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THE APPROXIMATION OF THE EQUATION FOR BENDING STIFFNESS OF TRUSS CONSTRUCTION

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Abstract

The bending stiffness of the construction is one of the key factors for stress condition analysis, stability and dynamic behavior. The parameter that directly influences the stiffness of the construction is the cross-section moment of inertia, so its defining is necessary. The way of forming the truss filler is also a parameter that significantly influences the bending stiffness, so the research of its influence is also needed.
This paper shows the simplified model which approximately defines the moment of inertia of truss construction. The most usual ways of truss construction filler forming for different spans are analyzed. The truss construction deflection dependence on the way of filling and span of construction is defined.

Key words: truss construction, moment of inertia

1. INTRODUCTION

By varying the stiffness values you can influence the change of construction parameters, such as: increase of stability, decrease of stress and deformations, unfailing work of mechanism, i.e. machine, provision of wanted functionality.

The moment of inertia is a parameter that directly determines the stiffness. The overhead traveling crane and boom-crane truss constructions consist of a great number of truss rods: horizontal, slope and vertical, so it is complicated to evaluate the moment of inertia of truss construction cross-section because it varies depending on the truss construction cross section position. In the beginning phase of construction design, it is very important to obtain the information about geometrical characteristics of the truss construction elements in order to reduce the calculating procedure.

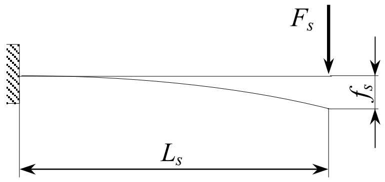
According to the researches [1], [2], [4], the moment of inertia is a sufficient parameter for truss construction stiffness analysis, i.e. the calculation of its deflection.

Except this parameter, it is very important to know the deflection dependence on the construction span and the way of forming the filler (i.e. the angle of the filler elements setting). This dependence enables determining the needed angle of the truss filler declension relating the tolerable deflection of the construction.

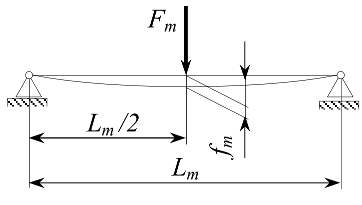
The problem was considered on particular examples of the portal revolving crane boom and the bridge crane, which does not diminish the generality for other types of space truss constructions. The simplified models for defining the dependence between the stiffness and the moment of inertia are shown in figure 1.

The construction greatest deflection values for the girders shown in figure 1 are evaluated as follows:

$$f_s = \frac{F_s \cdot L_s^{3}}{3 \cdot E \cdot I_s} \; ; f_m = \frac{F_m \cdot L_m^{3}}{48 \cdot E \cdot I_m} ; \qquad (1)$$



a)



b)

Figure 1

The forces by which the construction opposes the bending are calculated as follows:

$$F_s = c_s \cdot f_s \; ; \; F_m = c_m \cdot f_m ; \qquad (2)$$

so that the corresponding stiffness are defined by following expressions:

$$c_s = \frac{3 \cdot E \cdot I_s}{L_s^{3}} = K_s \cdot I_s \; ; \; c_m = \frac{48 \cdot E \cdot I_m}{L_m^{3}} = K_m \cdot I_m ; \qquad (3)$$

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2. DEFINING THE SIMPLIFIED EXPRESSION FOR BENDING STIFFNESS EVALUATION

The aim of defining the simplified expression for bending stiffness evaluation is to achieve the truss construction moment of inertia (i.e. stiffness) value in a simple and quick way, so the designer, in as short term as possible, could determine the main parameters of the construction.

The complex space truss construction moment of inertia can be defined by the following expressions [1],[3],[4] (fig. 2):

$$I_x = \sum_{i=1}^{4} \left(I_{\xi i} + A_i \cdot y_i^2 \right) \tag{4}$$

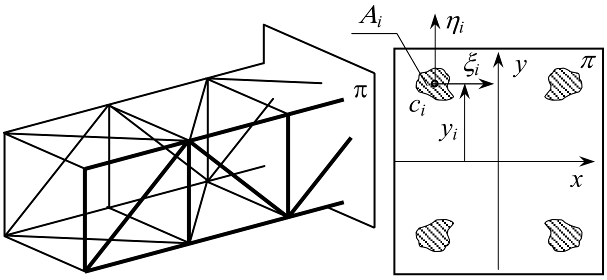


Figure 2

In the previous expression the influence of truss filler was neglected, so for evaluation a relatively simple expression is used. Error that is made by using of such expression for evaluating the moment of inertia (equation 4) can be significantly reduced by proper factors of correction ψ_s and ψ_m so that calculating values of the moment of inertia and bending stiffness are:

$$I_{rs} = I_x \cdot \psi_s \qquad I_{rm} = I_x \cdot \psi_m$$

$$c_s = K_s \cdot \psi_s \cdot I_x \; ; \quad c_m = K_m \cdot \psi_m \cdot I_x \; ; \tag{5}$$

3. DEFINING THE CORRECTION FACTOR VALUES

The correction factor value analysis ψ_s is thoroughly illustrated in [4] so that only some conclusions of analysis will be mentioned here. For analyzed values of stiffness $c_s \in (0{,}7 \div 5{,}4)$ correction factor value is : $\psi_s \in (1{,}03 \div 1{,}1)$ (Table1).

Table 1

stiffness c_s (kNcm)	calculated deflection f_r (cm)	deflection from MKE f_{MKE} (cm)	correction factor ψ_s
0.70	1.43	1.468	0.97
1.01	1.0	1.029	0.97
1.97	0.64	0.668	0.96
1.73	0.58	0.6	0.96
2.53	0.4	0.422	0.95
3.47	0.29	0.301	0.95
3.95	0.25	0.278	0.89
4.8	0.22	0.231	0.95
5.43	0.18	0.198	0.90

This analysis is shown in figure 3.

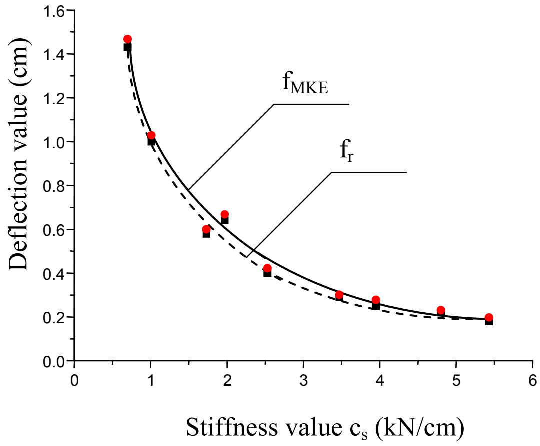
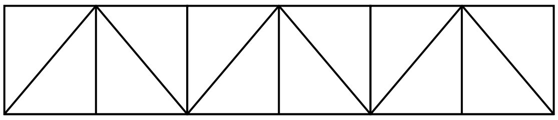


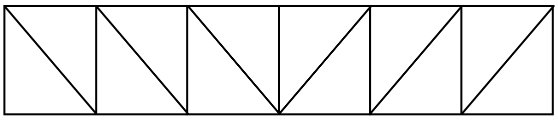
Figure 3

The practiced analysis [4] shows that the value ψ_s does not exceed 1,1 for analyzed boom spans $L \in (20 \div 35)$ m nor the stiffness value exceeds $c_s \in (0{,}3 \div 7)$.

For determining the correction factor value ψ_m the models from figure 4 are used.



a)



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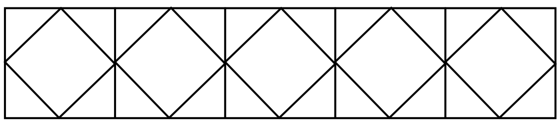

c)

Figure 4

Table 2

L(m)	20	25	30	35
f_{MKE} (mm)	36	46.1	56	66.6
f_r (mm)	44.5	55.8	67.0	78.3
f_{kr} (mm)	37.1	46.5	55.9	65.2
ψ_m	1.2			
Error (%)	3	1	0	2

The results of the analysis for the truss type shown in figure 4a are given in the Table 2. The deflection f_{kr} is obtained by correcting the moment of inertia value (4) i.e. by using the equation (5), where the correction factor is ψ_m = 1,2. The obtained results of deflection, by correcting the moment of inertia values, show a great accuracy for wide range of truss girder span.

Table 3

L(m)	20	25	30	35
f_{MKE} (mm)	42.5	54.5	66.3	78.8
f_r (mm)	44.5	55.8	67.0	78.3
f_{kr} (mm)	43.2	54.1	65.1	76.0
ψ_m	1.03			
Error (%)	2	1	2	4

The results of truss type analysis shown in figure 4b are given in table 3. The deflection f_{kr} is obtained by using the equation (5), where the correction factor ψ_m =1,3. The deflection results obtained by correcting the moment of inertia values show a great accuracy so one can even tell that for this type the correction is not necessary.

Table 4

L(m)	20	25	30	35
f_{MKE} (mm)	33	42.5	51.9	62.2
f_r (mm)	44.5	55.8	67.0	78.3
f_{kr} (mm)	34.2	42.9	51.6	60.2
ψ_m	1.3			
Error (%)	4	1	1	3

The table 4 gives the results of truss type analysis shown in figure 4c. In this case, as well, the deflection f_{kr} is obtained by using the equation (5), where the correction factor is ψ_m =1,3. The evaluated deflection results, by correcting the moment of inertia values, overlap in a great degree with the results of practiced finite element analysis.

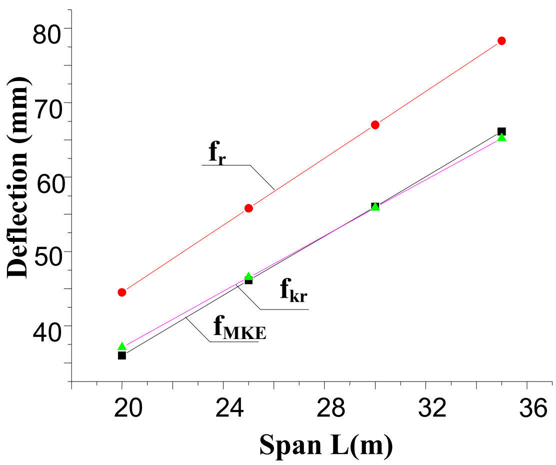

Figure 5

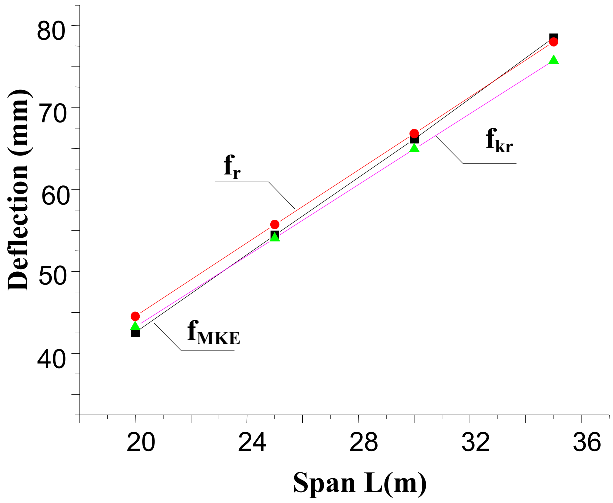

Figure 6

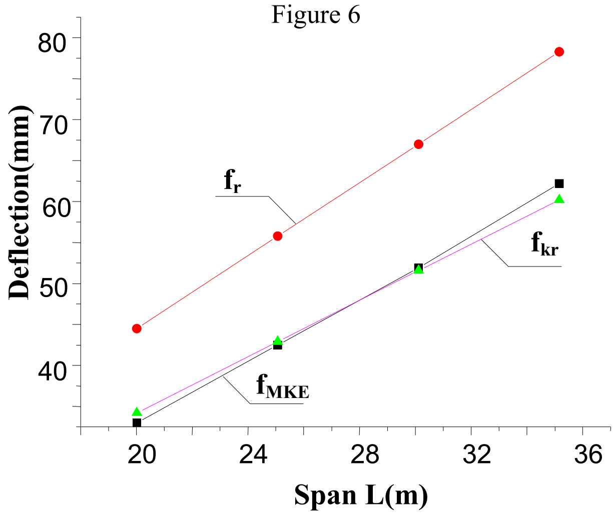

Figure 7

Figures 5,6 and 7 depict comparative values of maximum truss construction deflection. Figure 5,6 and 7 show the results of the construction type shown in figure 4a, 4b and 4c respectively. The deviations for other truss construction types [5] do not exceed the limits shown in tables 2,3 and 4.

In reference [1] the recommended correction factor value is $\mu \in (1,15 \div 1,4)$, but it is not more precisely defined for the construction type and span.

Also, it is important to consider the influence of the way the trusses are filled on their stiffness. The considerations are done for the diagonal angle toward the horizontal line $\alpha \in (30 \div 60)$ and the spans L=20;25;30;35 m, where the truss heights are equal. In figures 8÷11 we can see the influence of the way the truss is filled on its stiffness. Also, we can establish the relation between truss construction deflection and the way of filling the truss in relation to the filling angle, equation (6).

$$f = k_1 \cdot 2 \cdot L \cdot e^{\frac{-\alpha}{5 \cdot L}} \quad (6)$$

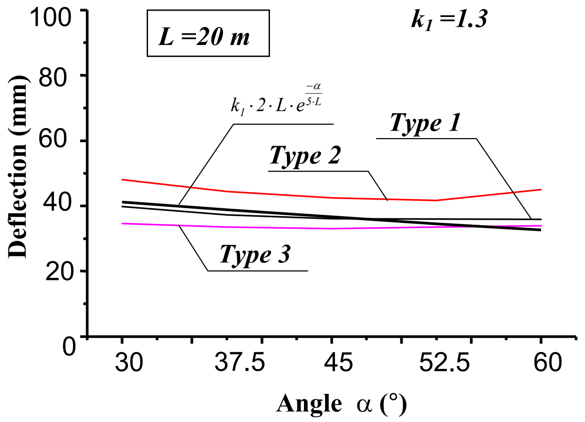

Figure 8

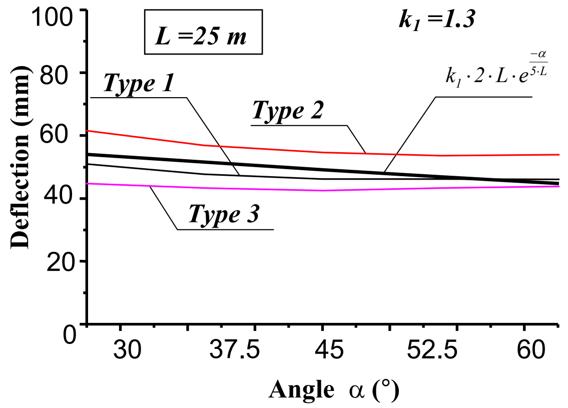

Figure 9

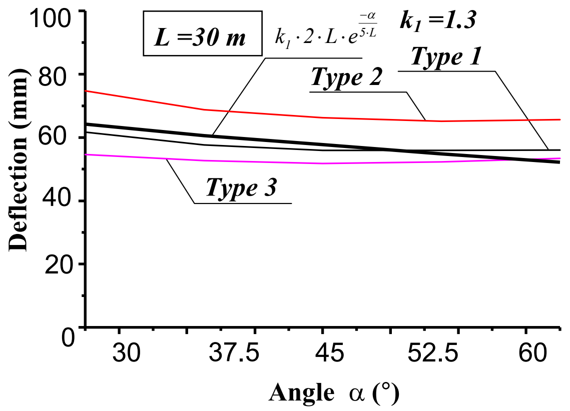

Figure 10

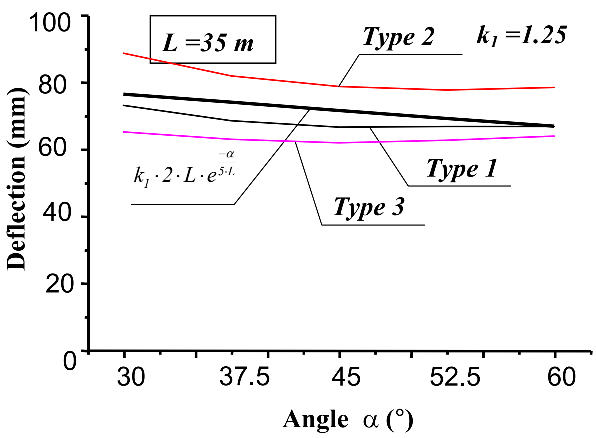

Figure 11

The analysis was also done for truss construction boom [5] where dependance between deformation and the way of filling the truss is established by following relation:

$$f_k = \left(\frac{L}{L_k}\right) \cdot \frac{k_1 \cdot L}{e^{m \cdot \alpha}} \qquad (7)$$

where L_k – the distance between the revolving pillar and the location where the boom is connected with the brace. Approximation practiced by the equation (7) gives a great accuracy [5], which can be noticed in the case of crane reach of L=14m (figure 12).

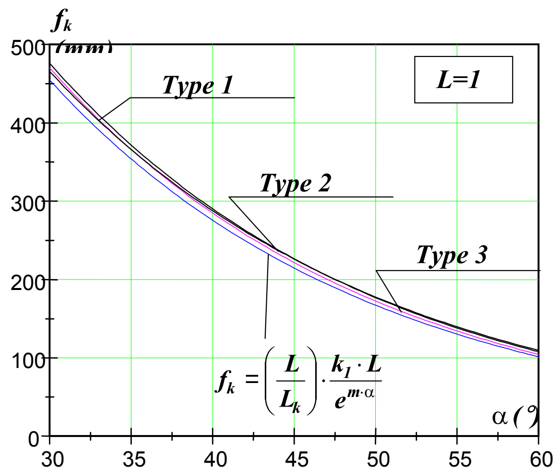

Figure 12

4. CONLUSION

Performed expression for the bending stiffness enables its relatively simple calculation. This approximation allows the designer to relatively quickly define the basic parameters of the construction with the smallest possible deviation in deformation and stress analyses.

The defined construction stiffness correction factors give a great accuracy in calculating and include the basic geometric parameters of construction.

5. LITERATURE

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