PROTOTYPE ARTICULATED JOINT IN CONNECTIONS OF THE CONCRETE PROTECTIVE BARRIER

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Abstract

The work describes methodology of selection of a prototype articulated joint used to connect the segments of the concrete protection barrier. The barrier and the joint have been made according to the original project of the authors of this paper. Dimensions of the component elements of the joint were defined on the basis of numerical calculations in LS-DYNA system, using finite element method. They also allowed to identify places sensible to damage. Based on the project, the experimental tests have been performed for the joint strength to stretching. The tests performed on the resistance machine showed improper technology and poor quality of welds joining individual elements, particularly the bolt with connecting steel. Results of these tests made the basis for introducing the changes to the project. Repeated tests confirmed their rightness. The final evaluation of quality and usefulness of the prototype articulated joint in the connections of movable protection barrier were defined during the crash tests on the test track of the Certified Research Laboratory of the Research Institute for Roads and Bridges. The crash tests were performed for selected collision criteria (TB11 and TB32), normal restrain level (N2), using three passengers cars. Applied concrete barrier test procedures are in accordance with the requirements of national standards, that make the equivalents of the European standards.

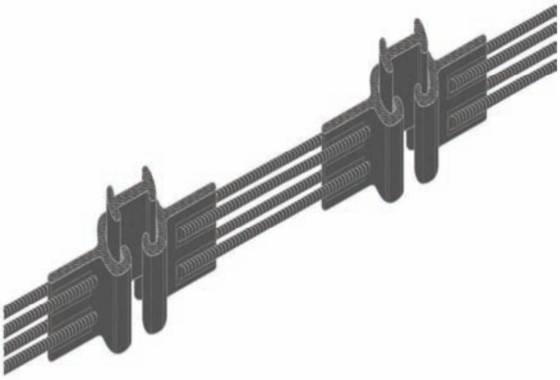
Keywords*: transport, road safety, concrete protective barrier, crash test, articulated joint*

1. Introduction

The efficiency of the moveable protection barriers, used on selected dangerous sections of the road, depends, among others, on the following factors:
- shape of transverse segment section,
- geometrical segment dimensions (weight),
- type of surface the barrier is placed on,
- working width (W) and dynamic deflection (D) of the barrier,
- structural features of articulated joint of the barrier segment connection (coupler).

Articulated joints of the barrier segments play very significant role. Numerous multivariate numerical tests [1, 2, 4] showed that structural features of connection have direct influence on side displacement and segment rotations. Improperly selected coupler flexibility can result in too high car body deformation and excessive barrier bending. If the restrain condition is not met then the coupler is torn during car collision with the barrier and kinematic connection of moveable segments of the protection barrier is broken. In both cases the protection barrier is disqualified and not admitted to using as the road protection system [5].

The most popular systems used in the European Union countries include DELTA BLOCK system, which can be used for various working width levels from W1 to W8, at required restrain levels from T1 to H4b and with collision intensity level A or B. DELTA BLOCK segments, apart from the reinforcement grid, consist of coupling joints installed during production process and they are able to transfer the following tearing forces: 350; 550; 750; 1300 kN [6].

a) 

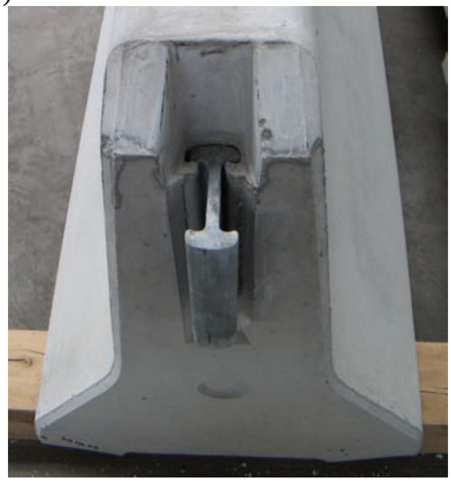
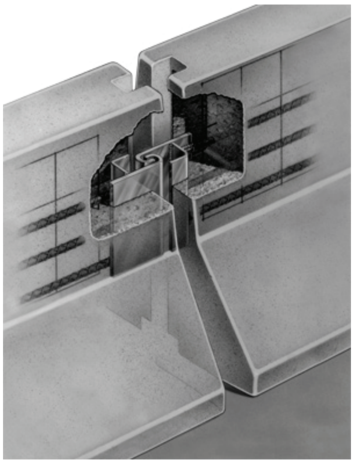
b) 

Fig. 1. The coupling in DELTA BLOCK system; a) coupling joints shape, b) coupling joints in concrete barriers' segment [6]

Proper shape of frontal walls of the DELTA BLOCK segments allows for barrier bending in a form of arc. The DELTA BLOCK system provides easy barrier assembly and quick replacement of damaged individual segments without any negative influence on the barrier operation efficiency.

J-J Hooks System is popular in the USA, in South America and in many European countries. This system allows for easy and quick connection of individual segments of the moveable barrier. Each segment is symmetrical (it makes the barrier installation easier) and is equipped with the same fixing elements on both sides. The joint consists of two identical steel J-shaped hooks (that's why it is called the J-J hooks, see Figure 2).

a) 

b) 

Fig. 2. The coupling in J-J Hooks system, a) scheme of coupling; b) the segments of J-J Hook barrier during assembly process [9]

FDOT Portable Concrete Gurb system used in the USA is also worth mentioning. It provides quick replacement of concrete barrier segments. Connection of the barrier segments is presented on Fig. 3. One end of each segment makes a vertical plane and the other end is folded. That type of barrier segment connection allows for barrier bending and forming a circular arc of a minimum radius of 20 m.

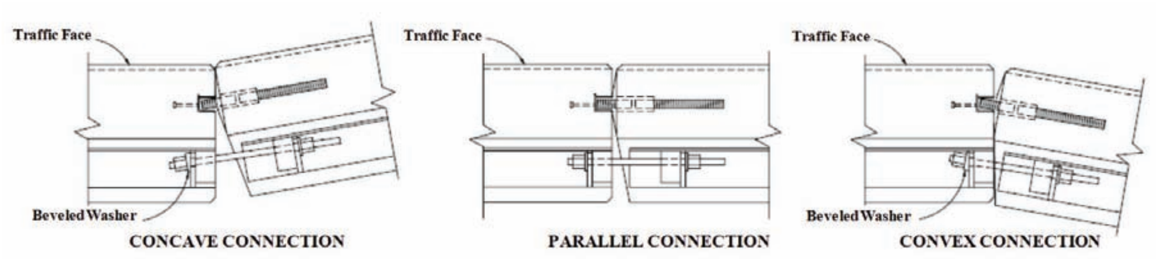


Fig. 3. Connection of the barrier segments in FDOT Portable Concrete Curb [10]

The most common types of connection of concrete barrier segments used in Poland include U-shaped handles made of steel rods anchored in a barrier segment and the steel rods, usually of 30-32 mm diameter, go through them [8].

2. Articulated joint – coupler project

Having analysed the literature [6, 7, 8, 9, 10], it was found out that contemporary structural solutions of articulated joints connecting the protection barrier segments need to satisfy several basic requirements, e.g. provide sufficient joint resistance to tearing, provide lateral displacement and limited barrier segment rotation, allow for quick replacement of segments damaged during collision and provide a possibility of making a passage for the rescue services. Considering the above assumptions (conclusions) the concept of articulated joint of the barrier segments has been developed – a metal coupler concept presented on fig. 4.

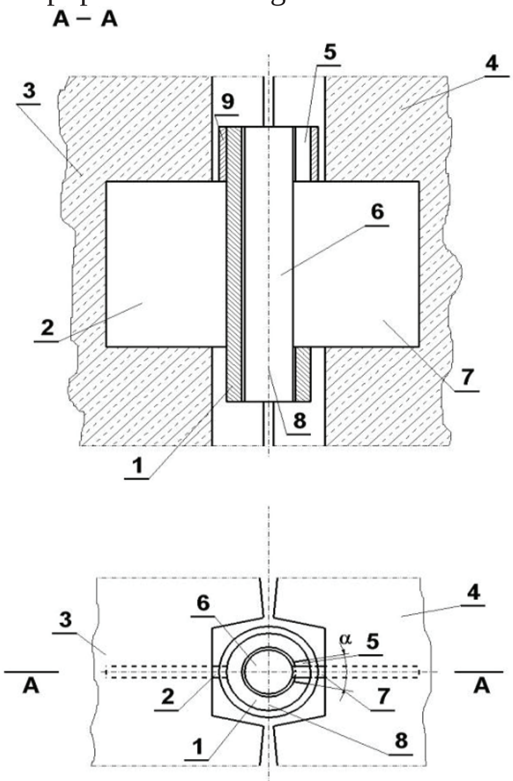


Fig. 4. Articulated joint connection of prototype concrete barrier – coupler project: 1- thick-wall pipe; 2 and 7 connecting steel; 3 and 4 – concrete barrier segment; 5- cut-out in the thick-wall pipe, 6- internal bolt; 8- rotation axis; 9- protecting sleeve

3. Numerical simulation

On the basis of accepted assumption concerning the coupler structure, its numerical model has been developed. It consists of three parts: a funnel and a bolt with connecting steel fragments and a protective sleeve. Developed model is presented on fig. 5. The main purpose of strength calculations was to select proper dimensions of individual coupler parts in order to provide a transfer of assumed load amounting to 350 kN. It was assumed that all elements will be made of standard metallurgical products.

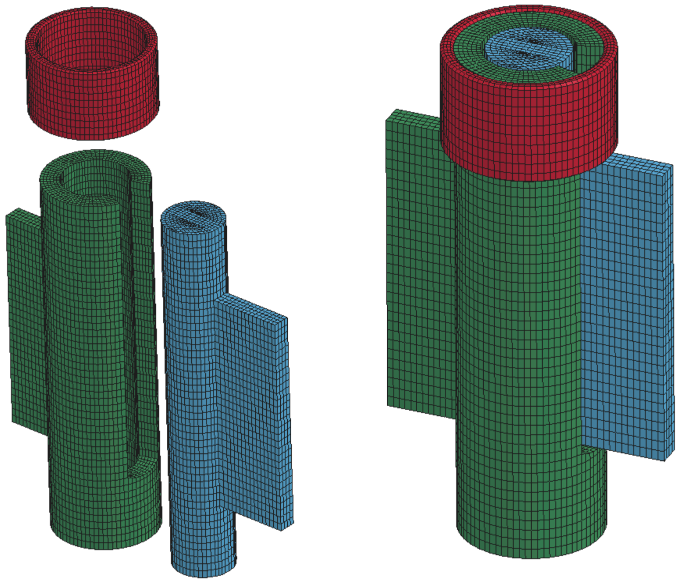


Fig. 5. Numerical model of coupling

All coupler elements were simulated using eight-node solid elements. Proper conditions of cooperation of individual parts were obtained by defining the conditions of contact between the funnel and the bolt and the protecting sleeve. Calculations were made in LS-DYNA system, using the finite element method. Calculations were carried out for stretching the coupler with assumed maximum force at axial position of a funnel and a bolt and at mutual twisting of cooperating elements by the maximum assumed angle amounting to 15°. Fig. 6 and 7 present the reduced stresses in the joint structure for the load conditions defined above. On the basis of obtained results, it can be stated that the maximum stress values occur in places where the bolt is connected with the sheet and they amount to about 385 MPa.

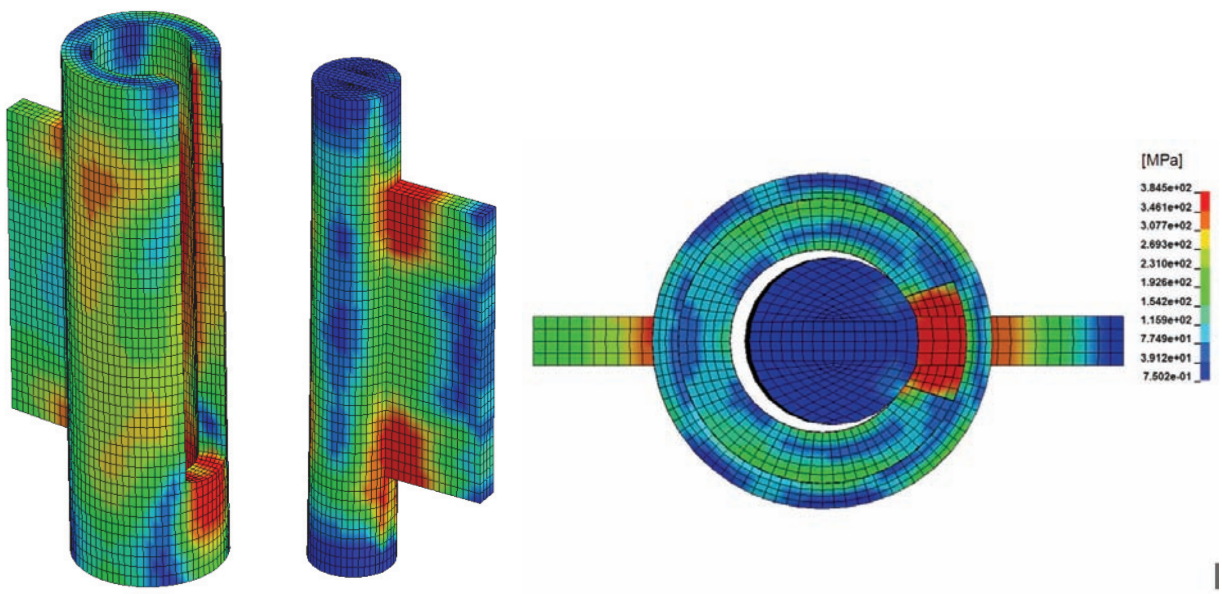


Fig.6. Reduced stress in coupling parts – axial loading

Additional bending of connecting sheets occurs in case of angular force load.

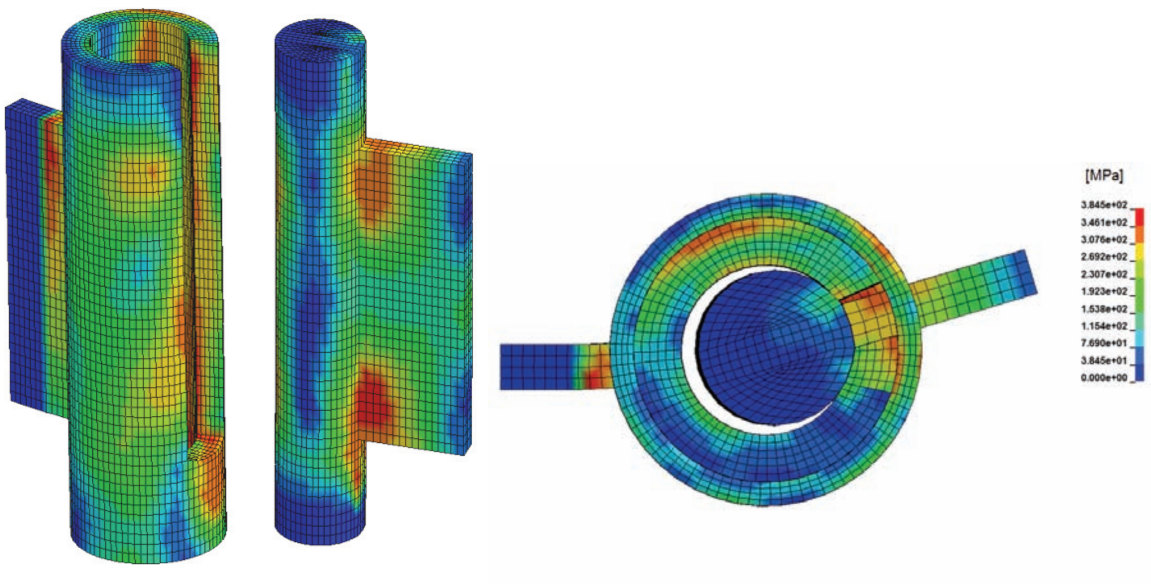
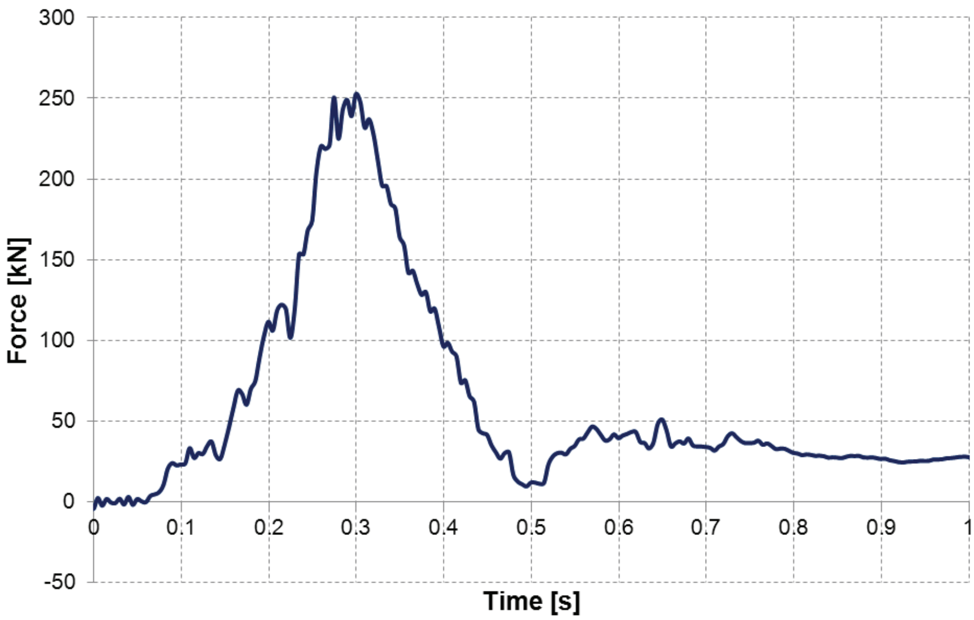


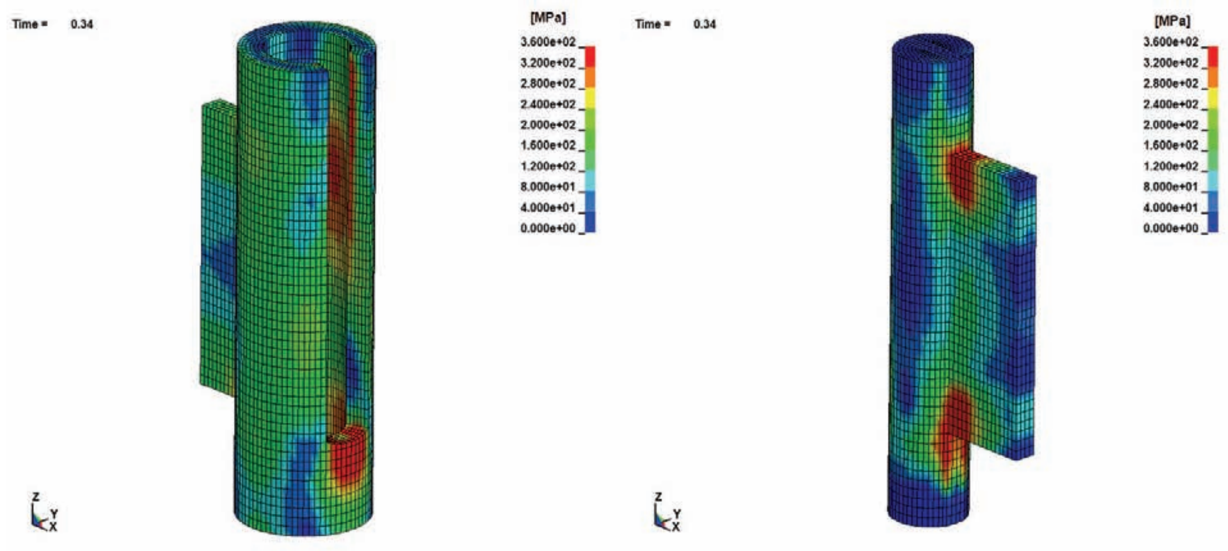
Fig. 7. Reduced stress in coupling parts –15° angle

During the second stage of numerical calculations, the behaviour of the structure loaded in a dynamic way was analysed. On the basis of a collision of a 1500 kg car with the protective barrier system, stretching force variations in connections of individual segments were defined. Fig. 8 presents the course of tearing force at the most loaded coupler which made the basis for further calculations.



Rys. 8. The course of force at the coupling during collision

Fig. 9. shows the stresses reduced at the coupler elements when the maximum values occur. Their distribution is similar to the load variants presented above. Once again, the connection of the bolt and the connecting sheet is the most stressed area.



Rys. 9. Stress in coupling elements – dynamic loading

4. Experimental tests

The couplers were manufactured at a specialist production company using metallurgical products with dimensions defined on the basis of resistance calculations (round ø 45 rod, thick-wall pipe of external diameter of ø 70 and wall thickness of 12,5mm, a pipe of external diameter of ø 85 and the 10 mm thick sheet) made of S355J2 steel. In order to check the quality of welds and evaluate the tearing force value, the tensile strength resistance tests were performed in the Material Resistance Laboratory of the Department of Mechanics and Information Technology of the Mechanical Department of the Military Technical University (fig. 10). The tests were performed with three complete sets of couplers (random selection from a batch prepared for the production of concrete segments).

Fig. 10. The tensile strenght tests of prototype coupler

The strength tests of the prototype coupler performed on the INSTRON type machine, indicated that they do not meet one basic resistance requirements as the static force tearing the coupler structure, only in one test, obtained the maximum value amounting to 228,5 kN, and not, as assumed, minimum value of 350 kN. The main reason were the improper welded joints (without visible penetration) on the coupler elements. Moreover, it was noticed that damages (weld tearing) occurred only on the welded connections of the sheet and the internal bolt. In order to eliminate the above defects, the thickness of the connecting sheet was increased from 10 to 12 mm and the welded connection technology has been changed. Three couplers were made once again according to a new concept (fig. 11). The tensile strength tests were repeated for them in order to check the quality of welds and evaluate the tearing force.

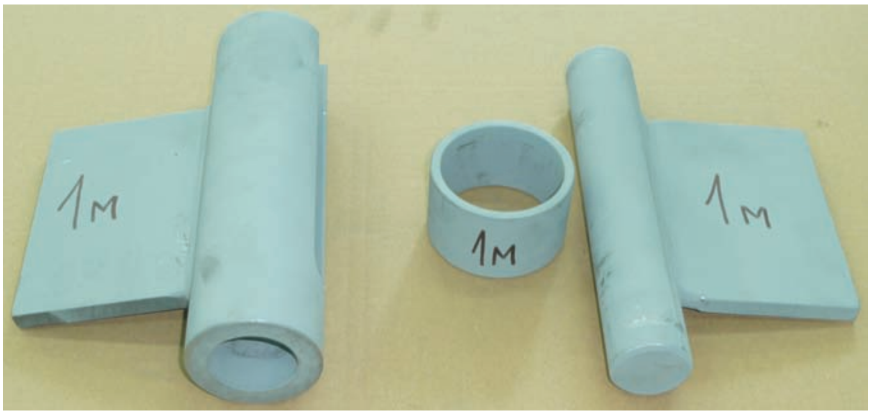


Fig. 11. The prototype coupler

Confirmation of assumed strength parameters was obtained and the tensile force in all tested couplers reached the values above 450 kN (fig. 12). So it was acknowledged that changes introduced to the coupler structure will provide proper operation of the prototype concrete barrier during a collision with a vehicle.

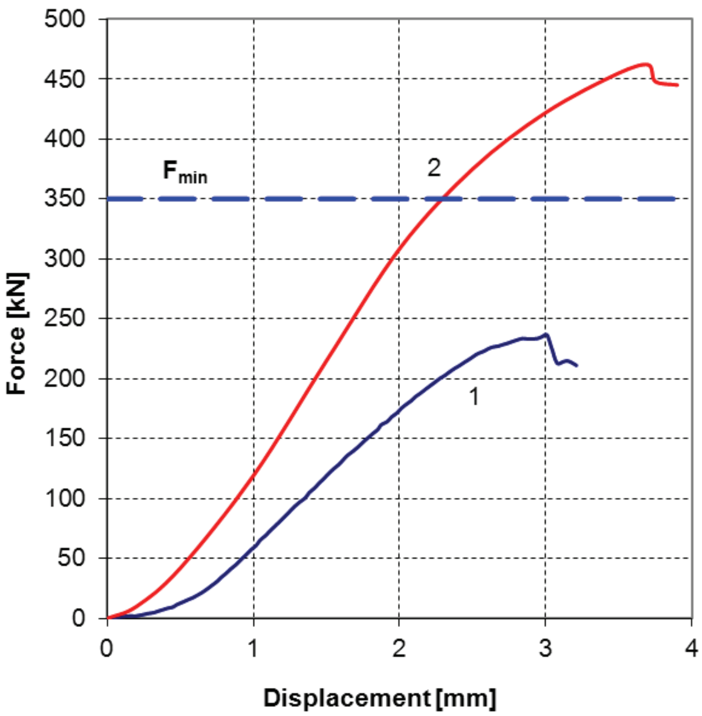


Fig. 12. Tensile strength characteristic: 1 – before modyfication, 2 – after modyfication

5. Conclusions

The paper presents selected fragments related to design and research on articulated joint of segments of the concrete protective barrier. Presented coupler structure provides a possibility of transferring the forces between adjoining segments, preserving a possibility of their mutual rotation. Performed numerical calculations allowed for choosing coupler element dimensions and the experimental tests allowed to verify the quality of joint within a scope of a possibility of transferring assumed loads.

Presented prototype articulated joint of the concrete barrier segments was used to build 15 - segment protective barrier. The couplers make an integral part of the barrier segments and therefore their usefulness in development of the road protective systems needs to be evaluated during the crash tests according to the requirements of national and European standards [8, 9, 10]. The tests were carried out on the test track of the Certified Research Laboratory of the Institute for Roads and Bridges for selected crash criteria (TB11 and TB32) and normal restrain level (N2) [5]. The tests have confirmed the rightness of changes made to the structure of articulated joints. They also showed that applied coupler structure and technology allows for easy connection, replacement or removal of the barrier segments if necessary.

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