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The Structural Analysis of the Classic Constructive Solution of a Bridge Deck with a Railroad – Part I

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This paper presents the structural analysis of a classic constructive variant of a bridge deck with a railroad, designed in accordance with SR 1911. The analysis was done using the SolidWorks Simulation software and focused only on the deck, without taking the pillars into consideration. The deck was loaded with the weight equivalent of a railroad car. A study of static analysis was conducted after the 3D structure of the deck was generated, in order to determine the distribution of tension and distortion on the deck elements, the areas with the greatest tension and distortion and solutions to minimize them.

Keywords: *bridge, deck, structural analysis, SolidWorks*

1. Introduction.

The object of the paper is the deck of a railway bridge.

The welded structures of metal bridges with a span ≤ 50 m have a structure consisting of a network of lonjerons (placed on the length of the deck) and struts (placed on the width of the deck) [1].

In the original design, the struts have a larger section than the lonjerons, the longitudinal stress being taken, through the struts, by the two marginal beams of the bridge [1], resulting in a heavy, oversized metallic structure.

The over-dimensioning of the structure is also conditioned by the welded joints between the lonjerons, struts and beams.

In the calculation of welded joints, the fact that operating forces generate combined stresses in welded joints is taken into account, making it necessary to determine equivalent stresses with a tolerance of 70 ÷ 80% of the resistance of the base metal [2].

From the analysis of the original constructive design of the deck, whose geometry is presented in Figure 1 and Figure 4, the following results arise:

- the deck dimensions: L x l = 23017 x 5066 mm;
- the number of the lonjerons = 6;

• the number of the struts = 10;

• the welded structure of the deck is made by welding the segments of the lonjeron with equal lengths (2522 mm) with central struts and of the lonjeron segments with variable lengths (1843 ÷ 3200 mm) with the marginal struts, resulting in a large number of welds placed in the area of the maximum moment of the deck.

The purpose of the paper is to analyze the structural design of the metallic railway deck using the SolidWorks program.

For an easy identification of further solutions for improvement of the original, constructive - technological design of the bridge, the lateral pillars of the bridge are excluded from the structural analysis, this being done only on the deck released from the joints with the beams.

Also, for the same purpose, the structure is considered to be a continuous one, excluding the welded joints between the struts and the lonjerons.

The calculation of the stresses and deformations in the elements of the metal structure of the deck is carried out.

The structural analysis has the following objectives:

• creating the 3D geometry of the original deck design, identified as **variant 1**;

• the structural analysis of the **variant 1** geometry, which aimed to determine the stresses and deformations on the deck.

2. The initial conditions.

The conditions of analysis were as follows:

- the analysis was carried out only on the deck structure (lonjerons and struts and sleepers), without taking the ribs, reinforcements, welds and the lateral pillars of the bridge into account, Figure 1;
- the load applied to the deck was equal to the weight of a wagon weighing 25 tons = 25000 Kg, corresponding to a force of 250000 N;
- the deck was fixed on four disk-shaped supports, with a diameter and height of 50 mm, placed on the marginal struts along the lonjerons direction, Figure 5;
- for the **variant 1** geometry, two I HEM profiles were used: profile I HEM 160 h1 180 x b1 166, for lonjerons, Figure 2, profile I HEM 320 h1 359 x b1 309, for struts, Figure 3;

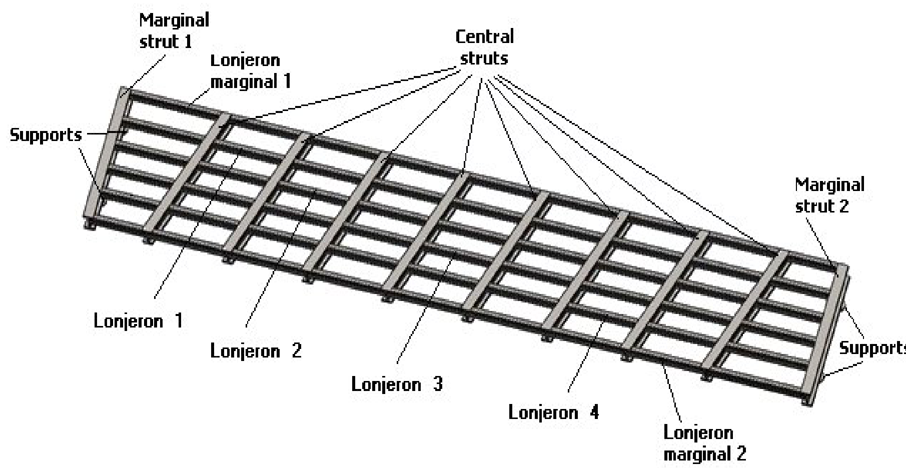

Figure 1. The 3D Geometry of the deck **variant 1**

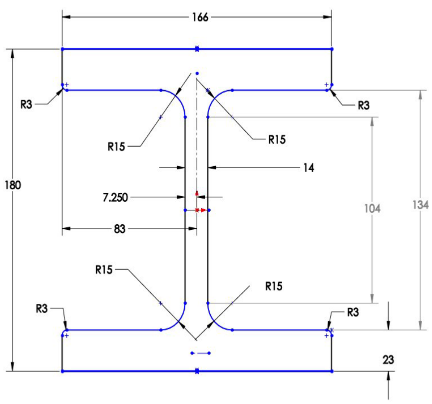

Figure 2. Profile I HEM 160 h1=180 x b1=166.

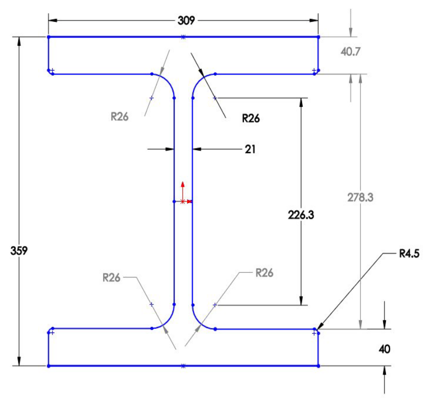

Figure 3. Profile I HEM 320 h1=359 x b1=309.

3. The geometry of variant 1.

The geometry of **variant 1**, Figure 4, is designed in the following configuration: the profiles I HEM 320 h1 359 x b1 309 are assigned to the struts and the profiles I HEM 160 h1 180 x b1 166 are assigned to the lonjerons.

The mass properties of **variant 1** are shown in Table 1.

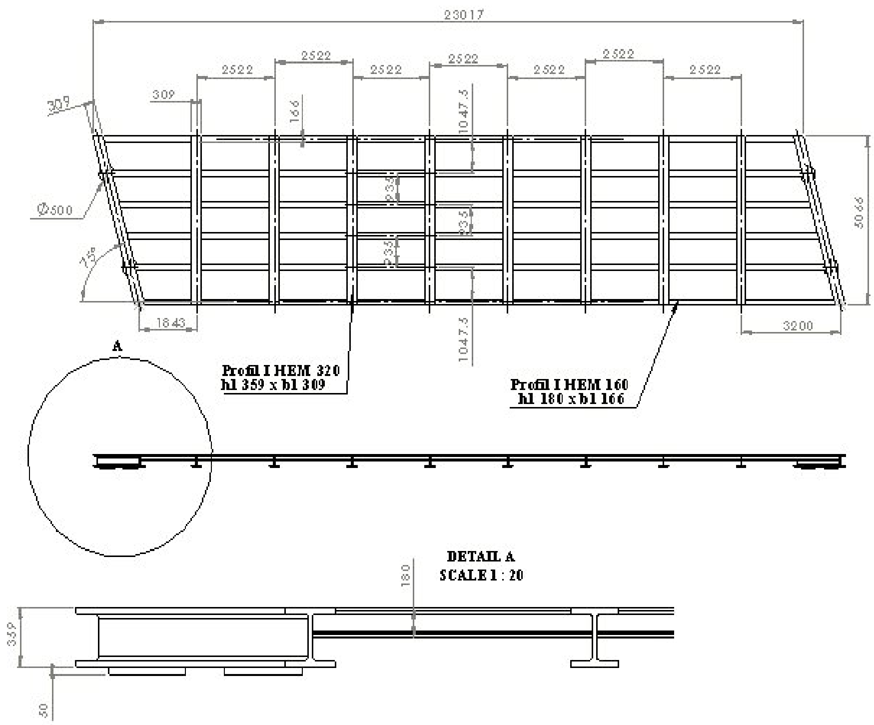

Figure 4. The geometry of the **variant 1**.

Table 1

Property	Values	Units
Mass	22726872 / 22,7	grams / tons
Volume	2887785569	cubic millimeters
Surface area	222901407	square millimeters
Center of mass	X=12005.87 ; Y=34.29 ; Z=2450.02	millimeters

4. The structural analysis of variant 1.

The geometry of **variant 1**, was loaded on lonjerons no. 1 and 4, made from profile I HEM 160 h1 180 x b1 166, on each of the 18 elements corresponding to the lonjerons a force of 13889 N was applied, which multiplied 18 times generates a total prescribed force of 250000 N. The discretization was made with beam elements for profiles and solid types for supports, Figure 6.

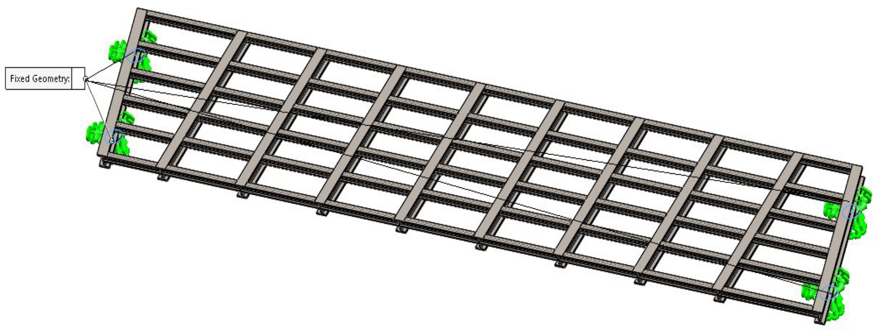

Figure 5. The fixed geometry of the **variant 1**.

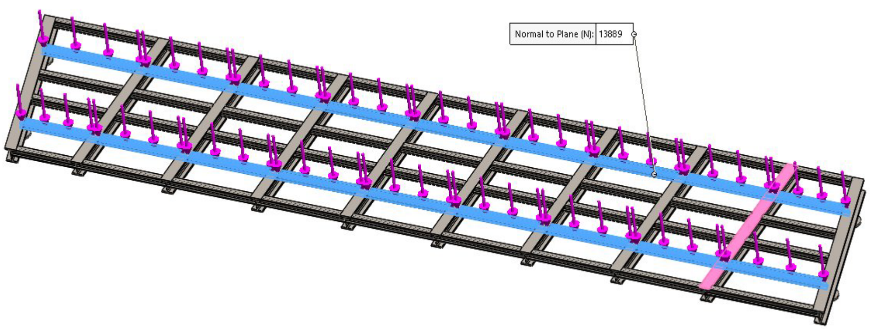

Figure 6. The loads applied to the **variant 1**.

The results are presented as the distribution of maximum stress and displacement. Maximum stress is the highest stress on the extreme fibers of the cross-section, the value of which results from the combination of axial tension with the two bending stresses on the two characteristic directions of the profile section.

Figure 7 shows the distribution of stresses on the struts, which demonstrates that the stress on them is very small, not exceeding 6 MPa. The maximum tension resulted in the area of the four supports, with a value of 313,482 MPa.

Figure 8, respectively, the graph in Figure 9, shows the stress distribution on lonjerons, measured at the middle of each segment. The two figures show that the tensions vary along the length of the lonjerons, with a maximum of about 120 MPa in their central area, the maximum values recorded at 313,482 MPa being due to the stress concentration on the supports.

The maximum displacement was recorded in the middle of the deck, with a value of 187.7 mm, Figure 10.

These values show that maximum stress is obtained on lonjerons, while the struts stress values are small.

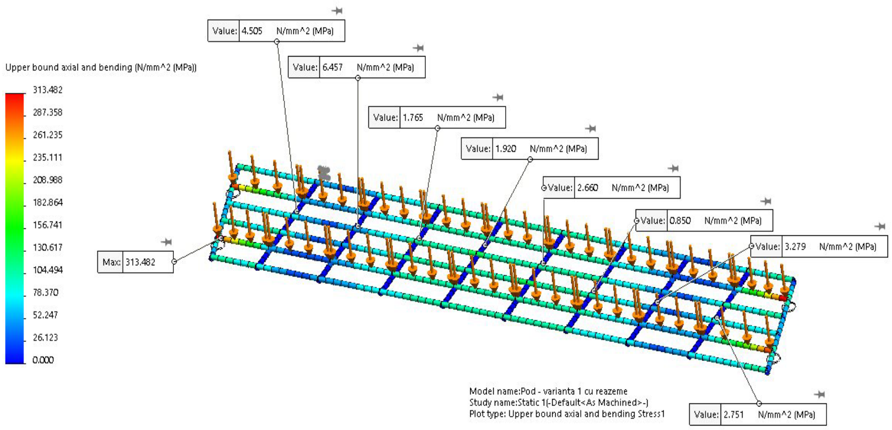

Figure 7. The upper bound axial and bending distribution on the struts for the **variant 1**.

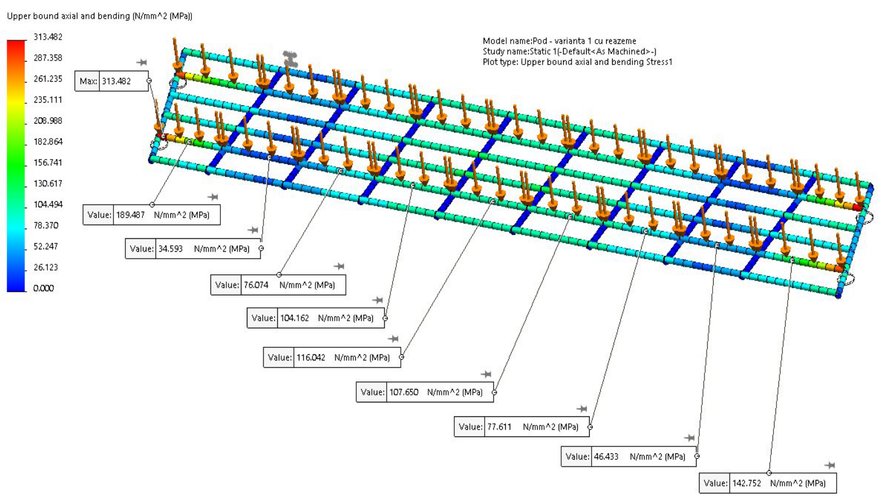

Figure 8. The upper bound axial and bending distribution on the lonjerons for the **variant 1**.

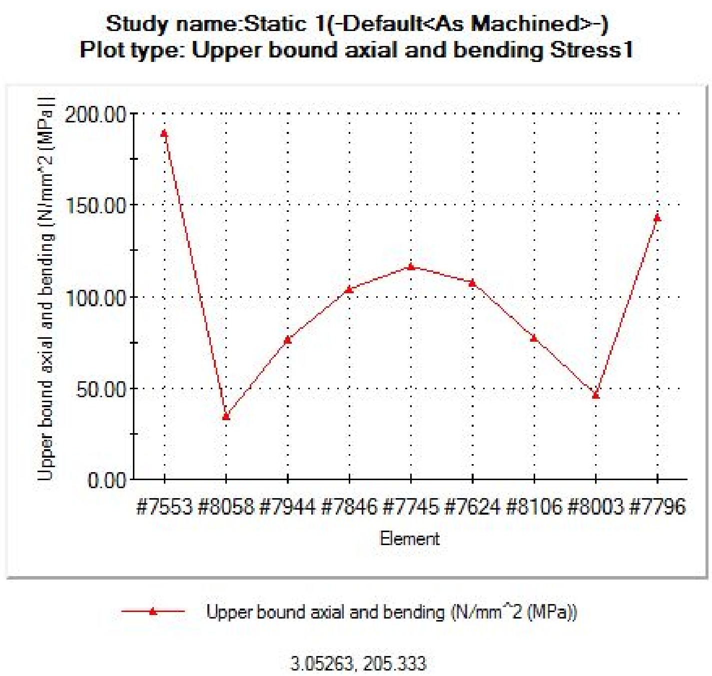

Figure 9. The upper bound axial and bending distribution along the lonjerons for the **variant 1**.

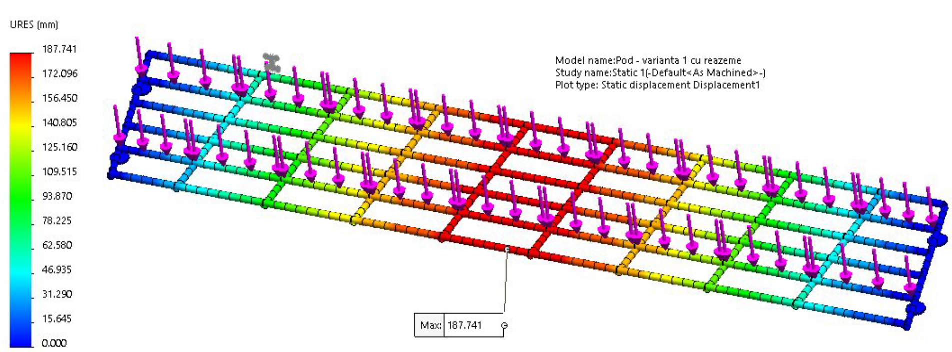

Figure 10. The displacement distribution for **variant 1**.

4. Conclusions.

The structural analysis of stresses and deformations in the metallic deck elements, in the original design, without connections to the marginal beams of the bridge, taking into account the material properties of the components made of steel S 355 (Elastic Modulus = $2.05 \cdot 10^{11}$ N / m2, Poisson's Ratio = 0.29, Yield Strength = 350 MPa) highlights the following conclusions:

• the maximum stress of 313,482 MPa (near to the Yield Strength limit of the material) is placed at the supports and is due to the concentration of stresses, which can be ignored in the analysis;

• the stress distribution on the struts (not exceeding 6 MPa) revealed that those are not loaded, because they are oversized;

• the stress distribution on lonjerons (with a maximum of about 120 MPa) highlights that they are loaded, with the main stress being recorded on the length of the deck rather than on its width;

• the maximum displacement was recorded at the middle of the deck, having a value of 187.7 mm, indicating that the lonjerons are undersized.

• this constructive solution presents the disadvantage of a large number of welds placed in the maximum momentum area of the deck.

Because of the last reason, in part II of the paper, a new geometry is proposed and analyzed in structural terms (with the enlarged section of the lonjerons and the reduced section of the struts) [3].

References

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