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STRESS DETERMINATION IN REINFORCED I-SECTION BOTTOM FLANGE OF SINGLE GIRDER CRANE

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Abstract

Rapid development of industry has brought to a growing need for installation of single girder bridge cranes and monorail tracks. "I" section has been recognized as the most appropriate one for the main girder. Limitations in their usage can appear due to the loss of lateral stability or occurence of local stress increase under trolley wheels when total stresses go beyond the limit values. The paper considers the references of number of authors for calculating the stress in the zone of wheel and section contact in order to determine its carrying capacity. Comparison was made between obtained and finite element method (FEM) results and experimental researches. On the base of comparison, designers were given the references that can be of great importance for choice of calculation method from the point of determining the maximum stress values of "I" section bottom flange.

Keywords*: I-section, single-girder crane, bottom flange stress, crane runway.*

1. INTRODUCTION

With growth of industry and widening of production capacities there is a greater need for installation of single girder bridge cranes or monorail tracks which serve the production plants. In order to establish this transport system, its static calculation must be done. Static calculation is defined by certain technical regulations. These regulations are not the same in all countries, so a difference appears in the calculation way of single girder bridge cranes and monorail track structures. Common is the fact that bottom flange, upon which trolley runs, is critical for dimensioning the I-section (Figure 1).

In the paper the analysis was done of bottom flange stress of standard INP section with reinforcement and reccomendation was given for its stress determination.

At points below the wheel, the biaxial bending of flange profile appears, so there occurs biaxial stress state that is superimposed with stresses of global loading (Figure 2) [1].

These girders are usually made from various types of I sections with additional reinforcement (Figure 3a) or without it (Figure 3b). The paper considers the case of bottom flange reinforcement (Figure 3a). The aim of the research in this paper is comparative analysis of the results of bottom flange local stresses values obtained using different expressions recommended in literature and regulations. Regardless of its great influence, lateral stability of the bottom flange was not considered in the paper. Lateral stability influence is of special significance if it comes to the cranes of bigger span an capacity.

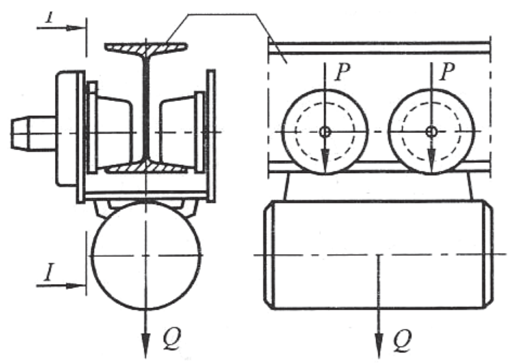


Fig. 1 Wheel-track contact

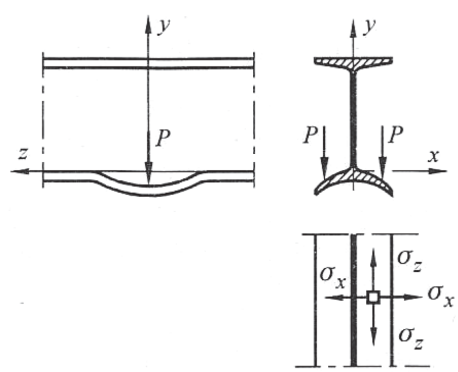
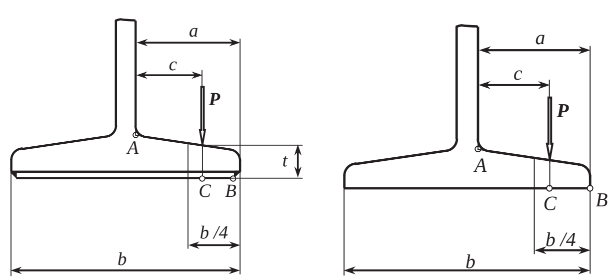


Fig. 2 Biaxial local stresses on flange



a) *b)*

Fig. 3 Review of bottom flange characteristic points

2. RECOMMENDATIONS FOR CALCULATION OF I-SECTION BOTTOM FLANGE

Bottom flange local stresses depend on 3 parameters:

-trolley wheel pressure force (P),

-wheels position related to profile edge (a-c) and

-bottom flange thickness below the wheel (t).

Contact of wheel and flange is near the flange outer edge. In a local perspective, the flange is subjected to bending.

We usually use Mendel's expression for calculating the local stress, according to standard JUS C.B3.131 [1-3]. Bottom flange stresses depend on point location.

Stresses in point "A" read:

$$\sigma_{x,l}^{A} = \pm k_{A,x} \cdot \frac{P}{t^2}$$

$$\sigma_{z,l}^{A} = \pm k_{A,z} \cdot \frac{P}{t^2} \tag{1}$$

$$\sigma_{z}^{A} = \sigma_1 \cdot \frac{y_A}{y_{max}}$$

Stresses in point "C" read:

$$\sigma_{x,l}^{C} = \mp k_{C,x} \cdot \frac{P}{t^2}$$

$$\sigma_{z,l}^{C} = \pm k_{C,z} \cdot \frac{P}{t^2} \tag{2}$$

$$\sigma_{z}^{C} = \sigma_1$$

Stresses in point "B" read:

$$\sigma_{z,l}^{B} = \pm k_{B,z} \cdot \frac{P}{t^2}$$

$$\sigma_{z}^{B} = \sigma_1 \tag{3}$$

Coefficients (by Mendel) given in previous expressions depend on relations of values c and a (Figure 4).

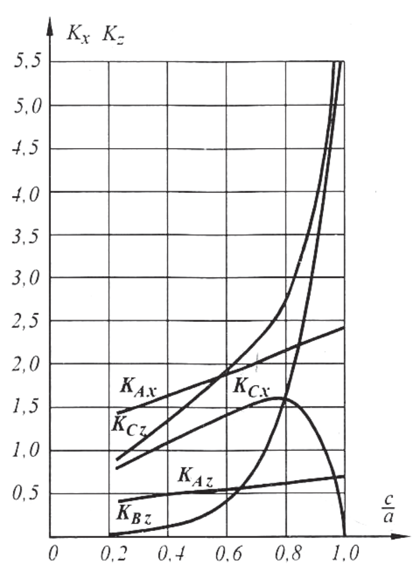


Fig. 4 Bottom flange bending coefficients [2]

Expression that is often used is stress check by swiss recommendations B1[4-5]. By this recommendation bending moment M_x should taken by the section 1-1 which has width *2.2 a* (Figure 5). On base of that we get the expression:

$$\sigma_x = \frac{M_x}{W_x} = \sigma_{z,1} \tag{4}$$

Standard Euronorm EN 1993-6: 2007(E) [6] defines three characteristic sections for calculation (Figure 6).

Characteristic section lines are:

-"0"-line in connection between web and flange plate,

-"1"- wheel loading line,

-"2"-flange outer edge.

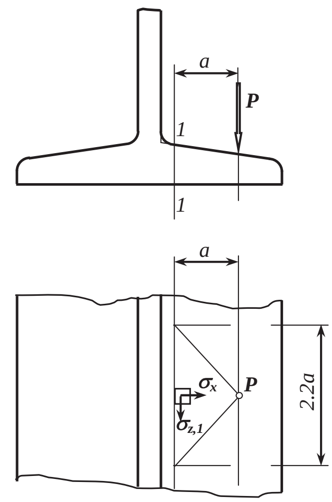


Fig. 5 Characteristic points for calculation [4]

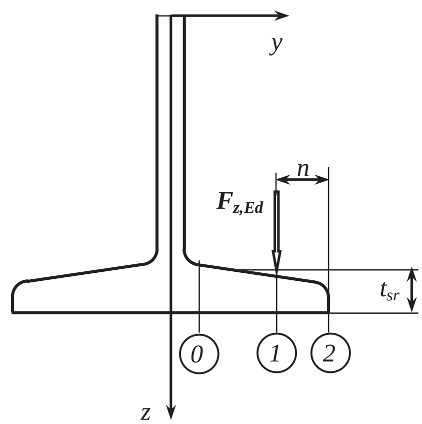


Fig. 6 Characteristic sections for calculation [6]

Calculation method depends on trolley wheels distance. If the trolley wheels distance is not less than *1.5 b* (b-flange width) bending stresses are:

$$-\sigma_{\sigma x,Ed} = c_x \cdot \frac{F_{z,Ed}}{t_1^2} \tag{5}$$

$$-\sigma_{\sigma y,Ed} = c_y \cdot \frac{F_{z,Ed}}{t_1^2} \tag{6}$$

- $\sigma_{\sigma x,Ed}$ - longitudinal bending tension,

- $\sigma_{\sigma y,Ed}$ - transverse bending tension,

- t_1 - belt thickness in section under force.

Coefficients (c_x, c_y) depend on cross section in which the stress is calculated as well as on parameter μ:

$$-\ \mu = \frac{2n}{b - t_w}, \tag{7}$$

- t_w - web thickness.

Abramovič [7] defined the expression which totally matches the recommendations regulated by Euronorm [6], difference is only in marks in the picture. By [7], coefficients (c_x, c_y) can be obtained by reading from diagrams shown in Figure 7, where axis x matches axis y in Fig. 6, and axis z to axis x. Parameter λ matches parameter μ.

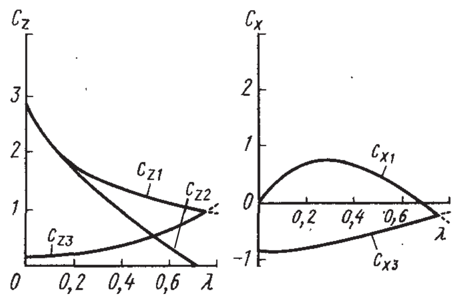


Fig. 7 Diagrams for coefficients determination [7]

When bottom flange is reinforced by a plate of thickness t_2, obtained stresses in previous expressions are corrected by coefficient k which depends on relation of thicknesses t_{sr} and t_2 (Table 1).

Table 1.

t_{sr} / t_2	*0,25*	*0,5*	*1,0*	*2,0 & more*
k	*0,85*	*0,75*	*0,6*	*0,5*

By Alexandrov [8] three points are referential for the calculation. Layout of points matches Mendel's methodology, i.e. the standard JUS C.B3.131 (Figure 8).

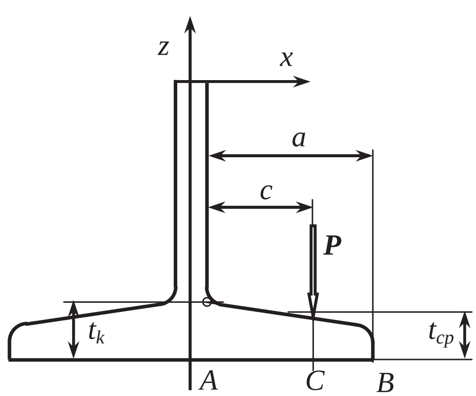


Fig. 8 Characteristic points for calculation [8]

Local bending stresses are:

$$-\ \sigma_x = \pm \frac{k_1 \cdot P}{t_k^2} \text{ - in plane } xy, \tag{8}$$

$$-\ \sigma_y = \pm \frac{k_2 \cdot P}{t_k^2} \text{ - in plane } yz, \tag{9}$$

Sign "+" relates to point "A", and sign "-" to point "C".

Local bending stress at flange end, parallel to plain yz, is:

$$-\ \sigma_{y,cb} = \pm \frac{k_3 \cdot P}{t_{cp}^2}\ . \tag{10}$$

By Ricker [9-10] there are three points that respond to the method shown in [8], where expressions for stress calculation match those given in Euronorm [6].

Besides the local stress increase, a number of authors dealt also with researches of girder lateral stability [11-17].

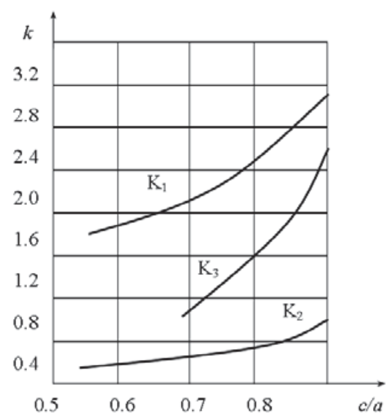


Fig. 9 Diagrams for coefficients determination [9]

3. EXPERIMENTAL STRESSES DETERMININATION

Verification and comparison of obtained results using the previously mentioned recommendations was carried out by experimental examination. Single girder crane that was examined has the following technical characteristics:

-Loading capacity *Q=5 t,*

-Bridge span *L=11,7 m,*

-Longitudinal distance of trolley wheels *b=300 mm,*

-Electric winch type Balkancar T10632.

Girder cross section is shown in Figure 10.

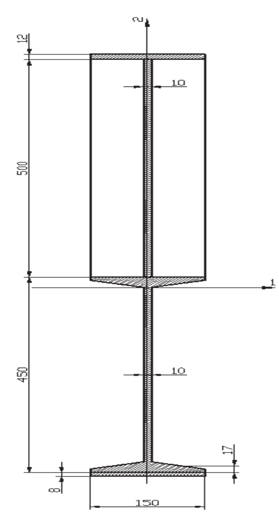


Fig. 10 Girder cross section

Strain gauges layout is shown in Figure 11. In figure 12 the strain gauges positions are shown in relation to the edge of flange. Strain gauges middle line 2-3 matches the middle line of strain gauge 6.

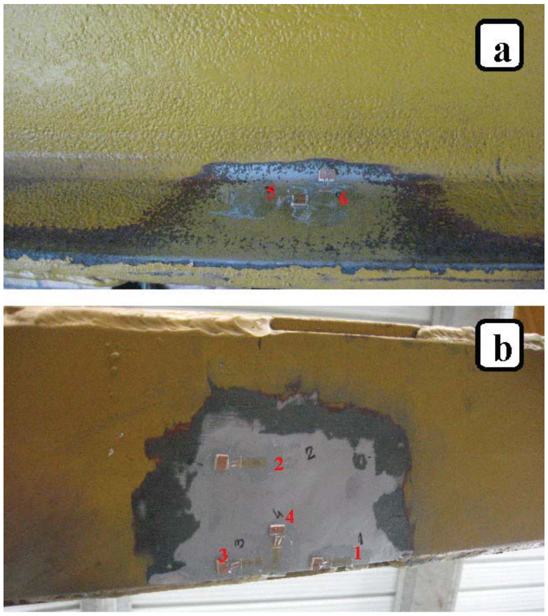


Fig. 11 Strain gauges locations on bottom flange a) inner side b) outer side

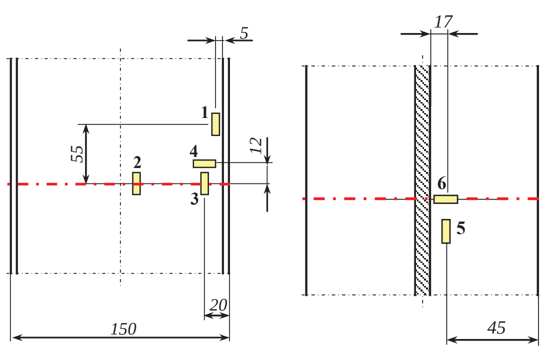


Fig. 12 Strain gauges locations on bottom flange a) inner side b) outer side

Measurings were done for three cases (Figure 12):

-first wheel is distant 150 mm from the line 2-3,

-first wheel is above the line 2-3,

-line 2-3 is between the wheels.

To compare the results with previously mentioned recommendations, the results for the case when the wheel is above the line 2-3 will be analysed in the paper.

At experimental examination there was used the strain guage of following characteristics:

-type LA-22 10/120,

-resistance R=120 Ω ±0.5 %,

-constant K=2.05±1%.

Scheme of measuring equipment chain is shown in Figure 13.

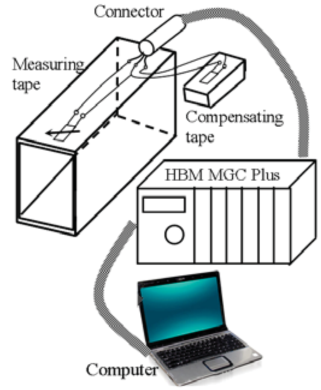


Fig. 13 Scheme of measuring equipment

4. STRESS DETERMINATION USING THE FINITE ELEMENT METHOD

Verification and comparison of obtained results of previously mentioned recommendations was also done by finite element method (FEM). Techical features of single girder crane on which the examination was done are given in section 3. 3D model of single girder crane was formed by synthesis of all structural parts. Model represents a continuum discretized by ten-nodal tetrahedral elements.

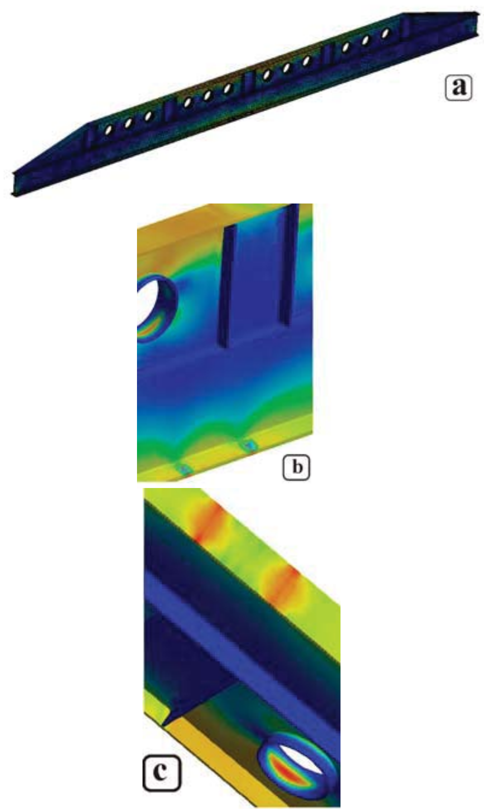


Fig. 14 Stress distribution: a) main girder b) bottom flange – inner side c) bottom flange – outer side

5. COMPARATIVE PRESENTATION OF STRESSES

Evaluation of results obtained using some of recommended expressions can be done by comparing with results obtained by experimental examination and FEM method. Comparison was done for points "C", "A"and "B", and results are shown in tables 2,3&4 respectively. Axis *z* is directed along axis of main girder, while axis *x* is directed transversely to it.

Table 1

Stress in "C" [kN/cm^2]		Force *P (kN)*				
Method		20.7	31.2	42.2	51.7	67.8
FEA	$\sigma_{,z}$	2.9	4.0	5.1	6.4	8.6
	$\sigma_{,x}$	0.4	0.7	0.8	1	1.4
	$\sigma_{,u}$	3.0	4.0	5.3	6.5	8.6
Testing	$\sigma_{,z}$	2.6	3.8	5.2	6.4	8.6
	$\sigma_{,x}$	1.7	2.2	2.8	3.3	4.3
	$\sigma_{,u}$	2.3	3.3	4.5	5.5	7.4
[6]	$\sigma_{,z}$	3.5	5.0	6.7	8.1	10.5
	$\sigma_{,x}$	0.6	0.9	1.1	1.4	1.8
	$\sigma_{,u}$	3.2	4.7	6.2	7.5	9.7
[2]	$\sigma_{,z}$	3.9	5.6	7.3	8.9	11.5
	$\sigma_{,x}$	2.1	2.9	3.8	4.6	5.8
	$\sigma_{,u}$	3.3	4.8	6.4	7.7	10.0
[8]	$\sigma_{,u}$	0	0	0	0	0
[7]	$\sigma_{,z}$	2.2	3.3	4.4	5.3	6.9
	$\sigma_{,x}$	0.5	0.7	0.9	1.0	1.3
	$\sigma_{,u}$	2.0	3.0	4.0	4.9	6.3
[4]	$\sigma_{,u}$	0	0	0	0	0
[9]	$\sigma_{,u}$	0	0	0	0	0

Table 2

Stress in "A" [kN/cm^2]		Force *P (kN)*				
Method		2070	3115	4220	5170	6775
FEA	$\sigma_{,z}$	1.2	1.7	2.2	2.6	3.4
	$\sigma_{,x}$	-1.5	-2.1	-2.7	-3.2	-4.2
	$\sigma_{,u}$	2.3	3.3	4.3	5.0	6.6
Testing	$\sigma_{,z}$	2.0	3.2	4.2	5.1	6.7
	$\sigma_{,x}$	1.2	1.9	2.4	2.9	3.8
	$\sigma_{,u}$	1.7	2.8	3.6	4.4	5.8
[6]	$\sigma_{,z}$	1.6	2.5	3.2	3.9	5.2
	$\sigma_{,x}$	-0.9	-1.3	-1.7	-2.0	-2.6
	$\sigma_{,u}$	2.2	3.3	4.3	5.2	6.9
[2]	$\sigma_{,z}$	1.9	3.0	3.8	4.6	6.2
	$\sigma_{,x}$	2.0	3.0	3.7	4.4	5.9
	$\sigma_{,u}$	2.0	3.0	3.8	4.5	6.1
[8]	$\sigma_{,z}$	1.8	2.8	3.6	4.4	5.9
	$\sigma_{,x}$	1.5	2.1	2.7	3.2	4.2
	$\sigma_{,u}$	1.7	2.5	3.2	3.9	5.2
[7]	$\sigma_{,z}$	1.5	2.4	3.1	3.8	5.1
	$\sigma_{,x}$	-0.5	-0.7	-0.8	-1.0	-1.3
	$\sigma_{,u}$	1.8	2.8	3.6	4.4	5.9
[4]	$\sigma_{,z}$	2.5	3.8	4.8	5.8	7.8
	$\sigma_{,x}$	1.1	1.6	2.0	2.4	3.2
	$\sigma_{,u}$	2.1	3.3	4.2	5.1	6.8
[9]	$\sigma_{,z}$	1.4	2.2	2.8	3.4	4
	$\sigma_{,x}$	2.4	3.5	4.4	5.3	7.0
	$\sigma_{,u}$	2.1	3.1	3.9	4.7	6.2

Table 3

Stress in "B" [kN/cm^2]		Force *P (kN)*				
Method		22.5	30.4	41.1	51.7	67.7
FEA	$\sigma_{,z}$	1.7	2.2	2.8	3.4	4.4
Testing	$\sigma_{,z}$	2.4	3.3	4.6	5.9	7.8
[6]	$\sigma_{,z}$	3.8	4.9	6.5	8.1	10.5
[2]	$\sigma_{,z}$	2.5	3.4	4.5	5.6	7.2
[8]	$\sigma_{,z}$	2.7	3.6	4.7	5.9	7.7
[7]	$\sigma_{,z}$	2.0	2.6	3.5	4.4	5.7
[4]	$\sigma_{,z}$	0	0	0	0	0
[9]	$\sigma_{,z}$	0	0	0	0	0

6. CONCLUSION

Results obtained in this paper can be of great importance at designing single girder bridge cranes but also monorail tracks at which the bottom flange is -"I" profile. Researches have shown the necessity of stress check in characteristic sections which are defined in literature, i.e. in sections "C","B"and "A".

Point "A", beneath the radius that connects web and flange, has the lowest stresses, so the stress analysis in it is of less importance.

Stresses on outer edge of flange under point "A" are higher and should be checked.

For stress determination in point"C", best results gives the methodology defined in [7], while for point "B" methodology defined in [2] and [8].

For stress determination in point "A", the best results are given by methodologies defined in [7] [2]and [9], but also the results obtained by methodologies [8] [4] and [6] do not have big deviations.

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