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# Analytical Calculation And FEM Analysis Main Girder Double Girder Bridge Crane

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***Abstract*** **– The cranes are now not replaceable mode of transport of materials and finished products both in production halls and in the open space. This paper made the whole analytical calculation of double girder bridge cranes to be used in laboratories exclusively for testing, determined by the maximum bending stress and deflection of the main girder. After calculating the dimensions, we created a model cranes in software CATIA V5. The same model was subjected to FEM analysis of the same name software.**

**At the end of the paper comparison has been done.**

**The objective of the calculation and analysis of the model was to develop a model crane and to serve for the next tests. Dimensions of the crane are given according to the laboratory where it will be located.**

***Keywords*** **– Bridge crane, bending stress, deflection, finite element method.**

## 1. Introduction

Bridge cranes are used for handling in large workshops or storage. Usually working under the roof, and if necessary in the open. They move by two parallel rails placed along the length of the hall or storage on pillars or consoles. [5]

The main parts are, bridge and the driving winch, which moves along the of the bridge. The movement of cranes (of the bridge) on the rails and the driving winch (carts) across the bridge to transport from one place to another within the working range of the crane. Bridge crane with two main carriers, at previously explained, consists of a of the bridge A and the driving winches B (Figure 1). [1]

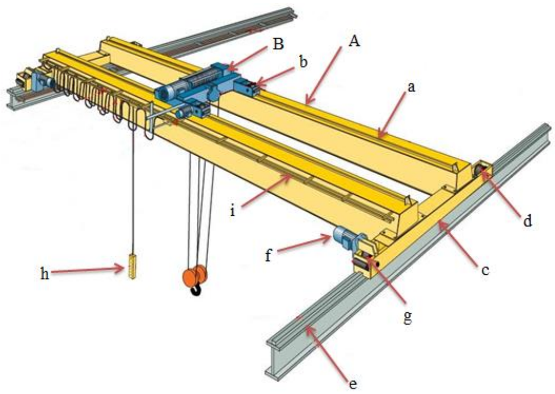


*Figure 1. Double girder bridge crane*

The bridge is a steel structure made up of two main carriers, which are placed along the rail (a) for the movement of the wheels (b) the driving winches. The ends of the main bearing are firmly are tied to the transverse carriers (c) where they placed wheels of the bridge (d) which are moving on rails placed on carriers of the crane trails (s). The drive of the bridge is achieved by direct connection of the engine and gearbox (f) with the drive wheels (g). Control of all crane movements is done by steering (h), shown in Figure 1.

In this paper we observed the double girder bridge crane with a span of the bridge of 2m and the I cross-section of the main girder.

## 2. Analytical calculation

Analytical calculation and adopting a I profiles IPE 80 to the profile that will be used for major carriers, and solving simple static problems, Figure 2, [1], [2]

$$\frac{M_{s\max}}{W_y} \leq \sigma_{doz} \tag{2.1}$$

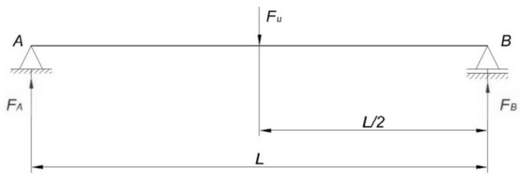


*Figure 2. The problem presented as a static designed*

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where:

$\sigma_{max}$ [MPa] – maximum bending stress,

$W_y$ – resistant moment of inertia (long-axis) of I profile,

$M_{smax}$ – maximum bending moment.

we have come to bearing capacity profile of 6,4 kN.

Checking carrier IPE 80 to lateral torsional buckling over expression:

$$\sigma_{max} \le \frac{\sigma_D}{\upsilon} = \alpha_p \cdot \chi_D \cdot \frac{\sigma_v}{\upsilon} \quad (2.2)$$

where:

$\sigma_{max}$ [MPa] – maximum bending stress,

$\sigma_D$ [MPa] –marinal stress of torsional buckling,

$\upsilon$ = 1,5 – degree of safety,

$\alpha_p$ - coefficient of cross-sectional shapes,

$\chi_D$ - nondimensional coefficient of lateral torsional buckling.

A this calculation we have less capacity profiles IPE 80 which amounts to 4.8 kN.
Because the purpose crane was taken to its load capacity of 2452,5 N (250 kg).

## 3. Dimensioning of carts winch

As noted in the previous section it is established that the load capacity cranes are to be 250 kg, on the basis of which we dimension the carts winch. Their design is simple, consisting of four carriers, two of which (carriers 1 and 2) are used to enable the movement of carts (installation of wheels), and the other two (carriers 3 and 4) to carry only winch.

Figure 3 shows the basic design of carts winches.

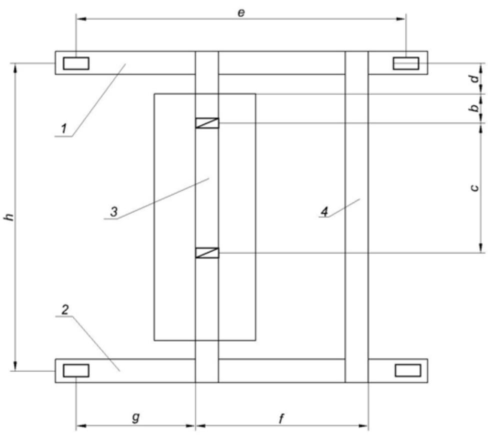



*Figure 3 Carts winch*

Based on figure 3 we started to a structural analysis of the problem, which is determined by a cross-section of each carrier, and adopted the optimum corresponding to all carriers. The first step was to calculate carrier 3 because it is directly connected to the winch and load winch lifted, setting simple static problem, shown in figure 4. We can reach the dimensions of the cross section (because construction carts will work with square pipes and material Č.0361). The dimension *h* corresponds to the range of the bridge, which was adopted in part 2.

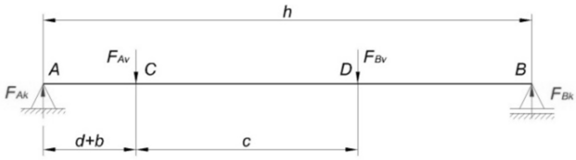



*Figure 4 carrier winch as beams with two supports and two forces*

By setting static equation for the problem in Figure 4. we have,

$$\sum M_B = 0 \quad (3.1)$$
$$F_{Ak} \cdot h - F_{Av} \cdot [h-(d+b)] - F_{Bv} \cdot [h-(d+b+c)] = 0$$

The second equation would be that the sum of the vertical force equals zero,

$$F_{Ak} - F_{Av} - F_{Bv} + F_{Bk} = 0 \quad (3.2)$$

From the two previous equations we determined the reaction in supports A and B. On the basis of a reaction and the expression for the allowed stress,

$$\sigma_s = \frac{M_{s\max}}{W_y} \le \sigma_{doz} \quad (3.3)$$

where,

$\sigma_s$ [MPa] – bending stress

$M_{s\max}$ – maximum bending moment,

$W_y$ [$cm^3$] – resistant moment of inertia,

$\sigma_{doz}$ [MPa] – allowable stress for the selected material (16 kN/$cm^2$).

From equation (3.3) we calculated value resistant moment of inertia, and based on these values adopted a square tube dimensions 40x40x2. For other carriers (1,2 and 4) we have made the same calculation. Also for all the carriers where adopted the same cross-sectional dimension pipes.

After dimensioning trolley winches, by Andrea method [3] determining the pressures on the same wheels are designed for a specific trolley winch shown in Figure 5.

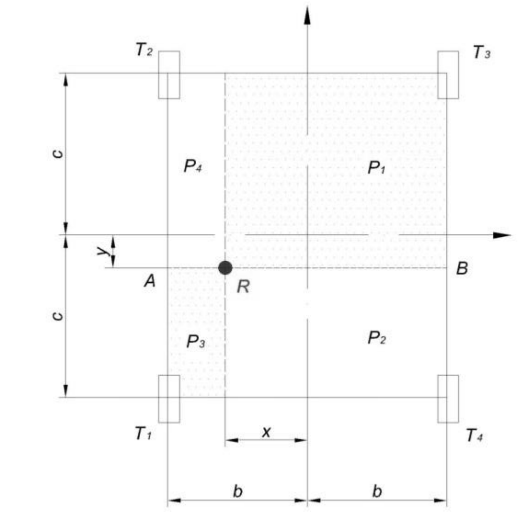



*Figure 5 Determination of pressure in the wheels trolley winch*

The resultant force R corresponding to the maximum load capacity of the winch and it is 2452.5 N.

The pressure at the trolley winch can be calculated at any point by the expression,

$$T_i' = \frac{R}{4bc} P_i, \qquad i = 1,...,4 \tag{3.4}$$

where is,

$$P_1 = (b - x)(c - y) \qquad P_3 = (b + x)(c + y)$$

$$P_2 = (b - x)(c + y) \qquad P_4 = (b + x)(c - y)$$

If we introduce the known values we will get pressures on wheels 1,2,3 and 4, and they amount to,

$$T_1 = 1080,2\,\text{N} \qquad T_4 = 319,5\,\text{N}$$

$$T_2 = 821,6\,\text{N} \qquad T_3 = 243,4\,\text{N}$$

Using force to wheels 1 and 2 we will check the main carrier (check stress and deflection).

As the wheels 1 and 2 are in direct contact with one main carrier crane which in this case is more burdened than the other carrier, forces from the wheels are transferred directly to the carrier, as shown in Figure 6.

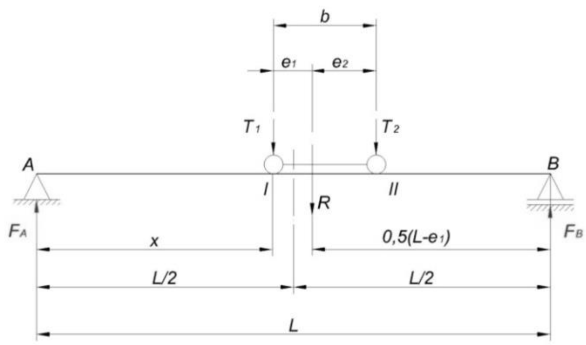



*Figure 6 The carrier burdened with forces of the wheels 1 and 2*

By setting up a simple static of the equilibrium conditions we will come to the value of reactions in supports for the main carrier. Then, over expression 3.3 we will determine the value of bending stress carrier in section I, and it is,

$$\sigma_{sI} = 39{,}58\,\text{MPa} < 160\,\text{MPa}$$

Here we also check the deflection over expression,

$$f = \frac{F}{3} \cdot \frac{l^3}{E \cdot I_y} \cdot \left(\frac{a}{l}\right)^2 \cdot \left(\frac{b}{l}\right)^2 \leq \frac{1}{750} \cdot L \tag{3.5}$$

Where,

- $F = T_1$ = 1080,2 N – force from wheel $T_1$ ,
- $L$ = 2 m – length of carrier,
- $a_1 = x = 0{,}5(L - e_1)$= 0,913 m,
- $b_1 = l - a_1$ =2 – 0,913 = 1,087 m,
- $E$ = 210 GPa – modulus of elasticity for steel,
- $I_y$ = 80 cm$^4$ – moment of inertia of the axis y.

And deflection amounted,

$$f = 1{,}72\,\text{mm} \quad < \quad \frac{1}{750} \cdot 2000 = 2{,}66\,\text{mm}$$

## 4. The formation of the geometric models and FEM analysis

The geometric model was created based on the dimensions obtained analytically and depended on the purposes of their own cranes, Figure 7, [8], [9], [10].

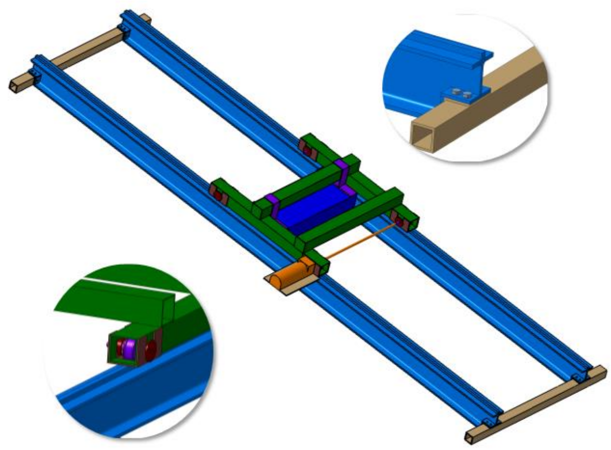


*Figure 7. The geometric model cranes*

After the formation of the model it is started with FEM analysis in software CATIA V5, [4], [6], [7], [11] , [12]. Figure 8 shows the model for analysis with defined mesh of finite elements, constraints and loads.

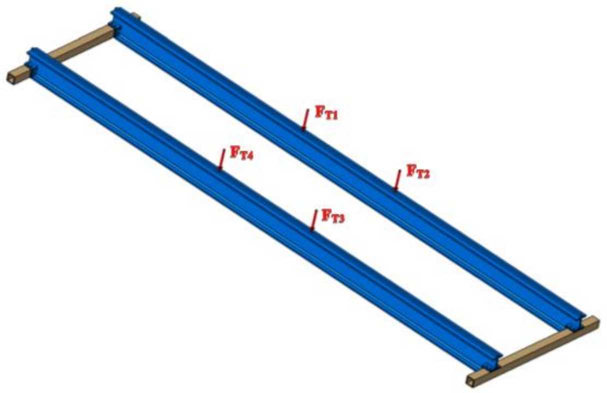
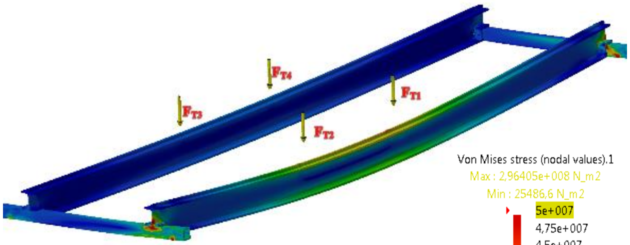


*Figure 8 Model for FEM analysis*

After calculation the obtained results are shown in Figure 9.



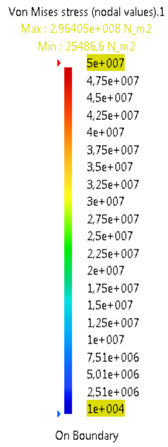



*Figure 9 Results stress after FEM analysis*

The value of stress at the point 1 amounts,

$$\sigma_{sI} = 32{,}8\,\text{MPa}$$

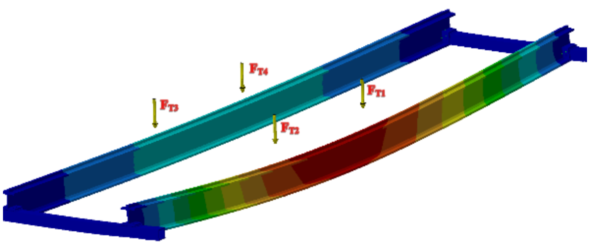
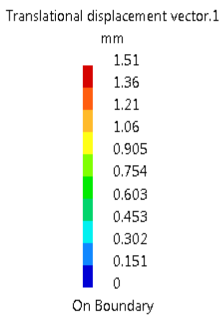


*Figure 10 Results displacement after FEM analysis*




The value of deflection (displacement), Figure 10 is the center of the girder,

$$f = 1{,}51\,\text{mm}$$

## 5. Results

Analytics has given results that are related to the ideal state, while the FEM analysis yielded results that were affected by many factors, the type of load, assigning limits to the ways of relying alone carrier.

The difference in the results for the case when it calculates stress through analytical and FEM analysis is 17.1%, while the deflection is slightly smaller difference of 12.2%.

## 6. Conclusion

In this paper was made a calculation and design of the basic structure of the model bridge cranes. Calculated are the main girders, side girders and trolley winch. When designing a model crane taking care of the area in which the crane works, taking account of these limitations is dimensioned length of the bridge crane and the range of the bridge. All checks of the main and side girders are met.

The second step was to model the crane in the software CATIA V5 which was done. Modeling is primarily done for the sake of the necessary models in numerical analysis, which is also made in this software, as well as for better visual presentation cranes.

The following numerical analysis of 3D finite element in the software CATIA V5 was made, which has not yielded good results. In numerical analysis, special attention is focused on the most loaded main carrier model cranes.

After these checks, a physical model of the crane was made, which is located in the laboratory and will be used exclusively for the next tests.

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