THE VALIDATION OF AN ANALYTICAL MODEL FOR STRENGTH CALCULUS OF HIPERSTATIC STRUCTURES USING STRAIN GAUGE MEASUREMENTS

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Abstract: In this paper, it is presented an experimental model, based on strain gauges measurements, used to validate an analytical model for strength calculus of three dimensional hiperstatic structures under static loadings. There will be presented all the experimental apparatus used, and in the end, a particular case will be used in order to estimate the errors between the experimental and analytical model.

Keywords: hiperstatic structures, mechanical strength, mechanical stress, strain gauge, data acquisition

1. INTRODUCTION

Many metallic structures, that are designed to sustain different loadings, used in practical engineering are hiperstatic (the unknown parameters given by the reaction forces and closed contours are higher than the equilibrium equations written for a three dimensional body). In order to make a complete strength analysis of a metallic structure, there must be used three methods: analytical, experimental and finite element analysis.

In this paper it is presented an experimental model, based on strain gauges measurements, used for validation of an analytical model for strength calculus of hiperstatic structures under static loadings. This analytical model was presented in [1]. Other analytical methods for statically undetermined structures were also presented in [2] and [3], but no experimental validations were made. The structure's geometry is presented in Figure 1 and Figure 2.

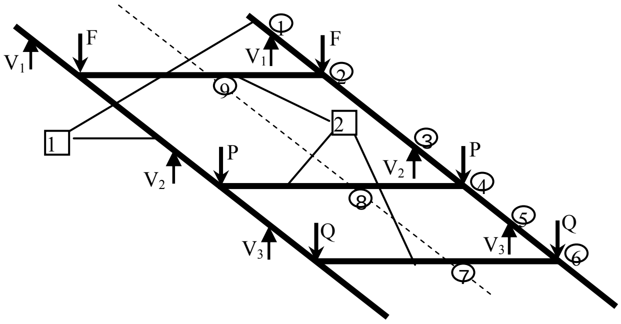

Fig. 1.The geometry and loading scheme of the metallic structure [1]: 1 - longitudinal beams; 2 - transversal beams.

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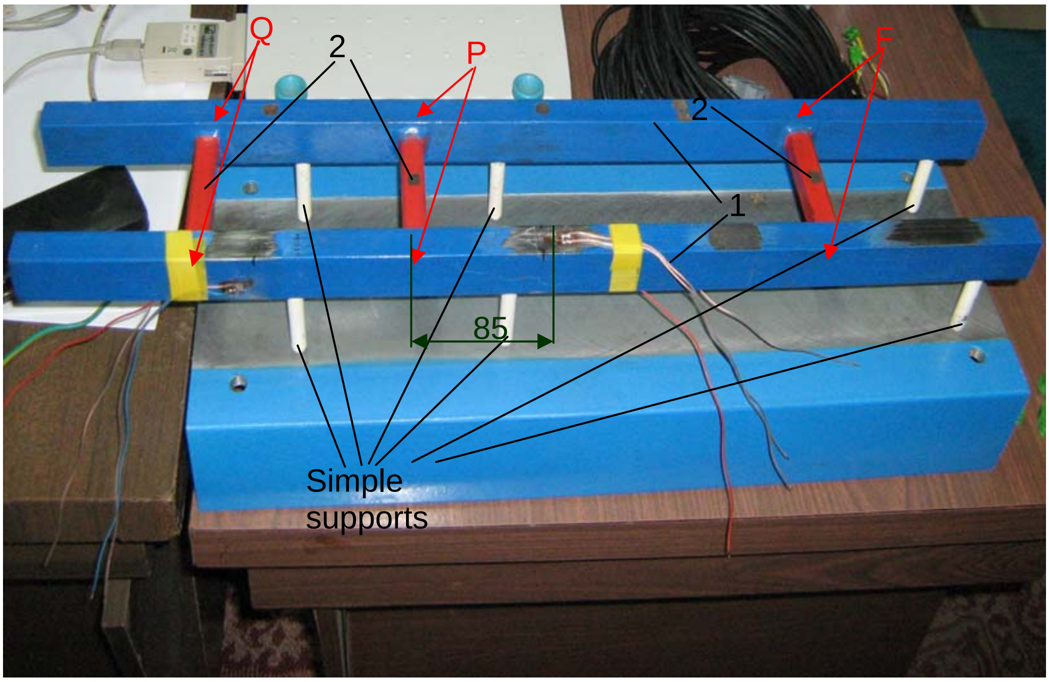

Fig. 2.The general view of the studied metallic structure:
1 - longitudinal beams; 2 - transversal beams.

2. THE EXPERIMENTAL MONTAGE

2.1. Strain gauge installation

The measurements system is SPIDER 8, made by HOTTINGER BALDWIN MESSTECHNIK (HBM) from Germany presented in Figure 3. It was connected directly to a notebook through an USB port.

Fig. 3. The general view of the measurements system SPIDER 8.

The software, that makes the connection between SPIDER 8 and the notebook, used for real time measurements recording is called CATMAN EASY presented in Figure 3.

2.2. Strain gauge bonding. Measurement areas presentation. The experimental montage.

HBM strain gauges have been used for the measurements and were glued by the structure using Z70. Two experimental half bridges have been created and presented in Figure 4 and 5. The first half bridge has two active strain gauges (the stress obtained is twice bigger than the normal result) and the second half bridge has an active strain gauge and the second strain gauge is for thermal compensation. Analyzing the Figures 4, 5 and 6 we can observe that the strain gauges are bonded on the 3 - 2 and 6 - 5 gaps. The experimental montage has been made using the indications from [4] and [5] regarding this kind of measurements.

2.3. The loading schemes

After completing the experimental montage, the next step is to statically load the structure and data acquisition with the used measurements system. The metallic structure is loaded with weights considering two variants: - variant 1 - the force F is 50 N and P = Q = 0; variant 2 – the force P = 50 N and F = Q = 0. There have been obtained the strain curves from Figures 7 and 8 measured in μm/m.

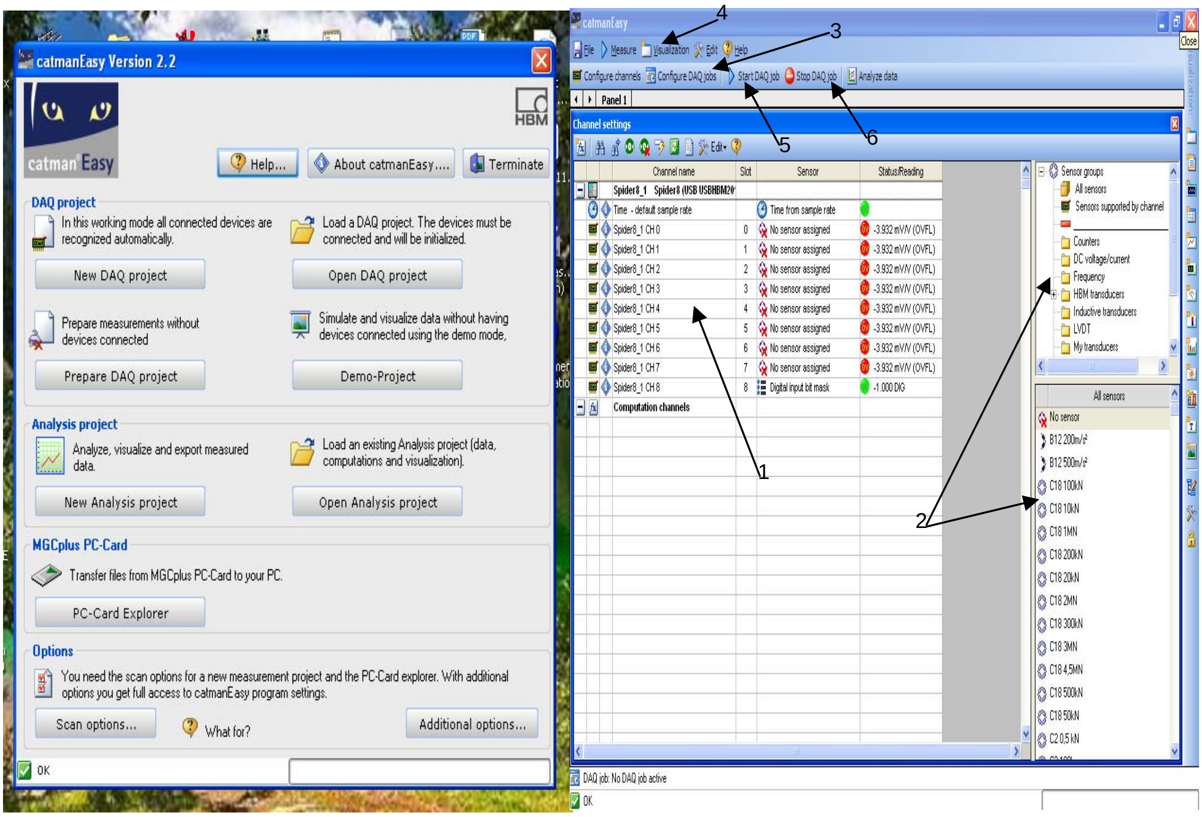

Fig. 4. The CATMAN EASY software interface:
1 – measurements channels list; 2 – transducers and bridges list; 3 – experimental setup panel; 4 – the measurements start; 5 – the stopping measurements panel.

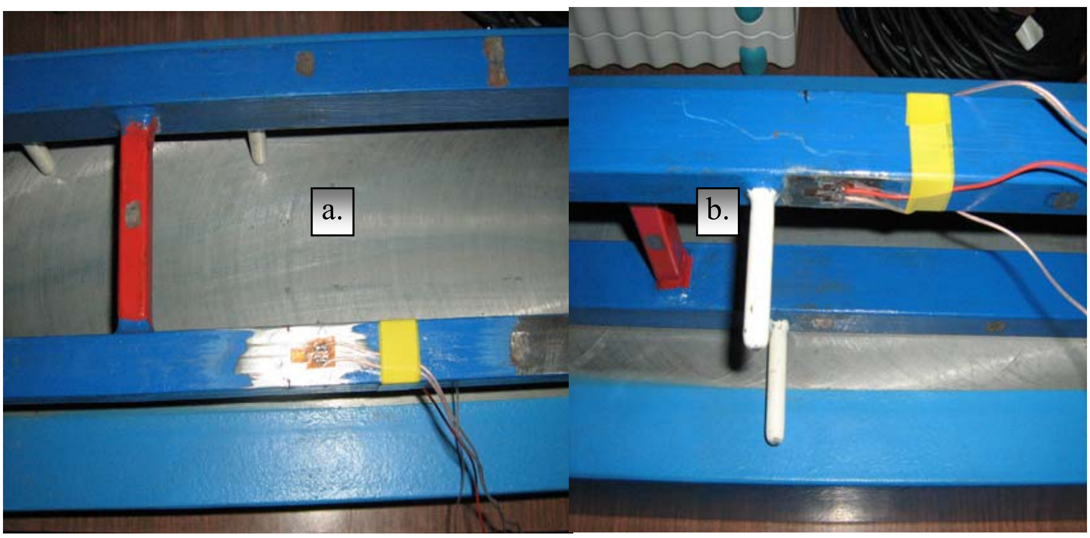

Fig. 5. The first half bridge:
a – the upper strain gauge; b – the lower strain gauge.

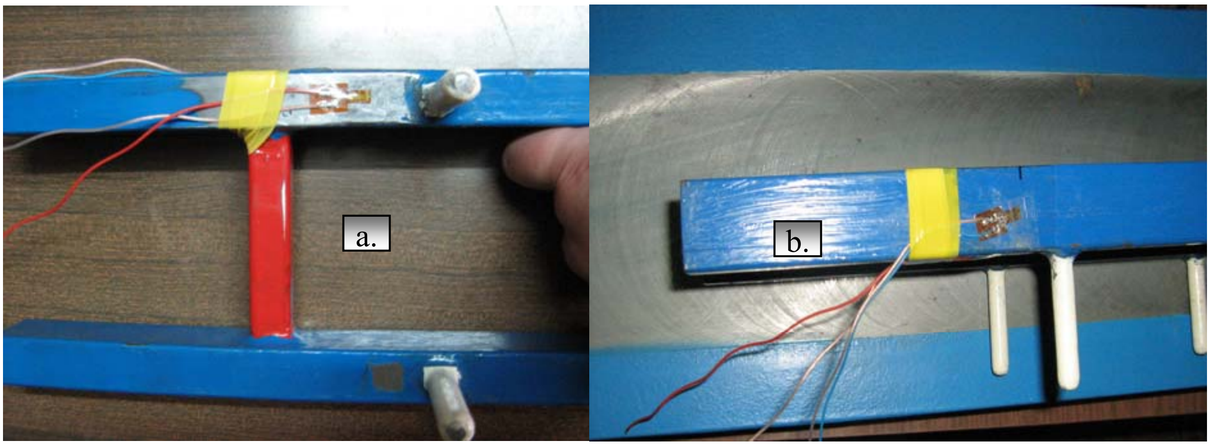

Fig. 6. The second half bridge:
a – the lower strain gauge; b – the side strain gauge.

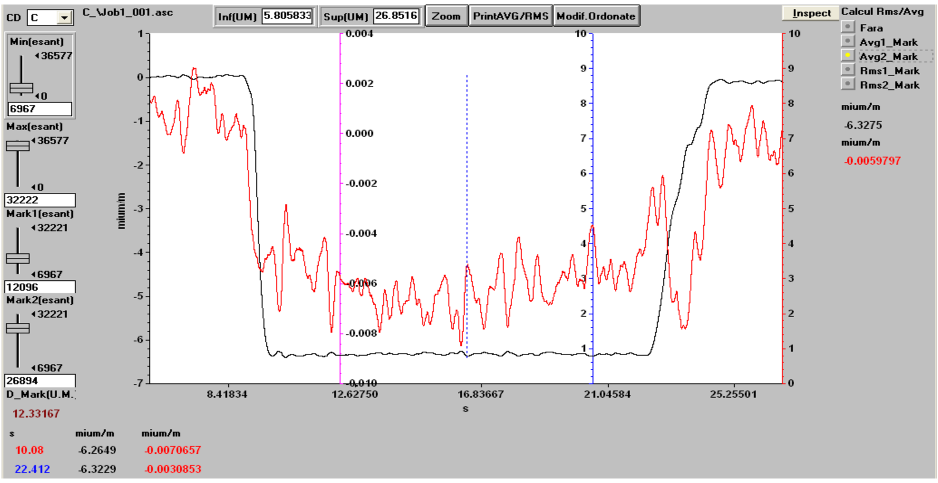

Fig. 7. The strain graphic obtained from variant 1 loading scheme.

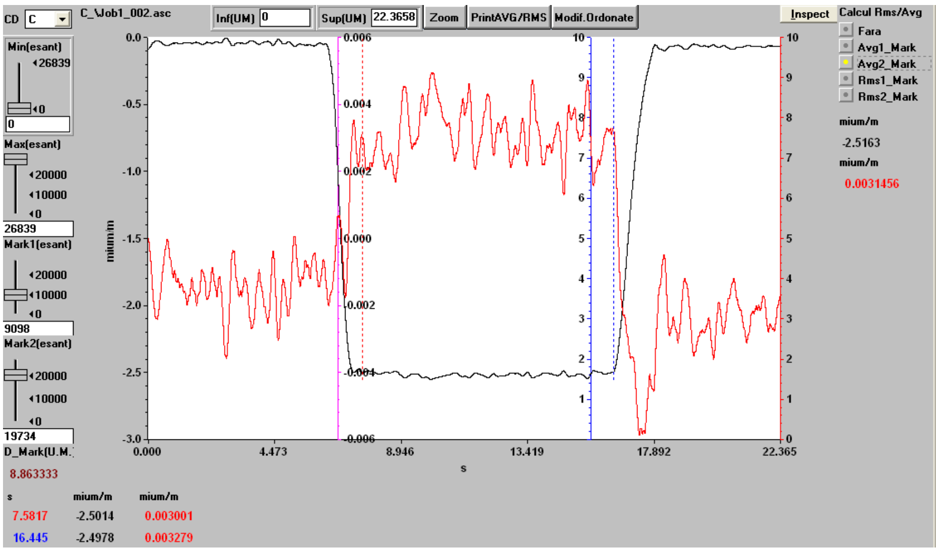

Fig. 8. The strain graphic obtained from variant 2 loading scheme.

3. CONCLUSIONS

In this paper it is presented an experimental model, based on strain gauges measurements, used for validation of an analytical model for strength calculus of hiperstatic structures under static loadings. This analytical model was presented in [1], based on the *force method* and built according to [6], chapter 4, pp. 278-307, and the theoretical aspects are used for a particular case defined in this way:

$F = 50$ N, $P = 0$ N, $Q = 0$ N, $a = 108$ mm, $b = 209$ mm, $c = 58$ mm, $d = 76$ mm, $e = 58$ mm, $f = 110$ mm, $h = 40$ mm, $E = 2.1 \times 10^5$ MPa, $G = 0.8 \cdot \times 10^5$ MPa, $b_1 = h_1 = 30$ mm, $g_1 = 2$ mm, $b_2 = h_2 = 15$ mm, $g_2 = 2$mm

The strain gauges from the first half bridge are bonded at x = 85 mm from the gap 4 (as shown in Figure 2). Using the relations (2)...(9) from [1] we can obtain the stresses graphics for each considered variant. In Figures 9 and 10 there will only be presented the graphics from the gaps where the strain gauges are bonded.

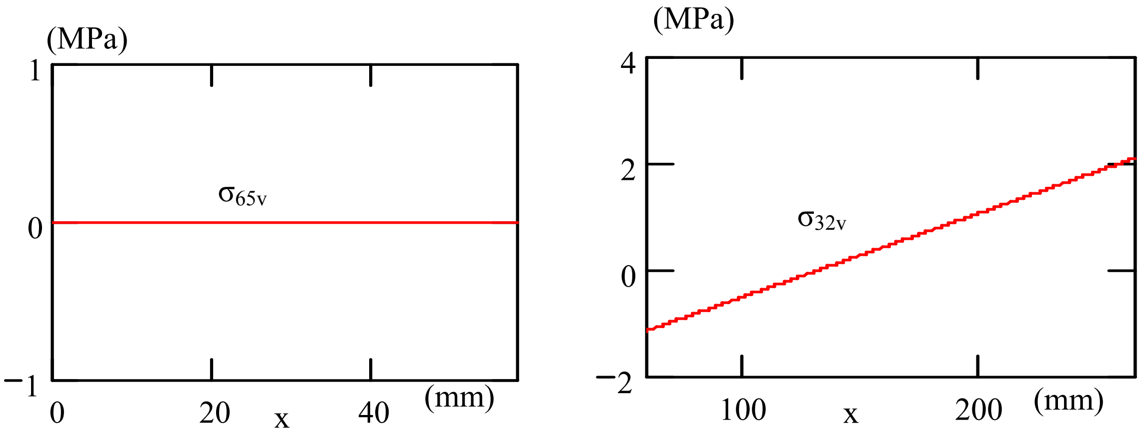

Fig. 9. The stress graphic obtained from variant 1 loading scheme.

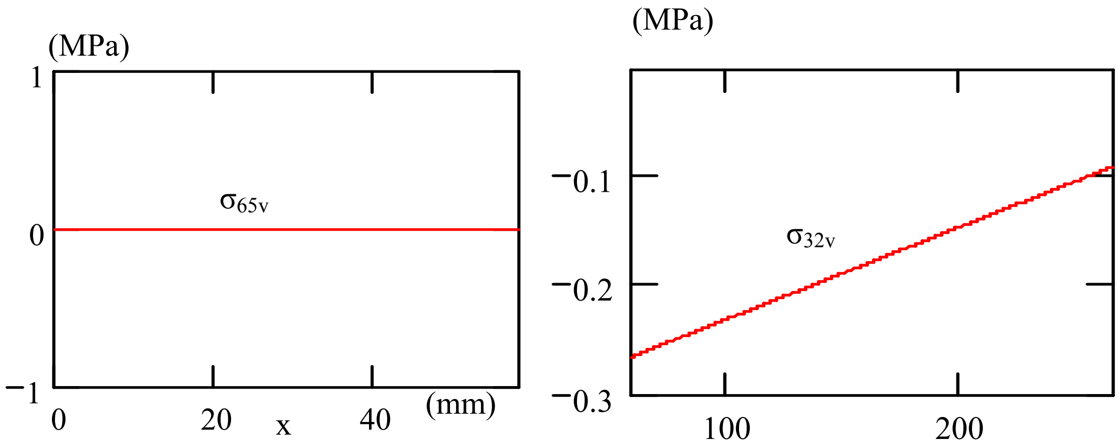

Fig. 10. The stress graphic obtained from variant 2 loading scheme.

From the Figures 9 and 10 we can extract the following conclusions:

- in both loading variants the stress on the 6 - 5 gap is zero;
- on the gap 3 - 2, the stress is -0.738 MPa for the variant 1 and -0.244 for the variant 2.

From Figures 7 and 8, for the 3 - 2 gap, we can see that the strain is -6.3275 in the variant 1 and -2.5163 in the variant two (measured with the strain gauges from the first half bridge). On the 6 - 5 gap, the strain is 0.005979 in the variant 1 and 0.0031456 in the variant 2 (measured with the strain gauges from the second half bridge). Using the Hooke's law, we can calculate the next stresses (the values are in MPa):

- variant 1: -0.6643975 on 3 - 2 gap and 0.000627795 on 6 - 5 gap;
- variant 2: -0.2642115 on 3 - 2 gap and 0.000330288 on 6 - 5 gap.

The first general conclusion is that, on the 6 - 5 gap, using the analytical model, the stresses are zero and using the experimental model the stresses are almost equal to zero (0.000627795 in the first variant and 0.000330288 in the second variant).

On 3-2 gap we have different stress results from the two loading variants. The stresses obtained by the analytical model are: - for variant 1: -0.748 MPa ; - for variant 2: -0.244 MPa. The next step is to estimate the errors using the relation (1).

$$\Delta[\%] = \frac{\left|\sigma_{\exp} - \sigma_t\right|}{\sigma_{\max}} \cdot 100 \quad (1)$$

The next errors are obtained: - for variant 1: ***11.18%*** and for variant 2: ***7.65%***. The errors obtained Δ [%] are lower than 15 %, which are allowed in technique and they appear especially because of the simplifying assumptions used in the analytical model according to [1]. We can say that the analytical model presented in [1] is validated by the experimental montage shown in this paper.

ACKNOWLEDGEMENT

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