

Metal Structures II

Design project II

Crane supporting structures

Example of calculation part I

Single-hook crane SPe1H-A4;

Working area 32,0 x 75,0 m;

Height of lifting: 8,0 m;

Steel: S 355;

Location: Gdańsk, harbour

Lifted element weight: 200 kN

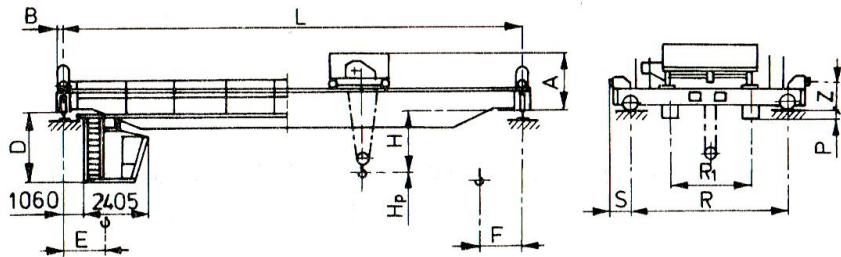


Photo: W. Bogucki, M. Żybertowicz, Tablice do projektowania konstrukcji metalowych, Arkady, Warszawa 1996

Udźwig Q	Rozpiętość L	Masa suw- nicy	Nacisk koła N_{max}	$H_{p\ max}$	A_{max}	A_{min}	B
kN	m	t	kN	m			
200	8-11	18,2	160	16,5	2390	2075	210
	11-14	20,6	167				
	14-17	22,4	172				
	17-20	24,2	177				
	20-23	27,3	186				
	23-26	29,4	192				
	26-29	34,1	206				
	29-32	37,2	215				
* 32-35	40,8	225	2495	2175	245		

D	E	F	H	R	R_1	Z	S	P	GNP	
			mm							
2450	1100		200	4100	2500	900	630	605	60	A4
2720				5000				460		
2960		610								
2920		1000	100	5050		1200	610			
3105							860			

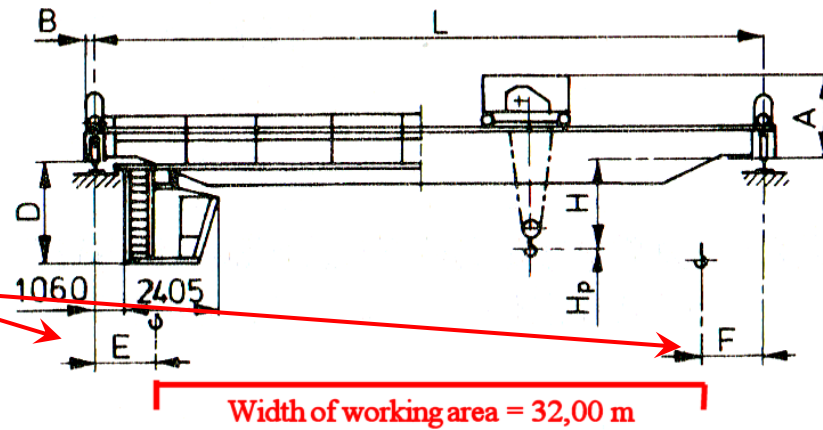
Max height of lifting for SPe1H-A4: $H_{p, \max} = 16,5 \text{ m}$ – covers required range of 8,0 m.

Range of "dead zone" for SPe1H-A4:

$$E = 1,10 \text{ m}$$

$$F = 1,00 \text{ m}$$

Photo: Author



Together: working area and „dead zone” $L = 32,00 + 2 \cdot \max(E; F) = 32,00 + 2 \cdot 1,10 = 34,20 \text{ m}$ of distance between rail axes.

Maximum wheelbase for SPe1H-A4 is 32,0 – 35,0 m; covers required range.

For this spacing, mass of gantry is **40,8 t**.

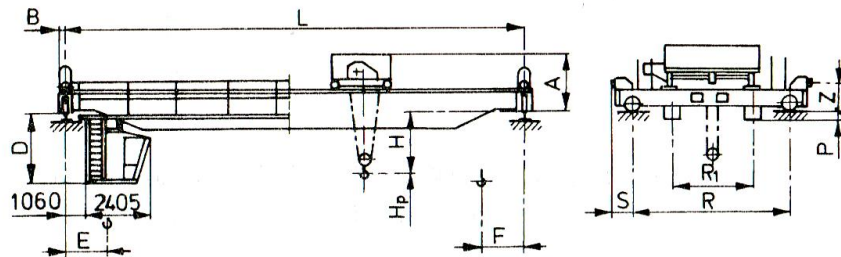


Photo: W. Bogucki, M. Żybartowicz, Tablice do projektowania konstrukcji metalowych, Arkady, Warszawa 1996

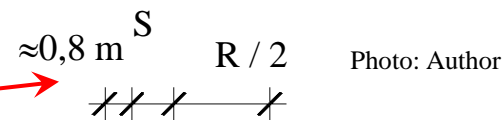
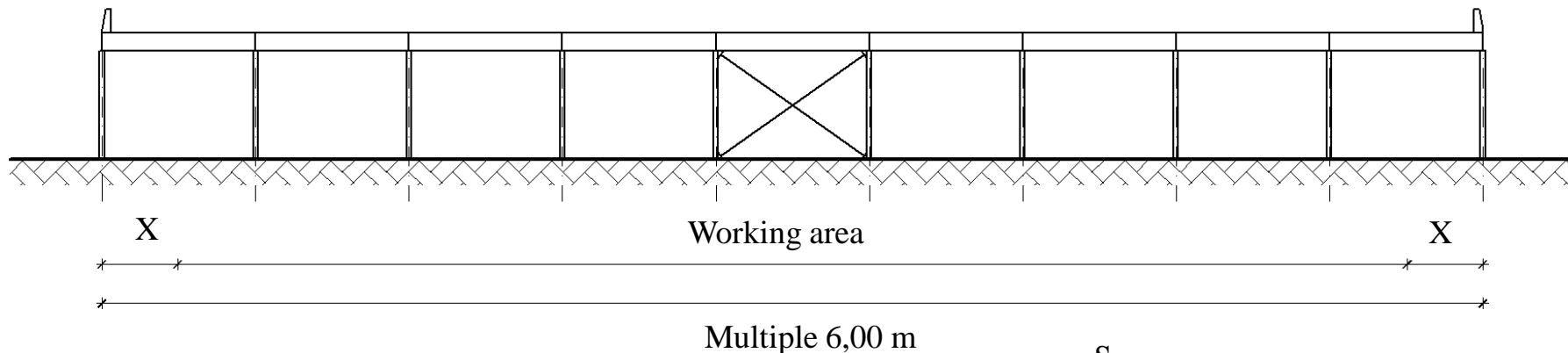
Udźwig Q	Rozpiętość L	Masa suwnicy	Nacisk koła N_{max}	$H_{p,max}$	A_{max}	A_{min}	B
kN	m	t	kN	m			
200	8-11	18,2	160	16,5	2390	2075	210
	11-14	20,6	167				
	14-17	22,4	172				
	17-20	24,2	177				
	20-23	27,3	186				
	23-26	29,4	192		2495	2175	245
	26-29	34,1	206				
	29-32	37,2	215				
	32-35	40,8	225				

D	E	F	H	R	R_1	Z	S	P	GNP
			mm						
2450	1100	1000	200	4100	2500	900	605	60	A4
2720				5000				460	
2960				630				710	
2920		1000	100	5050		1200	610		
3105							860		

Rail height $h = 0,10$ m

Rail head height: $8,00 + h = 8,10$ m

The highest point of crane: $8,10 + A_{max} = 8,100 + 2,495 = 10,595$ m (important for wind action)



$$X \geq 0,8 + S + R / 2$$

For SPe1H-A4:

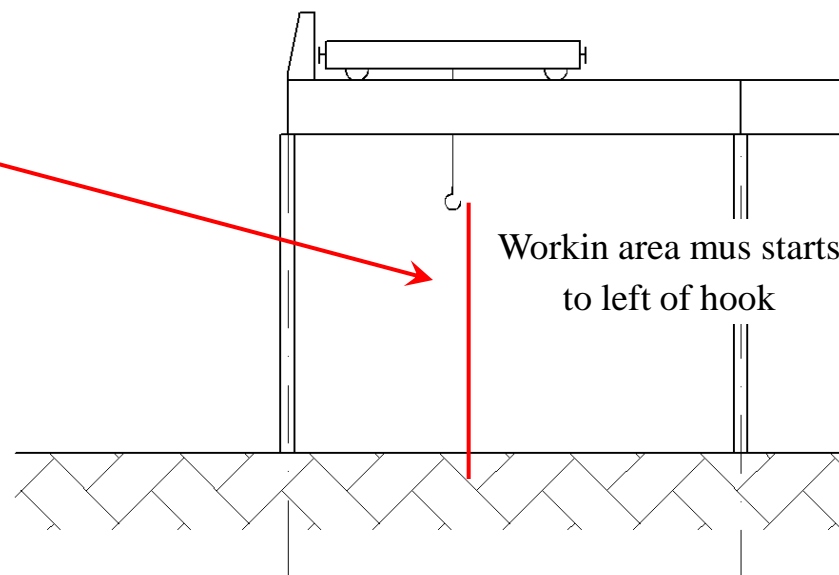
$$S = 0,63 \text{ m}$$

$$R = 5,05 \text{ m}$$

$$X \geq 3,955 \text{ m}$$

$$n \cdot 6,0 \geq 3,955 + 75,0 + 3,955 = 82,91 \text{ m}$$

$$n = 14$$



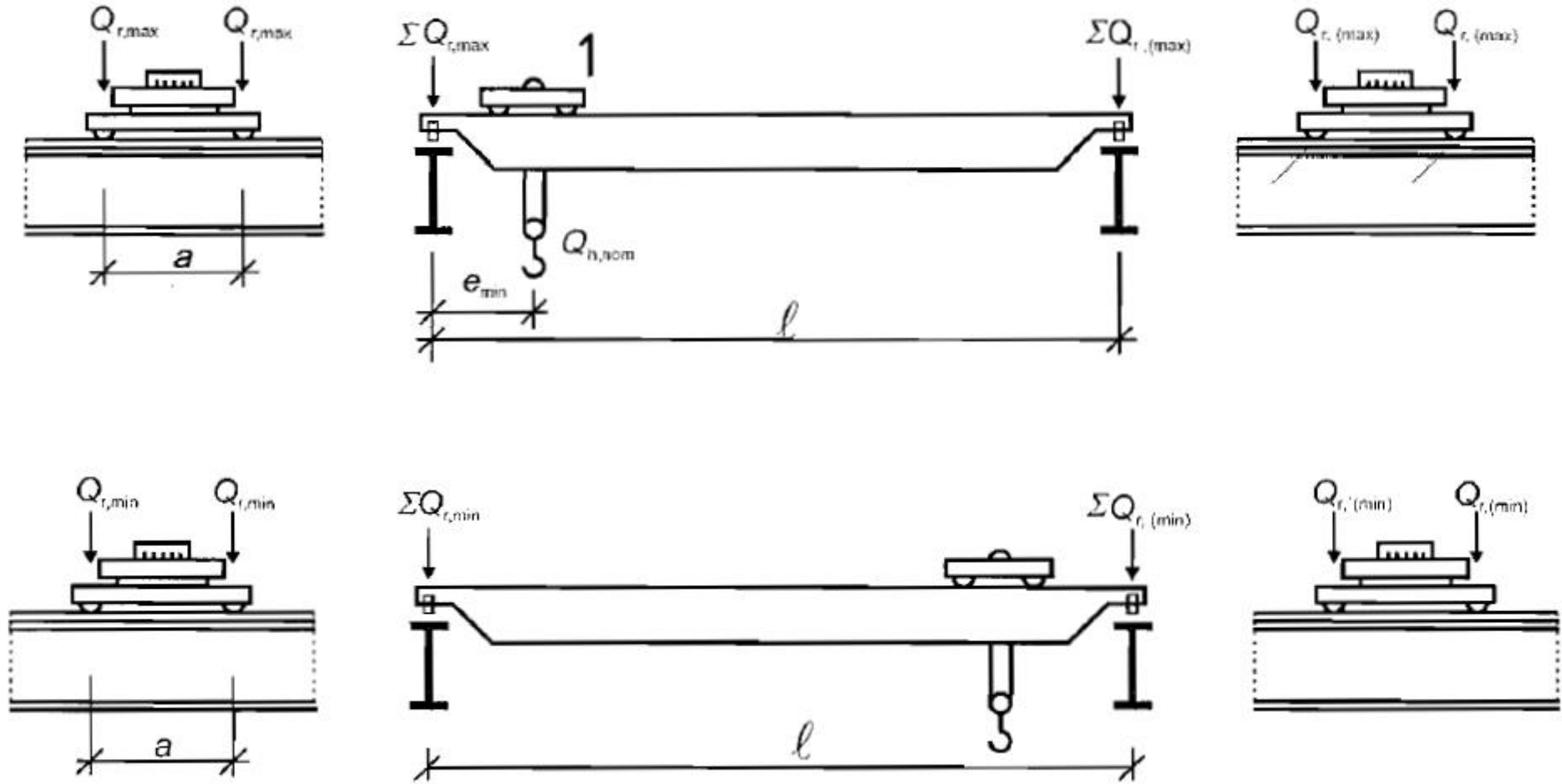


Photo: EN 1991-3 fig. 2.1

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Data about loads:

Udźwig Q	Rozpię- tość L	Masa suw- nicy	Nacisk koła N_{max}	H_t
kN	m	t	kN	t
	8-11	18,2	160	
	11-14	20,6	167	
	14-17	22,4	172	
	17-20	24,2	177	
<u>200</u>	20-23	27,3	186	1t
	23-26	29,4	192	
	26-29	34,1	206	
	29-32	37,2	215	
	32-35	<u>40,8</u>	<u>225</u>	

Photo: W. Bogucki, M. Żybartowicz, Tablice
do projektowania konstrukcji metalowych,
Arkady, Warszawa 1996

Crane mass: $m = 40,8 \text{ t}$

Crane deadweight (characteristic): $Q_{c,k} = m \cdot g =$
 $= 40,8 \cdot 9,81 = 400,248 \text{ kN}$

Crane deadweight (design): $Q_c = 1,5 \cdot Q_{c,k} =$
 $= 600,372 \text{ kN}$

Hoist load (characteristic): $Q_{h,k} = 200 \text{ kN}$

Hoist load (design): $Q_h = 1,5 \cdot Q_{h,k} = 300 \text{ kN}$

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Total vertical load (characteristic):

$\Sigma Q_{r,k} = \text{crane weight} + \text{hoist load} = 400,248 + 200 = 600,248 \text{ kN}$

Total vertical load (design):

$\Sigma Q_r = \text{crane weight} + \text{hoist load} = 600,372 + 300 = 900,372 \text{ kN}$

Max and min loading on runbeam (characteristic):

$$Q_{r, \max, k} = N_{\max} = \mathbf{225 \text{ kN} (\#t / 8)} \approx Q_{r, (\min), k}$$

$$\Sigma Q_{r, \max, k} = 2 N_{\max} = 450 \text{ kN} \approx \Sigma Q_{r, (\min), k}$$

$$\Sigma Q_{r, (\max), k} = \Sigma Q_r - \Sigma Q_{r, \max, k} = 600,248 - 450,000 = 150,248 \text{ kN} \approx \Sigma Q_{r, (\min), k}$$

$$Q_{r, (\max), k} = \Sigma Q_{r, (\max), k} / 2 = 75,124 \text{ kN} \approx Q_{r, (\min), k}$$

Max and min loading on runbeam (design):

$$Q_{r, \max} = Q_{r, (\min)} = 1,5 \cdot 225 = 337,500 \text{ kN}$$

$$\Sigma Q_{r, \max} = \Sigma Q_{r, (\min)} = 1,5 \cdot 450 = 675,000 \text{ kN}$$

$$\Sigma Q_{r, (\max)} = \Sigma Q_{r, (\min)} = 1,5 \cdot 150,248 \text{ kN} = 225,372 \text{ kN}$$

$$Q_{r, (\max)} = Q_{r, (\min)} = 1,5 \cdot 75,124 \text{ kN} = 112,686 \text{ kN}$$

Reactions from crane and lifted element are not symmetrical. Difference between $Q_{r, \max}$ and $Q_{r, (\max)}$ (337,500 kN ; 112,686 kN) comes from various position **crab of crane** on **frame of crane**.

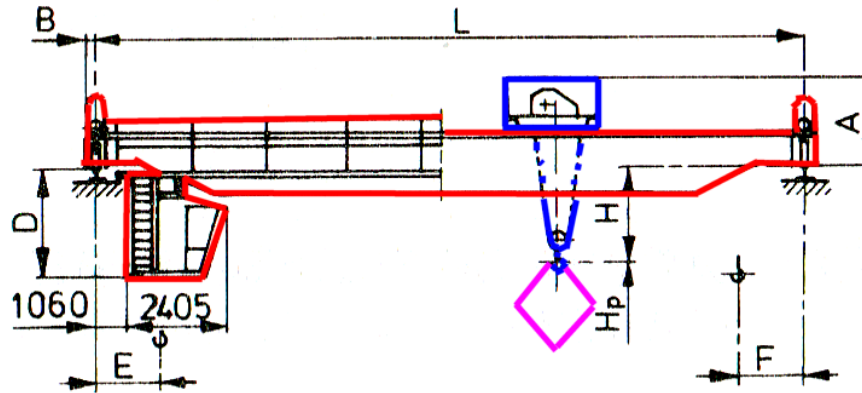


Photo: Author

Frame of crane is not completely symmetrical (cabin), but, in simplification, could be taken into consideration as symmetrical. This means:

- reactions from **frame of crane** will be symmetrical;
- reactions from **crab of crane** depend on position of crab;
- reactions from **lifted element** depends on position of crab.

Information presented in table ($Q_{r, \max, k} = N_{\max} = 225 \text{ kN}$) are for extremelly position of crab.

Weight of frame of crane: $Q_{\text{frame}, k} = Q_{c, k} - Q_{\text{crab}, k} = 400,248 - Q_{\text{crab}, k}$

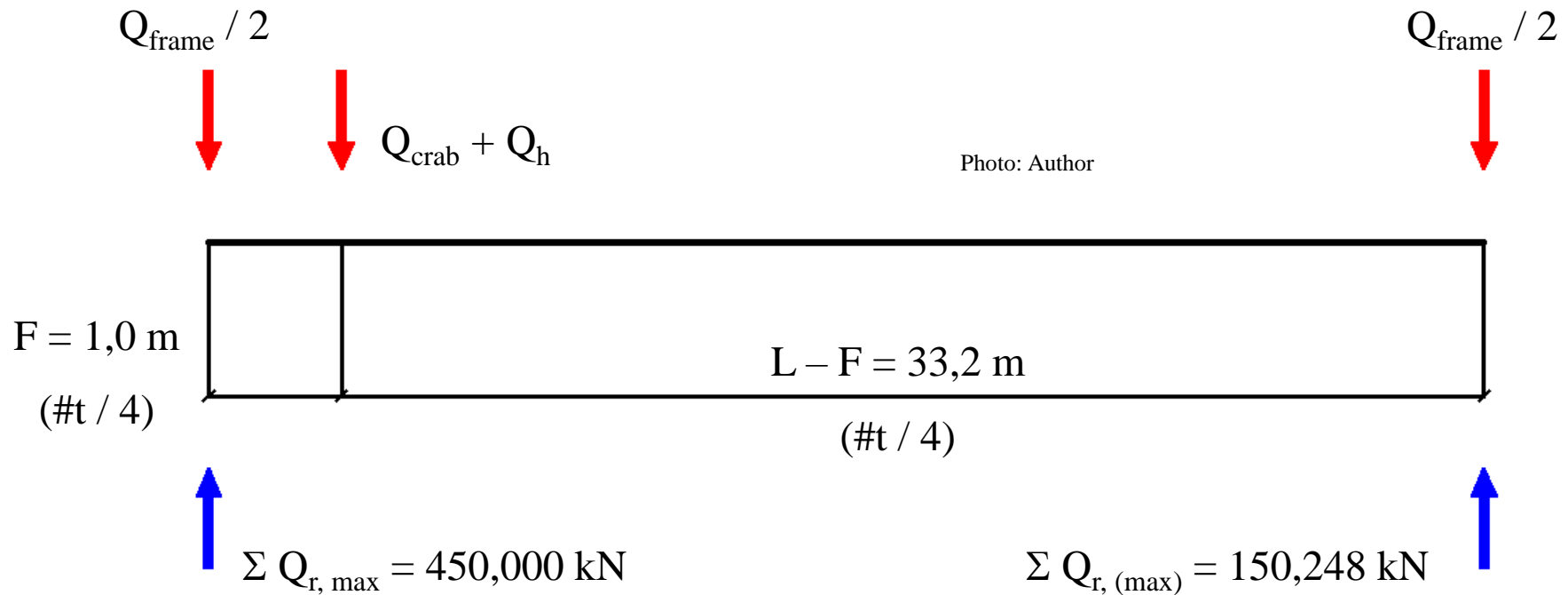
Weight of crab of crane: $Q_{\text{crab}, k}$

Hoist load $Q_{h, k} = 200 \text{ kN}$

Reactions:

$$\Sigma Q_{r, \text{max}, k} = 450,000 \text{ kN} \approx \Sigma Q_{r, (\text{min}), k}$$

$$\Sigma Q_{r, (\text{max}), k} = 150,248 \text{ kN} \approx \Sigma Q_{r, \text{min}, k}$$



ΣY , Left runbeam

$$\Sigma Q_{r, \max, k} = (Q_{c, k} - Q_{crab, k}) / 2 + (Q_{crab, k} + Q_{h, k}) (L-F) / L = 0$$

$$450,000 = 200,124 - 0,5 Q_{crab, k} + 0,971 Q_{crab, k} + 194,135$$

$$55,741 = 0,471 Q_{crab, k}$$

$$Q_{crab, k} = 118,346 \text{ kN}$$

 ΣY , Right runbeam

$$\Sigma Q_{r, (\max), k} = (Q_{c, k} - Q_{crab, k}) / 2 + (Q_{crab, k} + Q_{h, k}) F / L = 0$$

$$150,248 = 200,124 - 0,5 Q_{crab, k} + 0,029 Q_{crab, k} + 5,865$$

$$55,741 = 0,471 Q_{crab, k}$$

$$Q_{crab, k} = 118,346 \text{ kN}$$

Average value

$$Q_{crab, k} = 118,346 \text{ kN}$$

$$Q_{frame, k} = Q_{c, k} - Q_{crab, k} = 281,902 \text{ kN}$$

Design values:

$$Q_{crab} = 1,5 \cdot 118,346 = 177,519 \text{ kN}$$

$$Q_{frame} = 1,5 \cdot 281,902 = 422,853 \text{ kN}$$



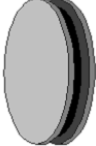
Summation:

Load	Characteristic [kN]	Design [kN]
Hoist load Q_h	200,000	300,000
Crane (total) Q_c	400,248	600,372
<ul style="list-style-type: none"> • crab Q_{crab} • frame Q_{frame} 	118,346 281,902	177,519 422,853
Total (H+C) ΣQ_r	600,248	900,372
Max for one wheel $Q_{r, max} = Q_{r, (min)}$	225,000	337,500
Max for pair wheels $\Sigma Q_{r, max} = \Sigma Q_{r, (min)}$	450,000	675,000
Min for one wheel $Q_{r, (max)} = Q_{r, min}$	75,124	112,686
Min for pair wheels $\Sigma Q_{r, (max)} = \Sigma Q_{r, min}$	150,248	225,372

Values important for next steps of calculation

EN 1993-6 5.6.2 (6) - horizontal forces can be applied to one or both runbeams:

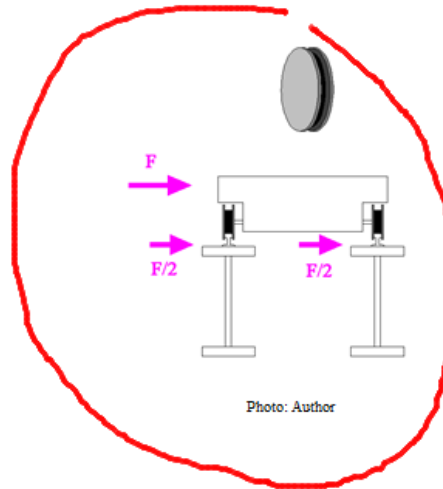
Photo: Author

Loads	Type of wheel	
	 	
$H_{L,i} ; H_{T,i}$	both	both
$H_{S,i, j, k}$	both	both
H_{T3}	one	both
H_B	both	both
$H_{B,2}$	both	both
H_{TA}	both	both
medium wind	one	both
strong wind	both	both

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Additional information for calculations, the same for everybody:

- One crane only
- Assembly crane, HC1, S0
- Steady hoisting speed $v_h = 0,08 \text{ m / s}$
- Hook $\rightarrow \varphi_3 = 0,0$
- $\varphi_4 = 1,0$
- $\varphi_5 = 1,5$
- $\eta = 0$
- Single wheel drive, $m_w = 2$
- Friction coefficient $\mu = 0,2$
- Wheel flanges, $a_{ext} = R$
- Fixing of wheel IFF
- Longitudinal velocity of crane $v = 0,7 \text{ m / s}$
- Spring constant of the buffer $S_B = 65 \text{ kN / m}$
- $\xi_b = 0,5$
- Rail supported on an elastomeric bearing pad



Each types of loads and actions are applied evenly to each wheels on both run-beams.



Many types of crane actions have dynamic character. There are special calculation for this case:

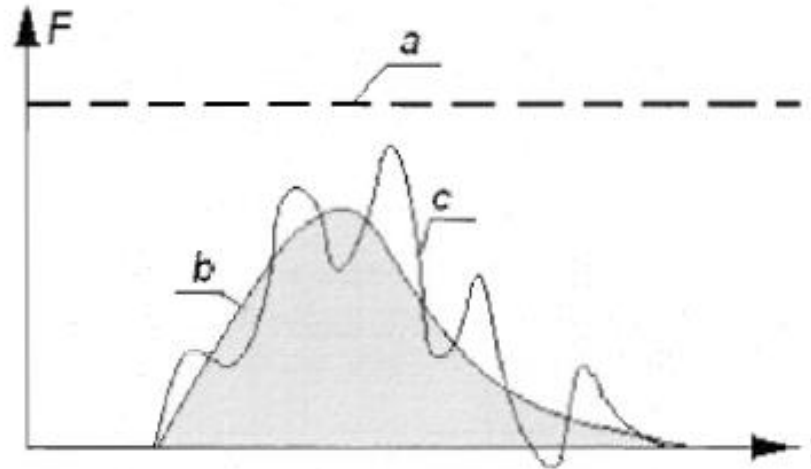


Photo: EN 1991-1-7 fig. 1.1

Key :
 a : equivalent static force
 b : dynamic force
 c : structural response

$$F_{\varphi,k} = \varphi_i F_k$$

F_k – equivalent dynamic force; φ_i – dynamic coefficient; $F_{\varphi,k}$ – equivalent static force

Dynamic factors	Effect to be considered	To be applied to
φ_1	Excitation of the crane structure due to lifting the hoist load off the ground	Self-weight of the crane
φ_2 or φ_3	Dynamic effects of transvering the hoist load from the ground to the crane Dynamic effects of sudden release the payload if for examle grabs or magnet are used	Hoist load → #2 / 16
φ_4	Dynamic effects induced when the crane is travelling on rail tracks or runways	Self-weight of the crane and hoist load
φ_5	Dynamic effects caused by drive forces	Drive forces
φ_6	Dynamic effects of a test load moved by the drivers in the way the crane is used	Test load
φ_7	Dynamic elastic effect of impact on buffers	Buffer loads

EN 1991-3 tab. 2.1

	→ #2 / 17	Symbol	Section	Groups of load									
				ULS							Test load	Accidental loads	
				1	2	3	4	5	6	7	8	9	10
1	Self-weight of crane	Q_c	2.6	φ_1	φ_1	1	φ_4	φ_4	φ_4	1	φ_1	1	1
2	Hoist load	Q_h	2.6	φ_2	φ_3	0	φ_4	φ_4	φ_4	η	0	0	0
3	Acceleration of crane bridge	H_L H_T	2.7	φ_5	φ_5	φ_5	φ_5	0	0	0	φ_5	0	0
4	Skewing of crane bridge	H_S	2.7	0	0	0	0	1	0	0	0	0	0
5	Acceleration of barking of crab or hoist block	H_{T3}	2.7	0	0	0	0	0	1	0	0	0	0
6	In-service wind	F_W^*	Annex A	1	1	1	1	1	0	0	1	0	0
7	Test load	Q_T	2.10	0	0	0	0	0	0	0	φ_6	0	0
8	Buffer force	H_B	2.11	0	0	0	0	0	0	0	0	φ_7	0
9	Tilting force	H_{TA}	2.11	0	0	0	0	0	0	0	0	0	1
For out of service wind, see Annex A													
η is the proportion of the hoist load that remains when payload is removed, but is not included in the self-weight of the crane													

EN 1991-3 tab. 2.2

φ_1 ; self-weight of crane Q_c

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EN 1991-3 tab. 2.4:

$$\varphi_1 = 0,9 , 1,1$$

Values 0,9 or 1,1 are assumed depending on which of them will give more unfavorable effect in analysis of load combination.

Value 0,9 could be used in two cases:

- multispans continuous run-beam;
- big value of vertical upward force ($\varphi_3 \neq 0,0$).

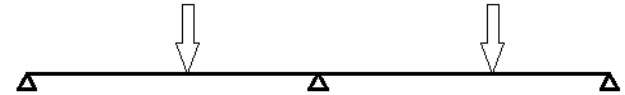


Photo: Author

For analysed case:

$$Q_{c,k} = (\#t / 13) = 400,248 \text{ kN}$$

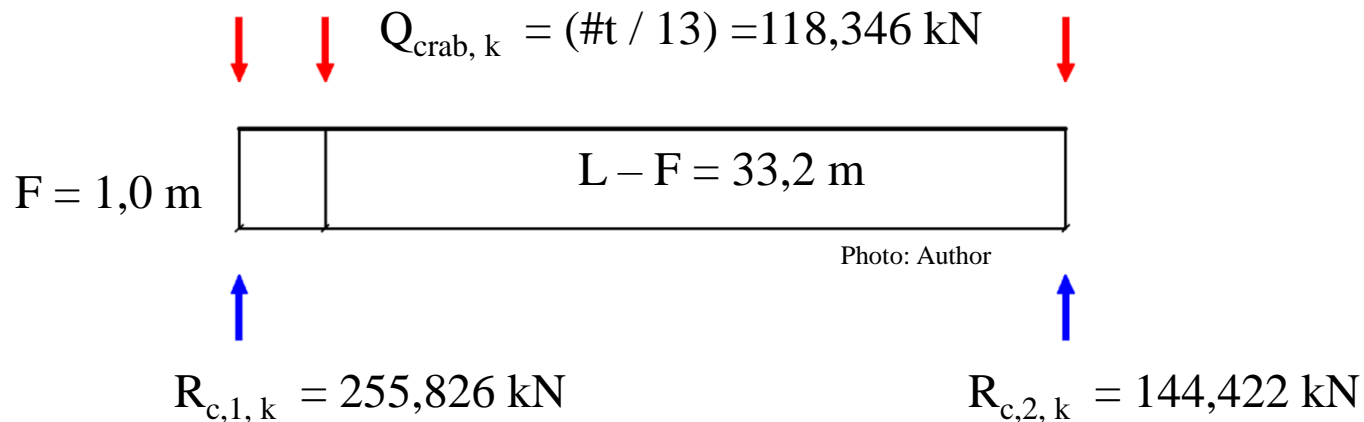
$$\varphi_1 = 1,1$$

Vertical forces, applied to run-beams, depends on position of crab (according to # / 11).

Calculatin tce same as for $Q_{r, \max}$ and $Q_{r, \min}$, but without participation of Q_h :

$$Q_{\text{frame}, k} / 2 = (\#t / 13) = 281,902 / 2 = 140,951 \text{ kN}$$

$$Q_{\text{frame}, k} / 2 = (\#t / 13) = 281,902 / 2 = 140,951 \text{ kN}$$



Design values:

$$R_{c,1} = 382,803 \text{ kN}$$

$$R_{c,2} = 216,633 \text{ kN}$$

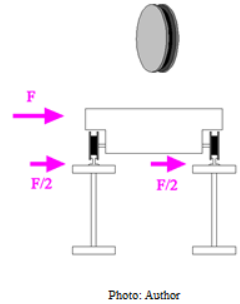
For one wheel:

$$R_{c,w,1} = 191,402 \text{ kN}$$

$$R_{c,w,2} = 108,317 \text{ kN}$$

Additional information for calculations, the same for everybody:

- One crane only
- **Assembly crane, HC1, S0**
- **Steady hoisting speed $v_h = 0,08 \text{ m/s}$**
- Hook $\rightarrow \varphi_3 = 0,0$
- $\varphi_4 = 1,0$
- $\varphi_5 = 1,5$
- $\eta = 0$
- Single wheel drive, $m_w = 2$
- Friction coefficient $\mu = 0,2$
- Wheel flanges, $a_{ext} = R$
- Fixing of wheel IFF
- Longitudinal velocity of crane $v = 0,7 \text{ m/s}$
- Spring constant of the buffer $S_B = 65 \text{ kN/m}$
- $\xi_b = 0,5$
- Rail supported on an elastomeric bearing pad



φ_2 ; hoist load Q_h



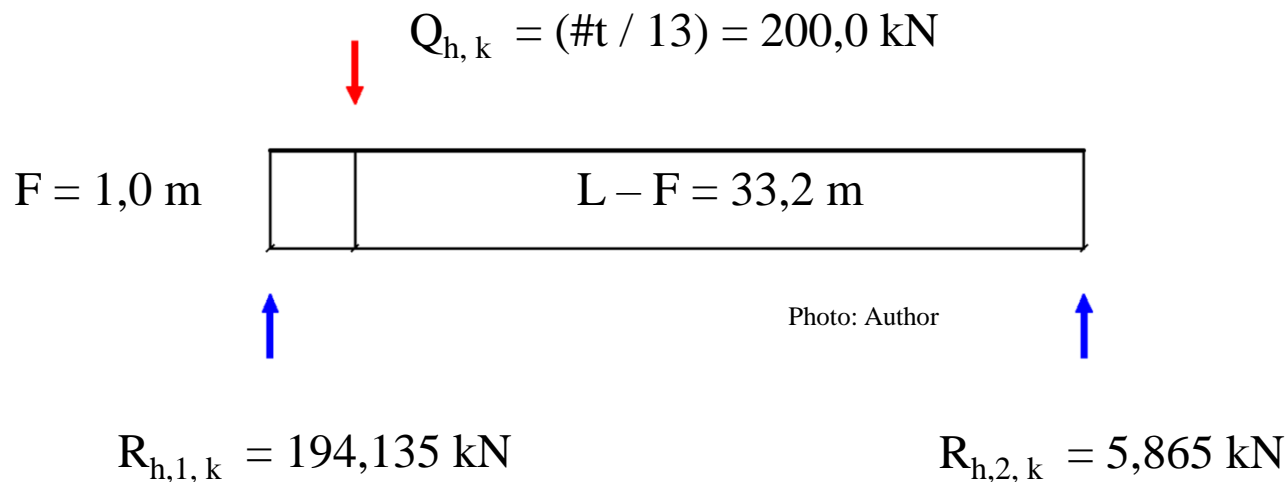
Lec # 2 / 27-28

Hoisting class of appliance	β_2	$\varphi_{2, \text{min}}$
<u>HC1</u>	<u>0,17</u>	<u>1,05</u>
HC2	0,34	1,10
HC3	0,51	1,15
HC4	0,68	1,20

$$\varphi_2 = \varphi_{2, \text{min}} + \beta_2 v_h = 1,064$$

$$Q_{h, k} = (\#t / 13) = 200,0 \text{ kN}$$

Vertical forces, applied to run-beams, depends on position of crab (according to #t / 11).
 Calculatin tce same as for $Q_{r,max}$ and $Q_{r,min}$, but without participation of Q_c :



Design values:

$$R_{h,1} = 291,202 \text{ kN}$$

$$R_{h,2} = 8,798 \text{ kN}$$

For one wheel:

$$R_{h,w,1} = 145,601 \text{ kN}$$

$$R_{h,w,2} = 4,399 \text{ kN}$$

Additional information for calculations, the same for everybody:

- One crane only
- Assembly crane, HC1, S0
- Steady hoisting speed $v_h = 0,08 \text{ m / s}$
- Hook $\rightarrow \varphi_3 = 0,0$
- $\varphi_4 = 1,0$
- $\varphi_5 = 1,5$
- $\eta = 0$
- Single wheel drive, $m_w = 2$
- Friction coefficient $\mu = 0,2$
- Wheel flanges, $a_{ext} = R$
- Fixing of wheel IFF
- Longitudinal velocity of crane $v = 0,7 \text{ m / s}$
- Spring constant of the buffer $S_B = 65 \text{ kN / m}$
- $\xi_b = 0,5$
- Rail supported on an elastomeric bearing pad

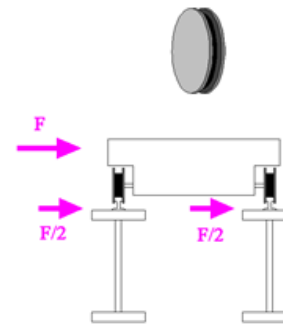


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$$\varphi_3 = 0,0$$

$$\varphi_4 = 1,0$$

$$\varphi_5 = 1,5$$

$$\eta = 1,0$$



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$\varphi_5 ; H_{L,i} ; H_{T,i}$ - acceleration of crane bridge



Lec #2 / 32-38

Additional information for calculations, the same for everybody:

Photo: EN 1991-3 fig. 2.7

- One crane only
- Assembly crane, HC1, S0
- Steady hoisting speed $v_h = 0,08 \text{ m/s}$
- Hook $\rightarrow \varphi_3 = 0,0$
- $\varphi_4 = 1,0$
- $\varphi_5 = 1,5$
- $\eta = 0$
- Single wheel drive, $m_w = 2$
- Friction coefficient $\mu = 0,2$
- Wheel flanges, $a_{ext} = R$
- Fixing of wheel IFF
- Longitudinal velocity of crane $v = 0,7 \text{ m/s}$
- Spring constant of the buffer $S_B = 65 \text{ kN/m}$
- $\zeta_b = 0,5$
- Rail supported on an elastomeric bearing pad

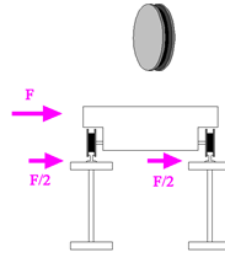
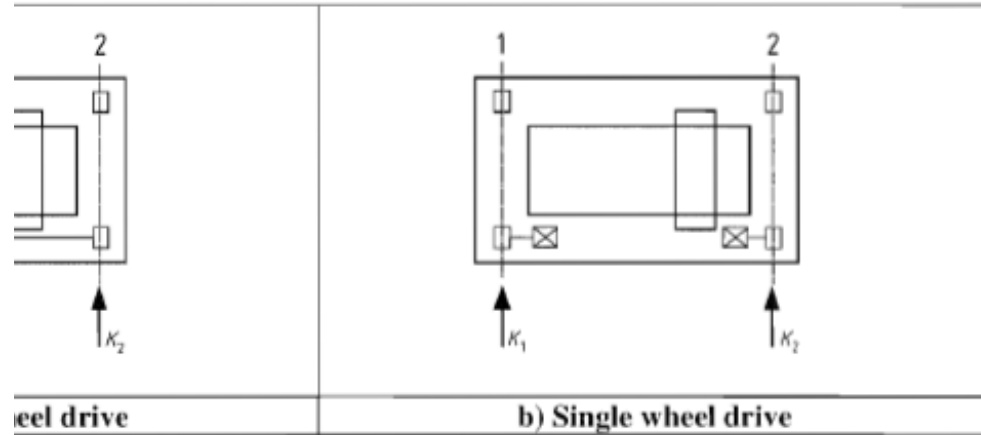


Photo: Author



	Central wheel drive	Single wheel drive
$\Sigma Q_{r, \min}^*$	$Q_{r, \min} + Q_{r, (\min)}$	$m_w Q_{r, \min}$

$$K = K_1 + K_2 = \mu \Sigma Q_{r, \min}^*$$



$$\begin{aligned}\Sigma Q_{r, \min, k}^* &= (\Sigma Q_{r, \max, k} + \Sigma Q_{r, (\max), k}) = (\#t / 13) = \\ &= 2 \cdot 75,124 \text{ kN} = 150,248 \text{ kN}\end{aligned}$$

$$\xi_1 = \Sigma Q_{r, \max, k} / (\Sigma Q_{r, \max, k} + \Sigma Q_{r, (\max), k}) = 0,750$$

$$\xi_2 = 1 - \xi_1 = 0,250$$

$$l_s = L (\xi_1 - 0,5) = 34,100 \cdot (0,750 - 0,500) = 8,525 \text{ m}$$

$$K_k = \mu \Sigma Q_{r, \min, k}^* = 0,2 \cdot 150,248 = 30,050 \text{ kN}$$

$$M_k = K_k l_s = 30,050 \cdot 8,525 = 256,176 \text{ kNm}$$

For one wheel:

$$H_{L,1, k} = H_{L,2, k} = \varphi_5 K_k / n_T = 1,5 \cdot 30,050 / 2 = 22,538 \text{ kN}$$

$$H_{T,1, k} = \varphi_5 \xi_2 M_k / a = 1,5 \cdot 0,250 \cdot 256,176 / 5,05 = 19,534 \text{ kN}$$

$$H_{T,2, k} = \varphi_5 \xi_1 M_k / a = 1,5 \cdot 0,750 \cdot 256,175 / 5,05 = 57,069 \text{ kN}$$

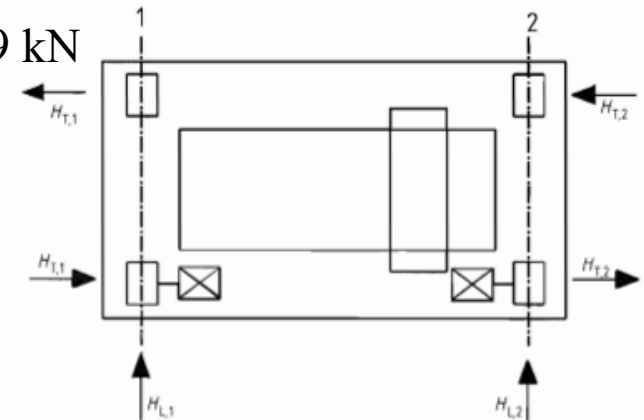
Design values:

$$H_{L,1} = H_{L,2} = 33,807 \text{ kN}$$

$$H_{T,1} = 29,301 \text{ kN}$$

$$H_{T,2} = 85,604 \text{ kN}$$

Photo: EN 1991-3 fig. 2.3



H_{S,i,j,k} - skewing of crane bridge



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Additional information for calculations, the same for everybody:

- One crane only
- Assembly crane, HC1, S0
- Steady hoisting speed $v_h = 0,08 \text{ m/s}$
- Hook $\rightarrow \varphi_3 = 0,0$
- $\varphi_4 = 1,0$
- $\varphi_5 = 1,5$
- $\eta = 0$
- Single wheel drive, $m_w = 2$
- Friction coefficient $\mu = 0,2$
- Wheel flanges, $a_{ext} = R$
- Fixing of wheel IFF
- Longitudinal velocity of crane $v = 0,7 \text{ m/s}$
- Spring constant of the buffer $S_B = 65 \text{ kN/m}$
- $\xi_b = 0,5$
- Rail supported on an elastomeric bearing pad

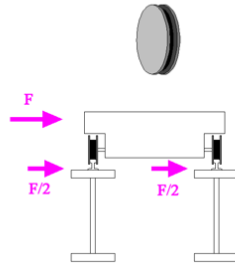


Photo: Author

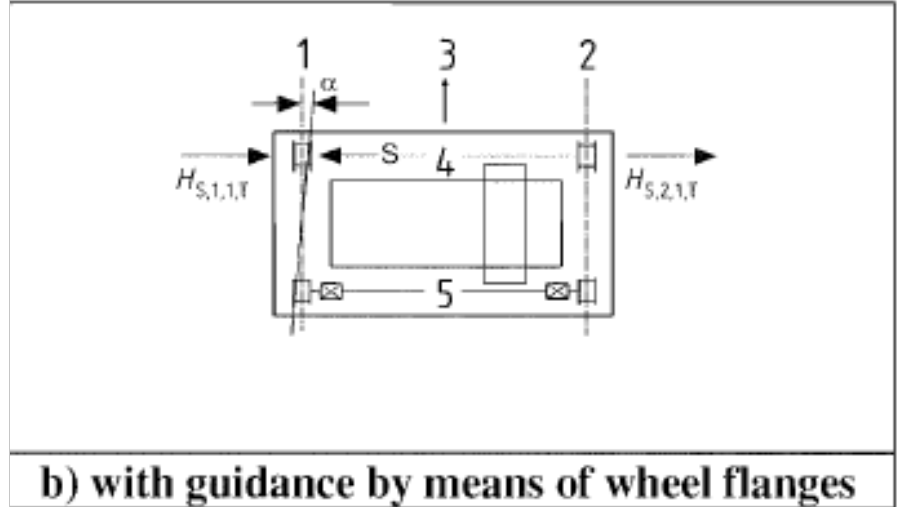


Photo: EN 1991-3 fig. 2.4

$$S = \lambda_{S,1} f \Sigma Q_r$$

$$H_{S,1,1,T} = \lambda_{S,1,1,T} f \Sigma Q_r$$

$$H_{S,2,1,T} = \lambda_{S,2,1,T} f \Sigma Q_r$$



$$\Sigma Q_{r,k} = (\#t / 13) = 600,248 \text{ kN}$$

System	$\lambda_{S,1}$	$\lambda_{S,1,j,L}$	$\lambda_{S,1,1,T}$	$\lambda_{S,2,j,L}$	$\lambda_{S,2,1,T}$
IFF	S_{1F}	0	$\xi_2 S_{1F}$	0	$\xi_1 S_{1F}$

$$H = n h$$

EN 1991-3 tab. 2.9

$$S_F = (\Sigma e_j)$$

$$S_{1F} = 1 - S_F / H$$

$$\xi_1 = 0,750$$



$$\xi_2 = 0,250$$

e_j - distance of the pair of wheels j from the guide elements \rightarrow all flanged wheels, so

$$e_1 = e_2 = 0,000 \text{ m}$$

$$n = 2$$

$$S_{1F} = 1 - S_F / H = 1 - 0 = 1,0$$

Fixing of wheels according to lateral movements	Combination of wheel pairs		h
	Coupled (C)	Independent (I)	
Fixed / Fixed (FF)			$[m \xi_1 \xi_2 l^2 + \Sigma (e_j)^2] / \Sigma e_j$
m – number of pairs of coupled wheels (m = 0 for independent wheel pairs);			

EN 1991-3 tab. 2.8

m - number of pairs of coupled wheels (m = 0 for independent); so m = 0

$$e_j = 0,000 \text{ m}$$

$$h = \Sigma (e_j)^2 / \Sigma e_j = 0,0 \text{ m}$$

$$f = \min \{ 0,3 ; 0,3[1 - \exp (-250\alpha)] \}$$

$$\alpha = \min (\alpha_F + \alpha_V + \alpha_0 ; 0,015 \text{ rad}) \quad \text{EN 1991-3 (2.11)}$$

Angles α	Minimum values of
$\alpha_F = 0,75 x / a_{\text{ext}}$	$0,75 x \geq 5 \text{ mm}$ for guide rollers
	$0,75 x \geq 10 \text{ mm}$ for wheel flanges
$\alpha_V = y / a_{\text{ext}}$	$y \geq 0,03b$ [mm] for guide rollers
	$y \geq 0,1b$ [mm] for wheel flanges
α_0	0,001 [rad]

EN 1991-3 tab. 2.7

Due to the fact that the SPe1H-A4 gantry is one of the heaviest, the largest cross-section of the crane rail, **SD 100**, was adopted. Width of rail head $b = 100 \text{ mm}$.

Since no detailed data on x and y dimensions are available, the minimum values multiplied by a safety factor of 1,5 were adopted:

$$x = 10 \cdot 1,5 = 15 \text{ mm}$$

$$y = 0,1 \cdot 100 \cdot 1,5 = 15 \text{ mm}$$

$$a_{\text{ext}} = R = 5,05 \text{ m}$$

$$\alpha_V = y / a_{\text{ext}} = 0,00297 \text{ rad}$$

$$\alpha_F = 0,75 x / a_{\text{ext}} = 0,00223 \text{ rad}$$

$$\alpha = \min (\alpha_F + \alpha_V + \alpha_0 ; 0,015 \text{ rad}) = \min (0,0062 ; 0,0150) = 0,0062 \text{ rad}$$

$$f = \min \{ 0,3 ; 0,3[1 - \exp (-250\alpha)] \} = \min (0,3 ; 0,236) = 0,236$$

System	$\lambda_{S,1}$	$\lambda_{S,1,j,L}$	$\lambda_{S,1,1,T}$	$\lambda_{S,2,j,L}$	$\lambda_{S,2,1,T}$
IFF	1,000	0	0,250	0	0,750

For one wheel:

$$S_k = 141,658 \text{ kN}$$

EN 1991-3 tab. 2.9

$$H_{S,1,1,T,k} = 35,415 \text{ kN}$$

$$H_{S,2,1,T,k} = 106,244 \text{ kN}$$

Design values:

$$S = 212,487 \text{ kN}$$

$$H_{S,1,1,T} = 53,123 \text{ kN}$$

$$H_{S,2,1,T} = 159,336 \text{ kN}$$

Buffer forces related to movements of crab $H_{B,2}$ \longleftrightarrow

Lec #2 / 48

Buffer forces related to movements of crab can be assumed as:

EN 1991-3 2.11.2

- **0,1 (self-weight of crab + hoist load);**
- In other case, this force should be determined as for the crane movement;

$$Q_{\text{crab}, k} = (\#t / 13) = 118,346 \text{ kN}$$

$$Q_{\text{h}, k} = (\#t / 13) = 200,000 \text{ kN}$$

$$H_{B,2,k} = 0,1 \cdot (118,346 + 200) = 31,835 \text{ kN}$$

For one wheel: 7,959 kN

Design value:

$$H_{B,2} = 47,753 \text{ kN}$$

For one wheel: 11,938 kN

φ_6 ; test load Q_T



Lec #2 / 57

Static test load	Dynamic test load
$Q_T \geq 1,25 Q_h$	$Q_T \geq 1,10 Q_h$
$\varphi_6 = 1$	$\varphi_6 = 0,5 (1 + \varphi_2)$

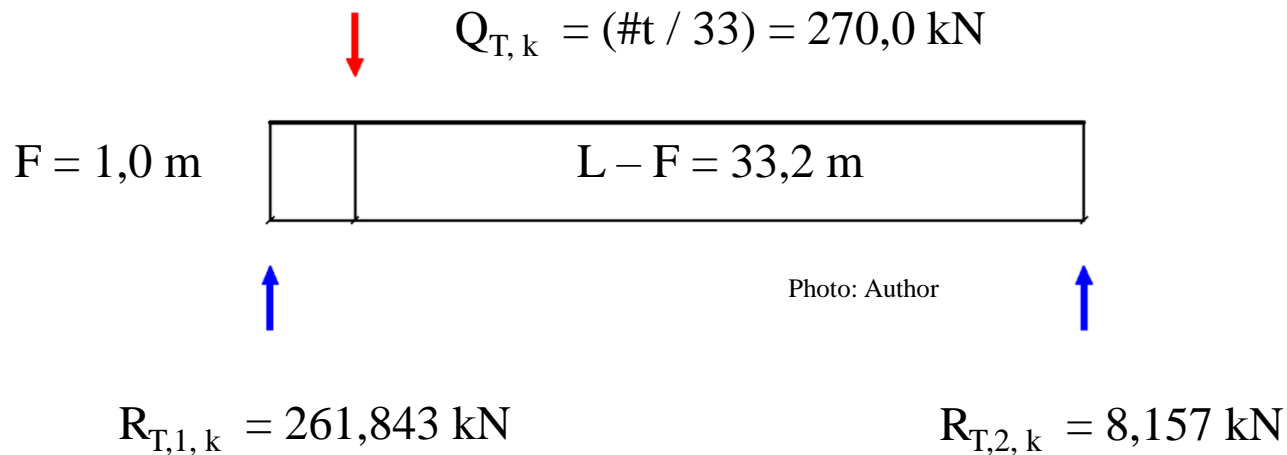
EN 1991-3 (2.13), (2.14)

$$Q_{h,k} = (\#t / 13) = 200,000 \text{ kN}$$

Test load was assumed to be 10% higher than the minimum load.

Static test load		Dynamic test load	
Charateristic	Design	Charateristic	Design
$Q_{T,k} = (1,25 + 0,1) Q_{h,k} =$ $= 270,000 \text{ kN}$	$Q_T = 405, 000 \text{ kN}$	$Q_T = (1,10 + 0,1) Q_h =$ $= 240 \text{ kN}$	$Q_T = 360, 000 \text{ kN}$
$\varphi_6 = 1$		$\varphi_6 = 0,5 (1 + \varphi_2) = 1,032$	
$\varphi_6 Q_{T,k} = \mathbf{270,000 \text{ kN}}$	405,000 kN	$\varphi_6 Q_{T,k} = 247,680 \text{ kN}$	371,520 kN

Vertical forces, applied to run-beams, depends on position of crab (according to #t / 11).



Design values:

$$R_{T,1} = 392,764 \text{ kN}$$

$$R_{T,2} = 12,236 \text{ kN}$$

For one wheel:

$$R_{T,1} = 196,382 \text{ kN}$$

$$R_{T,2} = 6,118 \text{ kN}$$

φ_7 ; buffer forces H_B

Lec #2 / 58 - 61



EN 1991-3 tab. 2.10

Additional information for calculations, the same for everybody:

- One crane only
- Assembly crane, HC1, S0
- Steady hoisting speed $v_h = 0,08 \text{ m / s}$
- Hook $\rightarrow \varphi_3 = 0,0$
- $\varphi_4 = 1,0$
- $\varphi_5 = 1,5$
- $\eta = 0$
- Single wheel drive, $m_w = 2$
- Friction coefficient $\mu = 0,2$
- Wheel flanges, $a_{ext} = R$
- Fixing of wheel IFF
- Longitudinal velocity of crane $v = 0,7 \text{ m / s}$
- Spring constant of the buffer $S_B = 65 \text{ kN / m}$
- $\xi_b = 0,5$
- Rail supported on an elastomeric bearing pad

Buffer characteristic	Values of dynamic factor φ_7
$0,0 \leq \xi_b \leq 0,5$	1,25
$0,5 \leq \xi_b \leq 1,0$	$1,25 + 0,7 (\xi_b - 0,5)$

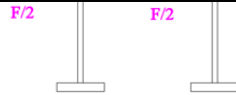


Photo: Author

$$v_1 = 0,7 v_{\max} = 0,49 \text{ m / s}$$

$$m_c = \text{mass of crane} = (\#t / 8) = 40,8 \text{ t}$$

$$H_{B,1,k} = \varphi_7 v_1 \sqrt{(m_c S_B)} = 31,542 \text{ kN}$$

For one buffer: 15,771 kN

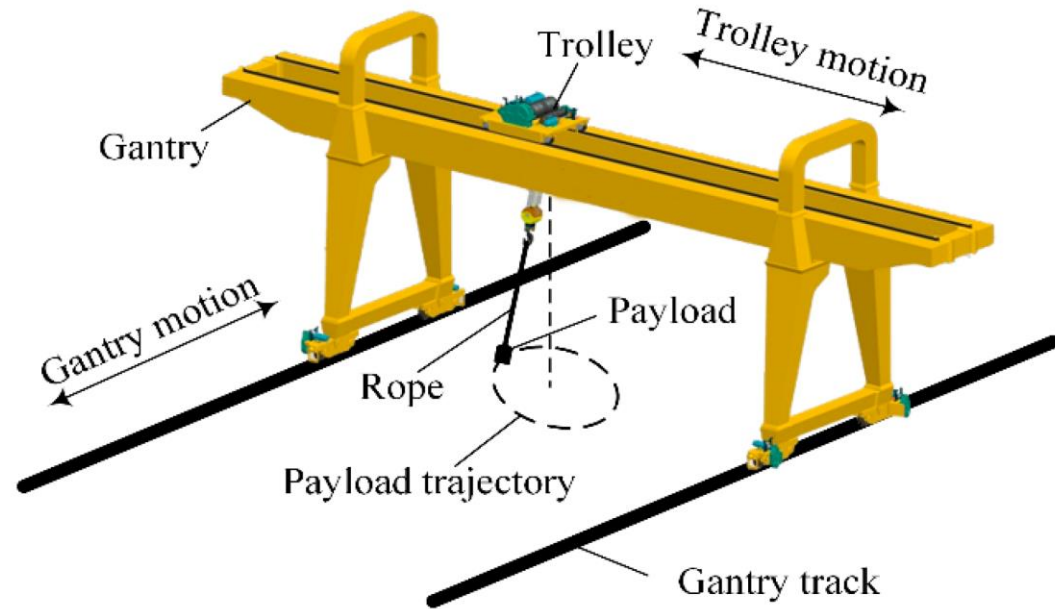
Design value:

$$H_{B,1,k} = 47,313 \text{ kN}$$

For one buffer: 23,657 kN

Tilting forces H_{TA}

Lec #2 / 62 - 63



EN 1991-3 p. 2.11.3

Photo: Research on Nonlinear Control Method of Underactuated Gantry Crane Based on Machine Vision Positioning, H. Shi, G. Li, X. Bai, J. Huang

Not concerns analysed case, $H_{TA} = 0,0$

		Symbol	Direction	Groups of load									
				ULS							Test load	Accidental loads	
				1	2	3	4	5	6	7	8	9	10
1	Self-weight of crane	Q_c	Vertical	1,1	1,1	1	1,0	1,0	1,0	1	1,1	1	1
2	Hoist load	Q_h	Vertical	1,064	0,0	0	1,0	1,0	1,0	1,0	0	0	0
3	Acceleration of crane bridge	H_L H_T	Longitudinal Transversal	1,5	1,5	1,5	1,5	0	0	0	1,5	0	0
4	Skewing of crane bridge	H_S	Longitudinal Transversal	0	0	0	0	1	0	0	0	0	0
5	Acceleration of barking of crab or hoist block	$H_{B,2}$	Transversal	0	0	0	0	0	1	0	0	0	0
6	In-service wind	F_W^*	Longitudinal Transversal	1	1	1	1	1	0	0	1	0	0
7	Test load	Q_T	Vertical	0	0	0	0	0	0	0	1,0	0	0
8	Buffer force	H_B	Longitudinal	0	0	0	0	0	0	0	0	1,25	0
9	Tilting force	H_{TA}	Longitudinal Transversal	0	0	0	0	0	0	0	0	0	1

Analysis of coefficients shows that for further analysis only groups 1, 5, 6, 8, 9 should be taken; others will give lower values. Wind action is still not calculated.

Calculation of wind is possible only after analysis of beam geometry. Wind acts in horizontal direction; initial assumptions about geometry of cross-section is made according to vertical actions. So, wind this is no problem for initial assumptions.

Dead-weight of run-beam is very small in comparison do dead-weight of crane and lifted element. It could be taken into consideration, that dead-weight is not greater than 10% of others. Max bending moment for initial assumptions is calculated for vertical actions and finally is increased up 10%:

$$M_{V, \max} = M (1,1 \cdot Q_V)$$

For initial assumption possible is simplification: crab of crane is in half of crane and vertical forces for left and right run-beam are the same.

Dynamic factors will be taken into consideration.

Five combinations (according to #t / 37) will be analysed detaily. Vertical force for them are as follow (design values):

$$Q_{c, \max} \text{ for one wheel} = 191,402 \text{ kN (\#t / 20)}$$

$$Q_{h, \max} \text{ for one wheel} = 145,601 \text{ kN (\#t / 22)}$$

$$Q_{T, \max} \text{ for one wheel} = 196,382 \text{ kN (\#t / 34)}$$

$$1) \quad \varphi_1 Q_c + \varphi_2 Q_h = 1,1 \cdot 191,402 + 1,064 \cdot 145,601 = 365,462 \text{ kN}$$

$$5) \quad \varphi_4 Q_c + \varphi_4 Q_h = 1,0 \cdot 191,402 + 1,0 \cdot 145,601 = 356,143 \text{ kN}$$

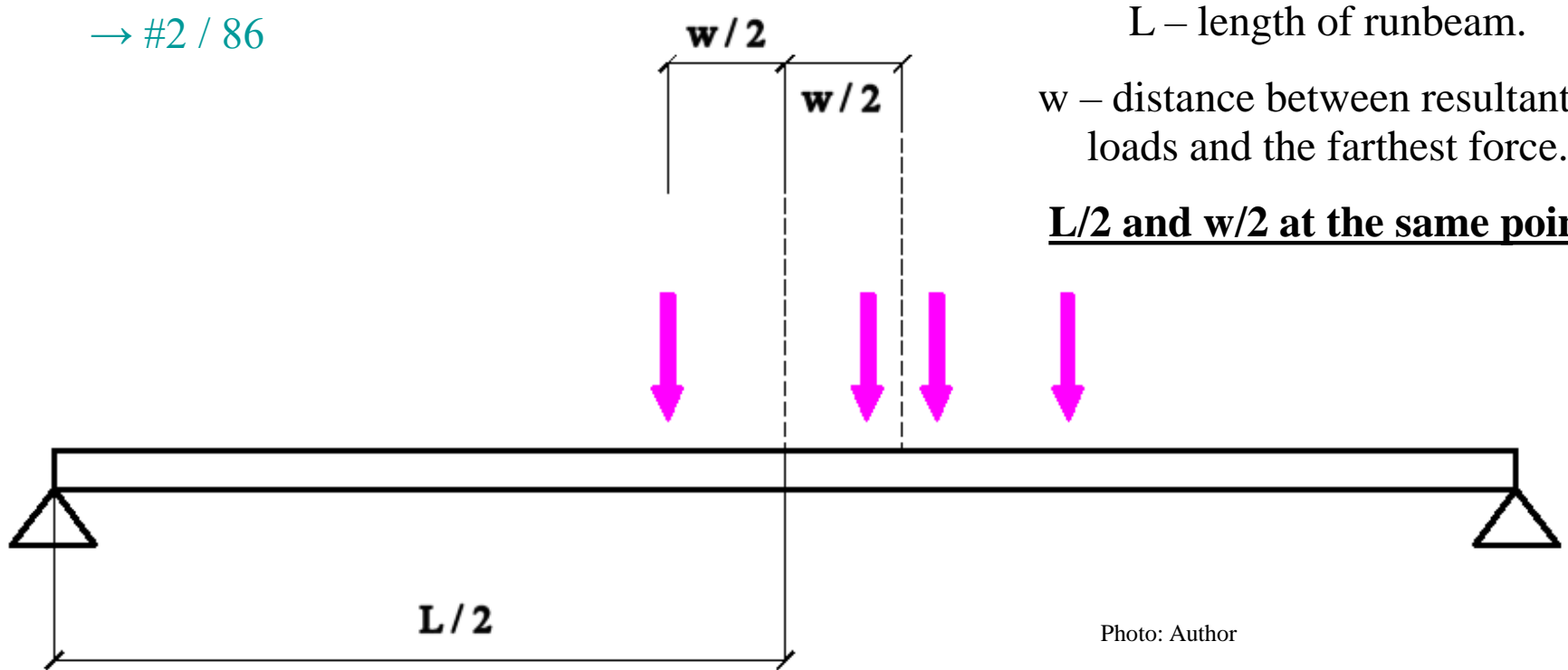
$$6) \quad \varphi_4 Q_c + \varphi_4 Q_h = 1,0 \cdot 191,402 + 1,0 \cdot 145,601 = 365,143 \text{ kN}$$

$$\mathbf{8) \quad \underline{\varphi_1 Q_c + \varphi_6 Q_T = 1,1 \cdot 191,402 + 1,0 \cdot 196,382 = 406,924 \text{ kN}}}$$

$$9) \quad 1,0 Q_c = 1,0 \cdot 191,402 = 191,402 \text{ kN}$$

$$M_{V, \max} = M (1,1 \cdot Q_V) = M (447,617 \text{ kN})$$

→ #2 / 86



For this scheme, we have M_{\max} (Culman theorem)

→ #2 / 87

Loads as close of support as possible.

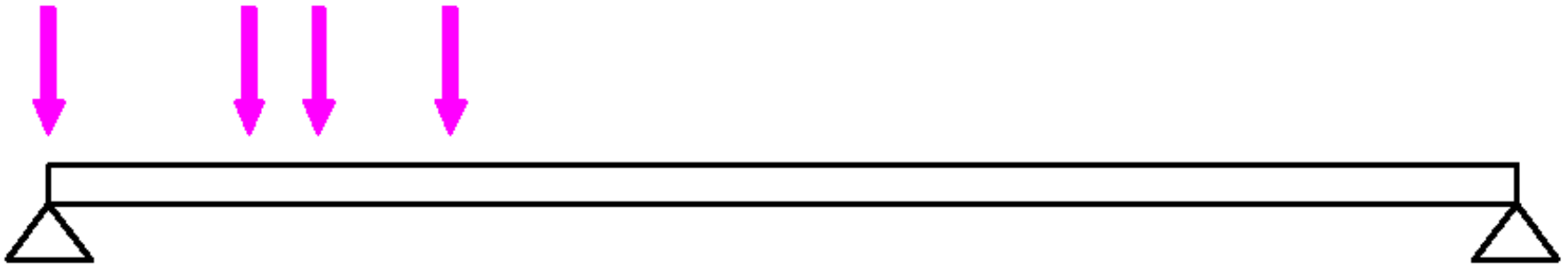


Photo: Author

For this scheme, we have R_{\max} , V_{\max}

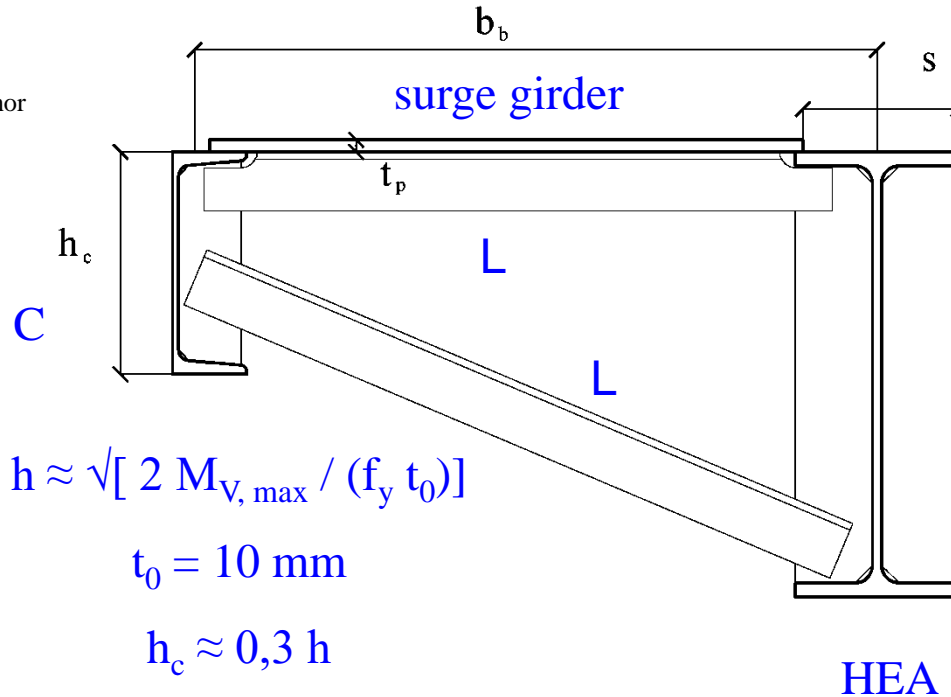
Forces are applied according to Culman theorem.

For analysed case (length of beam 6,00 m, distance between wheels 5,05 m) only one force will be applied in half of span.

$$M_{V, \max} = Q_V L / 4 = 447,617 \cdot 6,000 / 4 = 671,426 \text{ kNm}$$

HEB, HEA, IKS, welded I-beam plate surge girder

Photo: Author



$$h \approx \sqrt{[2 M_{V, \max} / (f_y t_0)]}$$

$$t_0 = 10 \text{ mm}$$

$$h_c \approx 0,3 h$$

$$b_b \approx \max (70 \text{ cm} ; L_b / 20)$$

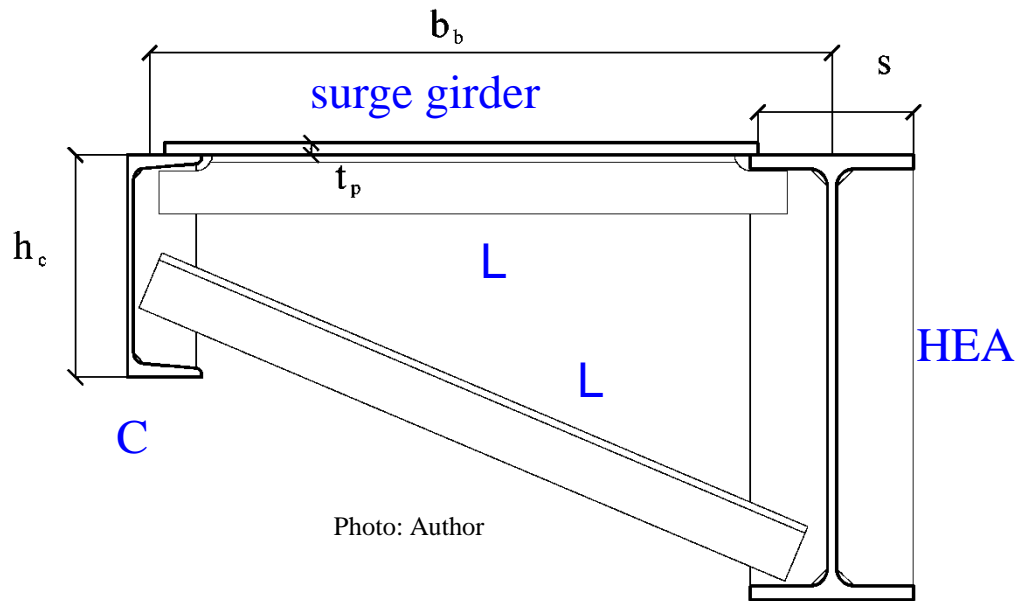
$s =$ enough space for rail and connection with beam

$$t_p \approx 0,5 (t_f + t_w)$$

$b_b / t_p \rightarrow$ no IVth class of cross-section



Photo: despaw.pl



S 355

$$h \approx \sqrt{[2 M_{V, \max} / (f_y t_0)]} = 0,615 \text{ m} \rightarrow$$

HEA 650

$$h_c \approx 0,3 h \rightarrow \text{C 200}$$

$$t_f = 26 \text{ mm}, \quad t_w = 13,5 \text{ mm}$$

$$b_b \approx \max (70 \text{ cm} ; L_b / 20) = 80 \text{ cm}$$

$$t_p \approx 0,5 (t_f + t_w) = 20 \text{ mm}; \text{ the thickest riffled plate was adopted: } 10 \text{ mm}$$

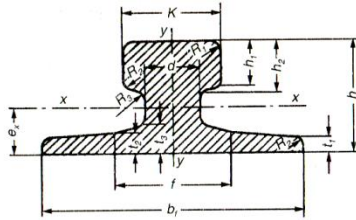
Surge girder:

$$\varepsilon = \sqrt{(235 / f_y)} = 0,814$$

Limit III / IV class of cross-section for bending: $72 \varepsilon = 58,6$

$$b_b / t_p = 800 / 10 = 80 \rightarrow \text{is in range of IV section class.}$$

Photo: W. Bogucki, M. Żybartowicz, Tablice do projektowania konstrukcji metalowych, Arkady, Warszawa 1996

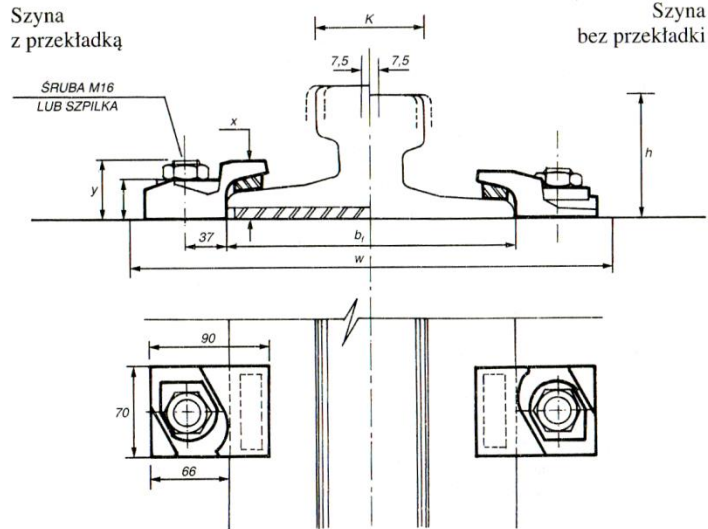


**SZINY DŹWIGOWE (PODSUWNICOWE)
wg PN-62/H-93410**

Długości handlowe: szyny SD 65 i SD 75 6÷12 m
szyny SD 100 6÷15 m

Wyróżnik ozna- czenia	Wymiary										Wymiary			Pole prze- kroju	Masa	Odległość środką ciężkości	Moment bezwładności		Wskaźnik wytrzymałości	
	K	b _f	h	h ₁	h ₂	d	f	t ₁	t ₂	t ₃	R ₁	R ₂	R ₃	A	m	e _x	I _x	I _y	W _x	W _y
	mm										mm			cm ²	kg/m	cm	cm ⁴		cm ³	
SD 65	65	175	75	30	34,0	38	78	10	14,0	20	6	5	5	55,4	43,5	3,06	327	609	73,7	69,6
SD 75	75	200	85	35	39,5	45	90	11	15,4	22	6	6	6	72,1	56,6	3,50	543	1010	109	101
SD 100	100	200	95	40	45,5	60	100	12	16,5	23	9	6	6	95,6	75,2	4,30	888	1360	170	136

3120/15
mocowana śrubą lub kotwą



Minimalna szerokość
montażowa
 $W = b_f + 147 \text{ mm}$

Wysokość szpilki
lub śruby z nakrętką
 $H = Y - 7 \text{ mm}$

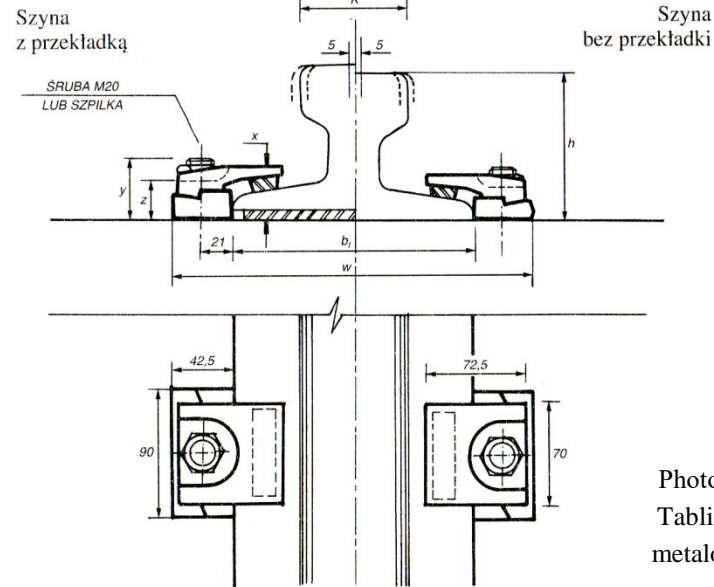
Typ szyny	b_f	K	h	Klemy do szyn na przekładce elastycznej	Klemy do szyn bez przekładki
	mm	mm	mm		
SD 65	175	65	75	3120/15/35/10	3120/15/35/17
SD 75	200	75	85	3120/15/35/10	3120/15/35/17
SD 100	200	100	95	3120/15/35/10	3120/15/35/17
S 24	115	53	90	—	3120/15/35/22
S 41	125	67	138	3120/15/35/13	3120/15/35/22
S 42	140	70,1	125	3120/15/35/13	3120/15/35/17
S 49	125	70	149	3120/15/35/10	3120/15/35/17
S 60	150	74,3	172	3120/15/35/10	3120/15/35/17

Wymiary z nakrętką (mm)				
Typ	X	Y	Z	Masa (kg)
3120/15/35/--	35	45	23	0,62
3120/15/40/--	40	50	30	0,82

Dane techniczne		
Dla śrub/szpilek	Klasa 4.6	Klasa 8.8
Maks. obciąż. boczn.	30 kN	75 kN
Moment napinający	160 Nm	390 Nm

7120/10

mocowana śrubą lub kotwą



Minimalna szerokość
montażowa
 $W = b_f + 95 \text{ mm}$

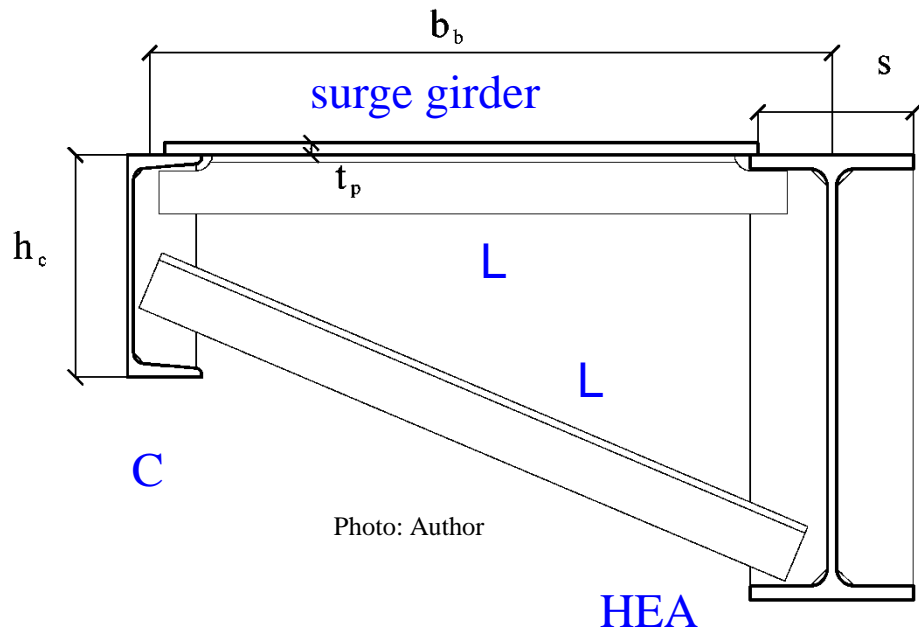
Wysokość szpilki
lub śruby z nakrętką
 $H = Y - 7 \text{ mm}$

Typ szyny	b_f	K	h	Klemy do szyn na przekładce elastycznej	Klemy do szyn bez przekładki
	mm	mm	mm		
SD 65	175	65	75	7120/10/38/13	7120/10/38/17
SD 75	200	75	85	7120/10/38/13	7120/10/35/17
SD 100	200	100	95	7120/10/38/10	7120/10/35/13
S 24	115	53	90	7120/10/35/10	7120/10/35/17
S 41	125	67	138	7120/10/35/10	7120/10/35/17
S 42	140	70,1	125	7120/10/38/13	7120/10/35/17
S 49	125	70	149	7120/10/35/08	7120/10/35/13
S 60	150	74,3	172	7120/10/38/10	7120/10/35/13
S 64	150	74	172	7120/10/38/10	7120/10/35/13

Wymiary z nakrętką (mm)				
Typ	X	Y	Z	Masa (kg)
7120/10/35	35	45	25	0,60
7120/10/38	38	50	29	0,64

Dane techniczne		
Dla śrub/szpilek	Klasa 4.6	Klasa 8.8
Maks. obciąż. boczn.	30 kN	75 kN
Moment napinający	160 Nm	390 Nm

Photo: W. Bogucki, M. Żybartowicz,
Tablice do projektowania konstrukcji
metalowych, Arkady, Warszawa 1996



$s \rightarrow$ width of DS 100 rail foot is 200 mm.
 Requirements for bolts securing crane rails
 are:

space width = width of the rail foot +
 approx. 150 mm \approx 350 mm

Flange width HEA 650 = 300 mm. We
 will need an additional overlay for the 400
 mm wide top chord with thickness non
 less than "old" chord (26 mm). It will be
 adopted plate 30 mm.

Surge girder is also working platform. Working platform must be supported with additional beams between the main beam and the auxiliary C-section. These additional elements will be L-sections 60x60x8.

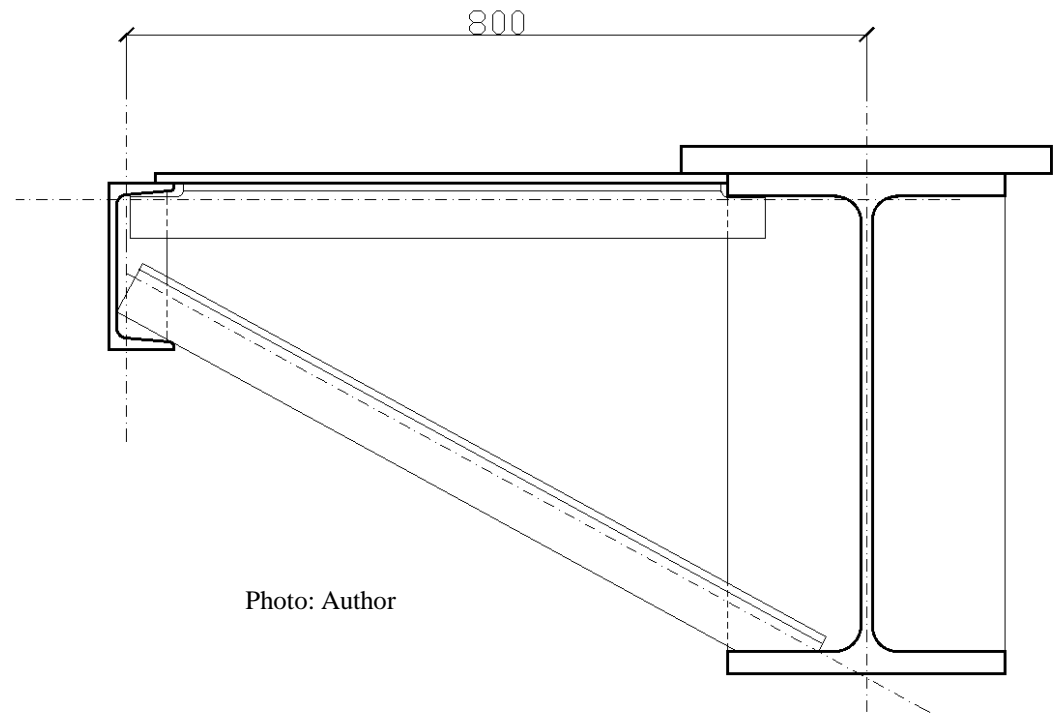


Photo: Author

Surge girder is supported transversally by L-sections. Recommended distance between transversal elements is:

$$L \approx d$$

In analysed case, because of problem with class of cross-section for surge girder, additional diagonal L-sections are recommended. Such complex made horizontal truss, cooperated with plate surge girder. Thank to this, surge girder in Ivth class of cross-section could be adopted without additional problems.

$$L = 1000 \text{ mm} \quad ; \quad d = 800 \text{ mm}$$

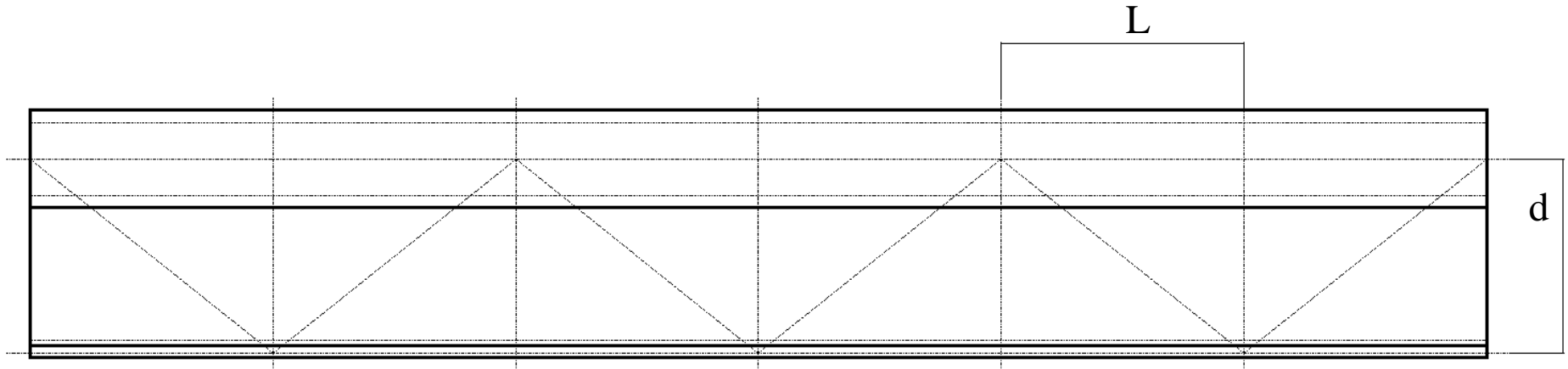


Photo: Author

Dead-weight of beam:

HEA 650: 190,0 kg / m

Additional plate 30x400mm: 0,942 kN / m

Surge girder 10x800 mm: 0,628 kN / m

Rail DS 100: 75,2 kg / m

C200: 25,3 kg / m

L-sections 60x60x8: 7,08 kg / m

Approximate length on L-sections per 1,0 m

length of beam: $0,800 + 1,03 + 1,28 =$

$= 3,11$ m

Additional elements (gusset plates, bolts...):

3,0 kg / m

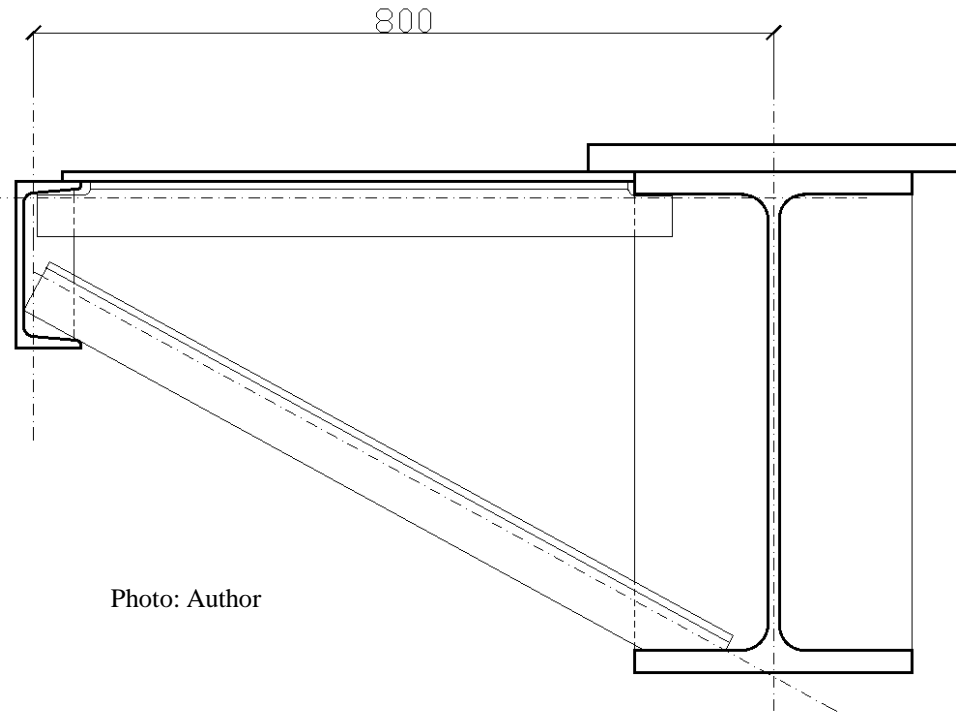


Photo: Author

Photo: Author

$$q_k = 4,665 \text{ kN / m}$$

$$q_d = 6,298 \text{ kN / m}$$

Gdańsk – 2 wind region (EN 1991-1-4 Photo. NB.1)

Average wind 20 m/s

$q_{b,0} = 0,42$ kPa, max wind velocity 26 m/s (EN 1991-1-4 tab. NB.1)

c_{dir} adopted 1,0; c_{season} adopted 1,0 (EN 1991-1-4 tab. NB.2, EN 1991-1-4 4.2.(2))

Harbour – probably distance to seashore is smaller than 200 m → terrain category 0 is adopted (EN 1991-1-4 tab. 4.1):

$c_e(z) = 2,98 (z / 10)^{0,176}$ (EN 1991-1-4 tab. NB.3)

Analysis of influence of terrain roughness was omitted.

$z_0 = 0,003$ m; $z_{min} = 1,0$ m (EN 1991-1-4 tab. 4.1)

Rail head height: 8,10 m ; the highest point of crane: 10,595 m → wind is calculated for total crane and structure as for $z = 10,0$ m.

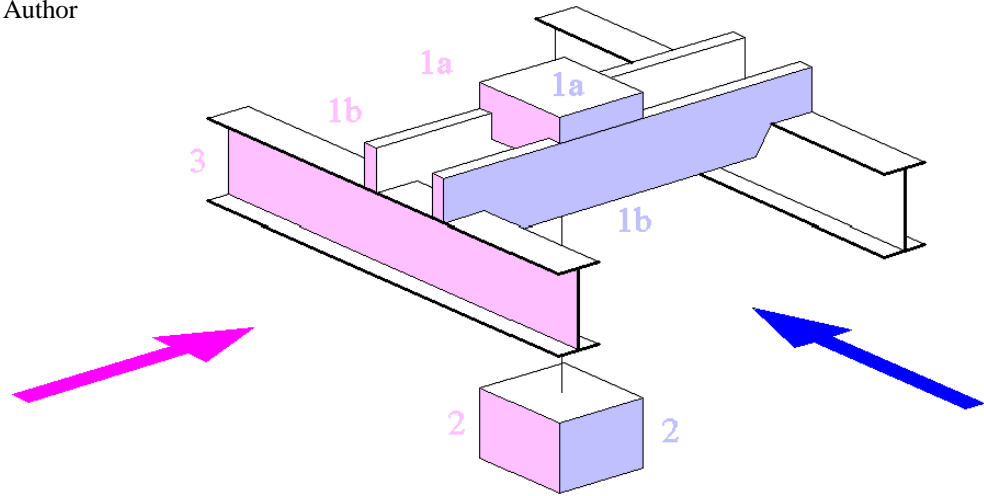
$$q_k = c_{dir} c_{season} c_e(10) q_{b,0}$$

$$q_d = 1,5 q_k$$

	Average wind	Max wind
Characteristic	0,745 kPa	1,247 kPa
Design	1,118 kPa	1,871 kPa

Photo: Author

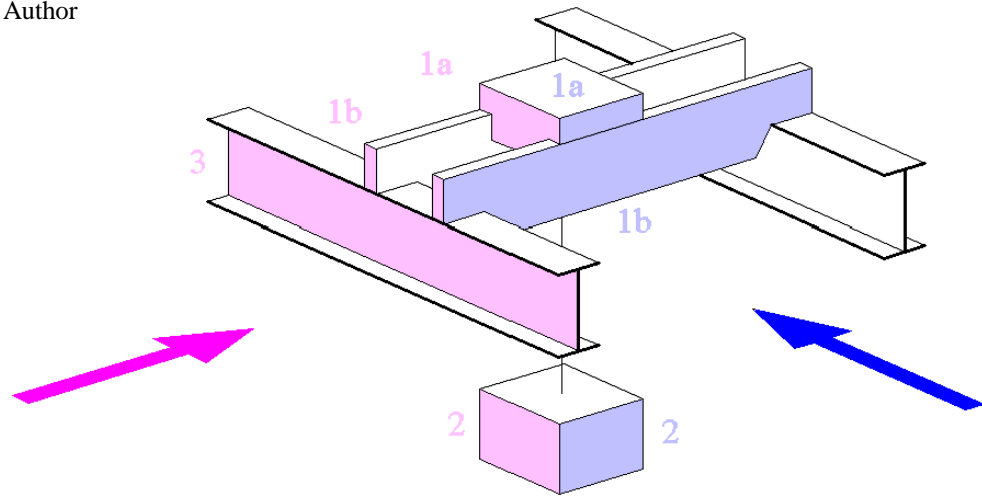
Wind must be analysed in two two independent directions: longitudinal and transversal.



Effect of longitudinal: wind actions on hoist load and crane will be applied to run-beams as horizontal longitudinal forces in points under wheels.

Effect of transversal: wind actions on hoist load and crane will be applied to run-beams as horizontal transversal forces in points under wheels + horizontal transversal continuous loads, applied to run-beams.

Photo: Author



Areas:

$$1a_{\text{long}} \approx 0 \text{ m}^2$$

$$1a_{\text{trans}} \approx R \cdot A = 5,05 \cdot 2,495 = 12,600 \text{ m}^2$$

$$1b_{\text{long}} \approx L \cdot A = 85,080 \text{ m}^2$$

$$1b_{\text{trans}} \approx 0 \text{ m}^2$$

$$2 \approx 3,5 \sqrt{Q_h} [\text{t}] = 3,5 \cdot \sqrt{20,4} = 15,803 \text{ m}^2$$

Average wind	Characteristic	Design
Longitudinal F	Total: 75,158 kN For one wheel: 18,790 kN	Total: 112,737 kN For one wheel: 28,184 kN
Transversal F	Total: 21,160 kN For one wheel: 5,290 kN	Total: 31,740 kN For one wheel: 7,935 kN
Transversal q	0,477 kN / m	0,716 kN / m

Max wind	Characteristic	Design
Longitudinal F	Total: 112,787 kN For one wheel: 28,197 kN	Total: 163,181 kN For one wheel: 42,295 kN
Transversal F	Total: 31,755 kN For one wheel: 7,939 kN	Total: 47,632 kN For one wheel: 11,908 kN
Transversal q	0,797 kN / m	1,194 kN / m

Workers activity

Photo: megatem-ec.pl



- ◆ Vertical forces are applied to area $0,3 \times 0,3 \text{ m}$;
- ◆ Where materials can be deposited, $Q_k = 3,0 \text{ kN}$;
- ◆ If stairs, platforms and walkways are provided for normal access only, $Q_k = 1,5 \text{ kN}$;
- ◆ Horizontal loads applied to guardrails, $H_k = 0,3 \text{ kN}$;
- ◆ **Each loads can be omitted, when structural memebers are subjected to crane actions;**

→ #2 / 65

EN 1991-3 p. 2.9

Loads applied to beam (concentrated forces and continuous load) make results in 6 cross-sectional forces, that must be taken into account:

- Vertical bending moment M_V ;
- Bending moment in the horizontal plane M_H ;
- Vertical shear force V_V ;
- Shear force in the horizontal plane V_H ;
- Axial force N ;
- Torsional moment M_T generated by loads applied to the rail head;

In the case of torsional moment:

- For vertical forces, eccentricity of $e_y = \max(0.25 b_r ; 0.5 t_w)$ is assumed, where b_r is width of rail head (100 mm) and t_w is thickness of web (13.5 mm); in the case under consideration $e_y = 25$ mm;
- For horizontal forces, eccentricity is distance from center of gravity of I-section to rail head level; in case under consideration it is approximately half depth of HEA 650 + thickness of additional plate on upper flange + height of the rail, i.e. $e_z = 445$ mm

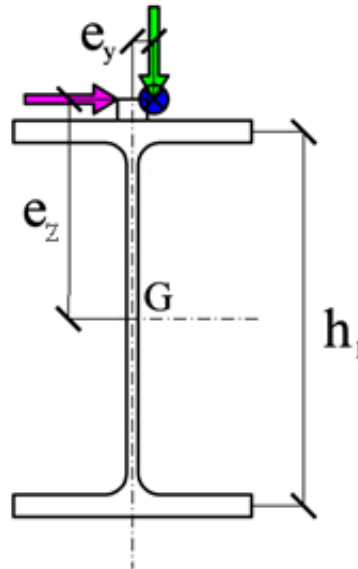


Photo: Author

Static scheme of beam

- Vertical hinge supports at both ends
- Horizontal hinge supports at both ends
- Longitudinal hinge supports at both ends
- Anti-torsional supports at both ends

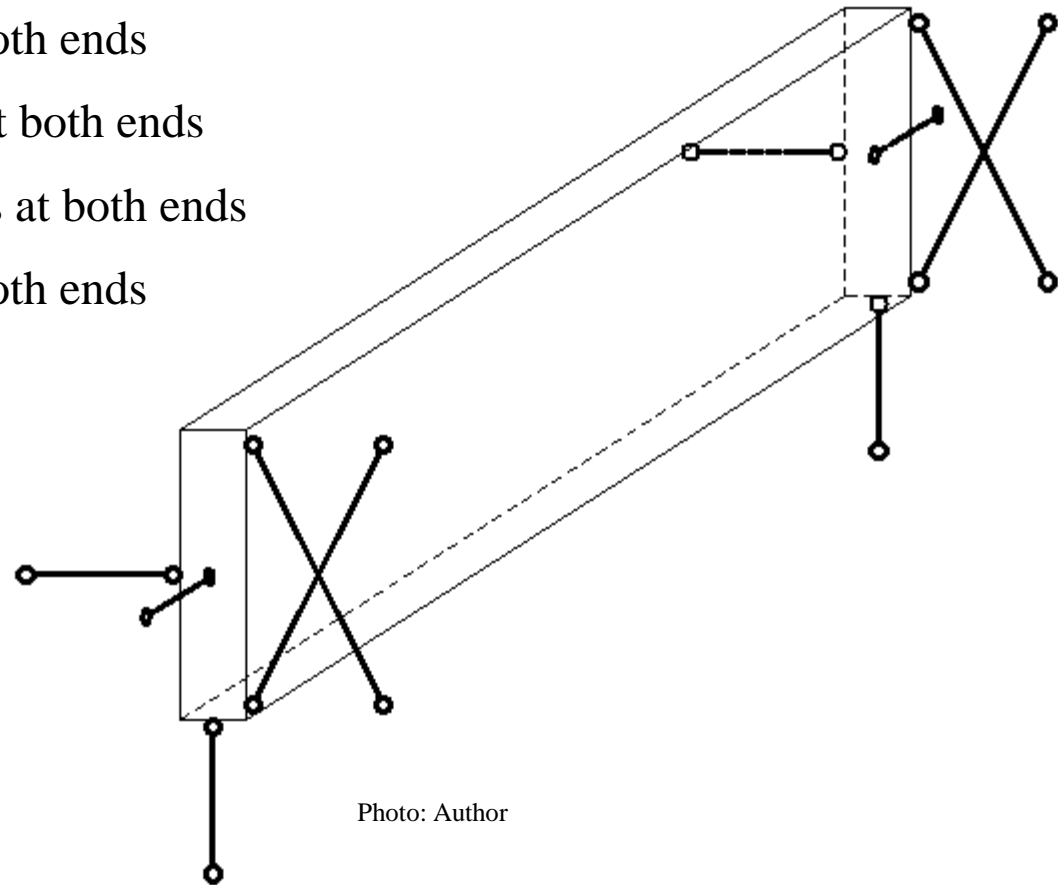
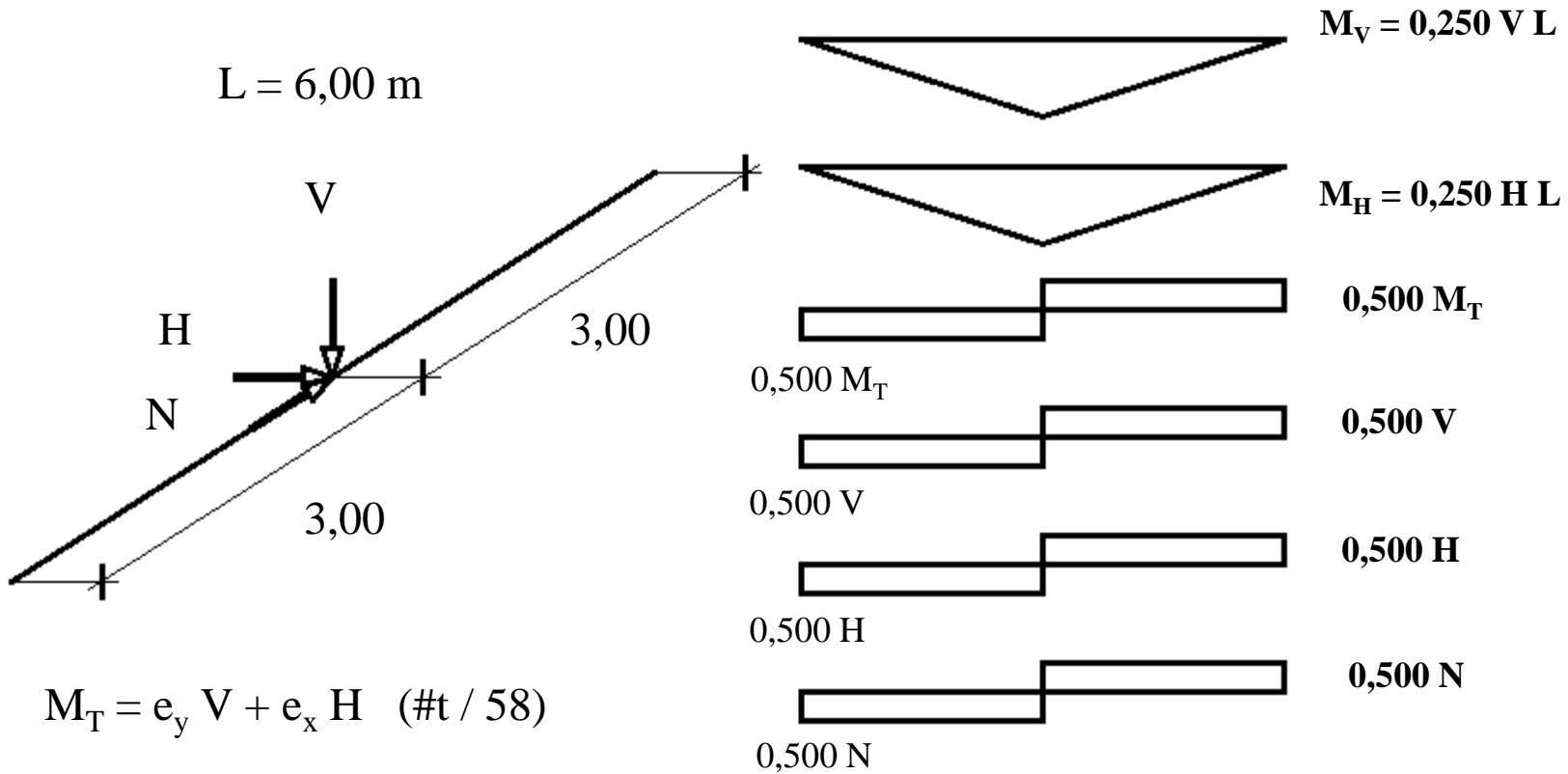


Photo: Author

Load	Notices
Crab acceleration $H_{B,2}$	Completely symmetrical for any direction of movement and number of beam; #t / 61-62
Buffer force H_B	
Dead-weight of structure	Completely symmetrical for any direction of movement and number of beam; #t / 63
Wind (any kind)	Completely symmetrical for any direction of movement and number of beam; #t / 61-63
Dead-weight of crane Q_c	Loads for one beam much bigger than for second, but into consideration can be taken strenuous; #t / 61-62
Hoist load Q_h	
Test load load Q_T	
Acceleration	Unsymmetrical for beams and directions; #t / 64
Skewing	Unsymmetrical for beams and directions; #t / 65

Max M

The same directions and values of forces for both beams



$$M_T = e_y V + e_x H \quad (\#t / 58)$$

Photo: Author

The same shapes and values of forces for both beams

Max V

The same directions and values of forces for both beams

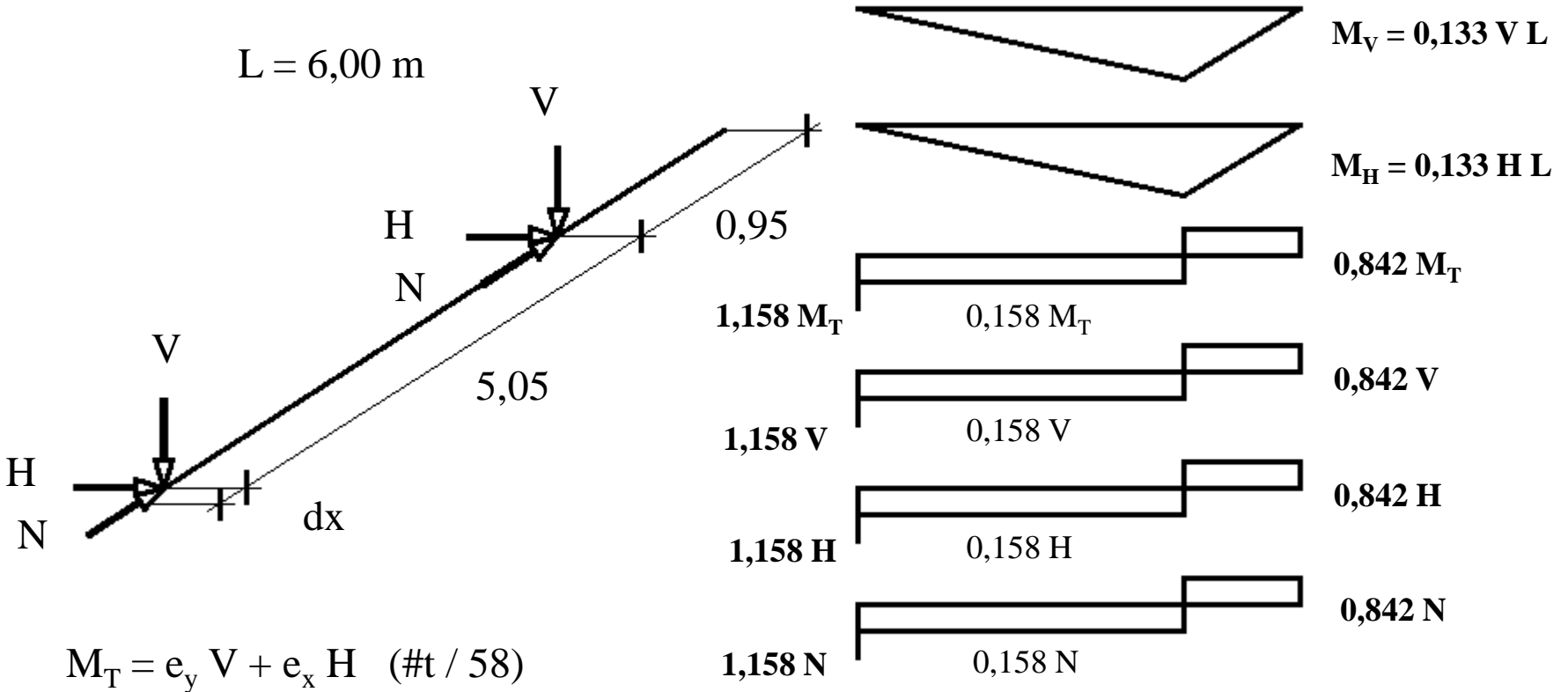


Photo: Author

The same shapes and values of forces for both beams

Max M and V

The same directions and values of forces for both beams

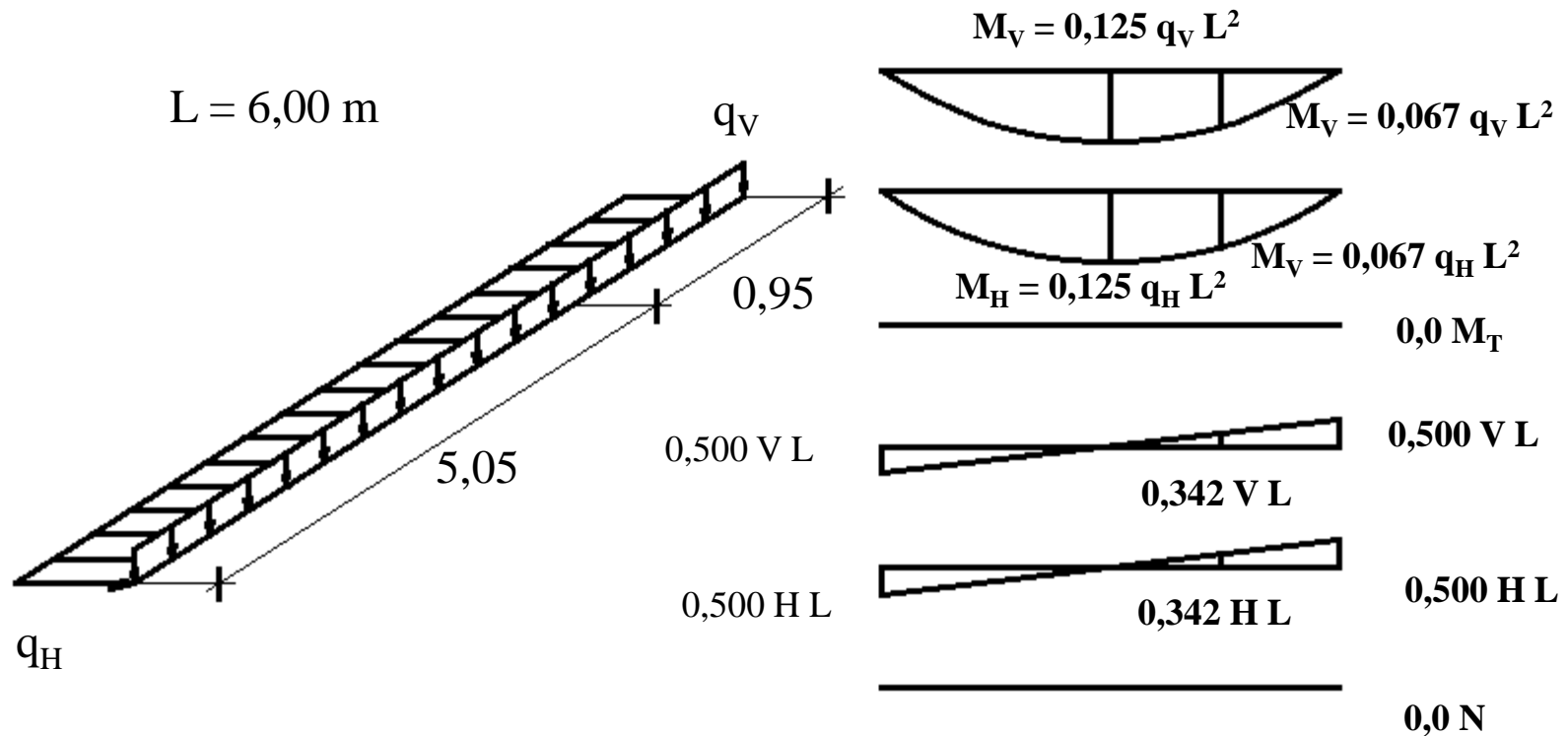
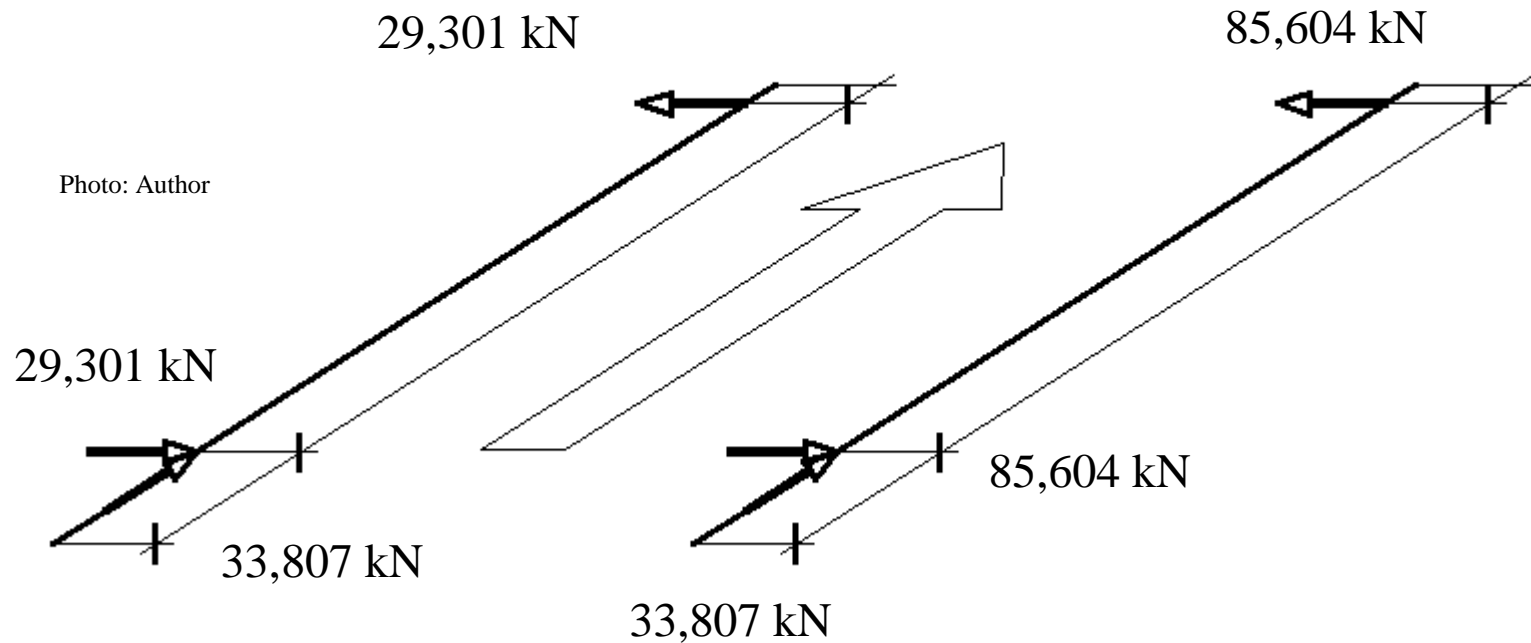


Photo: Author

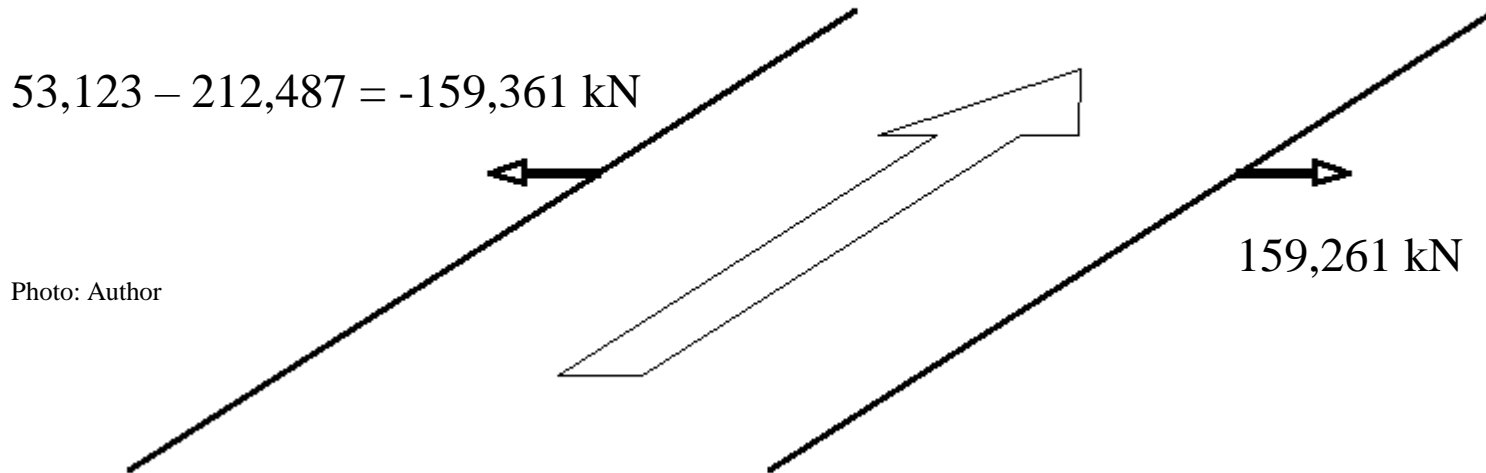
The same shapes and values of forces for both beams

Acceleration



Various values of forces for left and right beam, but in the same directions for both. Values on left and right depends on position of crab. Additionally, change of direction of forces along beams. Combinations depend on directions of crane's movement.

Skewing



The same values of forces for left and right beam, but in opposite directions for both. On left beam, force is opposite to each other type of loads (except forces from acceleration). On right beam, force has the same directions for each other loads (except forces from acceleration).

Additional information for calculations, the same for everybody:

• One crane only

- Assembly crane, HC1, S0
- Steady hoisting speed $v_h = 0,08 \text{ m / s}$
- Hook $\rightarrow \varphi_3 = 0,0$
- $\varphi_4 = 1,0$
- $\varphi_5 = 1,5$
- $\eta = 0$
- Single wheel drive, $m_w = 2$
- Friction coefficient $\mu = 0,2$
- Wheel flanges, $a_{ext} = R$
- Fixing of wheel IFF
- Longitudinal velocity of crane $v = 0,7 \text{ m / s}$
- Spring constant of the buffer $S_B = 65 \text{ kN / m}$
- $\xi_b = 0,5$
- Rail supported on an elastomeric bearing pad

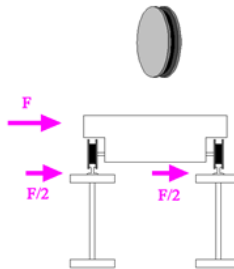


Photo: Author

One crane only – max two vertical and two horizontal forces on one beam.

Distance between the wheel axes is 5,05 m, which is comparable to beam span of 6,0 m. In such situation it is not possible to adjust forces according to Culman's theorem - one of them will "escape" beyond beam.



Additionally, combination W - max wind case in combination with dead-weight of crane should be considered.

For ULS, the maximum values of internal forces out of 1, 5, 6, 8, 9, W will be important.

For SLS, the minimum values of internal forces will be additionally important. A separate F combination should be calculated for fatigue LS.

Consider the effects:

- for the left and right beam;
- for positions max M and max V;
- for parallel and perpendicular wind;
- for two directions of the crane's movement;
- for two extremely position of crab;
- for cross-sectional forces under force and over support;

1) $1,0 \cdot \text{dead-weight} + 1,1 \cdot Q_c + 1,064 \cdot Q_h + 1,5 \cdot \text{acceleration} + 1,0 \cdot \text{wind average}$

5) $1,0 \cdot \text{dead-weight} + 1,0 \cdot Q_c + 1,0 \cdot Q_h + 1,0 \cdot \text{skewing} + 1,0 \cdot \text{wind average}$

6) $1,0 \cdot \text{dead-weight} + 1,0 \cdot Q_c + 1,0 \cdot Q_h + 1,0 \cdot \text{crab}$

8) $1,0 \cdot \text{dead-weight} + 1,1 \cdot Q_c + 1,5 \cdot \text{acceleration} + 1,0 \cdot \text{wind average} + 1,0 \cdot Q_T$

9) $1,0 \cdot \text{dead-weight} + 1,0 \cdot Q_c + 1,25 \cdot \text{buffer}$

W) $1,0 \cdot \text{dead-weight} + 1,0 \cdot Q_c + 1,0 \cdot \text{wind max}$

Max M, under force

Force	Combination			
	5, wind longitudinal	5, wind transversal	8, wind longitudinal	8, wind transversal
M_V [kNm]	533,846	533,846	726,419	726,419
M_H [kNm]	239,042	254,171	192,609	207,734
M_T [kNm]	35,686	37,254	31,178	32,745
V_V [kN]	187,396	187,396	251,587	251,587
V_H [kN]	79,681	85,798	64,203	70,319
N [kN]	14,092	0,000	39,447	25,355

Max V, under force

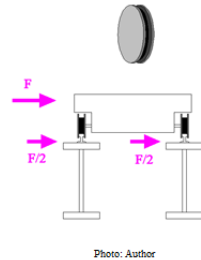
Force	Combination			
	5, wind longitudinal	5, wind transversal	8, wind longitudinal	8, wind transversal
M_V [kNm]	272,726	272,726	375,175	375,175
M_H [kNm]	127,170	133,936	102,468	109,232
M_T [kNm]	60,033	62,736	52,503	55,142
V_V [kN]	302,651	302,651	410,748	410,748
V_H [kN]	134,023	143,014	108,118	116,947
N [kN]	11,865	0,000	54,564	55,142

Max V, over support

Force	Combination			
	5, wind longitudinal	5, wind transversal	8, wind longitudinal	8, wind transversal
M_V [kNm]	0,000	0,000	0,000	0,000
M_H [kNm]	0,000	0,000	0,000	0,000
M_T [kNm]	72,704	76,335	13,473	17,102
V_V [kN]	409,143	409,143	557,810	557,810
V_H [kN]	159,361	170,701	0,000	11,337
N [kN]	32,637	0,000	91,360	58,723

Additional information for calculations, the same for everybody:

- One crane only
- **Assembly crane, HC1, S0**
- Steady hoisting speed $v_h = 0,08 \text{ m/s}$
- Hook $\rightarrow \varphi_3 = 0,0$
- $\varphi_4 = 1,0$
- $\varphi_5 = 1,5$
- $\eta = 0$
- Single wheel drive, $m_w = 2$
- Friction coefficient $\mu = 0,2$
- Wheel flanges, $a_{ext} = R$
- Fixing of wheel IFF
- Longitudinal velocity of crane $v = 0,7 \text{ m/s}$
- Spring constant of the buffer $S_B = 65 \text{ kN/m}$
- $\xi_b = 0,5$
- Rail supported on an elastomeric bearing pad



Simplified approach can be adopted

$$S0 \rightarrow \lambda_{i, \sigma} = 0,198 \quad \lambda_{i, \tau} = 0,379$$

$$\varphi_{fat,1} = (1 + \varphi_1) / 2 = 1,05$$

$$\varphi_{fat,2} = (1 + \varphi_2) / 2 = 1,032$$

$$\varphi_{fat} = \max(\varphi_{fat,1} ; \varphi_{fat,2}) = 1,05$$

$$Q_{r, \max, i} = 337,500 \text{ kN}$$

$$Q_{e, \sigma} = Q_{\max, i} \varphi_{fat} \lambda_{i, \sigma} = 70,166 \text{ kN}$$

$$Q_{e, \tau} = Q_{\max, i} \varphi_{fat} \lambda_{i, \tau} = 134,308 \text{ kN}$$

In span:

$$M_{V, fat, \max} = M_{V, fat}(Q_{e, \sigma}) = 105,249 \text{ kNm}$$

$$V_{V, fat, \max} = V_{V, fat}(Q_{e, \tau}) = 67,154 \text{ kN}$$

Over support:

$$M_{V, fat, \max} = M_{V, fat}(Q_{e, \sigma}) = 0,000 \text{ kNm}$$

$$V_{V, fat, \max} = V_{V, fat}(Q_{e, \tau}) = 155,529 \text{ kN}$$

Thank you for attention

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