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Development of a finite-element model for bench testing of road fence rack

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Abstract. The article compares the results of mathematical modeling by the finite element method (FEM) with the results of bench tests of steel racks of a road fence. The object of the study was a road fence rack made of steel 3, with a cross section in the form of a channel (No. 12). As a result of mathematical modeling, we obtained the dependences of the force in the rack on the movement, as well as the energy absorption of the racks. The obtained parameters were compared with the empirical results of field tests.

1. Introduction

In an accident, as a result of the interaction of the vehicle with the road fence, the vehicle elements and the fence deform and the trajectory of the vehicle changes. We should note that road barriers are a rigid structure, designed for the set energy absorption value provided by GOST [1]. Therefore, when installing them, we must take into account that collisions with barriers can lead to more serious consequences than leaving a road in the absence of barriers.

The aim of the proposed work was the development of a finite element model of bench tests of a road fence rack. We chose a road rack with a height of 750 mm with a cross-section in the form of a channel (No. 12) as an object of study, because it is one of the most used in the elements of road construction [2].

Full-scale bench tests were carried out for the selected rack in accordance with GOST [3]. Bench tests of the road fence racks were carried out on a specialized bench, which allows applying static or shock load, created by a horizontally moving mass (loading element) at a given value of the loading speed, to the object of study. The purpose of full-scale tests was to determine the nature of the deformation and strength characteristics when applying a static load.



2. The main part

When conducting field tests for a specialized laboratory bench, we imposed a number of requirements:

- 1) the height of the application of the load from the level of the lower plane of the rack or soil plate should be in the range from 300 to 600 mm;
- 2) the load on the fence rack should be at least 50 kN;
- 3) the rack loading speed (loading element speed) should be in the range from 1 to 80 mm / min;
- 4) the stroke of the loading element must be at least 500 mm.

The loading element must be absolutely rigid. During the tests, we measured the force and deformation at the contact point of the loading element and the fence rack. According to its results we built the load diagram "Force - movement of the rack at the contact point " (Figure 1.). The diagram allows to calculate the amount of energy absorption, numerically equal to the area of the figure under the curve of the diagram. According to the calculation results, the energy absorption was 6.3 kJ.

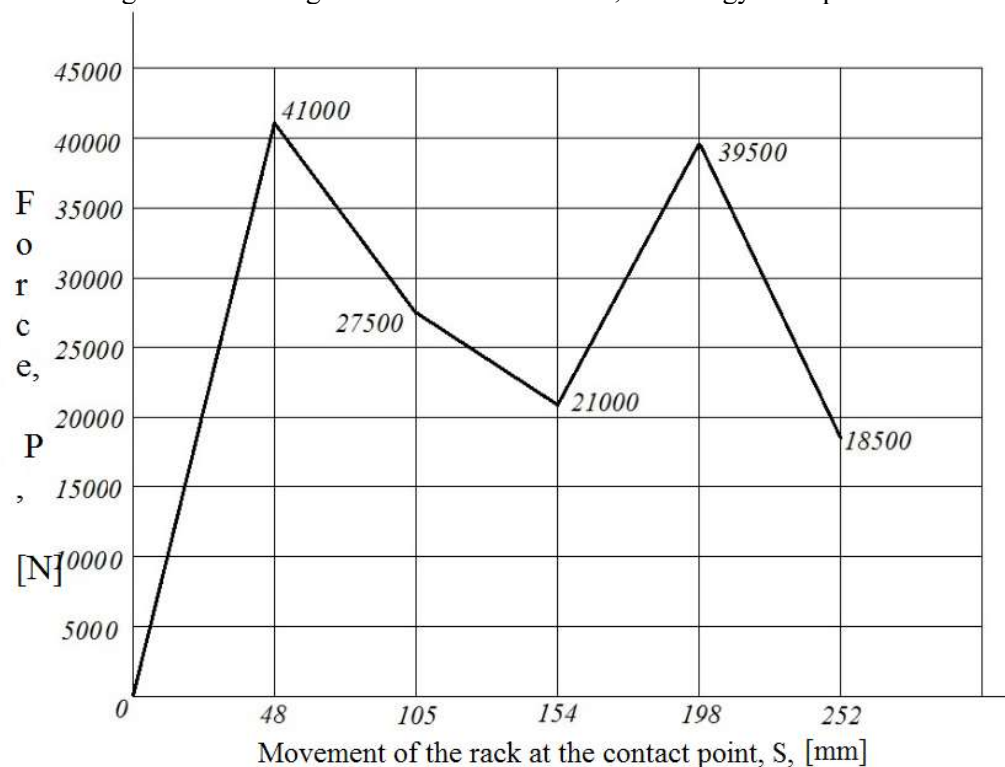


Figure 1. "Force - movement of the rack at the contact point".

In order to reduce material costs for multiple expensive full-scale tests, we implemented mathematical modeling of the loading of the road fence racks using the FEM. Solid-state geometric and finite element (FE) models of the object of study were created without simplifications (Figure 3.).

The thickness of the rack of the road fence is much less than its geometric dimensions, so the rack was modeled in the form of a shell [4-16].

According to the results of the FE analysis performed in the LS-Dyna software package, according to the existing methods [4-13], the diagram "Force - movement of the rack at the contact point" was obtained again (Figure 4.). For the new diagram, according to the calculation results, the energy absorption value was 6.15 kJ.

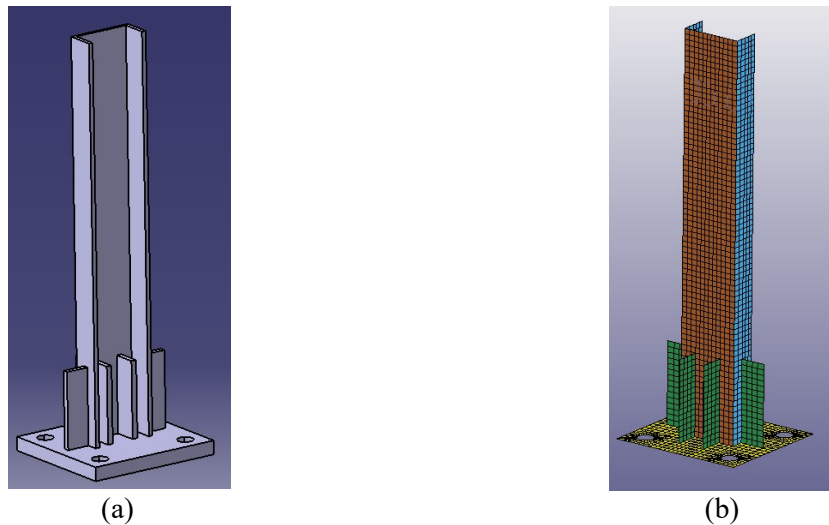


Figure 2. Rack models: (a) –geometric model; (b) – FE model.

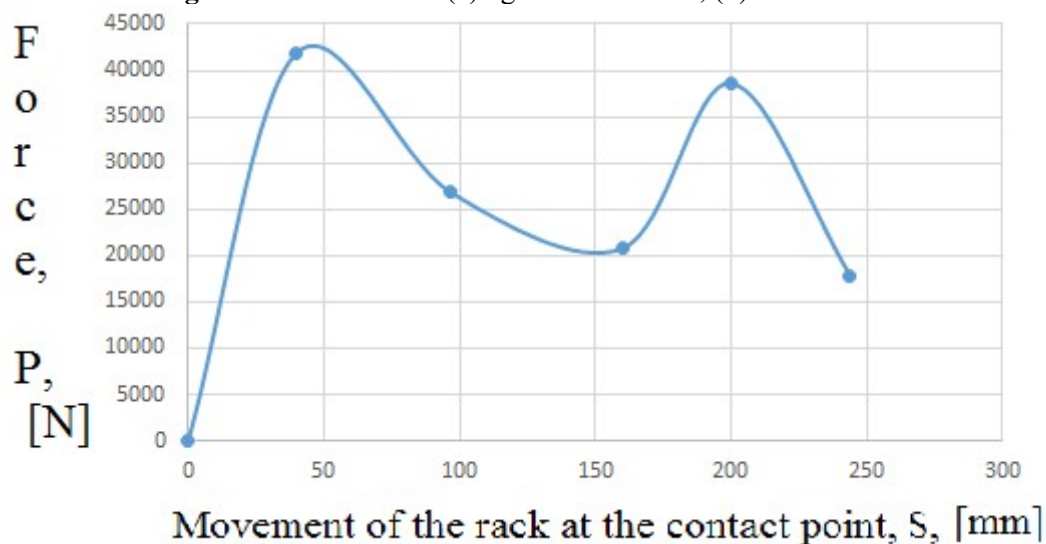


Figure 3. "Force - movement of the rack at the contact point".

As can be seen from the diagram (see Figure 3), with a force of 41900 N, plastic deformation of the rack occurs.

Comparing the results obtained in mathematical modeling of the tests of the road fence racks with the results of full-scale bench tests, we can conclude that the energy absorption value is almost the same. Consequently, mathematical modeling is an equivalent substitute for a full-scale (expensive) bench test, with a calculation error Δ :

$$\Delta = \frac{E_s - E_m}{E_s} \cdot 100 = \frac{6,3 - 6,15}{6,3} \cdot 100 = 2,38 \quad (1)$$

where E_s – energy absorption value obtained during a full-scale experiment, E_m - energy absorption value obtained by the results of mathematical modeling.

Figure 4 shows a comparative analysis of the operation of the rack in full-scale and virtual experiments.

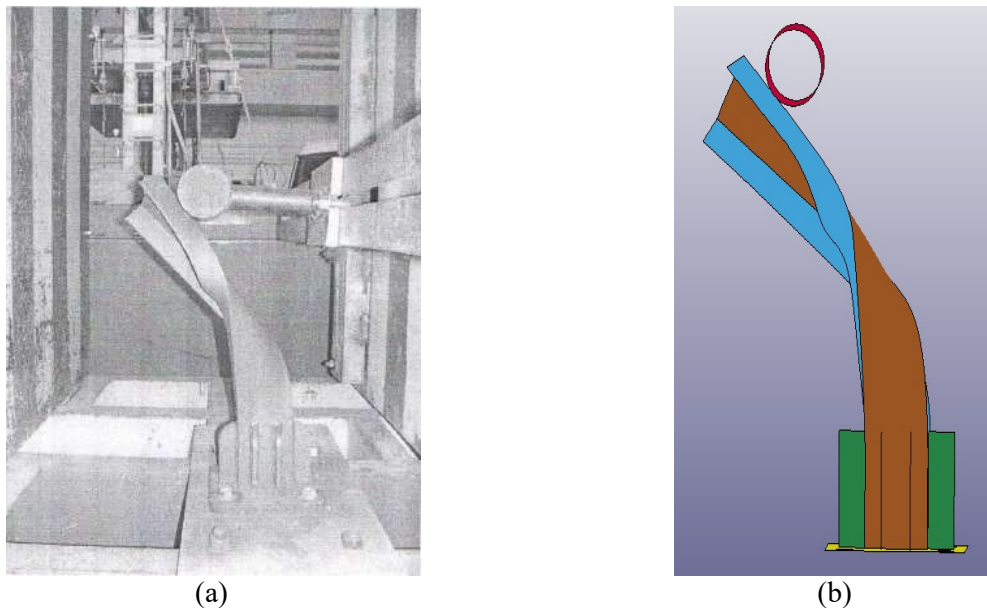


Figure 4. Comparison of the results of the racks of the road fence: (a) - bench tests of the racks; (b) - virtual rack tests.

3. Conclusion

Based on the results of the work, we can make the following conclusions:

- 1) The value of energy absorption obtained as a result of modeling converges with the value of energy absorption obtained during field tests, with an error of 2.38%;
- 2) The time of implementation (preparation + conduct) of the experiment during modeling is much lower than the time spent on the full-scale experiment (preparation + conduct);
- 3) Material costs for design development (taking into account further modifications and their tests) during a virtual experiment will be significantly lower than material costs for conducting full-scale bench tests. The difference in material costs will increase with an increase in the number of research objects.

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