2 (2-35)
$S_{MW\ 25}$	N	Load due to wind effect for q = 250 N/m^2 (2-35)
S_R	N	Load due to forces not reacted by torques (2-33)
$S_{Rmax\ I}$	N	Maximum type R load in loading case I (2-34)

$S_{Rmax\ II}$	N	Maximum type R load in loading case II (2-35)
$S_{Rmax\ III}$	N	Maximum type R load in loading case III (2-36)
S_{Rmin}	N	Minimum type R load in bearing calculation (4-14)
S_{Rmean}	N	Mean type R load in bearing calculation (4-14)
S_{RA}	N	Load due to accelerations/decelerations (2-33)
S_{RG}	N	Load due to self weight of crane parts (2-33)
S_{RL}	N	Load due to working load (2-33)
S_{RW}	N	Load due to wind (2-33)
$S_{RW\ max}$	N	Load due to out of service wind (2-36)
$S_{RW\ 25}$	N	Wind load for q = 250 N/m^2 (2-35)
S_T	N	Load due to buffer effect (2-21)
S_V	N	Variable load when calculating structural members subject to large deformations (3-23)
S_W	N	Load due to in service wind (2-31)
S_{Wmax}	N	Load due to out of service wind (2-31)
S_b	mm^2	Root sectional area of bolt (3-15)
S_{eq}	mm^2	Equivalent sectional area of tightened bolt (3-15)
S_p	m^2	Area of members of lattice girders and towers (2-29)
s	m	Span of lifting appliance (8-4); Rail centres of crab (8-5); Distance between travel rails of lifting appliance (8-8)
T	h	Total duration of use of lifting appliance (2-8)
T	J	Total kinetic energy in luffing motion (2-56)
T	°C	Ambient temperature at place of erection (3-7)
T	N	Force parallel to joint plane in bolted joint (3-19)
T	s	Duration of cycle (5-24)
T0 to T9	-	Classes of utilisation of mechanisms (2-8)
T_1	s	Period of oscillation (2-46)
T_a	N	Permissible load per bolt which can be transmitted by friction (3-19)
T_c	°C	Test temperature for impact test (3-8)
T_i	h	Total duration of use of mechanism (2-39)
T_m	s	Mean duration of acceleration or deceleration (2-46)
t	s	Time when calculating loads due to horizontal motion (2-48)

t	mm	Thickness of structural member when choosing steel quality (3-6); Thickness of cylindrical shell wall in buckling analysis (3-44); Thickness of web of trolley rail girder (8-6)
$t_1, t_2 \ldots t_i \ldots t_r$	s	Duration of different levels of loading (2-8)
t_1, t_2, t_3	s	Duration of action of couples M_1, M_2 and M_3 (5-18)
t^*	mm	Ideal section thickness when choosing steel quality (3-6)
t_d	s	Duration of deceleration when calculating loads due to horizontal motion (2-51)
t_{mc}	s	Average duration of a hoisting cycle (2-39)
U0 to U9	-	Classes of utilisation of lifting appliances (2-3)
Δu	V	Permissible voltage drop (5-8)
V_L	m/s	Hoisting speed (2-16); (5-17)
V_s	m/s	Theoretical wind speed (2-22)
V_t	m/s	Nominal travel speed of appliance (2-21)
v	m/s	Steady horizontal speed of point of suspension of load (2-45)
v	mm	Distance of extreme fibre from centre of gravity of section in crippling calculation (3-34)
v	m/s	Travel speed (5-22)
W	J	Work done per unit time during starting (5-26)
W_0, W_1, W_2	-	Notch cases of unwelded members (3-48)
W_i	s^{-1}	Angular velocity of a mechanism part about its centre of rotation when calculating loads due to horizontal motion (2-45)
W_{max}	J	Maximum value indicated for motor of work done in starting without hook load (5-26)
x	Ω/km	Reactance per unit length (5-9)
x	m	Coordinate of point of suspension of hoist rope along an axis parallel to the direction of travel (2-47)
x_1	m	Coordinate of position of centre of gravity of suspended load along an axis having the same direction, sense and origin as the axis of x (2-48)
Z_A	-	Assessing coefficient for influence A (3-4)
Z_B	-	Assessing coefficient for influence B (3-6)
Z_C	-	Assessing coefficient for influence C (3-7)
Z_p	-	Minimum practical factor of safety for choice of steel wire ropes (4-15
z	m	Coordinate expressing horizontal displacement of load relative to crane (2-48)

z_d	m	Displacement of load during travel motion of crane (2-51)
z_m	m	Displacement of load during travel motion of crane (2-51)
α	-	Ratio of sides of panel in buckling calculation (3-41)
α	-	$\frac{M_{med}}{M_{max}}$ (5-24)
α_i	-	Ratio of duration of use of mechanism during a hoisting cycle to average duration of cycle (2-39)
α_m	°	Angle of inclination of rope during acceleration of crane (2-49)
β	-	Time coefficient relating to acceleration of crane (2-46)
β_{crit}	-	Critical value of β (2-52)
γ_c	-	Amplifying coefficient of loading depending on crane group (2-30)
γ_m	-	Amplifying coefficient of loading depending on mechanism group (2-34)
$\Delta_{\ell 1}$	mm	Shortening of joined elements under the tightening force in bolted joints (3-15)
$\Delta_{\ell 2}$	mm	Extension of bolt under tightening force (3-15)
Δ_s	mm	Divergence in span of crane (8-4); Divergence in crane rail centres (8-8)
δ_b	-	Elastic coefficient of bolted joints (3-15)
η	-	Shielding coefficient in calculation of wind force (2-28); Poisson's ratio (3-39); Overall efficiency of mechanism (5-17)
Θ	°	Angle of wind relative to longitudinal axis of member (2-29)
$\kappa, \kappa', \kappa''$	-	Safety coefficients applying to bolted joints (3-15)
κ	-	Ratio of the extreme stress values in fatigue calculation (3-24)
κ	$m/\Omega mm^2$	Electric conductivity (5-8)
$\kappa_x, \kappa_y, \kappa_{xy}$	-	Ratio of extreme individual stresses $\sigma_x, \sigma_y, \tau_{xy}$ in fatigue calculation (3-52)
λ	-	Coefficient applied to horizontal forces in travel motions (2-20); Slenderness of column in crippling calculation (3-33)
μ	-	Mass constant in calculation of loads due to acceleration of horizontal motion (2-46); Coefficient of friction in threads (3-14); Coefficient of friction of contact surfaces in bolted joints (3-13)
ν	-	Safety coefficient for critical stresses in structural members (3-3)
ν'	-	Dead weight coefficient in calculation of structural members subjecte to significant deformation (3-23)
ν_E	-	Safety coefficient for calculation of structural members depending on case of loading (3-10)

ν_R	-	Safety coefficient for calculation of mechanism parts depending on case of loading (4-3)
ν_T	-	= ν_E. safety coefficient for calculation of bolted joints depending on case of loading (3-19)
ν_V	-	Safety coefficient for buckling (3-22)
ν_K	-	Safety coefficient for verification of fatigue strength of mechanism parts (4-11)
ξ	-	Experimentally determined coefficient depending on crane type for calculating dynamic coefficient (2-16)
ρ	-	Reducing coefficient applied to critical stresses in buckling calculation (3-40)
ρ_1	-	Coefficient used to determine the dynamic test load (2-31)
ρ_2	-	Coefficient used to determine the static test load (2-31)
σ	N/mm^2	Calculated stress in structures in general (3-10)
σ_0	N/mm^2	Tensile stress for $\kappa = 0$ in calculation of fatigue strength (3-50)
σ_1	N/mm^2	Working stress in the root section of bolts (3-15)
σ'_1	N/mm^2	Equivalent stresses permissible for bolts (3-15)
σ_{+1}	N/mm^2	Permissible tensile stress for $\kappa = +1$ in fatigue calculation (3-50)
σ_A	N/mm^2	Amplitude of the permissible maximum stress in bolts for fatigue calculations (3-16)
σ_E	N/mm^2	Apparent elastic limit of steel (3-10)
σ_G	N/mm^2	Tensile stress due to permanent load (3-4): Stress due to dead weight (3-23)
σ_R	N/mm^2	Ultimate tensile strength (3-10)
σ_R^E	N/mm^2	The EULER Stress (3-39)
σ_V	N/mm^2	Stress due to variable loads (3-23)
σ_a	N/mm^2	Permissible tensile stress for structural members (3-4): Permissible stress for mechanism parts (4-3)
σ_{af}	N/mm^2	Permissible normal stress for verification of fatigue strength of mechanism parts (4-11)
σ_b	N/mm^2	Initial stress in calculating bolted joints (3-14)
σ_{bw}	N/mm^2	Endurance limit of materials of mechanism parts under alternating bending (4-6)
σ_c	N/mm^2	Permissible fatigue strength in compression for structural members (3-49): Calculated compressive stress for mechanism parts (4-4)
σ_{cg}	N/mm^2	Compression stress in wheel and rail (4-25)

σ_{cp}	N/mm^2	Equivalent stress used in calculating structural members (3-12)
σ_{cr}	N/mm^2	Critical stress used in calculating structural members subjected to large deformations (3-23)
σ^{v}_{cr}	N/mm^2	Critical buckling stress (3-39)
$\sigma^{v}_{cr.c}$	N/mm^2	Critical comparison stress used in buckling calculation (3-40)
σ_{d}	N/mm^2	Endurance limit of materials of mechanism parts (4-8)
σ_{f}	N/mm^2	Calculated bending stress in mechanism parts (4-4)
σ^{v}_{i}	N/mm^2	Ideal buckling stress for thin walled circular cylinders (3-44)
σ_{inf}	N/mm^2	Lower stress in determination of stress spectrum (2-13)
σ_{k}	N/mm^2	Fatigue strength of mechanism parts (4-10)
σ_{kx}	N/mm^2	Fatigue strength for normal stresses in the x direction (4-12)
σ_{ky}	N/mm^2	Fatigue strength for normal stresses in the y direction (4-12)
σ_{m}	N/mm^2	Arithmetic mean of all upper and lower stresses during the total duration of use (2-13): Permissible stress in conformity tests to ISO 3600/1 (3-16)
σ_{max}	N/mm^2	Maximum stress in fatigue calculation for structural members (3-24)
σ_{min}	N/mm^2	Minimum stress in fatigue calculation for structural members (3-25)
σ_{n}	N/mm^2	Bearing pressure in riveted joints (3-13)
σ_{p}	N/mm^2	Theoretical tensile stress in bolt due to tightening (3-14)
σ_{sup}	N/mm^2	Upper stress in determination of stress spectrum (2-13)
$\sigma_{sup\ max}$	N/mm^2	Maximum upper stress in determination fo stress spectrum (2-13)
$\sigma_{sup\ min}$	N/mm^2	Minimum upper stress in determination of stress spectrum (2-13)
σ_{t}	N/mm^2	Permissible tensile stress in fatigue verification of structural members (3-49): Calculated tensile stress in mechanism parts (4-4): Tensile stress in rope (4-34)
σ_{v}	N/mm^2	Reduced buckling stress of thin walled circular cylinders (3-44)
σ_{w}	N/mm^2	Permissible stress in alternating tension/compression in fatigue verification of mechanism parts (3-48)
σ_{wk}	N/mm^2	Permissible alternating stress in fatigue verification of mechanism parts (4-7)
σ_{x}	N/mm^2	Normal stress in the x direction when calculating structural members (3-12)
σ_{xa}	N/mm^2	Permissible stress in fatigue verification of structural members (3-52)

$\sigma_{x\,max}$	N/mm^2	Maximum stress in fatigue verification of structural members (3-52)
$\sigma_{x\,min}$	N/mm^2	Minimum stress in fatigue verification of structural members (3-52)
σ_y	N/mm^2	Normal stress in the y direction when calculating structural members (3-12)
σ_{ya}	N/mm^2	Permissible stress in fatigue verification of structural members (3-52)
$\sigma_{y\,max}$	N/mm^2	Maximum stress in fatigue verification of structural members (3-52)
$\sigma_{y\,min}$	N/mm^2	Minimum stress in fatigue verification of structural members (3-52)
τ	N/mm^2	Shear stress in general (3-12): Calculated shear stress for mechanism parts (4-4)
τ_a	N/mm^2	Permissible shear stress when calculating structural members (3-11)
τ_{af}	N/mm^2	Permissible shear stress in fatigue verification of mechanism parts (4-11)
τ_b	N/mm^2	Torsional stress in bolts due to tightening (3-14)
τ_{cr}^{v}	N/mm^2	Critical buckling shear stress (3-39)
τ_d	N/mm^2	Endurance limit of materials of mechanism parts (4-8)
τ_k	N/mm^2	Fatigue strength of mechanism parts (4-10)
τ_{max}	N/mm^2	Maximum shear stress in fatigue verification of mechanism parts (3-25)
τ_{min}	N/mm^2	Minimum shear stress in fatigue verification of mechanism parts (3-25)
τ_w	N/mm^2	Endurance limit under alternating shear of materials of mechanism parts (4-7)
τ	-	Ratio of duration of action of a known torque to motor running time (5-24)
τ_{wk}	N/mm^2	Endurance limit under alternating shear in fatigue verification of mechanism parts (4-7)
τ_{xy}	N/mm^2	Shear stress when calculating structural members (3-12)
τ_{xya}	N/mm^2	Permissible shear stress in fatigue verification of structural members (3-52)
$\tau_{xy\,max}$	N/mm^2	Maximum shear stress in fatigue verification of structural members (3-52)
$\tau_{xy\,min}$	N/mm^2	Minimum shear stress in fatigue verification of structural members (3-52)
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Prepared by Section I	- **HEAVY LIFTING EQUIPMENT**	
Erstellt durch die Sektion I	- **KRANE UND SCHWERE HEBEZEUGE**	

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