SAFETY ASSESSMENT AND BLAST PROTECTION OF SELECTED SOFT TARGET

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ABSTRACT

The article deals with safety assessment of the building which can be considered as soft target. The building can be a place of the future bomb attack. The article specifies assessment of such blast loaded structure based on the maximal value of the pressure on the window, as crucial part of structure, and the level of possible injury of people. At the end blast protection of selected object is design. The aim of the article is to show the possible threat of persons in the building of Žilina University canteen where a social event takes place.

KEYWORDS

blast wave, bomb attack, debris, windows resistance, safety

CLASSIFICATION

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INTRODUCTION

Over the last few years, the number of terrorist attacks in Europe has increased considerably, causing considerable tension and nervousness. Not only in Europe, but around the world, terrorist attacks and other violent crimes are increasingly concentrated in the vicinity of targets that are easy to access, characterized by a high concentration of people and a relatively low level of protection – soft targets and critical infrastructure that make us more concerned with protecting and defending these goals. With theoretical aspects of critical infrastructure protection deal Hofreiter and Zvaková [1].

Due to the activities of Slovakia, it is not excluded that some terrorist cell in Europe decides to attack our state as revenge for the activities of Slovakia in the global fight against terrorism. However, due to the overall Slovak atmosphere and the position of Slovakia, it is more likely to increase radicalism either in the form of right-wing radicals, religious conservatism or fundamentalism, but also in the activities of individuals with the aim of combating the lack of society (such as the legalization of light drugs, registered partnerships of same-sex partners, against inappropriate citizens or immigrants). Recently, such attacks by so called Lone Wolves are unfortunately more frequent, and they are no longer only abroad, but they are already in our territory. On December 28, 2011, at street of Protifašistických bojovníkov in Kosice in the McDonald’s fast-food there was an explosion of a trap explosive system that only by chance accidentally did not injure the customers of operation. The attacker’s personal goal was to alert on the animals killing [2].

The target of these attacks could become the academic ground as a space for meeting political streams, progressive views, and significant liberalism. Discussions on the prohibition of abortion or, on the contrary, on the legalization of light drugs can cause individuals to intervene and demonstrate their disagreement. Therefore, it is not excluded that the academic ground will become the target of a Lone Wolves’ attack in the future. The act of such a “Lone Wolf” can also be a common revenge for unsuccessful college studies.

SOFT TARGETS

With soft targets, many problems are now linked, from the inability to create a single internationally valid definition, to the creation and application of appropriate security system. An increased number of terrorist attacks and other violent crimes is putting pressure on an urgent solution to this issue. Attacks on soft targets have recently become the most used way of influencing government powers and intimidating people.

In order to work on creating an appropriate security system that can be applied to protect selected objects, soft targets need to be properly defined. Despite the absence of a definition, the concept of soft targets generally refers to people, people assemblies, and objects in which a large number of people are concentrated, these objects are not at all or insufficiently protected against terrorist attacks and other violent crimes.

Based on the above , we can consider as a soft target:

- schools, school facilities (gymnasiums, dining rooms, dormitories etc.),
- Sports facilities
- shop centre,
- theatres and cinemas, concert halls,
- bureau,
- cafes, restaurants, bars,
- churches and church monuments,
- markets and fairs,

- polyclinics and hospitals,
- hotels,
- square,
- museums and galleries,
- train and bus stations, airports, ports, train sets, airplanes,
- various gatherings of people.

These objects are also specific because we talk about them as soft targets only in relation to serious incidents (violent crime – such as mass shooting) or terrorist attacks against which they are poorly protected. This means that in the case of other types of crime, such as property crimes, they are / can be adequately protected (they have a quality camera system, alarm security and emergency systems, physical protection, ...).

The identification of risk soft targets that could become the target of the attack is very important, but at the same time it varies depending on the particular local environment under consideration. For the purpose of this article, we studied soft targets in the local environment of Žilina city. Using the CARVER method to identify important and very important things (objects), we identified as a risky soft target in the city of Žilina the building of Canteen of the University of Žilina.

OBJECT DESCRIPTION

The building of the University Canteen of University of Žilina is the scene of various cultural and social events. Recent social event, connected with celebrations of the 65th anniversary of the founding of the University of Žilina, where hosted over 600 former and current members of the academic community. The canteen of University of Žilina is shown in Fig. 1.

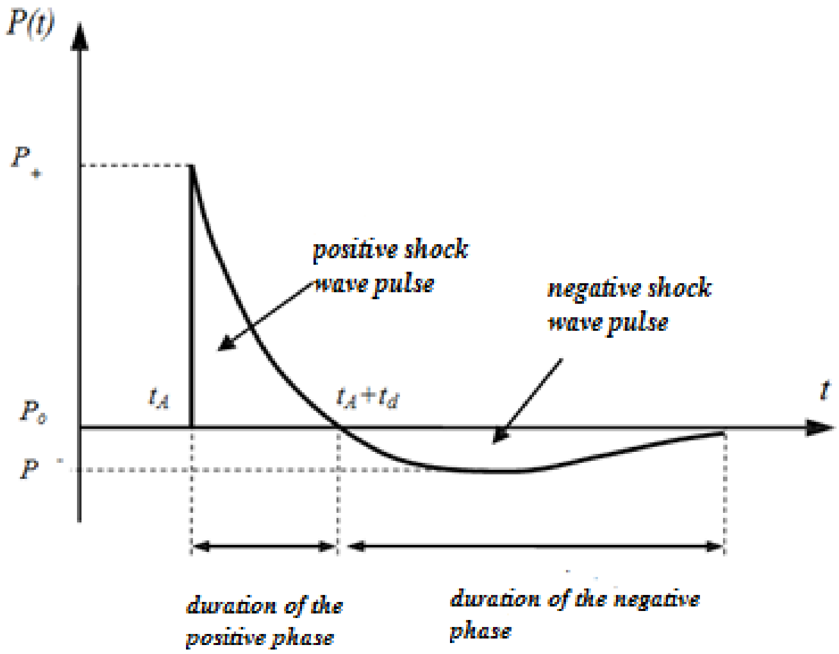
The building is located on the street Vysokoškolákov 26 in Žilina. It is situated in a forested area in a mild hill. There are three access roads to the building, one designed for cars and two for pedestrian access. Due to the large number of students and tearchers and other personels eating daily in this facility, the potential risk of the attack is a great.

Structure of the building consists of fenestration (glazing) and bearing pillars. The glazing is composed of a series of 32 glass panes with two glasses in frames made of plastic profiles reinforced with galvanized steel. The height of the glass wall is 354 cm and the width is 704 cm. In the case of a bomb attack the most vulnerable part of the building to the violation and the subsequent threat to the population are glazed walls. For these reasons we will focuse on the fenestration.

Figure 1. Fenestration of the surveyed structure.

BLAST WAVE PROPAGATION

In the case of initiation of a explosion system, a very strong exothermic reaction occurs. During the reaction, the solid and liquid component of the explosive gas is transferred to the high pressure gas. Explosive products are expanded into the environment under high pressure and strive to find balance with the surrounding environment, resulting in a shock wave. This is characterized by a change in pressure, density and temperature on its frontage. The shockwave process is characterized by a steep increase in pressure at the beginning of its course. Once the maximum value has been reached, the phase goes down, which continues until the negative phase produces a vacuum for a very short period of time, resulting in the drawing of the vapor and air from the environment towards the epicenter of the explosion. Upon leveling, a positive shock wave occurs, but no more than the first recorded pulse. The entire process is generated at very short time intervals, in the order of hundredths of a second [3].



P_0 – initial (zero) value of pressure
P_+ – maximal pressure
P_- – minimal pressure
t_A – arrival time of blast wave
t_d – duration of blast wave

Figure 2. Propagation and phase of pressure wave [3].

During the blast wave, we recognize the two phases – positive and negative. The size of the negative phase pressure is much smaller than in the previous positive part. In analyzes of determination of the response of a construction structure when initiating a explosive system, it is contemplated to idealize the course of the pressure wave to the triangular waveform, i. e. linear function. In further analyzes, such function will be considered.

WINDOWPANE FAILURE

Two cases may occur when the window is damaged. Either the glass breaks or the entire window pane is thrown out.

The breaking of the window panes, when the pressure wave is applied, occurs if one achieves either the bending strength of the glass or the critical angle of the window pane. The removal of the entire window structure from brick or other wall construction material determines how is secured the shear load bearing capacity of the window-to-wall connection. The draw-off of the entire window wings determines on the direction of the load on the window wing and the shear strength of the window frame tructure and further the tensile or shear or bending strength of the hinges according to the arrangement of the entire window structure [4].

The possible deflection of the glass is also the deformation of the window leaf by bending. If the bending capacity of the frame is exceeded, the window frame may break. In case of large deformations, therefore, the bending capacity of the glass is exceeded, resulting in horizontal cracks at the point of greatest stress and thus in the reduction of the load-bearing capacity of the whole window pane [4].

How much pressure is created and the construction is affected by explosion it depeans on many parameters. The basic parameter is the type of explosive substance, the weight of the explosive and the distance from the building. It is decisive how the pressure wave propagates, whether it is perpendicular or oblique, or is reflected or obstructed by an obstacle.

In the bomb attacks mentioned, homemade explosives are used. The worldwide trend is that ammonium nitrate and fuel oil (ANFO) is the most commonly used. Ammonium nitrate is industrially produced in huge quantities and under certain circumstances is itself capable of explosion. With a small amount of fuel added, its sensitivity and explosive properties increase sharply. For our research, we have selected the factory-produced called DAP-2, which has the same properties, as a substitute for the homemade ANFO explosives.

The explosive is a mixture of ammonium nitrate, kerosene and dye. Its detonation velocity is 2 600-2 700 m/s and the explosion heat is 3 830 kJ/kg. At a density 0,65 g/cm^3 the PCJ detonation pressure is 2,95 GPa. With resistance of the object from the effect of explosion of homemade ANFO explosive deal Zvaková and Kavický [10].

Therefore, to determine the maximum value of the overpressure of such a window pane can be made in two ways. When exact mechanical properties of the glass are known, calculating its ultimate strength, i.e. flexural strength, or as mentioned, the angle of the window pane break is possible. In our case, we do not know the precise mechanical properties of the glass used and therefore we will proceed according to the research of Makovicka [4].

Window failure can be estimated from nomograms (Figure 3) based on experimental and theoretical analysis of window glasses under triangular overpressure of blast wave. The maximum overpressure size depends on the size of the glass surface, the glass age (differentiates new and old glass, 10 years), the thickness of the glass and the duration of the overpressure. In our case for 85×85 cm^2 = 0,7225 m^2 glass panel, we expect 10-year glass, 3 mm thick.

Using the above mentioned DAP 2 explosive, considering the distance of the pane from the center of the explosion 1 m and the weight of the charge of 0,5 kg, the length of the overpressure is determined by 1,5 ms. From the graph (Figure 3), based on the above values, we determine the size of the wave pressure, which is approximately 10,0 kPa. An explosion of 10,0 kPa will cause damage of the glass. With procedure of the window systems reaction to a shockwave load deals Zvaková in [9].

Ratio of dimensions of window $a/b = 1$.

By the aforementioned procedure, we obtained the maximum pressure that the analyzed pane will carry. In order to suggest possible protection of the object and people, it is necessary to find out what type of explosive, how much weight and distance will cause such explosion. Several approaches from different authors exist to determine strength. We will describe the procedure according to Mills [3]:

$$P = \frac{1{,}772}{z^3} + \frac{114}{z^2} + \frac{108}{z} - 0{,}019. \tag{1}$$

This is the law of the third root, which introduces the reduced distance z

$$z = R \cdot W_R^{-1/3}, \tag{2}$$

where R is the distance from the center of the explosion and W_R is the reduced weight of the charge.

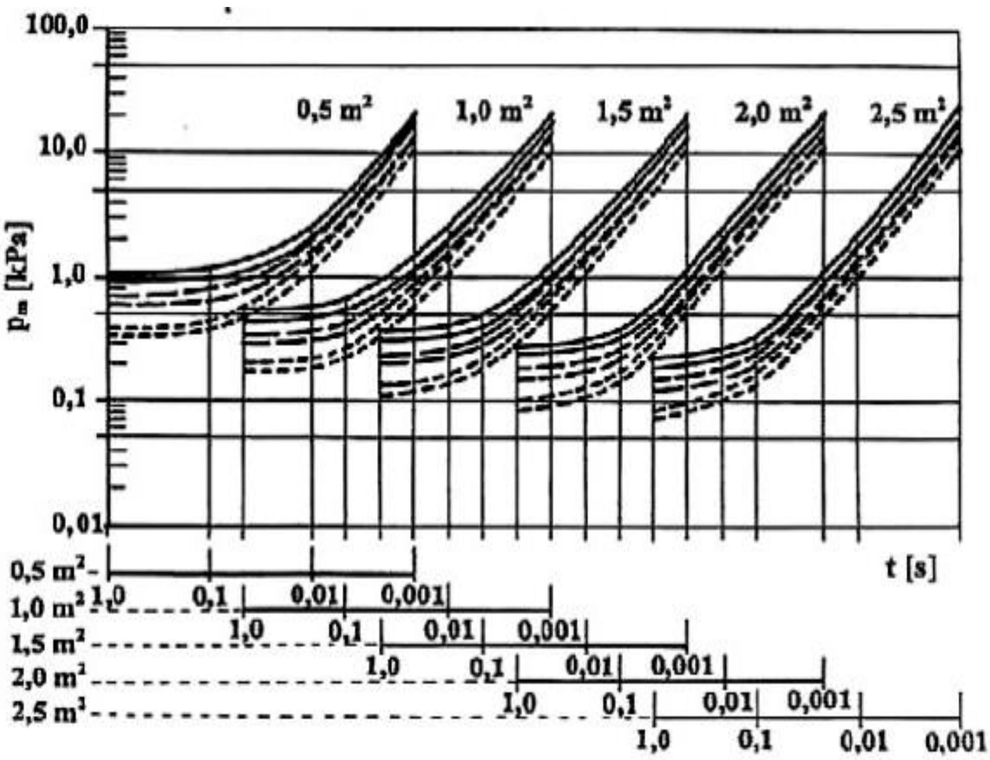


Figure 3. Strength of a window glass [3].

Hence, if the maximum pressure is 10 kPa, from formulas (1) and (2) we obtain that a pressure of 10 kPa on the pane is created with 0,5 kg of DAP 2 explosive at the distance of 10 m. Thus stand-off distance is very critical. It is clear from Table 1 that the closer the source of the explosion is, the greater pressure on the structure is induced. At a very close distance, the pressure increases markedly. The second part of the table shows the pressure-to--weight ratio. From these values, it is possible to assure a devastating effect of the explosive, even with a small amount of the explosive if it is close to the construction.

Table 1. Influence of change of pressure of the explosive system on the distance and weight of the charge.

distance, m	10	8	6	4	2	1	0,1
pressure, kPa	9,77	13,00	19,45	37,60	159,42	958,58	815 532,00

weight, kg	0,5	1,0	1,5	2,0	4,0	6,0	8,0	10,0
pressure, kPa	9,77	13,14	15078,00	1801,00	25,77	32,27	38,14	43,67

As well as window panes, window frames have been experimentally verified. Table 2 was compiled to estimate the strength of the window frames [4].

Table 2. Damage to buildings at various pressures [4].

Pressure, kPa	Effect
< 0,5	No damage
0,5 – 1	Small damage to window fills (only part, glass cracks without debris, etc.)
1 – 2	Greater damage to window fills, partial wiping of glass wreckage)
2 – 5	Partial damage to door and window frames, façade and interior wood partitions
5 – 20	Window destruction, damage to light structures and common brick structures
10 – 30	Partial disruption of the buildings of mostly family houses
20 – 30	Significant disruption of urban multi-story buildings

INJURIES OF PERSONS

In the previous calculations, the pressure required to destroy the windows was set to 10 kPa. From Table 3, it follows that the standing person will be buried in the level of 15 kPa. As we suppose, people staying in the dining room behind the window panes, will be damaged by the secondary, by flying out fragments of the windows. Because the structure is not sufficiently resistant to destruction and structure breakage, fragments penetrate into space in the direction of shockwaves and threat the persons. Especially dangerous are small overpressures in the range of 5 kPa to 20 kPa, in which it is highly probable that people will be wounded by wreckage (at a great distance of tens to hundreds of meters) of broken glass windows and doors, at this pressure the slags are not thrown to the ground, [4]. Extreme fragments of different sizes are created by the shock wave effect, resulting in interruptions in the integrity of the window panel, which are capable of acting on a relatively large area. Flying glass fragments most often cause traumatic injuries or penetrate human bodies that are unable to withstand this kind of action. Larger objects coming from damaged building materials cause a devastating injury caused by a combination of weight and speed of the body [5].

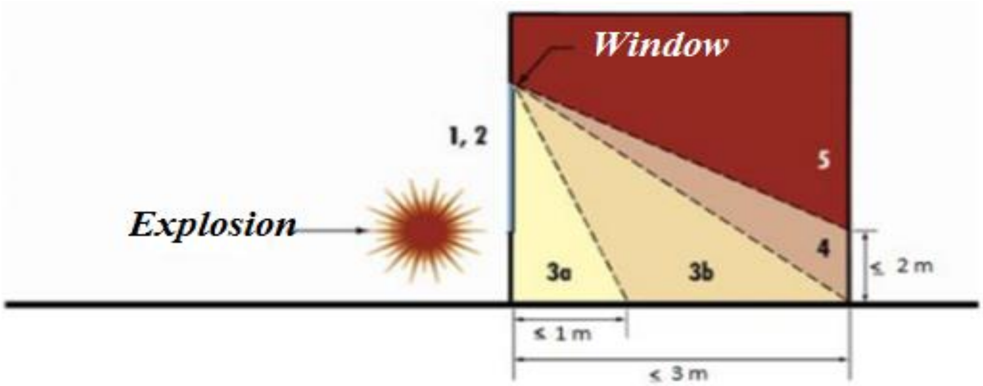


Figure 4. Areas of varying degrees of injury caused by fragments of broken glass [5].

In order to determine the possibility of damage caused by glass fragments, a scale of injuries can be used from a material viewpoint and a method of solving the window filler. The scale has several points. The difference between stages 3a-3b represents the boundary level of injury, where the severity of the point 3b derives the assumption of injury to persons exposed to the cracks created by the window fillers. Another level can be determined at the point between points 4 and 5, where people at the place indicated by point 5 have very serious or even fatal injuries [5].

Table 3. Injury of persons at various pressures.

Vulnerability Group	Overpressure, *P*, kPa	Description of the injury	
0	< 10	Damage from the direct action of the pressure wave is unlikely	
1	10 – 30	Easy injuries to people	At a pressure of approx. 15 kPa, the standing person is buried
			At a pressure of about 34 kPa, the earbuds will crack
2	30 – 150	Severe injuries to persons	
3	150 – 200	Fatal injuries	

PROTECTION DESIGN

A potential bomb attacks is very difficult to predict, but due to the unfavorable current situation in the world and the increasing number of anonymous threats, appropriate protection features have to be applied. One solution could be the installation of protection against waves caused by an explosive system. The bomb attack will cause considerable damage to the building, which means disturbing the bearing system of the entire building. One solution is to use additional material (so called terofit technique) to increase building resistance. By using recyclable materials they have dealt with research Figuli, L. et al. in [6]. The solution will be the PAXCON PX3350 protective spray application for bearing walls (Figure 5). This type of spraying is used to dampen the action of explosive ammunition, is particularly suitable for enhancing building resistance – significantly reduces secondary damage. The PX 3350 is spray-applied and applied to the walls of a building that is exposed to the risk of a bomb exploding. Spray walls resist explosions due to their ability to bend, ultimately resisting explosions much larger than normal uncoated walls [7].

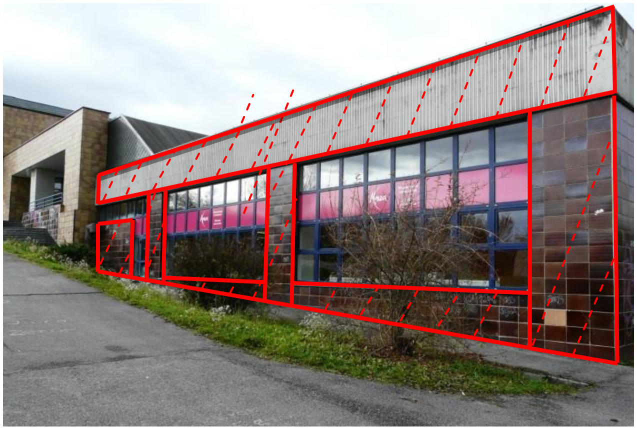


Figure 4. Application of PAXCON PX3350 [9].

Figure 5. Installing security films [9].

Subsequently, because of the large glazed part of the building, it is necessary to install safety glasses for windows, which prevent the glass from breaking into the interior of the building. Security window films are polyester or PET films that are applied on glass surfaces, in order to hold together possible shatters after glass cracking. The main advantages of security films is that they can be applied on glass after manufacture or installation (Figure 6), i.e. in the form of pure retrofitting product. These films are available in various thicknesses, generally in the order of 100 μm, up to 525 μm [7]. For the better protection of present people, special bomb blast net curtains and catchers are intended to protect people inside buildings from exterior explosions. The nets cover windows inside buildings and are aimed to catch and retain flying shards of glass, preventing the whole glass panels from being dislodged by blast wave.

CONCLUSION

When we determine the maximum pressure load that the windows transfer to the building of Canteen of University of Žilina, we have come to various partial conclusions. An overpressure value caused by 10 kPa explosion to which the window pane is low. Such a pressure in itself will not cause very serious personal injury. Persons will, despite this claim, be seriously threatened and injured due to the secondary effects of fragments of broken glass. A pressure of 10 kPa can already develop a 0,5 kg DAP 2 load at a distance of 10m from the building. In order to protect the population and the building, effective action should be taken to prevent catastrophic consequences, to increase the strength of window panes, to prevent access to the immediate vicinity of the windows.

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