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# STUDIES ON THE EFFECTIVENESS OF THE INNOVATIVE ROAD SAFETY SYSTEM

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***Abstract***

*The paper evaluates the effectiveness of the innovative road safety system equipped with prototype component segments composed of a body made of a plastic filled with reinforced concrete. Main advantages of the new safety barrier include increased resistance to corrosion as well as easy transport and assembly directly on a road section being secured. Model tests were performed on a car of 900 kg weight allowing for carrying out the TB11 tests according to the EN 1317-2 standard. LS-DYNA software was applied for modelling, using the finite element method.*

*The work presents the numerical test results, trajectory of vehicle movement after collision as well as the concrete barrier displacement. It also includes examples of stress in steel bars and joint coupling. Detailed assessing of simulation test results were made on the basis of ASI, THIV and PHD index. They were calculated on the basis of velocity and acceleration courses of selected car bodywork points.*

*Numerical test results confirm the fact that this system meets the normative requirements. They allow for qualifying that system for B impact severity level and W4 working width. The results presented in the paper make the initial stage of the study and further calculations will be oriented towards a possibility of meeting the requirements for higher restraint levels.*
***Keywords****: road safety barrier, crash tests, computer simulation, LS-DYNA, FEM*

## 1. Introduction

Permanently increasing road traffic intensity related to increasing number of road users forces continual development of the road network. In order to increase the safety level of car passengers, road designers introduce additional components of the road infrastructure restraining vehicles and pedestrians against entering danger zones. The most often solutions include road safety barriers [9, 10]. A road safety barrier is an equipment used for physical prevention from pulling off the road in dangerous places, moving out beyond the road crown, crossing the road and entering the lane for the opposite direction traffic or preventing from a vehicle collision with objects or stable obstacles located near the road. Many types of barriers available on the market allow designers to adjust the protection level to particular road conditions. However regardless of the type, all barriers used on the roads in the European Union have to meet the requirements of the EN 1317 standard [1 - 4]. That standard defines requirements for safety barriers within a scope of their abilities to restrain vehicles with simultaneous limitation of the area needed for stopping or proper guiding a vehicle back on the road. The acceleration severity index (ASI) and working width make the most important parameters used for evaluation of the safety barriers.

## 2. Test objects

Innovative safety system, developed by Fiedor-Bis from Chorzów, makes a single-sided concrete safety barrier composed of segments of length L=2.5 m and heights H=0.86 m (Fig. 1). Each segment consists of a polyethylene case, called the body, segment reinforcement and concrete filling. The use of plastic body makes the novelty of that solution. The application of the plastic increases the corrosion resistance of the barrier segments and allows for easy system assembly by filling the concrete directly on the road. Individual segments are connected by a steel bolt. The segment reinforcement was made of BSt500S steel ribbed bars.

*Fig. 1. Segment case made of polyethylene layer, so-called body*

Barrier segments were connected by 32 mm diameter bars made of S235JR steel (Fig. 2). While the segment filling was made of C16/20 class concrete, characterized with a resistance guaranteed at the level of 20 MPa.

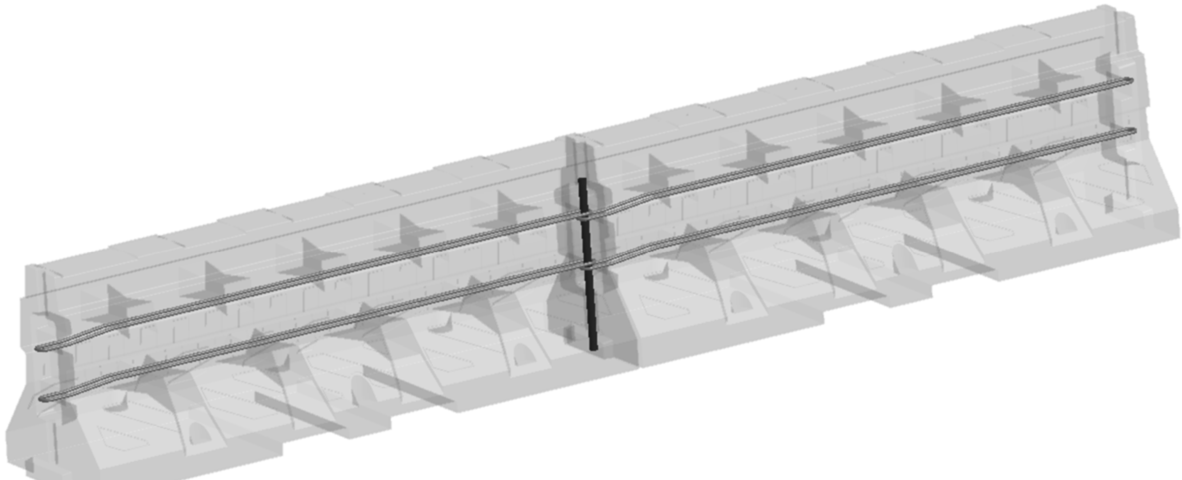

*Fig.2. Safety barrier segment connecting method*

Road safety systems are subject to evaluation in crash tests using various types of vehicles, depending on a declared restraint level. Geo Metro (Fig. 3), developed and supplied by National Crash Analysis Center [8], car model was used for simulation tests in the considered case. That model is mostly made of four-node shell elements [5]. Individual body items are connected by means of beam components, mapping the welded joints. Large car components characterized with significant weight and rigidity (engine, gear box, wheel hubs) were modelled by means of rigid solid elements. Proper operation of the car chassis (particularly important when wheels hit the barrier segments) was obtained by introduction of discreet flexible-damping components and the use of flexible tire model. The Geo Metro car model consists of about 193 000 components in total.

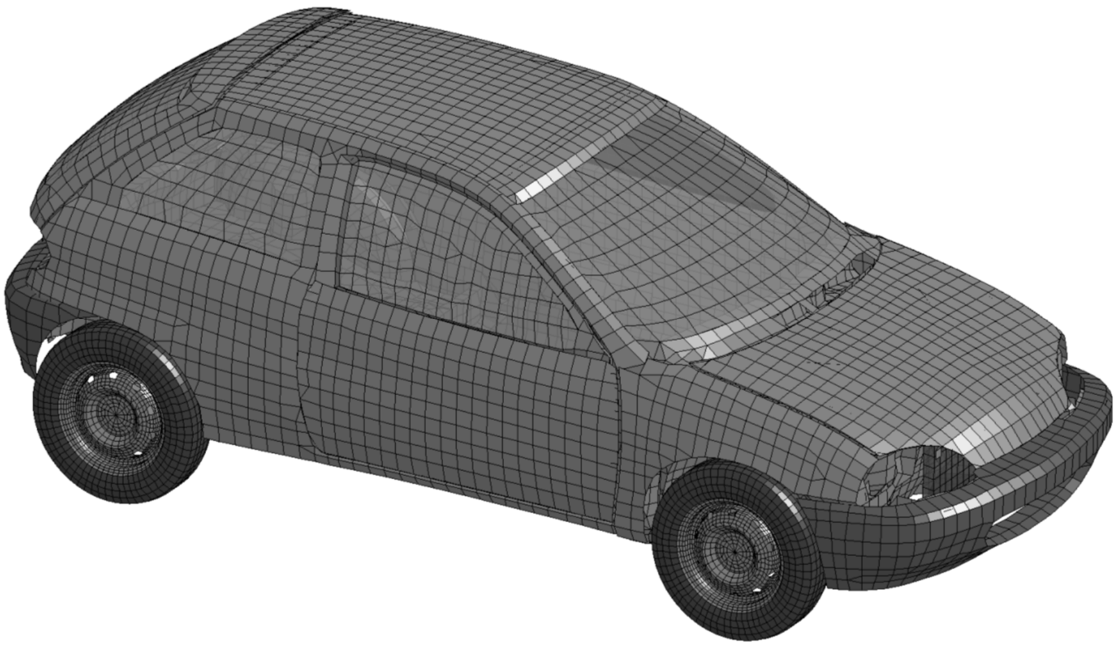

*Fig. 3. Numerical model of the Geo Metro car [8]*

The 60 m-long safety barrier was modelled with 24 segments. It was composed of two segment model types: deformable segments (no. 9 and 10 – Fig. 5) and non-deformable ones. Figure 4 presents a non-deformable segment with reinforcement bars and a bolt, while figure 5 shows applied configuration of segments used in the crash tests.

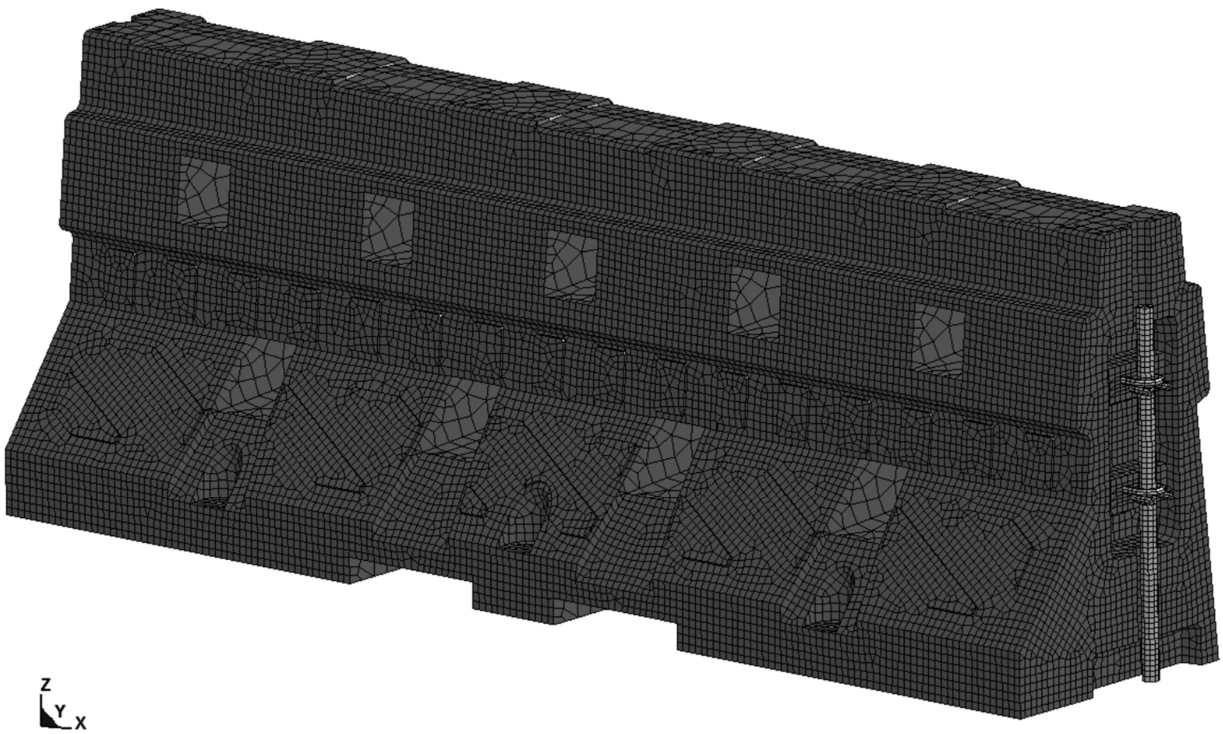


*Fig. 4. A view of a non-deformable barrier with reinforcement bars and a bolt*

Apart from that, a point of impact where the test car hits was located on a deformable segment no. 9 (Fig. 5). The CSCM_CONCRETE material model was used to imitate a concrete block, allowing for cracking and crushing.

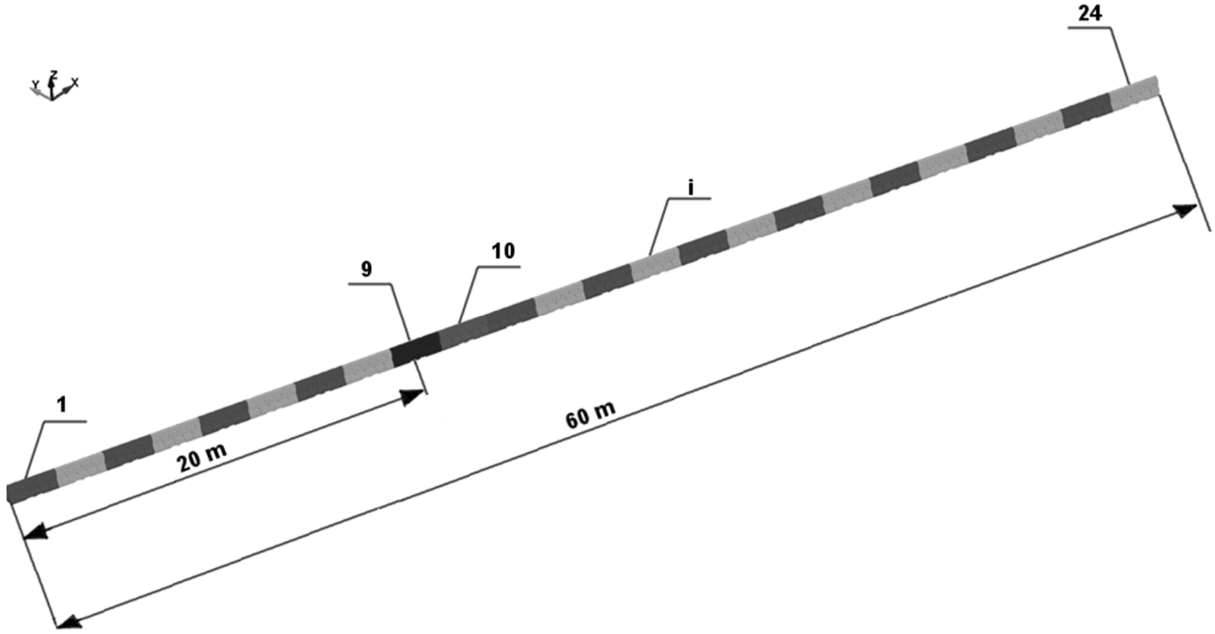


*Fig. 5. Barrier configuration using two deformable segments (9 and 10): i – segment number*

## 3. Test conditions

Numerical tests met the normative requirements included in EN 1317-2 [1–4] for criteria according to TB11. The simulation of a collision of a car and a safety barrier was carried out according to a diagram presented on Fig. 6. The tested car, weight of 900 kg, was moving with an initial speed of 100 km/h, and then it hit the safety barrier system placed at the angle of 20° relative to direction of the car movement.

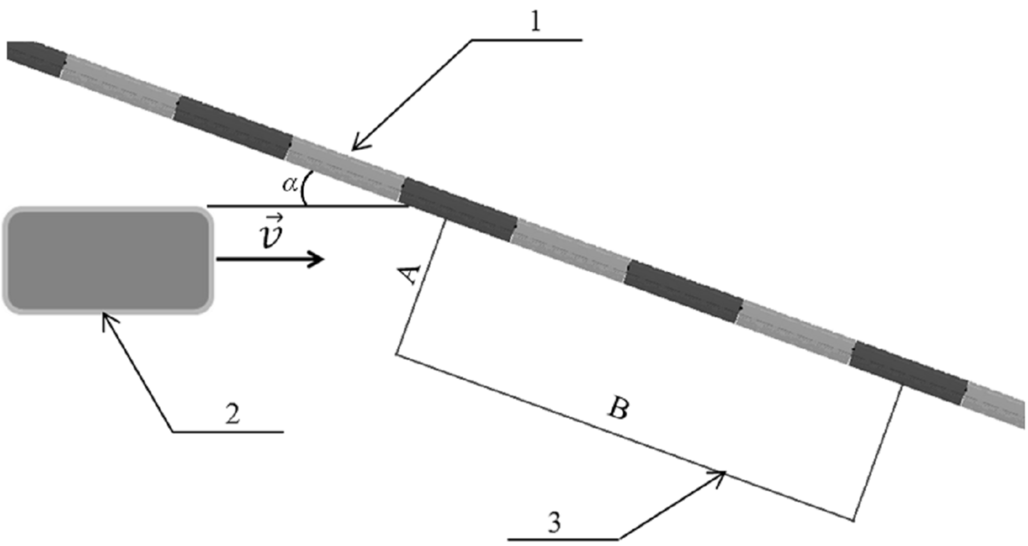


*Fig. 6. A diagram of a test track used for simulation tests – collision of vehicles with a rigid or deformable safety barrier, according to PN-EN 1317-2, where: 1 – segment safety barrier; 2 – test vehicle; 3 – acceptable test car reflection field (A - width, B – length, measured in [m]); v – impact speed [km/h]; α – impact angle in degrees*

LS-DYNA software was applied for modelling, using the finite element method [7]. The main goal of performed simulation tests was to carry out the quality and quantity evaluation of the results of a collision of the car and the prototype barrier.

## 4. Numerical test results

Fig. 7 presents selected phases of the collision of the car and the prototype barrier. During the test, the front part of the car body hit the barrier, the car wheels approached the side surface of the barrier and then the vehicle was smoothly guided out of the impact zone. As a result of the collision, small car body deformations occurred, limited to the frontal part of the car. Due to friction of the car components (mostly the rim of the left front wheel), the polyethylene coat was scratched in the point of impact, however it was not broken.

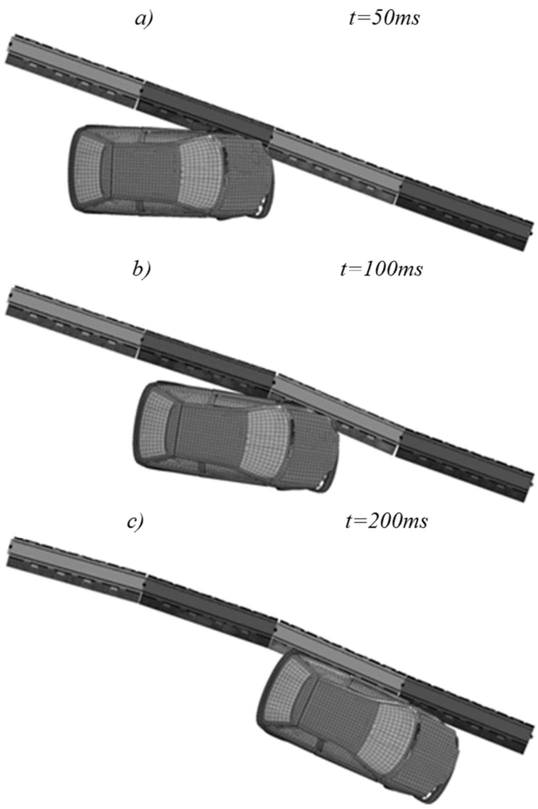


*Fig. 7. Stages of a collision of the car and the barrier: a) for t = 50 ms, b) for t = 100 ms, c) for t = 200 ms*

Figure 8 presents a deformation of metal elements of the coupler between the segments involved in the collision. Reduced stress maps were placed on them. The car impact has not caused significant effort of metal elements. Bolt tension values did not exceed 420 MPa. The maximum tension occurred in the area where the bolt was installed in the concrete block and in the area of a contact with lower ties.

*Fig. 8. Coupler deformation and tensions*

As a result of performed numerical calculations the following results were obtained:

a) maximum dynamic deformation (D): 0.516 m,
b) working width (W): 1.066 m (W4),
c) acceleration severity index (ASI) = 1.244,
d) theoretical head impact velocity index (THIV) = 16.3 km/h,
e) post impact head deceleration index (PHD) = 11.7 g.

The above indexes allow qualifying tested system for B impact severity level.

## 5. Summary

The paper attempts to evaluate the innovative road safety system. Presented considerations refer to a 900 kg car, which makes a popular segment of the passenger car market in Europe. That choice also results from normative conditions. That type of the car makes the basis of the restraint system tests.

Numerical test results confirm the fact that this system meets the normative requirements. They were calculated on the basis of the courses of accelerations of the gravity centre of the car and they allow for qualifying that system for B impact severity level and W4 working width.

The results presented in the paper make the initial stage of the study and further calculations will be oriented towards a possibility of meeting the requirements for higher restraint levels.

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