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PROTECTION OF SOFT TARGETS – VERIFICATION OF THE EFFECTIVENESS OF THE ANTI-TERRORIST BARRIER

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Abstract. The security of the population and its protection in the context of terrorist attacks is currently one of the major topics of the professional public and security forces. A number of attacks in the last decade have targeted soft targets, which, according to a generally valid definition, can be considered as places with a high concentration of people and a low level of security against violent attacks. In order to ensure maximum effectiveness in protecting soft targets, a number of procedures and methodologies have been developed to determine appropriate measures and their appropriate application. From a technical point of view, these include mechanical barrier systems and elements. It is mechanical barrier elements that are the focus of this article, which uses a selected specific device to present its function, its possible applications, and the issue of testing before use in practice.

Keywords: Mobile barrier, crash test, impact, antiterrorist.

1. Introduction

In recent times, several terrorist attacks have been perpetrated, which naturally caused a response not only among the general population, but also among the professional public and the security forces. A number of attacks in the last decade have targeted so-called soft targets, which, according to a generally accepted definition, can be considered as places with a high concentration of people and a low level of security against violent attacks. Terrorists have exploited their inherent vulnerability because of their open and public location. These include attacks on gatherings during religious festivals, tourist sites, entertainment, or shopping centres.

Regarding the effort to ensure maximum effectiveness of soft target protection, a relatively large number of methodologies have been developed to select the right measures and their application. Measures can be categorized according to several criteria, the most basic of which include a division according to the time of use. These include preventive measures, which operate before an incident and seek to minimise the probability of its occurrence, measures applicable during an incident, which may include, for example, the response of security system staff and their action according to a prepared plan, and measures operating after an incident and mitigating its effects. From a technical point of view, these include organisational and security measures, signalling and monitoring systems and, finally, mechanical barrier systems and elements.

Mechanical barrier elements are the focus of this article, which presents their function, possibilities of application and the issue of testing before use in practice.

2. Barrier elements and systems

Currently, traffic safety barriers consist mainly of concrete or stone elements, which usually have low containment and low aesthetic value. This issue is summarised in general terms in a document prepared for the European Commission "Review on vehicle barrier protection guidance" [6]. Which explicitly states: "... in the European Union detailed documentation on installation methodologies, cost and available products is rather limited ... special care should also be paid on barrier aesthetics and the integration of security by design concepts in the construction of such systems in particular for public spaces, like city centres".

Technical devices of this type can be divided into two groups, namely universal (and generally speaking less attractive) and created in accordance with their location. A debated issue, worldwide, is of course the parameter of the level of containment of the proposed product, in addition to its appearance.

A basic and generally portable solution that can be seen in many Czech and foreign cities is the New Jersey concrete crash barrier, in several different designs and sizes. An example is illustrated in Figure 1.

Both experts and city residents for appearance and efficiency sometimes reject these barriers [1]. The efficiency is limited, among other things, largely by the correct placement and use. As a stand-alone element, the functionality is very limited, as is the case if no attachment to other elements or to a solid base is made. It is therefore a barrier that can deter, restrain

FIGURE 1. New Jersey crash barrier used in Prague [1].

FIGURE 2. Concrete blocks used in Melbourne [2] and large-volume planters in Prague [3].

FIGURE 3. Combination of designer flowerpots and benches in Cardiff [4] and Benches offered as a safety measure in the UK [5].

and, if used correctly, stop a potential attacker, but in most cases will not be effective to the extent required. The aforementioned appearance criterion is also not to be overlooked.

Stand-alone concrete or similar material cubes, which can be found in various European countries, seem to be less effective and in many designs not very suitable. In addition, to restricting or preventing access to the traffic flow, they can act as part of the urban furniture, e.g. like in Figure 2. However, these solutions also have many critics and are therefore not very welcome.

The significantly higher efficiency, but very unsuitable appearance for urban use in peacetime, is often mentioned for other types of devices, namely the Czech Hedgehog [7]. Thus, more suitable solutions include, for example, urban furniture that is combined with greenery – the large-volume planters known in Prague, but a more interesting and aesthetically acceptable solution than concrete blocks. The Figure 3 shows the use of the 'flowerpot' motif in Cardiff, Wales. However, the use of even these barriers is bound by many rules and cannot, in principle, be used on their own. In this picture when used with benches. These also can be a safety barrier. However, their risk lies in the purpose of their installation and their very nature – the citizens sitting on them will be the first (only) people at risk in the event of a terrorist act.

FIGURE 4. Urban furniture – MM_at_p_02.

FIGURE 5. Collision configuration – side views.

3. Tested equipment and testing methodology

One of the newly developed devices of this type on the territory of the Czech Republic is an urban furniture, namely a modified flowerpot (see Figure 4), which will be referred to as MM_at_p_02 in this article for commercial reasons. It is a planter with a steel frame, an aluminium insert for the substrate and a wooden lining. The dimensions are 1495 × 1495 × 1000 mm and the weight of the pot is approximately 490 kg. The weight, including the sand used as a substrate, is 2450 kg.

The device in question was subjected to a barrier test by a passenger car (in this case a Skoda Octavia, 1500 kg) according to PAS 68:2013 standard [8]. According to the chosen configuration (see Figure 5), the vehicle hit the object at the prescribed speed of $51\,\mathrm{km\,h^{-1}}$ (thus complying with the specified limits of $48 \pm 3\,\mathrm{km\,h^{-1}}$) perpendicularly, thus verifying its impact properties. The focus is on the behaviour of the vehicle and the obstacle during the impact and in the short interval afterwards. To observe the deformation of the internal parts of the vehicle during the impact, the bumper was removed from the car. One of the test conditions was that the vehicle was not braked. Thus, after the impact, the vehicle moved to its final position by inertia and without deceleration produced by the braking system.

The entire test was recorded by a set of cameras, including high-speed cameras, and the test was monitored from both the exterior and interior of the vehicle. The deceleration of the car was monitored by several 3-axis accelerometers in the area of the car's airbag control unit location. The movement in the interior of the vehicle was also monitored, as well as the deceleration acting on the vehicle's occupants, represented by a Hybrid III 50 percentile male test dummy with 3-axis accelerometers in the head, chest and pelvis area. Values recorded also include vehicle weight, vehicle speed or displacement and obstacle deformation.

All of these data served as auxiliary indicators to evaluate the suitability of the obstacle design used in the test.

4. Results of testing – the vehicle and MM_at_p_02

The test was primarily to determine how the tested barrier reacts to being struck by a passenger car. The car was damaged and slowed down by the impact with the barrier in the front part of the bodywork, with the expected unprompted stopping and thus restraint of

FIGURE 6. Selected details of the impact and overall movement (top left: first contact, deformation of the grille and contact with the bumper reinforcement, bottom left: global maximum, maximum penetration of the vehicle into the obstacle).

the car by the barrier. Some frames from the process are shown in Figure 6.

The barrier was also damaged, by a displacement of 5.304 m in the direction of the x-axis, as well as by the deflection of one wall of the wooden lining, mechanical damage, and deformations to the internal aluminium liner. The test can be described by the classification code PAS 68:2013 Planter V/1 500(M1)/48/90:3,8/0.

After the impact with the barrier at full overlap, there was an area deformation of the bow, which extended up to the headlight mounting point. Thus, the external body elements were significantly deformed (breakage of the bonnet including the bonnet and the left and right front wings). The bumper reinforcement was deformed, with the deformation members destroyed, and the reinforcement was fractured. The impact was also transmitted through the brace to the supporting body stringers, which were also deformed. The deformed and fractured brace was further pushed through the radiator walls into the engine compartment where the engine accessories were damaged. The vehicle was immobilized. Final position and deformation of the car could be seen in Figure 7, the course of acting acceleration in Figure 8.

From the point of view of the auxiliary criteria for the evaluation of the main purpose of the impact test, it can be stated that some biomechanical criteria used to assess the effects of the impact on the vehicle occupants were slightly exceeded. These include, for example, the THIV criterion, whose limit value is $33\,\mathrm{km\,h^{-1}}$, in which case a value of $36\,\mathrm{km\,h^{-1}}$ was reached, the PHD criterion was exceeded (by 3.9 g) and the 3 ms criterion was exceeded (a maximum of 86.85 g was reached with a limit value of 80 g). In terms of other criteria (ASI, HIC) the limit values were respected.

Therefore, it can be considered that the device fulfils the expectations, since the incoming vehicle was arrested and the consequences for the crew would not have been severe. Therefore, in the case of an accident, the error forgiving traffic element rule is respected, and in the case of a terrorist attack, exceeding the mentioned limits is not a serious negative.

5. Results of testing – anti-terrorist effects

For such a used element of urban furniture, it is also necessary to evaluate the consequences of the impact on its surroundings, specifically on the inhabitants in the vicinity. The aim was therefore to evaluate the possible injuries of the people standing behind the tested object in the event of its impact and subsequent removal. The evaluation is based on the performed

Figure 7. View of the final position and deformation of the car.

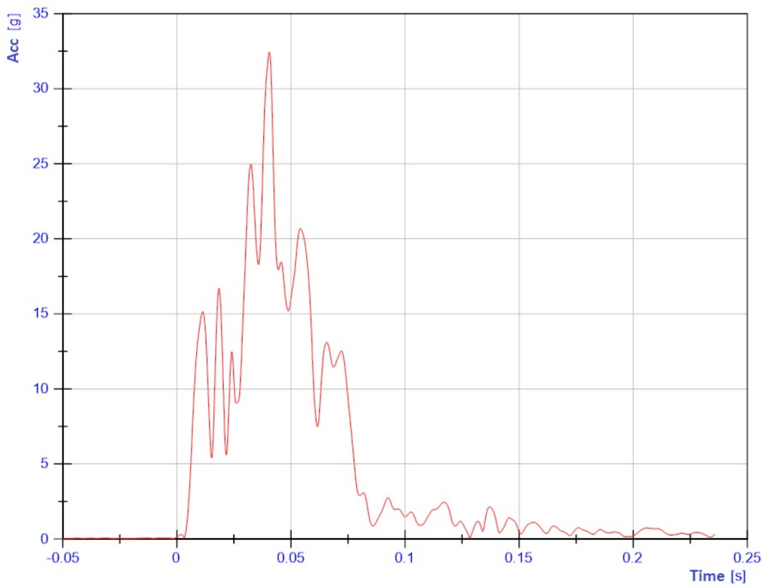

Figure 8. Course of the resultant acceleration acting on the vehicle.

impact test, on the analysis in the simulation environment and on data from the literature.

A comparative method was used to evaluate the consequences and severity of possible injuries, where data on similar impact tests and their evaluation were obtained from the literature. Due to the uniqueness of the performed test, tests with vehicle types whose front part of the body can be compared to the tested object in terms of its dimensions were used for comparison; specific values were taken from [10–12]. Due to the small sample size, small trucks with dimensions at least approximately matching the size of the obstacle were also considered. In addition to these sources, the simulation program PC-Crash 12.0, which is used, among other things, in expert practice, was also used and can be used in this sense for a simplified assessment. The person was simulated as a multibody object, which is struck by a solid object at a given velocity.

The velocity values were obtained by analysing the measured data in the crash test and are summarized in Table 1. In this way, the theoretical impact velocity

Distance from the object [m]	Impact velocity [km h^{-1}]
0.5	24.5
1	22.5
2	15.5
3	14
4	10
5	4.5

Table 1. Impact velocity as a function of the impact distance from the point of impact.

Distance from the object [m]	Impact velocity [km h^{-1}]	HIC15 [–]	Acceleration - shin [g]	Acceleration - chest [g]
0.5	24.5	247	145	40
1	22.5	227	133	37
2	15.5	156	92	25
3	14	141	83	23
4	10	101	59	16
5	4.5	45	27	7

Table 2. Biomechanical values as a function of impact velocity.

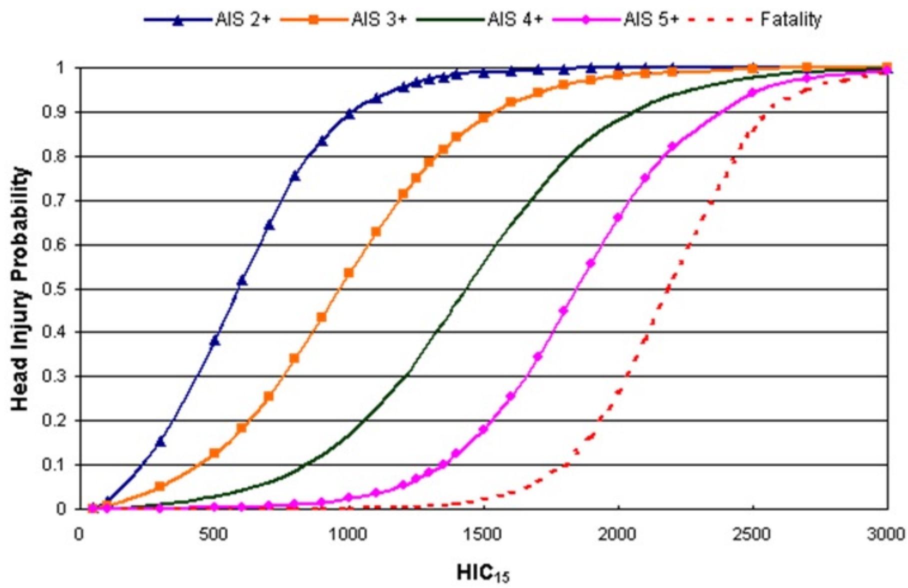

Figure 9. Dependence of HIC15 and possible consequences [9].

was found as a function of the distance of the person standing behind the test object.

The data from the individual sources ([10–18]) were compared to see if they were consistent with each other and could be included in the processing. The values were then averaged, as shown in Table 2.

The reference values were considered to be the acceleration data established by the European Enhanced Vehicle-safety Committee [11] and standardly used e.g. by Euro NCAP [13]. These are the following limits or dependencies:

- The development of a tibial fracture or more severe damage at a load of more than 150 g.
- The development of a fracture in the thoracic region or more serious damage at a load of more than 60 g.
- Head injury according to the graph in Figure 9, which shows the relationship between the magnitude of the HIC criterion and the probability of injury according to the Abbreviated Injury Scale (AIS) [9].

Based on a comparison of the highest values of the applied acceleration (at a speed of 24.5 km h^{-1}), the

Body area	Injury	Probability of injury	Fulfilling the limit value
Head	AIS2+ (headache, dizziness, minor fractures)	15 %	––
	AIS3+ (major fractures, unconsciousness)	5 %	––
Chest	fracture	the limit is not exceeded	67 %
Lower limbs	fracture	the limit is not exceeded	97 %

Table 3. Possible impact injuries.

possible injuries caused by the impact were determined, as summarised in Table 3.

6. Conclusions

The aim of the article was to present the status of the development of protective barriers applicable in urban environments for the protection of soft targets. It also includes the verification of the restraining capabilities and other properties of a specific anti-terrorism measure in the form of MM_at_p_02 flowerpot. The test and its evaluation were carried out according to the British globally used and recognised standard PAS 68:2013. Thus, the resistance to impact conducted by a moving vehicle at a defined speed was tested.

The evaluation included an assessment of the potential consequences to nearby residents, in addition to an indication of the effects on the barrier, the vehicle and its occupants. The evaluation was based on the performed crash test, on analysis in a simulation environment and on data from the literature. Based on a comparison of the measured values, literature and simulation data with generally applicable standards and conclusions used in the field of vehicle exterior safety assessment, it was determined that no life-threatening injuries should occur when the test object strikes a person.

It can therefore be concluded that the device can fulfil its purpose of restraining a vehicle used as a weapon against soft targets while maintaining the safety of the surrounding area to an acceptable degree. The resulting overall effect in protecting soft targets depends on the specific application and deployment.

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