DEVELOPMENT OF MOBILE ROAD BARRIER MADE OF ULTRA-HIGH PERFORMANCE FIBRE-REINFORCED CONCRETE

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1. Introduction

Mobile barriers can be used for more flexible protection against vehicle ramming attacks and can be easily removed when not needed. Since these barriers are usually not connected to the surface, their working principle usually uses just their mass and friction to stop the incoming vehicle. This means that they are very hard to set up, remove and transport. It is therefore desirable to have relatively light mobile barriers, that would interact with the impacting vehicle in such a way, that mass of the barrier is not the main stopping principle.

One such barrier is the Czech Hedgehog developed in the 1930s for military defence. The barrier consisted of three steel beams of the same length connected in their centres. The intended stopping principle was that the Hedgehog would roll underneath a moving vehicle, lifting its tracks off the ground, therefore completely immobilising it.

In this research, the Czech Hedgehog is revisited using ultra-high performance fibre-reinforced concrete with additional steel reinforcement. This barrier was tested in real life conditions using ordinary road vehicles.

2. Material

Ultra-high performance fibre-reinforced concrete (UHPFRC) that was used to create the barriers was applied in previous studies and is in detail described elsewhere [1,2]. Fibres added into the mix were straight steel smooth fibres with length and diameter of 14 mm and 0.13 mm, respectively.

3. First attempt

At first, the barrier was created to resemble the original Hedgehog in terms of size. 1500 mm was chosen for the barrier segments' length. Therefore, the assembled barrier was approximately 930 mm tall. The three segments, from which the barrier is assembled, are identical and are connected using a single steel bolt 20 mm in diameter. At the ends, there are steel plates which are welded to the reinforcement bars (two bars 6 mm in diameter). These plates are used to strengthen the segments' ends for better interaction with the surface. The assembled barrier is shown in Fig. 1. Weight of one segment is approximately 50 kg.

Fig. 1. The barrier for the first crash test.

The barrier was first tested with a full-scale crash test using an ordinary road vehicle weighing approximately 1300 kg. Speed of the vehicle before the impact was chosen to be 48 km/h (30 mph) according to the PAS 68 [3]. Three barriers were placed in a line perpendicular to the vehicle's path. Barriers were tied together using a steel rope. The barrier in the middle was placed directly against the incoming vehicle.

From the captured high-speed camera footage, it is clear, that the middle barrier failed very quickly after the impact. The steel rope connection between the barriers also failed, but was strong enough to propel the side barriers which caused damage to the sides of the vehicle, but didn't contribute to slowing the vehicle down. Failure of the barrier occurred, where the segments were bolted together. An important observation for later studies was the interaction between the barriers' steel ends and the asphalt surface. In Fig. 2 the segment can be seen carving into the surface, leaving in it approximately 5 cm deep groove.

Fig. 2. The first crash test.

4. Numerical simulation

After the first experiment, numerical simulations were carried out to better understand the behaviour of the barrier. All simulations were made using LS-DYNA. Barrier outlined in the previous chapter was simulated together with different variants in terms of size. Additionally, an asymmetrical barrier (with one segment longer than others) was tested. Asphalt surface was simplified in these simulations due to insufficient data from the experiment. Several surface parameters were tested, which confirmed that surface quality (in terms of its softness) plays a crucial role in the barrier's behaviour. For the next experiment, an asymmetrical barrier (Fig. 3) was chosen, as it showed the best behaviour for softer and moderately harder surfaces. Additional steel reinforcement was used.

Fig. 3. The second crash test setup.

5. Second attempt

The second crash test experiment was carried out with similar road vehicle impacting again at 48 km/h (30 mph). Two rows of barriers were placed against the vehicle to ensure it would come to a full stop. The barriers were also placed much closer to each other in one row and were not tied together. The vehicle impacted approximately to the centre of the first row.

This time, the barriers managed to completely stop the vehicle by lifting its front of the ground. From high-speed camera footage, it was clear that the second row of barriers was needed. The barriers did perform as expected based on the numerical simulations

Fig. 4. The second crash test result.

6. Conclusions

In this research, UHPFRC was used to revisit the Czech Hedgehog design to create a modern mobile barrier intended to stop a relatively fast moving road vehicle. It is clear, that simply copying the historical design will result in a non-effective barrier for these kinds of situations.

After the first crash tests, numerical simulations proved that the barriers need to be smaller than the original design and that asymmetrical geometry could prove beneficial in terms of interaction with the vehicle. This was confirmed with the second crash test, where a full stop of the vehicle was achieved, but two rows of the barriers needed to be used. It is clear, that the barriers' effectiveness is strongly dependent on the surface properties.

Acknowledgements

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References

[1] Bažantová Z., Kolář K., Konvalinka P., Litoš J., Petrtýl M. Controlled Hardening of Silicate Binders for the Optimization of High Performance Composites. *Key Engineering Materials*. 2016, **722**, 281-285.

[2] Kolář K., Bažantová Z., Konvalinka P. Suchá prefabrikovaná směs multifunkčního silikátového kompozitu. 2015. CZ 306663 B3. Czechia: Industrial Property Office

[3] BSI Group (2013) BS PAS 68 Impact test specifications for vehicle security barrier systems.