CRASH TESTS OF A CAR WITH MODIFIED ROAD BARRIERS

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Abstract

In this article experimental results of a car impact into a modified road barrier are presented. For crash tests a modified protection barrier SP-04, composed of guide poles, type B, and bridge posts IPE140, was chosen. The road barrier modification lies in using additional panels absorbing the impact energy. The protective panels, subjected to examination, consisted of a metal or a composite (laminate, glass-polyester) shield in which the foamed aluminium or polyurethane foam was a filling. The Suzuki Swift cars were prepared for the crash tests. Tests were carried out at the Automotive Industry Institute (PIMOT) in Warsaw, with the use of a test sample of the road barrier. For the safety sake the car's speed during the experimental examinations was limited to 50 km/h. Moreover, the vehicle hits perpendicularly in a properly modified road barrier's sector. During the test a registration of acceleration was carried out by the acceleration sensors placed in the car (among others in the centre of gravity and over the rear axle of a car). A crash test course of the system C-G was registered with the use of two cameras for fast shooting (Fantom v12). An image was recorded with the resolution of 1280x800 pixels and with frequency of 1000 shots per second. The shot exposure time equalled to 250 microseconds.

Keywords: *transport, road transport, car – road barrier system, crash test, experimental examinations*

1. Introduction

The main function of roadside safety barriers is to be capable of capturing and redirecting errant vehicles in order to protect vehicle occupants from hazardous roadside features. These roadside barriers are normalised under CEN norm EN 1317. According to this standard, the restraint system must sustain the impact of different vehicle types (from passenger cars to trucks or buses), under different collision conditions (i.e. vehicle's velocity, angle of impact and road conditions).

To provide appropriate safety levels for impacting vehicle occupants, the safety barriers should be designed so as to absorb as much impact energy as possible through their deformation and at the same time maintain their integrity. Practical observations of installed systems along Polish highways, which have not changed much in the past several decades, indicate that the current design of the road barrier is too stiff, which results in unacceptable decelerations during vehicle impact. By adopting the European transportation legislation, it was necessary to re-evaluate the safety barriers and propose certain design changes to increase the safety level.

This work is a continuation of the research on the protective panels' project – placed on existing road barriers systems – that will increase energy absorption levels as a result of a car's impact. The research is conducted in the Department of Mechanics and Applied Computer Science by a team under the direction of prof. Tadeusz Niezgoda. In this article the results of crash tests for chosen versions of energy-absorbing panels were presented. The research results will be used for numerical models validation of the discussed problem.

2. Description of the object of experimental crash tests

Experimental full-scale tests of the system C-MRB (car-modified road barrier) was carried out in the Vehicle Safety Laboratory of the Automotive Industry Institute (PIMOT) in Warsaw (Fig. 1). The examination stand enables carrying out crash tests of vehicles with a barrier (guardrail). For the sake of safety it is only possible to carry out tests with a perpendicular impact to the road barrier's surface. The tested vehicle is hitched to a special platform that is accelerated on the track with a help of a catapult. The catapult enables carrying out impact of whole vehicle weighting up to 2500 kg with a speed to 65 km/h. Before the impact, the car is released from the platform and with the force of impetus hits the barrier. The test is registered with the use of cameras designed for fast shooting. During the test measurements of accelerations are performed with the use of acceleration sensors respectively placed in the car. In the examined vehicle a driver manikin is also placed.

Fig. 1. Stand for vehicle crash tests with a modified road barrier in PIMOT's Vehicle Safety Laboratory

Based on the successful results of the static tests on the prototypes, three modified protection barriers composed of guide poles of B type and bridge posts IPE140 were chosen for crash tests. The spacing of posts was conditioned by the specificity of the examination stand. The distance between middle posts was 2 m, and the distance between side posts equalled to 1m. Posts of the road barrier were welded to two steel plates. The plates were fixed to a retaining wall and affixed to the base.

The barrier's modification lies in the assembling an additional protective panel on the barrier's guide bar, which was done in order to increase the barrier's energy absorption. For the experimental research three types of protective panels were prepared in shapes presented in Fig. 2, the length of the panels amounted to 2 m. The examined construction is depicted in Fig. 3a-c.

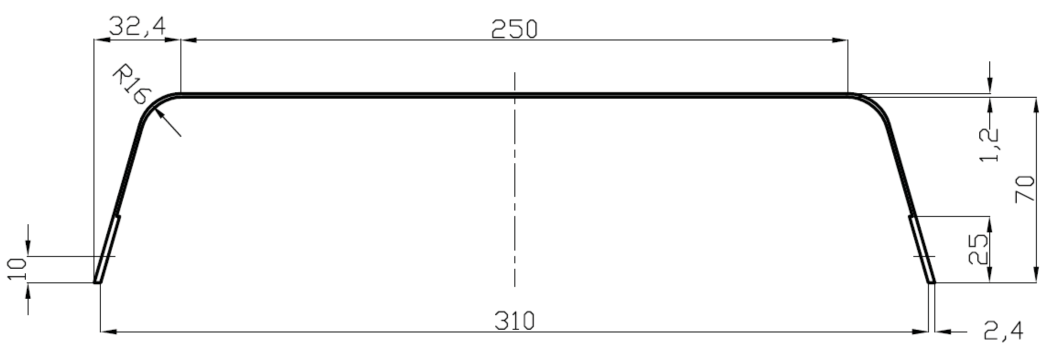

Fig. 2. The scheme of a protective panel with the casing of trapezoid form with the height of 70 mm

Fig. 3. Road barrier with a panel type 1A (a), 1B (b), 1BL (c)

The protective panel (marked as 1A) presented in Fig. 3a comprised a casing made of a steel sheet DC01, thickness 0.5 mm, filled with polyurethane foam (Ekoprodur). The panel was assembled to the guide bar by riveting. The rivet spacing was equal to 10 cm. The car Suzuki Swift with a mass 725 kg was used to the test with the described barrier.

In the protective panel (marked as 1B) depicted in Fig. 3b, instead of a steel casing, a casing from a composite material was used (a fabric with a straight interlace 0/90, 450g/m^2 - glass E, resin VE-11 M) with a thickness of 1.2 mm. The same polyurethane foam, as in the first case, was the filling of the panel. To the crash test the Suzuki Swift car with a mass of 715 kg was prepared.

The protective panel, marked as 1BL, comprised a composite casing and a filling in a cuboid form made of foamed aluminium. The panel is presented in Fig. 3c. A crash-test was performed with the use of a car with a mass of 720 kg.

3.Full-scale tests

3.1. Crash-test modified barrier type 1A – Suzuki Swift car

A crash test course of the system car-road barrier was registered with the use of two cameras designed for fast shooting. One of them registered the image from one side, the second one from top. Basing on the registered images it is possible to determine: the car's speed before the impact and displacements of chosen points of the tested road barrier. Image was recorded in resolution 1280x800 pixels with frequency 1000 shots per second. The shot exposure time was 250 microseconds. The selected shots from the crash test are presented in Fig. 4, whereas the protective road barrier deformation was presented in Fig. 5a. The examined car deformation is presented in Fig. 5b. Basing on the video analysis made with the use of a TEMA program the car's speed was determined in the moment of the impact with the barrier. This speed amounted to 45.8 km/h.

During the test a registration of acceleration was carried out by the acceleration sensors placed in the car (among others on the centre of gravity and over the rear axle of a car). Deceleration components' courses „in the impact direction" registered during the test are presented in Fig. 6. Maximal value of the acceleration on the centre of gravity is 19 g, and over the rear axle is 20.2 g.

Figure 7 presents resultant acceleration courses coming from the sensors spaced on the driver manikin. The maximal manikin's head acceleration value is 33.9 g, and the manikin trunk acceleration reaches maximal value of 25.7 g.

3.2. Crash-test modified barrier type 1B – Suzuki Swift car

The protective road barrier's deformation with the panel of 1B type caused by the Suzuki Swift car's impact is presented in Fig. 8a, and in Fig. 8b the car's deformation is presented. Basing on the video, from a fast camera, an analysis of the car's speed during the impact was determined. The speed was the same as in the former case, and it amounted to 45.8 km/h

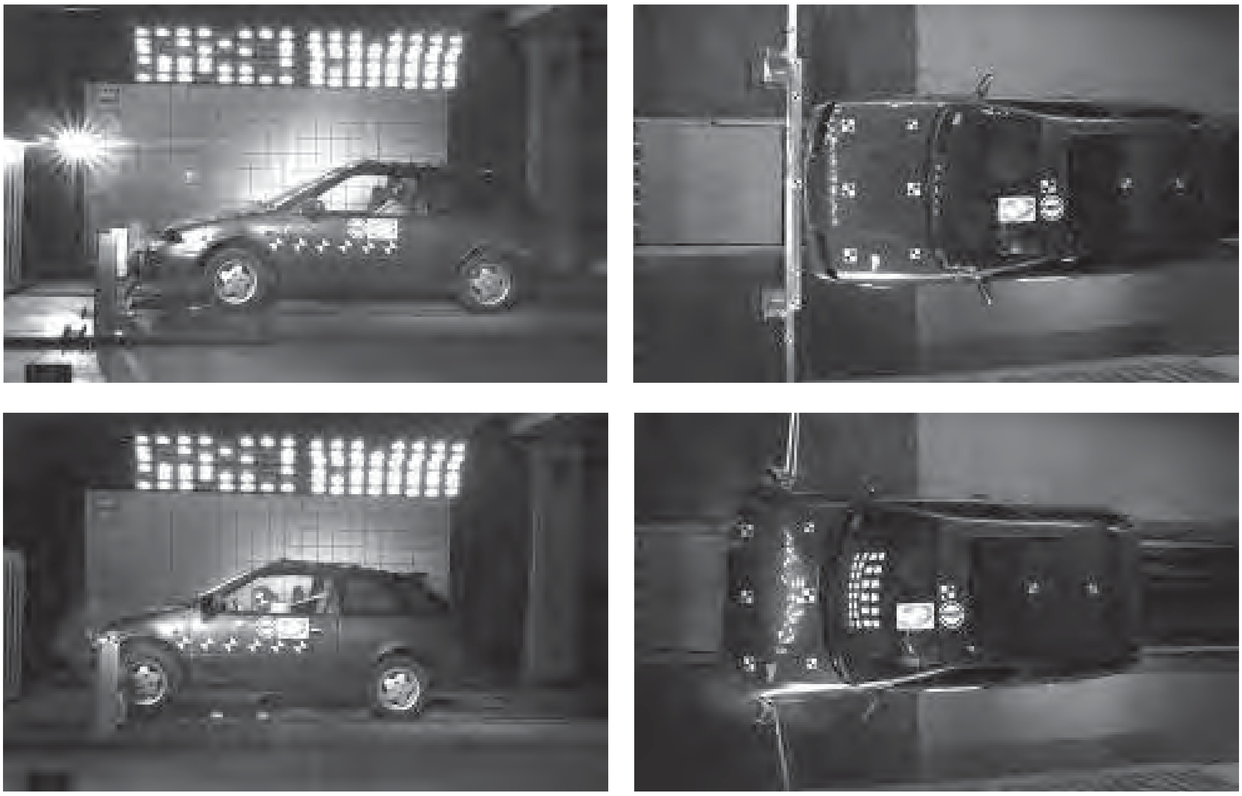

Fig. 4. The crash test course registered with the use of two synchronized cameras designed for fast shooting

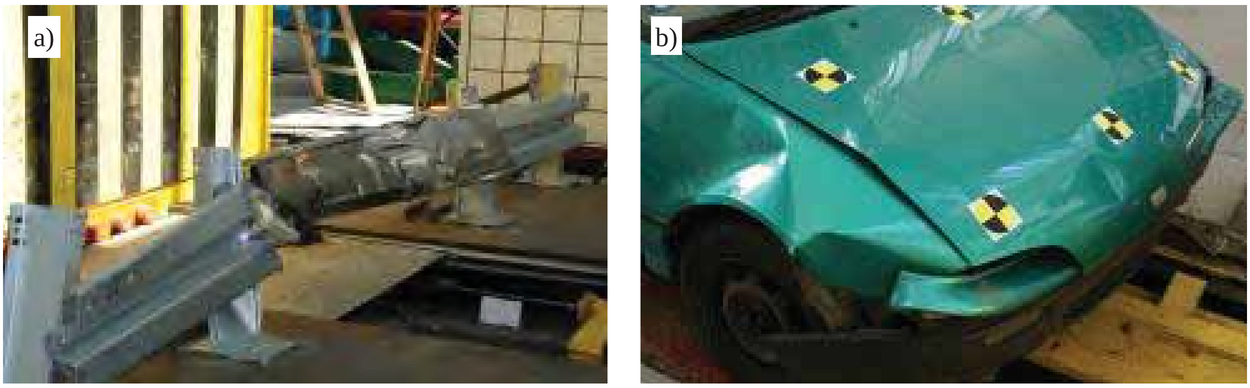

Fig. 5. Deformation of the tested protective road barrier type 1A (a) and Suzuki Swift car's deformation (b)

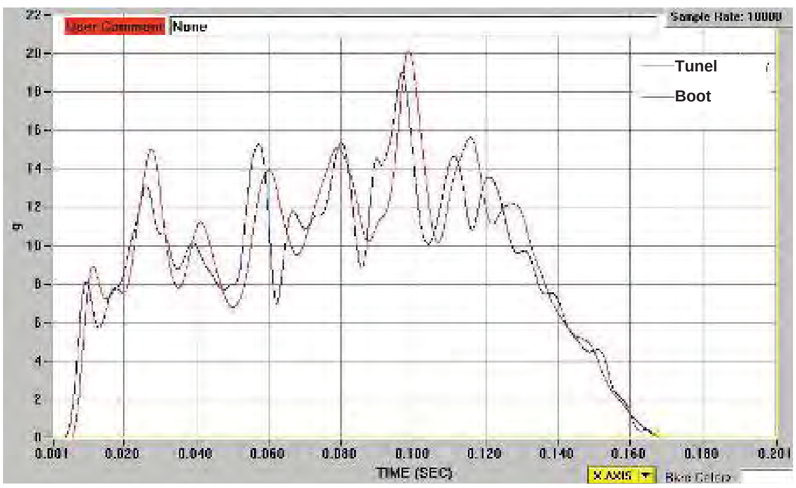

Fig. 6. Diagrams of deceleration constituents' courses „in the impact direction"(of chosen points) – Suzuki Swift

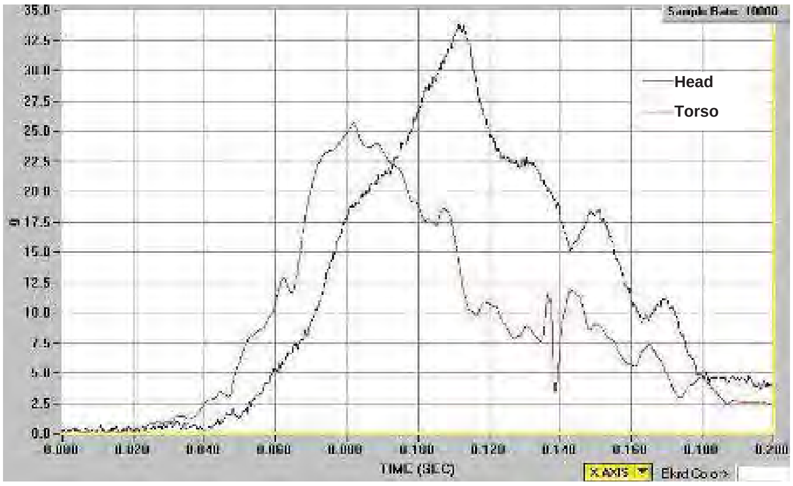

Fig. 7. Diagrams of the chosen resultant deceleration courses – Manikin HII

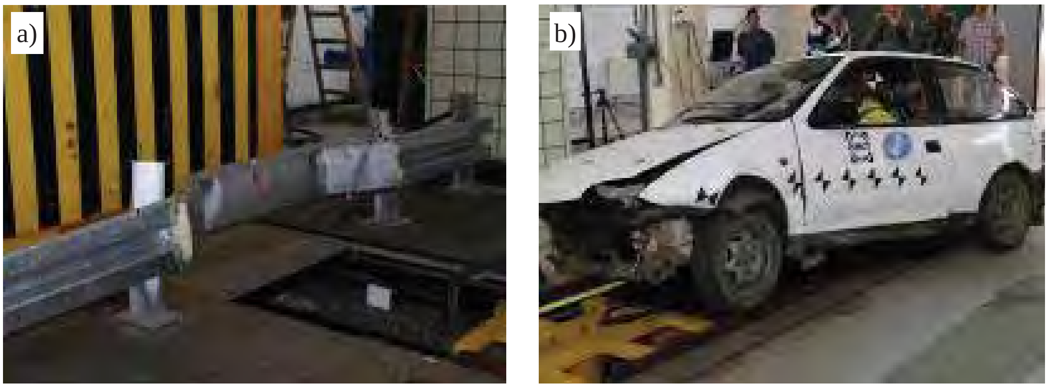

Fig. 8. Deformation of the tested protective road barrier type 1B (a) and Suzuki Swift car's deformation (b)

During the test the acceleration recording was made by acceleration sensors arranged in the car (among other on the central tunnel and in the boot). Courses of deceleration components „in the direction of the impact" were registered during the test Fig. 9. The maximum value of acceleration on the central tunnel amounted to 25.6 g, whereas, in the boot 19 g.

Figure 10 shows the progress of acceleration components coming from the sensors placed on the driver's manikin. The maximum acceleration value of the manikin's head is 38.8g, whereas the manikin's torso acceleration reaches the maximum value of 24.6g.

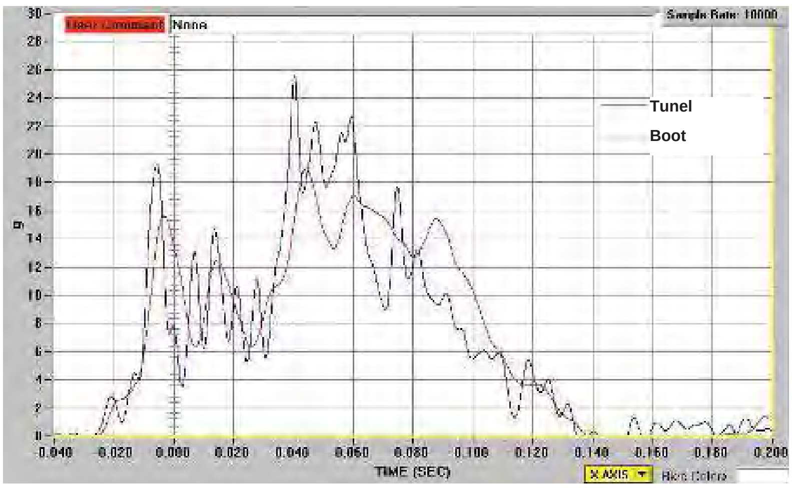

Fig. 9. Diagrams of deceleration constituents' courses „in the impact direction"(of chosen points) – Suzuki Swift

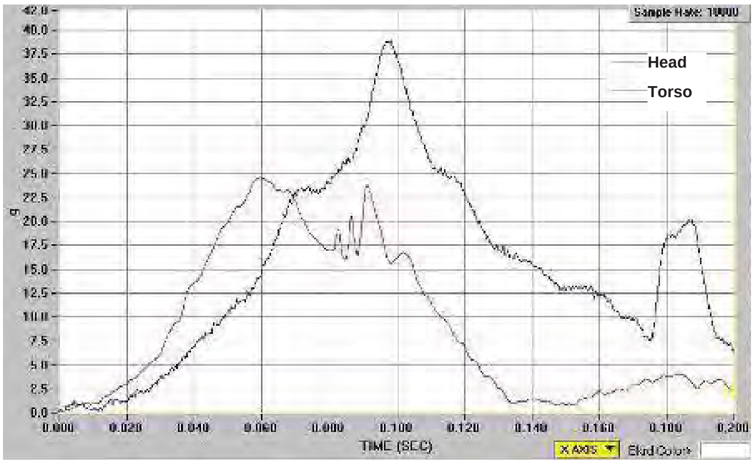

Fig. 10. Diagrams of the chosen resultant deceleration courses – Manikin HII

3.3. Crash-test modified barrier type 1BL – Suzuki Swift car

The protective road barrier deformation with the 1BL type panel caused by the Suzuki Swift car's impact is presented in Fig. 11a, and in Fig. 11b the car's deformation is presented. Basing on the video, from a fast camera, analysis of the car's speed during the impact was determined. The speed was slightly smaller than in both former cases and amounted to 45.5 km/h.

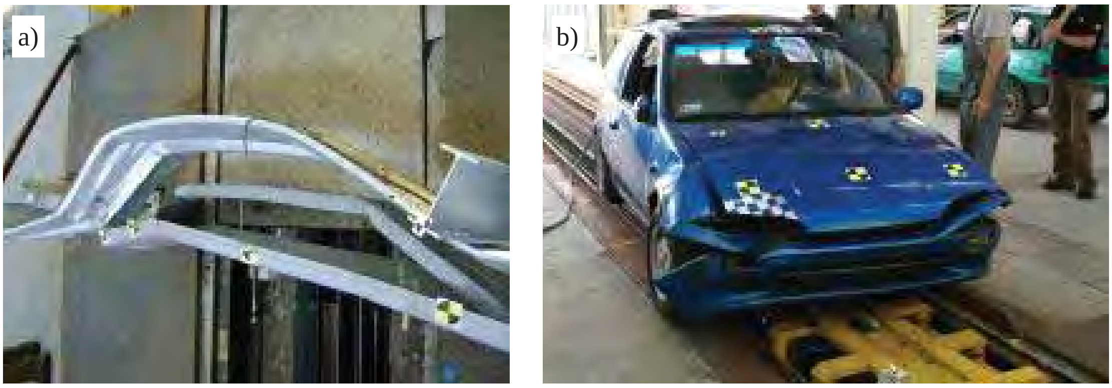

Fig. 11. Deformation of the tested protective road barrier type 1AL (a) and Suzuki Swift car's deformation (b)

During the test the acceleration recording was made by acceleration sensors arranged in the car (among other things on the central tunnel and in the boot). Courses of deceleration components "in the direction of the impact" were registered during the test (Fig. 12). The maximum value of the acceleration on the central tunnel amounted to 24.3g, whereas in the boot 28.7g.

4. Summary

In Tab. 1 the most important results of the crash-tests with the participation of Suzuki Swift cars are presented. For comparative purposes the results of the Suzuki Swift car impact with an unmodified barrier are presented. It should be brought to attention that the car's speed in this test was greater and equalled to 52.5 km/h.

Additional energy-absorbing panel parameters should be matched, taking into account the character of effects taking place during the vehicle's impact into a barrier. A fact, that the subject of protection is not only the vehicle but also the driver and passengers are inside the vehicle, should be also taken into consideration. In connection with this, beside the energy-absorption, the proper protective panel stiffness should be also taken into account because the force that destroys the protective panel decides over the accelerations functioning on the driver and vehicle's passengers.

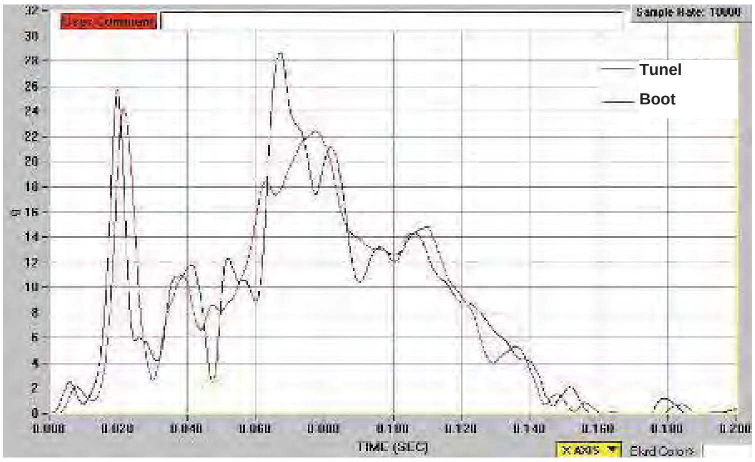

Fig. 12. Diagrams of deceleration constituents' courses „in the impact direction"(of chosen points) – Suzuki Swift

Tab. 1. Maximum registered values of deceleration during the crash-test

Test number	Barrier type	Car's speed [km/h]	Car's bulk [kg]	HIC	Deceleration maximum value [g]			
					Manikin Head Resultant	Manikin Torso Resultant	Car Centre. Tunel Imp. Direct.	Car Boot Imp. Direct.
-	Classic road barier	52.5	688	175	31.5	23.9	25.8	19.8
1	modified type 1A	45.8	725	138	33.9	25.7	19.0	20.2
2	modified type 1B	45.8	715	179	38.8	24.6	25.6	19.0
3	modified type 1BL	45.5	720	385	48.5	30.0	28.7	24.3

The energy-absorbing panel's stiffness should be matched taking into account the stiffness of other elements of the road barrier's construction. A too high stiffness of the panel, in relation to the other elements of the barrier, will cause low energy absorption of the panel, additionally causing the creation of great forces and accelerations. A too low stiffness of the panel will cause the absorption of a minor part of the impact's energy. It is advisable that the additional energy-absorbing elements exhibit similar properties independently of the loading direction. Foamed materials possess such a property (e.g. polyurethane foams).

The research conducted in this work was used in order to verify the correctness of numerical models of the barrier and the car. They also allow to carry out numerical simulations in accordance with the PN-EN 1317 standard.

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