NATO Science for Peace and Security Series - C:
Environmental Security

Soft Target Protection

Theoretical Basis and Practical Measures

Edited by
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This publication is supported by:
The NATO Science for Peace and Security Programme

Soft Target Protection

NATO Science for Peace and Security Series

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Series C: Environmental Security

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Springer
Published in Cooperation with NATO Emerging Security Challenges Division

Proceedings of the NATO Advanced Research Workshop on Soft Target Protection
Prague, Czech Republic
17–19 October 2018

ISBN 978-94-024-1757-9 (PB)
ISBN 978-94-024-1754-8 (HB)
ISBN 978-94-024-1755-5 (eBook)
https://doi.org/10.1007/978-94-024-1755-5

Published by Springer,
P.O. Box 17, 3300 AA Dordrecht, The Netherlands.

www.springer.com

Printed on acid-free paper

Preface

The advanced research workshop (ARW) ***Soft Target Protection*** was organized by the University of Žilina (Slovakia) and National Technical University "Kharkiv Polytechnic Institute" (Ukraine) in cooperation with Czech Technical University. The workshop has been supported by NATO Science for Peace and Security Programme.

The security situation in the contemporary world has deteriorated significantly over the last period, as is shown by the growing number of attacks on assets characterized by low levels of protection and high concentration of people – soft targets. Almost always, these attacks are accompanied by a large number of casualties. The deterioration of the security situation also entails an increased need to protect and advocate the soft targets. We are currently facing several problems – the inability to create a unified internationally valid definition of soft target, to applicate it for creating an appropriate security system. At the moment, very few countries have begun to put effort into the improvement of the situation. It is highly important to constantly raise awareness of the possibilities and ways to solving the problems.

The workshop was focused on the protection of soft targets, highly topical issue nowadays, due to the increasing number of terrorist attacks and armed conflicts, where innocent people are suffering. As NATO partner country, the Ukraine was chosen, which has direct tough with the war and suffering of innocent people. Thanks to the partnership of the Ukraine and Slovakia and attendance of great number of highly recognized speakers from various countries (the Ukraine, Slovakia, the Czech Republic, Hungary, Poland, Italy, Slovenia, and France), the workshop could bring mutual change of knowledge.

The workshop covered different areas of soft target protection, such as theoretical aspect of soft target protection, counterterrorism, technical and technological solutions for soft target protection, scheme and organizational measures, blast protection, and forces for soft target protection.

This publication contains selected papers from ARW *Soft Target Protection*, which took place at Masaryk Dormitory Congress Centre in Prague (Czech

Republic) on 17–19 October 2018. We are grateful for the contribution of all the authors and reviewers of the manuscripts.

Finally, as guest editors, we would like to express our sincere appreciation to the members of the scientific committee, the editorial committee, and the advisory board for accepting the opportunity to work with us.

We are grateful for the generous support of Czech Technical University in Prague, Faculty of Civil Engineering, for their help with the organization of the workshop, and we are most grateful to the staff of the Springer Nature BV for their assistance with editorial matters.

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Chapter 1
Investigation into the Benifits of Post-Fire Corridor Smoke Clearance in the Early Stages of Fire Development in Very Tall Buildings

Aaron Mc Daid, Murali Ramaiyan, Wali Hasan, and Tom Sagris

Abstract As building heights continue to grow to new levels, different fire safety challenges arise. In particular, challenges relating to fire safety has become a particular concern due to the difficulty of firefighting at such heights.

The main aim of this paper is to investigate the provision of corridor smoke clearance as a means to assist internal firefighting and early fire evacuation in a study of smoke dynamics during live and simulated tests. The study was conducted in a super high-rise tower during its construction stage and assessed using computational fluid dynamics modeling to further understand the different dynamic phenomena.

The experiments took place on the 19th floor of a 43-story residential building with a floor layout repeating throughout the building. The building is under construction and the experiment was carried out as part of the project task to measure the performance of the corridor smoke control system. Based on the study, the provision and activation of the post-fire smoke clearance within the common corridor upon a detection within the floor, the system aids the corridor to be tenable and safe environment for firefighters to carry out their firefighting, search and rescue operations. The system also helps to reduce the full incident floor evacuation travel time, as the visibility is maintained within a short period.

This research is considered as novel in that involves the use of live experiments and computer modeling to understand smoke behavior. It also assesses the benefits of corridor smoke clearance which is typically not used in high-rise buildings internationally. This paper describes the experiments, computational analysis and information gleaned from the research and provides conclusions for consideration by others in the field of super high-rise building design. By assessing the smoke movement within the egress corridor for a plausible fire scenario it is possible to understand the potential benefits of providing post-fire smoke clearance within the egress corridor.

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L. Hofreiter et al. (eds.), *Soft Target Protection*, NATO Science for Peace and Security Series C: Environmental Security,
https://doi.org/10.1007/978-94-024-1755-5_1

Keywords Fire dynamics · Super high-rise · Very tall buildings · Smoke control · Firefighting · Residential buildings

1.1 Introduction

The number of very tall buildings increases almost day by day, as the construction industry progresses, and technology enables to build even higher. But this gives rise to challenges in terms of the occupant evacuation, firefighting, fire suppression system design and smoke control system design. During a high-rise building evacuation, the time available to evacuate can be a key factor impacting the survivability of occupants. Fire engineers prescribe different active and passive fire safety measures, based on the prescriptive requirements of the project and the fire safety objectives of the design. These measures typically increase the likelihood of survivability by either preventing fire from spreading or improving the conditions of escape routes. This paper considers that latter which discusses the results of a live experiment that was undertaken on the 19th floor of a 43-story building. The term “Super High-Rise” to this paper refers to a building greater than 90 m in height.

1.2 Objectives

In order to study the impact of the corridor smoke control system within a super high-rise building structure, the study has the following objectives.

- To understand the impact of smoke dynamics within the corridor of the residential floor of the building for a given fire scenario
- To gain insight into the conditions for occupants and firefighters within the evacuation corridor during early stages of fire development for a fire scenario within a given apartment.

1.3 Fire Safety Challenges for Super High-Rise Buildings

As the building height increases the difficulties in firefighting can be considered to proportionally increase. Specifically access to the building, extending of evacuation time due to egress time and pressure difference within the building due to height and temperature differences. Below are some of the fire safety metrics which are affected by the building height.

1.3.1 High-Rise Occupant Evacuation

The full building evacuation time for super high-rise buildings are typically higher when compared to another type of buildings (low rise, midrise, and high rise). This can be attributed to;

- Occupant load (based on occupant load factor for the building occupancy) due to the number of occupied floors,
- Building's vertical travel distance to the building discharge point,
- Occupants' physical fatigues when using the building staircases for evacuation.

In most cases, full building evacuation through the staircases can be considered to be challenging and elevator evacuation or other methods (defend in place or refuge floor) can be considered for the super high-rise building. For the incident floor, evacuation is widely accepted to be required upon a confirmed fire for most countries.

As mentioned in British standards [1], the total building evacuation time is as shown in Eq. (1.1).

$$t_{\mathrm{RSET}} = \Delta t_{\mathrm{det}} + \Delta t_a + \left(\Delta t_{pre} + \Delta tt_{rav}\right) \tag{1.1}$$

The Required Safe Evacuation Time (RSET) for the floor evacuation depends on the fire/smoke detection time, the time is taken to alarm the occupants, the time taken to the floor occupants to recognize and respond to the building alarm for evacuation and the actual travel time. In most well-established prescriptive fire safety design codes internationally, fire detection and notification systems are designed to a system design standards. Hence, the detection and alarm time is considerably short, due to a technological advancement in system design and manufacturing. The pre-movement time can be improved by employing a higher degree of fire safety management in the building. One of the primary factors for the travel time is tenability along the egress routes. It is widely understood that the walking speed decreases as the smoke density increases due to the visibility reduction and irritancy of smoke [2]. Hence, active smoke extraction or smoke dilution within the egress route of the fire affected floor can potentially decrease the RSET and arguably improve the survivability on the incident floor in the early stages of fire development.

1.3.2 High-Rise Firefighter Access, Operations, and Rescue

Super high-rise buildings are above the reach of the typical fire department aerial ladders. Hence, many international prescriptive building design and life safety codes (such as NFPA 5000, IBC, BS 9999) recognize that the height of the buildings is above the reach of the fire department ladders and stipulate high rise buildings are to be designed with internal additional fire protection measures such as firefighting lift

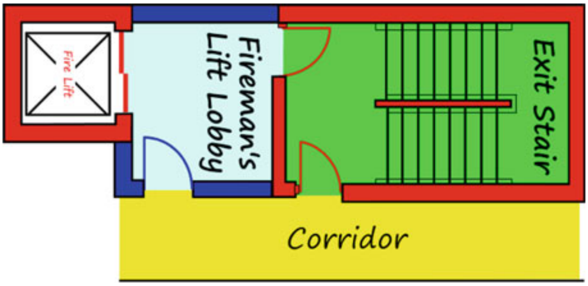


Fig. 1.1 Typical high-rise firefighters lift lobby arrangement in a high-rise

(fast access to the incident floor), protected firefighting lobby (fire separated environment to set up the firefighting operations to fight the fire) and arrangement of occupant evacuation without using the firefighting lobby [3] (to avoid smoke enters the firefighting lobby); See Fig. 1.1.

This arrangement provides a fire separated place for firefighters to set up their initial firefighting operations. However, in order for the firefighters to fight the fire or rescue any occupants, firefighters are required to pass through the incident floor smoke-filled corridor, if the smoke is spilled from the incident area to the corridor.

As the height of a building increases, the time taken for firefighters to reach the fire floor increases especially when the fire is on the upper floors. This typically leads to a well-developed fire with a considerable amount of smoke production due to the fire size (Q) (Heat Release Rate) being a factor of time (t), and fire growth rate (α) as mentioned in the following equations Eq. (1.2) [4].

$$Q = \alpha t^2 \tag{1.2}$$

It is also well documented that smoke production is proportional to the fire size [4].

1.3.3 *Pressure Difference within the Building Due to Stack Effect*

It is common that the high-rise buildings experience a pressure difference [5] throughout their height as a result of the differences between the inside building temperature and the outside air temperature. During winter, the temperature inside the building is higher than the outside air temperature and hence the entrained air to the building heated up by the building temperature and started to rise upward. The upward flow phenomenon in the building is a normal stack effect. The same phenomenon is reversed during summer and it is called as a reverse stack effect. In both the cases, the flow is based on the neutral plane of the building. A neutral plane is a horizontal plane where the indoor and the outdoor pressures are equal.

This effect is much noticeable in super high-rise buildings because of their height. Due to a pressure difference higher in very tall buildings, the stack effect causes air to move vertically upward or downward based on the air temperature inside and outside the building. If the stack effect is not controlled within the building by means of providing the smoke control system or smoke venting, it can cause the smoke to spread within the entire building.

1.4 High-Rise Firefighting Strategy

Typically, different building height reflects on firefighting strategy and operations. Different firefighting provisions are further reflected in building codes internationally in most developed countries, where firefighter lifts and lobbies become generally mandatory when a building is designed above approximately 23 m in height (High-Rise). It is considered that when a building is a high-rise, external ladder and hose stream reach is more limited. As such, generally, the fire service fights the fire from inside the building using the protected stairs and lifts. When the high reach ladder becomes ineffective due to the building height, the firefighting team is required to enter the building to access the vertical transfer mechanism such as protected stairs or a fire lift to reach the fire incident floor for firefighting or rescue operations. In order to reduce the firefighter's vertical travel time, fire lifts are mandatory requirements for high-rise buildings based on the NFPA requirement [3], which is also common for most of the international fire and life safety codes.

Depending on the height of the building, architectural design and the fire safety management within the building, the firefighter access to the fire floor and firefighting can be by different methods which are given below. All the methods for the firefighting add up to the total time taken for firefighters reach the fire floor which gives more time to the fire development and smoke production.

- Fire lift and fire lift transfer
- Firefighting bridgehead
- Firefighting staircase and an enclosed lobby

1.4.1 Fire Lift and Fire Lift Transfer

Access to the fire floor by a fire lift is the most commonly used method for the very tall buildings' firefighting, as the vertical travel time is comparatively lesser with the vertical travel via a protected stair. However, as the height of the lift shaft is higher, there could be a possibility of stack effect within the fire lift shaft. Hence, one of the design options is to break the lift shaft into multiple shafts and provide a protected transfer between them. This will reduce the stack effect, but increase the time to reach the fire incident floor if the fire incident floor is the top floor of the building.

In this design, considering the plausible worst-case scenario of fire at the top floor of a building, firefighters take the fire lift from the fire service access level for the building to reach the lift transfer level to transfer to the next lift and eventually to reach the fire floor. The number of transfers depends on the stack effect calculations and the height of the building. Hence, the total time taken for a firefighter to reach the fire floor depends on the fire lift velocity, fire lift door opening time and distance within the protected corridors in the transfer floors.

1.4.2 Firefighting Bridgehead

Firefighting bridgehead strategy can be used for a building with small floor area where there is no space for a protected place for firefighters for their firefighting and rescue operations. In this strategy, the design uses the bridgehead floor which is below the floor which does not have protected space for firefighting. If there is any fire in the floor above the bridgehead floor, firefighters arrive at the bridgehead floor and set up their firefighting operations to fight the fire in the above level. This provides protected space for the firefighters for rescue and firefighting operations. However, the firefighter is still required to pass through the smoke in the fire floor when they reach the fire floor for the firefighting and rescue operations.

1.4.3 Firefighting Staircase and an Enclosed Lobby

One of the most common firefighting strategy or the building design widely followed by many international fire and life safety codes is to provide a firefighting staircase together with the enclosed lobby. Staircase and lobby provide a protected space for the firefighters without being harmed by the fire or smoke. In recent days, the fire lift is also designed part of the staircase and lobby core, so that the firefighters reach the protected space in the fire floor via the lift. However, once the firefighters leave from the protected space, there is smoke in the fire affected floor which hinders the firefighting and rescue operations.

1.5 Experimental Study

1.5.1 Experimental Floor Layout

The floor considered for the experiment has a number of apartment units which open to the common straight corridor (Highlighted in Yellow)'; See Fig. 1.2. There are passenger lifts, firefighting lift and egress staircase located on both sides of the corridor. A lobby is provided in the middle of the corridor which separates the

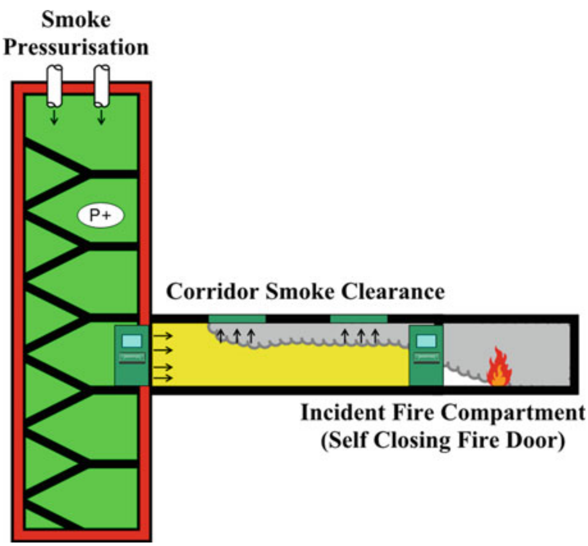


Fig. 1.2 Schematic view of corridor smoke clearance system

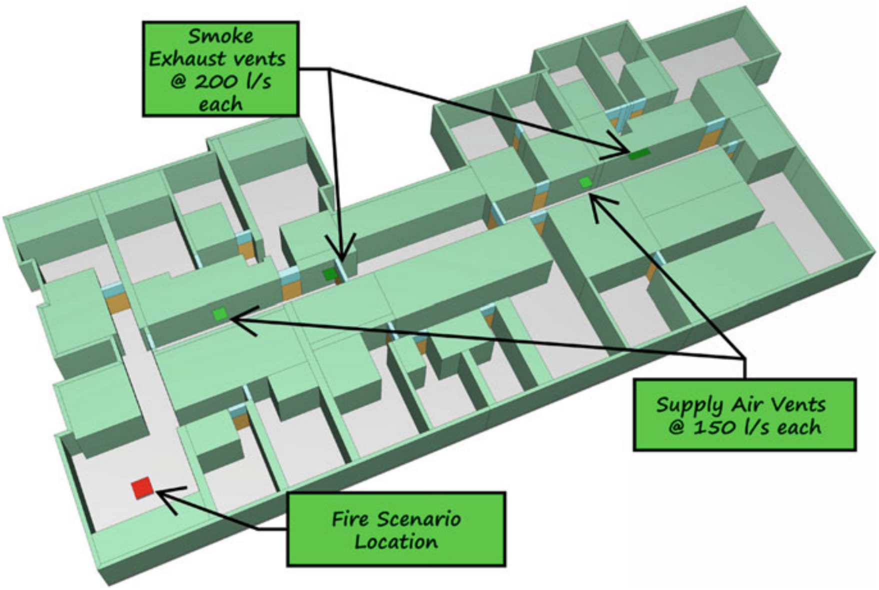


Fig. 1.3 Experimental floor layout

corridor into two parts. The lobby separates the firefighting lift, passenger lift and the staircase from the corridor. The distance between one end of the corridor (which is nearer to the chosen apartment for test) to the entrance of the lobby is 12 m and the lobby is 10 m long; See Fig. 1.3.

In order for the evacuating occupants to access the egress staircase, the occupants are required to open the apartment door traverse through the corridor as well as the lobby doors to enter the staircase. Hence, the lobby door opening is also considered for the live test and simulation.

The proposed system configuration includes the corridor smoke ventilation system sized based on 6 air changes per hour. Replacement Make-up supply air considers a provision of 4.5 air changes per hour (See Fig. 1.3).

1.5.2 Live Smoke Test (Events Chronology)

The experimental study for the use of the post-fire smoke clearance system in the early stages of the fire was carried out using a live experiment and a numerical simulation (Computational Fluid Dynamics). The performance of the system was assessed using the live experiment in the building and the results of the live test were modeled in the Computational domain to optimize and validate the model based on the live experiment results. The validated model is then used to study the behavior of the smoke within the corridor without the smoke control system within the corridor. The main performance criteria for the study focuses on the visibility and the smoke temperature along the means of egress corridor for the numerical simulation whereas the live experiment focusses on the visibility.

An idealized deterministic fire scenario was selected which considered the sequence of the evacuation of the occupant from the incident compartment. This considered a time allowance of 30 s for the incident compartment door to open and self-close; See Fig. 1.4 below.

1.5.3 Live Cold Smoke Test

The method of procedure for the live test has been formulated as follows to measure the conditions along the means of egress corridor.

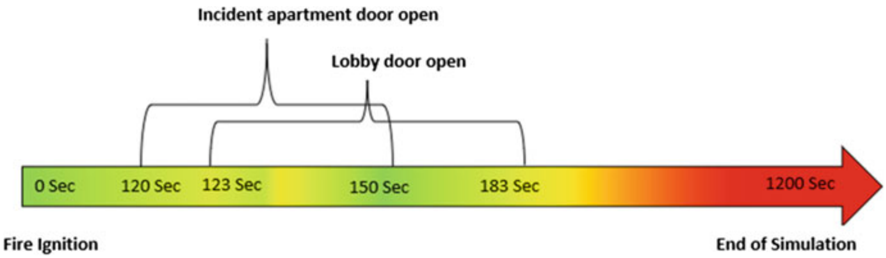


Fig. 1.4 Timeline of events

- Reviewed the system specification and drawings to determine the location of supply and extract grills, flow rates, and associated smoke ventilation components.
- Measured the extract and supply flow rates of prior to the experiment.
- Selected and identified the test location.
- Measured the ambient thermal properties.
- Setup the smoke generating machine inside the selected apartment.
- Closed the apartment door to simulate the actual condition.
- Turned on the smoke generating machine and recorded the time.
- Opened the apartment unit entrance door at 120 s to simulate the occupant egress from the apartment unit.
- Simulated the self-closing fire door mechanism in the apartment entrance door to close the door after 30 s of the opening.
- Simulated occupant egressing by opening the lobby door. The lobby door kept open for 60 s after 3 s from the opening of the apartment door.
- Recorded the time is taken to clear the smoke within the corridor (approximate visibility of 10 m or more, as per British standards [1])

As explained in the live test method of the statement, at 0 s the smoke was being generated from the smoke generation machine while the apartment entrance door is closed. The apartment entrance door was opened at 120 s to simulate the occupant evacuation from the apartment and the door was closed at 150 s to simulate the door's auto closing device. The test was carried out until the smoke (which entered the corridor due to the opening of the incident apartment door is opened) cleared from the corridor. The smoke machine continued to spill the apartment until the smoke cleared from the corridor, in order to account the smoke spilling through the apartment door leakage.

1.5.4 Numerical Simulation

In order to validate the live test and model the corridor without a smoke control system, a numerical approach was followed using an advanced CFD simulation software Fire Dynamic Simulator (FDS) [6]. The live experiment environment and design were modeled in the simulation software as a computational domain and the domain is further subdivided into small control volumes. The initial ambient conditions and the boundary conditions for the computational domain were set up based on the data collected from the live test.

The numerical model is then validated with the live test experimental results in terms of the smoke generation and the smoke clearance time in the corridor. The computational domain control volumes were chosen to optimize the model to reproduce the experimental test. Once the model is validated and optimized with the experimental results, the same model is then used to simulate another scenario which was to study the effect of the smoke spilling onto the corridor without the smoke control system in the corridor.

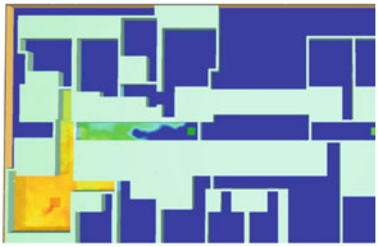
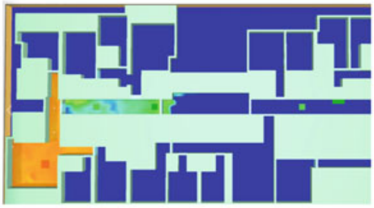
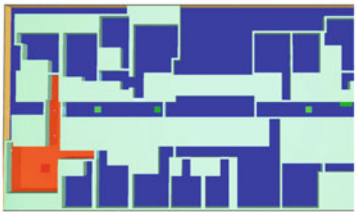
The numerical simulation for the two cases (with and without smoke control system in the corridor) were carried out for 800 s to study the impact of the extended smoke spilling from the apartment to the corridor through the door leakage. The fire size or the heat release rate for the simulation is calculated [4] based on the amount of smoke produced which was measured during the live test.

1.6 Results

1.6.1 Experimental Results

The following Table 1.1 gives a summary of the live experimental test and the validation of the computer numerical simulation model. The figures provided in the experimental test column was taken during the test at different time intervals to

Table 1.1 Experimental vs modeling results

Time	Experimental Test	Modeling Test
130 Sec		
150 Sec		
250 Sec		

compare with the CFD simulation slice files (Modelling test column) at the specific time period. As shown in the table, the apartment door is opened at 120 s and the smoke starts to spill the corridor at 130 s which is clearly captured in the experimental test as well as the modeling test. At 150 s, the apartment door is closed and at 250 s, the smoke was cleared by the smoke control system in the experimental as well as modeling test.

1.6.2 Modeling Results

Based on the live experiment, the corridor smoke clearance system clears the smoke approximately 250 s. The same has been modeled using Fire Dynamic Simulator [6] to replicate the results in the computational domain to model the experiment without a corridor smoke clearance system.

Figures 1.5 and 1.6 provides the comparison between the fire scenarios for with and without the corridor smoke clearance system. Based on the temperature data in both the cases, the environment is tenable as the temperature does not rise above 60 °C all the time except for a few seconds when the incident apartment door opens. Whereas the visibility level falls below 10 m for 250 s with the consideration of the smoke clearance system, but for the other scenario without the corridor smoke clearance system, the entire part of the corridor is untenable and the visibility falls below the 10 m level for the entire simulation.

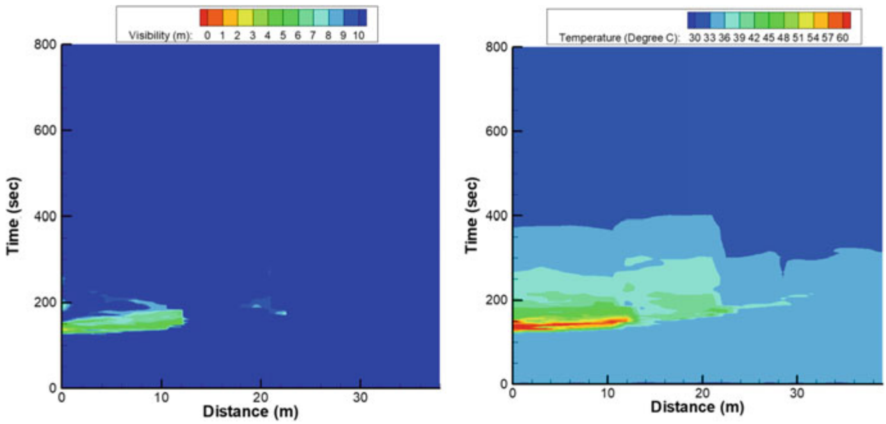


Fig. 1.5 Visibility and temperature over distance and time (with smoke clearance system)

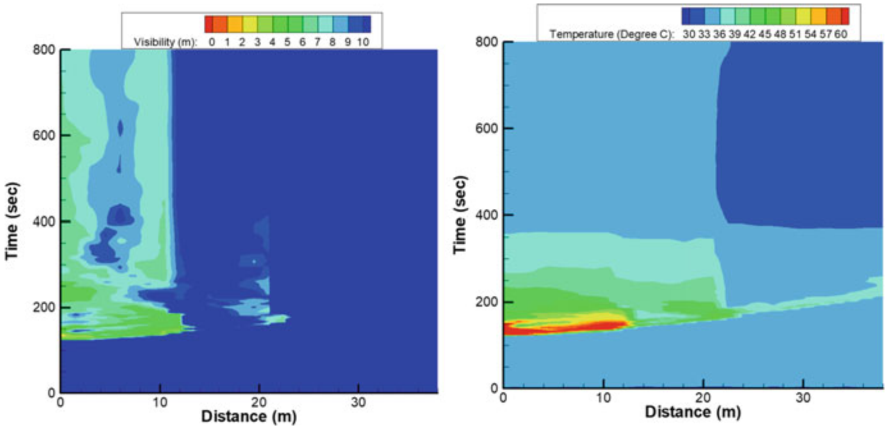


Fig. 1.6 Visibility and temperature over distance and time (without smoke clearance system)

1.7 Conclusion

This research considered a live and simulated experiment based on a deterministic fire scenario. The progression of fire development and smoke spread within the room considered the presence of a self-closing fire door in the incident compartment. Based on the simulations, it is evident that the visibility is very poor considering the no smoke clearance system in the corridor. The visibility level falls below 4 m within the corridor. This will have a negative impact on the firefighter's operations and also has a negative impact on the occupant evacuation. As explained earlier, if an egress corridor is filled with smoke, this will affect the occupants' visibility and in turns affect the walking speed. The visibility level falls below 10 m for both the cases, however, if there is any occupant who start to evacuate with a considerable delay time (due to mobility impairment or some other reason), the corridor without the smoke control system poses risk to the evacuating occupants.

The arrival time of the firefighter to the fire floor depends on the building notification system to the fire department (manual or automatic), the distance between the building & the nearest fire station and the vertical distance of the fire floor from the fire service access level. One can assume that the firefighter arrival time to the building can be in the range of 5–30 min considering the road traffic and availability of nearest fire stations. The scenario without corridor smoke clearance system does not provide a tenable environment for firefighting operations in terms of visibility.

Based on the live experiment and the numerical simulations, it is evident that the provision of a corridor smoke clearance system helps to improve the situation in the occupant evacuation and the entire process of firefighting operation. In the experimental configuration, the corridor length is small and hence the early stages of evacuation do not have any influence of the corridor smoke clearance system.

However, if the corridor length is longer and geometry is complex to reach the egress staircase, the occupant will take a longer time to reach the egress staircase. Hence, generally, a smoke clearance system in the corridor helps to improve the occupant evacuation as well as firefighting operations.

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Chapter 2
Laser Induced Shockwave as Delaminator of Composite Material for Ballistic Protection at High Strain Rate

Luminita-Cristina Alil, Michel Arrigoni, Marcel Istrate, Alexander Kravcov, Jérémy Le Pavic, and Gilles Tahan

Abstract Societal concerns on security push light weight armor for ballistic protection to remain a topic of interest. Ultra-High Molecular Weight Polyethylene composites (UHMWPE) have shown appreciable performances for ballistic protection, because of their ability to mitigate kinetic energy of projectiles by various mechanisms of dissipation and because of their lower density. Among dissipative mechanisms of interest, delamination is one of them. In order estimate the bond strength between two plies, the laser induced shock wave technique has been utilized on Tensylon® thin panels. Firstly, this paper introduces this technique and its capabilities with respect to the characterization of ballistic protections at very high strain rates (10^6 s^{-1}). Secondly, a set of experimental results is shown and interpreted to obtain the interply bond strength, through the spallation process. At last, experimental results are supported by a numerical model that is in the verge of being a predictive tool.

Keywords Tensylon® · UHMWPE · Ballistic protection · Laser shock wave · High strain rate

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L. Hofreiter et al. (eds.), *Soft Target Protection*, NATO Science for Peace and Security Series C: Environmental Security,
https://doi.org/10.1007/978-94-024-1755-5_2

2.1 Introduction

Societal concerns on security push light weight armor for ballistic protection to remain a topic of interest. Developing more efficient, light weight ballistic protective material is still a necessity for enlightening armored vehicle and personal protection; it will extend in a non-negligible way the autonomy and mobility. Composite materials open various possibilities in the field of ballistic armor due to their strong resistance and light weight. They have been extensively studied and thus they have been the object of numerous papers and even books [1, 2]. This association of fiber and matrix materials offers large combination of physical properties but has to be chosen in a relevant way. Cunniff presented a benchmarking of mechanical properties of the most utilized fibers in composite materials involved in ballistic protection [3].

With respect to these previous observations, we decided to focus on the delamination process that occurs during under shock and impact in composite material. In this paper we will present some of the results obtained by testing small UHMWPE laminate samples by the LASAT approach. Our motivations are developed in the following subsections of this introduction. Then, delamination experiments obtained by laser induced shock wave will be presented in paragraph 2. They are based on Photonic Doppler Velocimetry records of Tensylon samples subjected to laser induced shock waves. Paragraph 3 is dedicated to the loading induced by the laser induced shock wave. A numerical modeling of the delamination process is proposed in paragraph 4, by the use of the Finite Element Methods in explicit scheme. These results also include a discussion of key parameters of the model.

2.1.1 Motivation for Studying Tensylon®

By considering the most accessible fibers: glass, carbon, basalt, ultra-high-molecular-weight polyethylene (Tensylon®, Dyneema®, Spectra®), aramid (Kevlar®, Vectran®)... it is possible to use the Ashby method as a material selection process according to relevant criteria. In order to do so, the ratios ultimate stress over density and Young modulus over density were first considered for the mentioned fibers. The parameter introduced by Cunniff, $U*$, has been chosen for its evaluation with respect to the ratio of Young modulus over density. $U*$ is the product of fiber specific toughness and strain wave velocity and is expressed as (2.1):

$$U^* = \frac{\sigma\varepsilon}{2\rho}\sqrt{\frac{E}{\rho}} \tag{2.1}$$

Where σ and ε are respectively the ultimate tensile stress and strain of the considered fiber, E and ρ are respectively the Young modulus and the density of the fibers.

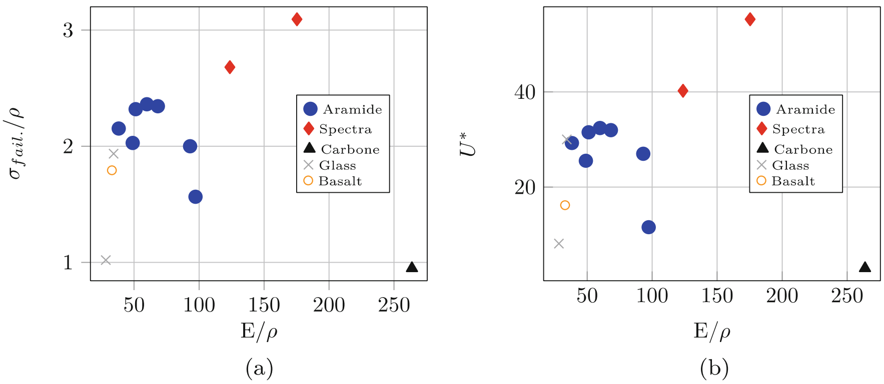


Fig. 2.1 Ashby method for material selection applied to fibers for composite used in ballistic protection. Left: Spectra (UHMWPE) exhibits the best compromise between stiffness, ultimate stress and density. Right: Spectra again shows the best score with respect of parameter $U*$ and the ratio E/ρ

Figure 2.1 shows both comparisons and highlights the fact that Spectra® - that belongs to the family of UHMWPE materials – is placed on the top right corner of the figure, meaning that this material is the most resistant, light and stiff in this material selection. Even though this Ashby approach appears to be basic, these preliminary observations strengthened our motivation to continue our research on UHMWPE. The choice of Tensylon® was brought by the partnership with STIMPEX S.A. Materials are described in Sect. 2.1.

2.1.2 Motivation to Focus on Delamination

Projectile penetration and perforation in composite plates are difficult topics to deal with so they involve various very brief phenomena that are occurring at the same time and are challenging to observe. Not only they strongly depend on the constitution of the target and the projectile itself, but also on the angle of incidence of the projectile, on its shape, on the boundary condition of the target... Energy dissipation mechanisms during the bullet penetration process can be the deformation and fragmentation of the bullet itself, but also friction, deformation, melting, fragmentation and delamination – or spallation – of the target and its constituents. Nevertheless, Zhang et al. [4] has proposed a relevant description of the phenomenon in UHMWPE (see Fig. 2.2a). They suggested a three stages description: at the first stage, the projectile interacts and penetrates the first plies of the target, by shear plugging, without causing large deformation. In the second stage, the projectile is deformed and expands in the cavity left within the composite. In the third stage, a spall appears close to the free surface and a crack is propagated in a rupture plane

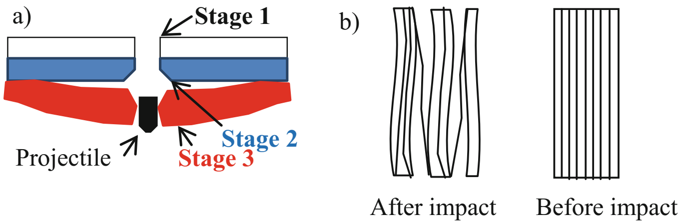


Fig. 2.2 Left: 3 stages damage mechanism proposed by Zhang on UHMWPE [4]. Right: accordion like multi-delamination in UHMWPE Dyneema® observed by Lässig after plate impact [5]

parallel to the free surface. Layers constituting the free surface are severely deformed and create a bulge. The projectile, at last, flies out of the target. Authors carried out experiments of shooting conically cylindrical steel projectile of 7.82 mm in diameter and 7.97 g in mass at about 700 m/s onto unidirectional plies of UHMWPE pressed in [0°;90°] of various thicknesses, respectively 8.4 mm, 16.92 mm and 25.24 mm. They observed the thicker the sample, the more represented bulge and delamination. For the thicker sample, they estimated stage 3 to be responsible of 72% of the bullet kinetic energy absorption. Delamination has also been reported by Lässig after plate impact experiments on UHMWPE recorded at high speed frames [5] (see Fig. 2.2b).

Under these considerations, this article proposes to assess the delamination of UHMWPE Tensylon®. Plies are manufactured by DuPont®, USA and pressed at STIMPEX S.A. in Romania in a [0°; 90°] stack sequence.

2.1.3 Some Considerations about Ballistic Impacts

Experimental measurements of the pressure induced by a ballistic impact on a target remain difficult to find in the open scientific literature. Some explanations for this limitation are, among others:

The mechanical failure of the sensors during the impact (damage, perforation),
The difficulty of implementing the sensors at the exact location of the impact,
The active surface of the sensor in front of the punctuality of the impact,
The geometrical singularity of bullets,
The diversity of projectiles.

It is therefore difficult to estimate this impact pressure other than by analytical simplifications or by the use of numerical simulation.

Hopkinson [6], on basic assumptions, proposed an analysis relying on the impact of a Mark VI steel bullet, 7.7 mm × 31.75 mm caliber, impacting a steel target at 610 m/s. He managed to estimate the duration of the peak pressure at about 52 μs for a maximum force of 19,300 Kg force distributed over the average section of the ball, that is to say more than 3 GPa.

Table 2.1 Estimated maximum impact pressure and duration of a ballistic impact

Target	$r_{projectile} = 3.5$ mm	$V_0 = 800$ m/s	$V_0 = 400$ m/s
PE	τ_p (μs) with (2)	8.0	12.6
	P_{max} (GPa)	2.5	1.0

Hutchings [7], based on a simple phenomenological analysis relying on the impact of a steel spherical, rigid projectile on a metal target, proposes to estimate the loading time τ_p during a ballistic impact by relation (2.2):

$$\tau_p = \pi.\omega_p \tag{2.2}$$

where ω_p is the pulsation in a plastic regime, expressed by the expression (2.3):

$$\omega_p = \frac{1}{r}\sqrt{\frac{3P_{max}}{2\rho}} \tag{2.3}$$

with r the sphere radius, P_{max} the "indentation pressure" at impact and ρ the density of the projectile.

The indentation pressure can be assimilated to the impact pressure that is determined via the shock polar technique (1D) as a first approximation. This latter approach carried out on a steel projectile impacting a bulk polyethylene target (PE) gives a maximum impact pressure of approximately $P_{max} = 2.5$ GPa for a projectile of incident velocity $V_0 = 800$ m / s (representative performance of an assault rifle). This pressure decreases to 1 GPa if the impact velocity is reduced by half (case of handguns). Applying formulas (2.2) and (2.3), the loading time induced by the ballistic impact can be estimated. These results are collated in Table 2.1 for a projectile radius of 3.5 mm (intermediate between 7.62 mm and 5.56 mm caliber).

These data were compared with numerical simulation results from Tham [8] who have reviewed various projectiles on a variety of Kevlar® composite helmet solutions. They announced pressure peaks close to 8 GPa for Fragment Surrogate Projectile (FSP) striking at 680 m/s with a diameter of 5.385 mm × 6.35 mm with an interaction duration of about 2 μs.

2.1.4 Motivation to Use Laser Induced Shock Waves

Laser induced shock waves are produced when focusing a short-duration and high-energy pulsed laser beam (~ ns, ~ J) on a small solid surface. In such a situation, the density of power, defined by relation (2.4) reaches a value of some GW/cm^2:

$$\phi = \mathrm{E_{max}}/(\tau.\mathrm{S}) \tag{2.4}$$

where ϕ is the density of power, E_{max} the maximum energy delivered by the laser source during duration τ and S the surface irradiated by the laser beam.

Under these conditions, the solid matter is quasi instantaneously dissociated into plasma and start its sudden expansion, in the same way as detonation products of high explosive do. The laser-matter interaction induces a shock wave in the irradiated material. The maximal pressure of this shock wave is called the ablation pressure and depends on the laser source characteristics and the irradiated material.

Laser induced shock wave have been extensively studied last decades for their involvement in the Laser Shot Peening (LSP) for material processing [9]. In LSP, the laser-matter interaction takes place in a water environment, that confines the plasma expansion, leading to stronger ablation pressures and longer pulse durations. Berthe [11] has proposed an analytical expression (2.5) that gives the maximum ablation pressure in function of the density of power involved in the laser irradiation (see Fig. 2.4):

$$\mathrm{P(kBar)} = 0.1\sqrt{\frac{\alpha}{\alpha+3}}\sqrt{Z(g.cm^{-2}.s^{-1})}\sqrt{I_0(GW/cm^2)} \tag{2.5}$$

Where P is the ablation pressure, I_0 is the incident density of power, α is a coefficient of laser-matter interaction that depends on the laser source, adjusted from experiments and Z is given by relation (2.6):

$$\frac{2}{Z} = \frac{1}{Z_{eau}} + \frac{1}{Z_{cible}} \text{ with } Z_i = \rho_{0i} C_{0i} \tag{2.6}$$

Where C_{0i} and ρ_{0i} are respectively the sound velocity and the density of the material $_i$.

Figures 2.3 and 2.4 show actually that it is possible, with a laser source, to generate the same pressure as the one undergone by the target during a ballistic impact. However, the pulse duration is more than 100 times shorter in the case of a classical laser induced shock wave. In the case of homogeneous materials, it could be possible to apply similitude laws that could result in a reduction of the target thickness, but in the case of composite or granular material, the thickness would become the order of magnitude of the grain or fiber size, what will induce predominant structural effects.

Laser induced shock waves have also been the object of the development of the LAser Shock Adhesion Test LASAT that permits the debonding of layered materials by inducing spallation inside the sample [10]. This technique has been successfully utilized for generating an interply debonding with composite materials [12]. This debonding is a consequence of the rarefaction of the shock wave at the free surface.

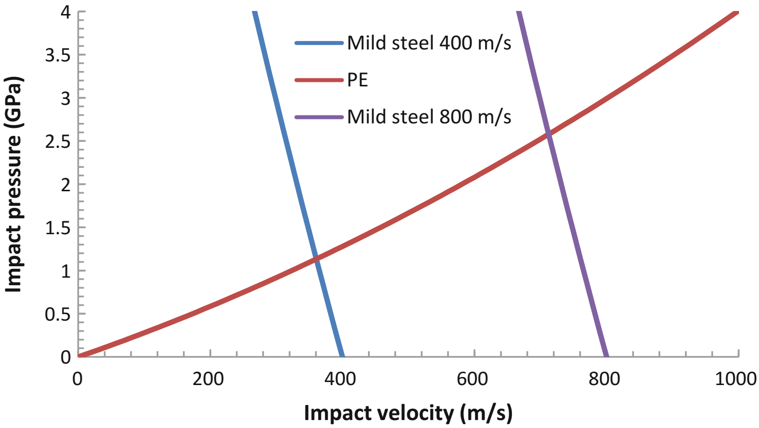
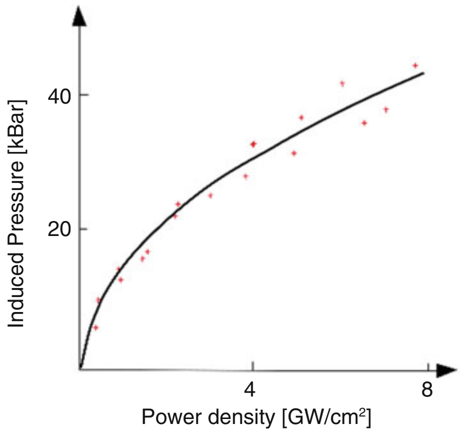


Fig. 2.3 Shock polar diagram for a 1D impact of a steel projectile on a PE target

Fig. 2.4 Ablation pressure during laser-matter interaction in water environment [11]



The resultant rarefaction wave interacts with the rarefaction wave of the unloading that creates a tensile stress. The wave propagation is represented in a Lagrange diagram (see Fig. 2.5.)

Laser shock waves and ballistic impacts can access the same level of pressure but not the same duration. As it was explained, the sample thickness cannot be diminished by a factor 100. Nevertheless, the shortness of the laser impulse makes possible the delamination process shown on Fig. 2.5, that support our idea of focusing on delamination.

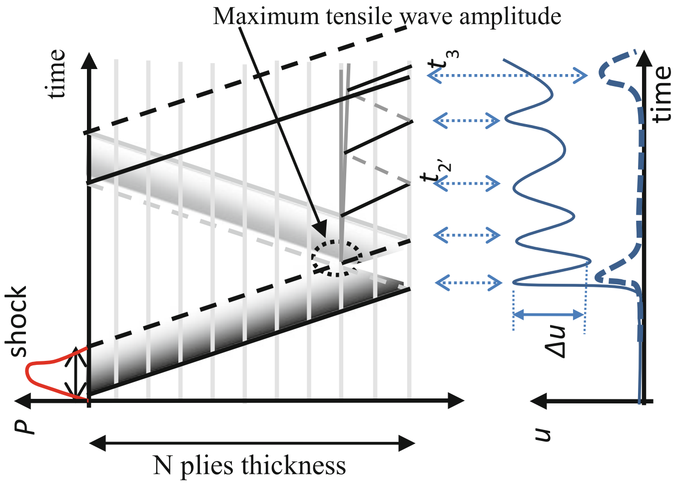


Fig. 2.5 Spallation process in composite material by laser induced shock wave

2.2 Experiments

2.2.1 Samples Description

Tensylon® HSBD 30A precursor tapes are bi-layered and bidirectional tapes. Each layer is composed of unidirectional UHMWPE fibres (UD) with about 20% of adhesive matrix [2]. These precursor tapes were submitted to quasi static mechanical tests for observing their mechanical response with respect to the strain rate in quasi-static regime in a tensile machine [13]. They were also stacked in [0°-90°] and pressed at 15.2 MPa and cured at 120 °C, in four stages for forming a plate (Table 2.2). From this 22 mm thick plate, cylinders of 20 mm diameter were cut and submitted to Hopkinson bars with strain rates up to 360 s^{-1} in order to determine a constitutive law [14]. They used an inverse approach by performing numerical simulation in order to fit experimental results. They determined a relatively precise parameter calibration for a simple plastic kinematic material model, by using two approaches: meso model and macro model. They suggested a Young Modulus of 3000 MPa, Poisson ratio of 0.47, Yield stress of 60 MPa and Tangential modulus of 500 MPa. In [15], a full UHMWPE plate of 500∗500 mm was impacted with 7.62∗39 mm FMJ with lead core bullet at 700 m/s. Micro and macroscopic observations are given and among dissipative mechanisms identified, multi-delamination is observed. An attempt to a numerical modelling is given in [16] including earlier advances performed by this research team. They implemented an approximate adhesive model and could obtain fairly satisfying results that allow them to evaluate strain rate at $1.16.10^5$ s^{-1}. They could estimate the stopping time of the projectile to be between 8 and 14 μs depending on the modelling assumptions, with an impact

Table 2.2 Pressing stages for Tensylon® hard ballistic plates

Stage	Pressure [MPa]	Temp. [°C]	Duration [min]
1	4.1	60	15
2	8.1	100	45
3	15.2	120	90
Cooling		120- > 30	Overnight

pressure of 2 GPa before elements deletion, in fairly agreement with data projected in Table 2.1. In the simulation, they highlight that having an adhesive model between plies changes significantly the results in term of interaction time between the bullet and the target and also in term of pressure at impact. It is thus a need to model delamination with a more accurate data, especially by knowing the interply bond strength. Another experimental campaign was then conducted to obtain the delamination threshold at very high strain rate by using the laser induced shock wave technique as a delaminator [17].

Samples were prepared from a Tensylon® plate that was water jet cut in small samples (10 × 20 mm), having thicknesses of and 2.45 mm (40 layers) and 1.15 mm (20 layers). During first attempts, it has been found that UHMWPE is transparent to the 1064 nm wavelength in such a way that the laser-matter interaction was not reproducible and not strong enough. To remediate this, a 15 μm layer of Aluminium foil was stuck on the irradiated face of the sample, with a cyanoacrylate Super Glue®. The thickness of this glue layer was measured by differences and estimated to be between 8 and 10 μm. It is assumed that the shock impedance of the glue matches with the one of the UHMWPE, in such a way that the shock propagation is not perturbed by this artefact.

2.2.2 Experimental Setup

The High energy laser source available at ENSTA Bretagne is a pulsed Nd-YAG laser, model Quanta-Ray Pro 350, manufactured by Spectra-Physics®. The maximum energy it can provide is $E_{max} = 3.8$ J max, in its fundamental wavelength $\lambda = 1064$ nm with a quasi-Gaussian pulse of duration at full width at half maximum $\tau = 9.2$ ns measured by ultra-fast photodiode. The laser beam diameter at the output is 13 mm with a small divergence. This beam is focused on the sample by a convergent lens to get a focal spot of area S on the sample. The focal sport was 3 mm of diameter. On the other side of the sample, at the center of the projected focal spot, a sensing laser of a Photonic Doppler Velocimetry (PDV) system – also called Heterodyne Velocimetry (HV) - manufactured by IDIL® is measuring the free surface velocity during the shock experiment. The wavelength of the PDV laser is 1550 μm. A layout of the experimental setup is shown on Fig. 2.6.

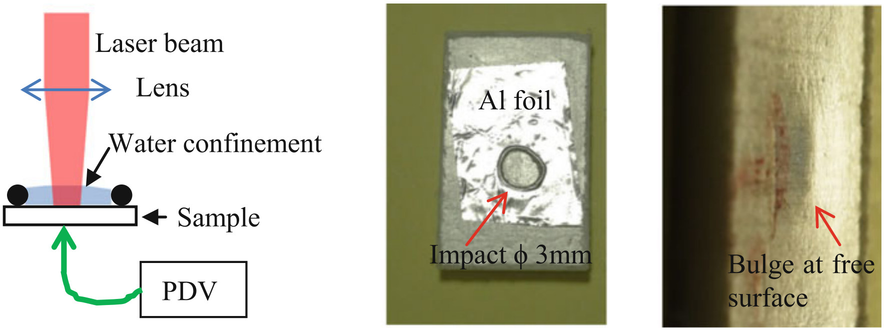


Fig. 2.6 Left: Experimental setup of laser shock wave on UHMWPE. Center: trace of impact resulting from the laser-matter interaction. Right: visible bulge at the free surface

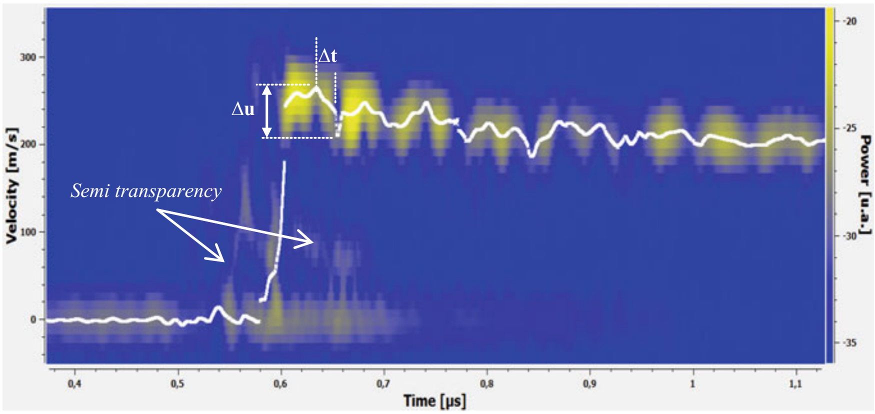


Fig. 2.7 Spectrogram of the PDV signal obtained for sample T-9 of 1.15 mm of thickness, irradiated at 1.8 GW/cm^2. In white, velocity data extraction by Cafeine software

2.2.3 Experimental Results

Experimental results are mainly from the PDV signals analysis and may be completed by macroscopic observations. They are exhibited and discussed in [17]. As an example, a PDV signal is shown in Fig. 2.7. The main shock wave reaches the rear face around 0.6 μs and the maximal velocity rises up to 267 m/s. Before and after this rising front, some parasites are visible because of the transparency of the UHMWPE to the PDV laser. The maximum free-surface velocity, noted u_0, and the first free-surface velocity valley, u_m, can be read on the PDV spectrogram after speed extraction with Cafeine software [18], giving the white marks on Fig. 2.7. The dynamic tensile strength σ_{spall} can be deduced from linear approximation (2.7)

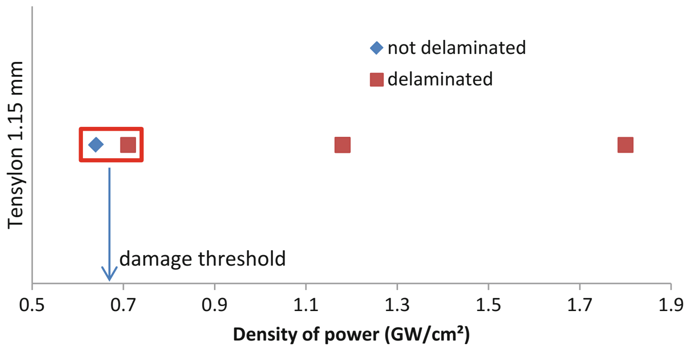


Fig. 2.8 Damage threshold in density of power for 1.15 mm thick Tensylon®

proposed by Novikov for isotropic material [19] but that has been extended to our composite materials, as considered in previous studies [12]:

$$\sigma_{spall} = \frac{1}{2}\rho_0 C_0 \Delta u \tag{2.7}$$

where $\Delta u = u_0 - u_m$ is the so-called "velocity pullback". From this velocity pull-back it is also possible to estimate the strain rate with the relation (2.8):

$$\dot{\varepsilon} = \frac{1}{2C_0}\frac{\Delta u}{\Delta t} \tag{2.8}$$

As an example of accessible values for shot T-9 presented (Fig. 2.7), $\sigma_{spall} = 45.8 \pm 5$ MPa with $\rho_0 = 0.94$ g/cm^3 and $C_0 = 1798$ m/s and the referred strain rate reached 2.2×10^6 s^{-1}. This strain rate acting between two plies and is thus related to the delamination process. A summary of the results obtained on the set of Tensylon® samples is given on Fig. 2.8. The damage threshold in density of power has been found between 0.64 and 0.71 GW/cm^2 for 1.15 mm thick Tensylon®.

2.3 Laser Shock Wave Characterisation

In order to perform a numerical modelling of these experiments, it is necessary to first model the laser shock loading, as it is the main input parameter. This section gives spatial and temporal profiles of the corresponding loading generated by the laser matter interaction.

In order to characterize the pressure profile induced by the laser-matter interaction of the ENSTA Bretagne pulsed laser, shots on 1 mm and 2 mm thick aluminum plates were performed with PDV records of the free surface velocity with the same experimental setup presented in paragraph 2.2. This procedure is detailed in [20].

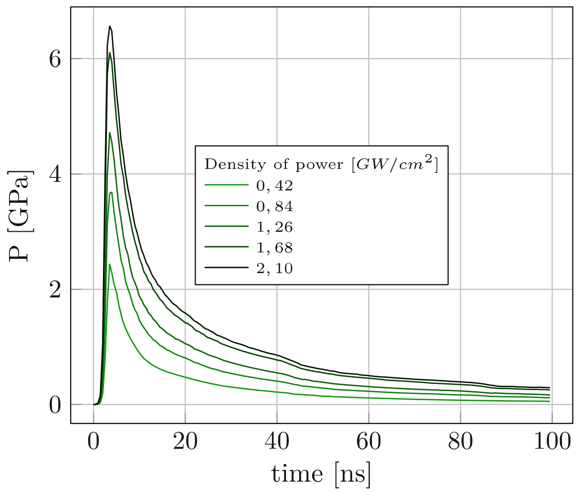


Fig. 2.9 Temporal profile of the pressure loading caused by the laser-material interaction with the ENSTA Bretagne pulsed laser characteristics (9.2 ns, 1064 nm) in confined water regime with a 4 mm focal spot

Table 2.3 Numerical values of the relation between energy density and the pressure generated by the ENSTA Bretagne laser

Parameter	*a*	*b*	*n*
Values	0.02922	−0.5867	0.3722

These tests provide a basis of comparison for validating the laser-matter interaction models. Figure 2.8 illustrates the pressure profiles as a function of the maximum energy fraction at the output of the laser, in water confined mode.

The energy distribution within the focal spot was estimated from a scan analysis of a laser shot on a photo paper. The average intensity obtained reveals a “flat-top” profile as delineated in Fig. 2.9 (red profile).

According to previous works, the pressure generated by laser shot could be calculated by using Eq. (9)

$$P(r) = a\phi^n + b \tag{2.9}$$

With P in GPa, ϕ in J/m^2, other parameters are listed in Table 2.1. This methodology is purely empirical. The fitted parameters are only available the presented laser and the laser pulse applied in this study. The pressure was calculated by using the ESTHER code as described as in [21] (Table 2.3).

As illustrated in Fig. 2.2, the energy density presents an evolution according to the radius of the laser spot. This energy density is estimated along the radius length. The associated pressure is calculated according the Eq. (2.9) previously presented. The procedure to obtain the equivalent pressure profile generated by the laser is delineated in Fig. 2.3.

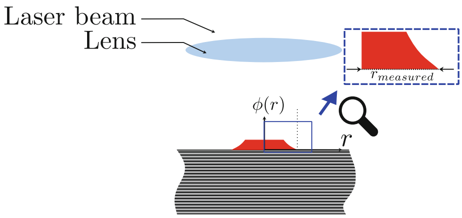


Fig. 2.10 Schematic illustration of the energy distribution in laser matter interaction

This procedure is detailed in the literature in [22]. This spatial distribution is normalized between [0;1]. The temporal profile is estimated from Fig. 2.1 and the pressure value is normalized between [0;1] also. The maximum value is given by the procedure illustrated in Fig. 2.10.

2.4 Numerical Modelling

The section describes the numerical modelling performed with Abaqus explicit of the experiment previously presented in paragraph 2. The sample is a Tensylon® UHMWPE composite made of 20 layers with a thickness of $1.15.10^{-3}$ m. An aluminum foil is located at the top of the sample for creating the laser-matter interaction, as explained in Sect. 2.2.

In order to simplify the modelling, strong assumptions are made. The laser shock wave is assumed to be generated on a line pattern whereas it is a quasi-circular spot. This approximation will not restitute the correct wave propagation in a long duration time but allows modelling in a 3D slice - 1D like geometry, since Abaqus cannot deal with cohesive contacts in 1D or 2D. In order to get an observation time shorter that the duration of a back and forth in the whole target, edge effects are not considered. The thin 3D slice ($5.0.10^{-5}$ m) of the structure is considered as illustrated in the Figs. 2.11 and 2.12. An 8-node reduced integration element type (C3D8R in Abaqus) is used to simulate the composite ply and the aluminum foil. Only one element is used in the model width, the influence on the mesh size will be discussed.

The UHMWPE Tensylon® is simulated with an elastoplastic behavior as described in Sect. 2.1. The numerical model considers the aluminum foil by using a Johnson-Cook behavior law [23].

Material characteristics of the constitutive law and Equation of State (EOS) are summarized in Table 2.4. They were taken from [5, 14]. The Abaqus module can only consider shear modulus when the Equation Of State (EOS) parameters is implemented in the model. The presented results considered a shear modulus $G = 850{,}0$ MPa to fit with the experimental data. The interfacial layer is simulated by contact cohesive interactions. Parameters used to simulate the interfacial stiffness between ply are presented in Table 2.5, where the interfacial is denoted K_i and the interfacial strength σ_i, with $i = n$, t_1 ot t_2 which correspond respectively the normal

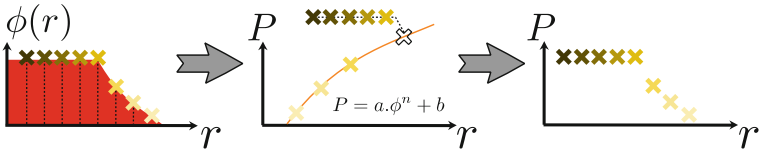


Fig. 2.11 Procedure used to estimate the equivalent spatial pressure generated by laser shock

Fig. 2.12 Viewcut of the specimen used for laser shock wave tests

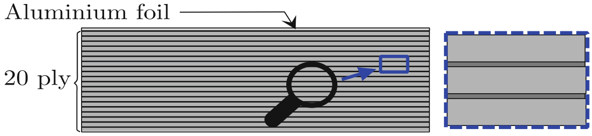


Table 2.4 Material data set for numerical simulation of Tensylon [14]. Missing data are completed by Dyneema parameters given by Lässig [5]

Parameters	Symbols	Values	Units
Mechanical properties [14]			
Density	ρ	960	Kg/m^3
Young modulus	E	2.5	MPa
Poisson's ratio	ν	0.47	/
Shear modulus	G	850	MPa
Elastic limit	σ^y	60	MPa
Tangential modulus	E^{tan}	500	MPa
Equation of state (EOS) [5]			
Grüneisen coefficient	Γ	1.6	/
Bulk sound velocity	C_0	1860	m/s
Shock EOS coefficient	S	1.8	/

Table 2.5 Interfacial parameter used for the cohesive contact

Parameters	Symbols	Values	Units
Stiffness of the interface			
Normal direction	K_n	$2.5.10^{+11}$	N
Tangential direction 1	K_{t1}	$2.5.10^{+11}$	N
Tangential direction 2	K_{t2}	$2.5.10^{+11}$	N
Initiation			
Normal direction	σ_n	45.0	MPa
Tangential direction 1	σ_{t1}	45.0	MPa
Tangential direction 2	σ_{t2}	45.0	MPa
Evolution			
Normal direction	G_I^c	3.0	N/m
Tangential direction 1	G_{II}^c	3.0	N/m
Tangential direction 2	G_{III}^c	3.0	N/m

and tangential directions. The fracture toughness is denoted G_i^c with $i = I$ (traction-compression), *II* (shear) or *III* (torsion) according to the crack opening mode.

Only, the shear modulus of the UHMWPE is considered in the Abaqus model. The equation of state (EOS) based on Mie-Grüneisen work is used. The velocity (normal to the surface) is averaged on a segment of 0.25 mm as illustrated (in red in Fig. 2.13) in order to represent alignment uncertainties (±0.5 mm) and the spot size of the PDV probe (0.1 mm).

Under the laser-matter interaction, the pressure arises and causes a strong deformation of the Tensylon. Waves propagate in the sample thickness and create multi delamination that is represented in Fig. 2.14. It was not possible to confirm by cutting and performing optical observation in the recovered sample because of the fiber toughness that make the material hard to cut and polish.

The numerical velocity presented the average values of nodes illustrated Fig. 2.14. The mesh size has a strong influence on the FEA results as visible in Fig. 2.15. According to these results a mesh size of $5.0.10^{-6}$ m gives acceptable results and will be utilized in the following.

The comparison between the velocity measured experimentally and the one obtained from the numerical model is presented in Fig. 2.16. The FEA results present the average velocity of the nodes selected on a length of 0.25 mm as explained in Fig. 2.14. They show a good agreement since the standard deviation is lower than 3.5 m/s.

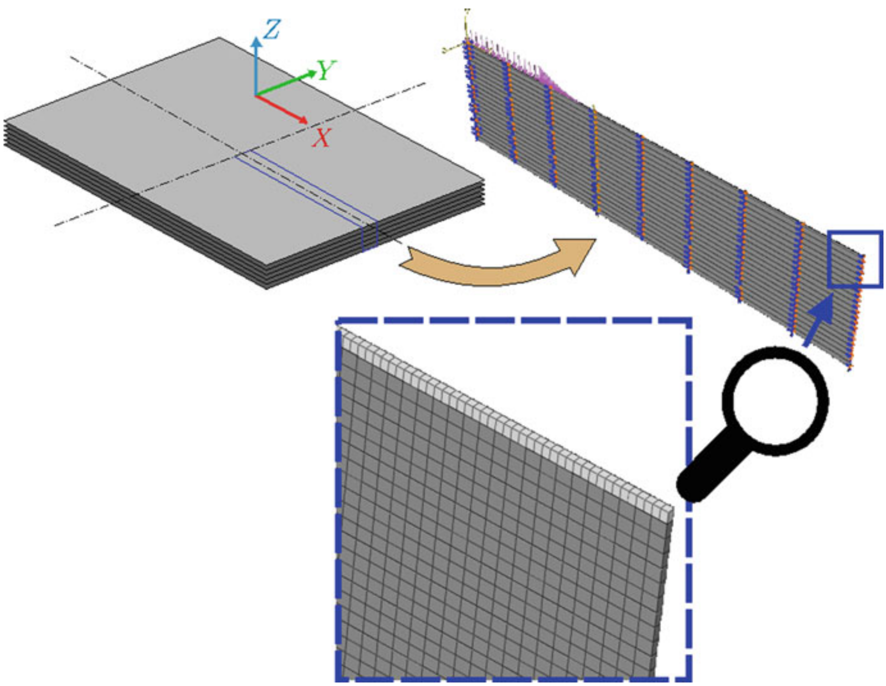


Fig. 2.13 Illustration of the model used to simulate laser wave experiments

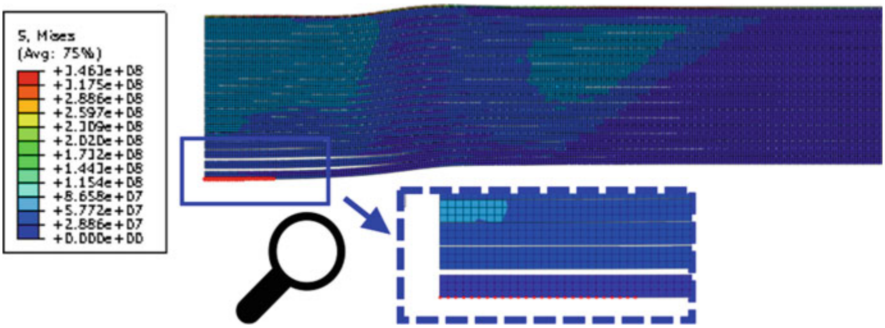


Fig. 2.14 Extraction of the velocity at nodes represented in red

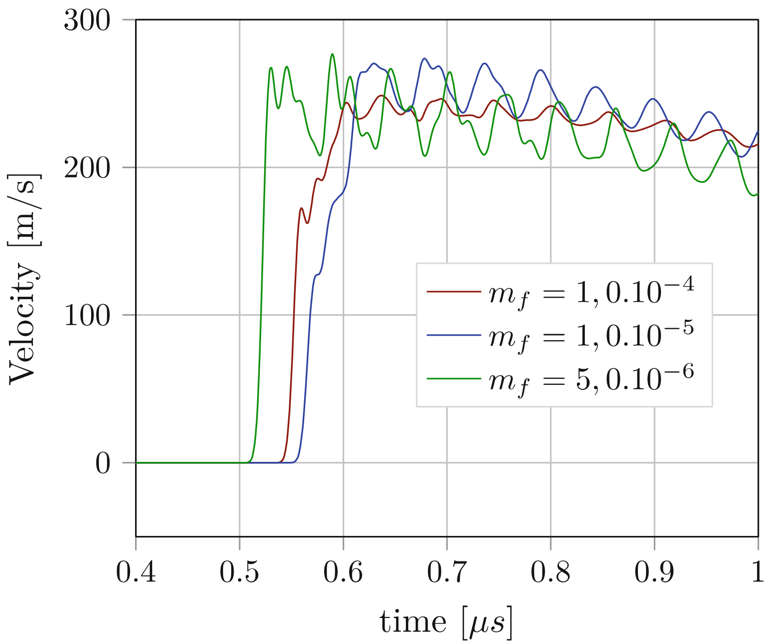


Fig. 2.15 Influence of the mesh size on the back face velocity

The velocity of the back obtained numerically is strongly sensitive to the interfacial stiffness of the model (Table 2.5). In order to evaluate this sensitivity, a parametric study is proposed. Figure 2.9 shows the sensitivity of the free surface velocity to the interfacial stiffness parameter *K*. Rather small discrepancies occur after 0.8 μs which is already far from the period of interest when delamination is initiated. Higher interfacial stiffness results in a drop of the free surface velocity, which means a reduction of the free surface bulging, due to a higher bending moment (Fig. 2.17).

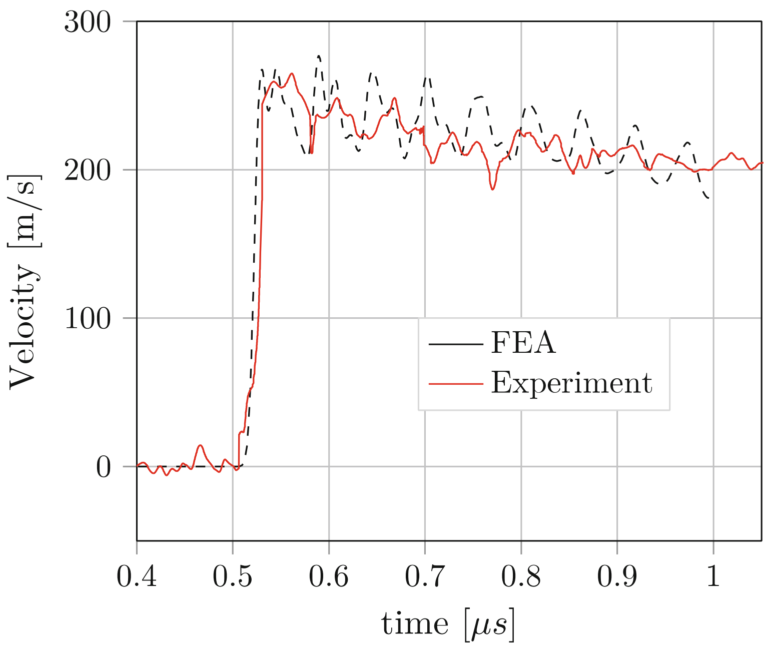
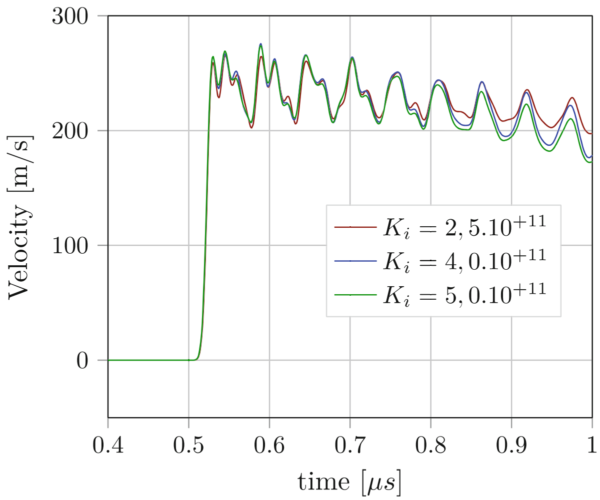


Fig. 2.16 Comparison of numerical and experimental velocity

Fig. 2.17 Influence of the interfacial stiffness on the back face velocity



2.5 Conclusion

In this study, a promising technique, derivate from the Laser Shock Adhesion Test, was successfully experienced to delaminate at very high strain rate a Ultra High Molecular Weight PolyEthylene composite material that is commonly used for the development of light weight armors and of ballistic protection. It was assessed that the technique is able to generate pressure loading comparable to those exerted by a ballistic impact. The duration of the laser induced shock loading is however of the order of thousand times shorter than the one of a ballistic impact. This allows tests at the laboratory scale and also its use for reduced scale samples, which presents economic interest. In addition, a spatial shape of the laser induced shock has been determined. It remains a key parameter as input data in the Finite Element Model. The numerical simulation, based on contact cohesive interactions in Finite Element Methods, has brought major advances in the modelling of the delamination. They provided a good agreement with Photonic Doppler Velocimetry records. The influence of the interfacial stiffness parameter has been studied and it is observed that its best value is of $2.5.10^{+11}$ N. Larger values yielded to underestimate the bulging of the free surface when it is spalled. The numerical simulation of the delamination showed a multi delamination, suspected since observed in larger samples impacted by real bullets in [15] but not evidenced in thinner samples subjected to laser induced shock waves due to the difficulty of obtaining a clear cut and polishing of the recovered samples. This is an issue that could be extensively prospected by the future use of a high resolution microtomograph. In the future, the parameter G_i^c will also be the object of further research in order to be better estimated. At last, another outlook will be to subject various composite materials for ballistic protection to the laser delaminator in order to point out the most resilient ones with respect to the delamination process.

Acknowledgements Authors would like to thanks NATO for having granted the “Soft target protection” workshop SPS ARW G5524. Authors also thanks the European Commission for allowing Luminita ALIL’s mobility in the frame of the ERASMUS program. At last, Authors thanks Region Bretagne, Finistère and Brest Métropôle Océane for their financial supports.

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Chapter 3
Dynamic Identification Techniques for the Vulnerability Analysis of Glass Soft Targets: On-site Vibration Experiments and Numerical Simulations on a Glazed Footbridge

Chiara Bedon

Abstract The use of glass in buildings as load-bearing material showed an exponential increase. Although it represents a relatively new solution for constructions, requiring appropriate design knowledge, glass is frequently used for facades, roofs, footbridges, etc. Deep care should be certainly spent at the design stage – to ensure reliable *fail-safe* requirements – but also during the life-time of glass structures. The brittle behaviour and limited tensile resistance of material, in addition to the high flexibility of glass assemblies, are responsible of major issues for structural engineers. Further criticalities are represented by time and ambient effects, or extreme loads. The vulnerability assessment of glass structures is hence an open topic, still requiring huge efforts. A combination of multiple aspects should be properly assessed to ensure appropriate protection and mitigation, especially for glazed *soft targets*. In this paper, dynamic identification methods are used for an in-service glass footbridge. On-site vibration experiments are discussed, including Finite Element numerical analyses, so as to explore the footbridge dynamic performance and assess its vulnerability.

Keywords Structural glass · Vulnerability analysis · Fail-safe design · Soft target · On-site vibration experiments · Finite-element (FE) numerical simulations

3.1 Introduction

Glass is largely used in modern constructions, in the form of facades and windows, roofs, walkways, stairs and load-bearing components in general (see [1–3], see Fig. 3.1). Compared to other (conventional) structural materials for constructions,

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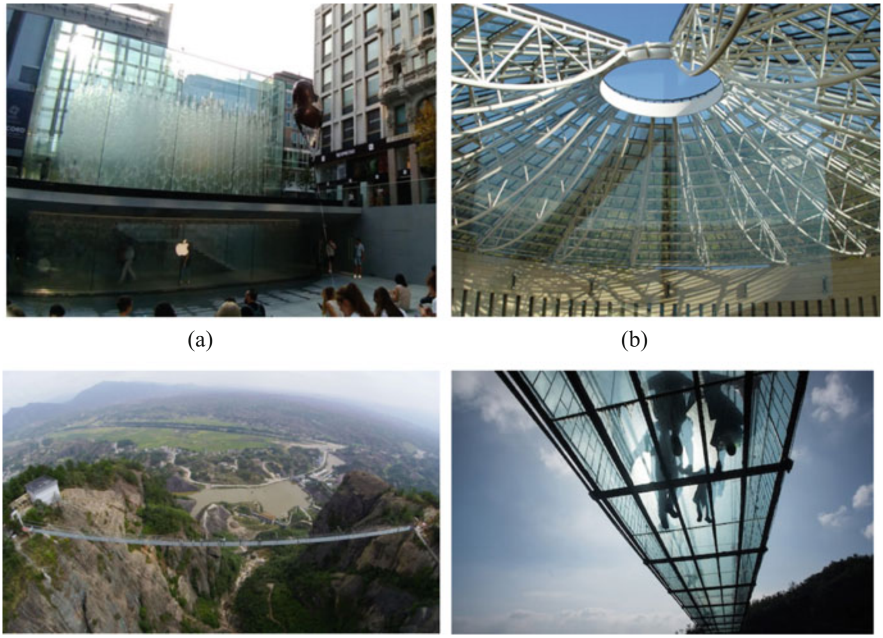
L. Hofreiter et al. (eds.), *Soft Target Protection*, NATO Science for Peace and Security Series C: Environmental Security,
https://doi.org/10.1007/978-94-024-1755-5_3



(a) (b)

(c) (d)

Fig. 3.1 Examples of structural glass in (**a**) facades, (**b**) roofs, (**c**) and (**d**) footbridges (www.telegraph.co.uk)

due to the low tensile strength and brittle behaviour, glass structural elements and assemblies are fragile and vulnerable components for constructed facilities. A special design attention is hence nevessarily required, especially for glazed structures that could be subjected to extreme events (both natural hazards or human induced loads).

Given the increasing number of tragic attaks, in this context, several research studies have been carried out in the last years, to assess the performance of glass systems under explosions and high-strain impact. A recent state-of-the-art of research projects spent on glass windows and facades under extreme loads can be found in [4, 5]. Most of the literature studies include laboratory investigations on glass dynamic properties (i.e., to characterise the material performance under high strain events), analytical solutions for the analysis of the response of glass panes subjected to shock, advanced Finite Element (FE) numerical modelling of windows under the effects of air blast waves, as well as laboratory (or field) blast tests, aimed at assessing the performance of traditional glass windows and the feasibility / efficiency of possible mitigation solutions. It is in fact generally recognized that while glass windows and facades represent the first barrier for people from the environment (extreme events included), glass itself represents a vulnerable load-bearing component in buildings, and could be hence responsible of causalities, in the form of soft targets.

This paper aims at extending the current knowledge on the availability and reliability of design and analysis approaches for the vulnerability assessment of load-bearing glass structures. As such, the research study is focused on the an experimental and FE numerical investigation of an in-service glass footbridge. The case-study system is located in Aquileia (Italy), and was realized in the early 2000 within the religious context of the Roman Age, UNESCO Heritage Site, Basilica of Santa Maria Maggiore. Based on dynamic identification techniques, the actual state-of-the-art of the glass structure is assessed. It is hence shown, in particular, how non-destructive testing can provide useful feedback for the preservation and mitigation of glass structures and facilities.

3.2 Glass in Buildings

3.2.1 General Design Concepts

Generally speaking, glass structures are commonly complex systems, belonging and interacting to full three-dimensional buildings to which they have offer specific functions. At the same time, the glass structures themselves must act efficiently, as stand-alone load-bearing assemblies, so as to ensure appropriate resistance and deformation capacity, robustness, redundancy, etc. in their life-time [1, 6, 7]. As a result, they require specific design methods before their construction, but also optimal operational conditions, both under service loads and in presence of extreme design actions (including natural events, terroristic attacks, etc. [5, 8]).

While *fail-safe* structural performances should be conventionally maximized and accomplished with the support of existing design standards for buildings, however, the performance and mitigation of glass structures subjected to severe loading conditions still represents an open challenge and requires huge efforts. In most of the cases, no specific design regulations are available in guideline documents for constructions. In addition, the operational conditions that these structures have to suffer can be consistently different from the original design assumptions, hence resulting in potential unsafe performances and additional risk for the citizens.

3.2.2 Structural Design Requirements for Glass Roofs and Footbridges

Glass roofs and footbridges are strongly attractive for designers and have unevaluable aesthetic impact (see Fig. 3.1). In structural terms, these horizontal load-bearing systems must sustain pedestrians and offer appropriate resistance and stiffness, hence should be conventionally checked – in service loads – towards maximum deformations and stresses due to permanent and human induced live loads, see [6, 7]. Outdoor glass structures, in addition, may be asked to sustain snow and wind effects. In service conditions, finally, their vibrations should be also properly limited, being glass panels often characterized by high flexibility and small thickness-to-overall size ratios.

Even more restrictive design requirements are given by design standards for buildings under seismic actions, in terms of deformation capacity of the glazing components with respect to the other load-bearing elements. Such a kind of limitation requires, in most of the cases, a careful detailing of connections that should allow a certain movement accommodation, but at the same time preserve the redundancy of the system [9]. Special care is then also required for a reliable estimation of the dynamic characteristics for the glass assembly to verify [6, 7], including vibration frequencies, modal damping ratios, modal shapes.

3.2.3 Glass under Severe/Extreme Loads

According to the literature ([5, 11], etc.), and based on past observations from some tragic terroristic attacks, it is commonly recognized that glass shards and fragments are the major issue due to extreme design loads. In the past, they have been responsible of more than 60% of the casualties, see Fig. 3.2.

Structurally speaking, such an issue has been minimized for years via the so-called blast-resistant design approach, aiming at offering appropriate static/dynamic performances to facades, while preserving the integrity under shock [5, 10, 11]. The achievement of a similar performance requires, for traditional glass facades, specific knowledge of their static and dynamic features, being responsible of the overall response and possible local effects.

(a) (b)

Fig. 3.2 Examples of damaged glass facades after the tragic attacks at (**a**) Istanbul and (**b**) Brussels airports

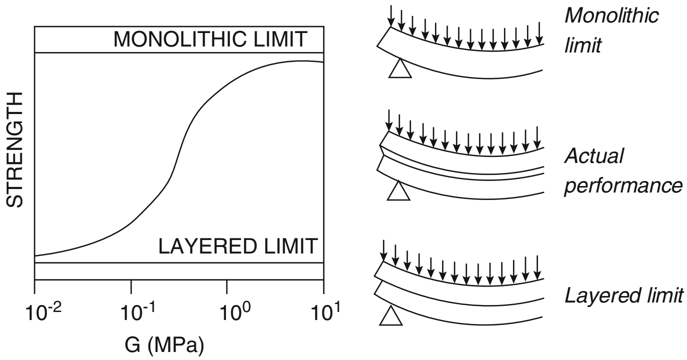


Fig. 3.3 Qualitative performance of a double LG panel in bending, as a function of the shear stiffness of the bonding interlayer. (Figure reproduced from Ref. [12] with the permission of Springer Nature, Copyright® License no. 4453711410573, October 2018)

Further critical configurations may derive, in glass structures in general, not only from extreme design actions, but also from ordinary operational conditions, hence careful attention is required through the full life-time of a given assembly. A combination of several aspects (including time, ambient and loading conditions) could in fact result – even in a limited period of time – in influencing parameters affecting the expected design performance of the glass structure.

Laminated glass (LG) systems, for example, are obtained by assembling multiple glass layers, bonded together via plastic layers ([1–3]). While Polyvinyl Butyral (PVB®) foils represent the conventional solution for glass sandwich sections, it is well-known that the mechanical properties of PVB (and others materials in use for glass applications [6, 7]) are susceptible to loading conditions. The actual structural response of a given LG member, as a result, is in most of the cases characterized by the presence of a relatively weak shear connection between the glass layers that hardly can offer a 'monolithic' performance (see Fig. 3.3).

As far as long-term loads, high temperatures or high relative humidity conditions, etc., are expected in the operational conditions of a given glass structure, as a result, a certain decrease of the shear modulus should be accounted for the bonding interlayers, with an appropriate analysis of the related structural effects. For most of the existing glass structures, however, the vulnerability analysis may result in uncertain predictions, and require advanced investigation approaches.

3.2.4 Non-destructive Methods for the Vulnerability Analysis of Glass Soft Targets

Within the design requirement of fail-sale performance goals, dynamic identification techniques and non-destructive testing could offer reliable and useful feedback, towards the assessment, preservation and enhancement of the structural performance of existing glass structures. According to the literature, no official definition exist for 'soft targets' [13, 14]. In terms of protection of citizens, however, the 'soft target' expression is mostly used to denote places with high concentration of people and low degree of security against possible attacks. The major distinction is made with respect to 'hard targets' – being representative of well-secured premises (i.e., government buildings, military premises, law enforcement offices, guarded non-governmental or commercial facilities, etc.). In other words, soft targets are vulnerable to attack and accessible to large numbers of people, such as sports venues, shopping venues, schools, transportation systems, religious facilities, open spaces, etc.

Given such a definition of soft targets, existing glass structures – due to their intrinsic vulnerability – can represent an additional source of risk for the citizens, requiring appropriate studies and possible structural health monitoring activities, so as to timely plan possible retrofit/mitigation interventions.

3.3 The Case-Study Glass Footbridge

In this paper, the dynamic performance of an existing glass suspension footbridge is preliminary analysed. The case-study structure is located in Italy, within the context of the Basilica of Aquileia (Udine). The Basilica includes the largest and one of the best preserved early Christian mosaics, and attracts over than 300,000 visitors every year. The glass footbridge object of study, in this regard, was realized in the early 2004, as a key strategy to preserve the roof mosaics and allow for their optimal visibility.

3.3.1 Geometrical and Mechanical Features of the Footbridge

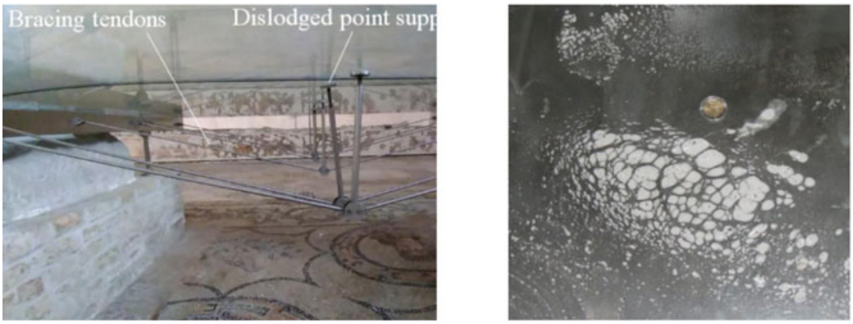
The structural design of the glass footbridge was intended to maximize the transparency of the load-bearing components, and minimize their visual impact. To this aim, 118 LG panels were used (79 in the central nave of the Basilica, and 39 in the crypt). The overall footbridge was hence composed of a series of LG plates, steel frame members and suspension tendons supporting the LG components, with lateral steel-glass handrails (see Fig. 3.4).

According to the original design concept, each panel was designed as a triple LG section, via 3 fully tempered (FT) layers (12 mm thick/each) and 2 PVB foils (0.76 mm thick). An additional layer composed of annealed glass (AN, 6 mm its thickness) was positioned on the top of the LG panels, to preserve the integrity under cyclic anthropic loads (Fig. 3.5(a)). No mechanical connection was used for the LG-AN layers, with surface contact interactions only. A small, non-structural metal

(a) (b)

Fig. 3.4 The case-study glass suspension footbridge: (**a**) general view and (**b**) detail

(a)



(b) (c)

Fig. 3.5 Case-study glass footbridge: (**a**) live loads; (**b**) steel tendon and (**c**) local delamination frame was finally designed along the $B \times L$ edges of each LG panel, to keep the AN plates in position and preserve the LG sandwich integrity from humidity.

Globally, the so-assembled LG panels cover up to 140 square meters of walking surface, and have variable dimensions, from a minimum of 1.35×1.35 m (herein labelled as G1-type panels), up to 1.45×2.65 m (G2-type). While the G1-panels are point supported via a set of point mechanical supports (i.e., corner and mid-span steel restraints), major flexibility – and hence vulnerability and uncertainties – are associated to the bending performance of G2-panels, being supported along the short edges only ($B = 1.45$ m, Fig. 3.4(b)) and spanning over $L \approx 2.65$ m. To limit the elastic deflections due to visitors, a bracing system was in fact originally designed, including pre-stressed steel tendons (10 mm the diameter, with three tendon pairs – 0.65 m spaced), and mid-span unilateral mechanical point supports, see Figs. 3.4 and 3.5.

3.3.2 *Operational Conditions*

After the construction of the footbridge, the structure was affected and still suffers for a combination of phenomena due to time, unfavorable ambient conditions (i.e., high humidity) and fatigue (i.e., continuous live loads due to visitors), see Fig. 3.5. For this reason, on-site vibration experiments were planned in 2017.

From a preliminary visual inspection of the glazed structure, for example, it was shown that:

- the tendons mid-span restraints – designed to half the span of G2-panels – proved to offer (in some cases only) a temporary/partial support for LG panels only, with local dislodgement of the unilateral supports (Fig. 3.5(b));
- the benefits of initial pre-stressing loads in the tendons were found to be mostly minimised by time effects; and
- partial surface abrasion and minor glass cracks, as well as condensation and debonding phenomena, were clearly observed for some of the LG panels (Fig. 3.5(c)).

3.3.3 *On-site Vibration Experiments*

The set of experiments was performed in November 2017, using the MEMS accelerometers prototyped in [15], see Fig. 3.6(a). Given the average size of G2-type panels, up to six MEMS sensors were used for each test repetition, and optimally positioned on the walking surface of the footbridge (i.e., *#n* sensors in Fig. 3.6(b)). Output-only experimental data were hence recorded (Fig. 3.6(c)). More details on experimental methods and assumptions within the campaign of dynamic testing can be found in [18, 19].

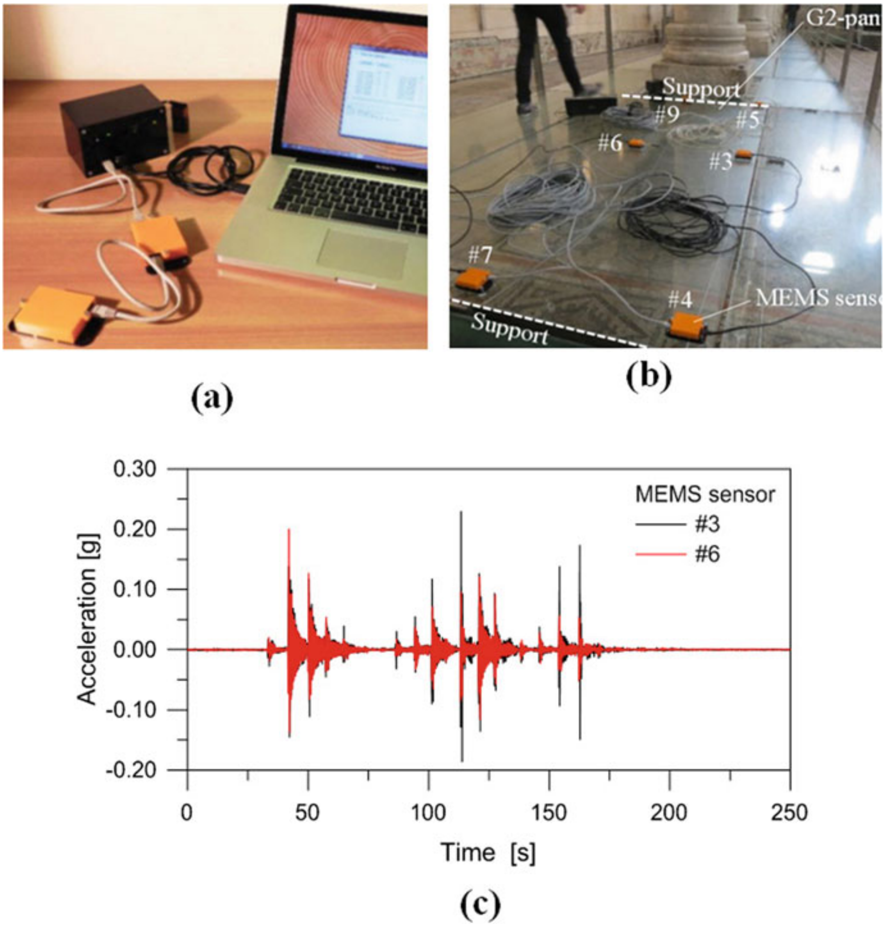


Fig. 3.6 Experimental modal analysis of the glass footbridge: (**a**) MEMS accelerometers; (**b**) test setup and (**c**) measurements

3.3.4 Finite-Element Numerical Modelling

A numerical investigation of the glass footbridge was then carried out in ABAQUS [16], to further explore the on-site experimental measurements (see Fig. 3.7). Special care was spent for the geometrical and mechanical description of the key structural components of the footbridge, as well as their reciprocal mechanical interaction under ordinary design loads. The typical FE numerical model herein discussed was described in ABAQUS to reproduce in detail the typical 1.45 × 2.65 m G2-panel, according to Fig. 3.7.

To this aim, 2D shell composite elements were used for the nominal LG section. Similarly, for the top AN layer, a shear flexible bond was defined on the upper face of the LG sandwich ($E_{SOFT} = 1$ MPa its stiffness), so as to account for a contact

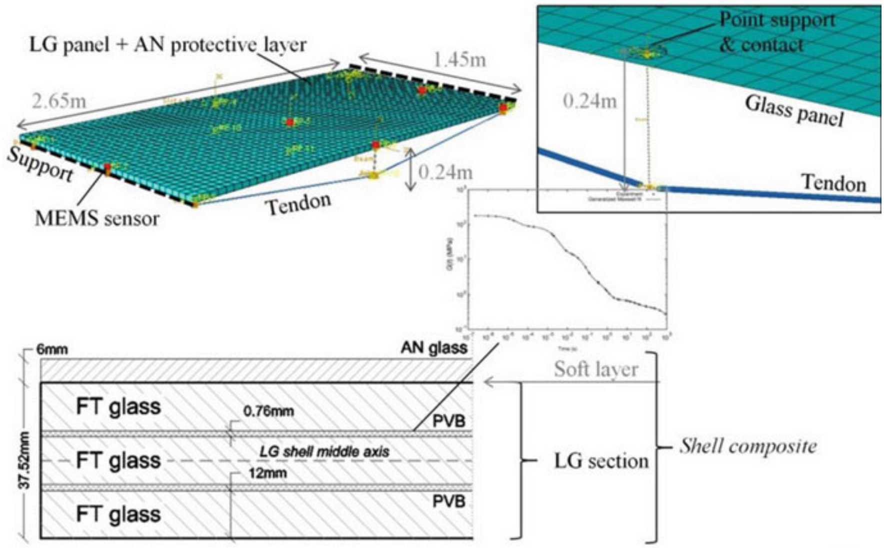


Fig. 3.7 Reference numerical model for the typical G2-panel (ABAQUS)

mechanical interaction. 1D beam elements were then used for the steel tendons (10 mm diameter). The MEMS sensors were described via lumped masses (0.15Kg/ each, Fig.3.7).

The so-defined structural components were supported to account for the actual restraints along B edges (i.e., Fig. 3.4(b)). A key role was indeed assigned to the mid-span steel point restraints, being responsible of the actual tendons-to-LG panels interaction. An unilateral point contact was hence defined, see Fig. 3.7, being able to react to compressive (vertical) loads only, while allowing free relative displacements/ rotations at the support-to-LG interface. In addition, based on the on-site visual inspection, pre-stressing loads in the tendons were fully disregarded.

The last uncertainty was represented by material properties. Nominal elastic features were reasonably considered for glass ($E_{glass} = 70GPa$, $\nu_{glass} = 0.23$, $\rho_{glass} = 2500Kg/m^3$) and steel ($E_{steel} = 160GPa$, $\nu_{steel} = 0.3$, $\rho_{steel} = 7850Kg/m^3$, with 1600 MPa the resistance at rupture), a tentative value was used for the shear stiffness of PVB (GPVB = 8 MPa and $E_{PVB} = 24$ MPa, with $\nu_{PVB} = 0.49$ and $\rho_{PVB} = 1100Kg/m^3$). According to [1, 6, 7], such a stiffness is suitable for short-term loads (3 s) and room temperature (20°), but it is in contrast with the operational conditions of the case-study footbridge (see Fig. 3.5 and [6, 7]).

3.4 Summary of Experimental, Analytical and Numerical Results

3.4.1 On-site Vibration Experiments and Preliminary Analytical Estimations

The experimental records from MEMS sensors were accurately post-processed [17], to detect the fundamental mode of the footbridge (Fig. 3.6(b)). The selected LG panels, in particular, showed a beam-like flexural response, with $f_{TEST} = 14.97$ Hz the estimated fundamental frequency and $\xi_{TEST} = 1.20\%$ the corresponding modal damping.

In parallel, simplified analytical calculations were also carried out, for a further preliminary of the collected experimental data. More in detail, the first frequency of G2-panels was calculated as:

$$f_k = \omega_k / 2\pi \tag{3.1}$$

where:

$$\omega_k = \left[\left(\frac{k\pi}{L} \right)^2 \sqrt{\frac{EI}{m}} \right] \tag{3.2}$$

and $k = 1$.

In Eq. (3.2), m is the linear density of each beam-like panel, L the nominal span, E the longitudinal modulus of elasticity, I the flexural inertia of the resisting section. For simplified analytical estimations, a $t_{mono} = 3 \times 12 = 36$ mm thick, monolithic section was roughly considered, in place of the actual nominal LG + AN section (Fig. 3.7), with $E = E_{glass}$. The second moment of area I of the equivalent monolithic system was then estimated as:

$$I = B \cdot \left(t_{mono}^3 \right) / 12 = 5.63 \cdot 10^{-6} \text{mm}^4 \tag{3.3}$$

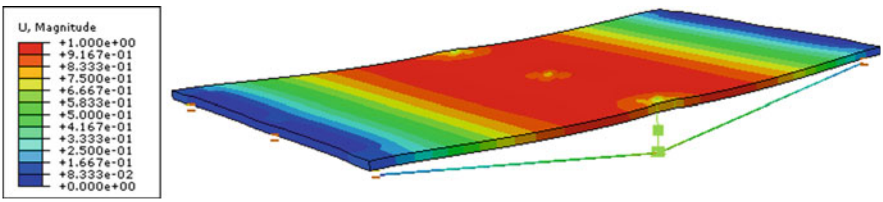
Following Eq. (3.1), a fundamental frequency $f_{AN} = 13.28$ Hz was hence calculated for the footbridge, with a scatter up to $\Delta_f = -11.2\%$ the exeperimental measurement, where:

$$\Delta_f = 100 \times (f - f_{TEST}) / f_{TEST} \tag{3.4}$$

3.4.2 *Finite-Element Numerical Simulations*

Within the full FE study, parametric analyses were carried out to investigate the sensitivity of the fundamental dynamic characteristics of the footbridge to some key input parameters, such as the actual shear stiffness of PVB foils (Fig. 3.8), the size and pre-stress level of the bracing steel tendons, the LG-to-AN features, etc. Even in presence of markedly different input parameters and mechanical assumptions, the FE predictions resulted in a fundamental beam-like modal shape of G2-panels well agreeing with the vibration test measurements (Fig. 3.8(a)). Conversely, severe variations were observed in terms of fundamental frequency f_{FE}, see Fig. 3.8(b). There, the Δ_f scatter values are defined according to Eq. (3.4).

Worth of interest in Fig. 3.8(a) is that both the analytical and the corresponding monolithic FE model are not able to account for the actual bending stiffness/restraints of the case-study footbridge (−11% the calculated frequency scatter). The bonding PVB foils proved in fact to have major effects on the dynamic parameters of the structure. Fine-tuning of FE dynamic predictions, in particular, resulted in an optimal E_{PVB} value in the order of ≈4 MPa, being well representative of time/ambient effects on the footbridge. Given the availability of such a reliable FE model for the existing structure, further detailed investigations will be planned in the future, so as to assess the actual vulnerability of the footbridge and its performance under possible extreme loading scenarios.



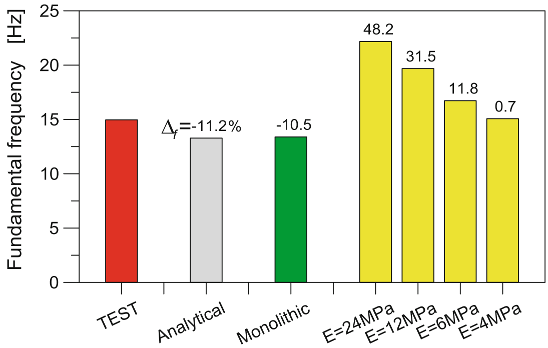


Fig. 3.8 Numerically predicted (**a**) fundamental modal shape and (**b**) frequency (ABAQUS)

3.5 Conclusions

In this paper, a preliminary dynamic characterisation of an existing glass suspension footbridge was presented, including on on-site vibration tests and numerical investigations. It was shown, in particular, that dynamic identification techniques can offer reliable feedback and support for the preservation, mitigation and enhancement of typically vulnerable structural systems. A combination of multiple aspects can markedly affect the modal estimations of the structure, hence requiring careful consideration towards *fail-safe* design performances. The post-processed data, in particular, confirmed the importance of non-destructive diagnostic investigations for retrofitting.

Acknowledgements This research study is part of the 'INVERSE' project ('Università degli Studi di Trieste – Finanziamento di Ateneo per progetti di ricerca scientifica – FRA2016'). Ing. E. Bergamo and Mr. R. De Marco are acknowledged for providing the experimental instruments and technical support during the on-site tests.

A special acknowledgement is for the So.Co.Ba Foundation 'Società per la conservazione della Basilica' (Mr. A. Bergamin), for facilitating the field experiments.

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Chapter 4
Performance of TGU Windows under Explosive Loading

Piotr W. Sielicki, Chiara Bedon, and Xihong Zhang

Abstract Glass windows and facades are very popular in buildings, both in the form of traditional partitions and novel adaptive skins. There, given a series of intrinsic material features, special care should be spent at the design stage, so as to ensure appropriate *fail-safe* requirements, especially in presence of extreme design loads such as impacts. Even more attention is required for complex glass assemblies such as Triple Glass Units (TGUs), where the interaction of multiple components (i.e. the glass layers and the bonding foils, with the framing members) as well as the presence of gas cavities can further affect the dynamic response of these systems. In this paper, major outcomes of a research project in progress for the performance assessment of TGU windows under explosive loading are reported.

Keywords Structural glass · Triple glass units (TGUs) · Vulnerability analysis · Soft targets · Explosions · Field blast experiments

4.1 Introduction

Glass windows and facades are popularly used in structures [1–3]. However, glass is typically fragile, as compared to other traditional building materials such as reinforced concrete and steel. Post-event investigations of terrorist bombing attacks and accidental explosions have cited the failure of glass windows being one of the major causes of personnel injuries and casualties. Many studies have therefore been

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L. Hofreiter et al. (eds.), *Soft Target Protection*, NATO Science for Peace and Security Series C: Environmental Security,
https://doi.org/10.1007/978-94-024-1755-5_4

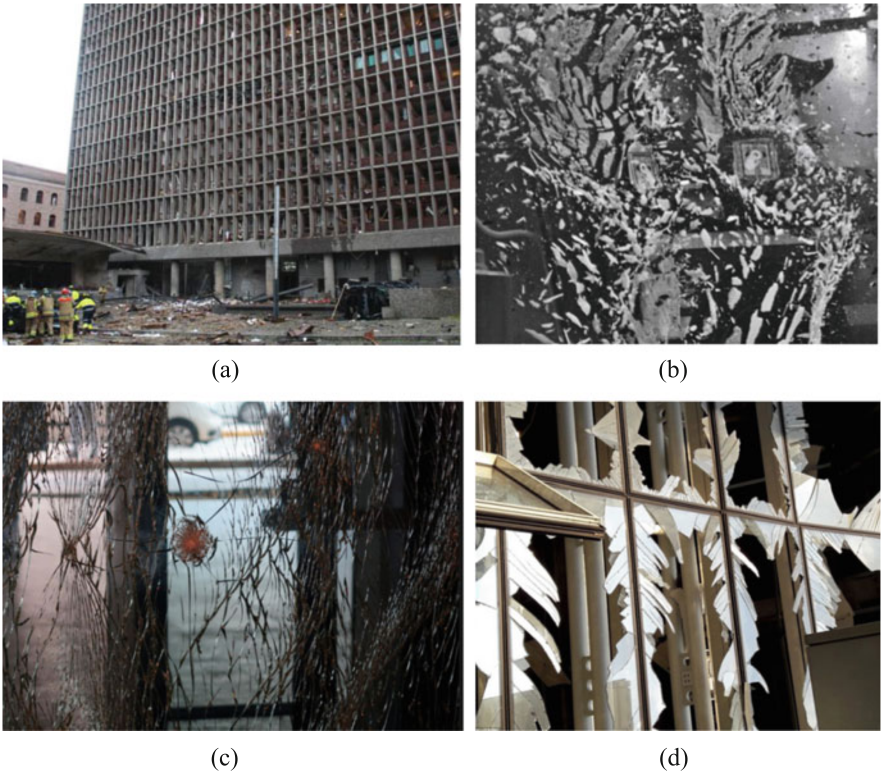

Fig. 4.1 Glass windows/facades under shock: (**a**) shattered glass windows in Norway attack, 2011 (Courtesy: Heidi Wideroe) and (**b**) flying glass fragments caused by controlled internal explosion [8]. Damage scenarios from the tragic attacks at (**c**) Instanbul and (**d**) Brussels Airports

carried out to investigate the behavior of glass windows/facades under blast loading for better protections of personnel and property safety [4–7].

To improve the blast resistant capacity of windows/facades and reduce glass shard threats from breakage of glass panels, different techniques and new materials have been developed in the last decades, of which laminated glass (LG) is one of the most commonly used mitigation approach for the retrofitting of glass window applications. There, multiple glass layers are bonded via flexible plastic foils, aimed at enhancing the impact and post-cracked behaviour of glass panels, as well as to avoid the ejection of fragments. However, load bearing glass members still represent a critical component in buildings, hence requiring further efforts and investigations, see Fig. 4.1.

4.2 Glass and Interlayers under Shock

4.2.1 Glass Material Properties

For the design of glass structures under extreme loads and impact, major issues are related to the intrinsic mechanical and thermo-physical properties of such a rather innovative constructional material. With respect to the performance of glass structures under shock, literature studies on glass mechanical properties primarily concentrate on annealed glass (AN). Compared to Fully Tempered (FT) or Heat Strengthened (HS) glass, produced by heat treatment which introduces surface pre-compression effects, AN glass is suitable for material investigations since amorphous and homogeneous. AN glass panels for traditional windows and facades normally fails at around 100 MPa or lower stress values, because of the existence of surface flaws. The European standard prEN 13,474–3 [9] reports the measured glass fracture strengths from over 700 ring-on-ring tests, varying from 30 MPa to 120 MPa. The split tensile strength tested on 15 × 15 mm (diameter × length) AN cylinder was only about 20 MPa [10]. Such a marked variation is not only due to the different types of tensile strengths measured, i.e., bi-flexural, split-tensile, etc., but is mainly attributed to the surface conditions of the different tested glass panes.

In this context, it is commonly known that materials behave in different ways under dynamic loading, as compared to their static performance. Glass has no exceptions, and the dynamic properties of AN glass have been studied by different researchers. With respect to static conditions, the influence of surface flaw becomes less prominent under dynamic loading, because there is not sufficient time for existing flaws to fully develop. The British code [11], in this regard, suggests a tensile DIF of 1.78 for glass, when designing windows against blast loading. Analytical derivations from Brown's equation, however, showed that AN glass strength could increase up to three times the nominal value [12–14], see Fig. 4.2(a).

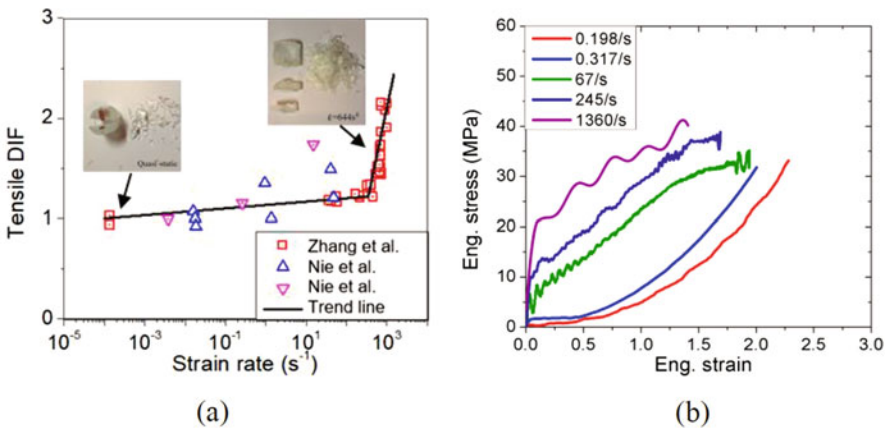

Fig. 4.2 Dynamic material properties of (**a**) glass and (**b**) PVB

4.2.2 Interlayers

Within a typical LG assembly, the mechanical interaction of multiple glass layers is strictly related to the bonding contribution of interlayers. While several solutions are currently available on the market, PVB® (Polyvinyl Butyral) still represent - since decades - the commonly used interlayer material for bonding LG members. In terms of mechanical performance, PVB layers have a typical non-linear, time-dependent response, with large failure strain (see Fig. 4.2(b)). In the regime of small strains, the tensile behavior of PVB can be described with a viscoelastic model. A generalized Maxwell series and Williams-Landel-Ferry equation can be employed to account for the time-dependence and temperature-dependence of shear modulus (see for example [15–18]).

4.2.3 Protection of Glass Soft Targets

Based on some recent literature efforts, the protection of ‘soft target’ is one of the key goals of *fail-safe* design procedures. However, no official definition exist for ‘soft targets’ [19, 20]. In terms of protection of citizens, for example, the ‘soft target’ definition is conventionally used to denote places with high concentration of people and low degree of security against possible attacks. These places can typically include sports venues, shopping venues, schools, transportation systems, religious facilities, open spaces, etc. The major distinction is made between ‘soft’ and ‘hard targets’ - being representative of well-secured premises (i.e., government buildings, military premises, law enforcement offices, guarded non-governmental or commercial facilities, etc.). Given such a general definition of soft targets, existing glass structures - due to their intrinsic vulnerability - can represent an additional source of risk for the citizens, requiring appropriate studies and possible structural health monitoring activities, so as to timely plan possible retrofit/mitigation interventions.

Based on past observations from some tragic terroristic attacks, it is in fact commonly recognised that glass shards and fragments are the major issue due to extreme design loads. In the past, they have been responsible of more than 60% of the casualties, see Fig. 4.1. Structurally speaking, the so-called blast-resistant glass windows and facades still represent an open topic for researchers and designers, since appropriate static/dynamic performances of these systems under service loads should be achieved, while preserving their integrity under shock. The achievement of a such an optimal performance directly reflects on added protection for the citizens, but requires, on the other hand, specific knowledge of their static and dynamic performances of glass structures, including global and local phenomena. Further knowledge is required for the blast performance assessment and enhancement of glass windows composed by multiple, i.e. by assembling multiple LG components in the so-called Double (DGUs) or Triple Glass Units (TGUs), so as to account for gas cavities and load sharing phenomena [21, 22], etc.

4.3 Field Blast Experiments

4.3.1 Literature Background

In this paper, the dynamic performance of Triple Glass Units (TGUs) under blast is analysed, via on-site field experiments. Especially in the last years, the assessment of the dynamic response of traditional glass windows under explosions attracted the attention of several research studies. Major feedback, in this regard, can be expected from shock tube or field experiments [22–24]. In the past, efforts were made by Morison and others, see [25–28], etc. While the blast wave source consisted in both solid explosive or shock tube loading (TNT, C4 or PETN the charge), the common aspect of these investigations was represented by the type of windows, i.e. with dimension in the order of 1.1 × 1 m (up to 1.25 × 1.55 m), and consisting in a single LG plate. Their LG section was in fact obtained by bonding two 3 mm thick AN layers via a middle PVB foil (1.52 mm). Recently, Makki et al. [29] also experimentally investigated the blast response of a LG window. In their study, special care was spent for the effects of combined blast loads and temperature variations, so as to assess the potential of cladding safety films.

4.3.2 Geometrical and Mechanical Features of the TGU Samples

The typical glass window for the research project herein summarised consisted of a TGU, given by three glass panels (0.88 × 0.88 m the net dimensions) and a polycarbonate frame. The final result (1 × 1 m window) is shown in Fig. 4.3, with an actual bending span of glass equal to 0.85 m. Compared to past efforts, the presence of two gas cavities at the interface of glass panes represented the key aspect of the experiments. More in detail, the three glass layers were made LG sections, in which two AN foils were bonded via a soft PVB film.

4.3.3 Experimental Methods

The field experiments were carried out in September 2018 at Poznan University of Technology, Poland. At the time of the tests, seven repetitions were carried out on a set of four TGU samples with identical geometrical/mechanical properties. To this aim, each TGU window was rigidly connected to a concrete reaction wall, via metal screws and an expansion buff foam (Fig. 4.4). The TGU samples were hence subjected to 10Kg of TNT. Within the set of experiments, variations were made in terms of location of the charge with respect to the TGU samples (see Table 4.1 and Fig. 4.4), and location of the measurement instrumentation.

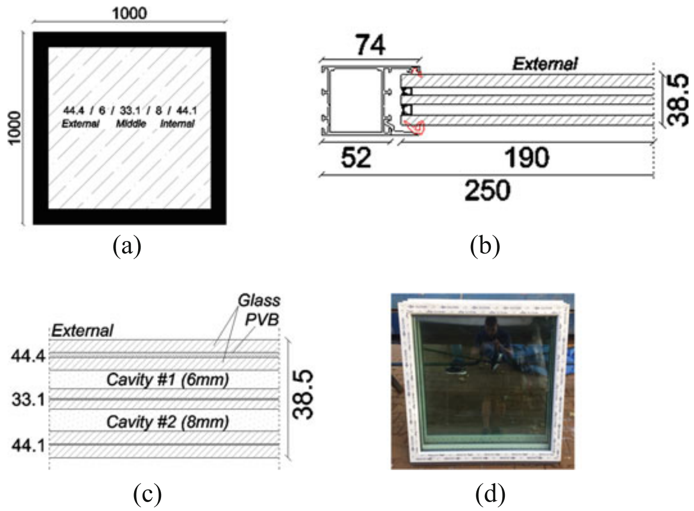

Fig. 4.3 Nominal geometry of the tested TGU samples (dimensions in mm): (**a**) front view, (**b**) cross-section (detail, with schematic section of the frame); (**c**) LG sandwich detail and (**d**) view of an assembled window

In particular, the stand-off distance for the explosive charge was changed in the range from 8 to 15 m, see Table 4.1. Accordingly, the accelerometers were positioned in the centre of the glass windows, or in the framing members. An high-speed camera was also used (Fig. 4.4), to capture the TGU windows response under shock (rear side).

The measurement instruments consisted in gauges and accelerometers that were placed within the test setup so as to properly capture the incident blast pressure on the front (i.e. exposed) and rear (unexposed) sides of the TGU windows, see Fig. 4.4, as well as the response of each sample. More in detail, conventional piezoelectric accelerometers (PCB®352A60 type, with a nominal mass of 0.006 kg) were used record the accelerations and then the displacements at a control point in the centre of each glass window. Given the nominal cross-section of TGU samples, no experimental measurements were made for the dynamic response of the middle LG panel, while the gauges – see Table 4.1 – were placed both on the frontal (i.e. exposed) and on the rear (i.e. unexposed) surface of each glass sample, see Fig. 4.4.

4.4 Summary of Results (Sample #W1)

For the sake of clarity, the experimental sample #W1 is primarily discussed in this paper. The TGU sample, see Fig. 4.5, was characterised by a stand-off distance of 15.10 m (0.99 m the height of detonation from the ground), and sustained a maximum overpressure in the order of 30 kPa. The full recorded time history can

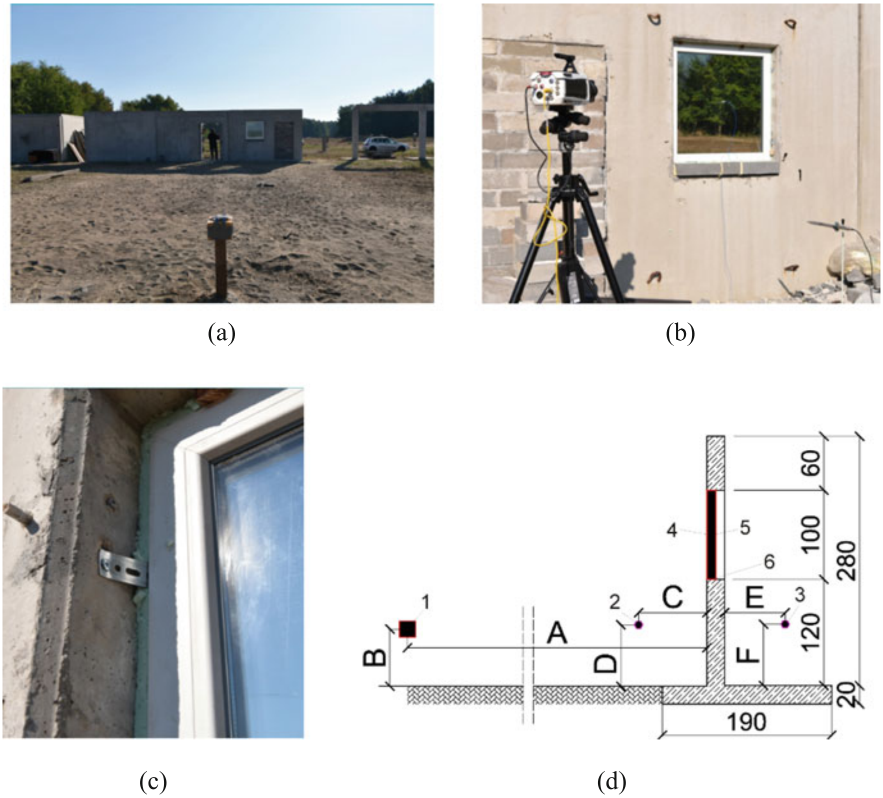

Fig. 4.4 Experimental setup: (**a**) frontal view, (**b**) rear side; (**c**) frame connection detail and (**d**) schematic setup (lateral view, dimensions in cm)

Table 4.1 Experimental setup for the field experiments (dimensions in m)

SAMPLE #	TEST #	TNT charge		Instruments: Gauge (overpressure)		Instruments: Accelerometer
		A	B	C	D	
W1	1	15.10	0.99	1.20	0.87	Middle / front
	2	15.08	0.99	1.18	0.87	Middle / front
W2	3	10.10	0.74	1.20	0.87	*Failure*
	4	8.08	0.69	1.20	0.87	Middle / rear
W3	5	14.39	0.80	1.23	0.86	Middle / rear
	6	10.69	0.80	*Failure*	*Failure*	Middle / rear
W4	7	10.69	1.00	0.80	0.91	Middle (frame) / rear

be shown in Fig. 4.5(a). According to Fig. 4.5(b), the backward deflection of the front (exposed) glass panel was measured after 0.03 s in the order of 2.5 mm, hence corresponding to 1/400 the window dimensions. Failure of the front glass panel occurred after 0.05 s.

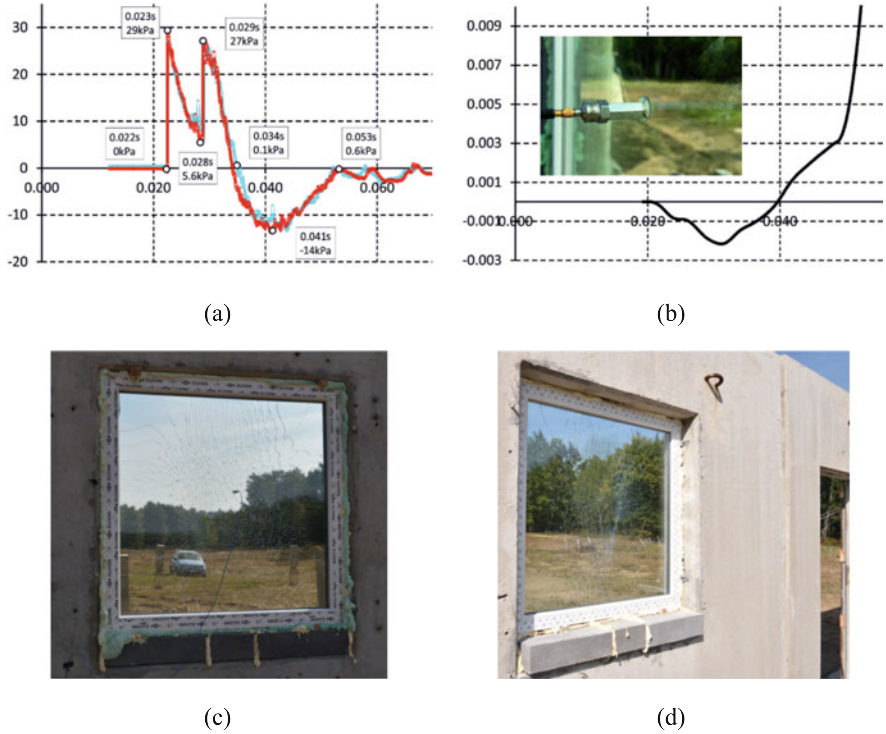

Fig. 4.5 Experimental results for the sample #W1: measured (**a**) overpressure (in kPa) and (**b**) displacement (in m) histories, as a function of time (in s). (**c**) and (**d**): Selected views of the Damaged #W1 sample after the experiment

To further assess the experimental observations and measurements, a preliminary Finite Element (FE) numerical study of the glass window was also carried out in ABAQUS [30]. Dynamic/Explicit analyses were performed.

At a first stage of the investigation, a simplified FE numerical model representative of the exposed LG panel (44.4) was only described, according to Fig.4.3, via 2D *shell composite* elements accounting for the nominal cross-section. Glass and PVB materials were characterised, respectively, via a tensile brittle constitutive law (*brittle cracking* damage model, see also [22]) and an equivalent, elasto-plastic stress-strain response [22, 31, 32]. Ideal rigid supports were defined along the edges of glass, hence disregarding the flexibility of glass-to-frame restraints, as well as the structural contribution of the middle and rear LG plates. The net bending span of the glass panel (0.85 × 0.85 m) was in fact accounted, with linear clamps for the four edges. A sweep mesh pattern was used for the shell elements, with an edge size spanning from a minimum of 5 mm (i.e. in the central region of the glass panel), up to 15 mm along the clamped edges (9000 elements, 55,000 DOFs, see Fig. 4.6(a)).

The input blast load was then described in the form of a uniform pressure, according to the experimentally measured pressure-time history. As shown in

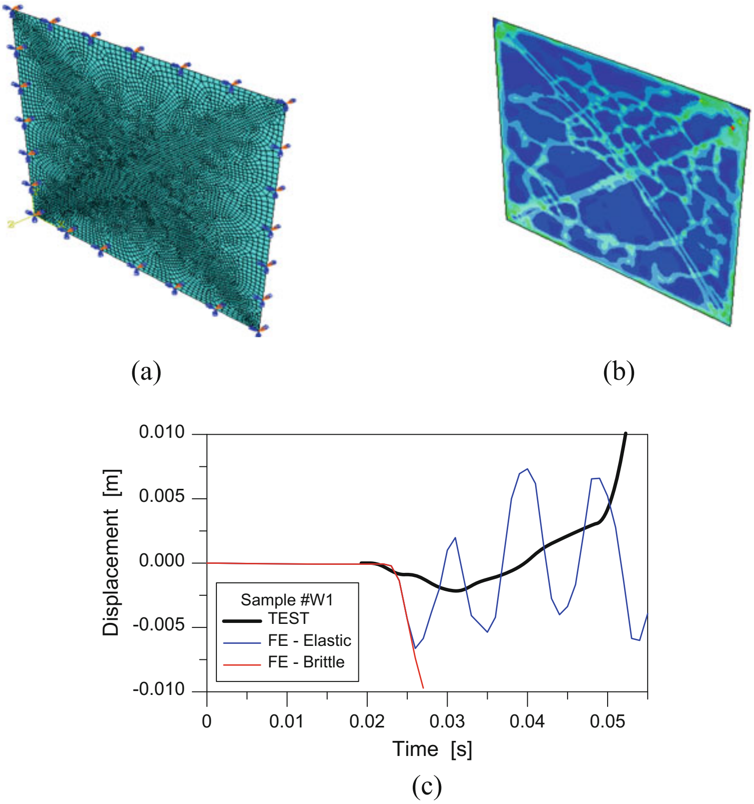

Fig. 4.6 (**a**) Simplified numerical model for the #W1 TGU sample (mesh pattern in evidence), with (**b**) cracks in glass (t = 0.025 s) and (**c**) time-displacement comparisons (ABAQUS)

Fig. 4.6, even such a simple FE model can qualitatively capture the crack pattern of glass (Fig. 4.6(b)). Otherwise, the global response and displacement evolution in time of the TGU window is strictly related to a combination of mechanical and geometrical parameters, including the tensile resistance of glass (45 MPa the nominal value for the FE model), the actual boundary conditions (see also [22]), the effective blast pressure-time history, the effect of gas cavities on the dynamic response of the full TGU assembly.

4.5 Conclusions

In this paper, the blast response of Triple Glass Unit (TGU) windows under blast has been preliminary investigated, based on field experiments and simple Finite Element numerical models. As known, glass windows represent one of the critical and most vulnerable components in buildings, hence requiring special care and design considerations under shock and extreme loading conditions. Further attention should be spent when these windows are obtained by a combination of assembled elements, i.e. like in the case of TGUs, where three laminated glass panels can mechanically interact via the interposed gas cavities, as well as are restrained to a supporting frame.

Acknowledgements The experimental project partly summarised in this paper was supported by the National Science Centre Poland, within the framework of the Miniatura project (N° 2017/01/X/ST8/01035).

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Chapter 5
Risk Management in the Protection of Soft Targets at Ukraine

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Abstract Approaches to the application of risk management in the protection of Soft targets are considered. The analysis were made of the current situation in the world and Ukraine with a terrorist threat at the above mentioned facilities, necessary measures to be offered to prevent or mitigate the possible negative consequences of the existing risks is performed. The characteristic has of objects of care out which are classified as "Soft targets" is shown, existing threats are shown. The main aspects of risk management of «Soft targets» are considered. It is proposed to consider the application of risk management in solving a complex problem of protecting civilian objects that do not have specialized and effective protection. The lack of such safety (protection) makes them vulnerable to terrorist attacks. The scope of this approach is to ensure that all strategic, managerial and operational tasks of the executive and other organizations, at all levels of government, are coordinated with the management's risk to protect "Soft targets" for all projects, functions and processes.

Keywords Soft target · Management · Protection

5.1 Introduction

A change in the state structure of the country is always reflected in neighboring states. The collapse of the Soviet Union gave impetus to the development of terrorism in Europe and other countries. The types of terrorism and its forms have changed. The latest type of terrorism is a hybrid war that the whole state of Russia unleashed against another sovereign state – Ukraine. In the countries of the former

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L. Hofreiter et al. (eds.), *Soft Target Protection*, NATO Science for Peace and Security Series C: Environmental Security,
https://doi.org/10.1007/978-94-024-1755-5_5

USSR, acts of terror were sporadic and rarely happened; this was the case even after its collapse. Mostly there were political and criminal acts accompanying violence. Freedom of the individual in the understanding of some people has the form of expression in the form of acts of violence against other fellow citizens. In the countries of the post-Soviet period, the police system and counterintelligence were and remain very strong. They are aimed at constantly monitoring the citizens. Perhaps that is why in these countries there are no open acts of terror and there are no registered terrorist organizations. But everything is changing, and now in Ukraine a large number of weapons are in the hands of people who are spreading out of the war zones of the cities of Donetsk and Lugansk. War grenades in houses began to explode; sometimes they fired pistols and even machine guns. As a rule, this or former warriors of an anti-terrorist organization or intelligence of a neighboring state eliminate unwanted citizens. First of all, the civilian population suffers from all this. Therefore, one of the main tasks for specialists in the field of civil security in Ukraine is the recognition at an early stage of the risks and threats of possible hazards, the development of effective measures to prevent them and the management of risks to protect soft targets. Soft targets in Ukraine are very vulnerable and their protection requires urgent action. To address these issues, it is necessary to introduce international protocols and standards into the social environment of the country. At the present hour it is progressing very slowly. Articles such as this and NATO international conferences with the participation of experts on terrorism such as General Dr. Jennifer Hesterman and others will help us better understand the intricacies of these issues and find ways to solve them at the national level.

5.2 General Characteristic of "Soft Target" at Ukraine

Safety and human health are often interdependent. The reason for this is connected with the organization of the management structure as a rule. The strong ties are between these disciplines. One of the strongest links between them is that one risk event can have consequences in many areas. The objects of "Soft targets" in Ukraine do not belong to the category of objects of increased danger which means that the local executive authorities trust to resolve security issues directly to the managers of such facilities at their own discretion.

The evolution of terrorism affects the history of the development of mankind which begins with individual cases of attacks on politicians and ends with massive planned attacks of well-organized paramilitary groups in the modern world. With the history of the development of science and technology, a parallel trend was terrorism. At different times, terrorism set different goals and objectives but the result remained the same: the death of people and the destruction of the infrastructure of cities, intimidation and panic among the population, and other negative consequences. Under modern conditions, terrorism began to take on various forms and sometimes merge with radicalism, extremism, banditry and other kinds of modern struggle for power and money. The analysis of the real events taking place now in Ukraine will be made after many years. However, even now it can be noted that our country occupied 11th place in the international ranking of world terrorism, and since 2017 is at 17th position, i.e. the indicators have improved, although it is among the 20 countries with a high level of terrorist threat [1].

Considering the issues of terrorism and possible vulnerabilities in soft-targeted objects, it is necessary to take into account the extensive practical experience of General Dr. Jennifer Hesterman, who he and his colleagues presented to us in the books "Soft target and crisis management" and "Soft Target Hardening Protecting People from Attack ". These books look at the nature and origin of terrorism in the world and evaluate protection systems against it. This is an appreciable contribution to the fight against terrorism, but now it is necessary to connect a scientific apparatus with the practice to improve the methods considered [2, 3].

The objects of the social structure related to the soft target are very diverse. Among them are such soft targets that should must be have hard protect as at there are helpless sick citizens of different ages and positions of them in society do not to play any rule. Such facilities include hospitals, clinics, and nursing homes. In their article, the authors are De Cauwer H, Somville F, Sabbe M, and Mortelmans LJ [4]. Hospitals: soft target for terrorism? Analyzing a similar situation in Ukraine, one can note its relevance for us. But also, as in the previous case, it is necessary to consider scientific approaches, analyze situations and develop protocols and standards to protect such soft targets from terrorist threats.

The terrorist actions didn't were registered in the territory of Ukraine until 2014, nor was the existence of terrorist organizations. The recorded cases of explosions and attacks on objects were of a criminal or political nature, connected with the redistribution of power of individual gangster groups or political parties. For the first time begin use the term terrorist attack was in connection with the actions of Russian paramilitary groups and the armies of the DPR (city Donetsk) and LPR (city Lugansk), and also in the Crimea at Ukraine. It this period of time from 2014 to 2018 years more 10,000 people died according to the UN data in these regions of Ukraine as a result of terrorist groups' attacks [5].

Our country was not ready for such acts of violence. Now our government and the people of Ukraine assess terrorist threats differently. Thus there is a real threat of the proliferation of weapons and terrorist groups throughout Ukraine and now this problem of protecting «Soft targets» has become very relevant.

It is proposed to consider the following issues:

1. General characteristic of "Soft target" at Ukraine
2. Approaches to the management of «Soft target»
    - Risk Management of «Soft targets»
    - Identification of risks
    - Risk assessment by the «Soft targets»
3. General conclusions

The goal of our research is to prevent terrorist attacks or other violent impacts on «Soft target» facilities by developing and implementing risk management technologies.

The history of the appearance in Europe of the term “Soft target” is very young and has no more than 20 years but meanwhile terrorism appeared long ago as a phenomenon.

If we follow the hierarchical levels of safety proposed by prof. Hofreiter [20–22] it should be noted that “Soft target” as objects of protection (care) are at the level of group security below which in the hierarchy – individual security [2].

Based on publications Ing. Zdeněk Kalvach [3] the “Soft target” is vital objects where there can be a significant number of people without special protection.

Typical soft targets include:

- Schools, dormitories, canteens, libraries,
- Religious objects and places of worship,
- Shopping centers, trading floors and commercial facilities,
- Cinemas, theaters, concert halls, entertainment venues,
- Meetings, parades, demonstrations,
- Bars, clubs, dance clubs, restaurants and hotels,
- Parks and squares, tourist attractions and attractions, museums, galleries,
- Sports arenas and stadiums,
- Important transport facilities, railway and bus stations, airport terminals,
- Hospitals, medical centers and other medical institutions,
- Public meetings, pilgrimages, fairs
- Cultural, sports, religious.

It is not possible to count the exact number of such objects and events in Ukraine because now they all enterprises have different forms of ownership, of legitimacy and some (meetings, parades and others) are of a periodic nature.

The city of Kharkov is one of the largest scientific and technical and developed centers of Ukraine. The population of the city is 1,450,082 people. The only city in Ukraine that has a full set of Council of Europe awards: Diploma, Honorary Flag, Table of Europe and the Prize of Europe [4]. In Soviet times it was the largest center of tank, tractor and turbine construction and the third largest industrial, scientific and transport center after Moscow and Leningrad. In the second half of the XX century – the main transport hub of South-Eastern Europe.

In the city of Kharkiv there are 142 research institutes, about 69 higher educational institutions (17 universities and 9 academies), including the Kharkiv University (the fifth in the Russian Empire, founded in 1805) and the Polytechnic Institute (the second polytechnic university of the Russian Empire, founded in 1885), in which 230 thousand students study; 16 museums, a city art gallery, 6 state theaters, 80 libraries.

The local government body is the Kharkov City Council. In 2012, it was one of the four cities of Ukraine that hosted the European Football Championship 2012. In Kharkiv there are more than 218 schools, 11 operating cinemas, about 30 theaters (including a zoo and a planetarium), 27 city hospitals and more than 30 polyclinics, more than 40 large shopping centers and others. The underground net (metro) is at

Fig. 5.1 Selected Soft target in the city of Kharkiv, Ukraine (square and park)

Kharkiv. In the squares of the city and in the parks there are always many residents of the city, which may be the object of a terrorist attack (see Fig. 5.1).

All of the above and similar institutions can be classified as "Soft targets". An analysis of past terrorist attacks in the world, revealed the following predominant forms of attacks that need to be considered in order to develop an effective security system to protect «Soft targets» from terrorist attack (Ing. Zdeněk Kalvach) [3] are:

1. Bomb:
   - Return bombs (except when the bomb is in the vehicle).
   - A bomb, delivered by mail,
   - Bomb in a parked vehicle,
   - A car loaded with a bomb and aimed at the target, driven by an attacking suicide;
2. Attack of suicide bombers;
3. Arson;
4. Assault with a weapon (pistol, machine gun, etc. – active shooter);
5. Hostages and barricade situation;
6. Attack with a cold weapon (knife);
7. The crowd attacks the soft target;
8. Vehicle aimed at the target.

The greatest danger for Ukraine's represented from the data given as p.p. 1, 3–6 and the destruction of infrastructure need added to mention above.

Issues of classification of terrorism and management risk are considered in the textbook "Fundamentals of Occupational Safety and Health of Man" (2018) [5] and the training manual "Safety of Living" (2005–2007) [6, 7] published by the NTU "KhPI", Kharkiv. The program material of universities in Ukraine does not cover in the proper volume such objects that characterized as «Soft targets» so they should be considered separately. The above-mentioned objects of protection "soft targets" have their own specifics, which requires more detailed study and consideration of approaches in managing their safety.

5.3 Approaches to the Management of «Soft Target»

Risk Management of «Soft Target» Risk Management of «Soft target» is invited to draw on the basis of standard ISO 31000:2009 [8]. The classic form of standard for risk management gives a list in order of preference as to how to deal with risk:

- Avoid risk, deciding not to start an activity that generates a risk;
- The adoption and preservation of risk by making an informed decision;
- The source of risk of removal;
- The likelihood of a hazard a change;
- The consequences are changing;
- Risk sharing with the other party or parties (including contracts and risk financing).

Let's perform the short analysis do of the above mentioned approaches to risks for situations with «Soft target» in Ukraine.

Avoid Risk, Deciding Not to Start an Activity that Generates a Risk
Regarding Ukraine, such purposes include meetings, rallies, demonstrations and the like. Such events are held quite often. They are initiated by political parties, trade union organizations, individual businessmen and deputies from the authorities. Other organizations and businessmen opening their business very carefully carry out calculations on the magnitude of the risks.

The Adoption and Preservation of Risk by Making an Informed Decision
Attending children to schools, attending meetings, going to shopping centers and cinemas and other places indicated as soft goals is an aspect of life that is necessary for a person. Each person chooses one or another store, one or another cinema at his own discretion but as a rule, he rarely thinks about the risks to his life, but thinks about the benefits and amenities, about the achievement of his goal of these visits. It is getting used people living in the threat environment. This is unacceptable but they have to live.

The Source of Risk of Removal
The removal of the source of risk can be achieved by building a fence, from which a sufficient distance must be walked to the establishment. The access at territory of the institution for third-party or suspicious people at the entrance need to limit. Prohibit the entry of vehicles in certain areas and establish observation points. Therefore, schools and hospitals must have fences and controlled walk-through.

The risk is determined by the danger to the life and health of people, which appears in certain places that must be identified and controlled. The achievement by the carriers of the danger, the chosen targets, should be as difficult as possible and take a long period of time for them.

The Likelihood of a Hazard a Change
The ideal option is when the dangers are minimal and cannot harm people. But the situation is when there are a lot of uncontrollable weapons and ammunition in the

country, including grenades which are in the possession of a certain part of the population. This is the result of hostilities in the east of the country. The Security Service of Ukraine is engaged in the prevention of the proliferation of weapons in the regions, but cannot completely stop this process. Consequently, weapons and explosives may appear in schools and other places where people are located. Therefore need control at the entrance and inside the «Soft targets».

The Consequences Are Changing
Risk analysis shows that there are no trifles in solving the issues of ensuring the necessary level of security on the ground. Even garbage bins, it is necessary to investigate based on the fact that with an explosion inside it, elements of this urn become striking factors. Glass showcases, with the explosion scatter the pieces of glass that hit living objects. Incorrectly stored gas cylinders with gas can cause buildings to collapse in an explosion caused by arson. In order to take all this into account, it is necessary for security specialists to do an analysis of possible event scenarios taking into account the above.

Risk Sharing with the Other Party or Parties
There are several options for implementing this approach. The first is when "the strong resists the strong." That is, a danger is prevented by a well-trained specialist (specialists) who have protection elements adequate to the level of threat. The second option, "smart (cunning) is opposed to the strong." In this case, the specialist has something other than the usual elements of defense and defense. The modern and computer technology comes to him aid. The third option, "let someone get lucky, but some does not." It this cases all people are insured on case of danger and then, receive compensation for damage to health.

In the ideal risk management process, the process of setting priorities is implemented, according to which the risks with the greatest loss (or impact) and the highest probability of their occurrence are processed first, and risks with less probability of occurrence and smaller losses are processed in descending order. In practice, the process of assessing the overall risk can be difficult, and therefore balancing existing material and non-material resources, to mitigate risks with a high probability of occurrence. In this case, there is a threat that objects with high losses, but with a lower probability of occurrence, can often be incorrectly identified, and therefore not have adequate protection.

Risk management also faces difficulties in allocating resources. Resources spent on risk management can be spent on more profitable types of production activities. Again, optimal risk management minimizes costs (or labor or other resources), and minimizes the negative consequences of risks.

Methods of risk management of protection of soft targets, for the most part consist of the following step-by-step actions:

1. Identify and characterize threats;
2. Assess the vulnerability of critical soft targets to specific threats;
3. Determine the risk (that is, the expected probability and consequences of specific types of attacks on specific objects)

4. Identify ways to reduce these risks;
5. Determine the priority of risk reduction measures based on the strategy.

Risk management should:

- create resources to perform risk reduction, and they must be adequate to the magnitude of the risk;
- be an integral part of organizational processes;
- be part of the management decision-making process;
- take into account uncertainties and assumptions;
- be systematic and structured;
- be based on the best available information;
- be adapted;
- consider human factors;
- be transparent and inclusive;
- be dynamic, iterative, and respond to change;
- be capable of continuous improvement;
- Constantly or periodically reevaluate.

In accordance with ISO 31000 [8] the risk management process consists of the following steps:

1. Define the risk in the chosen area of interest («Soft targets»);
2. Planning the process of object protection;
3. Performing operations:

- Connection to risk management of society;
- Identification of stakeholders – personalities and goals;
- Identification of the key indicators for assessing risks and constraints;

4. Defining the order of activities and performance indicators;
5. Development of risk analysis methods related to the process of protection of «soft targets»;
6. Mitigate or reduce risks using available technological, human and organizational resources.

Identification of Risks After defining the protection object – «Soft target», the next step in the process of risk management is the identification of potential risks (sources of hazards). Risks – in our case, these are events that cause a threat to the life and health of people in objects identified as «Soft target» when implemented. Therefore, the identification of risk can begin with identifying the source of our problems or the problem itself.

Initial analysis – sources of risk may be internal or external to the system (a soft target), which is the goal of risk management. Considering the significant number of such objects in cities and towns, the term softening can be used instead of management, because by its own definition the risk is associated with decision-making factors that cannot be controlled.

Examples of sources of risk and our problems are: stakeholders of a terrorist attack which may include recruited employees of companies.

Analysis of problems – risks associated with identified threats. For example: the threat of penetration of terrorists (intruders) into energy supply systems of facilities, abuse of confidential information, the threat of a planned accident, and others. Threats can come from various terrorist organizations, and even governments.

When the source of the threat is known, events that it can cause, events that can lead to a vital problem can be investigated. For example: confidential information that can be stolen even in a closed network; the launched quadrocopter hitting the plane during take-off that can make all the people on board victims.

The chosen method of risk identification may depend on the culture of the population, the experience of specialists and the appropriate level of necessary protection of the soft target [16–18].

Identification methods are formed using templates or developing templates to identify sources, problems, or events.

Identification of risks based on the goal – protection of «Soft targets». Any event which can supply the achievement of a goal, partially or completely, is defined as a risk.

Risk identification based on the scenario. When scripts are analyzed, different scenarios are created. Scenarios can be alternative ways to achieve the goal or analyze the interaction of forces involved in protecting a soft target. Any event that triggers an alternative to an unwanted scenario is identified as a risk.

Consider examples of spraying an unknown gas in Ukrainian schools in 2018. In Kharkov, at school №3, as a result of the spraying of unknown gas, 31 children sought medical help, 15 of them were sent to the hospital. "Six emergency medical aid teams were sent to the place, according to the father of one of the hospitalized schoolgirls Oleg Golovkov, according to the symptoms, the sprayed substance is not like pepper gas." According to the press service of the Kharkov Regional State Administration, the state of hospitalized children is estimated as moderate [9].

A similar case took place in Nikolaev (Ukraine) in the same year. In Nikolaev, due to the spraying of an unknown substance, 36 children were hospitalized in the school № 6; two of them are in intensive care [10].

Prime Minister Vladimir Groisman urged the National Police and the Security Service of Ukraine to check whether there is a connection between cases of spraying tear gas in schools in different regions. "We need to look more closely at the reasons why this is so, or it simply does not happen in a coordinated way, or it is already beginning to be coordinated between the schools," the prime minister said at a government meeting on May 23. He also noted that it is necessary to determine "who sells these cans, and how they fall into the hands of these children." [11].

Similar dispersal was in other schools, educational institutions, shopping centers and underground in Ukraine, Poland and Germany. Is this random event or actions were planned?

- Risk identification based on taxonomy. Taxonomy in the definition of taxonomic risk is a breakdown of possible sources of risk. A questionnaire, tables and

conclusions need to drawn that help to identify risks that based on taxonomy and knowledge.
- General risk check. For soft targets, information with known risks and events should be available. Each such risk can be tested for application in a specific situation.

Currently, many options are used to determine the magnitude of risk and a not quite correct understanding of the concept of risk has developed. It turned out because of the free determination of the probability of an event. Many researchers, because of the need to give practitioners a more convenient tool in their hands to determine risk, suggested using quantification methods, assigning difficult-to-determine points (for example, from 0–5, 1–10 and etc.) based on a priori information [19]. This led to the fact that the definition of risk, in the probabilistic expression that it should have, was reduced to finding some values that supposedly reflect a risk indicator. We believe that the use of points can take place, but then it is not a strict definition of the magnitude of the risk, but an indicator of the likely danger and it reflects the approximate level of this danger. These indicators should be called risk indicators, in contrast to the true values of risks, which are determined on the basis of calculations of the mathematical probability of an event.

There are many different risk identification formulas, but perhaps the most common formula for quantifying risk is the occurrence rate (or probability) (*P)* multiplied by the magnitude of the event (*C*) [15].

$$\mathrm{R} = \mathrm{PC} \tag{5.1}$$

Composite risk index. The above formula can also be rewritten as an aggregate risk index as follows: the risk index Rs is the product of the impact of the risk event (f) and the probability of its occurrence (P):

$$\mathrm{R_s} = \mathrm{fp} \tag{5.2}$$

The impact of a risk event (*f*) is usually evaluated on a scale of 1 to 5, where 1 and 5 represent the minimal and greatest possible risk impact (usually in terms of financial losses). However, the scale from 1 to 5 can be arbitrary and should not be linear.

The probability of occurrence (*P*) is also usually estimated on a scale of 1 to 5, where 1 is a very low probability of occurrence of a risk event, while 5 is a very high probability of occurrence. This axis can be expressed either in mathematical term (the event occurs once a year, once in 10 years, once in 100 years, etc.) Or it can be expressed in "simple English" (the event happened here very often, the event is known here, the event is known to occur in schools, etc.). Again, the scale from 1 to 5 can be arbitrary or non-linear depending on the decisions of experts on the subject.

Thus, the composite index can take (usually) values from 1 to 25, and this range is conventionally divided into three sub-ranges. The overall risk assessment is low, medium or high, depending on the sub-range containing the computed value of the

Composite Index. For example, three sub-ranges may be defined as 1 to 8, 9 to 16, and 17 to 25.

The Method of Risk-Indicator Famous method of Fine-Kinney does not consider the physic-chemical and other properties of the materials and mainly relies on the personal perception of dangerous and harmful factors of the area were people are. Who interrogated of people it is not always correctly identified those threats. The method of determining the Risk-Indicator that developed by the National Technical University "Kharkov Polytechnic Institute" tried to reduce the risk assessment to a more objective [12–14]. We proposed indicators of danger (symbol – *RI* – Risk – Indicators) that is defined by the following expression:

$$RI = \text{People} \times \text{Factors} \times \text{Probability}, \tag{5.3}$$

where, People – number of people that can be exposed to this factor;

Factors – number of hazardous factors (the factors which influence the result and leads to serious injury or death);

Probability – the Probability ranges from 0 (Absolutely impossible) to 10 (Expectations that happens). It's like at method Fine-Kinney. A possible presentation of risk indicators by the NTU "KPI" method is shown in Fig. 5.1.

Risk Assessment by the «Soft Targets» Once the risks have been identified, they should then be evaluated for their potential severity of impact (usually negative impacts, such as damage or loss) and the likelihood of such an occurrence. These values can either be simple to measure, in the case of the value of a lost building, or difficult to determine in the event of an unlikely event. Therefore, it is extremely important to make the best decisions in the assessment process in order to properly prioritize the implementation of the risk management plan.

The probability of risk occurrence is difficult to assess as mentioned above since past data is not available some time. In the end, probability does not mean certainty.

Similarly, the impact of risk is not easy to assess, since it is often difficult to estimate the potential loss in the event of a risk.

An attack on an object of the "Soft target" is the type of event that belongs to the category of random events and its event is determined based on the probability of this event. For example, suppose that there are 150 secondary schools in the city and these 100 schools are not equipped with video surveillance systems and police calling (VSPC). The terrorist chooses 3 schools to commit a terrorist act. What is the probability that all 3 schools are equipped with VSPC systems?

Let event A1 be all 3 schools with VSPC. Then from the classical definition of probability is

$$P(A1) = m/n, \tag{5.4}$$

where n is the total number of equally possible test outcomes; m is the number of outcomes conducive to the occurrence of the event A.

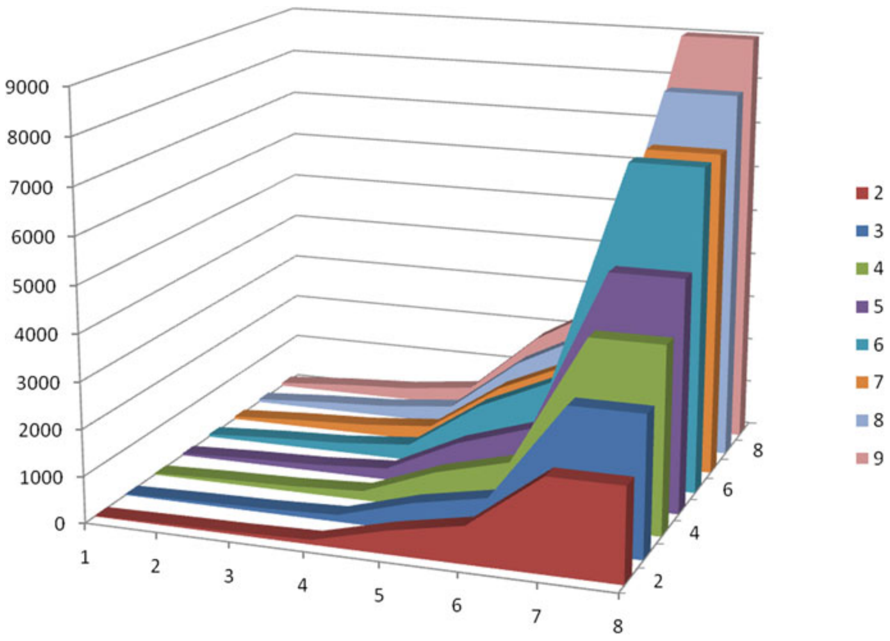

Fig. 5.2 Risk distribution of Risk-Indicators

In our case get

n = C3150 – the number of options to get a terrorist in 3 schools;
n = C3150 = 150! / 147! ·3! = 551,300.
m = C3100·C0150 – the number of options to get a terrorist in 3 schools with VSPC.
m = C3100·C0150 = (100! /97! ·3!)·1 = 161,700.
P (A1) = 161,700/551300 = 0.293,307.

Consequently, the probability of such event is very low but the probability of a terrorist act that would be having impunity is great.

If we change the conditions and accordingly determine the probability for 10, 50, 80 and 130 schools that would be not equipped with police control systems, and added A2 be 2 schools with VSPC then the probability values will be have the situations as shown in Fig. 5.2.

If now, in formula 5.1 to substitute the probability value found using mathematical calculations, the value of the risk will be completely different. But it will be the correct value of risk (Fig. 5.3).

After risk assessment and assessment, all risk management methods fall into one or more of the following four main categories:

- Avoidance (exclusion, withdrawal or lack of participation);
- Decrease (optimization – decrease);
- Exchange (transfer – outsourcing or insurance);
- Retention (adoption and budget).

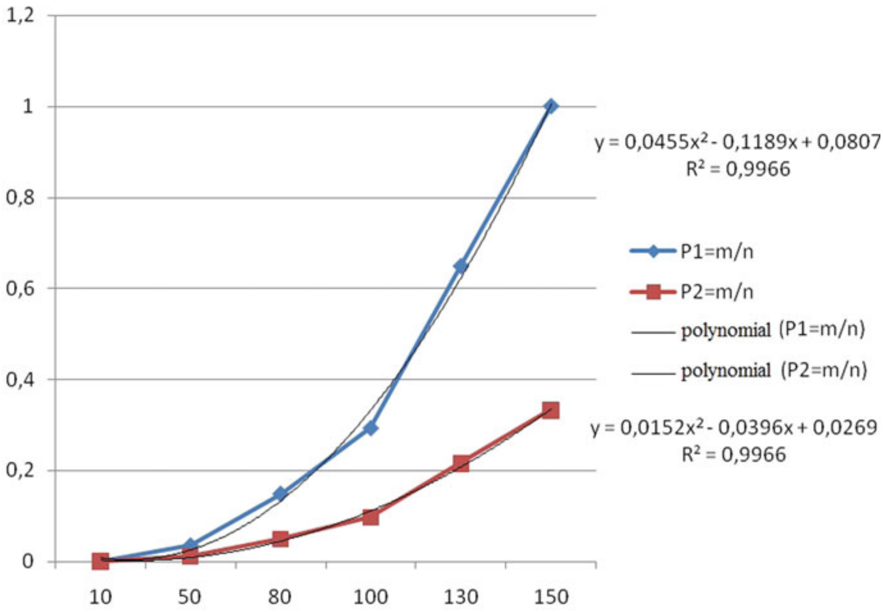

Fig. 5.3 Situations change and determine the probability for 10, 50, 80 and 130 schools

Ideal use of these strategies may not be possible for Soft target. Some of these may include trade-offs that are unacceptable for the organization or the person making the risk management decisions. US Defense University, calls these ACAT categories for Avoid, Control, Accept or Transfer.

Some quantitative definitions of risk are well grounded in statistical theory and naturally lead to statistical estimates, but some are more subjective. For example, in many cases, the decisive factor is the decision-making of people.

Even when statistical estimates are available, in many cases the risk is associated with rare failures, and the data can be sparse. Often the probability of a negative event is estimated using the frequency of past similar events or event tree methods, but the probability of rare failures can be difficult to estimate if the event tree cannot be formulated.

Statistical methods may also require the use of a cost function, which, in turn, may require the calculation of the cost of losing a person’s life. This is a difficult problem. In statistics, the concept of risk is often modeled as the expected value of an undesirable result. This combines the probabilities of various possible events and some assessment of the corresponding harm in one value. In the theory of statistical decisions, the risk function is defined as the expected value of this loss function as a function of the decision rule used to make decisions under uncertainty.

5.4 General Conclusions

1. Analysis of the state of the protection system of the category – «Soft targets» in Ukraine showed that their level of safety is low, and therefore, the risk of terrorist threat is high. The first steps that need to be done have been taken and now we need to start training the population and leaders of various structures that belong to «Soft targets» to the protection of people. Introduce in educational institutions the study of the prevention and mitigation of the negative consequences of existing risks for "Soft targets" in the academic disciplines that relate to civil protection.
2. At the moment, it is necessary to carry out a risk assessment of "Soft targets", develop systems and technologies of protection, develop a coordination system, and ensure people's safety in the care facilities, on three levels – object, regional and state. Particular attention must be outside the protection of people at the facilities. It is urgent to carry out preventive measures at all "Soft targets" objects, taking into account that they are real goals in the conditions of military operations in the East of Ukraine, at any moment can be affected.
3. When determining risk, it is necessary to clearly divide into two types of identifiable risks – risk indicators (indicating approximate risk levels) and natural risks (mathematically justified).

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Chapter 6
Measures for Soft Target Protection Inspired in Other Blast Vulnerable Structures

Damjan Čekerevac, Constança Rigueiro, and Eduardo Pereira

Abstract The paper deals with an improvement of soft target safety. This need is recognized in Europe due to very scarce literature on this topic and due to a rising trend of terrorist attacks on unprotected targets. The effort is made to introduce the existing blast protection practices adopted by oil and gas sector. Typical type of explosion related to processing of oil and gas is described as well as traditional mitigation measures. The special attention is given to structural mitigation measure known as blast wall. The design approaches available in design guides and recommended practices are introduced and the benefit of finite element modeling is discussed. Furthermore, the commonly applied strategies for protection of soft targets are presented. Strengths and weaknesses of use of blast walls for soft target protection are evaluated. Some recent findings of other authors are presented, notably about behavior of panels with innovative typologies and panels made of aluminum, stainless steel and composites. The recently developed solution used in design of objects in seismically active areas is presented for improvement of blast wall energy dissipation. The proposed solution is suggested for use in façade systems, temporary protection of public spaces or multipurpose interior walls that provide protection against fire and blast to evacuation routes and muster zones.

Keywords Soft target protection · Blast wall · Blast response improvement

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L. Hofreiter et al. (eds.), *Soft Target Protection*, NATO Science for Peace and Security Series C: Environmental Security,
https://doi.org/10.1007/978-94-024-1755-5_6

6.1 Introduction

Significant efforts have been dedicated to improving the safety and to further reinforce already hardened targets like military facilities, government buildings and transportation systems [1]. This turned the civilian objects, which are characterized by limited or non-existent protection, into more attractive targets in the eyes of terrorists. A trend of assaults at unprotected public space regardless of its purpose occurred in the recent years. This is demonstrated by recent terrorist attacks in Paris, Brussels and Barcelona in 2015, 2016 and 2017, respectively [2]. It is now understood that areas with large concentration of people like metro and train stations, airports, transportation systems, stadiums and concert halls, commercial centers and pedestrian zones have become a potential target of terrorist groups.

With this in mind, designers, builders, and operators have now to understand how to make the proper investments for mitigating low-probability but high-consequence events [3]. Most of the documents dealing with this topic are recent and the conclusions reached depend on the soft target type. Detailed documentation on security upgrade options for specific soft target is still rather limited in the European Union [2]. This paper represents an effort to improve the blast protection of soft targets by resourcing to the structural blast mitigation solutions already used in oil and gas industrial facilities, as well as to innovative solutions used in earthquake design.

6.1.1 Blast Protection in O&G Industry

Oil and gas process plants are usually complex facilities in which special measures must be undertaken to prevent potential catastrophes resulting from an explosion. An infamous example of the scale of this types of accident is the case of Buncefield refinery in England. In particular, oil and gas facilities located offshore are especially vulnerable to this type of events. The malfunction or failure of these massive and important constructions may cause human losses and may have significant environmental impact.

Besides the dead, live and environmental loads, O&G offshore structures must also be designed for explosions and fire. Hence, it is very important to develop measures that limit the effect of explosions on the overall performance of these facilities, or that could contain their devastating effects [4]. Additionally, these structures are often designed for remote locations in severe ocean conditions, resulting in very expensive construction and maintenance that requires implementation of light and efficient solutions.

6.1.2 Blast Load

Typically, the explosions occurring in oil and gas process facilities are the result of the ignition of the hydrocarbon. This hydrocarbon can originate from conductor or riser fracture at offshore platform or from any spillage due to the rupture of the process vessel. There are many other possible sources of ignition and those that are most likely will depend on the release scenario. For gas releases, the timing of any ignition is important in determining the risk and consequences. The ignition of this mixture under certain conditions leads to the release of large amounts of energy in the form of vapor cloud explosions. It is usually the delayed ignition of the gas mixture that leads to an explosion and its intensity will depend on the degree of confinement, congestion, ventilation regime etc. [5]. Even though the hydrocarbon explosions may occur at any facility which deals with extraction and processing of oil and gas, the severity of the explosion may vary onshore and offshore, depending on the structural layout adopted.

Vapour cloud explosion is typically the deflagration type. This explosion is characterized by the longer rise time of the overpressure compared to detonation explosions.

6.1.3 Non-structural Measures for Blast Mitigation

Safe design practices should be applied both for design of new and for the assessment of existing facilities. Since the risk of explosions in the petrochemical industry is always present, the appropriate safety measures should be considered from the early design stages. This may be done by addressing on one side the conditions leading to an accidental scenario or by limiting the severity of such events if they ever occur. Typically, this is done through control, mitigation and emergency response [6].

When risk of an accident remains high even after the adequate control measures are put in place, it is necessary to design both active and passive mitigation measures. This solution affects both the probability of occurrence of an accident and its intensity, by limiting the exposure critical factors. For example, the explosions in oil and gas industry may result from a fire or simply from the ignition of hydrocarbon, hence the accidental events may be successfully prevented if exposure to these factors remains low.

Passive fire protection systems which do not require external activation to become effective are often used. Such protection includes fire resistant boards, intumescents, ablative materials, cement-based coatings, mineral wool and other systems [4]. These solutions act as an insulation or absorb the heat, limiting the increase of temperature within the structural members.

On the other hand, active systems that require an activation are regularly used as well. Commonly used systems of this type are the firewater deluge system and various inert gases that prevent the ignition of flammable gases. In offshore sector, CO2 and N2 are frequently used for this purpose in unmanned areas. Also, good natural ventilation helps reduce the chance of an explosion [7].

6.1.4 Structural Measures for Blast Mitigation

Structural measures protect identified critical areas against fire and explosion. The critical areas are typically those providing shelter to workers onboard. Typically, structural measures are used to protect muster areas, temporary shelters and evacuation routes [4]. According to [8], the safety of these areas can be improved in two ways. On one side, the improvement of the ductile capacity of the connections and of the other areas where large stress concentrations are expected allows for plastic response of the structure. This leads to favorable response with larger dissipation of energy through plastification of the members. Another way to improve the safety of critical areas is to strengthen the secondary structure and to install the blast walls which physically separate hazardous area from rest of the structure.

The blast walls are equally used onshore and offshore. In this study the focus will be on their suitability for soft target protection. These elements usually consist of plates welded to the bearing structure, and the use of mechanical fasteners is not so common. Limited experimental research is publicly available on the blast response of panels. The various typologies of panels, including single plates and sandwich panels, were studied numerically [9–13]. Most of these studies were focused on the behavior of the blast wall as of an isolated element. In these studies, found in the literature, the response of blast walls was tested for detonating loads. Due to specific nature of the explosions offshore, recently, several authors have focused on the blast assessment of structures for gas explosions usually occurring after the ignition of hydrocarbon [14–17].

Blast walls on offshore structures provide physical barrier between the processing units and manned areas, minimizing the effects of explosive loads on workers onboard. Mainly they are made of steel and welded to the main structure or a module. They can be fabricated from the profiled plate or from the plate with stiffeners which is also known as a bulkhead.

6.2 Blast Protection for Soft Targets

A history of terrorist attacks has shown that bombing or an explosion is the most likely and most dangerous type of an assault on a soft target. According to Kvalach [18], out of ten most likely threats, half of them are related to bomb explosions resulting either from an explosive device, suicide bombing, mail bomb, car bomb or a suicide car bomb. All of these threat must be accounted for in order to design and efficient security system.

Despite a significant number of guidance and best practice documents, there is still no document in the form of official standard [2]. Therefore, due to a large number of threats, various types of soft targets and possible accidental scenarios, designing an efficient security system may be a difficult task for security officers, building designers and other professionals involved in safety and security.

6.2.1 Existing Protection Strategies

The same principles apply as discussed for blast mitigation strategies in oil and gas sector. More specifically, the target safety should be improved both in terms of hardening and strengthening.

Hardening is a process that encompasses all the security countermeasures that improve the robustness of a critical asset in order to reduce the casualties and damage. According to Bennett [19], hardening techniques can be a solution as simple as stack-ing sandbags around a piece of critical equipment, or more complex such as adding structural members to a building to provide additional support. On the other hand, strengthening or fortifying is a measure that improves the overall structural strength and stability. These two measures are often used together. This concept is also recognized by European commission [20] which points out that security by design should be applied from an early stage.

The right security countermeasures will significantly decrease the chances of a successful attack on a soft target. Bennett [19] points out that a well-structured protection plan for a critical asset will have eight layered, overlapping, and intermixed rings of protection, with the critical asset at the center and when measures are multipurpose.

Like in oil and gas industry, proactive countermeasures are the preferred ones when dealing with threats. Preventing the accident is the first step towards safe design. The aforementioned eight rings of protection include detect, delay, deny, defend, respond, and recover. These are reactive countermeasures, which are designed to identify or stop an adversary once it has arrived at the critical asset and have begun to initiate operations against the critical asset [19].

The reactive countermeasures have a wide range of effects. The first and the fourth ring, devaluing and denying are particularly interesting from the structural point of view. The first ring, devalue, deals with the overall appearance of a target. A solid and resistant structure will not be attractive for an attack. Denying refers to measures aimed to reduce the damage to critical assets through structural design and the use of protective equipment. In this way the attacker is denied the ability to cause casualties.

So far, the most effective countermeasure for blast attacks is distance. Maximum standoff distance allows for future improvement of assets to accommodate any other threats that may arise. Other measures turned out to be costlier or they vary in effectiveness and lead to unexpected consequences [19]. Compared to military and governmental sector, private building owners are much more cost effective. The costly solutions are avoided, unless the solution is multifunctional and can address other hazards at same time, like an earthquake for an example.

6.2.2 Application of Blast Walls for Soft Target Protection

The blast wall may be used as a hardening element to minimize damage in a critical asset. This can improve two rings of protection. Devaluing the soft target would make it less attractive for an attack. Additionally, denying would affect the adversary's ability to cause casualties or damage and reduce consequences if the attack occurs. This may be interesting for use in ground and first floors of buildings since, according to Jennifer Hesterman [1], previous experiences have shown that this is where the damage to the structure is highest.

These elements may be used to increase the blast resistance of a structure, to pro-vide a temporary shelter and protect building's muster zones and evacuation routes.

The protected space should be constructed from appropriately tested materials and, generally, not situated on the ground and first floors and also away from exterior walls. Also, accommodations may lack the internal walls that could protect against blast or corridors that can serve as evacuation routes. In such cases, measures such as blast-resistant glazing and clearly marked, regularly rehearsed exit routes are important [21]. This is where the blast walls or modular structures can find their implementation, providing protection for master zones.

Advantages The resistance of a structure can be improved through use of secondary protective elements such as blast wall, that can dissipate the energy and reduce the impact on the primary structure. Such lightweight systems can also be integrated in the façade system. Besides for external use, blast walls can be used for internal walls as well, providing safe evacuation routes and protecting designated building areas from blasts and fire.

Furthermore, due to its low weight, steel blast walls can be used for temporary protection in public spaces. This solution can provide both blast protection and also reduce the visibility, thus making the planning and execution of an attack more difficult and devaluing the soft target. Another advantage of this solution in the cases where it is used for protection of public spaces, is the ease of installation and dismantling.

Traditional blast walls made of a simple flat or corrugated steel plate with and without stiffeners can be combined with fire insulation providing multi-functional solutions. This light solution can be in the form of a sandwich panel or integrated in the modular structure as a designated safe zone.

Disadvantages There are also some downsides to this solution and to use of procedures established for mitigation of blast risks on offshore structures. First of all, blast walls in oil and gas industry are designed to resist mainly hydrocarbon explosions. Soft targets can be exposed to various types of explosive devices, many of which are improvised. Therefore, the peak pressure and pressure curve may be different and depend on many factors. An example of detonation type of an explosion can be a pressure cooker bomb, like the one that was used for an attack during Boston marathon. On the other hand, thermobaric blast explosives or aerosol bombs usually have lower peak pressures, but may have two shockwaves.

Another obstacle for use in buildings is the connection between the blast wall and the primary structure. In offshore facilities, structure is designed to be light and it is primarily made of steel, so the steel panels are usually just welded to the structure.

This doesn't need to be the case in civilian objects. Furthermore, if a highly deformable solution like a corrugated blast wall is chosen, in the case of an explosion this may lead to generation of large pressures in the neighboring room, behind the blast wall. This would cause additional damage to the structure.

Some of these disadvantages can be solved through use of innovative solutions developed for earthquake resistant structures or the naval sector. These solutions will be presented later on.

6.2.3 Analytical and Numerical Procedures for Assessing the Performance of Blast Walls

The structural members subjected to blast action may be analyzed both analytically by applying the single degree of freedom (SDOF) method, or numerically. The SDOF method is applicable in the cases where elastic and elastic-plastic behavior of systems can be realistically simplified with a single mass on a spring [22]. These include beams subjected to both concentrated and uniformly distributed loads, isotropic plates subjected to pressure and simple frames where mass can be lumped. The SDOF method is generally accepted as a valid approach for modelling the blast response. Different national [23, 24] and international standards and industrial recommendations [25], as well as governmental reports [26] suggest this approach. On the other hand, studies showed that this approach has its limitations and that it is not reliable in the presence of severe plastic yielding [27]. This is stated in American Petroleum Institute offshore recommendation practice [28] that states how linear-elastic analysis can be used for the low values of overpressures, whereas high overpressures require more complex analyses. This implies that SDOF does not provide reliable solutions when significant deformation is expected. The similar observation is given by Louca in the document published by Health and Safety Executive (HSE) [27].

If the excessive deformations are expected, the numerical modelling can be performed for design of blast walls. The design process of the blast wall, regarding its dynamic response, greatly benefits from this analysis. It integrates the non-linear behaviour of the materials and the detailed design requirements can be more precisely accounted for. Also, this approach allows the study of geometry and boundary conditions on the blast response which is usually assessed in terms of hinge rotations and ductility ratio [29]. Figure 6.1 shows the graphic representation of displacements and reaction forces along the edges of a bulkhead and corrugated type of blast wall. Using this approach, it is possible to trace the plastic deformation of elements in time, distribution of stresses and to measure the energy dissipation for different solutions. Additionally, numerical modeling can include the negative phase of the time-pressure curve and the interaction between the load and the structure may be taken into account as well.

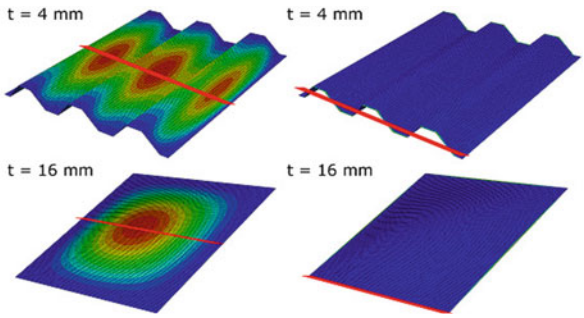

Fig. 6.1 Displacements (left) and reactions (right) for corrugated and bulkhead blast wall with thicknesses t = 4 mm and t = 16 mm

6.2.4 Potential Improvements of Soft Target Protection

The response of the blast wall may be improved by modifying the typology of the plate, applying alternative materials which are less commonly met in practice, or by focusing on the connection of the plate and the primary structure.

6.2.5 Typologies

The great potential of metal sandwich plates subjected to blast loads is emphasized by various authors. For blasts with period of 10^{-4} s, sandwich panels perform better than solid plates. Sandwich panels can dissipate the energy through plastic deformation of the core and face sheets. This makes the sandwich panel more efficient than the single plate of the same density [30].

Research on both stainless steel and aluminium sandwich panels subjected to blast loadings has been conducted recently [10, 31–34]. The studied typologies include pyramidal truss module, diamond folded, Y-frame folded and triangular folded core as well honeycomb typologies. Both in the case of stainless steel and aluminium, it is noted that the dynamic behaviour of honeycomb sandwich panel outperforms the one of the solid plate. According to the authors, more research is needed in order to better understand the behaviour of this element, particularly regarding the optimal configuration design [35].

6.2.6 Material

As previously mentioned, the blast walls offshore are usually made of steel. Recently, some researchers started to investigate the benefits of other materials such as fibre reinforced composites (FRC) and glass fibre reinforced polymers

(GFRP) for the blast response of members. According to Gibson [36], the significant weight reduction of up to 30% can be reached if FRC is used for sandwich panels instead of steel. Due to their high strength-to-weight ratio and adaptable mechanical properties, these solutions could find use in soft target protection. Initial experimental investigation of GFRP panels subject to air blast loading was conducted by Arora et al. [37]. Other authors initiated the numerical studies of compressive resistance of CFRP panels with corrugated cores [38]. Still, the resistance of these systems to air blast loading is not well understood [39].

According to Hamdan [8], GFRP sandwich panels showed to be promising solution for blast loads. Author concludes that more work is needed to characterize the behavior of these panels and suggests that future work focuses on the air blast response. Rejab and Cantwell [38] studied the response of sandwich panels with corrugated cores made of GFRP and (CFRP) with the aluminium sandwich panel of the same type. The authors noted that the response of thicker CFRP corrugations is comparable to that of aluminium honeycombs. It was also observed that this solution greatly outperforms the solutions with polymer and metal foam cores.

6.2.7 Connections

The latest trends in the design of buildings in seismically active zones show the great potential of friction connections for energy dissipation [40]. A similar concept was used by Erkman for the study of blast performance of steel modular buildings where the response of buildings with anchored and sliding foundations was compared [29]. This study showed that providing even limited sliding between blast resistant structures and their foundation can significantly reduce their foundation reactions and improve blast performance of structural members. The same principle was applied for the design of innovative impact absorbing connections between the steel panel and supporting steel work [41]. This solution integrated polymethacrylimide foam as a shock absorbing material. Additionally, a great effort was made to assess the bolted connections made of composite materials [42, 43]. This solution was also studied under the dynamic load [44], but the response of such solutions under high strain load is still not well understood.

The benefits of deformable slotted supports on the response of the bulkhead type of blast wall were recently studied numerically [45]. Abaqus finite element software was used to model sliding bolted connection. The plastic dissipation for the plates without stiffener was compared with the plastic dissipation of the traditionally supported plate, like previously discussed. The preliminary results indicated that significant energy can be dissipated in the joints by adopting a deformable sliding solution. The intensity of the transferred force onto the primary steelwork will depend directly on the type of the adopted solution, which in the case of this numerical study was a deformable connector. In order to better characterize the response of such solution and in the absence of experimental tests, it was suggested to try out different connector properties and to model the connection in more detail.

6.3 Conclusion

The presented study recognizes the need for improvement of safety measures of soft targets. It introduces blast protection practices adopted in oil and gas sector and proposes the implementation of these practices for protection of public spaces and objects that were not previously designed for this type of action. Blast walls were proposed for use as a portable blast protection element, for façade systems and for internal walls that protect muster zones and evacuation routes.

Strengths and weaknesses of the application of blast walls for soft target protection were discussed. Additionally, design procedures available for the assessment of blast resistance were described and the benefit of finite element modelling was presented. The obstacles to the implementation of blast walls for soft target protection through the use of different typologies, materials and boundary conditions must be overcome. It was concluded that:

- O&G protection measures related to the risk of explosion are good candidates to serve as a first inspiration in the design of 'blast walls' for soft target protection;
- Blast action and blast resistance can be more realistically assessed using finite element modelling;
- Deflection of the plate can be reduced by adopting sandwich panels instead of single plate solutions;
- The weight of panels may further be reduced through the use of CFRP and GFRP without compromising the resistance of a solution;
- Slotted bolted connections may improve the energy dissipation of a portable blast wall and may facilitate the installation within the objects.

Acknowledgement This work was partly financed by FEDER funds through the Competitivity Factors Operational Programme – COMPETE and by national funds through FCT – Foundation for Science and Technology within the scope of the project POCI-01-0145-FEDER-007633.

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Chapter 7
Civil Danger and Risk of Crisis Situation – Risk of Fire from Safety and Protection of Population as Possible Soft Targets

Iveta Coneva

Abstract The paper deals with security, fire protection and fire. The issue of security is wide, and its important part is, in particular, the protection of human life – so-called: soft targets in the military as well as in the civil sector, which can be components of critical infrastructure too. Anti-fire security is a matter of global concern, with its primary objective being to protect the health and lives of people, material values and the environment, with a focus on the civilian sector. Protection against fire is a system of prevention and repression, which is housed by the Fire and Rescue Service of the Ministry of the Interior of the Slovak Republic. Fires and blasts are unwanted, destructive phenomena, which cause significant economic losses in the national economy each year, as well as significant losses to the lives and health of the population – soft targets in the civilian sector. Examination of fires can be prevented, in the event of their occurrence they can be localized in time and then effectively eliminated by organized activity – by extinguishing.

Keywords Security · Fire protection · Protection of soft targets

7.1 Introduction

Security is explained as a state in which the subject (citizen, population) does not feel threatened in terms of its existence, interests and values. It is a sum of measures to ensure the internal security and state order, to safeguard the human rights and freedoms of citizens against crime, terrorism, organized violence etc., preserving the democratic foundations of the state, its sovereignty, territorial integrity and the inviolability of borders [1, 2]. The current interpretation of security is as follows [2, 3]: security is a state in which peace and security of the state are preserved, its democratic order and sovereignty, territorial integrity and the integrity of state

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L. Hofreiter et al. (eds.), *Soft Target Protection*, NATO Science for Peace and Security Series C: Environmental Security,
https://doi.org/10.1007/978-94-024-1755-5_7

borders, fundamental rights and freedoms, and in which lives and health are protected citizens, property and the environment [3]. The security risks on the territory of the SR that are currently occurring are divided [4]:

1. Military risks and threats.
2. Non-military risks and threats.

7.2 Military Risks and Threats

Military risks and threats to their size and extent represent a potential or direct threat to the security of the Slovak Republic by military forces and means. Involvement against them requires operational deployment of the armed forces, activation of the entire security system of the state or possible military assistance from abroad [2].

This group of risks and threats includes [2]:

- Extensive armed conflict with great impact on the state's vital interests. It has a low probability of occurrence and a long enough warning time before it may arise.
- Regional armed conflict with medium probability of occurrence. After the end of the Cold War, the security environment in Europe and in the world has a positive development, as the likelihood of the global war has declined. Security risks are regional conflicts in fragile regions and certain countries, states (e.g. Syria, North Korea and others).

7.3 Non-military Risks and Threats

Non-military risks and threats are activities directed against the interests of the Slovak Republic and not related to the use of military means. These risks can cause a significant threat to the interests of (security) of the population and the state due to the action of natural, technological, economic, internal and even international forces that are not capable of provoking an armed inter-state conflict. Non-military risks and threats can not only be targeted, managed and coordinated (e.g. organized crime, terrorism, etc.), but they may also have a spontaneous trigger mechanism and course (e.g.: natural disasters – floods, fires and others, environmental accidents, migration due to regional conflict, etc.).

The most important non-military risks and threats are [2]:

1. Uncontrollable migration.
2. International Organized Crime and Terrorism.
3. Criminalization of social relations.
4. Activities of foreign special services.

5. Failure or targeted disruption of information systems.
6. The excessive dependence of the Slovak Republic on the unstable sources of basic raw materials, energy and transport.
7. Negative demographic trends.
8. Environmental threats that are related to the environment. These may be industrial and technological accidents, natural crises (e.g. fires, explosions, etc.) that may cross the state border. They are often unpredictable, the nature and consequences of which are still threatening the lives of people (so-called soft targets) and property on a large scale.
9. Lowering the country's food security.

7.4 Fire

Every human activity has its security aspect, starting with state security, home security, security and protection of persons and property, fire protection and ending environmental protection. Natural and environmental crises may occur as a result of natural disasters (e.g. floods, fires, windstorms, tsunamis, etc.) and industrial, technological accidents (e.g. fires, explosions, leakage of hazardous substances and others).

They are accidental, unexpected, their course and consequences present a permanent risk to the health and life of humans (so-called soft targets in the civil sector), animals, tangible and intangible property and also cause environmental damage to soil, water and air protection. Fire is any unacceptable burning where the life or health of humans, animals, property, or the environment is endangered, resulting in damage to property, the environment, or the consequence of being an injured or killed person or animal [4].

Based on technical experience, specifically based on the nature and properties of flammable substances and materials, most European countries place fires in the relevant classes of fires. Fire classes are listed in Table 7.1 according to [5, 6].

The correct determination of fire class and type of combustible substance and material helps in the efficient selection of extinguishing agent suitable for firefighting by fire units. In the EU countries there is no classifying fire class of electrical equipment, it is not classified as a separate class with the appropriate designation. In the event of a fire of electrical equipment, the electrical current is switched off first and then it is possible to continue extinguishing according to the principles of other classes of fire, depending on the type of combustible substance. Pictograms in Table 7.1 – is a graphic depiction of fire extinguishers designed for extinguishing the relevant fire class [5, 6].

Table 7.1 Fire classes

Fire class	Fire characteristic	Flammable substance
	Fires of flammable substances in solid state, which tend to melt or burn with flame. They are usually of organic origin, burning tends to burn.	Coal, wood, paper, hay, straw, textiles and others
	Fires of flammable substances in the liquid state or liquefied solids that burn with flame.	Petroleum and petroleum products, tar, organic solvents, paints, lacquers, fats, resins, carbon disulphide and others
	Fires of flammable substances in the gaseous state, which burn with flame.	Acetylene, hydrogen, methane, propane-butane, carbon monoxide, natural gas, coke oven gas, blast furnace gas and furnace gas and others
	Fires of combustible metals and their alloys.	Magnesium, aluminum, sodium, potassium, uranium and thorium oxides, electron alloy and others
	Fires of electrical equipment.	Flammable substances of all classes of fire in connection with an electric current
	Fires of vegetable or animal oils and fats used in kitchen appliances and large capacity appliances.	Vegetable and animal oils and animal oils fats

7.4.1 Zones of Fire

The space in which the fire is including its basic and consequential phenomena can be divided into three interconnected zones. Fire zones characterize the development of a fire for a certain period of time and can be spatially overlapped. Figure 7.1 shows zones of fire.

As the fire progresses, the area on which the fire progresses increases and the rate of degradation of materials increases. Extremely expanding fires include fires in the open air (so-called "open fires") when the fire is not limited. The fire area can be divided into three zones [7, 8]:

1. Burning zone.
2. Preparation or thermal effect zone.
3. Smoke formation zone.

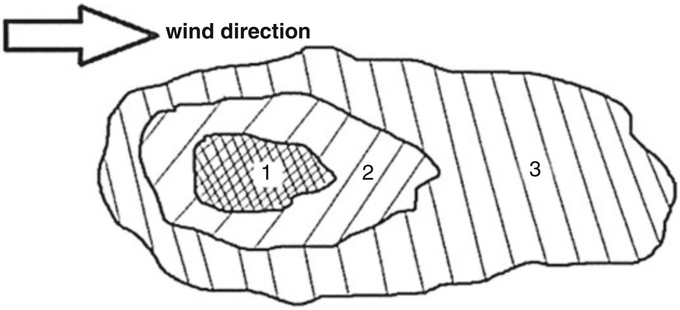

Fig. 7.1 Zones of fire

7.4.1.1 Burning Zone

This area is burning. The volume of space is filled and contains all gases and vapors that are bounded by the flame or the surface of the burning substance from which these gases and vapors are released. The burning zone is also delineated by building structures and tank walls. Burning volume and height are important when evaluating open fires. In this zone, the temperature is highest and the zone is characterized by a fire area. The generated and released heat from the burning zone is passed to the next zone, namely the preparation zone. Burning affects the type of combustible substance, the oxygen concentration and the amount of activation energy of the source.

Heat can be propagated in three ways [7, 8]: by conduction, by convection, and by radiation.

- Conduction – heat transfer is a result of interaction and movement of the basic particles of matter (atoms, molecules, free electrons). Higher temperature molecules (with higher kinetic energy) transmit some of their energy to neighboring molecules with lower temperatures [7, 8].
- Convection – (convection) heat dissipates in liquids (liquids and gases). The process of mass transfer of atoms and molecules of a substance while simultaneously transferring heat involves two phenomena: heat transfer by conduction at the contact of two particles (atoms or molecules) and heat transfer by flow when moving particles and volumes of matter that carry their internal energy. External fires transmit 60–70% of heat in this way. In fires, poisonous substances (so-called combustion products) are released and there are often poisoned and threatened persons [7, 8].
- Radiation – heat is transmitted in all directions evenly because of electromagnetic radiation. Electromagnetic radiation radiates from its surface any real body with a temperature greater than absolute zero. Of the total electromagnetic radiation that falls on the surface of the solid, part of the radiation is absorbed, the part bounces and then part passes through the solid. In this way, 30–40% of heat is released. It is typical of outdoor fires [7, 8].

7.4.1.2 Preparation or Thermal Effect Zone

The preparation or thermal effect zone is directly adjacent to the combustion zone. There is a process of preparing the material for burning (heating, changing properties, etc.), which significantly affects the fire situation. Materials are heated under the influence of heat and create hazardous situations for persons located near the fire or in the area where they are burning. Due to the high temperature, the materials lose their properties and steel structures may collapse or damage to machinery and equipment. In the case of internal fires, the preparation zone is bounded by the structure of the building and the walls. Fire may, however, extend to the outside area outside the building. The thermal effect band is in practice referred to as a area where the temperature is higher than 55–60 ° C [7, 8].

7.4.1.3 Smoke Formation Zone

Smoke formation zone is a part of the area near the burning zone, filled with smoke, in a concentration that threatens the health and lives of people, and makes it difficult for the fire brigade to work. In the smoke formation zone, tapping is usually a low air concentration (oxygen), reduced visibility, a large amount of fumes of combustion – smoke and often high ambient temperatures. The zone can be very extensive and the burning products with their toxicity can endanger life even at great distances. The smoke zone is characterized by a smoke area and smoke density [7, 8].

7.4.2 Phases of Fire

Intensity of burning – changes occur during a fire. In the case of internal fires that are not extinguished by extinguishing agents, the duration of the fire is usually characterized by four phases of fire. The length of the individual phases is usually very different and depends mainly on the amount of combustible substance, its fire-technical characteristics and the conditions affecting the spread of fire.

Figure 7.2 shows the fire stages, depending on the temperature and from time [8–11].

Ist Phase of Fire – Development of Fire Phase I of the fire is a time period from the onset of fire to the beginning of intense burning. According to fire statistics, phase I usually takes 3–10 minutes. The time depends on the type of flammable substances and the conditions of fire development. Since the burning intensity is still relatively low – this is the most advantageous phase for starting firefighting, for extinguishing fire with extinguishing agents. Disposal is simple and damage is minimal [8–11].

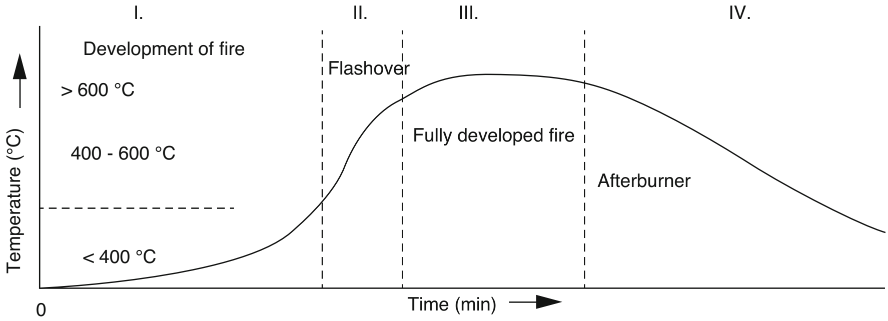

Fig. 7.2 Phases of fire

IInd Phase of Fire – Flashover IInd the fire phase is the time from the beginning of intense burning until the burning of all combustible materials, the substances present in the object, and the construction of the burning object. Characteristic of this phase is the rapid increase in temperature and fire area, increase of gas flow rate and proportional increase in damage. The situation at the site of the fire is complicated and requires high demands on the organization of firefighting, especially when the fire is at the end of the phase [8–11].

IIIrd Phase of Fire – Fully Developed Fire IIIrd the fire phase is a time period from the end of the II phase, t. j. all combustible substances are burning in a given object, and the burning rate reaches the maximum until the burning rate decreases. At this stage, the other supporting elements are also disturbed and the ceiling, the truss and the like collapse. Fire brigade intervention focuses on cooling and protecting surrounding objects, and it is up to the commander to decide whether to take action or let the object burning. The actual intervention on the object is very demanding, usually costly and inefficient [8–11].

IVth Phase of Fire – Afterburner IVth the fire phase is the time period from the beginning of the decrease of the burning intensity until the complete burning of the combustibles. At this stage there is a risk of collapse of the internal and peripheral masonry, chimneys, staircases, etc. The activity of fire units is focused on finding and concealing fire and hidden fires of fire. The attack commander may decide that only the surveillance will be carried over the object until the object is completely burned [8–11].

7.5 Conclusion

Security is a state in which a citizen does not feel threatened in terms of his or her existence, interests, and values. At present, military risks and threats and non-military risks and threats are present in the world. The issue of safety, protection of the so-called “soft targets” is currently up to date not only from a military point of view, but also from a civil point of view. Fire protection is concerned with the safety of persons, animals, property, but also with the protection of the environment [12]. Fire safety is aimed at preventing and subsequently resolving various crisis situations of natural, industrial and technological nature. One of the dominant crisis situations of a natural or industrial nature is the fire and the consequences associated with it [13]. To understand the origin, development, course and extinction of a fire, it is necessary to know the laws of the burning process. Fire is uncontrollable, unwanted burning that threatens the health and lives of people (so-called: soft targets), animals and causes significant economic and ecological losses in the economy, the state. Based on the types of flammable substances, the fires are divided into the appropriate classes of fire. External fires are divided into three zones and internal fires have four phases of fire. Knowledge of the theory and practice of burning processes helps us in time to prevent the occurrence of fires. The resulting fires must be localized in time and subsequently destroyed by the Fire and Rescue Corps of the Ministry of Interior of the Slovak Republic. The first responders play an important role of fire rescuing [14].

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Chapter 8
Simulation of Selected Parameters of Internal Fire in Case of Soft Targets Protection

Romana Erdélyiová

Abstract Terror, terrorism and terrorists, are nowadays words often used by media, political circles or debates. Preferred targets of terrorist attacks are public places with the high frequency of civilians called soft targets. Tall buildings (towers) dominate in international as well as national constructions. Victims of terror are threatened by terrorist attacks itself, but also by their consequences. The paper deals with a fire simulation in a building, where civilians are presented and can be considered as a soft target. Presented elevated temperatures caused by fire, as a consequence of terrorist attack, effect public safety in the building because of disrupted stability of the building. The paper shows usage of fire simulation out-puts for prevention and protection of soft targets.

Keywords Attack · Fire · Fire simulation · Heat stress · Soft target

8.1 Introduction

The topic of the growing number of extraordinary situations and public soft targets attacks is a theme of the day. This is due to rising technological progress, industrial modernization, arising production, equipment, technology expectations, as well as national public safety. In the past, I experienced several extraordinary situations and attacks on soft targets with fatal impact (bomb attack in volleyball stadium in Pakistan, attack in Oklahoma, terrorist attack in Petrohrad, Stockholm, Nice and all others). Due to a rising trend of anthropogenic extraordinary situations and soft target attacks, it is necessary to pay attention to precaution and readiness in this area. Correct identifying risk and its consequences are a key skill. Mentioned situations bear a high level of fire event risk which in fair conditions spreads and bring many witnesses and great material damages [1].

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L. Hofreiter et al. (eds.), *Soft Target Protection*, NATO Science for Peace and Security Series C: Environmental Security,
https://doi.org/10.1007/978-94-024-1755-5_8

At the present, I can experience several risk analysis methods and particular extraordinary situations analysis methods. In practice, mentioned tools offer wild range of combination possibilities which increases reflection of outputs, which helps plan precaution and reaction to extraordinary situations more effectively, as well as correct application of safety equipment, signal equipment, reporting equipment, fire safety equipment, evacuation, and other equipment. On the base of quality provided risk analysis, it is possible to start models and simulations applications. Software support in the context of extraordinary situations, especially with fire events is on top level currently. Today is fire simulation ascendant and developed and this is due to growing number of soft targets threat [2].

8.2 Fire Simulation of Soft Targets

A model is specifically made asset of observation, which copy exactly setting of characteristics of a real asset. As a model I understand simplified real picture, where some sides are made more general. Computer simulation is an effective way to study and understand comprising processes. It allows me to conduct experiments which real form is complicated or they give unreal results. Computer simulation logicality offers a possibility to show basic factors, to observe processes of evaluated properties, to watch its parameters and starting conditions change physical feedback. On the theoretical level is effective to use simulations that reflect the reality, are easy to use and respect computer hardware. Simulation programmer CFAST offers wide range of use for setting of fire resistance of building, of ventilation design, of identification of fire parameters or of any other usages in the area fire safety [3].

8.3 Description of Studied Construction

Buildings for living may become a target of soft attackers. Such buildings are occupied by a number of persons; many different meetings or entertainments could be arranged in there [4].

Model (see Fig. 8.1) was created to show four apartments connected with the corridor. Each apartment has dimensions: length 4 m / wide 4 m / height 2.6 m. The corridor has size: length 8 m / wide 1.5 m / height 2.6 m. Perimeter structures contain horizontal openings, some of them lead to the outside, other to apartment or into the corridor. Each model of apartment has 8 windows with the size: wide 1 m / height 1.3 m /parapet of window height: 1 m). Each apartment has one exit door leading to the corridor and from the corridor one exit door leading to the exterior part. All doors has the same size. All door was considered open in the simulation, apart from those leading to the exterior area. The floor and the ceiling of model were made from reinforced concrete, walls are from aerated concrete bricks. The fire load was simulated in various ways: as a fire from a sofa, a bed, a wardrobe, and a

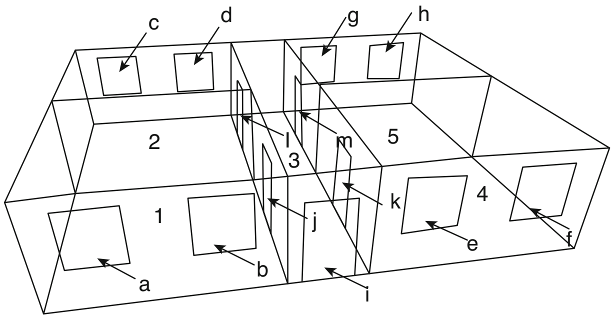


Fig. 8.1 Model of building for fire simulation

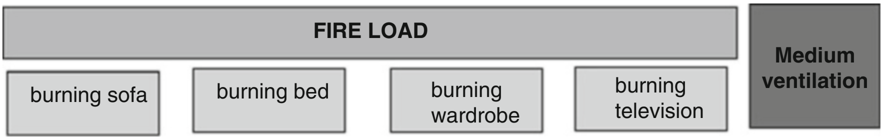


Fig. 8.2 Fire load on apartments

TV. Simulation time sequence was 2000s, to observe all phases of the fire event. The starting temperature was set as ambient temperature (20 °C).

Effect of Fire Load to Change of the Room Temperature For the simulation of fire load effect to the change of the ambient temperature and to the change of the neutral plane level, four various kinds of the fire load (see Fig. 8.2) were introduced. Fire loads was resulting from the previous fire events experiences and from the most possible furnishing of apartments.

Heat Release Rate Heat release rate (HRR) is the basic parameter to set a fire intensity in the room. It represents amount of energy released during fire of material per time unit. The highest speed of the heat release appears with the fire load from a sofa (see Fig. 8.3). Values of experienced fire load were used as model fire load.

It is necessary to set approximate heat value inside the burning room in individual phases of the fire. Before the volume flare, the heat in the room effects threatened persons. After the volume flare, the temperature is important for setting a fire resistance of the structure. Development of the fire brings significant pressure changes. In the upper level of reached room an overpressure occurs, in the lower part an under-pressure is presented. Between the overpressure and the under-pressure a neutral plane is presented (Fig. 8.4).

Gas Temperature in the Room 1 Graphs (see Fig. 8.5) indicate effects of various fire load and the heat development in room N°1. The highest temperature from the load of sofa was approximately 680 °C, from the bed 730 °C, from the wardrobe 720 °C, and from the TV 170 °C.

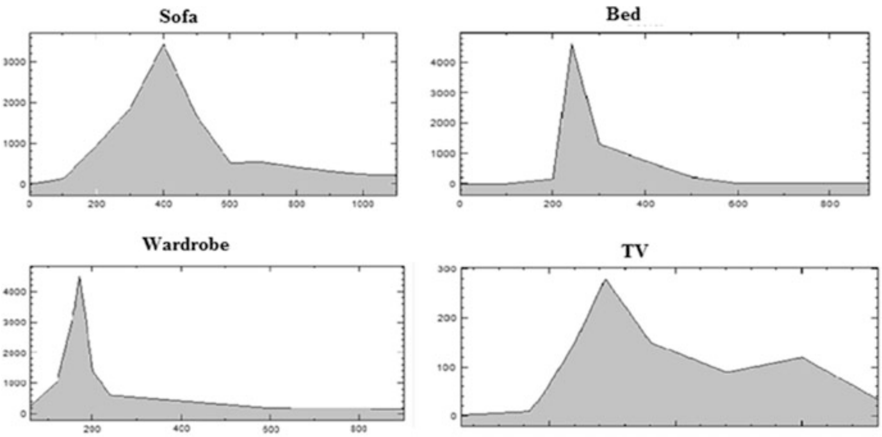


Fig. 8.3 Heat value of gas in apartment measured in close to fire area

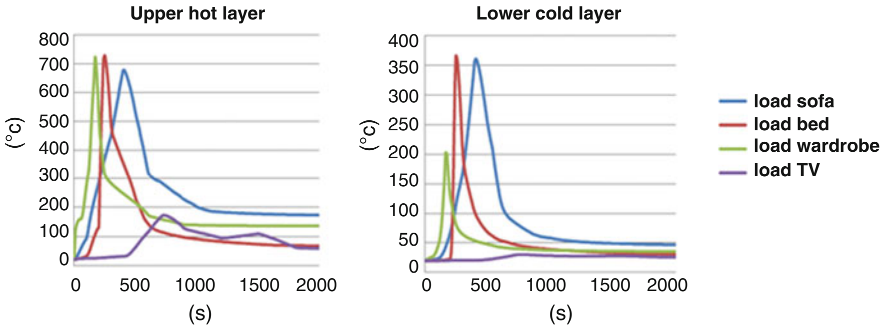
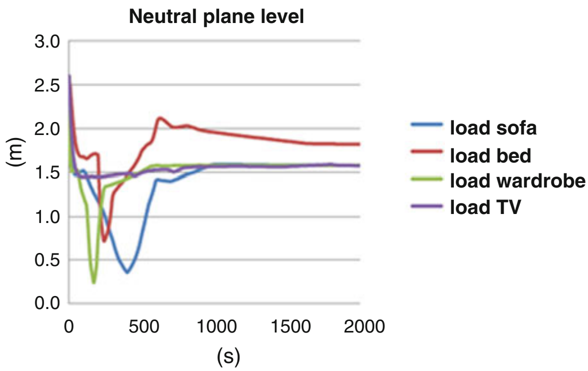


Fig. 8.4 Changes in the heat in room N°1

Fig. 8.5 Neutral plane level in the room N°1



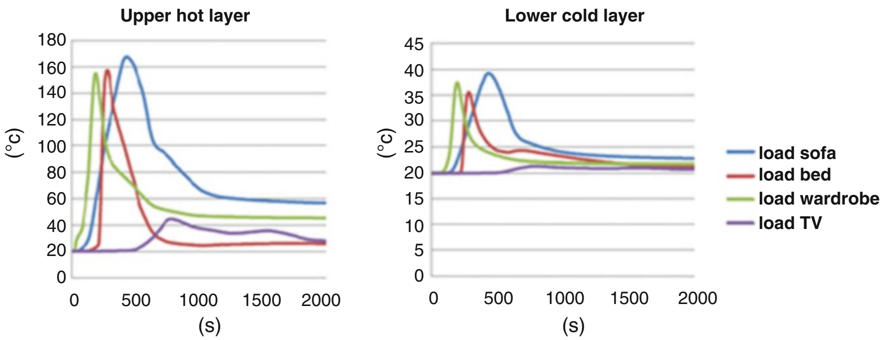
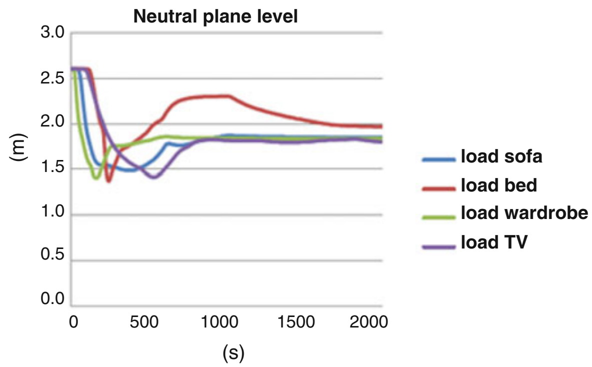


Fig. 8.6 The temperature in room N°2

Fig. 8.7 Neutral plane level in the room N°2



I can also observe the neutral plane level (see Fig. 8.6) in the fire simulation. The lowest value was from the load of sofa 0.36 m; from load of bed was 0.75 m; from the load of the wardrobe the level was 0.28 m; and from the TV 1.5 m.

Gas Temperature in the Room N°2 Graphs (see Fig. 8.7) indicate effect of various fire loads and the heat development in the room N°2. The highest temperature of the upper hot layer was approximately 167 °C (from the load of the sofa), the bed 157 °C, the wardrobe 155 °C and from the TV 5 °C. The highest temperature of the lower cold layer was approximately 39 °C for sofa, the load from bed 35 °C, the wardrobe 37 °C and from TV 21 °C.

In figure (see Fig. 8.8) I can see the effect of fire load to the neutral plane level in room N°2. The lowest neutral plane level is 1.49 m from the fire load of sofa, the bed caused 1.38 m, the wardrobe 1.41 m and the TV decreased the neutral plane level to 1.42 m.

Gas Temperature in the Room N°3 Graphs (see Fig. 8.9) indicate fire load effects to temperature in the room N°3. The highest temperature in upper hot layer from the

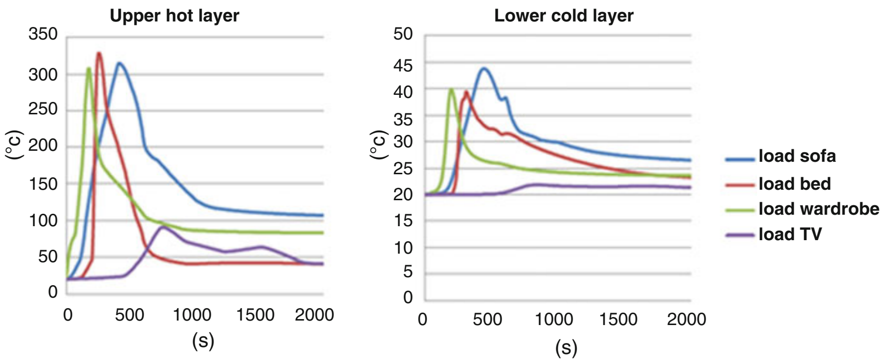


Fig. 8.8 The temperature in room N°3

Fig. 8.9 Neutral plane level in room 3

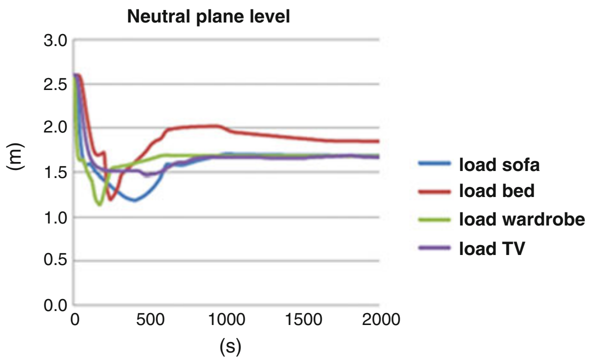
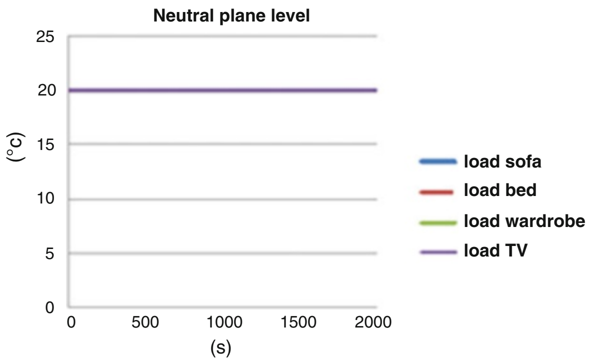


Fig. 8.10 Neutral plane level in room N°4



sofa load simulation was 314 °C, the lowest temperature in the lower cold layer was 44 °C.

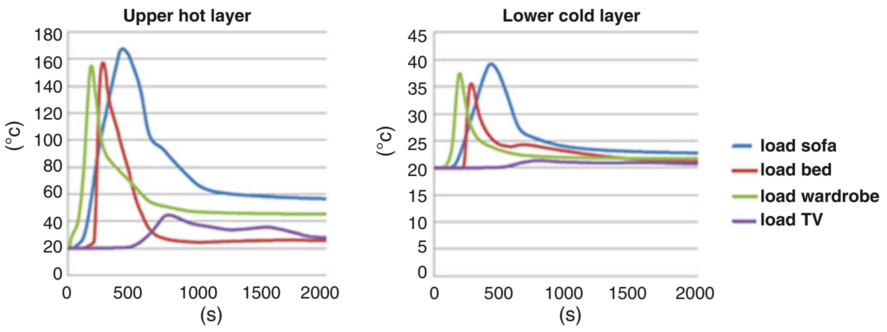
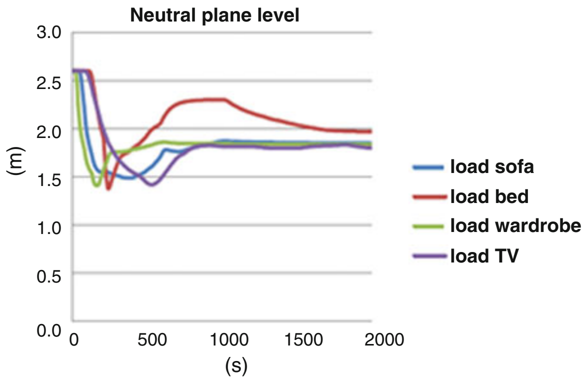


Fig. 8.11 The temperature in room N°5

Fig. 8.12 Neutral plane level in room N°5



In figure (see Fig. 8.10) I can see effect of fire load on the neutral plane level in the room N°3. From sofa load simulation influences the lowest neutral plane level of 1.9 m, from the bed load simulation it was 1.20 m, from the wardrobe simulation value was 1.19 m, and from the TV load simulation was neutral plane decreased to the value of 1.47 m.

Gas Temperature in the Room N°4 Graphs (see Fig. 8.11) indicate fire load effects to achieved heat in the room N°4. The room temperature did not increased, which could be caused by the thickness of the structures, by the low value of the thermal conductivity coefficient and principally by complete closure of the room. Because of the closure of the room, the space in the room did not split into upper hot and lower cold layer.

Gas Temperature in the Room 5 Graphs (see Fig. 8.12) indicate fire load effects to the temperature of the room N°5. The highest achieved temperature in upper hot layer from sofa load simulation was 167 °C. The highest temperature in lower cold layer from the fire load simulation from sofa was 39 °C.

Table 8.1 Results summary of complete living area

Fire load	Upper hot layer temperature [°C/s]	Lower cold layer temperature [°C/s]	Neutral plane level [m/s]
Room N°1 with the presented fire			
Sofa	676/400	361/410	0.36/400
Bed	727/250	366/250	0.72/240
Wardrobe	721/250	202/170	0.24/170
TV	174/730	30/770	1.50/720
Room N°2			
Sofa	167/430	39/430	1.49/340
Bed	157/280	35/280	1.38/240
Wardrobe	155/190	37/200	1.41/160
TV	45/780	21/780	1.42/520
Room N°3(corridor)			
Sofa	314/410	44/440	1.19/380
Bed	328/250	38/290	1.20/240
Wardrobe	307/180	39/200	1.19/150
TV	91/750	22/830	1.47/470
Room N°4.			
Sofa	20/–	–	–
Bed	20/–	–	–
Wardrobe	20/–	–	–
TV	20/–	–	–
Room N°5.			
Sofa	167/430	39/430	1.49/340
Bed	157/280	35/280	1.38/240
Wardrobe	155/190	37/200	1.41/160
TV	45/780	21/780	1.42/510

In figure (see Fig. 8.12) I can see the effects of fire load to neutral plane level in room N°5. The lowest neutral plane level value 1.49 m from sofa load, 1.38 m from the load of bed, the wardrobe caused 1.41 m, and the TV decreased the neutral plane level value to 1.42 m.

8.4 Results Summary of Complete Living Area

Results summary of the simulation indicate the effect of the fire load to room temperature changes and neutral plane level introduced in Table 8.1.

The temperatures in upper hot layer and in lower cold layer, from various fire loads, are different. The difference is mostly effected by diverse pressure relations and various layers transfer in individual rooms. The difference could also be caused by transmittance and absorption of individual layers effected by various contain of water, carbon dioxide and carbon monoxide. Highest values of temperature in individual loads were not achieved in the same time, which means that the fire behaviour is effected by the fire load in certain time. The temperature decrease is effected by burning the fuel out in the space. The neutral plane level is influenced by the heat release rate in individual fire loads and in dependence of various pressure values.

8.5 Importance of Simulation for the Soft Targets Protection

Soft targets protection is very important as many times those assets have high national importance. They are significant buildings, strategic assets, with great number of persons. As is described by Klucka et al. in [5] direct and indirect loss, per fire are presented. The importance of simulations of internal fire could be divided into several groups, from various points of view:

Precaution Simulating different type of fire in various places of the construction and in various conditions I can set the worst possible scenario of the fire which indicates the weakest point in the sense of the attack threat, which result is fire (explosion, impact). Simulation, I can find the amount of gases and their placing in the space and I can plan effective evacuation and means using for easier evacuation of individuals. Model can simulate an effectiveness of the fire safety equipment, thermal conductivity equipment, combustion products conductivity and other precaution actions as fatigue described in [6] and in [7] or dynamic loads [8, 9].

Construction of Buildings For new constructions which are in design phase, simulation offers a possibility to choose effective type of structure, dimensions of bearing elements, types of joints, or appropriate fire safety protection for construction parts. Construction could be projected to resist to expected fire loads, blast wave, direct force, and other dangerous factors. More about the blast wave design is described by Figuli in [10, 11]. Simulation programmers are able to simulate structural load (mechanical, heat, static, dynamic) and to find hazardous parts to be protected in case of the soft target attack.

Operation of Buildings As a results of simulating is possible to know expected number of people staying in individual rooms during the day, their flow, best places for the CCTV and fire detector system placement [12]; to avoid a blind spot, points for fire extinguishers with easy access to the most hazardous areas.

8.6 Conclusions

Simulation and modelling of various systems with the combination of great technological progress brings recently perspective advantages. Using simulation tools saves time, is economical and often can help to save people's lives. In cooperation with the growing computing performance, constantly grows an expectation to details, exactness, and credibility. Recently, the attention is focused on an evacuation, a fire protection and safety in constructions connected to its operation and especially with simulation and modelling. The paper introduces a model, shows a need of simulation and its advantage, because of a calculation of the fire load is usually slow and not exact. Various extraordinary situations, like floods, explosion, and intoxication of certain area or the fire can be simulated. Fire contains several characterising parameters: the neutral plane level, gas temperature in the room and temperature of release rate. From the point of view, an evacuation of persons and their safety the most dangerous is an internal fire. Currently is trend to build housing buildings and flat units, towers are being threatened from the natural and anthropogenic point of view. The most common danger in such buildings, in case of extraordinary situation, is an internal fire, which was simulated in selected part of the building. Especially effect of flammable material to change of the temperature in the room and the neutral plane level was studied in simulation. More is described in the research of Kadlicova et al. in [13]. The effect of the fire load in this case is considerable also to the neutral plane level. The neutral plane level changes in dependence of various heat release rate of individual fire loads so is dependent on the various pressure difference in the space. Practical output of paper is point out the possibility of using of simulation tools for application in precaution actions, fire safety protection, etc. Outputs from simulations are possible to use in practice for ventilation design, smoke control, fixed fire extinguishers design, electrical fire alarms design and for fire resistance estimation. Recently several applicable software are presented [14], who could be included into the fire safety prevention, HSE, and construction designing. Using of simulation in practice can bring an improvement of personal safety in buildings and providing more effective protection in that way, that situation in Sao Paulo in 1974, in New York in 2001, in Nigeria in 2002, in Bangladesh in 2013 would never ever repeat.

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Chapter 9
Methods of Protection of Soft Targets in Urban Area

Lucia Figuli and Vladimír Kavický

Abstract The paper shortly presents the possibilities of soft targets protection using technical measures against the blast wave creating in explosion in terrorist attacks. Technical can be based on two principles: measures ensuring the reduction of the blast load increasing the perimeter using so called stand-off distance, i.e. to increase the distance between the protected asses and source of explosive and in that way to decrease the pressure affected the asses. Or if it is not possible, to increase the blast resistance using so called retrofit technique.

Keywords Protection · Soft targets · Blast wave · Stand – Off distances · Physical barriers · Physical protection

9.1 Introduction

Increasing number of terrorist attacks during last decades brought the problem of soft target protection on the level of great importance. The terrorist attacks are not carried out by using not only explosions as in the past (Oklahoma bombing in 1995), but attackers resort to using other means as shooting (Bataclan attack in Paris in 2015) or vehicle impact (Berlin truck attack in 2016). Protecting innocent people as a soft target in terrorist attacks is very complicated task. Physical protection of soft targets consists of the system of technical, organizational and regime measures. Physical security generally involves the use of multiple layers of interdependent systems which include CCTV surveillance, security guards, protective barriers, and many other techniques. Alarm system are mainly focused on the detecting an intruder [1]. In protection design against blast are used mainly technical measures which are

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L. Hofreiter et al. (eds.), *Soft Target Protection*, NATO Science for Peace and Security Series C: Environmental Security,
https://doi.org/10.1007/978-94-024-1755-5_9

designed to deny blast wave damage, injure or harm facilities (buildings) and in this way to protect personnel and property. For the increase in blast resistant there are various methods for blast protection which can be selected in two groups: measures ensuring the reduction of the blast load and measures increasing of blast resistance.

9.2 Methods for Blast Protection – Technical Measures

9.2.1 Physical Barriers

Stand – Off Distance The firs approach is concerned with reduction of vulnerability using stand-off distance. The most cost-effective solution for mitigating explosive effects on soft target is to keep explosives as far away as possible. The distance between an asset and a threat is called stand-off distance (Fig. 9.1).

There is no ideal stand-off distance; it is determined by the type of threat, the type of construction, and desired level of protection [3].

As we have already mentioned the stand-off distance is the amount of space denied to an aggressor between his threat device and the area being protected. Since the destructive effects of an explosion decrease rapidly over distance, space is the most effective and cost-efficient safety measure of all the blast-mitigation strategies available to building designers and engineers [4].

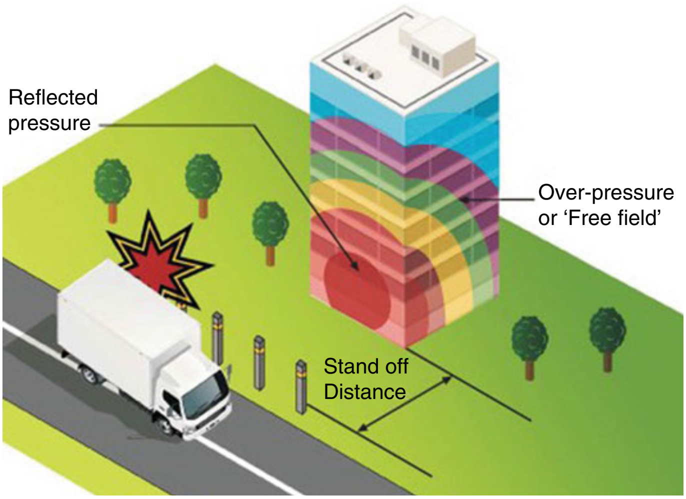

Fig. 9.1 Stand – off distance [2]

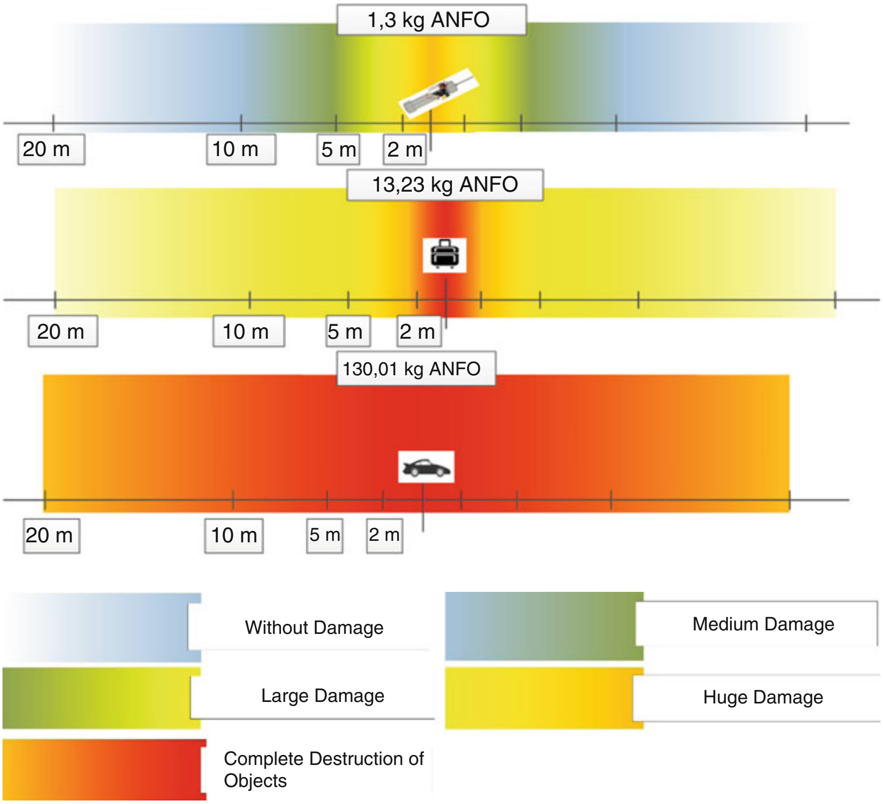

Fig. 9.2 Predicted distribution of pressure extension in the explosion of a tubular explosives, hand luggage and vehicle type of coupe produced by using non-standard ANFO explosives [7]

The main idea is to locate the perimeter line (perimeter protection) as far as is practical from the building exterior, maintain the required stand – off distance. Required stand – off distances depend on the source of explosion (type and amount of used explosive) [5, 6]. Distances for the most used explosive in terrorist attacks ANFO are obvious from the next figures (Fig. 9.2 and Table 9.1).

9.2.1.1 Anti-Blast Elements

Physical Barriers – Bollards, Planters, etc. Securing of stand-off distance can be provided by different anti blast elements. Physical barriers such as fences and walls, are main elements in security protection, but in some facilities, mainly for soft target protection, imposing perimeter walls/fencing will not be possible (e.g. an urban office building that is directly adjacent to public sidewalks) or it may be aesthetically

Table 9.1 Required Stand – off distances [7]

Type of improvised explosive device		Amount of explosive [kg]	Minimum stand- off distances [m]	Minimum outdoors distance [m]
	Tubular explosive	2.3	21	259
	Suicide belt	4.5	27	330
	Suicide vest	9	34	415
	Hand luggage/ suitcase	23	46	564
	Vehicle type of coupé	227	98	457
	Vehicle type of sedan	454	122	534
	Vehicle type of microbus	1814	195	838
	Delivery truck/ small truck	4536	263	1143
	Tank	13,608	375	1982
	Truck with trailer	27,216	475	2134

The perimeter line can be pushed out to the edge of the sidewalk by means of physical barriers

unacceptable (e.g. surrounding a shopping center with tall fences topped with razor wire) [8]. In that case different elements included in urban design as planters, bollards, or street furniture (e.g., mailboxes, bus stop shelters, light poles, works of art, street trees, planters, bicycle racks, seating, newspaper boxes, kiosks, and trash receptacles) can be use.

Traditional anti-ram prevents vehicle access for pedestrian protection and building security. We recognise two types of antiram barriers:

Passive barriers are fixed in place, do not allow for vehicle entry, and are used to provide perimeter protection away from vehicle access points. Passive barriers include: fixed bollards, engineered planters, heavy objects and trees, walls and ha-ha barriers, water obstacles, jersey barriers, fences.

Active barriers are used at vehicular access control points within a perimeter barrier system or at the entry to specific buildings within a site, such as a parking structure or a parking garage within an occupied building to provide a barrier for vehicle screening or inspection; they can be operated to allow vehicle passage. Active barriers include: retractable bollards, rising wedge systems, rotating wedge systems, drop arms crash beams, crash gates, surface-mounted wedges and plates [9].

Fig. 9.3 Designed physical barriers without no resistance capacity

9.2.1.2 Resistance Capacity

In the urban design there is sometimes an effort for the designing of anti-blast elements, but without the consideration of resistance capacity to blast or impact. Such elements are insufficient and unserviceable (see Fig. 9.3).

Recent events shows, that very popular antiram barrier in pedestrian area is using of so called jersey barriers using for road bridges. Specification of safety barriers are listed in EN 1317 Compliant Road Restraint Systems. According to this standard four containment performance classes are defined: Low angle containment T1, T2, T3; Normal containment N1, N2; Higher containment H1, H2, H3 and Very high containment H4a and H4b. From a test arise that the concrete safety barrier of containment class H4a is capable to resist of the impact of the vehicle with the weight of 30 t, with the angle of impact 20°and the impact velocity 65 km/h. Essential condition is, that the used concrete safety barriers has to be anchored properly. Minimal length of non-anchored barrier is 40 m for classes N1-H1, 50 m for class H2, 70 m for H3 and 80 m for classes H4a and H4b. Minimal length of anchored barrier is 20 m. Generally is impossible make the safety barrier in public space of the length of 20 m, even for the very high protection level 80 m. In this case installing to two or three concrete safety barriers (total length of 12 m) to block the access is insufficient.

In design, in an impact scenario of a vehicle into a concrete safety barrier, mechanical factors as vehicle speed, the impact angle, the static stability factor of the vehicle as well as the concrete safety barrier design and conditions have to be considered. Trajkovski et al. conducted crash analyses vehicle-concrete safety barrier (CSB) using finite element models (see Fig. 9.4) [10].

Research on the searching of new materials for physical barriers were performed by Stoller and Zezulova, applying the fiber reinforced concrete from auxiliary materials [11], conducted test of cementitious composites are described in [12, 13].

Generally in urban design, ordinary used planters, considering their as an anti-blast element (see Fig. 9.5a) are not efficient. Planters located on the surface rely on friction to stop or delay a vehicle and will be pushed aside by any heavy or fast-moving vehicles [9]. Otherwise, well-designed planters can form an effective vehicle barrier. Engineered planters need considerable reinforcing and below-grade depth to be effective and become fixed elements in the landscape design as is considered in [9], see Fig. 9.5b.

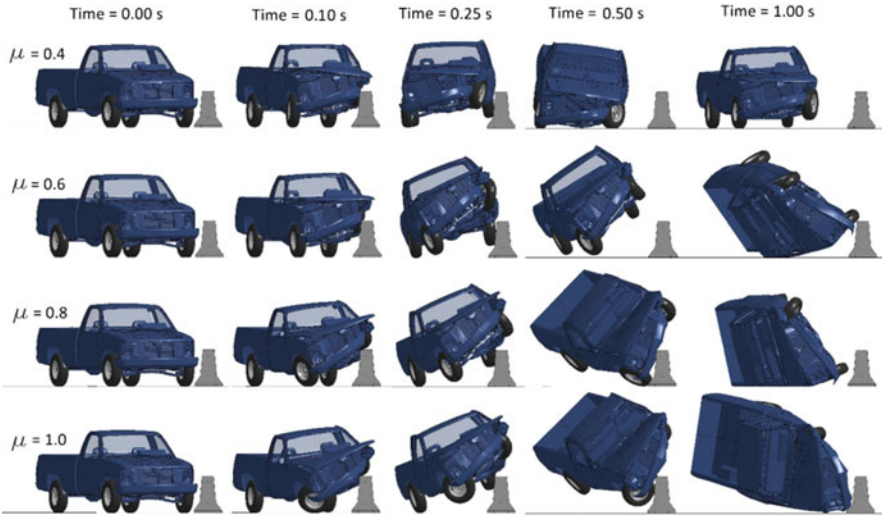

Fig. 9.4 Numerical simulation of resistance impact capacity of physical barrier [10]

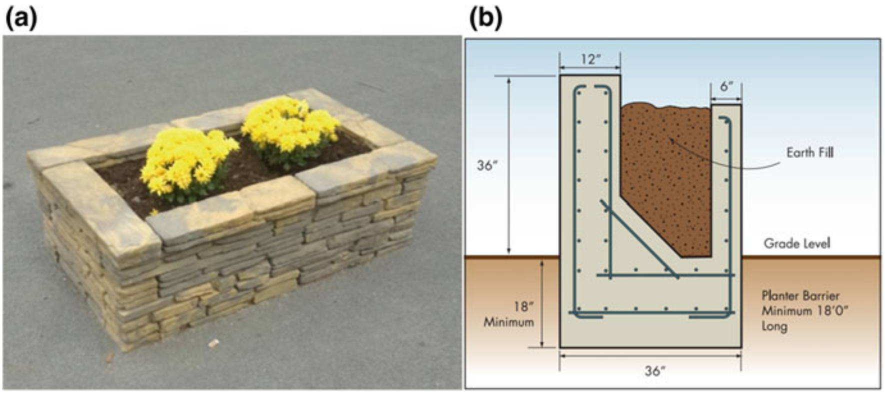

Fig. 9.5 Planters as an anti-blast element (**a**) ordinary planters (**b**) engineered planters [9]

Physical Barriers – Walls As we mentioned above to protect innocent people against the treats from impact and blast, the right physical barriers have to be designed. Zvaková et al. focused on the blast resistance of selected barriers in [14]. Physical barriers have to resist not only ordinary load condition but accidental condition too [15, 16] or extrem weather condition [17]. Structural elements (i.e. walls) designed for the standard load condition are not designed for an accidental load as blast or impact because loads are taken in the horizontal direction instead of permanent action and imposed loads (self-weight, snow) are acting in vertical direction. Even European standard valid for design of structures, EN 1991-1-7: Actions on structures – Part 1–7: General actions – Accidental actions highlights, the loads from "external explosion, war and terrorist activity" does not include this provision. Effects due to explosives are outside the scope of this standard. It takes into account only internal explosion from dust and gas.

9.2.2 Retrofit Technique

The second approach in security blast design is to increase the resistance of the buildings. Generally buildings are not commonly designed for such so called accidental load. To increase building resistance is possible with various retrofit technique, reinforcing existing building with reinforcement material. Numerous retrofit strategies have been developed, mainly for earthquake loads. With the increasing number of terrorist attack, attention is paid on the blast protection.

Retrofit techniques allow to reinforce the structure with other material, to create a composite structure. According to the layout, we can recognize conventional laminar composite structure with the number of horizontal layers, sandwich structure with two layers of material filled with the different material and honey comb, i.e. two layers of material filled with material in with honey comb structure.

Various materials and approaches are in the phase of research or testing for blast energy absorbing. Comparison of effectiveness from the precedent research is in detailed described in [5].

High Strength Concrete in Form of Additive Layer High strength concrete is normally used mainly for bridges and tall buildings. Experimental and numerical analysis of prestressed high strength concrete bridges are described in [18, 19]. For blast load, extensive research is missing.

Steel in Form of Sheets Analysis study of blast loaded steel plates were conducted by Trajkovski in [20, 21]. From the practical point of use steel sheets are laborious to install, add substantial dead load to the wall, and significantly increase cost.

Aluminum in Form of Foam Aluminum foam is a lightweight solid material retaining a lot of aluminum's original properties such as corrosion resistance and strength. Aluminum foam is a promising retrofit material because of its early onset of plastic deformation which allows it to dissipate blast load energy.

Fibre-Reinforced Polymers Fiber reinforced polymers (FRP) are composite unidirectional fabrics in a matrix which are attached to the surface of the masonry wall usually with epoxy or resin. The fibers add strength to the wall by preventing out-of-plane bending and shear. FRP increases the strength and ductility of the structure while limiting the amount of flying debris [22]. European project Operha (Open and fully compatible next generation of strengthening system for the rehabilitation of Mediterranean building heritage) proposed to develop an adaptable and reversible restoration solution for strengthening the masonry structures of historical buildings in Europe and the Mediterranean area. So called mortar fibre composite material

TYFO® HM system consist of basalt fibers woven into a two-way (0/90°) roving fabric with 25 × 25 mm mesh combined with cement polymer mortar [23].

Polymer Sandwich Composite Research of Kovacs is focused on the innovation of a high kinetic energy absorbing material [24, 25]. They we introduce a polymer sandwich composite, reinforced by ceramic spherical shells with a glass woven structure. Ceramic spherical shells are 0.8 mm (average) diameter, the glass fibre woven structure is 390 g/m^2 and the matrix material is epoxyresin (Araldite Ly 1564). There were 15 unidirectional and isotropic layers. Based on the practical impact test results and the experimented test samples we detected that the ceramic spherical shell diameter was important for kinetic energy absorption.

Composite of Polyurea and Polyurethane in Form of Coating Polyurea is an elastomer that is derived from the reaction product of an isocyanate component and a synthetic resin blend component through step-growth polymerization. It is used in a range of applications for its water, abrasion, and chemical resistance. Polyurea appears to be an effective retrofitting technique because it usually reduces the fragmentation of the masonry wall. Generally is apply as a spray-on material to the interior face of the wall. Polyurethane is a material that is similar chemically to polyurea, but it comes in a variety of different forms such as a spray-on adhesive and a thin film.

Water in Form of Protective Blanket W.A. Keen, P.C. Wagner suggest water blanket placed in the proximity of a confident explosion to absorb the energy [26]. Research presents test data demonstrating that water can indeed mitigate the gas pressure loading from a confined explosion; describes how water could be exploited in the design of facilities impacted by confined explosions, and estimates the benefits derived from water, in terms of the reduction in land area encumbered by hazardous debris from unhardened ordnance facilities, reduction in the cost of structures designed to fully or partially contain the effects from an internal explosion, and the increase in the safe explosive limit for existing ordnance facilities.

9.3 Conclusions

Designing of blast protection of soft target is a challenging issue. Choosing the right measures is possible only if the complex assessment of risk and treats analysis is done as well as structural analysis of selected assets. In the blast protection design, or assessment of blast protection of buildings a lot of key elements has to be taken in the consideration. The first step of valuable blast protection design is collaborate to risk analysis and consequently risk assessment as a basic data for blast load estimation. Secondly we can address the problem of assessment of blast-resistant of structure or the identification of facility vulnerability to an explosive event. Based on the structural assessment of the building we can design the right security means to increase the level of protection of soft targets. To design right security design for protection of assets using technical measures depends on the environment of the protected assets. If there is adequate space is possible to calculate with stand-off distance. In other case is required to increase the blast resistance using one of retrofit methods or their combination.

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Chapter 10
Advanced Experimental and Numerical Analysis of Behavior Structural Materials Including Dynamic Conditions of Fracture for Needs of Designing Protective Structures

Michal Grazka, Leopold Kruszka, Wojciech Mocko, and Maciej Klosak

Abstract The article presents the discussion of modern experimental and numerical techniques used to the design critical infrastructure protection structures. The article presents also the results of experimental researches on S235 steel sheet. The S235 steel sheets were tested using the Hopkinson Bar Technic and perforation tests. In researches were used 3D scanners and numerical controlled measuring machine for checking the final shape after the deformation. The article also presents the results of FEM analysis made using explicit solver. Full-scale CAD model was used in numeric calculations.

Keywords Steel perforation · Ballistic · FEM analysis · CNC measuring

10.1 Critical Infrastructures

Critical infrastructures, the meaning of these words takes on a new look in the era of commonly observed acts of terrorism. Critical infrastructure [1] is a term for describing the resources that are essential for the functioning of society and the economy.

Usually, the critical infrastructure is used for describing:

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L. Hofreiter et al. (eds.), *Soft Target Protection*, NATO Science for Peace and Security Series C: Environmental Security,
https://doi.org/10.1007/978-94-024-1755-5_10

- the production, transmission and distribution of electricity (energy),
- the production, transport and distribution of gaseous fuels,
- the production, transport and distribution of crude oil and petroleum products,
- telecommunications (electronic communication),
- water management (drinking water, sewage, surface water),
- the production and distribution of food,
- heating (fuel, heating plant),
- health care (hospitals),
- transport (roads, railways, airports, ports),
- financial institutions (banks); measures,
- security services (police, army, rescue).

Those elements are important and necessary for correct the countries functioning. Therefore, in the times of common acts of terrorism, it is necessary to introduce appropriate policies and systems to protect this infrastructure from damage or destruction. Many countries of the European Union [2] or NATO organization are currently introducing common programs for critical infrastructure protection. More about the protection of critical infrastructure in individual countries is described here [3–5].

One of the easiest ways for protect the critical infrastructure is using the correct building material. These materials connected with correct safety system used in buildings, guaranties good level of protection, the technical principles are described in [6].

10.1.1 Critical Infrastructures – Systems of Building Protection

In critical infrastructure buildings, we often observe many types of protective systems. You can meet in these buildings, for example:

- Special fire protection systems that protect against fire, but also allow smoke removal or safe evacuation of people inside (Fig. 10.1):

- Special systems for registering entrances and exits to the building [7] (Fig. 10.2):

- Special curtain and protection against undesirable intrusion into the confined space (Fig. 10.3)

All of these systems support the protection of critical infrastructure buildings, but do this not in 100%. The critical infrastructure buildings for better protection often were built from special material with dual purpose. One of such materials is a glass,

Fig. 10.1 Fire protection system for modern buildings [2]

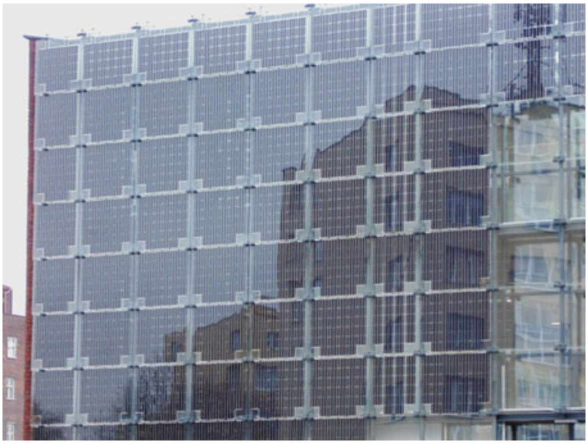
Fig. 10.2 In/Out control systems

which, apart from aesthetic functions in building facades [8], is often reinforced to increase the protective capacity of shock waves caused by explosion or penetration by foreign bodies like a projectile (Fig. 10.4).

The laboratory experiments results presented in article focused on another type of material commonly used in construction. This material is steel S235. Steel S235 is widely used in construction. Because this material is very popular in use, it is important to have basic information on the protective capabilities for this steel. In laboratory tests and computer calculations using the FEM method authors of this paper were tested steel S235, dynamic test of this type of steel was tested in [9]. They want to check the protection parameters of this steel.

Fig. 10.3 Unauthorized entering protection system

Fig. 10.4 Building glass front wall



10.2 Laboratory Set Up and Experiment Data

10.2.1 Laboratory Infrastructure Description

Laboratory tests of S235 steel sheet and numerical calculations of the dynamic perforation of this sheet were made on a measuring apparatus available in various

Table 10.1 Chemical composition of structural steel S235 [10]

Chemical composites	C [%]	Mn [%]	P [%]	S [%]	Si [%]
Steel S235	0.22	1.60	0.05	0.05	0.05

Table 10.2 Steel S235 yield strength [10]

Structural steel	Minimum yield strength at nominal thickness 16 mm	
	ksi	MPa
S235	33,000	235

Table 10.3 Steel S235 tensile strength [10]

Structural steel	Tensile strength MPa at nominal thickness between 3 mm and 16 mm
S235	360–510 MPa

research centers. Laboratory tests were performed in three different centers. Sheet metal perforation tests were performed in the dynamic research laboratory at the University of Agadir (Morocco). The material properties tests of this steel were made at the Motor Transport Institute, and the measurements of deformation after the laboratory test and numerical calculations using the FEM method were made at the Institute of Armament at the Military University of Technology. The structural steel S235 (ISO standard) or A283C (ASME standard) was used in tests. This steel according to description standards belongs to general purpose construction steels.

The chemical composition of structural steel is extremely important and highly regulated. It is a fundamental factor which defines the mechanical properties of the steel material. In the following Table 10.1 you can see the max % levels of certain regulated elements present in European Structural steel grades S235.

The Mechanical Properties of Structural Steel are fundamental to its classification and hence, application. Even though Chemical Composition is a dominant Factor of the Mechanical Properties of steel, it is also very important to understand the minimum standards for the Mechanical Properties.

The yield strength of structural steel measures the minimum force required to create a permanent deformation in the steel. The naming convention used in European Standard EN10025 refers to the Minimum Yield strength of the steel grade tested at 16 mm thick (Table 10.2).

The Tensile Strength of Structural steel relates to the point at which permanent deformation occurs when the material is pulled or stretched laterally along its length (Table 10.3).

Square steel sheet samples with dimensions 130 mm × 130 mm with two different thicknesses were used during the laboratory tests. The sheets thickness was 0.6 mm and 1.0 mm. The perforation laboratory tests were made on square steel sheets. Pneumatic gun was used during this laboratory tests [11]. The cylindrical steel projectiles with a diameter 12.7 mm and a conical tip with the approximately

Fig. 10.5 Plate-projectile configuration during the laboratory experiments

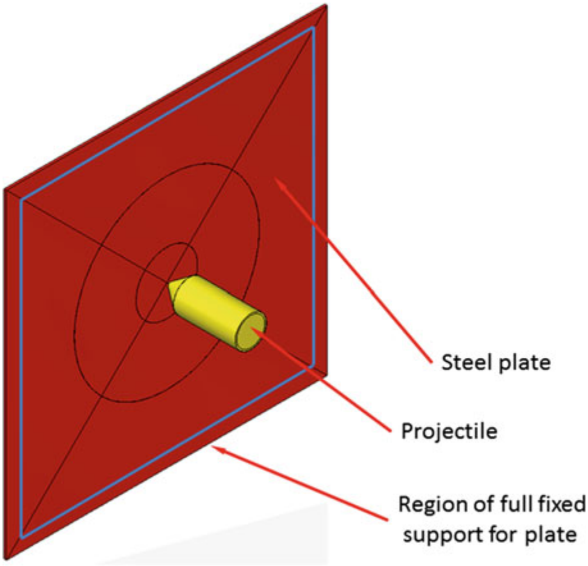


Fig. 10.6 Hopkinson Pressure Bar set-up for investigation of dynamic behavior of material [12]

weighing 28 g were used. These tests were carried out for two temperatures: room temperature (20 °C) and higher temperature (300 °C). The plates were mounted on the circumference (Fig. 10.5) so that they could not be displaced during the perforation by the projectile.

The dynamic properties of S235 steel was obtained by the Split Hopkinson Tensile Bar [12–15] tests (Fig. 10.6). Similarly, the fatigue from thy dynamical

Fig. 10.7 CNC measuring machine used for plate deformation calculation [12]

loading was researched in [16, 17]. The deformation of steel sample after the perforation in ballistic tests was measured using the coordinate measuring machines (Fig. 10.7).

10.2.2 Results of Laboratory Experiments

The perforation laboratory tests were carried out for two types of steel sheet thicknesses. The projectile impact speed was changed in range 0 up to 120 m/s and the tests were in two temperatures. Figure 10.8 shows the final sample shapes with the hole after the perforation.

During the tests, the initial velocity (v_0) of the projectile was measured at the moment of impact on the steel sheet and residual velocity (v_R) after the perforation. The results of these measurements are shown in Table 10.4.

The steel sheets after the laboratory tests were analyzed. The final shape and the figure of perforation holes were checked. In each of the described cases (Table 10.4), characteristics 4 petals were observed, on perforation region (Fig. 10.9).

In the next analysis step, the value of deformation on the surface of the steel sheets was measured. The measurements were made using a CNC measuring machine [1]. The results of these measurements were presented using 3D plots (Fig. 10.10).

The thickness of the steel sheet and the projectile impact velocity has influence on the final shape after the perforation. Normal shape which we expected to get is one side convex (positive deformation) (Fig. 10.10a, b). But the steel sheets which were in temperature 300 °C the final shape is different. The steel samples have positive

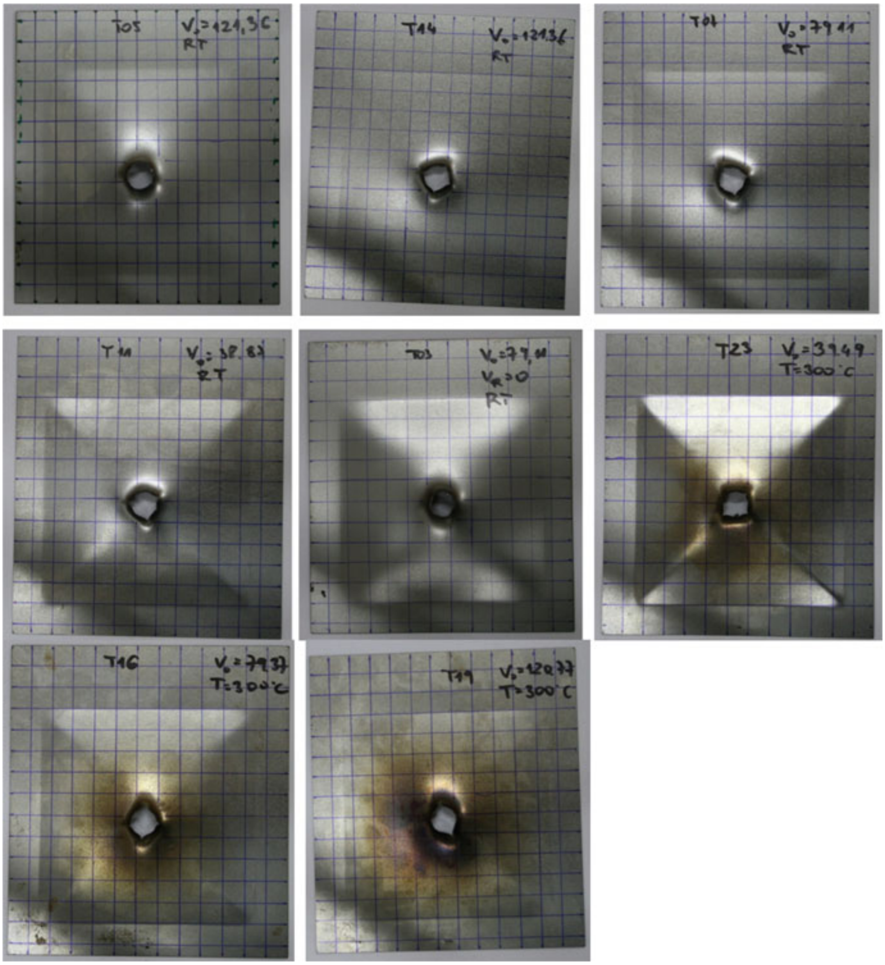


Fig. 10.8 Final results of ballistic experiments

and negative deformation (Fig. 10.10e, f). In these causes the temperature generates internal stresses which are observed on these samples. The maximum of deformation observed during the tests is 4 mm. The information about value of deformation was useful on next step of investigation. This information was use to validation results of numerical calculation.

10.2.3 Kinetic Energy Calculation

In laboratory test we record the impact speed and the residual speed of projectile. The information of projectile speed before and after perforation is useful for kinetic

Table 10.4 Velocity of impact and residual velocity of each ballistic test

Test no	Pressure (bar)	Temperature [C]	Impact velocity V0 (m/s)	Time (ms)	Residual velocity (m/s)
Steel thickness 0.6 mm					
T10	1.0	20	44.17	2.480	20.16
T9	1.5	20	54.11	1.440	34.72
T8	2.0	20	64.43	1.080	46.30
T7	3.0	20	79.11	0.740	67.57
T12	4.0	20	90.58	0.640	78.13
T13	5.0	20	100.40	0.540	92.59
T14	7.5	20	121.36	0.440	113.64
T23	0.8	300	39.49	4960	10.08
T22	1.0	300	43.55	2.100	23.81
T21	1.5	300	55.93	1.190	42.02
T20	2.0	300	64.60	0.890	56.18
T16	3.0	300	79.37	0.660	75.76
T17	4.0	300	90.91	0.570	87.72
T18	5.0	300	100.81	0.490	102.04
T19	7.5	300	120.77	0.430	116.28
Steel thickness 1.0 mm					
T2	2.0	20	64.93	–	0.00
T3	3.0	20	79.11	0.000	0,00
T6	3.2	20	83.06	2.400	20.83
T1	4.0	20	90.25	1.000	50.00
T4	5,0	20	101.21	0.780	64.10
T5	7.5	20	121.36	0.540	92.59
T24	2,7	300	75.50	0.000	0.00
T25	3.0	300	79.11	1.440	34.72
T26	4.0	300	91.24	0.830	60.24
T27	5.0	300	101.62	0.660	75.76
T28	7.5	300	122.55	0.490	102.04

energy calculation. Information about kinetic energy changing during the perforation, inform us about possibility to energy dissipation on material in dynamic load. Figures 10.11 and 10.12 show graphs with information about percentage change in kinetic energy of a projectile during penetration of a steel sheet.

The graphs on Figs. 10.11 and 10.12 show the kinetic energy changes. There is compered information about projectile kinetic energy changes after the perforation in steel sheet in temperature 20 °C and 300 °C. According to the information on graphs (Figs. 10.11 and 10.12), higher temperature decreases the protective capacity of S235 steel sheet. For temperature differences about 280 °C this protective capacity is lower around 5%. Also the thickness of the steel sheet is important on the protective capacity. Big thickness guaranties better protection abilities. How can we observe in Figs. 10.11 and 10.12 the total differences in kinetic energy recorded for 1.0 mm and 0.6 mm steel sheets is 14% higher for the 1.0 mm samples.

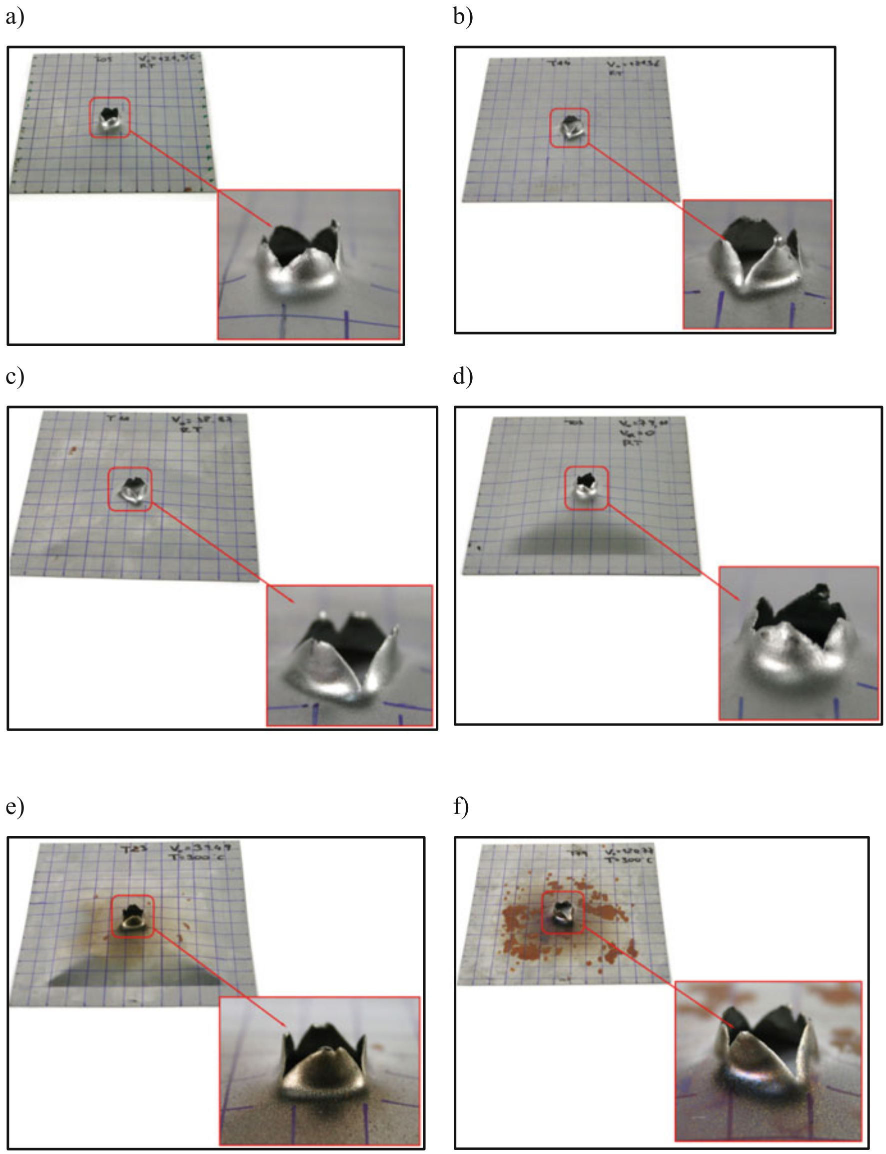


Fig. 10.9 Comparison the shape of penetration region for each tests

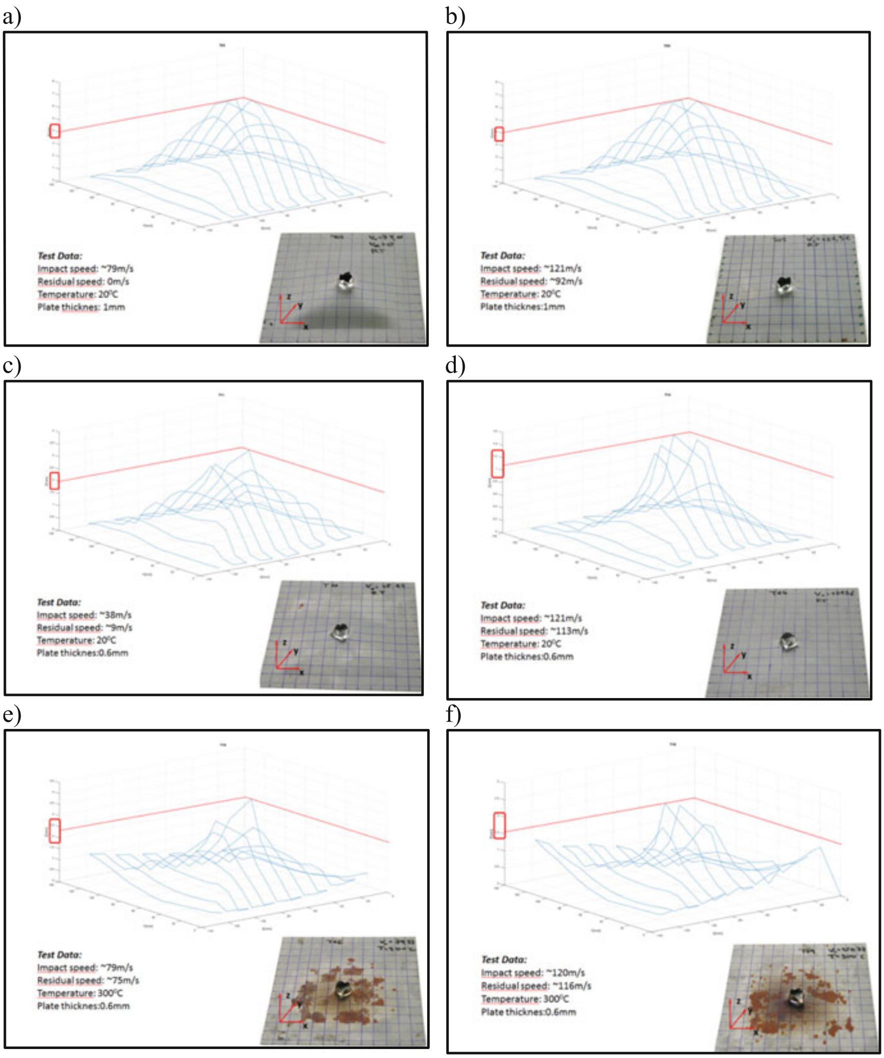


Fig. 10.10 Plate shape (deformation) after the ballistic tests

10.3 Numeric Calculation Using FEM Method

10.3.1 Numeric Simulation – Initial and Boundary Conditions

Numerical calculations were done using Ansys Workbench software [13]. Calculations were calculated in explicit solver. In the calculations full CAD models of S235 steel sheet and projectile were used (Fig. 10.13).

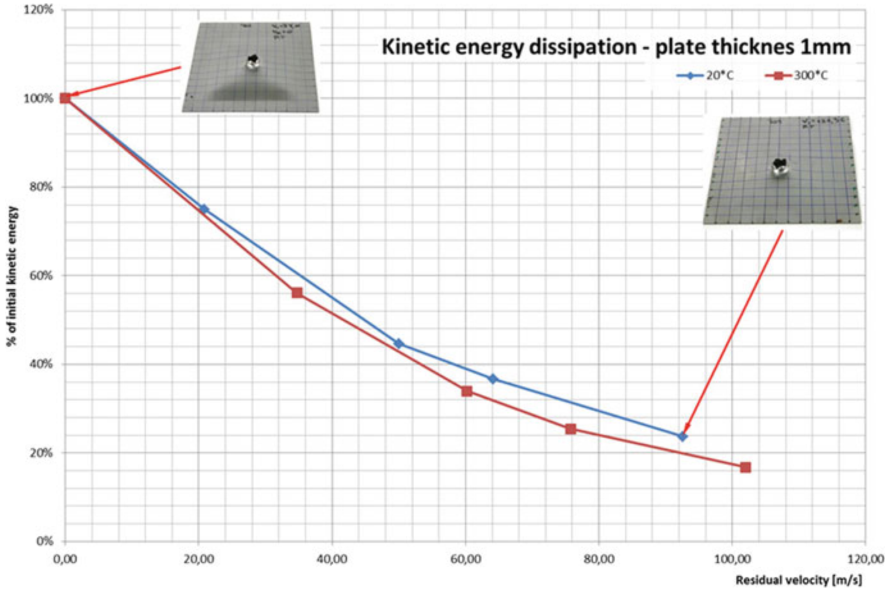


Fig. 10.11 Kinetic energy dissipation on 1.0 mm thickness steel plate

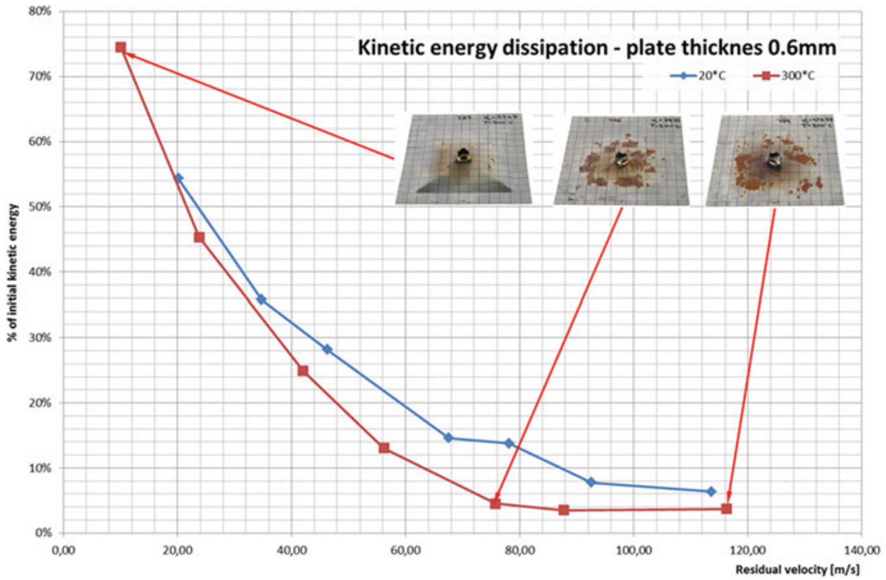


Fig. 10.12 Kinetic energy dissipation on 0.6 mm thickness steel plate

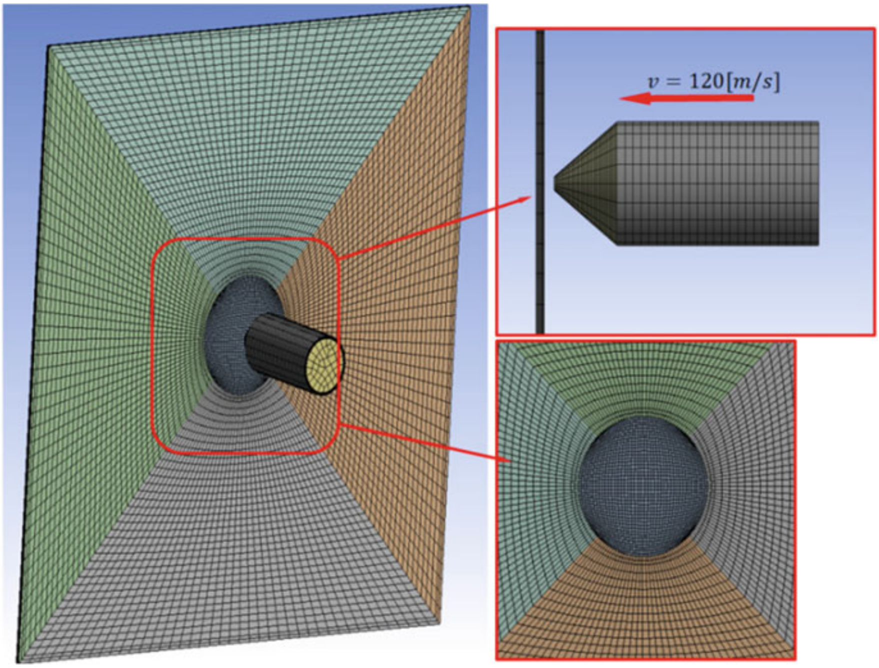


Fig. 10.13 3D cad model of steel plate and projectile used in numeric calculation

During the computer calculations the steel sheets were fixed in the same way as used in the laboratory tests (Fig. 10.14).

The explicit solver was used in the numeric calculations. This type of solver is dedicated for high speed material deformation. This calculation need to use specialist material models for good correctness between laboratory and numerical calculation results. The Johnson-Cook [13, 15] constitutive material model was used for describing the dynamic material behavior of S235 steel. The Johnson-Cook constitutive constants were approximated using data from static and dynamic tensile test. The static tests were done using MTS tensile testing machine. The dynamic tests were done using the Split Tensile Hopkinson Bar equipment. Figure 10.15 shows the stress-strain curves for 600 1/s deformation speed. In tests were used dedicated for this kind tests samples. They were flat samples.

The constants of Johnson-Cook constitutive model accepted for calculation were: A-280 MPa, B-667 MPa, n-0.72, C-0.071. The "m" parameter was omitted in computer calculation of perforation the steel sheet. There were no tests in lower and higher temperatures which are important in calculation this parameter.

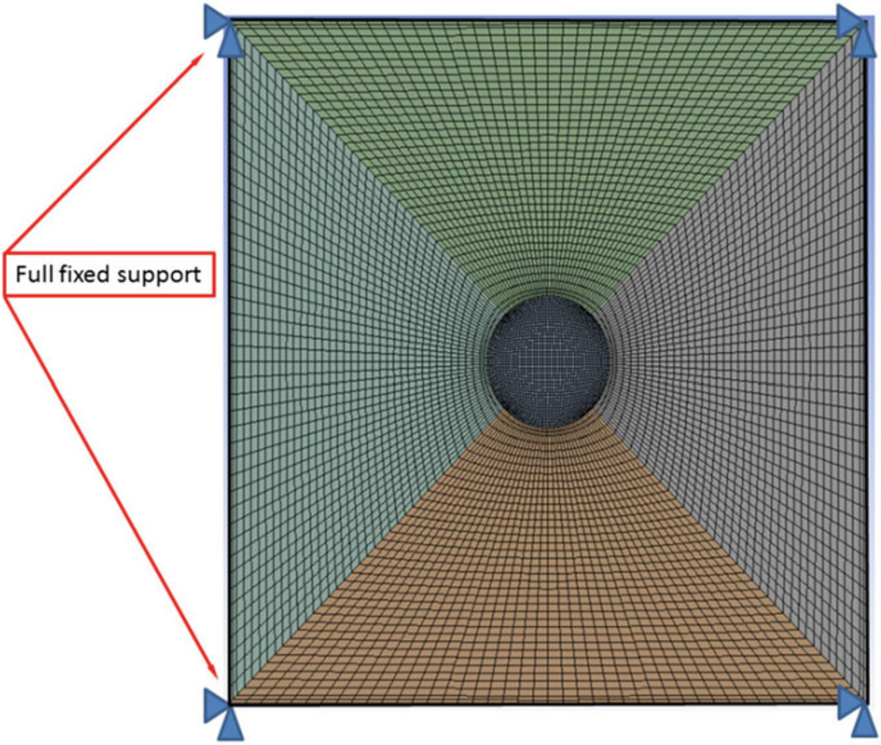
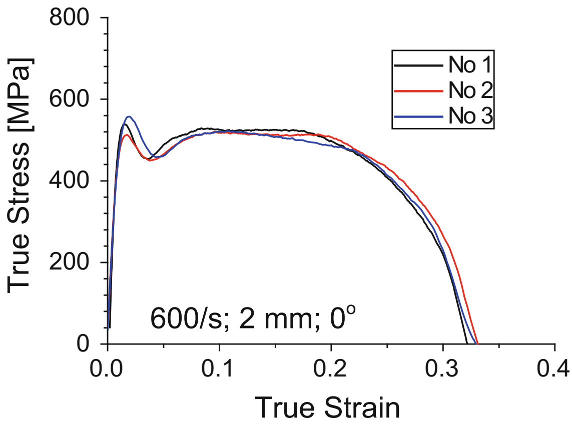


Fig. 10.14 Full fixed support used on external edges of steel plate

Fig. 10.15 True stress-strain curve



10.3.2 Numeric Simulation – Results

The computer calculations were made to get the perforation data. The results on numerical calculations were compared with laboratory test data. Figure 10.16a, b show final shapes of steel sheet after perforation and numerical calculations.

In both cases (numeric calculation, laboratory test), we observe the same characteristic 4 petals in region where was perforation. The final shape of steel plates was also same. The results of the computer simulation were also used to analyze the kinetic energy dissipation during the perforation the steel sheet. The results of computer calculations were compared with laboratory test data. Information about this comparison is presented on Fig. 10.17.

The results of dissipation the kinetic energy are presented on Fig. 10.17. The results of laboratory tests and computer calculations by FEM methods were compared. For steel sheet with thickness 0.6 mm, we observed the good correlation between results calculated by FEM method and from laboratory experiments.

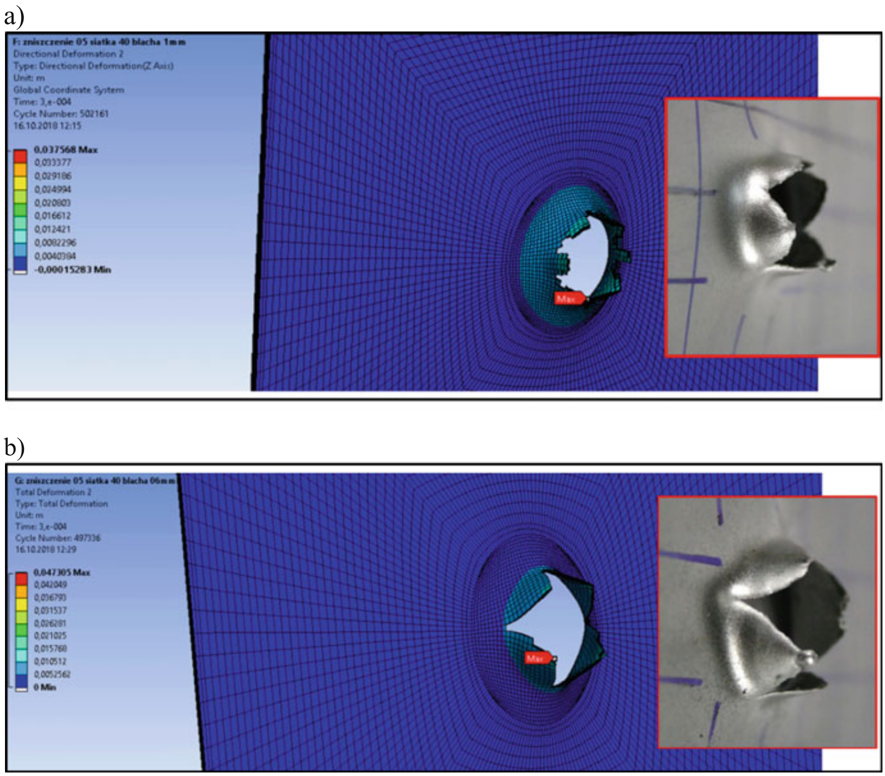
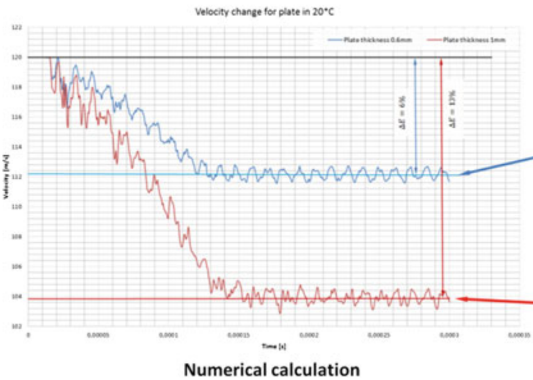


Fig. 10.16 Deformation and perforation regions - comparison



Pressure	No	T [C]	V0	t	VR	%Energy change
1,0	T10	20	44,17	2,480	20,16	54%
1,5	T9	20	54,11	1,440	34,72	36%
2,0	T8	20	64,43	1,080	46,30	28%
3,0	T7	20	79,11	0,740	67,57	15%
4,0	T12	20	90,58	0,640	78,13	14%
5,0	T13	20	[illegible]	0,540	[illegible]	[illegible]
7,5	T14	20	121,36	0,440	113,64	6%

Pressure	No	T [C]	V0	t	VR	%Energy change
2,0	T2	20	64,93	-	0,00	100%
3*	T3	20	79,11	0,000	0,00	100%
3,2	T6	20	83,06	2,400	20,83	75%
4,0	T1	20	90,25	1,000	50,00	45%
5,0	T4	20	101,21	0,780	64,10	37%
7,5	T5	20	121,36	0,540	92,59	24%

Results of laboratory experiments

Fig. 10.17 Kinetic energy dissipation observed in numerical model and laboratory tests

For steel sheets with thickness 1.0 mm the correlation between FEM method calculation and laboratory experiments is much bigger. Kinetic energy dissipation calculated by FEM methods is 13% and data from laboratory experiments shows the dissipation on 24%.

10.4 Summary

The article presents the results of laboratory tests and numerical calculations by FEM methods. During the tests the S235 steel sheets were tested. In these teste protective capacity on dynamic load was checked. For investigation were used modern measuring techniques. During the test Split Hopkinson Bar, Coordinate Measuring Machines and FEM analysis were used. Results of these experiments were presented in this paper.

The presented results as well as the methodology of conduct are important elements of the design of building panels, protective divisions of critical infrastructure facilities made of steel sheets related to determining the resistance of these panels to perforation in the conditions of fires.

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Chapter 11
Building a Security Culture as a Tool for Soft Targets Protection

Ladislav Hofreiter, Martin Halaj, and Richard Jankura

Abstract The soft targets protection becomes the priority of individuals, social groups and the state. Ensuring their protection will minimize damage to property and reduce the number of injured or victims. There are several ways and tools to protect soft targets.

The aim of this article is to analyze the relationship between the security culture and the soft targets protection. Individual levels of security culture support the soft targets protection, influence response to attacks on soft targets, and determine the scale of activities after attacking soft targets.

It is necessary to focus on the security awareness of individuals who can affect the active soft targets protection, or they are only their visitors. Security awareness is reflected in the behavior and actions leading to the soft targets protection. It is also important for the state to create positively influence on the security environment to minimize attacks on soft targets. One way of creating such an environment is to take into account the soft targets protection when new regulations and laws are adopted.

Keywords Security · Protection · Soft targets · Security culture

11.1 Introduction

With a growing number of terrorist attacks as well as other serious incidents (such as mass shootings), which are increasingly focusing on soft targets, the world's security situation is affected. Attacks, on soft targets are no longer an isolated issue, are happening regularly in cities and countries where a similar way of attack didn't anticipated in the past.

Soft targets are attractive for attackers, especially because of their minimal protection and the presence of large numbers of people. However, these facts cannot

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L. Hofreiter et al. (eds.), *Soft Target Protection*, NATO Science for Peace and Security Series C: Environmental Security,
https://doi.org/10.1007/978-94-024-1755-5_11

be neglected and must be addressed. It is important to analyze this problem thoroughly, and suggest possible ways of protection and defense of soft targets. Providing attitudes, values or views to the security of individuals and social groups play an important role in ensuring the soft targets protection. For this reason, the security culture may have a significant impact on the realization of the soft targets protection.

11.2 Definitions of Soft Targets

Many problems are currently linked to soft targets, from an inability to create a single internationally valid definition, to the creation and application of appropriate security systems to protect them. An increased number of terrorist attacks and other violent crimes is putting pressure on an urgent solution to this issue. Therefore, 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 these assets, the soft targets need to be properly defined. Until now, there has been no uniform definition of this term. In general, this term reflects human gatherings and assets in which a large number of people are concentrated, these assets are not at all, or are poorly protected against terrorist attacks and other violent crimes. The term soft targets is often wrongly associated with the terms: crowded places and places of mass gathering. It might seem that they actually express the same – assembly of a large number of people. The difference lies in the fact that crowded places or places of mass gathering are not associated with security significance. It is attributed only as a result of securitization of the threat of attack. These discrepancies are also evident in some of the definitions that have been made so far [1].

There are several definitions of soft targets, such as:

- As a soft target we mean places with more people and weak security against violent attacks. These are transport stations, tourist attractions or larger public events [2].
- There is no formal definition of soft targets. In security circles, the term is used to mean places with a high concentration of people and a low level of protection from attacks, creating an attractive target, especially for terrorists [3].
- The soft targets can be characterized from different perspectives and divided according to different criteria. Primarily they are crowded places. Most of these sites are understood in terms of infrastructure, and it is significant that they are perceived as a matter of course [4].
- Based on the definition of crowded places – open spaces or enclosures to which the public has free access and which, given their density and concentration of people here, may be identified as potential targets for terrorists [5].

Based on the above, we can consider the following objects as soft targets:

- commercial objects: business buildings, shopping centers, business complexes,
- schools and campuses, lecture halls,
- sports centers, e.g. swimming pools, sports halls,
- cultural objects, e.g. theatres, cinemas, museums, galleries,
- church objects, e.g. churches, places of pilgrimage, church monuments,
- traffic objects, such as railway stations, underground stations, airport terminals, ports,
- amusement places, e.g. bars, discos, clubs, concert halls and others.

Spaces that meet the conditions for classification as soft targets can be included, such as squares, boulevards, parks, marketplaces.

Events that can attract the attention of attackers and therefore may be classified as soft targets are:

- public mass gatherings, escorts, demonstrations,
- religious events,
- sporting events,
- great concerts and more.

The number of terrorist attacks rises every day, and soft targets have recently been the most sought-after objects of terrorists' interest, especially for their attractiveness in terms of attack success. This attraction lies mainly in:

- easy access to the building,
- objects are characterized by a low level of protection against such attacks,
- they are characterized by a high concentration of people in one place,
- there is only a small risk of failure of the attack,
- low costs associated with attacks.

Individual attacks on soft targets can be divided into the following groups:

- terrorist attack – terrorist groups or lone-wolves,
- other serious incidents/violent crime – organized crime or individual attacks (mass, serial, random).

The motivation of attackers varies, mainly determinative is if an attack of an individual where this motive is often unclear, or a terrorist group or lone wolf where it is possible to speak mainly about the following motivations leading to the planning and committing attacks [6]:

- religious motivation – especially in connection with the Islamic state, which perceives each person of another faith as an enemy to be eliminated,
- ideological motivation – involves extreme religious, political, ethnic or racial orientation, with the attackers being largely pre-prepared by professionals,
- experimental motivation – in terms of attacks on soft targets, this type of motivation is not frequent; terrorists mostly test the function of their devices or they wish for an uproar,

- destructive motivation – common reason is idiosyncrasism – disease resistance to a certain group of people,
- effective motivation – a terrorist attack committed under the influence of a strong affection. With the regard to soft targets, we are most often confronted with this motivation in the case of lone wolves.

11.3 Methods of Identification of Soft Targets

Depending on the security environment, it is very important to identify soft targets. It is possible to identify individual goals from two different perspectives – the state and the attacker. To greatest attention to be given identifying soft targets, because they are very easy to be targeted by terrorist attacks as well as other serious incidents, each of them could result in irreparable damage and huge losses to life.

The identification of these objectives, in the selected environment, is mainly based on the recognition of risk objects that meet all the prerequisites to be considered as soft targets and at the same time represent an attractive target for the attacker. One of the possible ways is to use the CARVER method. The CARVER method serves to identify important and very important things. The abbreviation comes from the following words:

- Criticality,
- Accessibility,
- Recuperability,
- Vulnerability,
- Effect on population and
- Recognizability.

11.4 Security Culture

The concept of security culture was first used in 1986 by the International Atomic Energy Agency (IAEA) following the Chernobyl nuclear reactor accident. The group, which investigated the accident, used the term weak security culture, as one of the identified factors contributing to the accident [7]. The IAEA investigators concluded that the security culture applies to the personal commitment and responsibility of all individuals involved in any activity affecting the security of nuclear installations. However, the group has left the concept open and has not provided guidance on how this culture can be evaluated and further developed. After this accident, security culture was at the center of interest, in order to optimize the impact of corporate culture on employee security-related behavior [8]. As a security culture can be part of anything, the definitions of security culture may vary in some parts. Here are some definitions of security culture from selected authors:

- Cox and Cox [9] argue that security culture reflects the attitudes, beliefs, perceptions, and values that individuals share in terms of security,
- Hale [10] says that a security culture refers to attitudes, beliefs and perceptions that groups define as norms and values and which influence their actions and their response to risks,
- Cooper [11] wrote that the security culture is an observable measure of effort that all members of the organization draw attention to and take action to improve security on a daily basis,
- Mohamed [12] sees a security culture as a sub-group of organizational or national culture that affects the attitudes and behavior of individuals in the context of ongoing security,
- Richter and Koch [13] perceive security culture as a tool that guides people's activities in relation to risks, accidents and prevention.

We can say that in all of these definitions above we find the common issue – each one focuses on the way how people think or behave in relation to security.

It is important to recognize and define the levels at which a security culture can be observed:

- Individuals,
- Groups/organizations,
- States.

The security culture on the level of individuals is a part of one's ordinary life, including its values, knowledge and abilities that are necessary to ensure its security and self-existence. Every person assigns security to other values and perceives security differently; therefore undesirable events request different acts. The security culture at the individual level reflects its readiness, abilities and skills to cope with the emergence of negative events.

An organization-level security culture is a set of rules and functions of the organization to ensure its security, protect its activities, and ensure the security and health protection of employees and visitors of the organization.

The level of states security culture can be characterized creating conditions in a state where security is provided for everyone at the required level. It reflects the response of state officials to possible threats to the security of the state and citizens. The state's efforts should be to educate its citizens in order to influence their security behavior in different situations.

11.5 The Relationship Between the Security Culture and the Soft Targets Protection

A security culture can significantly affect the level of protection of selected soft targets. This impact can be identified at individual levels of security culture (individuals, organizations and the state).

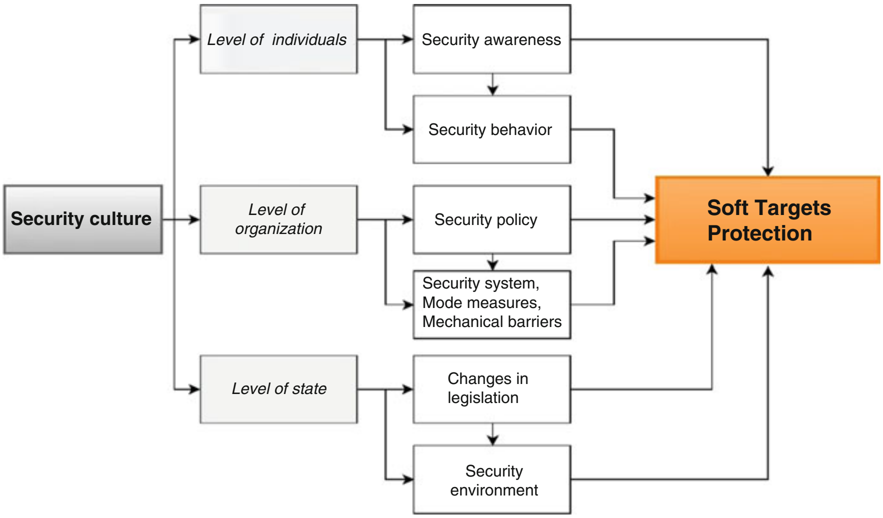

Fig. 11.1 The impact of a security culture, with its three levels, on the soft targets protection

An individual's security culture is very important for protecting soft targets, particularly from the point of view of building security awareness that individuals adapt to their security behavior. Based on the undeniable assumption that individuals are part of the security system, we can assert that security awareness is also part of it. Without achieving the necessary security awareness, individuals cannot perform their tasks to the full potential, and may disrupt the security system. The new risks and threats confirm the importance of protecting soft targets and thus building security awareness among individuals [14]. The security culture introduces the preconditions for a safe behavior of people in everyday professional and private life. An adequate security culture and sufficient security awareness of individuals can create an effective system of prevention and elimination of new security threats, such as attacks on soft targets.

Security education is important for building security awareness. This education must include caution about possible safety and security risks. Appropriate attention needs to be paid to this step needs, not just pro forma. Before testing or verifying the gained knowledge, it is necessary to provide individuals with the basic principles of behavior in the undesirable event (Fig. 11.1).

Protecting soft targets, it is important addressing with to security behavior. Behavioral security is the application of behavioral psychology to promote safe behavior of individuals. It includes the identification of practices (behavioral practices) that are critical for reducing the risks arising from their activities. Behavioral analysis focuses on changes in behavior. The analysis of applied behavior is the application of science to change behavior to real world problems. For this purpose, it is necessary to focus on:

- changes in the environment (security environment) that lead to changes in behavior,
- behavior and its manifestations,
- consequences of behavior (positive or negative reactions after a certain safety performance).

A part of the spiritual pillar of security culture is a set of ideological value systems, knowledge, skills and capabilities to ensure existential security. The human factor plays a significant role in achieving the required level of safety and security culture. It is necessary to realize that there is no perfect individual without errors.

Two groups of security culture individuals can be identified in the soft targets protection:

- individuals who have an impact on the level soft targets protection (individuals in management of organizations or states whose awareness and behavior are reflected in other levels of security culture),
- individuals who have no influence on the active soft target protection (individuals who do not have an impact on organizational and state, are regular visitors, but their security awareness and behavior play an important role in responding to the undesirable event that may be an attack on a soft target, where they are present).

Organizations or social groups should therefore clearly set out and express expectations about the behavior of individuals. A process of monitoring their behavior should be introduced to ensure compliance with standardized security procedures. The tracking results can be used as a feedback to reinforce or change behavior.

Errors of individuals cannot be completely eliminated, but in the most of cases can be limited or even excluded. The human factor is one of the most important element of building safety/security culture and the success of implementing preventive measures. Therefore, it is necessary to focus on identification of possible human errors and, to eliminate the probability of failure of a human factor. Human factor assessment is a complex and unpredictable process requiring knowledge of the different systems, facilities, and features of individuals.

The organization security culture is influenced by the adoption of security by senior management, and by providing sufficient resources, high quality security documentation and security practices, strict security compliance across all sectors of the organization, security training, and employee training. The organization ability deals with undesirable events by allocating and permanently accessing forces and resources, regular controls, measurement, and sustained security enhancements are also part of the security culture at organizational level.

Organizing the adoption of security policy, an important and fundamental document, confirming the effort addressing to the security issues in all of its sectors. Security policy contains a description of the protected organization interest as well as potential risks. It can be processed, comprehensively for the entire organization, or individually for each sector [15]. A well-designed and successfully implemented security policy of soft targets can serve as one of the preventive instruments for there on protect. The security policy may include regime measures, mechanical barriers or technical safeguards designed to ensure the security and protection of an organization, that can be considered as a soft target, in some circumstances [16].

The goal of a state security culture is to ensure a security environment guaranteeing to individuals a space to perform their activities and interests without fear of their lives, health or property. For this purpose, the state is able to adopt new laws and legislative adjustments that can increase the level of their security culture. Changes in legislation include: creating, issuing and updating laws, regulations and standards in a particular country. As we are currently talking more and more about the possible risks of attacks on soft targets, and the role of many authorities is to ensure their protection, it is necessary to reflect this effort and objectives in the proposals and newly adopted laws. These laws should adjust the procedure and means of ensuring security and soft targets protection.

11.6 Conclusion

Attacks by terrorist groups or individuals are no longer targeted against political agents or forces, but at present their targets are mostly soft targets, which are easily attackable (unprotected) assets, resulting in greater damage and a high number of casualties. Therefore, it is important to focus on their protection and defense by creating an appropriate system of protection. The security culture plays an essential role in designing of the Soft Target Protection System.

A security culture, at three levels (individual, organization and state level), forms security awareness, and affects security behavior. Also creates a security environment in an organization or state that may be less attractive for potential attackers. The level of security culture is reflected in the management of individuals, whether are directly involved in the soft targets protection or soft targets visitors (when security culture plays a crucial role in the response and behavior of individuals during the attack). Management of organizations, which can be considered as soft targets, creates and takes direct measures to ensure their protection, which is also conditioned by the level of security culture. State security culture is particularly important there is a evolve need to the protect on of soft targets in current legislation, because of affecting the quality of the security environment in the country.

Even, on the basis of these assertions, it can be concluded that the security culture greatly affects the active soft targets protection, their readiness for possible attacks, the reactions of the participants involved during the attack and the activities following the attack on the soft targets. This relationship needs to be further explored, to be expanded the acknowledgment about the impact and new conclusions have to be set.

The paper was supported by the Internal Grant Scheme of Faculty of Security Engineering, University of Žilina from the grant No. 201804.

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Chapter 12
Theoretical Basis of Soft Target Protection

Ladislav Hofreiter and Zuzana Kubíková

Abstract Over the last few years the number of terrorist attacks in Europe has increased considerably, causing significant tension and nervousness. Not only in Europe, but around the world, terrorist attacks and other violent crimes are increasingly concentrated on targets that are easy accessable, and characterized by a high concentration of people and a relatively low level of protection – soft targets.

In this paper, we will present methods of identifying factors that affect the protection of soft targets. We will use a mind mapping to identify an attacker, as well as conditions for attacking soft targets. We will also present possible concepts of soft targets protection.

Keywords Soft target · Qualitative methods · Assumptions and conditions of attack · Concepts of protection

12.1 Introduction

Security is a basic human need. Its importance and value increases as manifeste new security challenges and threats. The contemporary world can be characterized as a risk society. The nature of the risks is different, not only environmental and technological risks. The greatest threat to the persons has caused by a person, or another group of people. In today's world, security is also dependent on relatively small units or so called "lone wolves". These "solitaire" due to the frustration of their exclusion, lack, poverty, real or presumed threats to national or religious identity, or hatred, can cause a large threat. The objects of their attacks are, as a rule, easily accessible and therefore also vulnerable objects with many people, achieving an extremely high effect of their actions. In the last years are increasing attacks on targets that are characterized by limited protection means. Terrorists and others

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L. Hofreiter et al. (eds.), *Soft Target Protection*, NATO Science for Peace and Security Series C: Environmental Security,
https://doi.org/10.1007/978-94-024-1755-5_12

criminals more and more likely attack unprotected objects and places where people congregate, regardless of whether there is or is not a political, religious or other symbolic pretext. The recent attacks in Paris, Brussels, Barcelona, Nice and Manchester are typical attacks on soft targets [1].

These examples show that more than ever before, there is an urgent need to address the safety of people in open spaces or in freely available assets. It is directly related to one of the pillars of the Human Security concept, i.e. to ensure that the people are released from the fear to be a target and victim of the attack, anywhere and at any time. This means, to solve the problem of protecting so-called „Soft target protection". The key question is: is it possible to protect such type of targets?

The answer to this question is very difficult and complicated. Most of the attacks on the soft targets had the unknown character.

12.2 Methods

Theoretical approach to the soft target protection is based on clarifying the following questions: what is an object of protection, what threatens an object, and how to protect the object. The algorithm for solving this task is shown in Fig. 12.1.

Basis for soft target protection consist from the clear description of the object of protection. The optimal methods to clarify this aspect are the description method and

Fig. 12.1 Algorithm for the protection of soft targets

the mind map method. Mind map is a highly effective method that is ideal for identifying the structure of objects that may be the target of attack.

The second aspect lies in the clarification of factors, causes and conditions that allow attack on soft target. To identify the causes of the attack and to determine the plausibility of the attack, we will use the method of deductive causal analysis, especially FTA method. In this context, we will also use production rules and Boolean algebra as well as Fuzzy logic.

The goal of identifying possible method of attacking the soft target is to reveal the relationship among the types of attacker, his motive, intent and the equipment used from an attack. To solve this problem we will use a method of morphological analysis. Morphological analysis is non- quantified, a heuristic method for structuring and analyzing a set of relationships in a multidimensional, non-quantifiable complex of problem.

Based on the knowledge of the type of target and the presumably method of attack, we will use an inductive method to present possible concepts of protecting a soft target.

The basis for the analysis of all relevant factors and conditions for the protection of soft targets is presented in the Fig. 12.2.

12.3 Results

12.3.1 Description of Asset Protection

The protection of assets, in general, may be a physical, and protection of intangible asset. We need to know, if is necessary to protect a material object or group of objects, or if we need to protect the features performing or providing the objects. In this case, the assets of protection are specific; they are the objects and spaces that are soft and easy to attack [2]. These objects and spaces are also called “soft target”.

Soft Targets can be perceived from different perspectives. Security engineers define them as people and their lives to be protected. Soft targets are defined only in connection with terrorist or violent attacks, against objects and spaces that are not sufficiently protected. For civil engineers, soft targets are constructions and buildings to be protected or strengthen, and rescuers – as firemen, don’t think that the soft targets are associated only with attacks, but are considering also accidents with the possibility of leakage of a dangerous substance, meteorological impacts, fire, etc.

U.S. Department of Homeland Security states that Soft Targets and Crowded Places (ST-CPs), such as sports venues, shopping venues, schools, and transportation systems, are locations that are easily accessible to large numbers of people and that have limited security or protective measures in place, making them vulnerable to attack [3].

Jenifer Hasterman states that “Soft targets” are any venue that is not well protected or fortified, making it particularly vulnerable to an attack [4].

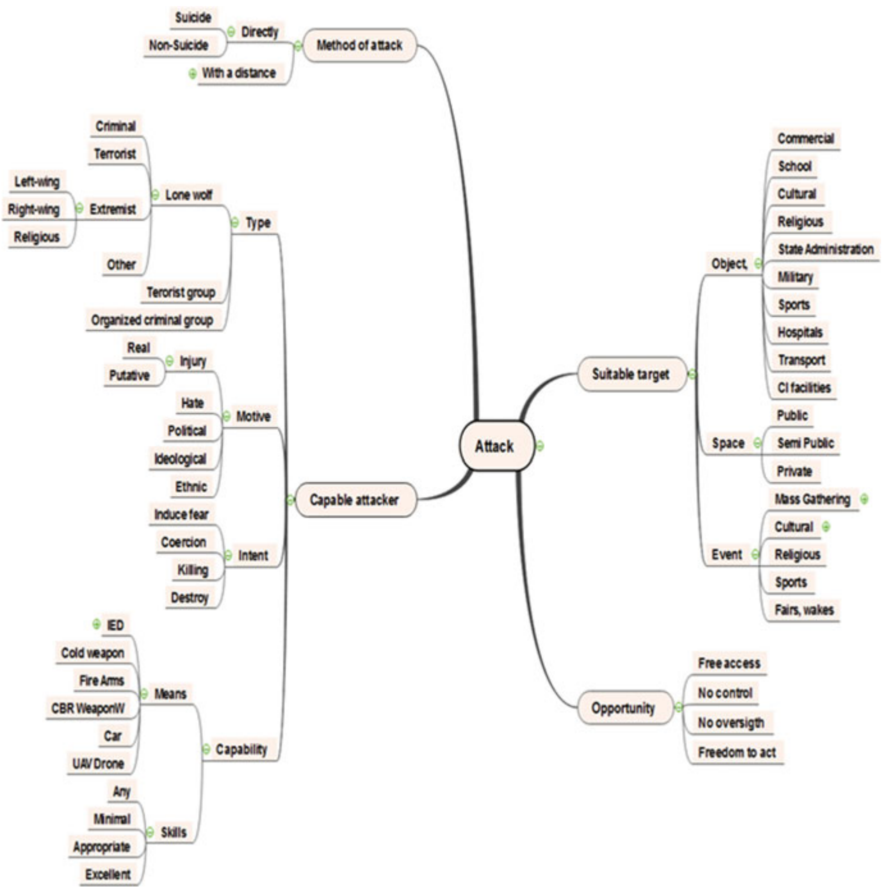

Fig. 12.2 Mind Map for Soft Target Protection

In the context of terrorism, "soft targets" can refer to areas where large amounts of people freely move and there is so much activity that ensuring controlled crowd flow is significantly difficult.

According to the English Oxford Living Dictionarie, Soft target is a person or thing that is relatively unprotected or vulnerable, especially to military or terrorist attack [5].

According to Travel Security Handbook a soft-target is a person who, due to their actions and/or a lack of appropriate protective measures, is at the mercy of existing risks and thus represents an easy target [6].

In Czech guidelines „Basics of soft targets protection" the term soft target is used to denote places with the high concentration of people and low degree of security against assault, which creates an attractive target, especially for terrorists [7].

In general, we can characterize and describe these objects of protection as follows:

- they are objects and places with mass occurrence of people,
- control entry and movement of people is difficult or impossible,
- they are relatively unprotected and therefore vulnerable,
- they are an easy target.

12.3.2 Identification of Factors and Conditions of the Attack

In this phase of analyzes we need to identify, the factors that are necessary to decide the need of protection. This means, we have to identify what can happen, why and how it can happen. We will identify factors which primarily determine the attack on the object.

An event that has the potential to jeopardize a soft target is an outward attack. Attack is a hostile violent act against an object with the intention of killing, destroying, and causing fear. According to the Black Swan theory attack on a soft target is event with the following three attributes:

- is unexpected, surprising,
- has an extraordinary impact on public morality,
- After the attack it is possible to clarify its causes and method of execution [4].

12.3.2.1 The Factors and Conditions of Attack

The necessary factors for the successful attack are:

- suitable target,
- capable attacker,
- Favorable conditions (suitable opportunity) for attack.

The factors identifying a suitable target are shown in Fig. 12.3.

The motive, the capability and the intent are the main factors that enable us to identify a capable attacker (see Fig. 12.4).

Favorable conditions, respectively a suitable opportunity to attack a soft target is when the attacker has free access to the target, his movements are not controlled, the targets are not monitored, and the attacker has the freedom to perform the attack (see Fig. 12.2).

12.3.3 Determining the Plausibility of Attack

The main content of these issues lies in the application of causality principles and production rules.

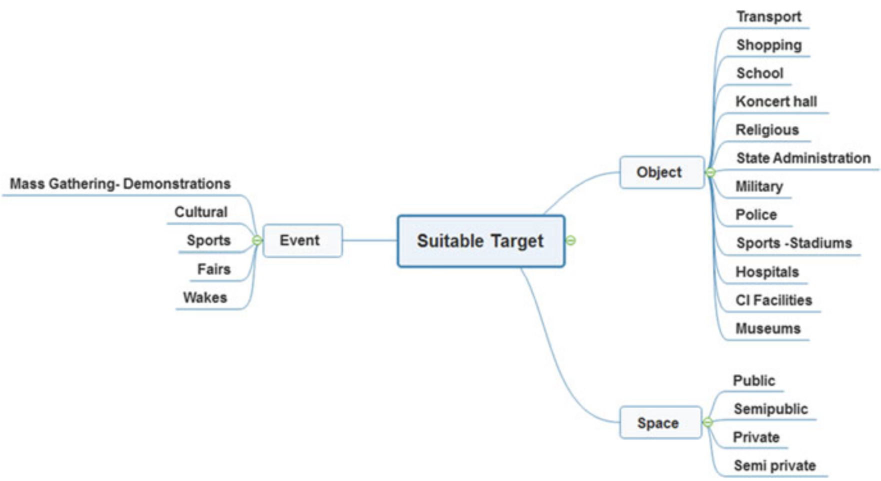

Fig. 12.3 Mind map for analysis factors of Suitable Target

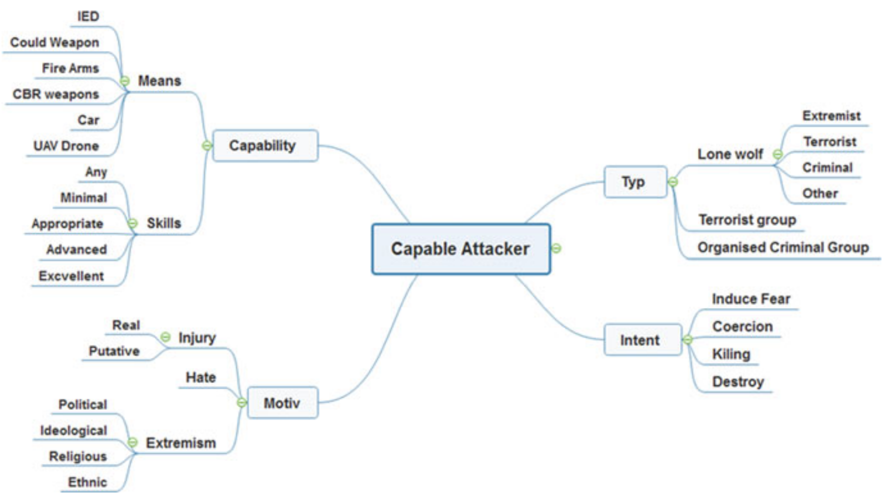

Fig. 12.4 Mind Map for analysis factors of Capable Attackers

We will create a logic diagram for the identification of causes and conditions of attack on a soft target (see Fig. 12.5). The diagram shows the logical relationships between the causes and their consequences. The logical relationship between causes and consequences is expressed depending on whether the causes are necessary or sufficient.

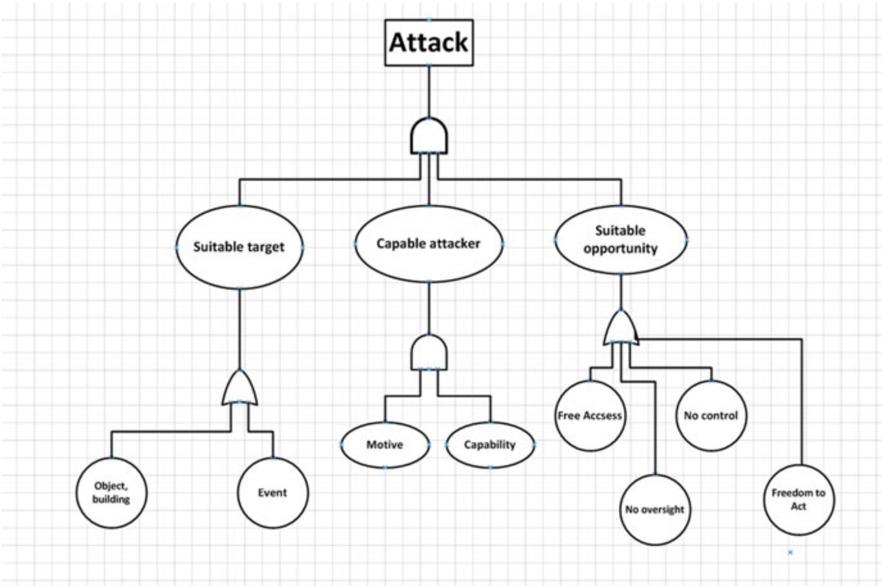

Fig. 12.5 The logical scheme of attack causes

12.3.3.1 Assessment the Plausibility of Factors

A suitable target for attack may be any object, building, public space, event with a mass occurrence of people. The possible types of targets are described in the chap. 3.2. (see Fig. 12.3).

The identification of the capable attackers (CA) is based on the assessment of the following conditions:

- their motivation (M), resp. the intention to perform an attack. Motivations for the attack depend on the type of attacker. The attacker's motivation may be M_1-political, M_2 – religious, M_3 – ideological, M_4 – racial, M_5 – hateful, M_6 – injury (real or putative), M_7 the need to kill (mass murderer) or other (M_n). They are sufficient causes for motivation. Each and any of the presented motifs fulfill the condition of being a motivating factor for the attack. Therefore, we can write as follows:

$$IF\ M_1 is\ 1\ or\ M_2 is\ 1\ or\ldots..or\ M_n is\ 1\ THEN\ M\ is\ 1 \tag{12.1}$$

- their capability (AC) to perform an attack, that is: to have the necessary means (NM) to attack and skills (S_k) to use them. Both are the necessary causes. We express this condition as follows:

$$IF\ NM\ is\ 1\ and\ S_k is\ 1\ THEN\ AC\ is\ 1 \tag{12.2}$$

Because of the existence of the motive (M) and the attacker capability (AC) the necessary conditions (causes), are:

$$IF\ M\ is\ 1\ and\ AC\ is\ 1\ THEN\ CA\ is\ 1 \tag{12.3}$$

$$IF\ M\ is\ 1\ and\ AC\ is\ 0\ THEN\ CA\ is\ 0 \tag{12.4}$$

$$IF\ M\ is\ 0\ and\ AC\ is\ 1\ THEN\ CA\ is\ 0 \tag{12.5}$$

A suitable opportunity (SO) to attack allows the free access, insufficient protection and movement control allows for the freedom of action.

12.3.3.2 Assessment the Plausibility of the Attack

According to the Boolean algebra and production rules, an attack (A) can occur if there is a suitable target (ST), a capable attacker (CA), and a suitable opportunity (SO) to attack. The existence of an attacker, a suitable target and opportunity are necessary conditions (causes). This condition is expressed as follows:

$$IF\ ST\ is\ 1\ and\ CA\ is\ 1\ and\ SO\ is\ 1\ THEN\ A\ is\ 1 \tag{12.6}$$

Without them there can be no attack (see Table 12.1).

Because of the current existence of a suitable target and capable attacker as well as suitable opportunity for attack is necessary condition, we evaluate the plausibility of the attack ($\wp(A)$) as follows:

$$\wp(\mathsf{A}) = \wp(ST) \wedge \wp(CA) \wedge \wp(SO)) \tag{12.7}$$

$$\wp(\mathsf{A}) = \ min\ (\wp(ST), \wp(CA), \wp(SO)) \tag{12.8}$$

Therefore: the plausibility of the attack on the soft target will have the same value as the minimum plausibility of any of its causes.

When any cause will have low plausibility, and the plausibility of attack is low. The range of plausibility values is shown in the Table 12.2.

Table 12.1 A truth table for plausibility assessment

Suitable target	Capable attacker	Suitable opportunity	Attack
1	1	1	1
1	1	0	0
1	0	0	0
0	0	0	0

Table 12.2 The range of values for plausibility assessment

Verbal description	Numeric value
Totally implausible	0
Almost non-plausible	0.1
Very non-plausible	0.2–0.3
Non plausible	0.4
Plausible	0.5–0.6
Very plausible	0.7–0.8
Almost plausible	0.9
Totally plausible	1

12.3.4 Identifying of Attack Tactics

We must seek answers to the question: how the attack happens, what tactics and what means the attacker used?

Attacks on ST take the form of the mass shootings in schools, in community centers, in cinemas, and in concerts; an edged weapon attack at shopping malls; vehicles are used as weapons to target individuals on a pedestrian walkway and at a public rally; and detonation or attempted detonation of improvised explosive devices at sporting events and other places of mass gatherings [3].

Attacks by terrorists are more likely to involve the use of improvised explosive devices, of which the main types as follows:

- person-borne (suicide devices on the person or bag carried device),
- vehicle-borne (which may be suicide or non-suicide devices),
- hand delivered or placed devices (non-suicide devices initiated typically by timer or remote control),
- Unmanned aerial vehicles (drones).

The attackers have recently used other means, such as, for example, vehicles, and firearms or could weapons.

The vehicles were used to attack a group of people in public spaces.

Firearms (pistol, machine gun, etc.) are used for attacks against individuals but also against large groups of people, these are so-called “mass shooting”.

Could weapons (knives, axes, bayonets etc.) use in the attacks against individuals, such attacks on public space causing fear and panic.

Tactics of attack and the means to attack will depend on attacker’s type, his motive and intent. These factors affect the choice of target and means of attack against the target. We will use a matrix of morphological analysis and according to the likely type of attacker, its motif and intent to determine the possible target of attack, attack tactics and probable means used to attack (see Table 12.3). In this way we exclude those factors that are least likely.

Table 12.3 Matrix for morphological analysis tactics of attack

Attacker			Target			Tactics of attack	Used means
Type	Motive	Intent	Object	Space	Event		
LW – crim.	Injury	Induce fear	Transp.	Public	Mass gathering-demonstrations	Directly-suicide	IED
LW – extrem.	Hate		Shopping	Semipublic			Could weapon
LW – terr.	Polit.	Coercion	School	Private	Cultural	Directly-non suicide	Fire arms
Terr. group	Ideol.	Killing	Cultural	Semiprivate	Religious		CBR weapons
Org. crim. group	Relig.	Destroy	State. admin.		Sports	With distance	Car
			Relig.		Fairs		UAV drone
	Ethnic		Milit.		Wakes		
	Other		Police				
			Sports				
			Hospit.				
			CI facilities.				

LW Lone Wolf

12.3.5 Draft Concept of Soft Target Protection

Protection is complex measures and activities for prevention of events, acts or phenomenon that could threat protected objects or spaces as well as to prevent entering unauthorized people to protect objects or spaces. In general, we can characterize three approaches to protecting soft targets: a proactive, preventive and reactive approach.

A proactive approach focuses on eliminating causes before they have a chance to appear. We must concentrate on eliminating those causes that create a threat. Eligibility and ability to eliminate causes of attack on a soft target is most dependent on intelligence and information about the security situation and its development.

Preventive approaches consist of creating of protective system to deterrent an attacker and/or prohibit him from taking an attack. We will use the relevant elements of security systems, police and security services.

Reactive approach is based on responding to events after they have happened. The essence of this approach is to ensure a timely response to the attack in order to activate rescue services and provide the necessary assistance to the victims of the attack.

A very effective method that can be used to plan the soft targets protection is the DDRM (Deter – Detect – React – Mitigate impact) method [7]. This approach integrates all three approaches – proactive, both preventive and reactive. It is an instrument designed to plan security measures designed to protect soft targets. After defining the possible threats that could affect the object (attacker, attack tactic etc.), we propose the best measures to deter, detect, react and mitigate the impact. Measures that prove to be most effective should be incorporated into the overall security solution for protecting soft targets. The final proposal should be reviewed to make sure it provides guidance at all stages – before (deter, detect), during (react) and after (mitigate) each of the cases identified as relevant threat.

12.4 Discussion

Designing protection of soft targets is not a simple problem. The effectiveness of measures to protect soft targets is primarily influenced by information. We have knowledge of the possible targets of the attack. We do not always have the knowledge of who will be the attacker, when the attack happens, how the attack will happen.

Our approach is based on the estimation of the credibility of the identified factors. This approach provides more possibilities for more detailed expression of the credibility of soft-protection agents. More detailed determination of the plausibility of attack and attack tactics is dependent on the expression of an optimal combination of relevant factors and their elements. An example of the solution is given in Table 12.4.

Table 12.4 Matrix for tactics of attack analysis

Type of target	Attacker			Tactics of attack	Used means
Object	Type	Motive	Intent		
School	Lone Wolf- former student	Injury	Killing	Directly- non suicide	Hand delivered IED
		Hate			Could weapon
					Fire arms

12.5 Conclusion

The following conclusions are suggested from the presented analysis:

1. Protection of soft target is a risk management method. It means it is a realization of set coordinated and systematic activities. These activities are focused on the elimination of the possibility of security threat intention by negative event, effect or activity.
2. Protection of soft target is a systematic activity to ensure the security using protective equipment and measures. Hardening of soft targets is not an easy task, and sometimes the hardening is too late, coming after an attack.
3. Protection of soft targets is possible where access control is possible.
4. Protection of soft targets is more a tactical than a technical problem,
5. With some attacks, preventative approach is impossible or difficult, especially when:

- the use of firearms for a longer distance,
- the use of short firearms or cold weapons in the crowd,
- the use of non-traditional IED carriers.

6. Prerequisite of effective protection is knowledge of the situation, i.e. information on the security situation and the prognosis of its development. The person or institution responsible for protection must:

- Know what you know and know how to use it,
- Know what he does not know and try to know.

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Chapter 13
Improving Safety of Soft Targets, Which Are Found Side by Side with Sewage Wells

Valentina Iurchenko and Elena Lebedeva

Abstract Improving safety of the soft targets includes protection of the objects that surround them. Compulsory element of immediate surrounding of the soft targets in urban environment is utility systems of city essential services. The sewage networks are open into ground space by means of mines and wells, located in the immediate vicinity of the soft targets as well. One of the potential preventive measures for protection of the soft targets, that are found side by side to sewage mines is engineering solutions that minimize the secondary effects, formed in these facilities: fire hazard/explosion hazard and high concentration of toxic gaseous compounds (hydrogen sulphide, alkyl sulphydrate, carbonic oxide and others). Concentration of methane in gas air environment of the sewage pipelines presents special hazard, which concentration in some areas of the sewage network exceeds the lower explosive limit. The technical solution is experimentally deduced, that allows efficiently and cost-effectively to minimize concentration of gaseous compounds in the sewage networks. The lasting monitoring of gas air environment compound in the urban sewage pipelines has been executed, as well in the mines (17.7% of total amount), located in the immediate vicinity from the various soft targets. It is found that methane concentration in gas air environment of the urban sewage mines has significantly decreased over the last 20 years. And at present the mines with explosive methane content and hazard content of toxic compounds in the neighborhood of the soft targets are not detected.

Keywords Soft targets · Sewage networks · Effects · Fire hazard/Explosion hazard · Minimization · Monitoring

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L. Hofreiter et al. (eds.), *Soft Target Protection*, NATO Science for Peace and Security Series C: Environmental Security,
https://doi.org/10.1007/978-94-024-1755-5_13

13.1 Introduction

At the present time the unprotected places of people meeting, where they communicate, study, take rest, live, travel and are treated, i.e. the facilities, named "soft targets", are subject to the terroristic attacks to the utmost. These are attackable facilities, chosen by terrorists that aim to kill and disable as many as possible people [1–3]. The soft targets are cheaper alternative to the attacks on more complex "hard targets", which are well secured and guarded facilities; the attack on the soft targets does not require complex and intense preparation of trigger men. In the meantime reliable protection of the soft targets in the urbanized territories represents the broad range of various activities, which are highly cost-based, including engineering ones [3, 4].

13.2 Safety of the Soft Targets in the Urban Environment

13.2.1 Ways to Improve the Security of Soft Targets

In many countries methods of safety improving of the soft targets and protection providing for the facilities of the urban environment are developed, as, otherwise, they are kept completely not protected, and therefore they are attractive for the terrorists. It led to the presentation of significant amount of recommendations (which consider current experience of hitting of the soft targets under terrorist attacks) [3–5], however they are not official standards. That is why such recommendations are not always known to the security staff members, community services members, owners of premises or other concerned persons, including persons who have professional knowledge of civil engineering and maintenance of engineering constructions. In the meantime in the Activities plan, presented by the European Commission COM (2017) 612 [6], whose aim is support for states with regards to protection and reduction of vulnerability of public space, it is indicated about the necessity of searching of technical solutions, that can help make public space more secure at the same time keeping their public and social character. The effective solution of this task is impossible without involving of information about technical features of city engineering systems and their operation, and also about potential risks produced by them.

It is recommended to take into consideration the facilities, that surround the soft targets, in the article [4] among ten main recommendations for increase in stability of the soft targets. In this document it is indicated that it is necessary to protect the whole area, and not the isolated section or the agency under strengthening of the soft targets. It is significantly right concerning the soft targets that are located tightly side by side or included in the complex of facilities of different assignment.

13.2.2 Impact of Utility Networks of City Essential Services on Soft Targets Security

The soft targets are mainly typical urban infrastructural facilities: schools, canteens, shopping centers, medical centers, cinemas and theatres, concert halls, clubs, restaurants and hotels, parks, museums, sports arenas, railway and bus stations, airport terminals, libraries and others [2, 4, 6]. Compulsory elements of their immediate surrounding are utility systems of city essential services, located in the underground space: water supply, sewer, heating supply, gas supply and electrical power supply networks, and without their operation proper functioning of these soft targets is impossible. Essential services facilities of the city can also become terroristic attacks objects. Although they can hardly be referred to the soft targets, as specialized guard and anti-terrorist protection of a number of facilities of such systems and their equipment are provided by the range of the legislative and department documents. The utility networks can become the element; where through the soft targets can be attacked in the nearest territory, or the element, that can be got in the danger area under the attack on the nearby soft targets.

The terrorist attacks on the utilities systems networks can cause formation of secondary effects that far exceed in their scale and severity of consequences of damage effects, resulting from the initial effect on the facility. For that reason the utility networks are the element that is able to intensify the damage effects of the terrorist attacks, which effect on the soft targets, as well as to weaken them. In that context the urban sewage networks draws attention, although water supply and sewage networks are excluded from the objects, that require protection [7], in the known governmental regulations about the requirements to the anti-terrorist protection.

13.2.3 Basic Risks for the Soft Targets, Formed in the Sewage Networks

Water discharge networks penetrate the whole underground space of cities and are open into above ground urban space by means of mines and wells, located in the territories of different facilities of urban infrastructure, including in close vicinity to the soft targets. Accidents of the sewage networks are followed by serious financial damage and strong pollution of the underground space with toxic gaseous and dissolved maters for this reason the sewage networks are always located lower than other networks [8, 9]. At present the sewage networks already draw attention of anti-terrorist services. Thus, under the program of detection Emphasis the Swedish scientists have developed a special sensor, which can be installed in the sewage network for detection of clandestine laboratories for production of explosive devices. As production of explosive devices is necessarily connected with emission

Fig. 13.1 The main hazards posed by sewage mines

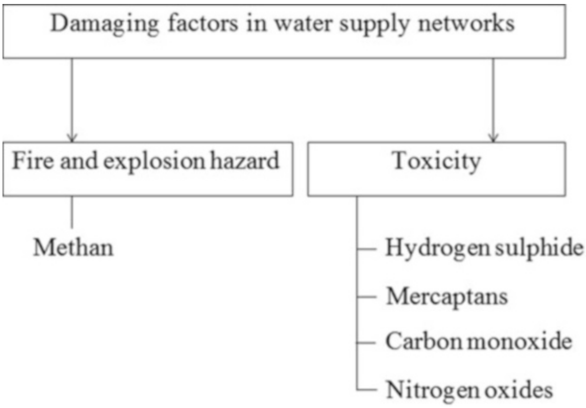

Table 13.1 Chemical compounds in air of the underroof space of the sewerage pipelines [9, 12]

Compounds	Concentration	Rate of MPC excess working area
CO_2, volume %	0.1–3.5	to 7
CO, mg/m^3	0–25	to 1.4
CH_4, volume %	0.2–6.0	to 3
H_2S, mg/m^3	0–250	to 25
SO_2, mg/m^3	5–30	to 3
Dimethylsulphid, mg/m^3	(1–4) 10^{-4}	to 10^2
NH_3, mg/m^3	0–5.0	to 4
NO_x, mg/m^3	0–5.0	–

of chemicals of specific nature into the sewage facilities, then location of clandestine laboratory can be found due to motion in the network regarding increase of specific matter concentration [10].

Under security system engineering for the specific soft target (place or event) potential hazards for guarded facilities, considering their surrounding with sewage facilities – pipelines, mines and wells must be considered, and then it is necessary to choose and implement appropriate security measures. One of the potential measures from the preventive ones is engineering solutions that minimize the secondary effects. Let us consider critical threats to the soft targets, that can form the most common ways of terrorist attacks (57% [4]) – Bombing/Explosion in the sewage networks. Not only direct destructive effect can be related to the main risk factors, but also the secondary effects, which are specifically formed in these facilities: fire/explosion hazard and high concentration of toxic gaseous compounds [9, 11] (see Fig. 13.1, Table 13.1).

As it can be seen from the data from Table 13.1, gaseous compound concentration in the gas air environment of sewage pipelines varies widely, achieving extremely dangerous values in some areas. Concentration of methane in gas air environment of the sewage pipelines presents special hazard. Its compound with air explodes on contact with flame or spark. The lower explosive limit is 5, the upper one is 15 volume % [13], and in some sewage networks areas its concentration can reach 6%.

13.3 Research Objective

Estimation of potential hazard of sewage mines of the city for security of the soft targets by means of monitoring of gas air environment compound in the sewage pipelines.

13.4 Research Methods

In the present work the results of the lasting monitoring of gas air environment compound in the sewage pipelines, executed together with sewage networks maintenance departments, are presented. The measurements of the gases concentration in the environment of the underroof space of the sewage networks were performed with three gas analyzers: UG-2, “Dozor”, a mine interferometer ShI-11.

13.5 Research Results

The regular control of gas air environment compound is carried out at 62 mines of sewage network of the city. From sewage pits, subject to control, 11 mines are in immediate vicinity from various soft targets (at a distance not more than 40 m):

- apartment block – 6 mines (11.3%);
- hospitals – 2 mines (3.2%);
- recreation areas – 2 mines (3.2%);
- nursery school – 1 mine (1.6%).

According to the measurements (see Fig. 13.2), over the last 20 years the tendency of decrease of methane concentration in gas air environment of city mines has been noted.

At present the mines with methane content ≥5% volume %. in gas air environment are not indicated. And if in the end of 90s and in early 2000 among sewage mines with increased methane concentration (≥5% volume %) 4 mines were located in immediate vicinity from the soft targets, then in 2006 such mines were not detected. In 2016 only one mine with methane content ≥2% volume % was registered, that is located at 30 m from the soft target – an apartment block. Methane concentration in gas air environment of sewage pipelines positively correlated with high toxic (second hazard class) hydrogen sulphide compound concentration (Table 13.2).

Fig. 13.2 The number of mines in the sewer network with a high content of methane

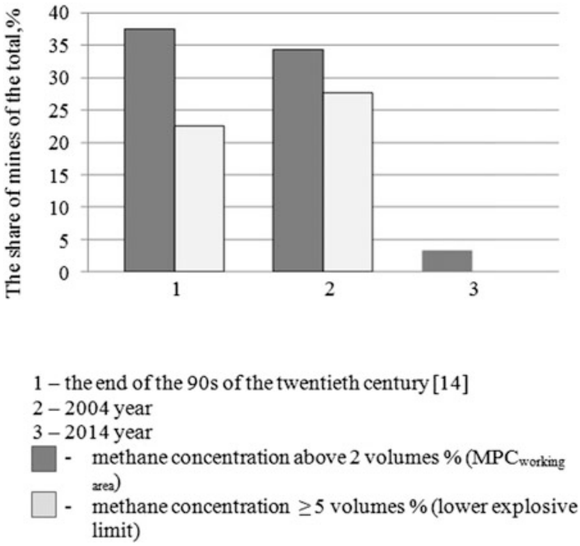

Table 13.2 The change in the concentration of gaseous compounds in the sewer shaft for 3 months

Month	SO_2, mg/m^3	H_2S, mg/m^3	CO, mg/m^3	CO_2, volume %	CH_4, volume %
May	35	110	0	0.6	0.2
June	35	125	0	0.6	0.4
July	35	132	0	116	2.16

Different methods of concentration decreasing of explosive and toxic compounds in gas air environment of sewage networks are examined experimentally and on operating sewage networks. It is found that the most advanced method is decreasing of the temperature of sewage water that is transported by the networks by means of heat pumps. Such measure allows practically to decrease these compounds concentration in networks twice, and consequently to decrease potential risk of secondary effects, formed in these facilities under terrorist attack.

13.6 Conclusions

On the basis of carried out theoretical, practical and experimental researches the following can be concluded:

- the sewage networks are dangerous neighbor objects for the soft targets, as they can intensify destructive effect of terrorist explosions:
- main secondary effects, formed in these objects under terrorist attack, are decrease of concentration of fire/explosion hazardous and high toxic gaseous compounds, formed in some areas of the sewage networks;

- under inspection of urban sewage mines, that are found side by side with the soft targets, the mines with dangerous methane content and toxic compounds (hydrogen sulphide, alkyl sulphydrate, carbonic oxide and others) are not detected at present.

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Chapter 14
Different Approaches of Numerical Simulation of Blast for Civil Engineering Applications

Matúš Ivančo, Lucia Figuli, and Chiara Bedon

Abstract The aim of the paper is to describe various approaches of numerical simulation techniques, with a special focus on air blast effects on structures. In this regard, the document summarizes and describes commonly available commercial software tools for the design and simulation of civil engineering structures and components under impulsive dynamic loads. In conclusion, some useful examples of numerical modelling of selected constructional elements are also presented.

Keywords Numerical simulation · Blast wave · Explosion effects · Blast resistant structures

14.1 Introduction and Analytical Methods

Especially in the last few years, given the increasing number of tragic events and observations from terroristic attacks, several research studies have been carried out to study the performance of constructional systems under explosions, with major efforts and attention for several blast-related effects and phenomena. These include laboratory investigations on material dynamic properties (i.e., to characterize their mechanical performance under high-strain pressures and shocks), analytical solutions for the simplified analysis of the response of constructed facilities under impact, numerical modelling investigations for the vulnerability assessment of materials and structures subjected to air blast waves, laboratory or field blast tests to validate the prediction and performance of buildings and assemblies, as well as the efficiency of possible mitigation and retrofitting solutions for novel or existing structures claddings.

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L. Hofreiter et al. (eds.), *Soft Target Protection*, NATO Science for Peace and Security Series C: Environmental Security,
https://doi.org/10.1007/978-94-024-1755-5_14

Within all these studies, the first fundamental steps are related to the reliable estimation and description of the structural behaviour of a given material/system under dynamic loads like explosions. For design purposes, the most suitable approach is represented by simplified methods, where a given complex mechanical system could be investigated based on simple computational models. Despite the computational advantage of such a general solving strategy, on the other hand the accuracy of simplified methods may be compromised, with severe effects on the reliability of blast-induced effects estimates and fail-safe design goals.

More in detail, to describe a given system, both the following analytical methods can be used:

1. Single degree of freedom.
2. Multi degree of freedom.

14.1.1 Single Degree of Freedom

The degree of freedom of the structure describes the minimum number of coordinates required to define completely the positions of all its parts of a system at any instant of time. A single degree of freedom system requires only one coordinate to describe its position at any time step (called springmass-damper system). Damping of blast loaded structures has much less importance because the maximum response will be reached in a very short time, before the damping forces can absorb much energy from the structure (Fig. 14.1).

Generally the effects of damping in blast analysis are not considered because of the reasons:

- Damping has very little effect on the first peak of response.
- The energy dissipated through plastic deformation is much greater than that dissipated by normal structural damping.
- Ignoring damping is a conservative approach.

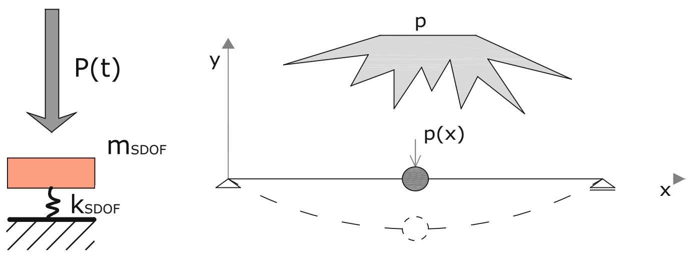

Fig. 14.1 SDOF system presentation [1, 2]

If we want to make the SDOF system response equivalent to the real system, equivalent SDOF factors are used to obtain the effective mass, force, and resistance terms [3].

14.1.2 Multi Degree of Freedom

A multi degrees system (MDOF) is a system requiring at least two coordinates to describe its motion. If they are independent of each other are called general coordinates and they are equal in number to the degrees of system freedom. The difference between MDOF system and the single DOF system is that we have n natural frequencies and for each of the natural frequencies corresponding to the natural state of vibration with a shift configuration known as normal mode. Vibrations in normal mode are free vibrations, depending only on the weight and stiffness of the system, its distribution.

Systems with 2 degrees of freedom can be solved analytically, but for a larger degree of free systems, numerical analysis using computer to find natural frequencies (eigenvalues) and mode shapes (eigenvectors) can be used [4].

14.2 Numerical Methods

Numerical methods have been developed to help engineers understand, to analyse, and predict all physical phenomena that occur under different load conditions. They are of great importance, especially for dynamic loads, because the fast-dynamic loads, such as blast load, are solved with analytical methods with difficulty and structural behaviour of such loaded structures is hard to describe.

14.2.1 CFD (Computational Fluid Dynamics)

The Computational Dynamics of Liquids is a fluid mechanics industry that uses numerical analysis and data structures to solve and analyze problems that involve fluid flows that are used to perform the calculations needed to simulate the interaction of fluids and gases with surfaces defined by boundary conditions.

For a reliable estimate of the explosion from a gas detonation, it is first necessary to know the intensity of the explosion itself, and this aspect may involve a series of uncertainties with severe effects on the numerical predictions. For example, the source explosion may not be symmetrical. In common practice, pressure waves can in fact reflect or deviate when construction/obstacle objects are struck. Even worse, blast waves can spread inside buildings or tunnels with very low decay rates. The use of CFDs for near and far wavelength forecasting, in this context, has many advantages. They include in fact more accurate energy estimates, hence resulting in enhanced blast wave pressure simulations, as well as the ability to evaluate unbalanced effects due by real/complex geometries, where gas cloud and ignition sites could change. This is essential in assessing the likelihood of a source of leakage as a cause of the explosion or in assessing the potential risk associated with the source of leakage due to the impact analysis [5].

14.2.2 TNO Multi-energy Method

The TNO multi-energy method proposed by Van den Berg determines the maximum overpressure due to the different gas explosion force depending on the limitation. Obstacles in the gas cloud can affect the degree of explosion of gases by increasing the flame rate, i.e., turbulence, which is caused by the passage of liquid through the obstacles, thereby accelerating the flame of the explosion. Given the fact that the turbulence regulates the force of the explosion wave, this method uses geographic conditions as the main factor in estimating the potential energy of the gas explosions (e.g., they are confined or obstructed). From different sources of ignition in the steam cloud, sub-explosions of different strengths are determined, positive overpressures and positive phases of duration are defined. The procedure for the determination of the explosion force with TNO MEM is as follows:

1. Determine an obstacle and/or an unrestricted region.
2. Determine the class number and estimate the strength of sources in each region.
3. Determination of the gas cloud radius.
4. Calculation of scaled distance, positive pressure phase and duration (explosion parameters).
5. Calculation of positive overpressure, duration and positive impulse (actual parameters).

Explosion parameters are determined based on the class number and the guidelines suggested by Kinsell, Roberts and Crowley can be used for the class number (Tables 14.1 and 14.2). However, these guidelines define the range of a class number rather than a specific value. The user can make a final decision when selecting a class number, although not sufficiently objective [6].

14.2.3 FEM (Finite Element Method)

Last very useful method called the Finite Element Method is method that divides the CAD model (structure) into small shapes of various geometry. All these shapes and components represents the so-called Finite Element network.

Table 14.1 Guidelines by Kinsella for class number [6]

Ignition energy		Obstacle density		Confinement			
Low	High	Low	High	No	Existing	No	Strength
	X		X		X		7–10
	X		X			X	7–10
X			X		X		5–7
	X	X			X		5–7
	X	X				X	4–6
	X			X	X		4–6
X			X			X	4–5
	X			X		X	4–5
X		X			X		3–5
X		X				X	2–3
X				X	X		1–2
X				X		X	1

Table 14.2 Guidelines by Roberts and Crowley for class number [6]

		TNOMEM charge strenght		
		Obstacle density		
Types of flame expansion	Mixture reactivity	High	Medium	Low
1-D	High	10	10	10
	Medium	9–10	9	7–8
	Low	9–10	7–8	6
2-D	High	9	7–8	4–5
	Medium	7–8	6–7	2–3
	Low	6	5–6	1–2
3-D	High	6	3	1
	Medium	3–4	2	1
	Low	3	2	1

After the division of a structure into the small parts, partial differential equations (PDEs) describing the physics are applied for each element. In each element a simple function (linear or quadratic polynomial) with a final degree of freedom (DOFs) is solved. Collecting the contributions from all the elements, a large system of isosceles matrix equations is created.

The type of solver used depends on the original physics, each type of physics brings a unique trace to the structure of the matrix. Customized numerical method is used to speed up the situation. The method is used mainly for structural analysis. During the last years, it has been found that the finite element method is also suitable for a large class of multi-physical problems [7].

14.2.4 Implicit and Explicit FEM

Numerical simulations can be used to predict the behaviour of different structural materials and components/systems affected by a given blast-wave. These numerical simulations are not intended to replace the experimental tests, but can be used as an efficient and robust tool in support of test scheduling, prediction and assessment of experimental results, or performance of parametric studies (by changing, for example, boundary conditions, geometry, material properties or explosion features). Most FEM solutions are based 1D (beams), 2D (shells) or 3D (bricks) type of elements. Each corner (i.e., extremity) of the element is defined by a node. The association of all elements represents the structure or the environment of the structure (boundary conditions or air) and is called the structure of the mesh.

Implicit and explicit time integration schemes are the two main available methods in use for FE dynamic analyses. The most appropriate method is selected, case by case, based on the nature of the problem to be solved, and in most of the cases requires a certain experience of the final user for the appropriate calibration of input parameters. Whilst the implicit methods are generally preferred for earthquake load and linear behaviour under impulsive dynamic loads, nonlinear phenomena due to shock events are mainly calculated using explicit time integration approach [8].

14.3 Solvers

The Lagrangian solver is the most commonly used, within the framework of structural FEM analyses. The network represents the structure and its deformation. For example, during the analysis of effects induced by a high-pressure load, the structure may be subjected to large deformations and the computational network may be highly deformed to generate premature convergence issues, and hence calculation aborts. In order to overcome this difficulty, Lagrangian's standard approach can be used. Such an assumption means that - according to Euler' assumptions - a given mesh/grid is fixed and the materials in use (solids, liquids or gases) can flow through this grid. Eulerian analyses are effective for applications involving extreme deformation to fluid flow. In these applications, the traditional Lagrangian elements became very distorted and lost the accuracy. Liquid spraying, gas flow and most penetration problems can be effectively resolved using Eulerian analysis [8] (Fig. 14.2).

To improve the quality of numerical access, many of the current codes include the Euler-Lagrange analysis link (but also the ALE - Arbitrary Lagrangian-Eulerian approach). In this case, the spatial domain is divided into two parts, the first part is dedicated to the Lagrangian solution, and the second part is for Eulerian solution. This combined approach is very useful in simulating, in a single run, the shock wave

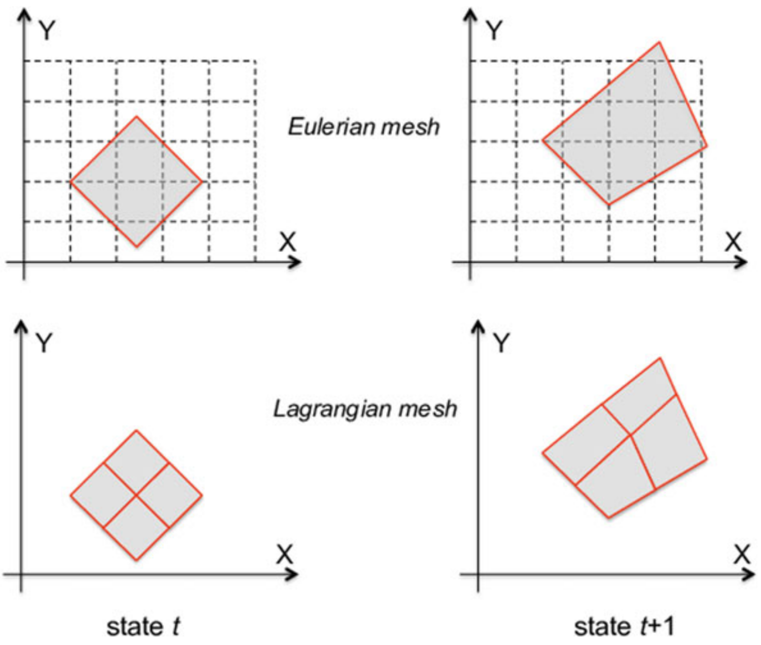

Fig. 14.2 Lagrangian vs Eulerian description [7]

propagation and structure response. Another possibility of increasing the accuracy of fluid structure interaction is to use mesh adaptivity (automatic mesh refinement AMR). The idea is to use very fine mesh fluids in structures and high pressure gradient zones to better capture the details of wave development in these areas [8].

14.4 A Brief Overview of Selected Commercial Software Packages

In Table 14.3, a concise overview of key features for the solving method and discretization approach is reported for a selection of possible software products.

Among the typical structural engineering software VISUAL FEA can be classified. It allows to do various types of analysis: Structure linear static (nonlinear, dynamic, sequentially staged), Heat conduction (steady state, transient), Seepage (steady state, transient, confined, unconfined), Coupled analysis (structure and heat conduction, structure and seepage) (Fig. 14.3).

The blast load can be simulated as a load on the element in the form of non- linear function. The response spectrum can be drawn based on the loads.

Table 14.3 Software products

Software	Implicit method	Explicit method	Discretisation		
			Lag.	Eul.	Lag/Eul
ABAQUS	X	X	X	X	X
ANSYS	X	X	X		
LS-DYNA	X	X	X	X	X
AUTODYN		X	X	X	X
MSC.DYTRAN	X	X	X	X	X
NASTRAN	X	X	X		
EUROPLEXUS		X	X	X	X
ASTER	X		X		
SOPHIA		X	X		
ProSAir		X		X	
Apollo Blast Simulator		X		X	
VISUAL FEA					

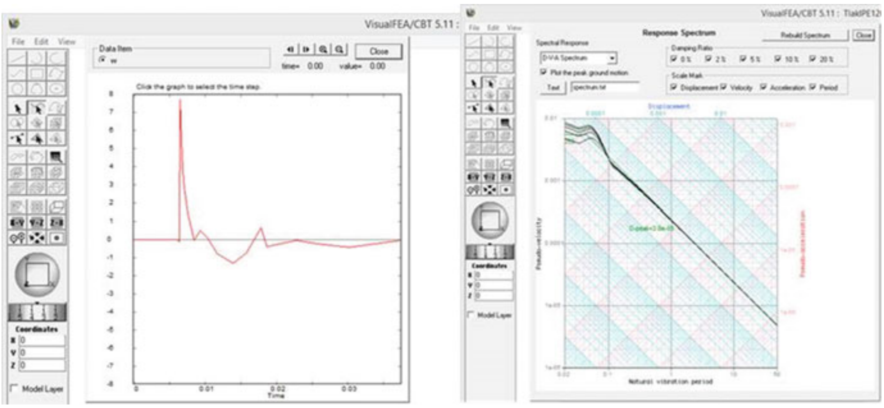

Fig. 14.3 Simulation of blast load in VISUAL FEA

14.5 Discussion of Typical Simulation Results for Blast Loaded Structures

The dynamic numerical simulation in ABAQUS is based on the Finite Element Method and the key input features from the user are related to the geometrical properties of the object/system to investigate, the used materials, the presence of possible constraints and contact interactions, as well as the mesh (Lagrangian or Eulerian), including time-varying loading pressures. While the potential of the software package is represented by a wide series of mechanical interactions/constraints and damage material models (see for example [9–11]), the simulation of the explosive event itself (i.e., the detonation and the blast wave propagation) is not available.

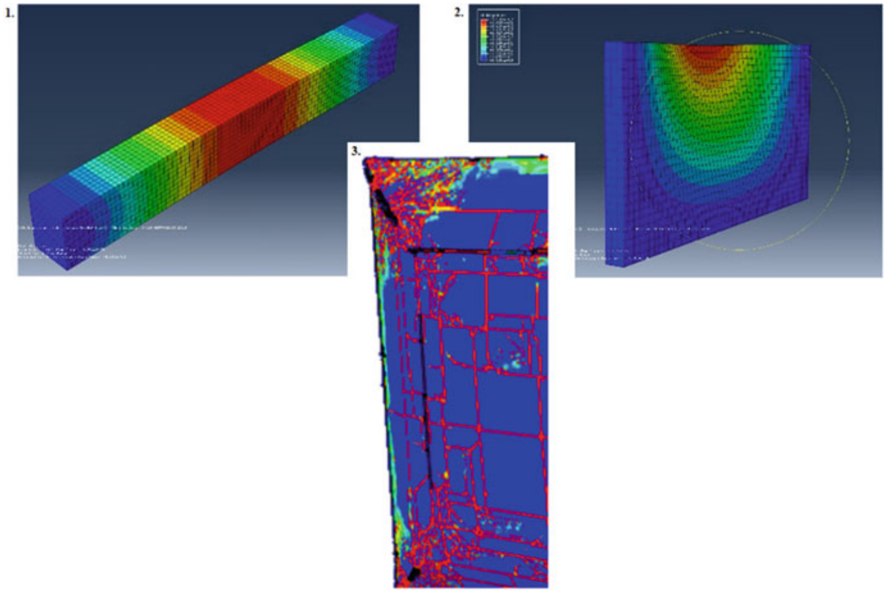

Fig. 14.4 Simulation of blast load

In Fig. 14.4, the effects of a given blast load at different time intervals are shown for several building components, such as: (1) A steel beam, (2) A concrete wall with steel reinforcement mesh, and (3) A tempered glass panel belonging to a curtain wall facade.

Of course, the process of building and loading the object takes a lot of time and several times more partial actions to finish the desired result (the simulation of blast load). The load results can be transferred as numeric data or charts into Excel and then work with them. The individual methods used in the blast wave simulation are described in the paper "Analysis of blast load steel beam" [10].

Another example of numerical simulation is reported in Fig. 14.5, in the form of selected results from AUTODYN, where the effects of a given blast wave on a concrete wall are presented. The concrete wall is anchored to the floor and its scaled distance from the charge is $Z = 1.0$ kg/m$^{1/3}$. In addition, the width of the wall is $b = 0.5$ m, $h = 0.5$ m is depth (wall stiffness $K = 5.14 \times 106$ N/m^2 and mass ratio = 20). The Eulerian mesh is used for air and for the explosive charge (TNT), while a Lagrangian mesh is used for concrete wall.

In Fig. 14.5, several phases of the blast wave propagation are shown, from the very beginning of the detonation, through the diffraction of the waves on the surface of the wall, until it is reformed behind the concrete wall [11].

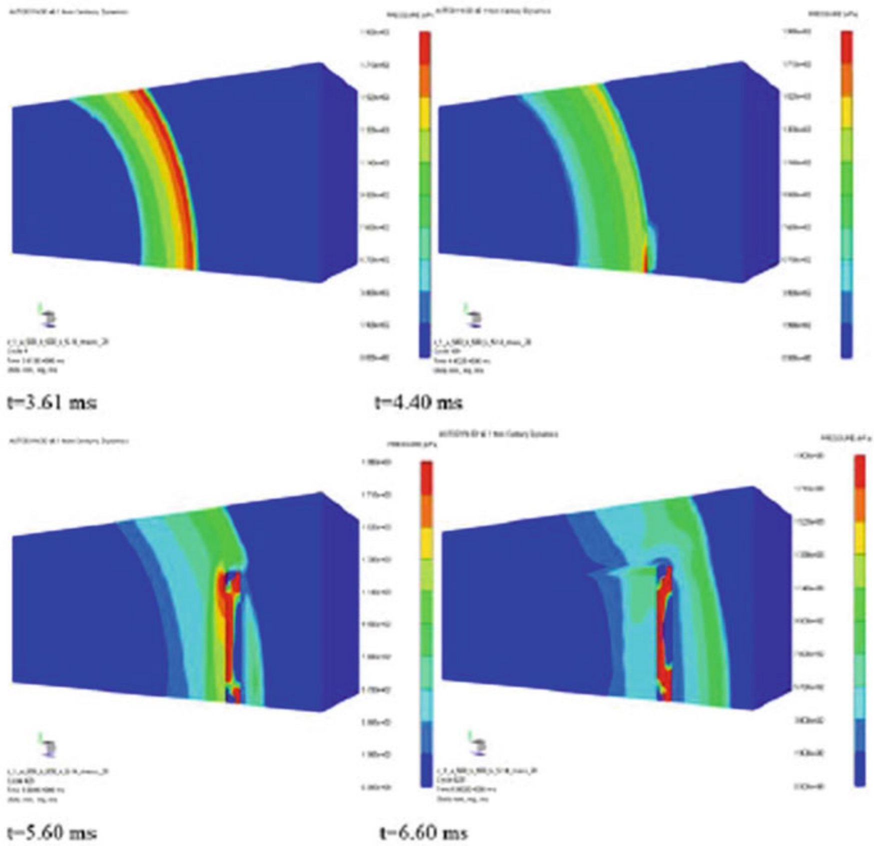

Fig. 14.5 Blast wave propagation on a concrete wall [12]

In Fig. 14.6, the reflected pressure and impulse at various points of the concrete wall can be observed, with evidence of selected time instants corresponding to (1) the front surface, (2) the base and (3) the back surface of the wall [11].

The results of changing the blast wave parameters in relation to the density of the mesh for different distances (R = 0.2 m, 0.3 m) can be represented in LS-DYNA by the finite element model as follows (Fig. 14.7):

At the same time, we can notice that when the mesh is refined, it is gaining a spherical shape even though the mesh is rectangular.

From Fig.14.8, it is also apparent that the coarse mesh models have maximum values along diagonals, while the minimum values are located along the axis [15].

For more numerical test see [16, 17].

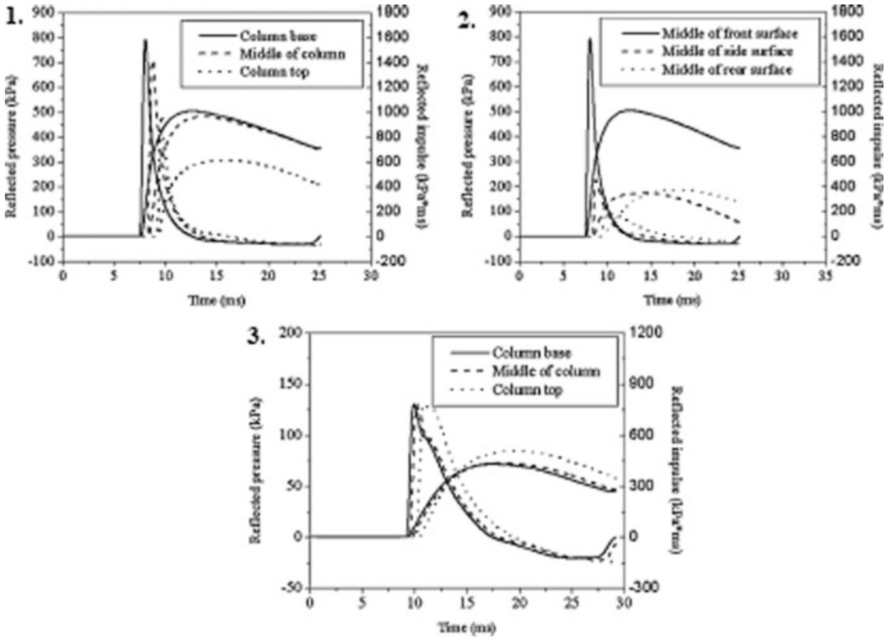

Fig. 14.6 Reflected pressure [13]

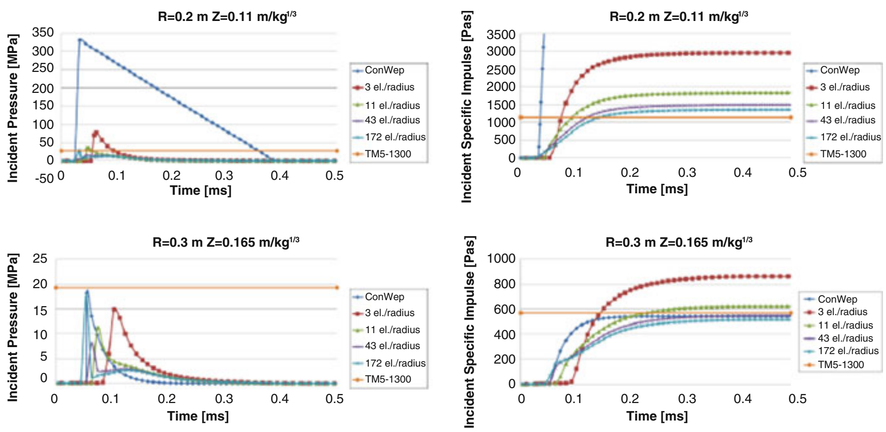

Fig. 14.7 Profile of blast wave in free air [14]

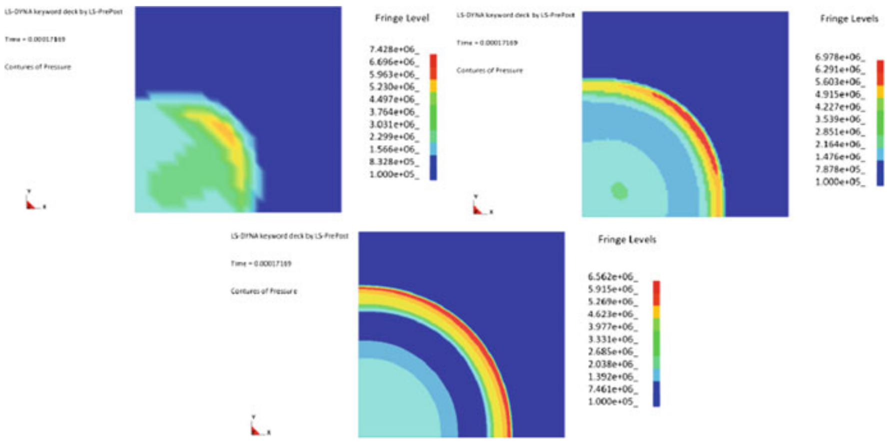

Fig. 14.8 Pressure contours for three different meshes [14]

14.6 Summary and Conclusions

In this paper, a concise overview and discussion of numerical approaches in use for the advanced analysis of structural materials, components and systems subjected to blast loads was presented. As shown, despite the many approaches exist and could be potentially used in the advanced numerical simulation of a given explosion and related effects on constructed facilities, the Finite Element Method (FEM) is largely used in most of the cases. Certainly, the accuracy and the time cost of calculations can be detected as the main reason for why many researchers choose the FE approach, in place of other possible methods. This is also the case of commercial software tools such as Abaqus, Ancys or LS-Dyna. Beside such a basic assumption, the importance of understanding the actual behaviour of building materials under the effects of an incoming blast pressure is the basis for understanding the consequences that may arise in such an extraordinary event, for the fulfilment of fail-safe design goals. The problem of assessing the potential risks that can greatly endanger the safety of people is further dealt with by prof. Loveček, et al. in [18, 19].

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Chapter 15
Assessment of the Evacuation Capacity of a Crowd, Including People with Disabilities

Mykola Khvorost and Karyna Danova

Abstract Vulnerability of population in the terrorist threat is the main idea of the article. Regardless of the threat source, the probability to rescue people of different ages, health conditions and other factors is different. The purpose of this study is to gather information, based to make managerial decisions in optimization of the protective measures for buildings, which can be referred to "soft targets". The goal of optimization is to provide maximum opportunities for rescuing people with different evacuation capacity, taking into account the characteristics of individual groups. This will improve the level of safety of people's staying in public premises.

Keywords Soft targets · Evacuation route · Persons with disabilities

15.1 Introduction

The role of terrorism, as a social phenomenon, has reached frightening levels at present. Terrorist attacks are aimed at undermining civism and violating the basic right of everyone – the right to safety. The urgency of the issue of the population protection from terrorist attacks is increasing day by day. The number of victims in civilian population is estimated in the thousands. The main focus of terrorists, regardless of motives in committing a terrorist act, is focused on causing maximum harm to civilian population, as well as material damage. The ultimate goal of any terrorist attack is to cause moral damage to the world community by causing human and material damage, demonstration of strength and desire for achieving the goal.

In these situations, the most important issue, is saving life and health of people who appear in the zone of terrorist attack, by preventing the perpetration of terrorist acts, reducing the influence on people in case that a terrorist attack has already been committed.

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L. Hofreiter et al. (eds.), *Soft Target Protection*, NATO Science for Peace and Security Series C: Environmental Security,
https://doi.org/10.1007/978-94-024-1755-5_15

15.2 Vulnerability of Soft Targets in the Context of Terrorism

Soft targets are the main vector of terrorist attacks direction. The more defenseless and numerous the victims of terrorists are, the greater response this terrorist attack will have in the media. At the same time, terrorist organizations that committed the attack, or an individual terrorist, will consider that their goal has been achieved.

According to the statistics [1], 61 people were killed as a result of terrorist attacks in the EU countries in 2017. Among the series of terrible events that led to the death of people, there were automobile-pedestrian accidents who were peacefully walking along the street, stabbings to death, an explosion in the stadium during a football match, shooting and other organized terrorist acts.

According to the statistics from 2016, the average level of the Global Terrorism Index (GTI) in the European Union countries was: GTI EU-28 = 1.816 (GTI_{max} = 5.964 (France); GTI_{min} = 0 (Latvia, Lithuania, Romania, Portugal, Slovenia) [2].

In Ukraine, terrorist attacks that take place in the context of an armed conflict in the east of the country are estimated by the global terrorism index GTI = 6.557, which is a high indicator, that can be compared with, for example, Sudan (GTI = 6.453) [2]. At the same time, civilian population and soft targets of the eastern region are currently under constant threat of committing terrorist acts.

Analysis of the features of terrorist attacks, both in Europe and in Ukraine, shows that only 6% of all attacks were directed exclusively at infrastructure facilities. The remaining 94% are aimed at the maximum possible damage to people [2].

In last ten years, the number of single terrorist attacks has increased [2]. In general, the consequences of a single terrorist attack are more destructive, because they entail a greater number of victims: on average, one single terrorist attack kills 7 people; while in the case of a group terrorist attack 3 people die [3]. However, it is much harder to prevent this type of a terrorist assault, because a single terrorist can easily get into premises with a large number of people, bypassing security obstacles.

The complexity of protection of soft targets from a terrorist threat is determined by a number of factors, among which we can define the most significant ones [4]:

- the factor of suddenness, difficulty in forecasting;
- security personnel could be unprepared for a serious terrorist attack;
- lack or absence of information on the nature of the threat during the initial period stage;
- large crowds of people;
- lack of special training of stuff;
- diversity within a vulnerable group;
- lack of collective and individual protection equipment;
- Lack of management of the situation.

In these conditions, the use of preventive measures aimed at protecting people from secondary harmful factors, and contributed to effective evacuation is the main way to reduce the number of victims among civilian population.

15.3 Role of the Evacuation Capacity in Assessment the Escape Time

15.3.1 Analysis of a Group of Factors Influencing the Outcome of a Terrorist Attack

The wide variety of objects that relate to the category of soft targets, and diversity of reasons that complicate their safety, leads to the understanding of the importance of solving the issue of ensuring safety.

When a terrorist act is committed at an assets of soft targets, the outcome of an attack for a person who appears in a danger zone depends on the combination of the following factors

$$C = \{A_s, L, S, E_c\} \tag{15.1}$$

where A_s is the total number of characteristics reflecting the peculiarity of the terrorist threat, such as: the type of weapon used to commit a terrorist attack (explosive, toxic or biological substance); defeating capacity, etc.;

L is the total number of factors allowing to localize and disarm a terrorist promptly, it is stipulated by efficiency and operational speed of the rapid response services, and by the means of preventive protection of the soft target;

S is the characteristics of evacuation routes that include: spatial parameters of evacuation routes (length, width, height of evacuation passageways, fire endurance of bearing structures and others);

E_C is the total number of characteristics reflecting the peculiarities of a people crowd who carries out the evacuation in the case of a terrorist attack.

The evacuation capacity E_c characterizes the ability of a person located in a dangerous zone to leave it or to reach a safe shelter in this zone within the allowed time T_a. This index is determined by two main groups of factors: a group of psychological factors A_m, which includes the ability to find the orientation in space, identify the danger, etc.; group of physical factors A_p: physical state, which allows to move at a certain speed in a safe direction; endurance of a person, etc.

$$E_c = \{A_m, A_p\} \tag{15.2}$$

The evacuation capacity is an indicator characterizing the ability of a person to perform actions effectively that are aimed at saving life and health in case of a terrorist attack.

By the evacuation capacity criterion, soft targets can be classified as follows:

- type 1 – soft targets with the greater number of elderly and disabled people (medical institutions, hospices, rehabilitation centers),
- type 2 – soft targets with the greater number of children (schools, child entertainment centers, children's hospitals),
- type 3 – soft targets of mixed type, that includes people who may happen to be present in the defeating area and which is difficult to predict (hotels, public transport).

The issue of ensuring the evacuation of diverse group of people should be resolved in different ways, taking into account the characteristics of each group of people that prevails at a particular assets of a soft target.

15.3.2 Evacuation Capacity as a Method of Determining the Design Parameters of Evacuation Routes

The allowed escape time is the one of the important safety parameter which is determined by the duration and scope of defeating factors of a terrorist attack, the presence and characteristics of the emerging secondary attacking factors and other factors.

The existing methods of estimating the time within which people can be evacuated from dangerous premises basically take into account the following aspects: location and number of evacuation exits, estimation of the shortest distance to the evacuation exit, determination of the optimal route based on mathematical models [5–8]; use of special technical solutions to decrease the time of evacuation [9]; architectural features of buildings and structures affecting the evacuation time [10, 11]; analysis of the features in behavior of people in a stressful situation in the context of the decision-making about evacuation [11–15].

Most of the methods for calculating the optimal evacuation route are focused on the graphic-analytical part of the problem solution and do not personalize the person who needs to be evacuated. At the same time, people who are in assets of soft targets, in most cases, have different characteristics, greatly affect the efficiency of evacuation measures [16]. Basically, the results that can be used to assess the evacuation capacity, obtained either using mathematical models or any volunteers who represent a homogeneous group of people who are often employees at the premises where dangerous situation is simulated. Therefore, these results are difficult to project onto the real situation.

There are some difficulties in predicting human behavior as representatives of individual groups (including persons with disabilities) and it is also hard to foresee human behavior in crowded public areas. Behavioral psychology of people in an extreme situation is studied by many scientists, but it is quite difficult to collect the experimental base. Some researchers, for example [14], use the respondents' questionnaire method regarding their behavior strategy in an extreme situation, but since this survey was conducted under normal conditions in the absence of a real threat, it is incomprehensible whether they can be used to predict real situations [17]. Controlled experiments [15] are more informative, but in most cases, they are focused on the behavior of a homogeneous group (for example, students aged 18–24), and also draw analogies with the behavior of humans and mice, ants [18].

The evacuation capacity assessment should take into account the fact that people who are in the dangerous zone may have disabilities in the following areas:

- restrictions of movement;
- restrictions of vision;
- restrictions of hearing;
- mental restrictions.

Accordingly, their evacuation capacity will be different.

To research the evacuation capacity, an expert evaluation technique was applied in the article. The group of respondents contained experts in civil safety issues, as well as doctors, whose sphere of activity includes issues relating to determining the functional state of people with disabilities. The respondents were interviewed in order to obtain graded assessment of the abilities of certain groups of people who could potentially be at objects of soft targets to implement certain evacuation stages. For these purposes, groups were formed according to the form of the basic disability and age. For comparison, as an etalon, an adult without any disabilities was selected. The expert assessment did not take into account aspects of psycho-physiological interaction between individuals and groups of people, since the purpose of the expert evaluation was to study the ability of an individual person, as a representative of a certain group, to carry out mental and physical activity to save the life in case of a terrorist attack.

The basis for developing the score scale is the principle of the equivalence of mental and physical abilities to implement the evacuation capacity.

The preparation period, during which the psychological abilities of a person are involved, is divided into 3 stages:

- D_1 – threat identification;
- D_2 – decision making as for evacuation;
- C – selection of the route of evacuation.

Assessment of physical ability to follow the chosen route and pass it effectively is estimated by

- V – ability to reach the sufficient speed of movement;
- S – ability to withstand the pressures;
- O – ability to overcome obstacles that may occur on the way of evacuation.

The score scale is based on the following principle: 3 points – the implementation of the concerned evacuation stage can be carried out effectively, 2 points – the implementation of the concerned evacuation stage is possible under certain conditions; 1 point – the implementation of the concerned evacuation stage is hampered.

The value of the evacuation capacity can serve as a tool for calculating the time of evacuation of people in the event of a terrorist threat in the presence of the average statistical characteristics of the preparatory period and the speeds of movement along evacuation routes.

In general, at the realization of terrorist threat, the total evacuation time can be represented as the sum of certain time periods during which the person's mental and physical abilities are involved:

$$T_e = T_{d1} + T_{d2} + T_c + T_{e1} \leq T_a \tag{15.3}$$

where T_{d1} – time period during which a person who happen to appear is in the zone of terrorist threat realization understands the fact of its committing and identifies it on the basis of the available information;

T_{d2} – time period during which a person makes a decision about the necessity for evacuation from the dangerous zone;

T_c– time period during which a person determines the direction of evacuation and chooses an evacuation route;

T_{e1} – time period when a person follows the chosen route to evacuate from the zone of a terrorist act. This time can also be represented as the sum of the time periods ti on each element of the evacuation route, including movement directly in the premises where the terrorist act was committed, passage time of doorways, staircases, etc., i.e.

$$T_{e1} = \sum_{i=1}^{n} t_i \tag{15.4}$$

The duration of the time intervals that form the preparation period T_p

$$T_p = T_{d1} + T_{d2} + T_c \tag{15.5}$$

can be 25-47 seconds [19], however, this indicator can have essential distinction for various groups of people who may happen to be in assets of soft targets. The period of identification of the threat will be longer for people who are under the influence of stress, alcohol intoxication, medical drugs, children or people with mental disabilities. These categories of people can make a wrong decision regarding to the threat nature, which can lead to the development of an incorrect evacuation strategy in the future. In view of this, these categories of people mostly cannot effectively implement their evacuation capacity at the beginning of evacuation.

It should be noted that analyzing the behavioral strategies of people under conditions of an unexpected threat, it is possible to presume the reaction to a dangerous situation with a certain degree of probability. For example, it is defined [12] that elderly people make a decision about evacuation 0.6 times faster than young people. However, it is obvious that the average speed of movement along the evacuation route of the elderly will be lower compared to the young people.

The decision making as for the necessity for evacuation depends on the degree of personal threat. At the same time, certain categories of people, due to their psycho-physiological characteristics, tend to underestimate the threat, which can lead to fatal consequences. Often the correctness of the decision making to evacuate depends on the degree of uncertainty: the greater the degree of uncertainty is, the more likely it is to make the wrong decision regarding to the necessity for evacuation and the route.

The speed with a person in a dangerous situation moves to the exit, for different evacuation groups, may differ significantly. The estimated speed of movement of people following the evacuation route, according to various sources, is in the range of 0.5–1.4 m/s [19–21]. The real significance for representatives of different groups can have a wider range, which makes it much more difficult to presume the consequences of a terrorist attack. Therefore, the indicator of the evacuation potential can be used to model the evacuation process of various groups of people who are at soft targets facilities.

The evacuation capacity of an etalon person could be estimated as

$$E_{c\,\max} = A_{m_{\max}} + A_{p_{\max}} \tag{15.6}$$

Taking this into account, the duration of the preparation period T_p, considering the value of the evacuation capacity j of the group A_{m_j} and the average time indicator, can be written as follows

$$T_{pj} = \frac{\left(2A_{m_{\max}} - A_{m_j}\right) \cdot \bar{t}_{mj}}{A_{m_{\max}}} \tag{15.7}$$

Similarly, the calculation can be carried out for a period of direct movement along the evacuation route T_{e1}.

As an example of implementation of this approach, we would determine the time for evacuation of representatives of different groups for the first rectilinear section of the evacuation route 10 m long. The average time of the preparation period for the basic variant $\bar{t}_{m_j} = 36$ s [19] and the average speed of movement $\bar{v} = 0.95$ m/s [20] were selected. In this case, the evacuation time of the reference variant for the first section of the evacuation route will be 10.5 s. Using the values of the evacuation capacity and the time parameters obtained in [12, 19–21], it is possible to calculate the evacuation time for representatives of groups with different evacuation capacity (Table 15.1).

The obtained results, based on the assessment of the evacuation capacity of different groups of people, are concordant to other studies proving that they can be used to determine the design parameters of evacuation time.

Further evacuation time for other sections of the evacuation route can be determined similarly by the formulas (15.3, 15.4, 15.5, 15.6, and 15.7). For sections of the route with various obstacles, the evacuation time can be calculated taking into account the characteristics of the density of the stream of people in the crowded public areas.

Table 15.1 The estimation of the evacuation time taking into account the evacuation capacity

Group	Duration of the preparatory period, s	Duration of the movement on the evacuation section, s	Total evacuation time for the initial section, s
Basic type	36	11	47
Restrictions of vision	52	16	68
Restrictions of hearing	40	11	51
Mental restrictions	60	12	72
Restrictions of movement	40	18	58
Elderly people	36	14	50
Children	52	13	65
Average value	**45**	**13**	**58**

The advantage of the methodology under consideration is the flexibility of the application and the ability to detail the factors that form the evacuation capacity of people, depending on the research objectives. Clarifying the data characterizing the components of the evacuation capacity can increase the accuracy of the results.

15.4 Algorithm for Implementing Preventive Safety for Increasing the Level of Evacuation Capacity

Ensuring the safety of people in the premises and at the territory of soft targets is realized by a complex of organizational and technical measures and means [22] aimed both at increasing the awareness of people considering their disabilities, and at using preventive constructive decisions at the design stage or in the formed space. For increasing the protection level in assets of soft targets, it is essential not to reduce the level of accessibility of safety measures, especially for people with disabilities. Maximum use of the evacuation capacity of the crowd, achieved by a set of preventive safety measures, allows people to carry out effective evacuation from dangerous areas or to reach safety zones following the specific route. This can not only reduce the number of victims, but also simplify the work of specialized anti-terrorist units.

The optimal evacuation route should be determined taking into account the evacuation capacity of each group. Moreover, information about the reasonable route should be provided in an accessible form for understanding. Also, it is necessary to take into account the effect of secondary harmful factors formed after activation of an explosive device or realization of another type of terrorist threat: for example, smoke, fire, fragments of broken glass and other objects. Also it is important to provide the information designation of the evacuation route for different group of people with disabilities that must be duplicated by another source: visual information must be duplicated by sound, etc. It is also possible to use blinking colored light sources or dynamic information screens [23]. The protection of soft targets, in which there are many children (type 2), should be focused on children's perception and take into account the peculiarity of the child's perception.

For people who a priori have low evacuation capacity (people in wheelchair, overweight people, etc.) it is necessary to create safe areas, because during the process of evacuation, they cannot just be effectively evacuated, in addition they could create additional obstacles for other participants of the evacuation process, which can lead to an increase of the number of victims.

The creation of safe zones is carried out within the framework of preventive protection by using architectural and construction methods.

The algorithm for protecting people relevant to soft targets, takes into account the evacuation capacity of groups of people, is shown in (see Fig. 15.1).

Information screens about the evacuation routes can be placed at the entrance and the information there must be encoded. The main emphasis should be put on creating identification marks that allow people with different evacuation capacity to move quickly and make a decision for choosing the best evacuation route. For example, each group of people can be assigned a certain color: the elderly – green, children – orange, people in wheelchair – blue, etc. In the future, the optimal evacuation route, calculated considering the characteristics of each category, should be indicated by the color defined for each category of people.

Providing people with information on a timely manner about a terrorist attack in an accessible form will reduce the degree of uncertainty, increase the probability of a correct assessment of the situation and making adequate decisions to rescue their lives. However, we should take into account the fact that information can lead to panic among people, which can reduce the evacuation capacity and increase the number of victims due to irrational behavior.

15.5 Conclusions

Assessment of the evacuation capacity of people of soft targets is a difficult issue due to the lack of a statistically reliable experimental base on the matter. However, the study of this issue is extremely important, since the probability of terrorist attacks at objects of soft targets remains high.

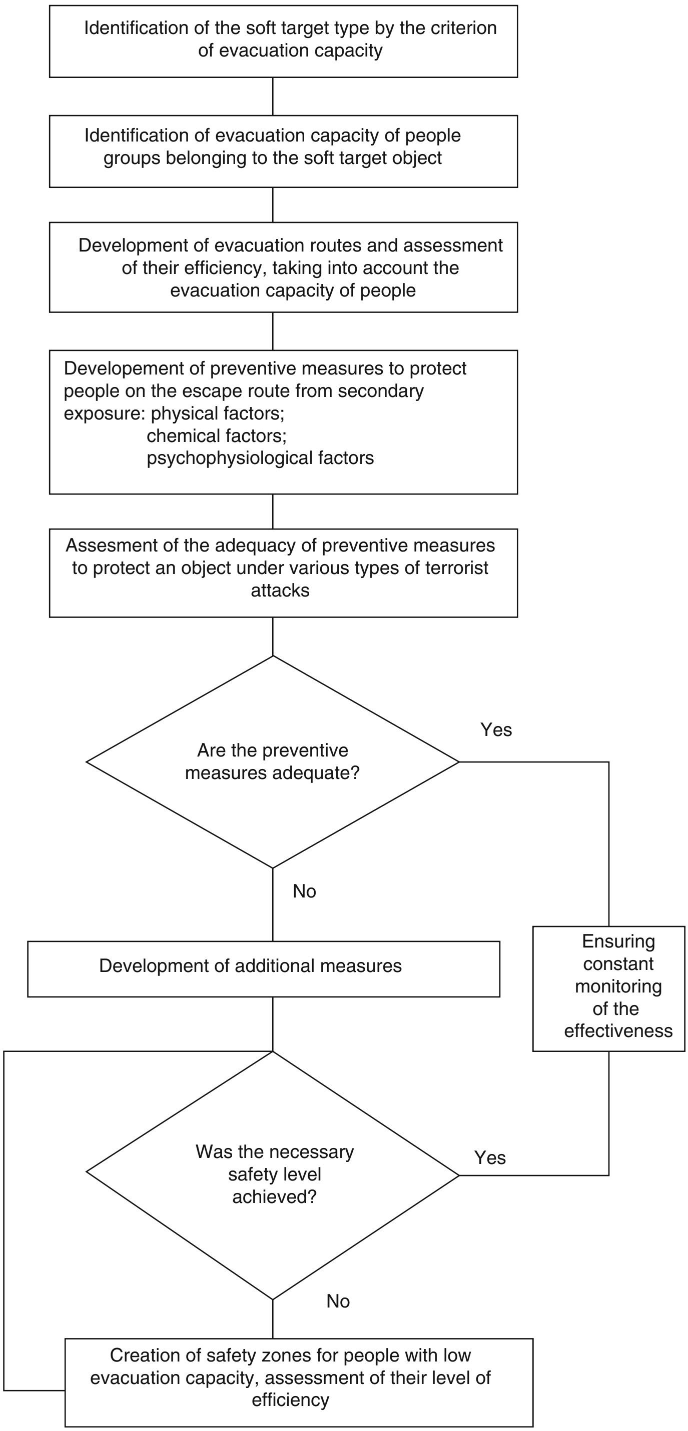

Fig. 15.1 The algorithm for developing preventive protection measures for people, taking into account evacuation capacity

Equally with measures to prevent terrorist acts, the issues of organizing the effective evacuation of people from a dangerous zone should be in the focus of continuative attention, both for owners of facilities and state structures responsible for the safety of citizens.

The article proposes the method for determining the evacuation capacity, taking into account various types of disabilities of people that may find themselves in a dangerous zone. Using the indicator of evacuation capacity, it is possible to generate a calculation model for assessment the parameters of evacuation routes in order to determine the priority directions for ensuring the protection of people in case of a terrorist attack at objects of soft targets.

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Chapter 16
Designing Principles for High Energy Absorbing Materials

Tünde Anna Kovács and Zoltán Nyikes

Abstract The focus target of our century and even of all centuries in the history is the security. Every state wants to guard their own functionality and citizens. The treasure of the nations are firstly peoples (soft target) and after all, buildings and assets.

The construction engineering used the traditional materials and designing a long time ago. In our century, the useful materials are changed and the building operations technologies are developed and changed. Great example is the new idea of 3D printed houses. In case of the new buildings many special loads have to be considered (earthquake, blast load, flood, etc.), and also this knowledge has to be taken into account in design of buildings, and there is a need to use resistant materials for such loads. Lot of innovated materials (metal foams, special composites) have appeared in the last decade. Polymer composites with new segments, like the reinforcing fibers (glass fiber, carbon fiber, aramid fiber) and the special property acrylates can be used. The functional innovation for special loads and high energy absorbing is supported on the basic theories of the designing principles by material selection and the combination with their realisation. The base of this innovation is the knowledge of the design principles of the requirements of these loads.

This work it can try to introduce the designing principles and the designing for high-energy absorbing materials what can be the base of the material science innovations.

Keywords High energy absorbing · Composite designing · Blast protection

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L. Hofreiter et al. (eds.), *Soft Target Protection*, NATO Science for Peace and Security Series C: Environmental Security,
https://doi.org/10.1007/978-94-024-1755-5_16

16.1 Introduction

The use of explosives worldwide in terror campaigns has rekindled international interest in the blast research. The knowledge of the blast effects is important to protect people and the way to prevent or mitigate damage [1]. The modelling of the complex load of the explosion with mathematical models and computational methodologies are very difficult because of the wide variety of explosives and blasting types. It can find some antiterrorism standards and design guides in the US and Canada for buildings [2, 3]. The application of the protocol can be useful during the new buildings designing and can be also suitable in case of the reinforcing of the old buildings. In this article, we wanted to review the basic knowledge of buildings protection and to describe principles for the innovation of the useful high energy absorbing composite materials. The chapters of this article contain the short review of the blast load, the defence materials required properties and the innovation possibilities. The designing method is shown in Fig. 16.1, using Ashby model [4].

16.2 Stress Analysis

A first step of the new material design process is a stress analysis based on the understanding of blast load and the effect of the explosion (see Fig. 16.2.) [5, 6]. The air-blast establishes high-intensity pressures what is the reason on the exterior walls, windows, roof systems, floor system and columns damage [5]. The Fig. 16.3. shown the pressure impulse diagram for a single degree of freedom elastic system with an ideal blast wave [6].

The nascent pressure and the effect of the blasting depend on the distance between the wall and the explosion centre, the quantity of the explosive, the TNT equivalent of the explosive and the position of the explosion (air-blast, floor-blast, etc.).

The building coating can increase the blast resistance of the walls in case of lower damage level, lower quantity of explosive, lower TNT equivalent range of explosive or higher distance between the burst center and the attacked wall. The analysed dynamic load is a special complex load. In a few seconds the pressure increase, the gas volume expand quickly and cause positive and negative phase. The shock wave becomes negative, followed by a vacuum. The positive phase duration is much longer than the negative phase [7–9]. The Fig. 16.4. shows one type of the blast attack, the shock wave is almost hemispherical on this case [5].

The blast load is determinable by numerical techniques (Lagrangien, Eulerian, Euler-FCT, ALE, FEM) [10].

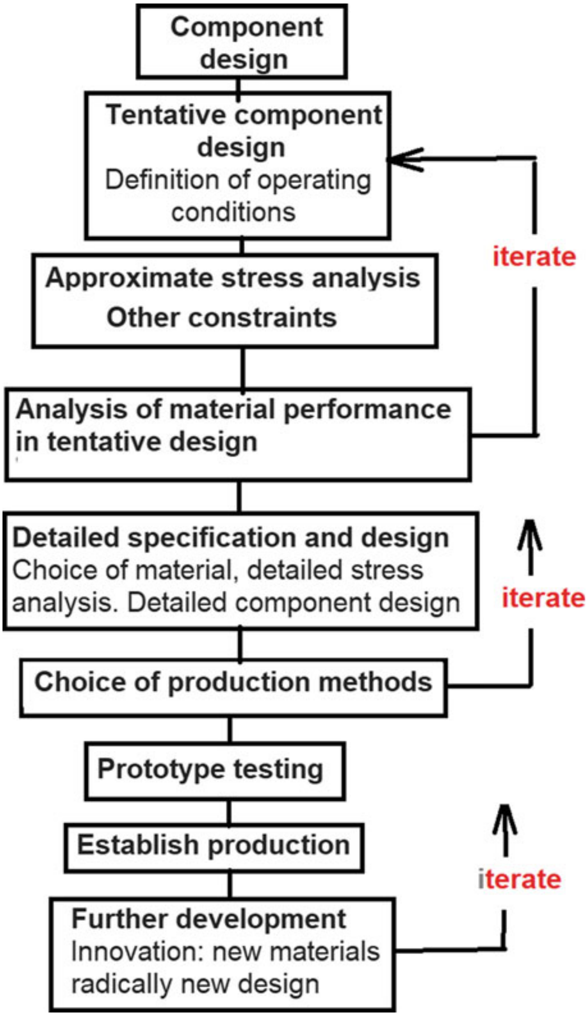

Fig. 16.1 Design methodology [4]

The theory is base of the determination of the rigid-body dynamics model (Brach 1991), has a serious limitation, needs to use a better approximation model like stress wave propagation in perfectly elastic media. The contact stress model base on Hertz theory (Johnson 1985) has been used to obtain a force-deformation relationship [12]. The elastic model can be extended to stress wave propagation in solids that are not perfectly elastic. By the way of modelling, it can use finite element methods (FEM). Some useful commercial software to determine the impact, like ABAQUS, LS-DYNA, [11, 12] etc.

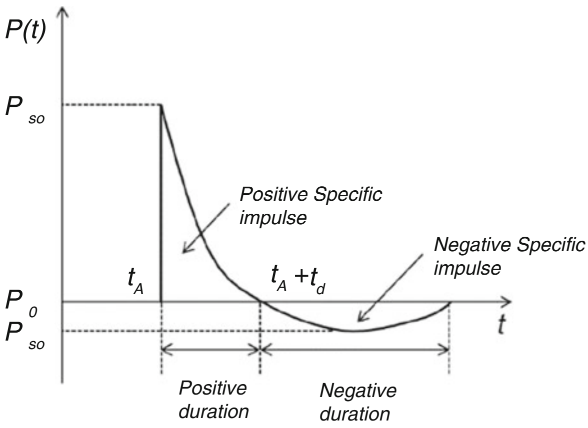

Fig. 16.2 Air-blast pressure time history [6]

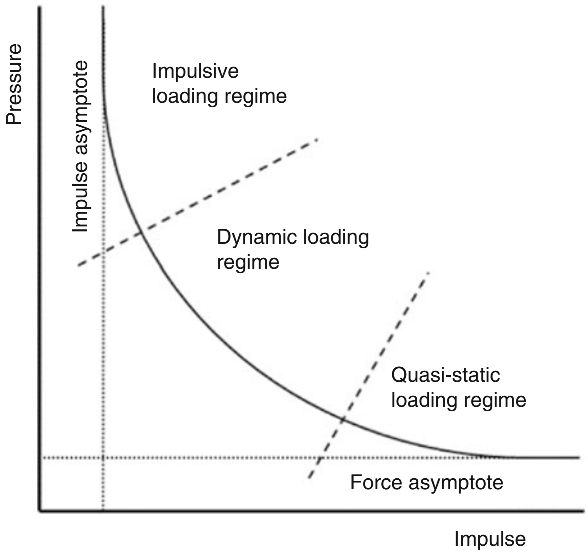

Fig. 16.3 Pressure impulse diagram [6]

16.3 High Energy Absorbing Materials

Materials show elastic-plastic behaviour under the load. Cellular materials have high energy-absorption characteristics (honeycomb, foams, woods, cellular textile, etc.) [11].

When a blast load is applied, the foam has to absorb more energy than the excessive energy input due to applying the cladding [13]. The next eq. (16.1) shows the energy input difference:

$$E_1 - E_2 \leq \sigma_{pl} \cdot A \cdot \Delta h \tag{16.1}$$

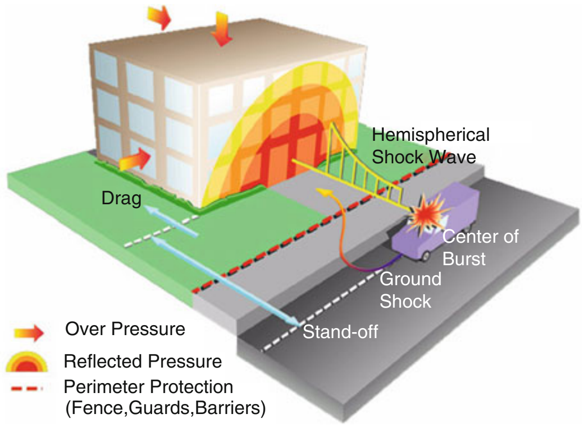

Fig. 16.4 One example of an explosion [5]

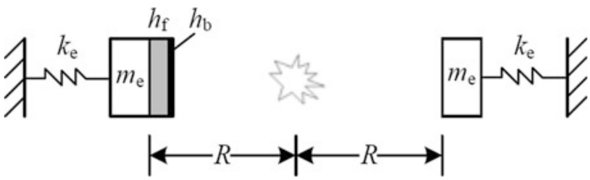

Fig. 16.5 Example for airburst: with and without foam cladding [13]

where E_1 and E_2 are energy input in situations with and without the lightweight cladding, respectively; A is an area of the structural member, fully covered by the foam cladding; Δh is the crushed distance of foam core; σ_{pl} is the plastic crushing stress limit of the foam [13]. In the Fig. 16.5. the foam layer of the sample shows effectiveness for blast mitigation.

On the base previous researches, it can conclude that the introduced structured materials have well energy absorption capability. Also, determinable that this structure energy absorption capability depends on the honeycomb or foam structure (isotropy, porosity, texture) in accordance with (Ashby et al.) [4].

16.4 Composites Design Principles for Blast Protection

On the base of the stress analysis [14, 15] can select material for the blast protective application. The base of designing is the knowledge of the material properties and the determined loads. It can find different FEM program to predict the blast load.

The composite materials compound mechanical and chemical properties, are well known. These data are the base of the designing. The plastic energy absorption capability of these materials is important. The useful materials are foams, fiber reinforced polymers and advanced composites.

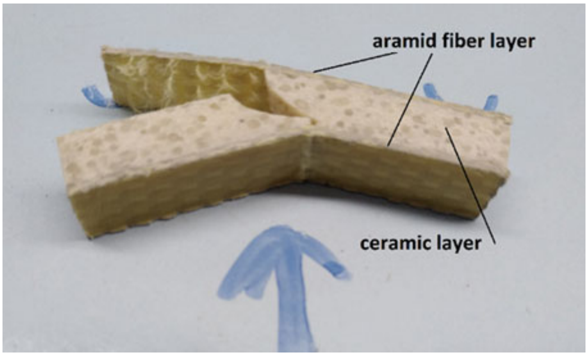

Fig. 16.6 Test sample composite after impact load

Fig. 16.7 Multilayer test sample composite after impact load [16]

The designed material needs to test by laboratory testing and analysed by numerical simulation. Simulation needs to create a model evaluated by the results of the laboratory testing.

On the base of our test result in accordance with the previous researches, we found a suitable way for blast protection material designing is the multilayer or sandwich structure materials. The Fig. 16.6. shows an aramid fiber layer adhesive joined by the ceramic layer. Under the impact test, the aramid showed good resistance and flexibility. Composite with ceramic showed high strengths. The Fig. 16.7. shows a multilayer composite - a composite reinforced by glass fibers and ceramic hollows. The ceramics hollows are hard but in this composite, shows a high energy absorption. The glass fibers task to increase the flexibility and the acrylic join all together. This special multilayer composite shows good resistance again impact load and this structure is a good example and basic experience of our research.

16.5 Conclusion

The results of the test are with the previous researches [4, 7, 10, 15, 16] showed that the bulk materials are not suitable for the blast protection, but the blast load designed composites materials (multilayer, sandwich, etc.) can unite numerous different mechanical, physical and chemical properties and can be suitable. We concluded that the multilayer composite showed better dynamic load resistance than the bulk materials.

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Chapter 17
Protection of Individuals as Soft Targets in North African and Arabian Countries

Vít Krajíček and Zuzana Kubíková

Abstract During the recent period, the negative trend of attacks against the so-called Soft Targets has begun to spread across the world. The Soft Targets are linked with violent crimes or terrorist attacks and are objects, areas in which are people or individuals whose security is not sufficiently. This dangerous situation forces us to constantly think about the possibilities of its correction, specifically about prevention of attacks and the direct protection of soft targets themselves. The aim of this article is to get acquainted about the protection (or even defence) of individuals in dangerous areas afflicted by terrorism or high crime rate and brings us closer to procedures and principles of ICESERVE24 as a provider of top-level personal protection services.

Keywords Soft target · Protection · Attacks

17.1 Introduction

With soft targets, many problems are currently associated, from the inability to create a single internationally valid definition to creation and the application of appropriate security systems [1]. In principle, however, soft target are people. Current security situation in North African and Middle East countries is very unstable.

Violent clashes (between the Tarhuna-based seventh Infantry Kani Brigade and the Salah Badi Somoud brigade) in Libyan capital, Tripoli, that broke out on August 27, resulted in 117 dead, more than 400 injured and over 25,000 displaced people. There is ongoing military operation in North Sinai in Egypt, almost every-days

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L. Hofreiter et al. (eds.), *Soft Target Protection*, NATO Science for Peace and Security Series C: Environmental Security,
https://doi.org/10.1007/978-94-024-1755-5_17

murders and stabbings in Jordan, Palestinian protests and Israeli shootings. Syrian civil war that started seven and half years ago in which more than 470,000 people were killed and approximately 7.6 million displaced. It means that people are trying to find ways to protect themselves during the stay in this areas. The best way how to take care in this situations is to hire a professional company that specializes in protecting people. One of the biggest and well-known company is ICESERVE24.

17.2 ICESERVE24

ICESERVE24, a private security company focusing on risk management, intelligence solutions, security services and mostly protection of individuals (as soft targets) in countries with challenging environment, with weak and undependable infrastructure, especially countries of the Middle East and North Africa. Company has three main operation centers, one on Cyprus, local 24/7 in Egypt in Cairo, global 24/7 in Slovakia and personnel spread around our countries of interest [2].

Company was founded specifically for the purpose of protection of people, which is very requested nowadays. People as soft targets are the most valuable and that is the reason, why they become a number one interest in terrorist's sight.

ICEWEEKLY & ICEMONTHLY solutions which can provide people with a framework of reference that allows for deeper insights in countries into a longer period of time. Data are compiled and reviewed by analysts and made into technical reports, forecasts, predictive reports between a week or a month-long period of time.

Analysts and researchers can also customize content per request to make sure that all client needs are met in the most efficient way. Dear Traveler Advisory provides important security and safety information for the traveler (client), regarding his country of interest's security situation. This document reminds all the standard procedures to be followed when visiting some countries and provides additional relevant information to consider when travelling to some particular country. For actual protection of clients, company uses trained personnel, professionals and modern sophisticated software technologies.

17.3 Applications Used for Help

After person will decide to buy services this company can provide him with, each new client is given the access to two special applications. First is the ICEALERTS that provides incident alerts reporting collected from a fusion of on-the-ground, local, news and social media sources. An alert feed to client's mobile phone with critical security emergency notifications. Through this alert platform, clients are able to view the risks within their own geographical location and assess potential threats within their own operating environment (Fig. 17.1).

Second is the ICETRACK, which is a web based integrated satellite and GSM tracking system, capable of real-time GPS tracking and two-way chat messaging.

Fig. 17.1 View on ICEALERTS mobile application

It is an app for iOS/Android smartphones and the client can track any asset on earth with it, whether people, vehicles, containers, or any moving objects. Company's operators are available 24/7and are monitoring all trackers at all time (Fig. 17.2).

17.4 Human Resources

It is very important to highlight the fact that this company does not employ bouncers or body guards but only security minded operatives; people who have a "controlled/ balanced ego, to anticipate threats and incidents. Most of the Close Protection

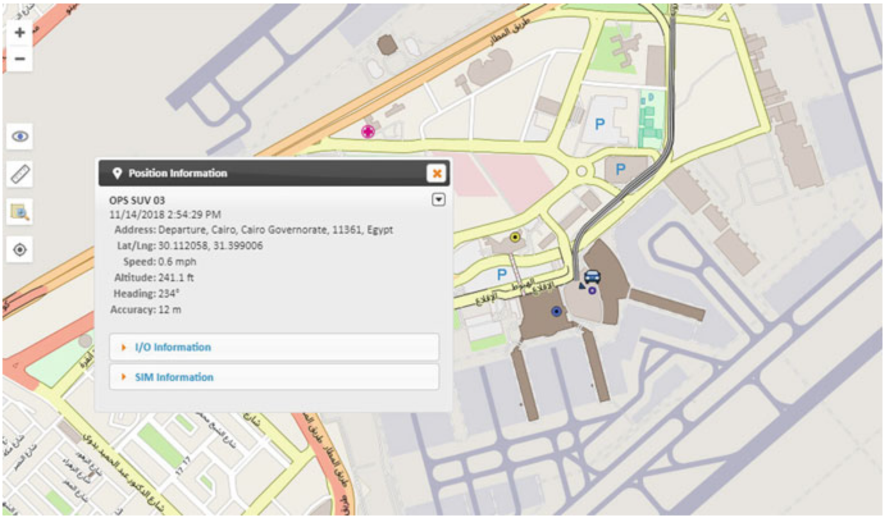

Fig. 17.2 ICETRACK viewed by operation centre officer on a client

Officers (CPO) have history in military forces, they served in Presidential Guard, Special Forces Detach, Government VVIP Units etc. It has no reason to hire people with big muscles to protect people against attackers when the most of attacks are taking place remotely. It is important to find people mentally on high level, able to think as potential invader, avoid dangerous situations and to conform their clients.

Team leaders in missions are multi bilingual, speak Swahili, English, Arabic, local Arabic dialects, fully conversant with the local environment, roads, tribes, conflict, human behaviors and customs in the areas to deal with any possible threat.

The main goals are anticipating a threat, an incident, road disruption and minimizing the impact of an adverse event that can directly or – most of the times – indirectly affect or cause harm, embarrassment to the client.

The aim is not just to protect the client "body on body". Company takes care also at securing the environment and detect any source of threat at the earliest opportunity possible. This is why the CPOs are just part of a larger sophisticated layered system of prevention/protection.

During the mission the Basic tactics on VIP protection by UN Peacekeeping PDT Standards for Formed Police Units, first edition 2015 must be followed. For example, during movement. The Foot formation – the choice of foot formation will depend on the threat, the number of officers assigned, and also the visual impact desired. Box- good all round defence, good visual impact but leads to gaps between officers. Diamond- will filter crowds around the client but can appear very aggressive V- will filter crowds around the client but widens the individual arcs of responsibility for officers. But Low Profile Formations is more requested as they draw less attention to the client.

17.4.1 In Case of Danger

The Close Protection Officers must analyze nature of the danger (fire arms, explosives, cold weapons etc.) and the direction where it is coming from. When the danger is announced, the protection team splits into two modules. The first module "Fixation module" is in charge to response to the threat by neutralizing the aggressor when necessary and if possible. The second module called "Evacuation module" is in charge of the extraction/evacuation of the client.

Mobile protection- during movements – Eliminate or reduce the opportunity for attack during movement by vehicle by using defensive skills and vehicle formations avoid any interaction with the attacker. High profile mobile protection operations-overt mobile protection operations with uniformed officers and marked vehicles provide high visibility presence intended to deter attack.

Low profile mobile protection operations- covert mobile protection operations by maintaining secrecy before the event and drawing the least attention to a movement in transit, mineralize the risk to the client.

There are only a few possibilities for static protection because most of clients are accommodated in luxury hotels with their own security.

17.5 Mission Planning

Before any mission can be started, ICESERVE24 will collect all necessary information about potential client.

Some of basic but needful rules:

1. Client must provide a service provider with all information such as – flight schedules, places to visit, time schedule, locations, accommodation;
2. After receiving all the necessary information, provider/company will evaluate the current security situation in location and will plan **the safest** routes for movements and check them together with locations, safe heavens if necessary. Provider will locate nearest police stations, hospitals, embassies etc. in case of emergency, etc.;
3. The team is chosen specifically for each mission – armed/unarmed CPO's, drivers, TL, resources as car, tracker;
4. Client will be provided with mission team information, icetrack and icealerts accounts if needed;
5. During the mission, team will provide information to an officer in SOC who will check it on tracker and constantly over watch movement of icetrack and compare it with information received from mission team. Then he will send updated information to client's contact person;

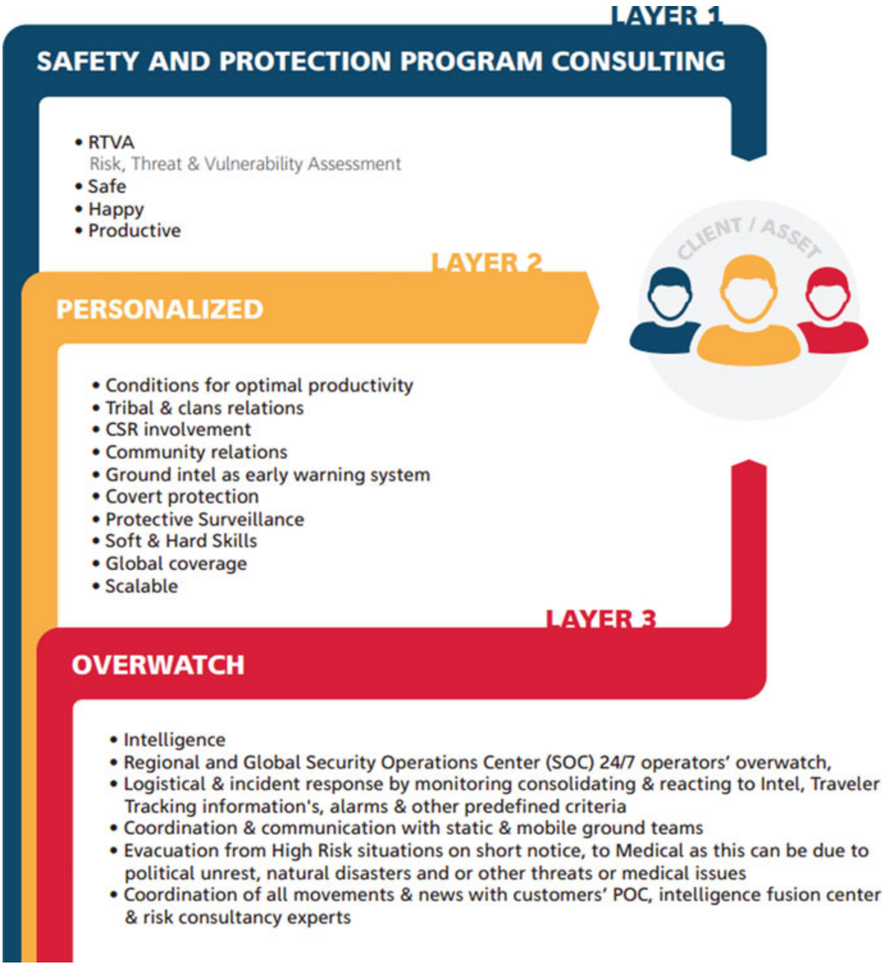

Fig. 17.3 Executive Journey Management at Al Thuraya holdings

The communication between on-the-ground team and GSOC must be clear and all time functional. That is the main reason why is used coded internet communication backed with radio and GSM communication and satellite phones. Coded because it is important to keep information classified, if potential attacker don't know where and when the client is located, he can't harm the client.

6. The mission will end after successful departure of client (Fig. 17.3).

17.6 Conclusion

Soft Targets. There are many perspectives we can see soft targets. Mostly, we can identify them as human lives or as assets, where people like to gather. But it is also not unusual to misconstrued their meaning. This issue can be find in [3]. Recently, one of the most popular way to attack soft targets is using explosives. More about the protection and studies of its effect on soft targets can be find in [4, 5]. Research conducted by Štoller and Zezulová in [6] is also focused on the use of the ultrasound method used for diagnostic of protective structures specifically under the blast load. In [7] the non-destructive testing method of quality control and the search for defects in composites, ultrasonic control system – Laser ultrasonic structuroscopy, is discussed in the context of examination of structural members of aerial vehicles. Laser ultrasonic testing is also discussed in [8]. Most of these researches are focused on protection of critical infrastructure, but as mentioned in [3], there is just small line between understanding of critical infrastructure and soft target as something different. Human life and objects as targets demand very different ways of their protection. If speaking of objects as buildings, various methodologies and alarm systems can be used. In [9] is e.g. defined the possibility of a more complex calculation of probability of detecting an intruder. Research conducted by Mózer and al. in [10] is dealing with fire safety and security measures and their mutual interaction, while Leitner and Figuli in [11] are dealing with fatigue life prediction of materials and structures.

As mentioned above, there are many approaches in the context of soft target protection. The main mission of this company is not to create a Hard Target out of so called Soft Targets by increasing their level of security system, but try to protect them on the most effective way. Company ICESERVE24 focuses its services especially on human protection and no objects as buildings, in areas when terrorist attacks and other violent crime increased dangerously during last few years. It is very important to spread information about companies like this and to get people know, that there is the ways to be and feel safer even though the security situation shows us otherwise.

The ICESERVE24 deliver progressive operational risk and threat assessments, robust due diligence capabilities, tailored travel threat assessments, alerts, and analytic publications specific to client's organization's needs and interests. When it comes to safety risk elimination the fusion of intelligence measures and actual physical protection of clients is necessary to maintain the highest standard of protection.

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Chapter 18
Experimental Analysis of Impact and Blast Resistance for Various Built Security Components

Leopold Kruszka and Ryszard Rekucki

Abstract This work is a review of selected own research in the field of resistance of selected built protective components for impacts by projectiles and air blast wave caused by the explosion of explosive material or air-fuel mixture. Background of those research were previously published (Kruszka and Rekucki, Appl Mech Mater 82:422–427, 2011; Kruszka and Rekucki, Resistance analysis of protective doors, windows and built wall to the effect of impact, blast loading and burglary. In: Proceedings of 7th international symposium on impact engineering, 4–7 July 2010. Military University of Technology, Warsaw, pp 421–445, 2010). Experimental bullet-proof investigation results of two types of steel protective doors under the comparative perforation tests using various projectiles shot from short and long typical fire-arms are presented here. The protective windows are tested under a soft impact of 30 kg mass and under an aerial shock wave due to the explosion of an explosive charge and a fuel-air mixture. The structural material of the door glazing, is Polish standard building steel, while the window leaves – Polish architectural protective glass of P4A class and duplex hardened glass.

Keywords Experimental testing · Blast · Impact · Protective doors and windows

18.1 Introduction

Currently, particularly after the terrorist attacks of September 11, 2001 in the USA, the interest of research centers around the world is growing in the problems of combating terrorism, crime and vandalism. One of undertaken directions is the development of experimental work broadly related to the protection of important buildings (banks, currency exchange bureaux), particularly of their supporting structures against terrorist-type actions [1–4], as well as of residential buildings.

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L. Hofreiter et al. (eds.), *Soft Target Protection*, NATO Science for Peace and Security Series C: Environmental Security,
https://doi.org/10.1007/978-94-024-1755-5_18

Elements of the building protection system include technical devices used in buildings to protect human life and health and to protect property, including confidential information. Among them we can mention the following:

1. Mechanical and construction measures providing a mechanical barrier which can be broken only with the use of force, leaving traces (also significant in the context of criminal investigation techniques). An important criterion is effective provided resistance. Mechanical barriers are primarily walls in combination with construction elements (doors, windows, ventilation, etc.) and mechanical devices (fixed and lowered steel bars, anti-burglary shutters, steel wire grids, locks, chains).
2. Electrical (electronic) alarm devices (anti-burglary and anti-robbery), which provide automatic signaling of attempts to break into or force entry to guarded premises. An important criterion of effectiveness here is the time between the signal and entry into the place of origin of the signal.
3. Fire alarm devices, serving to give a direct alert to persons in case of a fire hazard and/or to detect fire and give a suitable advance warning of it. They are also designed to protect people and property.
4. Devices for monitoring the outdoor areas around closed buildings. These are technical devices placed without protected space, usually within the boundaries of the site. They include mechanical and construction elements (fences, walls, barriers, gates, gatehouses, guardrooms, lighting), electronic detection devices (central security units, detectors, sensors, video/TV, entry control systems, transmission of information to higher units) and/or measures connected with related to staff and organization (personnel, observation, supervision, special groups, guard dogs, alarm action programs).

The optimal solution for securing buildings consists of mechanical and construction measures together with properly installed electronic alarm and control devices.

One of the most difficult tasks, the aspects of building security is to determine the degree of risk to particular premises and the amount that should to be spent on the work necessary to make them secure. This is the basis for analyzing the safety of "weak points" in a complex (a building) combined with calculation of costs and benefits. On the basis of the analysis the safety of buildings and premises, the most important task is to secure the door and window gaps [5]. Safety windows and doors are used as mechanical safety measures for these gaps.

This paper contains the research methodology and the results of an experimental analysis of the resistance of steel protective doors to impacts by various projectiles fired from typical short and long firearms, and of an aluminum protective window for cash desks to soft impact by a mass of 30 kg and the air shock wave produced by an explosion. The window pane was also subjected to a static force applied in the centre of the window. The structural material of the door leaves is construction steel, class A-0, type St0S, whereas the windows are made of anti-burglary building glass, class P4A. In order to properly design the protective construction elements, including evaluation of their impact resistance and to ensuring that the protective buildings are safe to use, the construction engineer must have knowledge in both, exterior and terminal ballistics. When calculating and checking structural protective elements of various types of building, including in particular shooting ranges (police and military), it is necessary to be familiar with certain formulae [6, 7]. It should be emphasized that the problem of penetration of the projectiles into a half-space or into a target has been widely analyzed for a long time, e.g. [8–11]. Numerical solutions to this problem can also be obtained by means of many commercial computer programs, e.g. AUTODYN 2D and 3D [12]. However, in order to obtain proper numerical and analytic solutions, particularly in the case of problems with projectile penetration, it is necessary to know the model and material parameters of the material used, and these can be obtained primarily through experimental analysis.

18.2 Tests of the Resistance of Steel Bullet-Proof Protection Doors

Testing of resistance to penetration by various projectiles fired from small-caliber firearms were carried out on the leaves of reinforced protective doors manufactured in Poland using St0S structural steel. These doors can be used in premises where goods of considerable value are stored, as well as in certain types of defensive structures. Currently, they are used as the basic element of mechanical protection in rooms of protected general and special buildings [13–17].

The doors were denoted with the codes “A” (steel plate doors for bank premises) and “B” (anti-burglary plate doors made of steel sheet, ribbed with shaped sections, for houses and other closed premises, e.g. currency exchange bureaux, cash desk counters, etc.). Penetration tests are among the basic strength tests aimed at determining the resistance of a material to perforation by pistol and rifle bullets. Problems relating to the resistance of structural building materials are not widely known, therefore materials related to experimental tests are not easily available [18]. It should be pointed out that perforation tests are of fundamental importance in criminal investigation techniques, in the investigation of criminal tracks [19].

18.2.1 Testing Methodology

The perforation tests were carried out on the experimental firing range belonging to the Central Forensic Laboratory of the Central Police Headquarters. During the tests the doors were fastened to a bullet trap, their frames being supported from behind on vertical wooden poles. On the front surface (the attack surface) of each door leaf, eight test sectors of the steel door were marked, numbered from I to VIII (see Fig. 18.1).

Three shots were fired into each sector, such so that the distance between impacts was not less than 15 cm. The shots were fired from a distance of 5 m in the case of short weapons and 10 m in the case of long weapons. On each occasion a measurement was taken of the bullet velocity v_k before striking the door. The experiments were performed according to the schedule in Table 18.1.

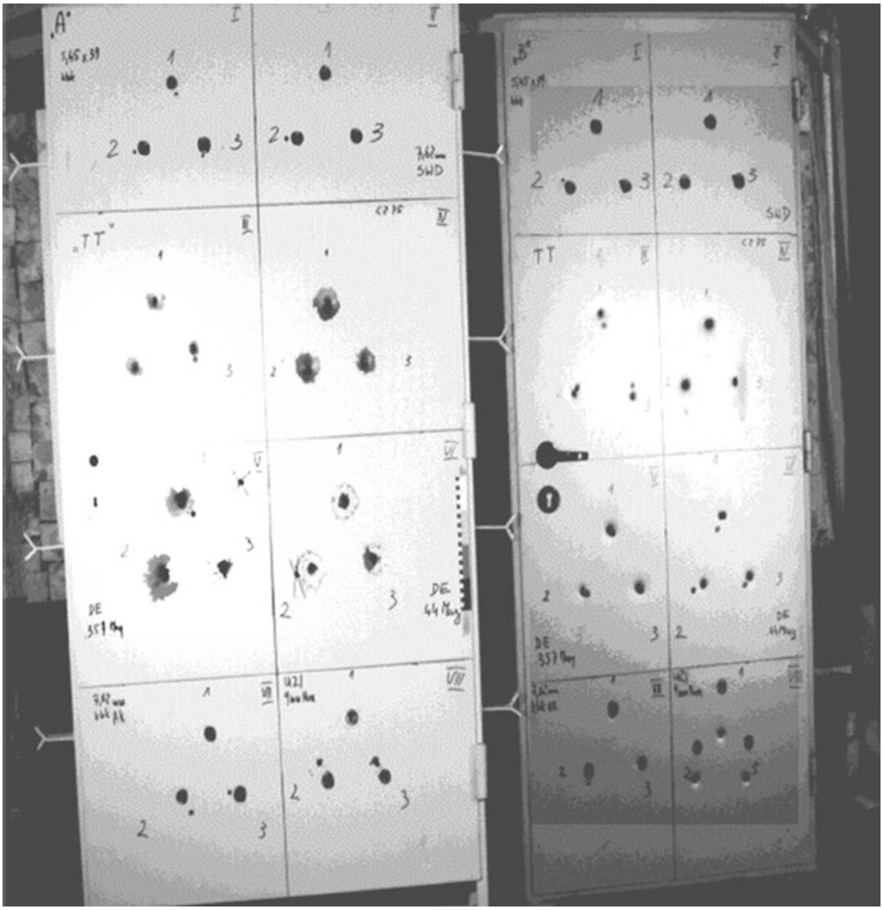

Fig. 18.1 Protective steel doors, type A (left) and B (right), following laboratory perforation tests

18.2.2 Results of Perforation Tests

To evaluate the perforation of the steel door, the following cases were considered:

1. a projectile passed through the back of the door;
2. a cracking of the back surface of the door caused by the projectile or part of it, even if the projectile was visibly detained at the back of the door;
3. a pass-through hole made in the door, even if the hole then has been closed by the projectile.

If none of these criteria applied, there was deemed to be no perforation. Sample results of perforation tests on type A protective doors are given in Tables 18.2 and 18.3.

Table 18.1 Schedule of perforation tests of protective doors

Sector no.	Weapon	Barrel length [mm]	Cartridge	Projectile
I	Kalashnikov AK 74 5.45 mm rifle	415	Medium cal. 5.45 × 39	FMJ 3.4 g
II	SWD cal. 7.62 mm sniper rifle	620	Rifle cal. 7.62 mm Mosin	FMJ 9.5 g
VII	Kalashnikov AK 47 7.62 mm rifle	415	Medium cal. 7.62 mm model 43	FMJ 7.9 g
IV	CZ 75 9 mm pistol	120	Pistol cal. 9 mm Luger	FMJ 8 g
V	0.357 Magnum Desert Eagle gun	161	Revolver cal. 0.357 Magnum	SJ 10.2 g
VI	0.44 Magnum Desert Eagle gun	161	Revolver cal. 0.44 Magnum	SJ 15.5 g
III	The TT-33 7.62 mm pistol	116	Pistol cal. 7.62 mm model 30	FMJ 5.5 g
VIII	UZI 9 mm machine pistol	260	Pistol cal. 9 mm Luger	FMJ 8 g

Table 18.2 Door type A test results – sheet metal thickness 3.0 mm

Sector no.	Shot no.	v_k [m/s]	$v_{k\ average}$ [m/s]	Impact energy E [J]	Puncture
Long weapon, fired from a distance of 10 m					
I	1	941.0	937.4	1494	**Yes**
	2	933.5			**Yes**
	3	937.7			**Yes**
II	1	846.6	846.3	3402	**Yes**
	2	854.1			**Yes**
	3	838.1			**Yes**
VII	1	718.4	715.1	2020	**Yes**
	2	711.3			**Yes**
	3	715.7			**Yes**
Short weapon, fired from a distance of 5 m					
IV	1	347.5	343.2	471	No
	2	339.1			No
	3	343.1			No
V	1	392.6	396.5	802	No
	2	389.2			No
	3	407.6			No
VI	1	446.7	446.3	1544	**Yes**
	2	445.8			**Yes**
	3	446.4			**Yes**
III	1	453.8	451.7	561	No
	2	447.4			No
	3	453.8			No
VIII	1	384.1	376.8	568	No
	2	372.5			No
	3	374.0			No

Table 18.3 Test results of type B doors – sheet metal thickness 2.5 mm

Sector no.	Shot no.	v_k [m/s]	$v_{k\ average}$ [m/s]	Impact energy E [J]	Puncture
Long weapon, fired from a distance of 10 m					
I	1	950.0	946.3	1522	**Yes**
	2	939.6			**Yes**
	3	949.3			**Yes**
II	1	843.8	864.8	3552	**Yes**
	2	881.6			**Yes**
	3	868.9			**Yes**
VII	1	706.1	710.8	1996	**Yes**
	2	717.6			**Yes**
	3	708.8			**Yes**
Short weapon, fired from a distance of 5 m					
IV	1	351.5	346.9	481	No
	2	346.0			No
	3	343.3			No
V	1	392.7	395.8	799	No
	2	396.5			**Yes**
	3	398.2			No
VI	1	456.2	449.4	1565	No
	2	445.5			**Yes**
	3	446.5			**Yes**
III	1	445.9	450.1	557	No
	2	444.1			**Yes**
	3	460.3			**Yes**
VIII	1	381.8	378.2	572	No
	2	378.6			No
	3	374.2			No

The perforation tests showed that the bullets from long weapons usually penetrate the steel structure of both types of door leaf. The type A reinforced steel doors have a slightly higher resistance to the projectiles fired from short weapons. The doors of that type were not penetrated by a bullet fired from the TT-33 pistol, UZI machine pistol, CZ model 75 pistol or 0.357 Magnum Desert Eagle gun.

The type B doors, on the other hand, were not penetrated by the bullets fired from the TT-33 pistol (every in three shots), UZI machine pistol, CZ model 75 pistol, 0.357 Magnum Desert Eagle gun (twice in three shots) or 0.44 Magnum Desert Eagle gun (every in three shots). When a long weapon was fired, a full perforation was recorded for both types of door.

The analysis of the data contained in Tables 18.2 and 18.3 shows that the perforation of the structure of the protective door leaves made of steel sheet (St0S structural steel) with a thickness of 2.5–3 mm requires impact energy E not less than approximately 1400 J depending on the caliber and shape of the bullet. In the case of SJ type bullets the energy required for perforation is about 10% higher than in the case of FMJ type. Noteworthy is the penetrability of a 2.5 mm thick plate by an FMJ 5.5 g bullet fired from the 7.62 mm TT-33 pistol from a distance of 5 m, when the kinetic energy of the impact is only about 560 J. However, the same bullet does not penetrate a 3 mm thick steel plate.

The average velocity of projectiles at the moment of impact with partition, vk average, when fired from a long weapon varied over the range 710–946 m/s. When a short weapon was used, the average impact velocity v_k was in the range 343–451 m/s.

18.3 Characteristics of Perforation Properties of Steel Door Leaves

The mechanism of destruction of the partition (door leaf) depends on the static and dynamic strength properties of the structural material, impact velocity of the bullet, shape of the bullet, method of fastening of the partition, and the dimensions of the bullet (caliber, length) and of the partition (thickness, length, width). Figure 18.2 shows certain types of perforations of thin and thick plates made of various structural materials [20]. In the tests of steel protective doors, the observed shot marks had a mechanism of destruction corresponding to the mechanism illustrated in Fig. 18.2f). A sample image of the shot marks obtained is shown in Fig. 18.3.

For determination of the depth of penetration of bullets in partitions made of various structural materials (steel, concrete, ceramic, reinforced concrete, earth, glass, etc.) a general terminal ballistic formula can be applied in the following form [21, 22]:

$$h_p = \left(\lambda_1\, \lambda_2\, k_p\, m\, v_k\, \cos\alpha\right)/d^2 \tag{18.1}$$

where:

λ_1 is the ogive coefficient,
λ_2 is the coefficient of influence of the caliber on the depth of penetration,
d is the bullet caliber [m],
m is the bullet mass [kg],
v_k is the bullet velocity at the moment of impact [m/s],
l_0 is the length of the ogive part of the bullet [m],
h_p is the depth of penetration [m],
k_p is a coefficient characterizing the strength properties of the material [m^2s/kg],
$\propto$ is the angle between the tangent to the path and the normal to the partition at the point of impact [°].

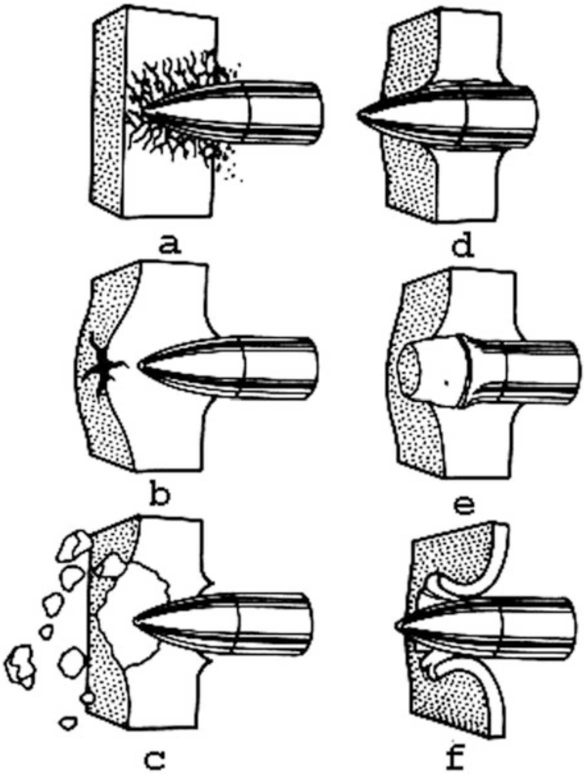

Fig. 18.2 Mechanism of puncture of various types of structural materials [18] **a** – brittle damage, **b** – puncture leaving radial cracks, **c** – spalling, **d** – plastic penetration, **e** – knocking out a cork, **f** – leaving a ductile crack

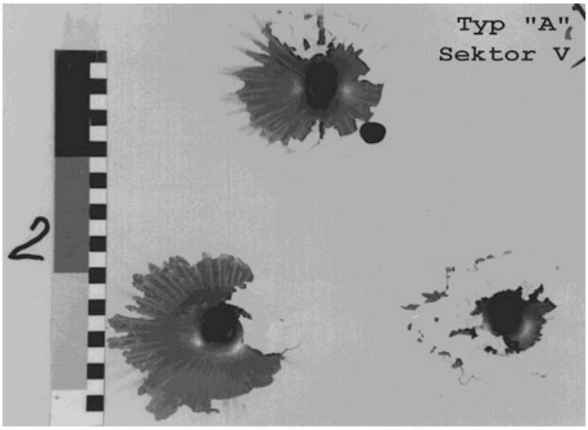

Fig. 18.3 Shot marks produced in sector V of an A type door

Coefficients that take into account the shape of bullet and ogive dimensions can be found according to the following formulae:

$$\lambda_1 = 0.5 + 0.4 \sqrt[3]{(l_0/d)} \tag{18.2}$$

$$\lambda_2 = 2.8 \sqrt[3]{d} - 1.3\sqrt{d} \tag{18.3}$$

Based on a series of experiments for evaluation of the required thicknesses of door plates made of certain types of structural materials based on assumed criteria of impact resistance, the formula given by de Marre can be used [21]:

$$m\, {v_k}^2/d^3 = \beta {h_p}^{1.4}/d^{1.5} \tag{18.4}$$

The constant β must be determined experimentally for a given type of structural material. Experiments have shown that the calculations based on formula (18.3) are more reliable for plates less than 25 mm thick.

In the tests of resistance to shots fired from the TT-33 caliber 7.62 mm pistol into the type B protective doors (Table 18.3, sector no. III) it can be in calculating the coefficient characterizing the strength properties of the material that the velocity of the bullet at exit was close to zero, since in one case out of three the bullet remained in the material in the final stage of penetration.

On that assumption, after the appropriate transformation of the formulae (18.1), we can calculate the value of the coefficient k_p characterizing the penetration properties of the structural plate of doors made from St0S steel. The following values were adopted for calculations based on Tables 18.2 and 18.3 and the conditions of tests performed on the doors: $d = 0.0762$ m, $m = 0.0055$ kg, $\lambda_1 = 0.708$, $\lambda_2 = 0.665$, $h_p = 0.0025$ m, $\alpha = 0°$, $v_k = 450.1$ m/s.

$$k_p = h_p\, d^2/(\lambda_1\, \lambda_2\, m\, v_k\, \cos\alpha) = 1.26 \cdot 10^{-7}\ \left[\mathrm{ms}^2/\mathrm{kg}\right] \tag{18.5}$$

The obtained value of the coefficient characterizing the perforation strength properties of St0S steel makes it possible, using Eqs. (18.1) or (18.4), to calculate the thickness of a steel door plate which will prevent their penetration by a given type of bullet fired from a weapon. For example, to prevent the door from being penetrated by a 7.62-mm projectile from the TT-33 pistol, the St0S steel plate must have a minimum thickness of 4.6 mm.

18.3.1 Empirical Evaluation of the Influence of the Shape of the Bullet Tip on the Depth of Penetration

The shape of the tip of the bullet has a strong effect on its ability to penetrate and perforate at speeds where the stresses produced within it are smaller than the

Table 18.4 Limit ballistic velocity [20]

Shape of bullet tip (caliber 6.35 mm)	Limit ballistic velocity [m/s]	
	Angle of impact	
	α = 0°	α = 60°
Hemisphere	875	1213
Cone	892	1262
Truncated cone	942	1273

dynamic yield of the material. The flatter the bullet tip, the higher the limit ballistic velocity. If the bullet strikes the partition with a speed at which the stresses within it exceed the dynamic yield of the material of which it is made, the shape of the tip has practically no effect on the value of the limit ballistic velocity. The confirmation of this, in Table 18.4 [20], results are given from tests of steel bullets with mass 14.6 g, diameter-to-length ratio 10, and Brinell hardness *HB* of 55.5 MPa. The bullet tips had the shapes of a hemisphere, cone, and truncated cone with a vertex angle of 40°. They were fired into steel plate with a thickness 12.7 mm and Brinell hardness *HB* of 38 MPa. The bullet struck the partition at angles of $\alpha = 0°$ and 60°.

The maximum velocity required to penetrate the tested steel plate was obtained for the bullets with a truncated cone shape, striking at angles of $\alpha = 0°$ and 60°. This velocity exceeds the minimum limit ballistic velocity obtained for the bullets with hemispherical tips by an average of 6.5%. Thus, based on the above empirical evaluation, in testing of the penetration resistance of protective steel doors, the influence of the shape of the bullet tip was not taken into account.

18.4 Testing Impact Resistance of the Structure on an Aluminum Protective Window

The structure of a cash desk window consisted of an aluminum frame and, within it, a three-part pane made of class P4A glass [24]. The middle (inner) pane is placed 30 mm into the interior of the structure and is connected to the edges of the other two extreme (outer) panes via six screwed steel distance sleeves. The height of the outer panes is 105 cm, and their width is 65 cm. The inner pane has a width of 50 cm and a height of 93 cm. The distance between the sleeves is 40 cm horizontally and 35.5 cm vertically. The depth to which the panes were set into the frame, in the case of those supplied for the tests, was 24 ± 2 mm. The structure of the cash desk window placed on a testing stand is shown in Fig. 18.4.

The structure of the cash desk protective window was fastened during the tests in a rigid frame on the testing stand, such thanks to which the conditions of fastening were similar to that occur when the window is in use. The tests were carried out in similar conditions to those in which the window would be used, i.e. at a temperature of 20 ± 20 °C and a relative humidity 50 ± 10%.

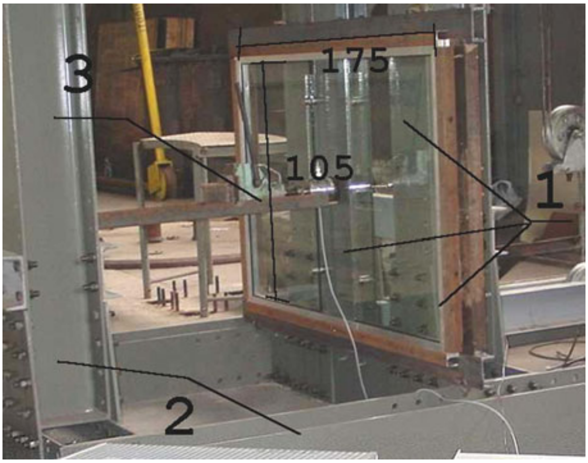

Fig. 18.4 Cash desk window fastened on the testing stand. 1 – cash desk window made of three class P4A panes measuring 105 cm × 175 cm; 2 – testing stand frame; 3 – system for applying static load and measuring force and displacement parameters of the middle pane

18.4.1 Tests of the Resistance of the Window Structure to a Static Load

This test involved applying a static load to the structure of a cash desk window, followed by visual examination and measurement of the value of the loading force and of displacement (bending) of the tested structure in the middle of the inner pane. The following devices and measuring instruments were used in the tests:

- the testing stand – a rigid steel structure set up vertically, to which the aluminum structure (casing) of the cash desk window was attached;
- a hydraulic servomotor producing a graduated loading from 0 to 5000 N, stepped every 500 N, with an accuracy of ±2%;
- a textolite plate, 100 × 100 × 20 mm, for transferring the load;
- a force measuring instrument – a CL 14 electronic converter with a measuring range from 0 to 5000 N and sensitivity of 1 mV/V;
- an instrument for measuring displacements (bending) – a PTx–100 converter transformer with a measuring range ± 50 mm and sensitivity of 203.39 mV/mm;
- a timer with a scale division not exceeding 1 s.

The positioning of the devices and measurement instruments and the method of fastening the protective window structure on the testing stand are shown in Fig. 18.4.

Methodology The cash desk protective windows were stored in the room where the testing took place for a period of 5 days, in a vertical position, as they would have when in use in their final position. After this time, for 24 h the window was mounted in the fastening structure of the testing stand (see Fig. 18.4). The zero position of the window and the readings taken from the measuring instruments was established. During the

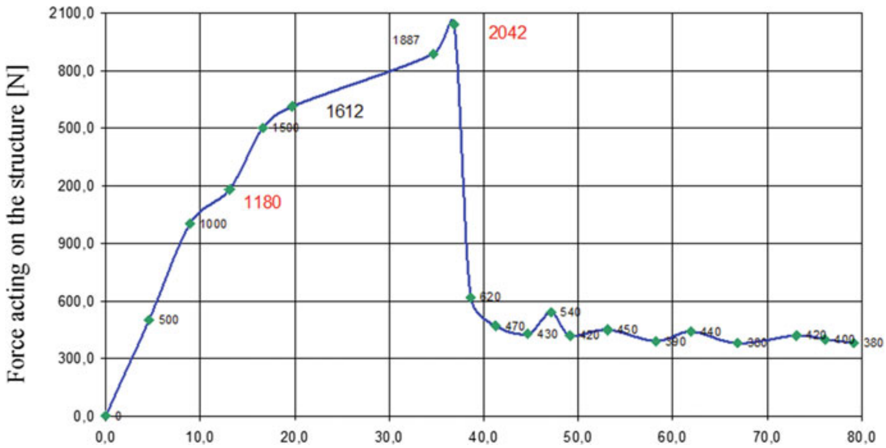

Fig. 18.5 Maximum displacements (bending) of the centre of the inner pane of the cash desk protective window, as a function of static force applied

tests of the resistance of the window structure, a static load was applied in the center of the span of the inner pane through the textolite plate (see Figs. 18.4 and 18.6).

Each loading force, graduated every 500 N, was maintained for 1 min. After this time the readings of the value of the force and the displacement of the center of the inner pane were made. After the pane cracked, readings of the force and displacement were carried out at characteristic points, but not less frequently than every 20 s. The total time of the test of the resistance of the window structure was 8 min 20 s. The test was taken to have completed at the moment when the outer panes were ejected from the window frame at a width of at least 30 mm.

Results of the Experiments The values for the displacements (bending) of the centre of the inner pane, recorded during the experiment, are shown as a function of the applied force in the graph in Fig. 18.5

With the load of 1180 N, horizontal cracking of the panes occurred, passing through the central fastening sleeve on the left-hand side as viewed from the direction of loading. The displacement value of the loaded (middle) pane at this force, was 13.08 mm. The graph clearly shows that at a maximum, the panes can withstand a static force of approximately 2042 N. At this force, severe cracking of the inner pane occurred (see Fig. 18.6), but thanks to the bonding of two layers of P4A glass with a nominal thickness of 4 mm and four layers of plastic sheet with a nominal thickness of 0.38 mm, the structure of the desk window still retains its protective properties. The steel sleeve attachments were not torn off from the panes despite of numerous local cracks in the glass surfaces. A further displacement of the center of the inner pane took place as the static force applied varied over the range

Fig. 18.6 Cracked panes of the cash desk window at maximum static load 2042 N – view from the side where the load was applied

Fig. 18.7 Cracks in the pane of the cash desk window at a maximum displacement in the central part, observed from the opposite side from the site of the place of load application

380 ÷ 620 N. When the inner edges of the panes were ejected from the window frame structure over a width of at least 30 mm, the displacement of the center of the cash desk window structure was 79.16 mm, and the displacement force was 380 N.

When the experiment ended, the extreme left lower edge of the pane (viewed from the side on which the load was applied) was ejected over a width of 31.2 mm. In spite of a large number of small cracks in the regions of the steel sleeves fastening the central pane to the extreme panes, the sleeves were not torn off – the initial spacing of 30 mm did not change significantly within a radius of around 80 mm. Cracks in the glazing of the cash desk window structure are shown in Fig. 18.7.

18.4.2 Tests of Window Structure Resistance to Soft Impacts

Methodology The tests involved applying a dynamic load to the structure of a cash desk window, followed by a visual examination and measurement of the value of permanent displacement (bending) of the tested structure in the center of the inner pane. Dynamic resistance testing of the window structure was carried out on the same stand as the static testing. To apply the impacts, a standard leather load bag with a diameter of 300 ± 20 mm was used, filled with dry sand to a total mass of 30 ± 0.2 kg (see Fig. 18.8). Due to the lack of relevant standards and regulations regarding the testing of such structures as cash desk windows with burglar-resistant panes, the tests were conducted in accordance with the methodology found in [13, 15, 17]

In the tests of dynamic resistance of the cash desk window, the dynamic load was applied in the center of the inner pane using a free pendulous movement of a bag suspended on a rope with of length of $l = 1500$ mm (see Fig. 18.8). The bag was released from a height of h = 800 mm, giving an impact energy E of 230 J.

The dynamic load was applied four times: three times until the moment when the panes were ejected from the pane groove over a width of at least 30 mm (the cash desk window suffered such damage that it could not provide anti-burglary protection), and a fourth additional time in order to check the dynamic resistance of the fastenings of the extreme panes and the middle pane using steel sleeves.

Results of the Experiments After each impact, a visual observation was made and the value of the center of the inner pane displacement was read. The results of the

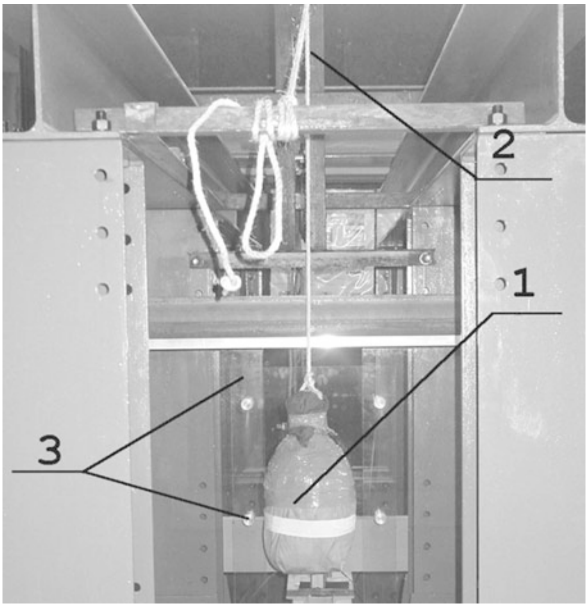

Fig. 18.8 Testing stand for tests of dynamic resistance to soft impacts. 1 – leather bag containing sand, 2 – rope fastening the load bag, 3 – window protective structure of the cash desk

Table 18.5 Maximum displacements of the center of the middle pane of the cash desk window under dynamic load

No.	Load bag impact	Displacement [mm]
1	First impact	35.36
2	Second impact	71.40
3	Third impact	129.20
4	Fourth impact	179.50

readings are contained in Table 18.5. Following the first impact by the bag released freely from a height of 800 mm, a more extensive cracking occurred than under a static load of 1612 N.

After the second impact, the displacement of the center of the inner pane was close to the value obtained at the maximum static displacement (static bending 79.16 mm, dynamic bending after the second impact 71.40 mm). Inside, the outer panes at the bottom and the top of the frame were ejected over a length of 19–21 mm. The panes were 2–4 mm shorter than complete ejection from the frame structure in the central part of the desk window.

After completing the third impact, it was found that on both sides the inner edges of the panes were ejected from the groove of the lower pane of the frame on 65–90 mm sections and up to a height of 3.6 mm measured at the extreme point of the pane from the vertical axis of the window.

According to the adopted methodology, three bag impacts are considered a determinant of the resistance of the cash desk window structure to dynamic load – the displacement of the center of the inner pane was 129.20 mm. Since no layer separation of the panes was observed, and there was a negligible quantity of glass splintering, a fourth load was applied to the cash desk window structure. As a result, the panes underwent further arch deformation by 50.30 mm. The length of total ejection of the panes from the pane groove increased to 120–160 mm on each side. In the side grooves, 1–3 mm more was needed for the panes to be completely ejected from the aluminum frame. The damage to the panes of the cash desk window following the fourth impact is shown in Fig. 18.9.

In the region of the steel sleeves connecting the panes, very minor radial cracking can be observed. Despite this cracking, the sleeves were not detached from the panes and continued to perform their function as a connector between the inner pane and the outer panes mounted in the aluminum window frame. During the loading, the entire three-pane structure of the window underwent deformation as a arch shape.

18.4.3 Tests of the Resistance of Window Structures to Explosion

This test involved applying an explosive load to the structure of a cash desk window, followed by a visual examination and measurement of the values of the overpressure of the air shock wave on the structure and the displacement (bending) of the tested

Fig. 18.9 The nature of cracking of the panes of the cash desk window following the fourth impact – view from the side where the load was applied. 1 – the pane ejected from the frame groove over the width of 140 mm, 2 – bending of the window panes

structure at the center of its span. The testing stand, in the form of a rigid steel structure, was set up vertically in a testing area and anchored, and then the aluminum frame (casing) of the cash desk window was attached to it. Measurement of the parameters of the air shock wave was made using M102A piezoquartz converters with a sensitivity of 1437.07 mV/MPa, and recorded with a digital oscilloscope with a frequency of 10,000 Sa/s. The method of fastening the window structure on the testing stand is shown in Fig. 18.10, and the digital oscilloscope used in the resistance tests is shown in Fig. 18.11.

Methodology The protective cash desk window was mounted on the testing stand (see Fig. 18.10) 24 h prior to being subjected to an air shock wave. The shock wave was generated using 60 and 100 g spherical charges of PMW-8 explosive meeting the conditions specified in a PN-V-87003:1999 Polish standard (sections 2.11 and 5.2.2). The charges were always suspended on the stand in such a way that the center of the charge was at the same height above the ground as the center of the cash desk window structure. The explosive charges were placed at the same distance from the middle pane of the desk windows and from the steel plate with a sensor recording the parameters of the reflected shock wave. After each impact, the window structure was visually examined and the displacement values were read. The resistance of the cash desk window structure to shock waves required the development and application of a separate methodology, because this structure fails to meet the requirements specified in a PN-V-87003 standard: the ones from section 5.1.1 due to its larger dimensions, and the ones from section 5.1.2 due to the lack of tightness of the pane surfaces (steel distance sleeves are placed between the panes).

Results of the Experiments Based on section 3 of the PN-V-87003:1999 standard, in the first experiment, a spherical charge of 60 g explosive was used, suspended at a distance of 130 cm from the middle pane of the cash desk window. The unit impulse

Fig. 18.10 The cash desk window structure on the testing stand. The spherical charge of the explosive is visible

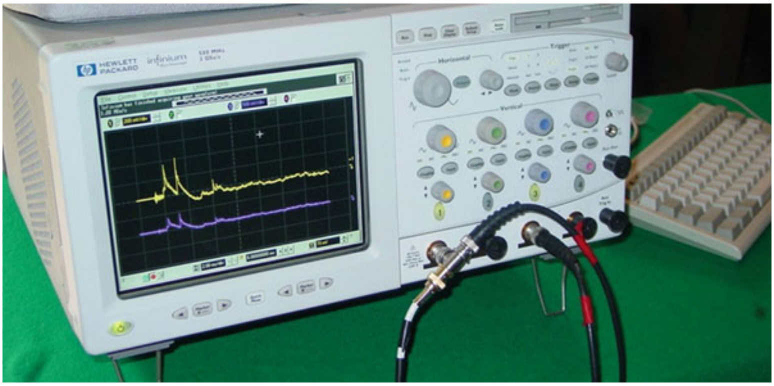

Fig. 18.11 Infiniium oscilloscope, showing a sample graph of pressure at the front of the air shock wave

of the reflected air shock wave produced by such a system corresponds to the parameters of a reflected air shock wave defined for a shock wave resistance class D2 (PN-V-87003:1999, Table 1: $p_{od} = 100$ kPa, $\tau_+ = 10$ ms). During the experiment, an Infiniium digital oscilloscope (Fig. 18.11) was used to record the pressure at the front of the shock wave as a function of time. After the first experiment, radial cracks appeared in the window panes. It was found that the displacement of the pane structure at the center of its span was 5.26 mm. Examples of changes in the value of overpressure of the air shock wave as a function of time, recorded during the third test, are shown in the graph in Fig. 18.12. The nature of the damage and the

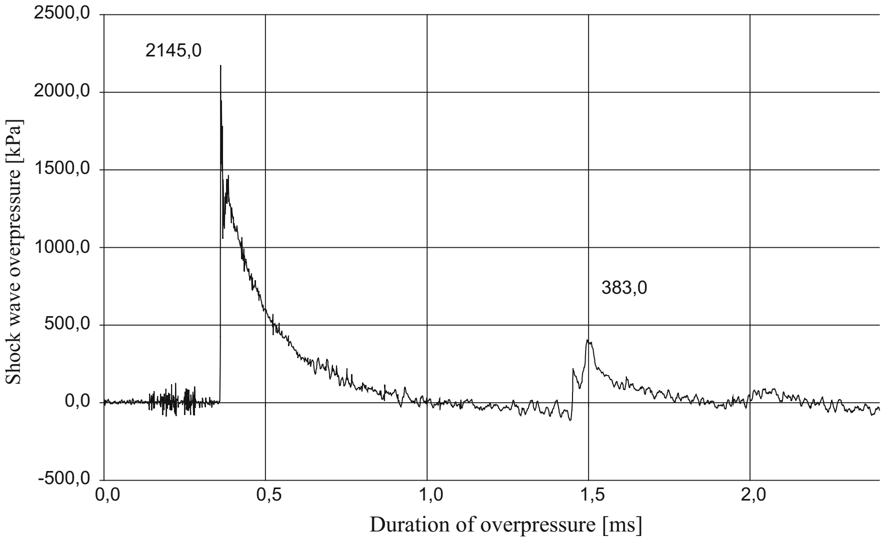

Fig. 18.12 Graph of changes in air shock wave overpressure as a function of time for the third test

directions of the cracks appearing after the cash desk window structure had been subjected three times to the overpressure of the air shock wave can be seen in Fig. 18.12.

Apart from cracking and slight bending of the protective window after the first experiment, no other damage to the tested structure was identified. Comparing the nature of the cracks formed in this experiment and their spatial distribution to those obtained in the dynamic resistance tests after the first bag impact, it can be stated that in the experiment with an explosive the cracks were less numerous and occurred in the outer panes (situated 30 mm closer to the center of the charge). This displacement of the center of the window was 30.1 mm less than in the case of the dynamic testing using the impacts with the bag. This being the case, in the second test, the structure of the cash desk window was subjected to a shock wave from the detonation of an explosive charge of 100 g suspended at a distance of 130 cm. After the explosion, it was found that the displacement at the center of the span increased to 11.87 mm (Table 18.5, No 2), which was accompanied by a slight increase in the number of cracks, particularly in the region of the fastenings using steel distance sleeves. This displacement at the center of the window was still smaller than the one following the first impact from the sand-filled bag: 35.36 mm – see Table 18.5, No 1. Ejection of the panes from the window frame did not exceed 6 mm. In the third test, the cash desk window structure was subjected to a reflected air shock wave produced by the explosion of an explosive charge of 100 g, suspended at a distance of 78 cm from the original plane of the middle pane. As a result of the detonation of the charge, a wave with overpressure of 2145 kPa was created and the duration of the overpressure phase τ_+ was 1.559 ms – see Table 18.6 and Fig. 18.12.

Table 18.6 Maximum displacements of cash desk window panes subjected to an air shock wave

No.	Mass of PMW-8 charge [g]	Distance of PMW-8 charge from pane [cm]	Overpressure p_{od} [kPa]	Duration of overpressure τ_+ [ms]	Maximum displacement [mm]
1	60	130	295	1.780	5.26
2	100	130	412	1.959	11.87
3	100	78	2145	1.559	38.43

Fig. 18.13 Damage to the cash desk protective window following the third application of the air shock wave

The shock wave with the above parameters caused the left pane to be ejected from the lower pane groove along a 130 mm wide section (see Figs. 18.13 and 18.14). There was also a significant bending of the pane structure together with a total breakage in the region of the lower left fastening (distance) sleeve. The bending of fastening points using distance sleeves compared to their initial position prior to the first experiment and the nature of cracking of the panes are shown in Fig. 18.14.

18.5 Tests of Shock Resistance of Laminar Protective Panes and the Structure of a Steel Protective Window Against the Explosion of a Fuel-Air Mixture

The structure of the protective windows consisted of a steel frame with rounded edges, containing a laminar protective pane of type (15 + 1 + 6 =) 22 mm, with dimensions 1048 mm × 2085 mm. In the frame structure the pane was secured with seals of 3.5 mm thick, glued at a distance of 20 mm from the outer edge of the pane [24]. The impact resistance of two types of laminar protective panes consisting of

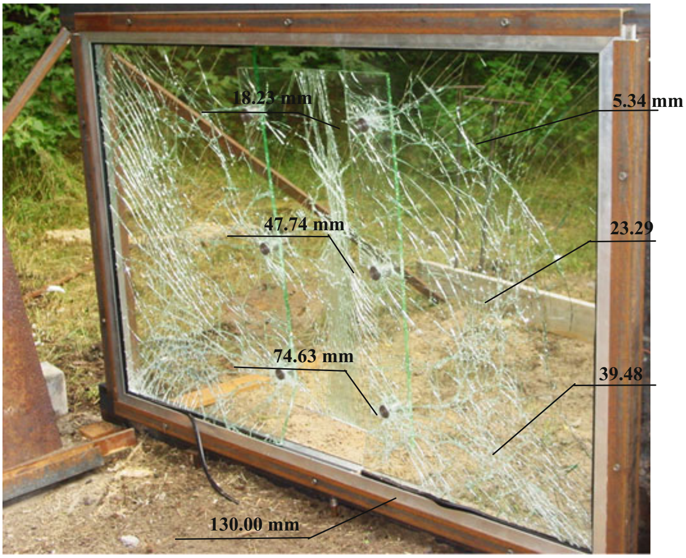

Fig. 18.14 Values of displacements of the cash desk window panes at the points of fastenings by means of distance sleeves following the third shock wave impact

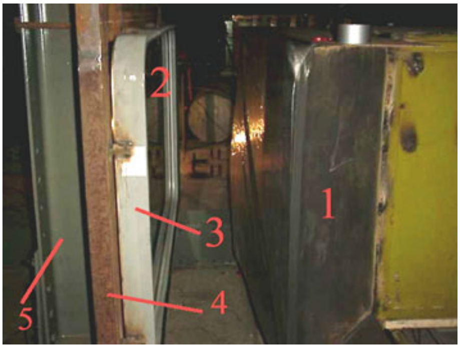

Fig. 18.15 The steel protective window placed on the testing stand. 1 – chamber for generation of load with a fuel-air mixture, 2 – laminar protective pane, 3 – steel window frame, 4 – testing stand fastening frame, 5 – testing stand support structure

two layers of tempered glass stuck together were also tested. Dimensions of the laminar protective panes: (15 + 1 + 6 = 22) mm × 1088 mm × 2125 mm and (13 + 1 + 6 = 20) mm × 1102 mm × 1152 mm. The overpressure of the shock wave was applied to the thicker layer (15 or 12 mm). The total thicknesses of the tested laminar panes were therefore 20 and 22 mm, respectively. The panes and the window had been stored for 10 days in a vertical position at the temperature at which the physical experiments were carried out.

The method of fastening the structure of the steel protective window and the laminar protective pane on the testing stands is shown in Figs. 18.15, 18.16 and 18.17. During the tests the panes were fastened to a supporting frame made of steel shaped sections. The tested pane, on the attack side, was fastened to that frame with

Fig. 18.16 The laminar protective pane (1088 mm × 2152 mm) placed on the testing stand. Symbols 1–5 like in Fig. 18.15

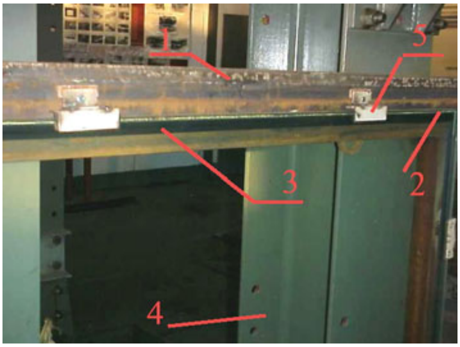

Fig. 18.17 Fastening of the laminar pane on the testing stand. 1 – shaped steel section of the support frame, 2 – tested protective pane, 3 – seal glued on the surface of the support frame, 4 – support structure of the testing stand, 5 – fastening clamps

clamps spaced every 400–500 mm. Between the clamp structure and the pane, a seal was placed over the entire clamped area – see Fig. 18.17.

18.5.1 System Generating the Explosive Load

In order to create conditions for the explosive load for the tested laminar panes and protective window – a minimum overpressure of 30 kPa with a duration of at least 200 ms was generated by the explosion of a fuel-air mixture. The explosion in the course of the experiments took place in a specially constructed explosion chamber (see Fig. 18.18.) The size of this chamber was selected so that the load on the tested pane and window was uniform evenly distributed over the entire surface. The loaded surface included practically the entire area of the pane fastened in the structure of the support frame.

The explosive load on 1088 mm × 2125 mm panes was generated using a chamber extended to these dimensions, so that the side of the chamber in contact with the tested pane had dimensions of at least 1040 mm × 2000 mm.

The open side of the chamber in contact with the tested pane or protective window, placing a container with the appropriate quantity amount of fuel had been

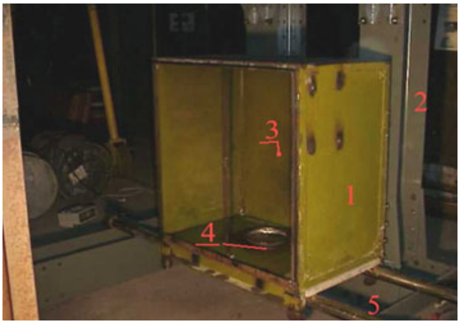

Fig. 18.18 Explosion chamber (for generating the explosive load). 1 – explosion chamber, 2 – stand structure, 3 – explosion initiation point, 4 – fuel container

Fig. 18.19 Location of pressure measuring elements. 1 – pressure measurement point on the front of the shock wave, 2 – fuel container, 3 – structure of chamber for generating the explosive load

in the changer, was closed a plastic sheet with a thickness of 50 μm. The fuel-air mixture contained hexane, with a concentration of no more than 2.0% in the mixture. Initial tests demonstrated a repeatable relationship between the maximum value of the overpressure wave and its duration on the one hand, and the fuel concentration on the other hand. Based on this information, a main testing program was designed. The testing system used to control the process of applying an explosive load on the panes and protective windows with a precision of up to 10% in the range from 50 to 900 kPa of the maximum overpressure of the wave reflected from the attack surface.

18.5.2 Methodology

The test involved applying a force from an explosion of fuel-air mixture to the laminar panes and the entire structure of a protective window, followed by a visual examination and measurement of the value of the maximum pressure of the reflected shock wave (see Fig. 18.19), namely recording both the varying value of the pressure on the attack surface of each pane and the displacement (bending) of the tested pane at the centre of its span (see Fig. 18.20) as a function of time. Figures 18.21 and 18.22 show the applied measurement circuit and the devices recording the measured physical values on the testing stand during the experiment.

Fig. 18.20 Location of displacement measuring elements. 1 – stand support structure, 2 – displacement sensor bracket, 3 – PSx-20 converter

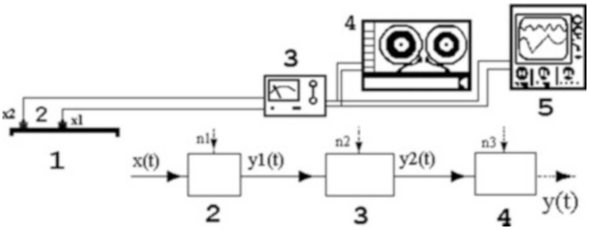

Fig. 18.21 Diagram of measurement circuit used to record pressure and displacement as a function of time. 1 – tested pane or protective window, 2 – PSx–20 sensor for displacement measurement and M102 sensor for pressure measurement, 3 – measurement amplifiers, 4 – V-STORE recorder, 5 – Infiniium digital oscilloscope – see Fig. 18.11

Fig. 18.22 Recording devices on the testing stand. 1 – Infiniium oscilloscope, 2 – V-STORE recorder, 3 – 482A17 amplifier, 4 – MPL-108 carrier wave instrument, 5 – PSx-20 converter

Before filling the container with the fuel, the chamber was heated for 30–40 min until the air temperature inside the chamber was approximately 600 °C. Before the heating began, the open side of the chamber was closed with a plastic sheet along the three edges. After reaching the required temperature, the container filled with the quantity amount of the fuel determined in the trials, was placed centrally on the bottom of the chamber (Fig. 18.19), and then the fourth edge of the chamber side was glued up – see Fig. 18.23. The heating of the chamber continued until the fuel completely evaporated and a fuel-air mixture was produced in the chamber, in practice for 18–20 min.

Fig. 18.23 Closing the chamber side which was to be in direct contact with the attack side of the tested protective pane, using a plastic sheet with a thickness of 50 μm

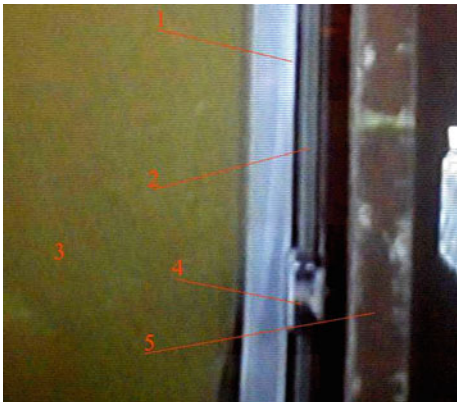

Fig. 18.24 Testing system at the moment before the explosion. 1 – plastic-covered edge of the chamber; 2 – tested glass sample; 3 – explosion chamber; 4 – clamp attaching the pane to the support frame; 5 – support frame

After being prepared in this way, the explosion chamber was moved up to the pane secured on the testing stand, achieving direct contact with the attack surface of the tested sample (see Fig. 18.24).

Then the process of explosive combustion of the fuel-air mixture was initiated – the start of the process is shown in Fig. 18.25. The air shock wave produced in the chamber struck the attack side of the tested pane, applying an impulse of overpressure to it, while at the same time the chamber began to move in the opposite direction – see Fig. 18.26. The values of pressure and displacement as a function of time were recorded simultaneously on the screen of the oscilloscope and on the magnetic tape of the V-STORE recorder – the measurement circuits are shown in Figs. 18.21 and 18.22. After the experiment was complete, a visual examination of the state of the pane surface, and of the fastening and sealing systems was made.

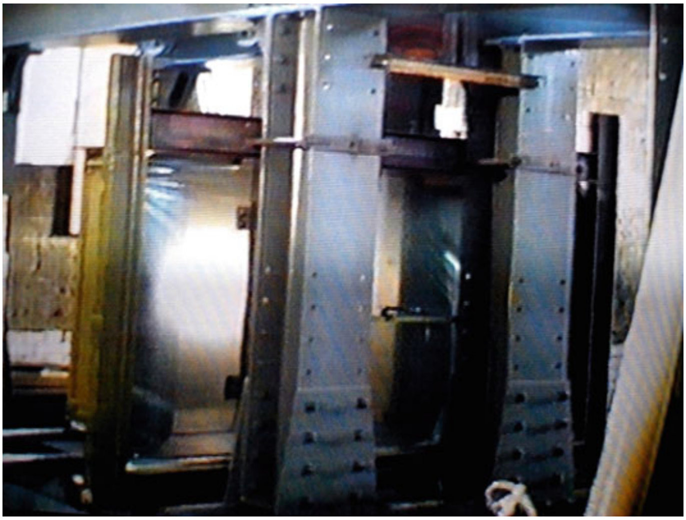

Fig. 18.25 Testing a laminar protective pane – start of the explosion of the fuel-air mixture in the explosion chamber

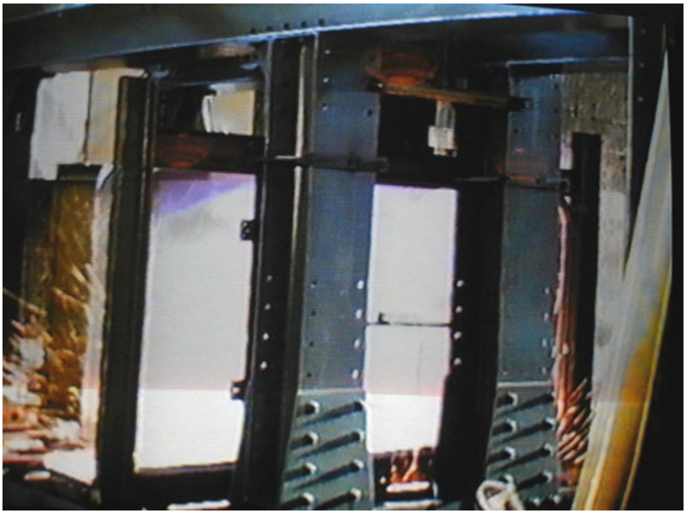

Fig. 18.26 The moment directly following the impact of the shock wave on the tested pane

18.5.3 Theoretical Prediction of Maximum Permissible Overpressure

A prediction of permissible overpressure values was made based on the results of the tests on the protective panes with various thicknesses and dimensions subjected to explosions of fuel-air mixtures, using the formula below:

$$p_p = (\sigma_w/0.684) \cdot (h/b)^2 \cdot (1+\alpha)^2/\left(1+0.22\alpha^2\right) \quad (18.6)$$

where:

p_p is the destructive pressure of the air shock wave in kPa;
h, b are the thickness and width of the pane in mm;
α is the ratio of the length of the pane to its width;
σ_w is the destructive stress under dynamic load; σ_w taken to be 90 MPa.

For the tested laminar protective panes, the following was obtained from the above formula:

– 139 kPa for a 1102 mm × 1152 mm pane with a thickness of 20 m,
– 116 kPa for a 1088 mm × 2125 mm pane with a thickness of 22 mm.

Hence, based on the above calculations, in the physical experiments, at the first load, a pressure with values not exceeding 80% of the above estimates was applied.

18.5.4 Results of the Experiments

The results for the maximum measured values in the dynamic tests using hexane fuel are presented. In each experiment, pressure changes over time were recorded in the center of the pane. In addition, in selected experiments, the displacement of this point of the pane was also measured over time.

Neither the laminar panes nor the protective window suffered damage. There were no visible signs of breach of the structure of the construction material. The tightness of the protective window was also maintained. Moreover, the system fastening the pane in the window frame continued to function properly after the tests and did not suffer any external damage.

It should be mentioned that during the experiment, apart from the shock wave, the panes and the window were subjected to the action of an intense flame. On the surfaces of the tested panes there is local damage occurred which slightly reduced the transparency of the glass, but did not deteriorate the general technical condition of either the panes or the window to such an extent as to prevent their continued use.

18.6 Conclusions

I. The analysis of the comparative results of the resistance of the structure of the protective door leaves to the projectile strike and the analyzes carried out lead to the following conclusions:

1. The tested protective door leaf structures do not provide full protection against the bullets fired from typical basic types of firearms.
2. The structural material (St0S structural steel) of the tested doors does not provide protection against the penetration by the projectiles fired from long firearms.
3. To make the doors bullet-proof against the projectiles fired from a short distance from a long firearm, the thickness of the steel sheet used should be increased to 5 mm.
4. The protective effect of existing door leaves (their resistance to bullets) can be obtained by introducing a new type of structural steel or by using layered structures, for example with ceramic inlays.
5. In order to determine the perforation properties of the sandwich door structures (and their resistance to bullets), it is necessary to carry out experimental studies, primarily perforation tests to determine the values of the necessary empirical coefficients.

II. Conclusions from the tests of the resistance of the structure of a cash desk protective window to soft impact, air shock wave and static force:

1. The structure of the cash desk window in static resistance tests withstands a force of 2042 N. The panes are ejected from the pane groove of the aluminium frame of the cash desk window only after the displacement of the center of the window by a minimum distance of around 80 mm.
2. In the dynamic resistance tests, even at the first impact with a load bag (impact energy $E = 230$ J) the panes crack, although the entire structure of the window retains its protective properties.
3. Following the third impact with the load there partial (over a width of up to 90 mm) ejection of the panes from the frame structure, at a displacement of the center with the window center displaced by about 130 mm.
4. Following the fourth impact, although the centre of the window is displaced by around 180 mm from its initial position, the cash desk window structure still retains its protective properties, preventing a break-in.
5. The structure of the cash desk window subjected to a reflected air shock wave with a unit impulse of 166 Pas retains its protective (anti-burglary) properties in spite of the cracking of a large area of the panes.
6. On application of the 380 Pas pulse, the panes were ejected from the pane groove of the aluminium frame over a width of at least 130 mm.

7. Because the unit impulse corresponding to the load conditions defined in the PN-V-87003:1999 standard (Table 1 for class D2) is 345 Pas, based on the above tests, the structure of the cash desk window made of P4A class panes should be classified in class D2 for air shock wave resistance.

III. Conclusions from the tests of the resistance of laminar protective panes and the structure of a steel protective window to the explosion of a fuel-air charge:

1. All tested panes and the window were subjected to an explosive overpressure of the shock wave with a maximum value of 30 kPa for a duration of 200 ms. The tested items were not destroyed and could continue to perform their protective functions.
2. Laminar panes of (13 + 1 + 6) mm × 1102 mm × 1152 mm transfer a dynamic load ten times greater than required by the user.
3. Laminar panes of (15 + 1 + 6) mm × 1088 mm × 2125 mm transfer a dynamic load seven times greater than required by the user.
4. A steel protective window with a laminar pane of (15 + 1 + 6) mm × 1048 mm × 2085 mm transfers a dynamic load 17 times greater than required by the user.
5. The action operation of the flame as a result of the explosion of the fuel-air mixture only slightly worsens the transparency of the panes and does not affect the protective function of the window.

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Chapter 19
Assessing Security of Soft Targets Using Complex Systems Analysis Methods

Bohus Leitner and Maria Luskova

Abstract The paper is dealing with issues of soft targets security represented by places with a high concentration of people and a low level of security against violent attacks. The aim of the paper is to assess the security of selected soft target object (with a large number of people) through appropriate methods for risk analysis, evaluation of results and proposal of indicators for implementing the methods into the practice. For solution of the issues analyses of complex systems methods – ETA and FMEA were used. Applying these methods resulted in a risk reduction at minimum required level. Based on the findings, the FMEA method was indicated to be the most effective due to flexible access to the object assessment. The results can be used as a basis for an assessment of soft targets security and also as an incentive in modelling of violent attacks.

Keywords Soft target · Complex systems · ETA · FMEA · Security assessment

19.1 Introduction

The security situation in the world is constantly worsening in term of terrorism and extremism and the incidence of violent attacks similar to (but not always ideologically motivated) terrorism on the most vulnerable targets – people is increasing, too. Organizers of such attacks are increasingly motivated to focus them on unprotected places with a high concentration of people regardless of whether they are politically or religiously symbolical by something. We talk about so-called soft targets.

The paper is dealing with assessment of security level and increasing the resilience of soft targets using selected methods of complex system analysis. Increased interest of terrorist groups in such objects also requires adaptation of the security system. In addition to the theoretical background of soft targets protection issues, the

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L. Hofreiter et al. (eds.), *Soft Target Protection*, NATO Science for Peace and Security Series C: Environmental Security,
https://doi.org/10.1007/978-94-024-1755-5_19

results of the application of selected system analysis methods (ETA, FMEA) to the model object are presented in the paper.

Threat scenarios have been proposed, based on the hazard analysis and the results of the ETA and FMEA methods, measures to increase the security of the object have been proposed, and the verification of their effectiveness and impact on the resilience level of the object has been performed.

19.2 Soft Targets: Characteristics, Potential Targets and Ways of Attacks

A soft target is a term commonly used by the security community to designate places with a high concentration of people and a low level of security measures against the execution of a violent attack and its possible consequences. These are primarily tourist attractions or various social (especially sport, political, religious or cultural) events and traffic nodes (stations, airports) or means of transport. In the wider definition of soft targets, schools, hospitals, as well as swimming pools, sport fields and other objects are considered to be such objects.

According to [1], the soft targets are “objects, spaces or actions characterized by the high concentration of people, an absence or a low level of security measures against violent attacks and non-inclusion between critical infrastructure objects.” Soft targets are “objects (buildings, premises, open spaces, etc.) in which a large number of people are grouped together at a certain place. These objects do not apply any or only slightly specific security measures to prevent a violent attack on the lives of persons in these objects, to ensure a rapid response to the attack, or to assist in managing a potential attack without losing people’s lives. A violent attack on this target could cause death or injury to a person or more persons who are near the destination”.

Based on the above mentioned, as well as [2], it is possible to include among the soft targets mainly:

- major traffic nodes train and bus stations, airport terminals,
- hospitals, clinics and other medical facilities,
- school facilities, dormitories, canteens, libraries, community centres,
- shopping centres, markets and business complexes,
- sport halls and stadiums,
- cinemas, theatres, concert halls, entertainment centres,
- public gatherings, processions, demonstrations, pilgrimages,
- cultural and religious monuments, museums, galleries,
- bars, clubs, discos, restaurants and hotels,
- cultural, sporting, religious and other events, . . .

For the state, the most important fact is that soft targets are large number. This significantly limits the practical possibilities of ensuring their security only by the state/public administration and increases the necessity for the implementation of the security measures by the soft targets themselves. Most of them are able to secure their security much better (e.g. better knowledge of the environment, contact with surrounding entities, presence of staff on site but also funding to increase security, etc.) as the state itself. An analysis of terrorist attacks, according to data from the Global Terrorism Database [3], also reveals the priority ways of attacking. When analysing threats, defining scenarios and defining a security system for soft targets, considering the following ways of potential attacks is needed:

1. Explosive attack (except when using a vehicle).
2. Suicidal attack by an explosive.
3. Explosives in postal packets.
4. Explosive in a parked vehicle.
5. Arriving a vehicle with an explosive with a suicide attacker.
6. Incendiary attack.
7. Attack by shooting weapon (pistol, submachine gun, etc. – active shooter).
8. Taking up the hostage and barricade situation.
9. Cold weapon attack (knife).
10. Attack on soft target by crowd.
11. Attack by arriving vehicle.

19.3 Principles of Soft Targets Protection

Soft targets are a large and very diverse group of subjects. They are characterized by security – relevant characteristics that differ them from other targets but also among themselves. Typical ways to commit terrorist attacks have been identified [4] and therefore it is possible to define the most of the relevant measures in advance. This makes it possible to target the protective and defensive elements more precisely, to formulate the principles of security and to recommend specific measures.

19.3.1 Establishment of an Appropriate Measure

To set up a functional soft target security system, it is needed to:

1. **Clarify protected interest**. At this stage, it is necessary to define what we value, what we do not want to lose, what could possibly damage us. Primarily it is about the health and life of people (violent attacks), property, information, social values, and also e.g. a good reputation.
2. **Define possible sources of danger (threat)** to protected interest. It is necessary to identify specific groups or categories of persons with potential motivation to attack. This is used to analyse previous similar attacks and to consider potential sources of threat. It is always necessary to take into account the specifics of a

particular object/action and usually specific threats (e. g. presence of VIP, risk date, pyrotechnics, media interest, resilience of buildings, effectiveness of current measures, etc.).

3. **Specify threatening ways of attack**. The basis of a high-quality soft-target security system is to define as precisely as possible the sources of threat. The security system must be the result of a thorough analysis of interests and potential threats. It is characterized by a systematic analysis of the threats to a specific target and then by setting up appropriate measures. This is a procedure based on relevant threats.
4. **Analyse specified threats by threat and risk analysis methods and identify priority threats**. The basic principle of relevant methods is to compare the likelihood of threat activation and impact rates (consequences) for individual threats. The threat rate overview is often expressed by a matrix which makes it possible to allocate resources to address priority threats more efficiently. Prioritization of threats makes it possible to determine their importance and to determine for which of them the resources will be allocated.
5. **Design and application of security measures**. Based on prioritization of threats and determination of appropriate measures, measures to increase the resilience of the object are applied. There are, for example, installed technical elements, elaborated specific security plans, determining not only preventive measures and routine procedures but also reaction if the crisis situation has not been prevented and its consequences have to be minimized.

19.3.2 Incident Timing

With all the planned incidents, it is necessary to work in three phases of time.

1. What can be done before the occurrence of the incident so that the likelihood of its occurrence and the extent of the consequences are reduced or the incident has diverged from the target.
2. What can be done when the incident is in progress.
3. What can be done to mitigate the impact when the incident has already taken place.

Before the incident: Prevention – deterrence:

- Preventive measures – reduce the likelihood of an attack, increase the speed and intensity of the response, and limit the extent of the consequences and reduce them more quickly.
- Deterrence tools – lead the attackers to decide not to choose the target.
- Crisis communication – leads to a calming situation and a mitigation of the conflict.

During the incident: Detection – immediate reaction:

- Immediate detection of unwanted activity or disturbance of protected zones – preferably before the attack itself.
- Immediate reaction of security personnel or other members of the security system – best according to a pre-planned Plan.

After Incident: Mitigation and adaptation:

- Follow-up to the prepared coordination plan for management and its defined priorities for each phase after the incident.
- Early renewal of the organization's activities and learned from a negative event.

The mentioned focus of security measures is the basis of a practically focused approach – DRRM (Deter – Reveal – Respond – Mitigate Impacts).

It is a methodological tool that verifies the effectiveness of security measures and reducing the level of threat the impact of which we want to reduce. The nature of the method: to list of possible incidents (which were rated relevant to the object and we want to minimize them), we will assign measures to deter, early detect, and respond as well as reducing impacts after an incident. The final form of the security system needs to be re-verified to determine whether it can reduce the threat rate before, during and after an incident. An immediate reaction that would stop an attacker (physical defence) is mostly only in the power of professional teams who are able tactically and technically eliminate the attackers while working with other people around. However, such teams are not usually available for soft targets.

However, instructed soft-target personnel (or other public present in the incident) may play a non-negligible role during the immediate reaction phase. In the case of a proper response, he may call for assistance, divert passers-by from the attack site, separate the attacker from by locking the area, warn others and also eliminate the attacker by his/her own strength within the necessary defence.

19.4 Security Diagnostics and Assessment of Soft Target Resilience

In order to select the appropriate security measures, each objective needs to be assessed individually, particularly with a view to clarifying the security relevant factors affecting two essential criteria:

1. attractiveness of the target from the perspective of the attacker,
2. real possibility of its security

19.4.1 *Basic Diagnostic Factors for Selecting Security Measures*

The basic factors in terms of the properties of soft targets:

1. **Openness to the public**. Especially if it is an outdoor action, a closed object or a public object. Such characteristic has an impact on the concept of security – whether measures can be taken at the entrances or in the open space.
2. **Own security personnel**. Using the own staff for security tasks significantly extends the security system's capabilities. The presence of security staff or organizational services reduces the attractiveness of the target.
3. **Amount and concentration of persons**. For a soft target, the amount and concentration of people at a certain point in certain time is primarily a factor influencing the focus of the security system and the preparation of security procedures.
4. **Presence of the police**. Police is a major deterrent; its presence decreases the attractiveness of the target. Usually, the police are present only short time, locally or only to maintain public order. If there is a permanent police in the building, it is not a soft object.
5. **Presence of the media**. For terrorists or otherwise motivated attackers, the media presence is very attractive. Especially, if it is an important event with TV transmission in real time.
6. **Target symbolism**. If the entity is a symbolic target for attackers, the threat of the subject increases significantly. For a soft target, this means taking into account in the security plan the ways in which the attacks of specific violent groups are carried out and adapting their security strategy to extreme threats.

Important factors in self-protection:

7. **Organizational structure**. It has a significant impact on the ability to formulate and implement a security policy, to develop a realistic security plan, and to manage the implementation of security measures for soft target. More entities in one vulnerable location (such as a business centres) create a need for coordination of individual entities. This is related to voluntary activity for common security interest and sharing possible costs.
8. **Resources and finances for security.** The budget for security and the appointment of a security manager, i.e. person in the organizational structure of the organization responsible for the security agenda and the definition of measures.
9. **Ability to identify risk situations**. It examines whether the subject is able to assess which activities and situations are at risk, what to focus on, what to consider as significant and to solve by their own choices.

Based on the above factors, every soft target can clarify what are its strengths and weaknesses and what are its opportunities or risks (e.g. using the SWOT analysis) it is possible to determine what should be the primary focus for the development of own security.

19.4.2 Improving the Resilience of Soft Targets

Soft targets protection requires a completely different, specific approach as defined e.g. for security of critical infrastructure objects [5, 6]. At the conceptual level, this requires the establishment of cooperation between the state, the self-government and the private entities. At the tactical level, this requires new training methods for the police, a new way of communicating with the public, identifying priority soft targets and their gradual resilience increasing. At the operational level, e.g. organization of the actions it is needed to involve the available personnel in the security management system, consult the police with security measures before each major action and progressively improve the management of the foreseen threat scenarios.

According to [1], soft targets can be protected in several ways:

- **Physical security** – plays a key role, e.g. staff checking people at the entrances to buildings, execution of walks or operator and security technology in the control room.
- **Electronic security equipment** – e.g. a camera system used to monitor the internal and external spaces and movement of persons, alarms and alarm systems, detectors of metals and explosives, as well as access and attendance systems that serve, in addition to registration purposes, also to "complicate" the entry of an unauthorized person or to restrict it movement around an object.
- **Mechanical security equipment** – e.g. security doors, in the case of external actions, concrete blocks [7–9], columns preventing the entrance of vehicles, or turnstiles that serve in the buildings to arrange and authorize the entry and exit of persons [10].

19.5 Case Study: Evaluation of the Asset from the Point of View of the Soft Target Protection

Selected object: Business and entertainment centre (BEC).

19.5.1 Characteristic of the Soft Target

The BEC has a total of 80 shops and services, 2 cinemas, 6 cash points, underground garages and technical facilities. The technical facility consists of the Security Operation Centre, the Centre of Administration and the Cleaning and Technical service.

The basement floor (Fig. 19.1) consists of underground parking and one operation (car wash). On the ground floor there are shops and services, a total of about 40 facilities. There are four entry points to the ground floor building, which serve

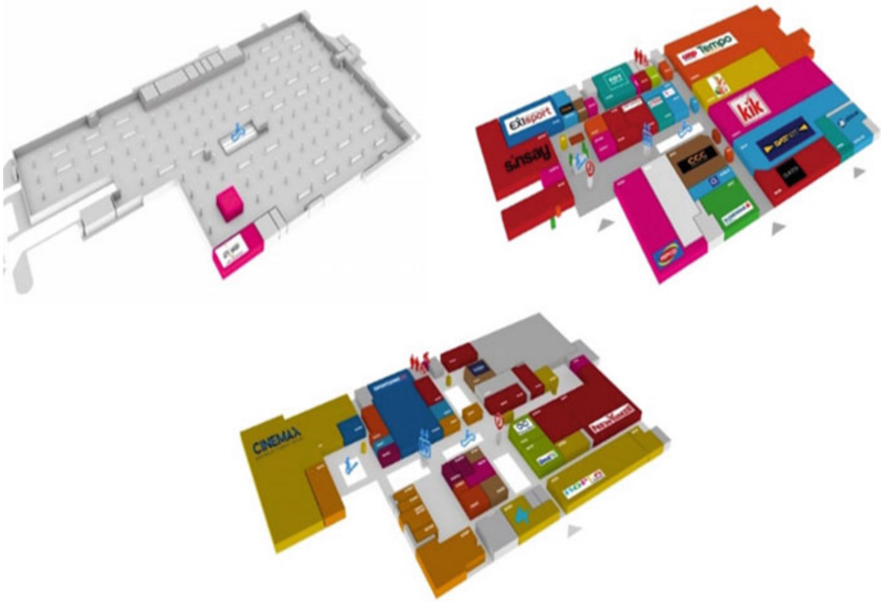

Fig. 19.1 Basement, ground floor and first floor of the BEC

also as an emergency exits in case of evacuation. The first floor serves for shopping and entertainment (40 shops, a cinema and a technical centre). From the first floor lead two emergency exits and a stairway. The BEC object has two emergency exits on each floor and an evacuation lift. On the ground floor there is possibility of exits through four access points, two of which are directly from shopping units. From the basement the exit is possible through two access points. The BEC object was analysed in detail from the standpoint of the external security environment (location of object, access roads, nearby surroundings and neighbouring objects, engineering networks, Integrated Recue System units arrival time, . . .) and internal security environment (number of floors, arrangement of operations and support services, exits, number and character of entrance points in the building, permeability of emergency exits, security systems, entrance control, evacuation routes, technical infrastructure and key technology provision, location and building and technical solutions of parking lots and other factors).

The increased risk is due to the location of the centre along the main road, the large number of entrances to the building object, unsecured access to the technical section – no mechanical system. There is insufficient number of cameras and non-monitored entrances to the building from the view of electronic security. The critical issue is simple access to the ventilation system, the entry point is without any security. The high risk is also unsecured access to the terrace, the parking lot in the building as well as other identified security risks.

The time of arrival of all Integrated Recue System units in case of necessity is maximum 10 min. In case of a favourable traffic situation, it is possible to expect the arrival of Integrated Recue System units within 5–6 min.

19.5.2 Defining and Analysing Scenarios for Threats Related to Attacks on Soft Targets

Within the security analysis, four most likely scenarios, which could have a significant impact on the number of victims, were identified and there is a higher frequency of their occurrence, too. Selected scenarios:

- attack by firearm,
- vehicle attack,
- attack using an explosive stored in a bag or backpack,
- chemical attack.

These scenarios were analysed using the ETA – Event Tree Analysis and FMEA -Analysis of possible failures and their consequences. Each analytical method has its strengths and weaknesses. However, it is important to select the right method for a particular purpose. E.g. according to [11], ETA is known for its clarity, while the FMEA stands out in simplicity but a prerequisite is the involvement of experienced professionals to objectively assess the degree of severity, probability and possible consequences of incidents.

ETA – Event Tree Analysis Four selected scenarios were considered in the analysis which appear to be the most serious in terms of the number of victims and the frequency of their occurrence. Since the analyses are rather extensive, only conditions and results for one scenario – **attack by a chemical dangerous substance released into the ventilation system are presented**. In the case of the BEC object being analysed, this is the most risk threat, since access to the ventilation system is possible because it is not secured enough, access is possible from the parking lot. There is also no rapid detection of hazardous chemicals. This type of attack actually threatens most of the people in the facility. The results of the probability analysis of the individual scenarios for the attack by the chemical dangerous substance are in Fig. 19.2

A key measure is the elimination of the access to the ventilation system, preferably through a mechanical interlocking system. In case of an attack through the ventilation system, it is also important to immediately identify the chemical attack (chemical detectors) for the possibility of early evacuation and minimization of losses. With the implemented measures, the most risk result was eliminated to half of the value (see Fig. 19.3).

FMEA – Analysis of Failures and Their Consequences The analysis of possible errors and their consequences on the BEC object contains defining 20 problems that

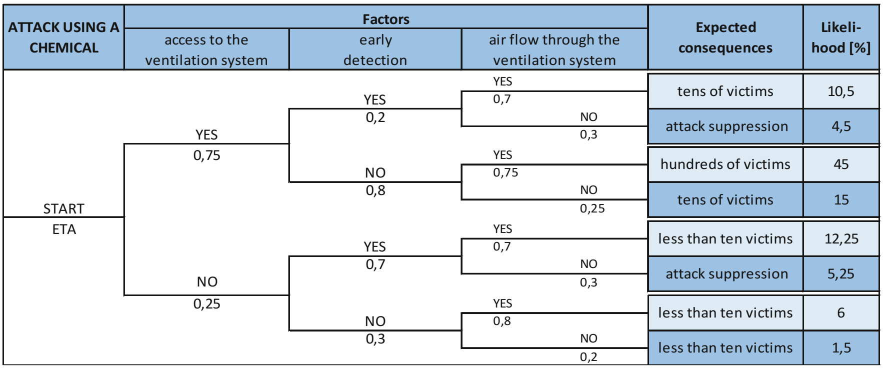

Fig. 19.2 ETA – chemical dangerous substance into the ventilation – current state

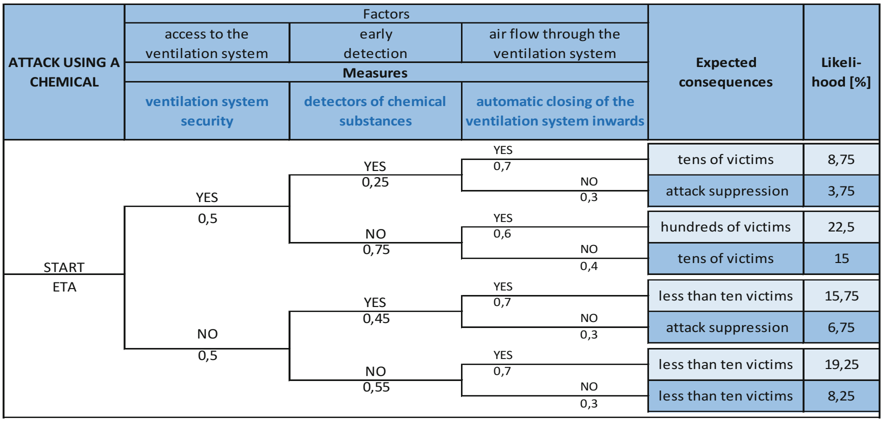

Fig. 19.3 ETA – chemical dangerous substance into the ventilation – after measures

may arise. The analysis consisted in assessing the severity (S), the probability (P) and the detectability of the problem (D) through the value of the parameter RPN – Risk Priority Number, representing conjunction of the 3 factors

$$\mathrm{RPN} = \mathrm{S} * \mathrm{P} * \mathrm{D} \tag{19.1}$$

If the value exceeded 100, appropriate permanent measures were defined based on the root cause and, once introduced, the RPN was determined again. To illustrate the progress of the analysis, only the severity of the adverse event in terms of possible health risk (Fig. 19.4) and the predicted frequency of occurrence are shown (Fig. 19.5).

Additional classification tables have been introduced in the implementation of the FMEA method focusing on other important factors such as the possibility of detecting an undesirable event, possible consequences of an asset nature, etc.

Problem severity	Possible health damage	Rating
Very high	death	10
	serious injury - 2 or more people hospitalization	9
	serious injury – 1 person hospitalization	8
High	injuries with the incapacity for work – 2 or more persons	7
	injuries with the incapacity for work – 1 person	6
Medium	injuries requiring treatment - 2 or more persons	5
	injuries requiring treatment – 1 person	4
Low	minor injury 2 or more people - no treatment required	3
	minor injury 1 person - no treatment required	2
Negligible	no damage to health	1

Fig. 19.4 FMEA – classification for event severity: possible injury to health

Problem: likelihood	The frequency of problem occurrence	Rating
Very high	Once a day	10
	Once a week	9
	Once 2 weeks	8
High	Once a month	7
	Once 3 months	6
Medium	Once 6 months	5
	Once a year	4
Low	Once 5 years	3
	Ones 10 years	2
Negligible	Once 50 years	1

Fig. 19.5 FMEA – classification for event severity: frequency of occurrence of the problem

Out of the total of 20 identified threats, 7 risk scenarios were identified for the BEC object (Fig. 19.6). These were threats relevant to the soft targets: a cold weapon attack, attack by shooting weapon, a chemical attack through the ventilation system, and an attack by a vehicle driven into persons at a bus stop, a suicide bomber, an attack by an explosive stored in abandoned luggage and an acid spray.

The Attack of Chemical Released into the Ventilation System After introduction of all measures within the anti-chemical threat, it is possible to reduce the probability of a successful attack by 51.4% but still to a relatively high value of 28% (see Fig. 19.7)

The Attack of Chemical Released into the Ventilation System After introduction of all measures within the anti-chemical threat, it is possible to reduce the probability of a successful attack by 51.4% but still to a relatively high value of 28% (see Fig. 19.7)

For chemicals, it is a major problem that even after detection, it is not usually possible to prevent the spread of the substance. After the introduction of the measures, it is possible to expect a significant improvement in the number of

Problem	Risk category	Before the measures				Immediate measures	Root cause	Permanent measures	After the measures			
		S	P	D	RPN				S	P	D	RPN
a cold weapon attack	attacker	9	5	7	**315**	action by the security service, detention of the offender, handing over of police	**insufficient controls, identification and monitoring of suspects**	installation of smart video system	8	4	3	**96**
attack by shooting weapon	attacker	9	3	7	**189**	action by the security service, detention of the offender, handing over of police	**insufficient controls, identification and monitoring of suspects**	installation of smart video system	9	3	3	**81**
a chemical attack through the ventilation system	attacker	10	3	6	**180**	evacuation of persons, suction through the ventilation for maxi-mum performance	**insufficient security and monitoring of access to the ventilation system**	mechanical barriers to access to the ventilation system	10	1	5	**50**
an attack by a vehicle driven into persons at a bus stop	attacker	8	3	7	**168**	evacuation in case of explosion	**insufficient barrier systems**	building a defense system	10	1	7	**70**
a suicide bomber	attacker	10	3	6	**180**	detention of the offender, evacuation of person	**insufficient control of suspects**	random checks of person	10	1	6	**60**
an attack by an explosive stored in abandoned luggage	attacker	9	3	7	**189**	evacuation of persons	**capturing an explosive into an object**	random baggage checks	10	2	3	**60**
an acid spray	attacker	6	3	6	**108**	rescue call, first aid	**a ban on bringing bottles into the building**	control of visible bottles	7	1	8	**56**

S– severity P – probability D – detectability RPN – Risk Priority Number (RPN = S * P * D)

Fig. 19.6 FMEA analysis – results (before and after the implementation of measures)

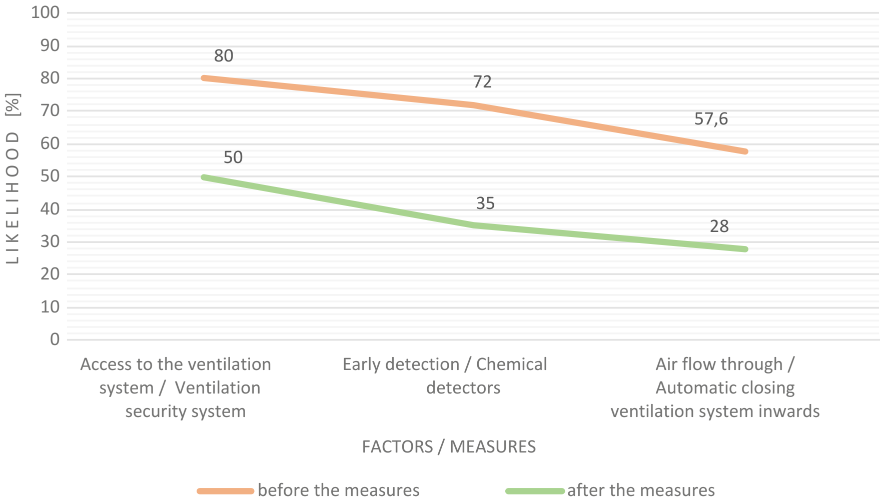

Fig. 19.7 FMEA – comparison of the likelihood of an incident (before and after the measures)

predicted casualties from tens to individuals (see Fig. 19.8). An increase in the likelihood of an attack disposal in 250% is significant but the absolute value is still low at 12%.

The results of the FMEA analyses revealed that the first three threats can be significantly eliminated by introducing appropriate measures (Fig. 19.9). In the first scenario – a cold weapon attack, the threat decreased in 70%. In the case of a

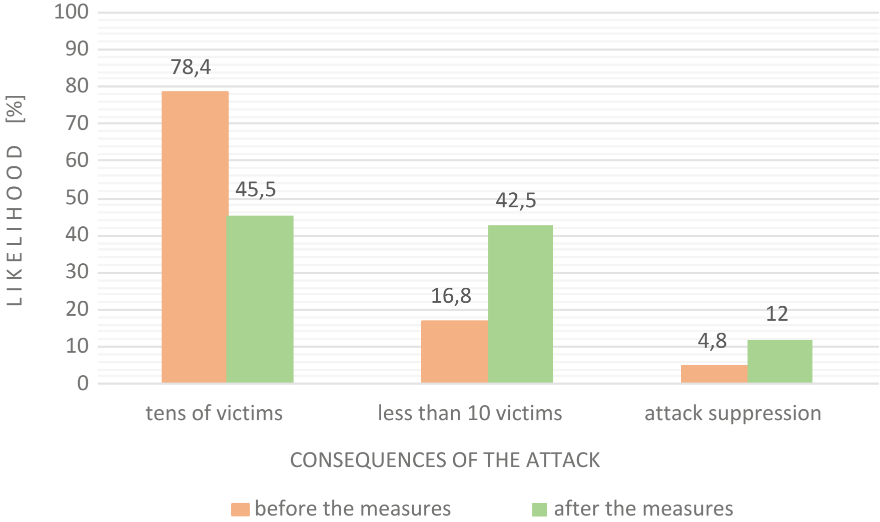

Fig. 19.8 FMEA – comparison of the consequences of the attack (before and after the measures)

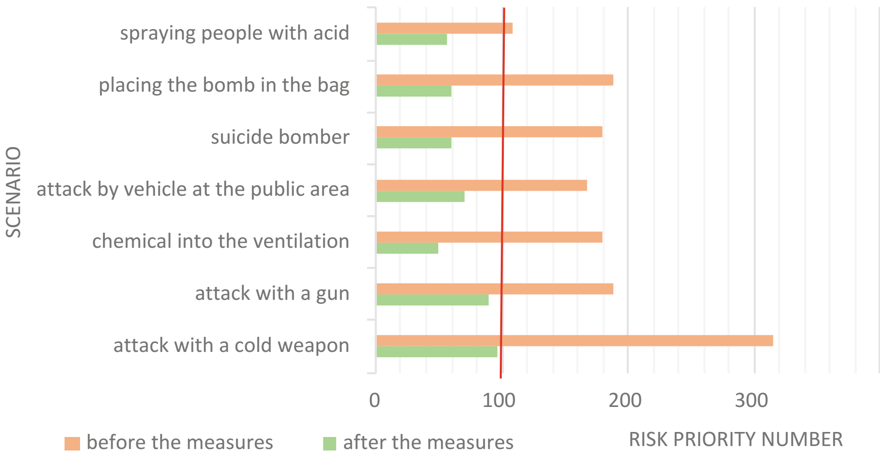

Fig. 19.9 FMEA – results (before and after the measures implementation)

short firearm, the threat was reduced by 57.1% and in the case of attack by the chemical released into the ventilation, an improvement of up to 76.2% was achieved. See Fig. 19.6.

For RPN coefficients with value above 100, immediate countermeasures were set and a root cause was determined (Fig. 19.6). Consequently, permanent measures have been introduced to reduce the frequency of occurrence and consequences of the undesirable event. Efforts were to find such measures that would reduce the RPN value below 100 points. The attack by the vehicle driven into persons at the bus stop in front of the BEC, the attack by suicide bombers, the attack by placing the explosive in abandoned luggage and attack by acid scourging – the threat level was reduced by 50%. The most significant positive change was the implementation of mechanical protection system of the access to the ventilation system.

19.6 Conclusions

In general, it can be said that soft targets are not protected in any country sufficiently. Soft targets cannot be protected by police or other unit from the outside from capacity reasons. They always require the active cooperation of all entities located in a vulnerable place. Objects categorized as soft targets are always different because each object has its own specifics that are reflected in different changing values.

For all soft targets, however, the same principles for enhancing their resilience are valid which can be characterized as follows:

- Know own security features and character – analyse what or who is to be protected and against whom, to define strengths and weaknesses.
- Methodologically set up security development – identify threats, define scenarios, assess the probability of occurrence and possible impact of threats, define security measures, determine competencies and responsibility for measures and practice the relevant scenarios regularly.
- Define measures to prevent and mitigate impacts – early detection of a threatening attack and defining measures for subsequent mitigation of impacts on protected interest.
- Involve unskilled staff – co-operation and involvement of local staff, e.g. assistance with adherence to preventive measures and reporting suspicious activity.
- Standardize security procedures – the exactness and system of the actions taken in every situation and for everyone (mainly evacuation, designation of a secure temporary hide place, . . .).
- Elaborate Management Coordination Plan – allow to limit stress-related mistakes in respective situation, division of tasks among more persons and so eliminating dependence on one person, a clearly formulated way of communication, appointment of a coordinator with his/her representatives.
- Increase security awareness – through regular training, familiarizing staff with likely scenarios, practicing procedures.
- Collaborate with the Integrated Rescue System (IRS) units – allow to inspect the object, involve appropriate units in the preparation of security actions, inform about suspected and security incidents.
- Implement rigorous authorization and entry control – enable detecting intentions of violent activity, detection of suspicious behaviour, physical control to detect the weapon, preventive security interview and others.

- Analyse surroundings and work with other soft targets – create communication channels with surrounding entities, share information and etc. [3].

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Chapter 20
Security Risk to Filling Station

Katarína Mäkká, Katarína Kampová, Darina Stachová, and Katarina Petrlova

Abstract Within this contribution we want to point out that filling stations, as endpoint of gas and oil cycle, in view of the attractiveness can be attractive target for terrorists because of the ensured media attention. Due to the low level of security against violent attacks (lack of presence of security personnel or police at the filling station), public accessibility and the content of a large number of flammable liquids (relatively readily available during the loading process) are easy targets for terrorists. In general, this means that a deliberately initiated attack in the filling station area will have negative consequences for the life and health of the population. Precisely, the modeling of terrorist attack and its negative consequences on the life and health of the population was a foundation for all other theoretical and practical activities performed within this contribution.

Keywords Filling station · Soft target · Security risk

20.1 Introduction

Crisis phenomena are part of the everyday life of a society that has to deal with the consequences of anthropogenic and natural, economic, technological, social and other crisis phenomena and adequately to react. The security situation in Europe is fundamentally affected with massive migration of population, the metropoles of the countries are increasingly targeted by terrorist groups, important institutions of the public and business sectors are trying to resist cyber-proliferation [1]. Attackers are targeting objects that fundamentally reduce the functioning of the state, most often attacking transport and energy infrastructure, cultural and sporting events, major

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L. Hofreiter et al. (eds.), *Soft Target Protection*, NATO Science for Peace and Security Series C: Environmental Security,
https://doi.org/10.1007/978-94-024-1755-5_20

state and political institutions, and other objects, with the intention of causing fear and panic, disrupting the critical infrastructure of the state and, last but not least, to point out the strength of theirs organization [2, 3].

All sectors of the oil and gas industry might be subject to various terrorist threats. All people, as well as terrorists groups, are well aware of the importance of constant supply of oil and gas materials worldwide. The whole oil and gas supply chain, such as exploration sites, piping systems, refineries or the distribution stations might be easy target for successful attack.

Performed analysis of the logistical requirements for ten likely attack scenarios shows that most of the attacks are within the field of international terrorism groups [4]. International terrorist organizations have made several successful attacks on energy infrastructure sector. Therefore, the question of the possible scenarios of attacks against the oil and gas industry, can be raised. The probability of successful attack on the oil platform is very low [5]. On the contrary, a higher probability of success can be achieved by a coordinated number of attacks on filling stations.

20.1.1 Soft Targets and Their Classification

In the literature, there is no uniform definition of the term "soft targets" is defined in a variety of ways, and there is no uniform definition. Soft target is commonly referred to places with a high concentration of people and a low level of security against attack. Such targets are currently very attractive, especially as targets of terrorist attacks.

On the other side, "hard targets" are well protected areas, such as government buildings, military areas, law enforcement agencies, as well as some well-protected and guarded non-governmental or commercial facilities.

The society's focus on protecting soft targets reflects an innovative approach to safety management. As part of this approach, more attention is paid to the perspective of the attackers and the probability of attack rather than its impact and social consequences is being examined.

Soft targets can be categorized by functionality [6]:

- schools, dormitories, canteens, libraries,
- religious sites and places of worship,
- shopping centers, market places and commercial facilities,
- cinemas, theatres, concert halls, entertainment venues,
- gatherings, parades, demonstrations,
- bars, clubs, dance clubs, restaurants and hotels,
- parks and squares, tourist monuments and places of interest, museums, galleries,
- sporting arenas and stadiums,
- important transportation sites, railway and bus stations, airport terminals,
- hospitals, medical centers and other health care facilities,
- public meetings, pilgrimages, fairs,

- cultural, sports, religious and other events,
- community centers [6].

Based on the above classification, it should be noted that the safety plan as a safety management document must be handled separately for each individual object and must include the subject's specifics and safety requirements for that object.

The main criteria included in the security plan of object, which should define the final solution of protection, are the suitability for the potential attacker and the feasibility of the security measures. These bases of the criterion include several significant factors that must be within the scope of the protection plan considered:

- public accessibility,
- security personnel,
- many people concentrated in one place,
- presence of the police force,
- presence of the media,
- symbolic value of the target [6].

20.2 Security Risk to the Filling Station

The distribution process of the fuels is basically an open system [4]. In the fuel transport process the most vulnerable component, the truck, is visibly marked as carrying hazardous, flammable products. Because of this, every truck is highly visible in the traffic flow. The process of fuel transport by road has periods where vehicles are stationary during loading and unloading or parking. This increases success of an attack as compared to a moving target.

Filling stations are generally without significant physical security [4]. In addition, they are situated in densely populated areas, which increases the number of potential victims in the event of an attack. Moreover, environmental damage resulting from uncontrolled leakage can be perceived by terrorists as "added value".

Based on the above-mentioned idea that filling stations, may in some circumstances, be consider a soft target a study of a particular filling station was carried out. Purpose of this study was to assess the risk of a terrorist attack and model its negative consequences.

In order to carry out the case study it was necessary to obtain basic operational and technical information about the filling station object. The filling station is located in the cadastral area of Žilina on a separate plot of land on Kysucká cesta. Plot is part of an industrial-commercial of the town with a residential area of adjacent streets. The filling station area is adjacent to the south with the production facility complex, on the west with a multifunctional building housing residential, commercial and office space (Fig. 20.1). In the vicinity of filling station there is a highway connecting Žilina – Ľavobrežná, which serves as the main bypass of the city. Crossroads of the main road Bratislava – Žilina, the road Žilina – Čadca and direction Žilina – Martin is an important communication node with high traffic density.

Fig. 20.1 The area of selected filling station

20.2.1 Prognostic Modeling of Attack on Truck in the Filling Station

As an example, we model an attack on a stationary fuel truck at a filling station Attack occurred when the tanker was being unloaded into storage tanks. This event was modeled by the TerEx software tool. The results of modeling are presented in Table 20.1.

20.2.2 Effects of Modeled Attack on Truck

Explosive Effects of Gasoline In the case of leaking gasoline, a vapours from the puddle, acquire 60% lower explosive limit at D type atmospheric stability at a distance of 41 m from the leakage site. In the cloud explosion, vapours automotive gasoline driven by explosion will reach the impact of the airborne shock wave at a distance of 57 m from the point of escape. A direct contact with cloud will hit people at a distance of 18 m from the point of escape, severe injury will suffer people located in the vicinity of 49 m, the threat of persons by glass scrapes was set at 89 m. Explosive effects will damage buildings at a distance of 34 m from the point of explosion, which in this case may damage the adjacent building. For F-type atmospheric stability, the zones of danger due to the explosion are larger.

Table 20.1 Explosive and radiation effects

Effect	Consequences	
POOL FIRE	1st degree burns at a distance from the flame [m]	134
	Distortion of steel strength at a distance from the flame [m]	17
	10% mortality from the source[m]	77
	50% mortality from the source [m]	66
BLEVE	Range of fireball [m]	198
	Burning time [s]	13
	1st degree burns [m]	479
	10% mortality from the source [m]	259
	50% mortality from the source [m]	209
	Distortion of steel strength at a distance from the flame [m]	99
PLUME atmospheric stability D/F	Threats to people by direct contact with clouds [m]	18/59
	Severe damage to buildings [m]	34/68
	Threats to persons outside the building by serious injury [m]	49/89
	Threat of persons by window glass [m]	89/ 144

Heat Effects of Gasoline People at risk of heat radiation in a model fire variant are at a distance of 134 m from the flame and are characterized by first degree burns when humans are exposed to flame for 1 min. Fatal threat to humans by heat radiation in a model fire variant is possible within a distance of 52 m from the flame. 50% mortality of individuals was determined at a distance of 66 m from the reservoir. Radiant fire heat can disturb steel structures to a distance of 17 m, which will affect the construction of the filling station at most.

In the case of BLEVE effect, the diameter of the fire ball would reach max. 198 m and burning time was set at 13 s. Fatal threat to humans by thermal radiation in a model fire variant is possible within a distance of 235 m from the flame. 50% mortality of individuals was determined at a distance of 209 m from the tank. Radiated fire heat can be at risk for humans located within 500 m of the tank, resulting in first degree burns.

Toxic Effects of Gasoline When a gasoline escapes from the truck ´s tank during unloading, a pool from which petrol evaporates is generated around the dispenser stands. The substance under consideration does not have serious toxic effects on the human body, inhalation of gasoline may cause headaches, dizziness, nausea, and contact with the skin its irritation.

Table 20.2 Number of people in the filling station

Time	Number of persons in total	Number of persons outside buildings
8.00	20	8
9.00	25	7
10.00	38	19
11.00	32	9
12.00	39	11
13.00	88	55
14.00	19	9
15.00	46	22
16.00	31	17
17.00	40	15
18.00	26	13
18.30	15	10

Table 20.3 Estimated number of persons in the filling station area

Number of persons	N_{in}	N_{out}
Daily time	33	55

20.2.3 Estimated Number of People Being Present at Filling Station

The filling station is located on an area of 1500 m^2 and represents an area where people (employees, customers) can move freely. The presence of the persons is important for the calculation of social risk [7].

The presence of the persons in the filling station varies within 24 h, it is different in day and night. For the case study the daily time is considered. The persons estimate was based on a survey of the number of persons in the filling station during the day from 8.00 to 18.00 at 15 min intervals. Table 20.2 shows the average number of people present in the filling station during the day.

In the case of attack part of people would be in the filling station building (N_{in}), part would be outside the buildings at the dispensing stands (N_{out}). The consequences of modeled event would be diametrically different for both population groups [8].

In the worst case scenario, it is assumed that in the case of an attack on truck during loading, there are 88 persons in the filling station. In the handling area besides the tanker driver, there are four fuel cell drivers in their vehicles, as well as people moving freely in the filling station area – 55 people (bus tourists, capacity 66 seats). Therefore, 55 people outside the building are considered (Table 20.3). Other people are inside the filling station building.

Table 20.4 Estimated number of fatal injuries in the filling station

Number of dead	Inside	Outside
Daily time	5	56

Based on experience, it is possible to estimate the probability of injury to the persons inside and outside buildings. In the event of fire, it is assumed that people inside the building are protected from thermal radiation if the building is not ignited [9].

The fire threshold for the building is set at 35 kW. m^{-2}. In the model case of fire, thermal radiation reaches 35 kW. m^{-2} at a distance of 25 m from the loading point. If the building is burning, people are supposed to be protected from heat radiation by clothing for as long as the clothing does not ignite. The protective clothing reduces the number of deaths by a factor of 0.14 when compared to the absence of protective clothing, so the number of fatally injured persons inside the filling station building would be $33 * 0.14 = 4.62$. Persons outside building (on the handling area of dispensers) would be hit by heat in the event of a fire and fatally injured with the probability of $P_E = 1$ [10] (Table 20.4).

The number of fatally injured people during the day was set at 61 people.

It is clear that the final consequences of deliberate attack on truck with gasoline are inevitably linked to uncertainties that arise from the input data used, the chosen exposure factors, the estimation of the presence of the population and its behavior during the occurrence of an attack. Therefore, it is important to take into account the uncertainty and extrapolation inaccuracies that are associated with the estimates and calculations made [11]. Assessing the consequences of deliberate attack and determining the social risk that may be limited by: used software, input data, limited application of acquired data, and the presence of the population in the filling station or in the vicinity of filling station, from the behavior of persons at the occurrence of an attack.

Determination of toxic, explosion and radiation effects was also a surprise for the station's managers, as the emergency plan of the filling station was developed only for the case of water hazard. It does not deal with the occurrence of an emergency event related to the leakage of fuel, ignition and fire during the unloading process.

20.3 Conclusion

Based on an analysis of terrorist attack consequences, it can be stated that filling stations as endpoint of distribution process of oil industry are attractive targets for terrorists. Terrorist groups are able to meet logistical requirements for successful attacks on filling stations. Coordinated attack on the filling stations will cause a significant disruption to the oil and gas distribution process. Security forces can't prevent this type of attacks due to the large number of such places in the country.

Ultimately, it will have significant socio-political impact on the national economy, as the oil and gas industry is a major component of every national critical infrastructure. In addition, filling stations are attractive for terrorists because of the ensured media attention.

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Chapter 21
Hostile Vehicle Mitigation (State of the Art)

Jan Holub and Pavel Maňas

Abstract This paper is focused on basic principles and used forms how to reduce risk of potential terrorist attack committed by vehicle as a significant threat to soft targets. Firstly is briefly outlined phenomena of vehicle used during attack on the soft target. In the second part of the paper are written main ways how to protect areas from hostile vehicles, mainly focused on creating of safe perimeter.

Keywords Hostile vehicle · Soft target protection · Vehicle-ramming attack

21.1 Hostile Vehicle

The use of civilian vehicles as a possible weapon is a phenomenon whose potential risk has been rising again in recent years. Use of the vehicle (at that time the horse-drawn carriage) as the explosive carrier, can be found in the aftermath of the First World War, when the attack on Wall Street was carried out in 1920. This attack can be seen as one of the first VBIEDs (Vehicle Borne Improvised Explosive Device) when about 30 people died and another 148 were injured [1]. The first use of the vehicle as SVBIED (Suicide Vehicle Borne Improvised Explosive Device) was in 1927, when a local farmer killed 44 people, including 38 children [2]. The first use of the vehicle, itself as a weapon, when the attacker drives the vehicle into a crowd is considered to be an attack by Olga Hepnar in 1973, when she rammed with the truck to the tram stop and killed eight people.

There have been dozens of other cases when vehicles have been used as carriers for explosives. In the nineties of the twentieth century, one of the greatest attacks was carried out using an explosive-filled truck in Oklahoma City. In response to this attack, the US government issued a regulation to increase the protection of federal buildings from possible terrorist attacks. For new buildings, manuals are issued to

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L. Hofreiter et al. (eds.), *Soft Target Protection*, NATO Science for Peace and Security Series C: Environmental Security,
https://doi.org/10.1007/978-94-024-1755-5_21

provide designers instructions how to achieve the required level of protection for the given conditions. For example, the Department of Defense provided UFC (Unified Facilities Criteria) documents on the WBDG website (Whole Building Design Guide) [3].

Vehicle-ramming attacks have also increased recently. The last time, one of the leading truck attack, was during celebrations in Nice in 2016, and the attack in Berlin in the same year on the Christmas markets. Information about these attacks has been sent worldwide and could have inspired further attacks.

21.1.1 Hostile Vehicle Threat

The danger of using vehicles as a weapon is mainly because:

- requiring minimum training and skills of the attacker;
- of easy accessibility of vehicles;
- it could be done without any logistical background (no connection to any other person, illegal material, etc.);
- it is difficult to predict and prevent them;
- having a high moral impact on society.

The use of the vehicle itself as a weapon is currently becoming a more popular strategy for so-called “lone wolves” and persons planning to commit a violent act, without links to a larger organization.

Most public areas are free of any protection from possible vehicle-ramming attack, currently. Certain protection occurs around government buildings and new buildings complexes. Around government buildings it is a reaction to the dangers of VBIED in the most cases, but it has also the effect of reducing possibility of vehicle-ramming attacks. In the case of the new buildings complexes there are often both measures.

Overall in the western world, the use of a vehicle as a weapon could be considered more dangerous than the use of explosives only. Even because the construction of a functional bomb is more demanding and easily traceable than attack caused by vehicle. The chemicals used to make explosives could be at least partially controlled by their sales, while vehicle sales and lending could be regulated hardly. In addition, the use of a bomb could have been less effective than the terrorists expect in the attack, because it is hard to predict fragments spreading.

The most vulnerable to hostile vehicle attack are areas where a large number of people are concentrated and there is no limitation of vehicle access. On the other hand, government buildings and public administration sites are not so frequent places to hostile vehicle attack. That could be attributed to the fact that some of the measures to increase safety have often been implemented in these buildings. Here, we could see the trend that attackers are choosing easiest targets with minimal protection and the greatest impact on human lives.

Possible targets are mostly places where more people are concentrated with no, or minimal protection, such as:

- stations and public transport stops;
- pedestrian and rest zones;
- assemblies and public events;
- shopping centers;
- sports stadiums;
- schools.

A high concentration of people could be expected at a predictable time, along with the minimal possibility of armed security forces presence which could potentially prevent the attack, at these locations. That are reasons, why these sites appear to be suitable places for a possible attack.

21.2 Methods of Protection

Methods of protection against VBIED and the vehicle-ramming attacks are basically very similar. One of the main principles of protection is to increase the distance between places available by vehicles without any limitation and protected area. In the case of VBIED, every meter of distance that the eventual exploding vehicle is further off reduces the effect of blast wave on the target, and in case of fragments the risk of being hit and impact energy is reduced. To increase the distance from a protected object, one of the basic ways is creating a physical obstacle to prevent the vehicle from getting closer. For this purpose, it is mainly used:

- bollards;
- concrete elements;
- trees;
- fences and railings;
- urbanistic elements.

These individual elements will be described in more detail below, in text.

Another option for increasing protection is the changing our behavioral. One of those is the introduction of regime measures related to the physical protection of given areas. Another is changing of way how we designed public spaces.

In the case of VBIED, it is possible to increase the protective properties of buildings by using the principles of protection against blast wave and possible fragments. However, this issue is so extensive that this work will deal only with the creation of a safe perimeter and thus an increased distance from protected areas. The fact that a citizen could detect any possibly danger increases the possibility to alert security forces before the attack actually starts.

21.2.1 Behavioral Measures

One of the basic means of enhancing security, as like with other types of terrorist attacks, is the change in our approach, both at the level of individuals and the whole state apparatus.

The first of these measures may be public awareness in this case. The government of Australia that on the webpage of the Australian National Security Agency [4] gives a number of manuals. On how to behave in places with a greater concentration of people where a terrorist attack is threatened, for example. In these manuals readers learn the basics of the issue and possible measures against specific dangers. The informed public has a better chance of responding adequately to the dangerous situation.

States are debating whether an increase in the number of armed civilian by small firearms can help to eliminate an attacker and reduce the total loss of life. On the contrary, it could increase the availability of weapons for potential attackers and the possible increase the number of crimes committed by weapons. If this possible correlation in not taken in account, an armed civilian is more capable of stopping a possible attack, rather than an unarmed civilian. It is also because it is not uncommon for the attacker to continue in the attack with a firearm or with a cold weapon. In this case, an armed citizen may stop the attack before the units of security forces reach the attack site, and may eventually stop the attacker from an escape from a crime scene.

Limitations on the Vehicles Availability Trucks are the most dangerous for hostile vehicle attack, as in the case of VBIED or vehicle-ramming attack. There is possible to establish within the individual states the tightening of the availability of these vehicles for the general public. One of possibilities could be making it more difficult to rent such a vehicle. Certainly, a more thorough examination of a potential vehicle rental customer may be possible. In this case, any linking of the criminal records and vehicle renting could be considered as a privacy violation. However, if the trend of vehicle-ramming attacks continues, it could not be ruled out that some of the states will use a similar principle.

Another possibility how to limit access to vehicles, both freight and passenger, could be a medical examination for applicants for a driving license. There could be used a certain psychological examination for potential applicants when attempting for a driving license to identify assumptions about aggression and violent behavior. Alternatively, the applicant would bring an extract from the police records from where applicant for a driving license would not be able to obtain a driving license in the case of repeated acts of violence and aggression, or if he had already lost his driving due to aggressive or violent behavior in the past. That measure could also result in a consequent reduction of the road accidents in general, because of the aggressive drivers are more likely to exceed the speed and riskier behavior on the road, which both holds the leading position in the causes of traffic accidents. There could be argued if these measures would have the intended impact or lead to disproportionate administrative burdens and repression of citizens.

However, the introduction of these measures does not mean that a potential striker does not get access to the vehicle. There is always a chance that a potential attacker could obtain a vehicle through crime, such as the attack in Berlin in 2016. There the attacker killed the truck driver and then, using that truck, committed a terrorist attack on the Christmas markets in Berlin, where he killed 12 people.

Regime Measures If it is evaluated to be desirable, it may be decided to use the regime measures in the protected area. These may concern the use of guardians and technical means or both.

One of the basic elements of protection using this method are guarding posts where each vehicle must enter the guarded area. This implies creating a perimeter that cannot be circumvented or disrupted. That perimeter is usually created by a physical barrier that prevents unwarranted entrance by vehicle created by barriers such as posts, fences, walls, height division, etc. In case of a VBIED attack, the distance from the protected object is the decisive factor. It is important whether the vehicle could not enter the perimeter without suffering the decisive damage.

For the entrance, there is the decisive ability to stop the vehicle before entering the protected area itself. This is mostly achieved by some of the active protection features such as pull-out posts, rising feet, sinks, gates, etc. These can be controlled by the operator, guard or the user with the appropriate entry privileges, for example, with chip cards and security codes.

Regime measures could be introduced for a certain period of time only and even at places not originally intended for this purpose. This may be a temporary increase of security measures on a specific event or within general increasing of the risk of an attack. There you can use some of the mobile elements supplemented by a guard post. in this case, even in the case of permanent guard posts, the human factor of the guards play an important role, such as their abilities and training, as well as the level of security means, such as their toughness, technical condition, etc. When the guard is armed and trained, the ability to stop a possible attack and to disable offenders is increasing.

Using of the CCTV could decrease the number of security staff, however possibly could increase duration before guard intervention and probability of human failure due to inattention.

Public media can be used on a massive basis to inform about increasing security measures, such as police exercises, when train interventions against a possible attack. These messages can cause fears for the attacker, and discourage him from making an attack, or at least delay him, giving the security forces more time for his eventual disclosure.

Deterrent Elements If the security measures are obvious at first glance, the attacker may be deterred from any attack. One of the basic principles is to increase the number of security staff. This approach is also referred as a demonstration of strength. Increased occurrence of security staff can also potentially neutralize the attacker before attack or almost immediately after the attack itself.

Another option is to place the security features so noticeable that they are clearly visible. For example, it could be used distinctive colouring of protective measures, to place warning signs on protective measures, etc. This procedure can be used also for the elements whose ability to stop any attack is basically small or whether it is a dummy measure.

21.2.2 Perimeter

The basis for creating a perimeter, is a system of passive elements creating a physical barrier that prevents the vehicle from getting close to the protected object. Active elements could be used for appropriate level of security where vehicle entrance into protected area is necessary. For proper operation, the use of high-quality materials is necessary to ensure the sufficient toughness of the protective elements. The work of Štoller and Zezulová [5] could be used for the review. There are currently many projects that are looking for other ways to create the most effective protective features with the help of innovative ideas and materials. There is also an effort to incorporate the security features as much as possible into space to become part of the architectural design of the site. The exception is the elements designed to present security measures and, on the contrary, intended to discourage potential attackers.

There are standards to determine the level of protection for a particular element. However, these standards are not often unified within a single state, and different testing methods and subsequent designations for the toughness of individual elements may occur. For example, in the US, SD-STD-02.01, Revision a [6] and ASTM F 2656 [7], which should replace it, are the most commonly used standards. Many companies still categorize level of protection by SD-STD-02.01. The conversion between these standards can be quite simply expressed as follows:

- K12 = M50-P1;
- K8 = M40-P1;
- K4 = M30-P1.

For a broader overview could be used the WBDG webpage [8] where the comparison of these standards is more subdivided. Conversely transfer between other standards are not as simple as between US ones. For example, the transfer between the British PAS 68 and US standards is not straightforward due to it uses different test vehicle weights and a different impact speed. Therefore, it is necessary to use the barrier according to the standards accepted by the respective states.

Because of the difficulty and financially demanding, the field testing is usually reduced to necessary minimum, it is desirable to create simulation model of security element prior to creating the prototype with respect to the relevant standard. In the case of the use of modern computing software, it is possible to model the blast wave propagation and design elements against it also [9].

Changes in Architectural Urban Design An increase in security measures is frequently being applied during planning, with the help of appropriate design elements for architectural features, at present. Certain advice and suggestions for designers can be found in manuals or country-specific handbooks. These recommendations are mostly of a general nature and could be applied independently on the territory, so designers can be inspired by recommendations across countries. These principles could be described as filling space by the obstacles to prevent vehicles from entering protected area generally. Thereby meeting the requirement to increase the distance from the protected object or territory, or at least reduce its speed and thus reduce the potential impact of the attack.

It is possible to use elements that would be directly identified as an obstacle to vehicle entry, or have another primary function, and the obstacle function would only be secondary. Whatever the primary purpose of an element is, an adequate aesthetic integration into a space, which does not interfere with the overall concept of the project, could be achieved by the appropriate design. Arsenal Football Club's Emirates Stadium is the example of this appropriate design. Vehicles have limited access to this stadium. It is achieved, for example, by the use of concrete planters, steel sculptures, which are the hallmark of the club and large concrete letters, which create the name of the club and prevent the car entering the pedestrian zone around the stadium. Overall, changes in urban design could be observed to reduce the risk of a possible terrorist attack [10].

To increase security following examples could be used:

- concrete flower pots;
- sculpture made of concrete or stones;
- steel bollards;
- planting of vegetation;
- ornamental earth bank and walls;
- fences and railings;
- reinforced urban elements;
- different height divisions;
- minimize straight sections;
- appropriate layout of parking spaces;
- built-in active elements.

Some of these measures will be described below, due to the fact that some of these elements could also be used for sites already built where it is desirable to increase level of protection. On the other hand, some measures increasing protection are additionally difficult to realize, for example using different height division. In order to rebuild already existing premises, it is necessary to consider if the measure is appropriate for a particular site or if a more suitable alternative must be founded.

Height division may be an appropriate tool for separating pedestrian zones from communication sites. This includes the use of ramps, stairs, cascades, but also water elements, such as various imitation of rivers, ponds, etc. For sufficient safety it is recommended to create a minimum height of at least 500 mm. In the case of ramps, it is desirable to ensure that the start of the ramp is protected from the possible entry of the vehicle on it. Possible escape of the endangered people would be even more limited on a ramp. Protection of a ramp could be achieved, for example, by fitting a concrete flower planter at the beginning of a ramp, positioning ramp where is not possible to drive, or design ramp in such way that do not allow the vehicle to turn on it. In the case of stairs, it is necessary to consider if their height is sufficient that is not possible to go upstairs with the vehicle. The possibility of a car driving down from them should be limited as well. It can also be used, for example, to lower the road ahead of the pavement curb, which will be used as a water drainage channel. This can lead to an increased height step between the road and the sidewalk. That can cause damage to the attacking car or at least slow it down. Those measure could also be applied when new stops for public transport are created and where the whole stop could be elevated. The negative aspect of this measure is risk of pedestrian falling and consequent injury.

Appropriate layout of parking spaces could also achieve some protection against vehicle-ramming attack. Parked cars create a certain barrier to access in the sidewalk or the pedestrian zone. Currently, in some cities there is a lack of parking space, so it is likely that a significant number of parking places will be occupied. Possible gaps should not create sufficient space to drive with the vehicle at high speed without collision and in the event of a collision, the vehicle should be damaged or at least slowed down. The effect on trucks will be significantly smaller in this case. On the contrary, there is a greater risk of using a vehicle like VBIED.

However, for public spaces is premise that there is still a possibility of vehicle transit, for example for supply or for emergency vehicles. One of the possible ways how to reduce risk in these places is to minimalize the direct stretches. In the case of the newly created pedestrian zones where direct stretches would be minimized, the attacking vehicle should not be able to increase their velocity unduly. It could be achieved by appropriate divisions, for example, using chessboard arrangement planted trees or other architectural elements. These obstacles are called “chicane”. Necessary changes to the direction could be used, for example, to enter in the zone with another active barrier. The vehicle entering to the area is forced to change the direction and slow down. Benefit is that active security element have not be dimensioned in the same way as to prevent the vehicle access in the full speed (Fig. 21.1).

A properly designed railing can also limit the vehicle from driving into the crowd. The stopping action of the railing can protect both from the eventual entry of the vehicle on the sidewalk and reduce the possibility for the pedestrian to enter the road where it is not desirable. In this case, it is necessary to design a sufficient massive and deep anchorage together with a sufficient strong rail construction. This measure is particularly suitable in places with a high frequency of vehicle movements, such as public transport stations and stops along the frequented roads, where more often happens unintended accident than deliberate attack.

Ornamental earth banks and walls prevent not only by vehicle-ramming attack into a protected area, but also reduce the risk caused by VBIED. The height of these earth banks is recommended 900 mm in the case of a perpendicular base and 1200 mm at a base with a minimum angle of 50° [4]. It is possible to divert part of the impact of the blast waves in the lower floors by using the earth banks. It can be used in cases, where there is a bigger concentration of people on the ground floor, as

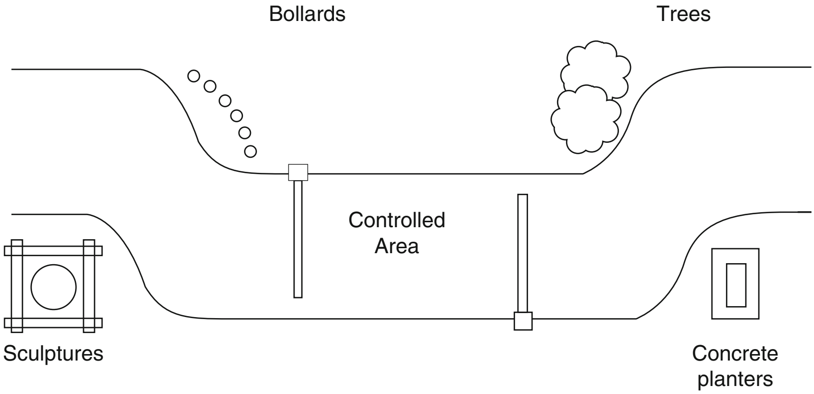

Fig. 21.1 General idea how to use chicanes (figure is not in the scale)

opposed to higher floors. Trees or shrubs can be placed on the top of the ornamental earth banks, increasing the aesthetic value of this measure. Planted vegetation, if it is in the sufficient density, can also reduce the effects of the blast waves and fragments spreading.

Overall, by an appropriate design could be created a space where the risk of possible hostile vehicle attack will be minimized without disrupting the appearance of the environment. The integration of protective elements is also desirable for psychological reasons. If the user is not aware of the security features, they do not feel threatened by the attack and the place could create a positive atmosphere.

Bollards Currently used elements are bollards. The reason for their use is their form, which does not disturb the character of the contemporary architecture, the inhabitants have become accustomed on them already, and their small size do not reduce the usability of the surrounding area (Fig. 21.2).

Bollards are mostly from steel, but bollards from reinforced concrete could also be used. The advantage of steel bollards is their greater resistance, but the disadvantage is their higher purchase price. A certain compromise is a steel tube filled with concrete. To ensure the required durability, it is necessary to firmly anchor the bollards in the ground. For concrete pillars, an extended base of the foot is used, with the sufficient deep foundation. For steel posts, a steel flange is included in the foot, which extends the area of contact with concrete, and ensures the distribution of forces in the bearing. Not only the width, but also the depth of foundation is important. So far, there are not many studies on the impact of the subsoil on the overall resistance of the foot. However, it is advisable to provide sufficient compacted subsoil and minimize disturbance of the subsoil in the vicinity as it is possible.

Bollards are mostly tested for impact by a vehicle in form that there are several bollards in a row. The impact is directed to the axis of the vehicle, so the main impact force is stopped primarily by the one bollard. However, in the case of a terrorist

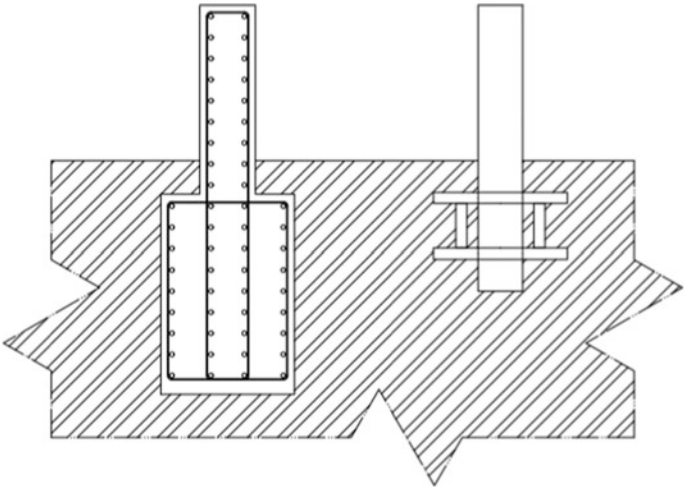

Fig. 21.2 Example of bollards foundation (figure is not in the scale)

attack, it could be assumed that such an intervention would not occur. The individual pillars must therefore be sufficient to ensure stop the vehicle. The recommended maximum distance between bollards is 1200 mm. In this case, is not intended to use again motorcycles or non-standard narrow vehicles. In places, where such attack could be, the bollards could be joint with cables or chains. Using such a procedure, interaction between the surrounding columns could be expected, and the impact loads resistance could be increased.

Bollards may be permanent or non-fixed. Non-fixed bollards are used if there is a need to secure access and only a temporary opening or closing of the entrance is expected. These bollards could have foundation covered with the plug. If it is needed, the plug is opened and the post is attached. Another option is a collapsible post, which could be stored in a bed and, if necessary, erected and locked in the active position. Others may be removable, which are further included among the active elements.

Concrete Elements Concrete elements as a barrier are often used in connection with the architectural design, when the element is mostly aesthetic or other useful. It could be various statues and sculptures, concrete flower planters or blocks that can also serve as a rest place for the inhabitants, whether benches are installed or not.

Anchoring is important there, as with bollards. The advantage over the bollards is usually the greater weight of these elements and the higher stopping capacity associated with it. It is also important to correctly design the reinforcement with respect to the expected direction of impact load. In the case of smaller elements, it is advisable to consider joining them to interact together, as described above for bollards.

Planting of Vegetation Appropriate planting of vegetation could create a barrier. Grown trees is considered to be a barrier against vehicle-ramming attack. The effect of this measure would be more effective on personal vehicles and it would be more a psychological effect on the driver in the case of trucks. It always depends on the specific size of the tree and the way how it is settled. Using grown trees as "chicane" could be achieved that the vehicle is forced to change direction and consequently it reduce speed. Planting already grown trees can be used to complement other elements in the perimeter. Planting of the vegetation to pedestrian zones is generally desired because of the positive appearance of the environment.

Shrubs and the other greenery may be suitable to reduce the effects of the blast wave and reduce spreading of the fragments. The density of the given crop is important. It is advisable to use evergreen plants in given climatic conditions.

Compared with the other passive elements, regular care have to be given to greenery throughout the year. It is necessary to secure irrigation, care for plant health, and possible cutting and forming due to growth. Appropriate design of the CCTV should also be considered, in the case of planting vegetation and their growing. It is not desirable for vegetation to create blind spots in the camera system. in the case of deciduous trees, it is also necessary to ensure that the leaves are cleaned and that there is no clogging of the rainwater drainage system.

Urbanistic Elements Common urban elements, such as benches, trash cans, stops, street lighting, etc., could also be used to protect citizens from hostile vehicle attack after appropriate adaptation. Generally it is important, for these elements, to have a reinforced structure capable of withstanding the impact of the vehicle or damaging it and slowing it down at least. It is necessary to perform software simulations, ideally undergo field testing.

In the case of the installation of reinforced trash cans, it is possible to increase their safety potential by a special trash can body which is bomb resistant or at least to redirect the explosion into the desired space.

At public transport stops there is a high concentration of people and it is appropriate to reinforced them accordingly also. It could be made by height division, by the railing, or the construction of stop itself could be reinforced to reduce the consequences of the hostile vehicle attack.

Mobile Elements Mobile elements would be commonly used to build barriers to protect the area, if additional security measures need to be added. These mobile barriers are used in case of the public events, or can often be seen as a follow-up to one of the attacks, as was in the case after the terrorist attack on the Christmas markets in Berlin.

Basic ones are concrete roadblocks often referred as Jersey barrier. Their advantage is the low cost of production, the disadvantage is the need of machinery to handle them. These barriers are primarily designed to redirect the impact of a vehicle, and they are not fully effective, in the case of a direct impact. They are also unable to stop truck, if they are not anchored properly. Unanchored Jersey barrier could absorb only force caused by impact of the vehicle as is great their force caused by gravity and friction between barrier and the basis of the barrier. If a strategy of two vehicles is used during the attack, when the first vehicle breaks the barrier and the other goes behind it, one barrier alone is insufficient protection. It is necessary to anchor the barrier to the ground, or at least to connect multiple individual barriers together to increase the weight and overall resistance of the system, in order to increase level of protection.

Water-filled plastic roadblocks could be only used for reducing speed and they are not providing sufficient protection against trucks. It is necessary to connect multiple water-filled plastic roadblocks together.

That danger of hostile vehicle attack is currently up to date illustrates the fact that Hesco also introduced the Terrablock series, designed for the urban environment [11]. It is the modification of the classic MIL units, redesigned to better fit with its appearance into the urban environment. Terrablock units can be supplemented with anti-climbing protection or pedestrian and vehicle gates. The advantage of this system is easy transport. It is because of the units are transported in the folded state and they are unfolded on site. The disadvantage is the necessity of filling of the units. Material for filling have to been brought to the given place, with the help of a truck, and then filled either by hand or mechanization. This system is suitable for long-term use. The subsequent emptying, folding and transportation of the units together with the filling material does not appear to be beneficial for frequent displacement.

Active Barriers Active barriers are those perimeter elements that could serve as a passive element of a barrier or could be "deactivated" in the case we need to allow certain vehicles to enter the protected area. The advantage of these elements is the possibility of their "deactivation" (or activation) according to the needs of the security staff or by using other control options such as input cards, codes, etc. the disadvantage of the active barriers is their higher purchase price and the necessity of maintenance. Active barriers are used only where it is necessary and most of the perimeter is made up of passive elements only. The active barriers could be usually found in entrances, often supplemented by a guard post. The security staff there could allow access to the protected area after the vehicle has been inspected.

The appropriate activation time is, from full insertion to full extension, between 3 to 12 s, for active elements. Some of active elements may work in the so-called "Emergency mode" when the time needed to full extension is even shorter. Further, the ability to work in cycles is evaluated, i.e. full extension and retraction, where it is desirable not to overheat the rising mechanism. The suitable mechanism should be considered according to the expected number of cycles per day. Each active element should be able to be manually operated into an active or inactive position in the event of an emergency, such as a failure of rising mechanism or a power outage. Another important criterion for choosing the right active element is the depth required to founding the element correctly. For example, the bollards usually have a greater foundation depth than wedges. This parameter can be decisive, if there is an engineering network under the place where would be the active element built.

It seems to be advantageous to interconnect the active barrier with a detection system capable of evaluating a potentially dangerous vehicle and independently deciding to active the barrier. There could be a normally accessible area where it is not necessary to have a guard on the active barrier, but in the case of imminent danger, the software could evaluate the potential risk in a timely manner and trigger the immediate activation of the security element. In the case of sufficiently sophisticated software, the human factor hazards are eliminated and the time required to activate the device will be significantly reduced.

The US Department of Homeland Security has issued a manual dealing with active barriers for protection against hostile vehicle attacks, where the basics of this issue are further elaborated and serve as assistance to select the appropriate active element [12]. An Excel worksheet in which a basic database of features offered in the US is produced, in the case of a project originating in the US. This workbook could be taken as informative, for other countries. This workbook could also be found on the US Department of Homeland Security website [13].

Extending wedges are iron plates that rise at an angle from their bed. They are attached to the bed aside from the vehicle. The wedges are lifted hydraulically or pneumatically. Some types are for greater structural strength equipped with chains, on the rising parts. That help the wedge to cope with high load from the impact of the vehicle and take part of the impact energy. If the wedge is in the upright position, it is supplemented with warning signs and warning colour to prevent possible oversight.

The traditional active barriers are gates and drop arms. It is a reinforced version of commonly used devices, where it is important that both sides would be into reinforced frame or mounted in the closed state. Drop arms can be reinforced by cables inside of the drop arm which could help to stop the vehicle. The possible load on the steel rope by pulling could be higher than loading by bending for beam represented by drop arm. The rope is equipped with a mechanism that locks it in both supports when gate is closed.

So called "Tiger trap" as an active barrier is rather a theoretical use because it is not produced in series, at present. From active barriers is "tiger trap" among the most demanding and expensive option, both because of the complex construction, the size of excavation work, due to the depth of foundation, and maintenance. Therefore, use of this element is only for the protection of important objects where it is desirable not to disturb the appearance of the surroundings and it is not advantageous to use the wedges. The advantage of this system is high stopping ability. In addition, it is necessary to expect more demanding maintenance because of the complex construction (Fig. 21.3).

An innovative system is the use of special net to stop vehicles that have high stopping capability. At lower speeds the system do not cause injury to driver, in many cases, the airbag will not be activated even. The function is based on two supporting pillars between is placed the net, which laid in the bed. The net is pulled out above ground level between the pillars, in case of activation. Low speed vehicles could be captured without serious damage. The vehicle will be seriously damaged, if is captured in high speed. This principle could also be used against boats where the net is in a quiescent condition below the surface [14].

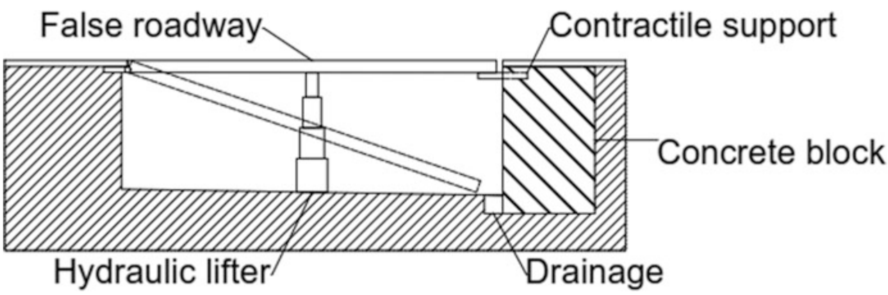

Fig. 21.3 Active "tiger trap" sketch (figure is not in the scale)

21.3 Conclusion

This paper is focused on the state of the art of measures that can be used to mitigate impact of hostile vehicle attack. That phenomenon has recently begun to emerge again. Therefore it is necessary to be prepared that this phenomenon would be probably present in our society due to the worsening security situation across the world and the radicalization of ever larger groups of the people.

Four people have been killed as an average per attack, over the last 10 years. The statistically significant impact is made by the Nice attack, where was killed 86 people, including shooting after vehicle-ramming attack. However, this type of attack affect the lifestyle of our society, and it is therefore appropriate to take action to protect the citizens. As has been outlined in the work, it is currently best way to apply the protective elements as part of the architectural solution of the newly created spaces, where the passive barriers of the perimeter would be supplemented by automated active barriers.

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Chapter 22
Participation of the Armed Forces of the Republic of Poland in Crisis Management

Slawomir Mazur, Monika Ostrowska, and Cezary Podlasiński

Abstract Crisis management is an indispensable element of national security and plays a very important role in the resolution of any security-related problems as well as the prevention of and preparation for potential threats. Since crisis situations of a non-military nature occur in every country, in order to ensure effective protection should they occur, joint action by several state bodies is required. The elements which support the non-military defence system are: the Police, the State Fire Service, the Border Guard, specialist rescue units, and the Armed Forces. The objective of this article is to present the options for utilising the Armed Forces of the Republic of Poland in crisis management.

Keywords Security · Crisis management · The armed forces

22.1 Introduction

Management is a system to help organize society can itself. It includes some elements of planning, evaluating present conditions and the ability to collect, analyse and process information to improve the quality of a specific field [7]. There are many definitions of management. It is very often defined in a specific context, since we can talk about private management (e.g. management of one's own time, abilities, etc.) as well as public management (e.g. managing company's resources, risk management, system management related to a specific field). It is a very broad term, and thus allows us to include in its scope a number of issues.

Crisis management is an indispensable element of national security. It plays a very important role in the resolution of any security-related problems as well as the prevention of and preparation for potential threats. It consists in the maintenance and restoration of stability to any given situation. Crisis management is characterised by

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L. Hofreiter et al. (eds.), *Soft Target Protection*, NATO Science for Peace and Security Series C: Environmental Security,
https://doi.org/10.1007/978-94-024-1755-5_22

purposeful action undertaken by governmental bodies at all levels of the state organisation, and employing specialised organisations, such us guards and inspections, as well as the general public [7].

The objective of this article is to present the options for utilising the Armed Forces of the Republic of Poland in crisis management.

In the context of crisis/crisis situation's targets we can specify two targets domains: hard and soft. Generally, hard targets refer to secured objects or areas that may include government locations, military premises, etc. Whereas soft targets are easily accessible to public i.e. shopping centers, transportation hubs (airports, railway stations), religious sites, entertainment centers (sport arenas, clubs/bars) and many more. From security perspective hard targets are both MoD and MoI/A responsibility, however, soft targets domain belongs usually to ministry of interior, regional/municipal authorities and further low enforcement entities i.e. police, municipal guard.

Obviously in severe crisis/crisis situations responsibility of soft target protection may be delegated to MoD and further to the Armed Forces, based on existing legislation and executive directives.

22.1.1 Crisis Management

According to J. Rogozińska-Mikrut, "crisis can be understood as a situation which involves a threat to the fundamental values, interests and objectives of institutions and social groups. The notion of crisis also includes situations in which the rights and liberties of citizens and their life and property are at risk. It is also worth adding that, as a rule, a crisis covers a substantial area and continues for an extended period of time" [6]. Its causes can be external (military operations, economic phenomena) or internal (catastrophes, strikes) [2]. On the other hand, in order to determine whether an event has the characteristics of a crisis, the above-quoted author uses the term 'the severity of the crisis'. She closely relates this notion to "crisis", as it facilitates the drawing of the characteristics of a potential crisis in terms of time and scale. "The severity of the crisis is a derivative of two values: the scale (magnitude) of the threat and the time which passes from the moment of signalling the possibility of a given event to its occurrence. This assessment can change to a very large extent" [6].

Nowadays, a crisis is often, wrongly, associated with a crisis situation. E. Nowak argues that this is untrue and goes on to list three factors which allow us to differentiate between a crisis and a crisis situation. The first factor states that crisis is part of a crisis situation. The second factor: all crises are crisis situations, but not every crisis situation involves a crisis. The third and last factor, according to the author, is the very differentiation between a crisis and a crisis situation. The appearance of symptoms of a crisis does not have to disturb the core of the organisation, but does pose a challenge to the subjective state of normality of its operation [4].

Crisis management is an activity pursued by public administration bodies, which forms part of national security management. It consists in preventing crisis situations, preparing to take control through planned actions, responding to crisis situations, removing their effects and recreating resources and critical infrastructure [14].

Sienkiewicz P. and Górny P. define crisis management as a "decision-making process aimed at selecting a rational strategy to counteract real and/or potential crisis situations. It is a manner of managing the specific resources of the system, ensuring recovery from the crisis, or maintaining normality despite the occurrence of symptoms of a crisis situation." [7].

Crisis management is characterised by rules facilitating the effective implementation of statutory tasks. These are:

- The rule of territorial primacy – which means that the territorial division of the state forms a basis for the operations of authorities.
- The rule of one-person management – one-person bodies are authorised to made decisions and are responsible for them.
- The rule of public authorities' responsibility – in crisis situations they take over the decision-making competences and responsibilities.
- The unification rule – awarding the administrative authorities with overall power guaranteeing that their duties will be fulfilled.
- The universality rule – crisis management is organised by public authorities in collaboration with the existing specialist institutions and organisations, and the general public; furthermore, a public authority may impose an obligation to provide in-kind or personal services.
- The threat categorisation rule – the division of threats into groups by type and size, as well as assigning legal, organisational and financial solutions.

The process of crisis management is composed of two periods. The first is the stabilisation period, and includes prevention and preparation stages, i.e. taking action before the crisis situation takes place. This period encompasses all the organisational actions taken at all levels of government, the preparation and implementation of projects preventing potential threats, and the development and implementation of operational procedures. The second period involves implementation including the response and reconstruction stages [19].

22.2 The Organisational Structure of the Armed Forces of the Republic of Poland

The organisational structure of the Armed Forces of the Republic of Poland is hierarchical in nature. In time of peace, commander-in-chief of the Armed Forces is the President of the Republic of Poland, who fulfils his duties through the Minister of the National Defence. Until January 2014, i.e. the amendment of the Act on the Office of the Minister of National Defence and some other acts, the Armed Forces were administered by the Chief of the General Staff, to whom the Armed Forces General Command was subordinate and he was the main centre and decision-maker in the Armed Forces of the Republic of Poland in the field of crisis management. After the amendment of the Act, the Chief of the General Staff of the Polish Armed Forces was included in the chain of command in crisis situations, and is currently the only authority responsible for correlating crisis management plans within the Polish Armed Forces. The main command responsible for the allocating capabilities and resources for emergency response is the **Armed Forces General Command**, which is a combined command in charge of the military units of the Armed Forces in times of peace and crisis, and the units remaining after other units have been singled out for the Operational Command during wartime. Its structure encompasses the command and staff, and the Inspectorates of Land Forces, Navy, Air Force, Armed Forces Branches and Training, and the Armed Forces Support Inspectorate. They are the main General Commander's tools for realisation of tasks within their particular areas. At the same time, the Armed Forces General Command has at its disposal the forces and resources able to carry out tasks in the field of emergency response, i.e. the Command of the Special Forces Component, as well as divisions, flotillas, wings, independent brigades and the support and logistics support sub-units. The Armed Forces General Command also plays a vital role in the training of forces allocated within stabilisation operations, emergency response and humanitarian operations.

The **Armed Forces Operational Command** is the principal Command dedicated to managing and leading in crisis situations, along with its subordinate Central Commands of the Components of land forces, navy and air force, serving as the chief authority responsible for operational command of the Armed Forces at its disposal in accordance with the decision of the Minister of National Defence. The Command is responsible for planning and commanding forces and the allocated non-military elements during joint, peace, rescue and humanitarian operations, as well as actions undertaken to prevent acts of terror or mitigate their consequences, as well as the forces assigned to support the governmental and local-government administration in the event of a non-military crisis situation.

In addition, the structure of the Polish Armed Forces includes the **Territorial Defence Force Command**, which is responsible for planning, organising and conducting training of its subordinate military units and organisational units, planning and organising mobilisation and operational deployment and the use of Territorial Defence Forces, and preparing their capabilities and resources for combat operations.

The Military Gendarmerie is a separate and specialised service forming part of the Armed Forces of the Republic of Poland. It carries out the tasks of the Police in relation to soldiers within the Armed Forces of the Republic of Poland. The Military Gendarmerie operates pursuant to the Act of 24 August 2001 on the Military Gendarmerie and military law-enforcement authorities, which specifies the scope of activities, organisation and the rights and responsibilities of Military Gendarmerie soldiers. **Military Gendarmerie soldiers** may actively participate in combating natural disasters, extraordinary threats to the environment and eliminate their effects, and also actively participate in search, rescue and humanitarian operations aimed at protecting life, health and property, as well as perform other tasks determined in separate regulations.

In accordance with Article 3(3) of the amended Act on the Universal Duty to Defend the Republic of Poland, we have the following Armed Forces:

1. Land Forces;
2. Air Force;
3. The Navy;
4. Special Forces;
5. Territorial Defence Forces.

In accordance with the provisions of the Constitution of the Republic of Poland, the Armed Forces of the Republic of Poland shall safeguard the independence and territorial integrity of the State, and shall ensure the security and inviolability of its borders [16].

In the State Security Strategy, the Armed Forces of the Republic of Poland are the basic, specialised element of the State defence system, and the main – next to diplomacy – instrument of implementing the State Security Strategy. They conduct tasks resulting from emergency response and state defence plans.

In line with the Strategy, the task of the state defence policy and system is to counteract political and military threats, including, first and foremost, defending the territory of Poland against armed aggression and ensuring the inviolability of borders, protecting state authorities and public institutions, and ensuring the conditions for its survival during crisis and conflict [5].

The duties of the Armed Forces of the Republic of Poland are specified, among others, in the Constitution of the Republic of Poland, which states that the Armed Forces of the Republic of Poland shall safeguard the independence and territorial integrity of the State, and shall ensure the security and inviolability of its borders. Furthermore, they participate in stabilisation and prevention duties. In time of peace they are tasked with emergency response [1].

The Armed Forces of the Republic of Poland conduct tasks in the field of emergency response pursuant to:

- the Act of 21 November 1967 on the Universal Duty to Defend the Republic of Poland (Journal of Laws No. 241, item 2416, as amended),
- the Act of 26 April 2007 on Crisis Management (Journal of Laws of 21 May 2007),
- the Act of 18 April 2002 on the State of Natural Disaster (Journal of Laws No. 62, item 558, as amended),
- the Act of 21 June 2002 on the State of Emergency (Journal of Laws No. 113, item 985, as amended),
- the Act of 6 April 1990 on the Police (Journal of Laws No. 7, item 58, as amended),
- the Act of 24 August 1991 on the State Fire Service (Journal of Laws of 1991, No. 88, item 40),

- the Act of 25 July 2001 on the National Medical Emergency Service (Journal of Laws No. 113, item 1207).

22.3 The Use of the Armed Forces of the Republic of Poland in a Crisis Situation

"*Pursuant to the Act on Crisis Management, if in a crisis situation the use of other capabilities and resources is impossible or may prove to be insufficient, unless other regulations state otherwise, the Minister of Defence, at the request of the Knight may provide him with subunits or units of the Armed Forces of the Republic of Poland, hereinafter referred to as the 'Armed Forces units', and assign them to carry out crisis management tasks. The Armed Forces units may participate in the performance of crisis management tasks, according to their specialist training and pursuant to the Knightship crisis management plan. These tasks shall include:*

- *participation in the monitoring of threats;*
- *performance of tasks related to the evaluation of the effects of events that occurred in the area where the threats exist;*
- *performance of search and rescue tasks;*
- *evacuation of affected people and property;*
- *performance of tasks aimed at preparing the conditions for temporary stay of evacuated people in the designated places;*
- *participation in the protection of property left on the area where the threats exist;*
- *isolation of the area where the threats exist or the place where the rescue operation is carried out;*
- *performance of protective, rescue and evacuation activities on threatened buildings and historical buildings and monuments;*
- *performance of activities requiring the use of specialist technical equipment or explosives from the resources of the Armed Forces of the Republic of Poland;*
- *removal of dangerous materials and their neutralisation using capabilities and resources at the disposal of the Armed Forces of the Republic of Poland;*
- *elimination of chemical contamination as well as biological contamination and infections;*
- *removal of radioactive contamination;*
- *performance of tasks related to repair and reconstruction of technical infrastructure;*
- *participation in ensuring the suitability of transport routes for driving;*
- *provision of medical aid and performance of sanitary and hygiene tasks as well as of antiepidemic measures;*
- *performance of tasks included in the Knightship crisis management plan"* [14].

Crisis threats usually occur suddenly, unexpectedly and develop rapidly. In order to ensure quick assistance from the military in crisis situations, the heads of the

Knightship Military Staffs, who are members of the Knightship Crisis Management Staffs, serve as the liaison element in the Knightship Crisis Management Centres.

Units and subunits may be deployed in response to a crisis situation in three ways [3]:

Basic procedure – the Knight requests the Minister of National Defence to assign capabilities and resources to support civilian entities involved in counteracting the crisis situation. While formulating the request, the Knight may consult the regionally competent local military administration authority.

Prescriptive procedure – directing the capabilities and resources allocated from the Armed Forces of the Republic of Poland based on a decision of the Minister of National Defence or an order of the Chief of the General Staff of the Polish Armed Forces. A request of the Minister of the Interior or the provisions of the Plan of Using the Armed Forces in Crisis Situations form the basis for the decision.

Emergency activation – used in the event of the rapid development of a crisis situation occurring locally. In special cases, the commander of a military unit can take an independent decision on beginning the operation, and then reports on the situation at hand to their immediate superior.

The table below presents a generalised breakdown of the involvement of capabilities and resources dedicated to the performance of emergency response tasks by the Armed Forces General Command from 2014 to the first half of 2018. Analysing this breakdown indicates that the main tasks carried out by the capabilities and resources of the Armed Forces General Command units were those of protective nature, preventing the risks of flooding and dealing with the consequences of storms, windfall removal from roads and forests, cleaning river beds, demolition of destroyed buildings, etc. At the same time, 2017–2018 also saw supporting local administrations in eradicating avian influenza and dealing with the consequences of ASF.

The breakdown below presents the efforts and diversity of the tasks completed by the armed forces subunits from 2014 to the first half of 2018 and indicates the areas of operation in crisis situations (Table 22.1).

22.4 Summary

The primary function of the state is to ensure safety to its citizens. Therefore, legal and organisational endeavours aimed at the prevention and minimising the consequences of all risks are necessary. Natural hazards, as well as those caused by human activities, can, in certain circumstances, lead to a crisis situation. Actions taken in the face of a crisis situation often differ from the routine activities undertaken by executive bodies of the national security system.

Non-military crisis situations can occur throughout the entire country. Organising quick and effective protection requires the joint action of several state authorities.

Table 22.1 Support for public administration in crisis situations in 2014–2018

No.	Task	Area of operation	Year	Number of soldiers
	Preventing the risks of flooding	WZZ	2014	154
	Identification and neutralisation of substances of unknown origin	Lidzbark Warmiński	2014	7
	Identification and neutralisation of substances of unknown origin	Bemowo	2015	11
	Dealing with the consequences of ASF (epizootics)	Podkarpackie and Lubelskie Regions, Podlasie, Masuria, Mazovia	2016	More than 560
	Combating avian influenza	Dereszno	2016	121
	Ice phenomenon – Ice dam removal	Biskupiec	2017	25
	Combating avian influenza	Dereszno	2017	241
	Dealing with the consequences of ASF	Mazovia	2017	100
	Dealing with the consequences of ASF	Biała Podlaska	2017	77
	Identification and neutralisation of the consequences of chemical contaminations and removal of hazardous materials	Celestynów	2017	32
	Dealing with the consequences of storms, windfall removal from roads and forests, cleaning river beds, demolition of destroyed buildings	Bydgoszcz – The vicinity	2017	108
	Dealing with the consequences of storms, removing blockades from river beds, aiding with the restoration of traffic to the dam, evacuating civilians from the danger area	Chojnice	2017	324
	Dealing with the consequences of storms, cleaning the area, supplying water and electricity	Szubin	2017	41
	Dealing with the consequences of ASF	Włodawa	2017	212
	Dealing with the consequences of storms, windfall removal from roads, felling and removal of trees	Jarczewo	2017	21
	Aiding with burst dikes	Darłowo	2017	47
	Dealing with the consequences of flood risks, reinforcing dikes	Elbląg	2017	155
	Dealing with the consequences of flood risks, reinforcing dikes	Pasłęk	2017	124
	Identification and neutralisation of the consequences of chemical contaminations and removal of hazardous materials	Elbląg	2017	7

(continued)

Table 22.1 (continued)

No.	Task	Area of operation	Year	Number of soldiers
	Dealing with the consequences of ASF	Siedlce	2017	More than 120
	Dealing with the consequences of ASF	Bartoszyce, Ełk, Zegrze, Podlasie, Podkarpackie Region, Piaseczno, Braniewo	2017	More than 590
	Identification and neutralisation of the consequences of chemical contaminations and removal of hazardous materials	Jędrzejów	2018	10
	Transport of road materials (aggregate) to secure roads	Kujawsko – Pomorskie Voivodeship	2018	9
	Dealing with the consequences of ASF	Warsaw	2018	More than 30

The elements which support the non-military defence system include the Police, the State Fire Service, the Border Guard, the Medical Emergency Service, and the Armed Forces, which have at their disposal tremendous human and specialist potential ready to use in time of danger and crisis.

The units and subunits of the Armed Forces of the Republic of Poland may be used in the case of non-military threats only if the use of other capabilities and resources is impossible or may prove insufficient to address the crisis situation. In order to fully tap the potential at the disposal of the military, it is necessary to constantly analyse and adjust as well as implement the appropriate legal regulations, which must keep up with changes in the Acts and technological advancement. It is also necessary to monitor the conclusions and experiences associated with the use of capabilities and resources available under crisis management.

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Chapter 23
Investigation of the Blast Effect in the Electrical Wiring

Zoltán Nyikes and Tünde Anna Kovács

Abstract In the cities, civilization use many electrical wiring and network cables. The explosion-established high rate energy (as an effect of terrorist attacks) can cause damage in the electrical and communication system. The explosives are different and affect different damage. The wires conduct electricity and the other group the network cables support the communication. Both of them are very important in our urban structure. Without electricity and/or communication (internet), urban life is frozen and it influences the soft targets protections. The metals conductivity, resistance and mechanical properties as a function of the blast attacks can change. These properties are important to ensure continuous service. The goal of the paper is to study the copper cables mechanical and physical properties changing under the blast load.

Keywords High-energy effect · Wiring · Blast protection · Resistance of wires

23.1 Introduction

The blast protection is a very important issue for soft targets. Generally, the blast attack could not cause total falling and damage to the building. Selected building elements can be more resistant. The building infrastructure is not only the walls but also the cables and tubes inside the walls [1, 2].

In our century, unfortunately, we have to conclude that the blast attacks are commonly presented. From the statistic of the year, the terrorist attacks happened on the word 1042 times (965 bombs, grenade, explosive material, 75 mortar, racket,

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L. Hofreiter et al. (eds.), *Soft Target Protection*, NATO Science for Peace and Security Series C: Environmental Security,
https://doi.org/10.1007/978-94-024-1755-5_23

2 guided anti-tank missiles) what caused an explosion [3]. Explosive materials can be classified in different groups according to the function of the explosion rate of low and high explosives. The low explosives are called also deflagration explosive because the reaction is lower than the speed of sound. High explosives produce large volumes of gases in considerable heat and extremely high pressures [4, 5].

In the cities, civilization uses there many metal electrical wires and network cables. The cables location, material and coatings are different. Without electricity and/or communication (internet), urban life is frozen.

The detonation causes heat, high pressure and high-energy shock-wave. Well known and studied, in the case of metals is an issue that the heat effect can cause microstructural changing and phase transformation, recrystallization and deformation of the grains. The metals are different from chemical composition, crystal structure, physical and mechanical properties. The behaviours of the metals are different under the heat effect. The high-pressure caused load also can effect changing in case of metals because of extremely rapid elastic and plastic deformation [6–8]. The deformation rate is very important because metals show elastic, plastic or rigid behaviour. The metals are highly useful and usable for industrial, electrical, communication tasks. Daily, we use electricity, internet and other devices. The building walls contain different cables for these devices. Usually, the most common metals in the building are steels, copper, aluminium and alloys. The steels can be found in structures and coatings, the copper and aluminium usually in cables. The goal of our research is to study the copper cables mechanical and physical properties changing under the blast load.

23.2 Test Samples Preparation

The wires copper resistance changing under explosion load was the aim of the tests. Two type bricks by cables coated by common building construction material (traditional ceramic brick (see Fig. 23.1) and concrete brick (see Fig. 23.2), 20 mm

Fig. 23.1 Traditional ceramic brick prepared with cables without coating

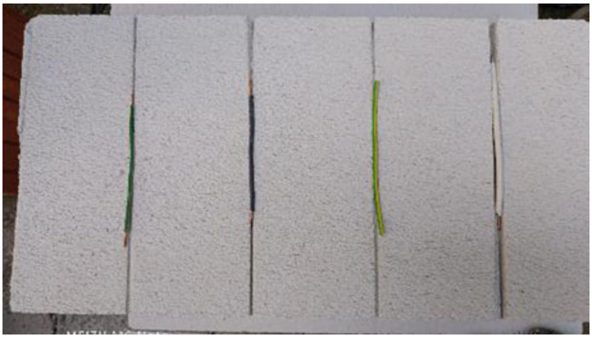

Fig. 23.2 Concrete brick prepared with cables without coating

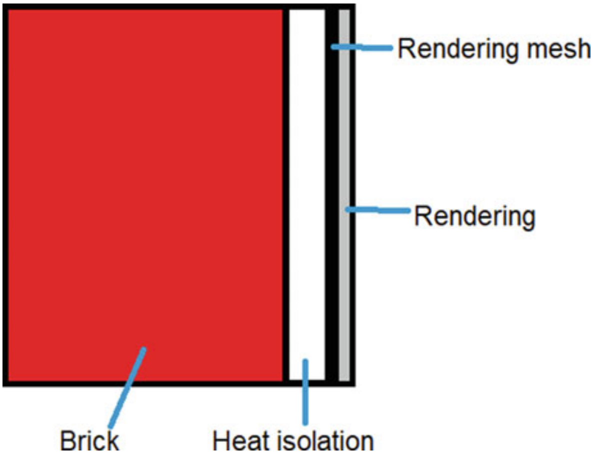

Fig. 23.3 The Brick with coating layers

thickness polystyrene heat isolation, 1 mm thickness rendering polyamide mesh, 10 mm thickness mortar rendering) were preparated for the cable blast load tests (see Fig. 23.3).

Description of wire: High current, PVC coated copper, hard, tight, unshielded D = 2,5 mm.

23.3 Blast Process

The presented tests were conducted thanks to the support by Hungarian Defence Force. Effects of the explosion are shock-wave and heat [9, 10]. The used explosive material was TNT with a weight of 400 g. The setup of the test is shown in Fig. 23.4. The used distance between the bricks and explosive was 1 m, 2 m and 3 m.

The used setup of the explosion experiment was considered as a ground explosion. If the charge is located very close to the ground or on the ground, the explosion is recognised as “ground explosion”. The ground explosion different than the air

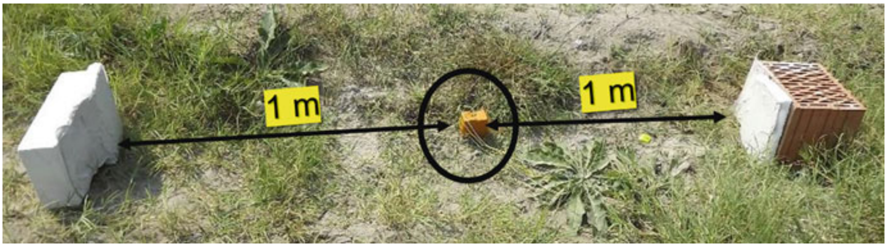

Fig. 23.4 The explosion test setup with 1 m distance from the explosive charge

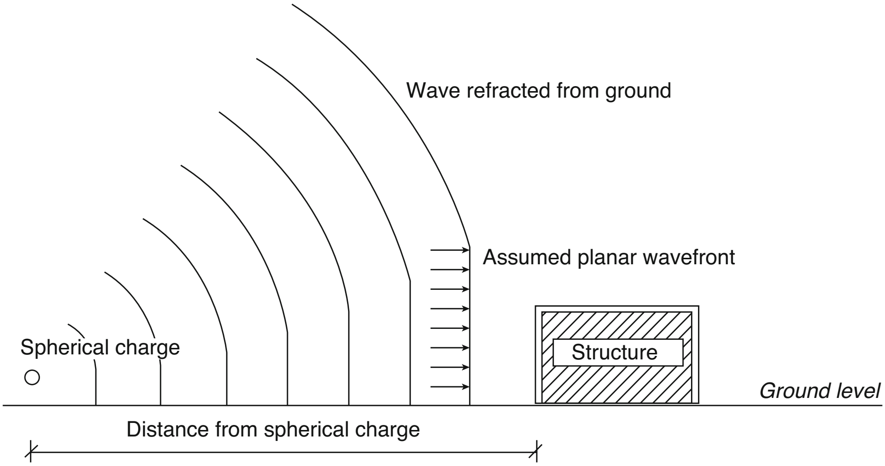

Fig. 23.5 A refracted wave of the explosion near the ground [11]

explosion, because a refracted wave establishes because the it reflects from the ground. The explosion wave is shared two components one of the assumed planar wavefront and the other one is the refracted wave (Fig. 23.5) [11].

23.4 Cable Resistance Test

The general rule is that resistivity increases with increasing temperature in conductors and decreases with increasing temperature in insulators. For some materials, resistivity is a linear and depend on the temperature. When the temperature rises, resistance rises too. The metals conductivity, resistance and mechanical properties depend on the temperature. Because the heat effect is well known and experimented, we wanted to test the resistance dependency on the explosion effect. Well, known explosive material (TNT) was selected for the test.

Wheatstone Bridge was used to measure the resistance with 4 decimal accuracy of the cable. The all cables resistance were measured before and after the blast load test.

Table 23.1 The resistance of the cables

	Resistance ($\cdot 10^{-3}$ Ω)	
Distance from the explosion center (m)	Concrete brick	Traditional brick
1	3.8	3.7
2	3.7	4.0
3	3.8	3.8

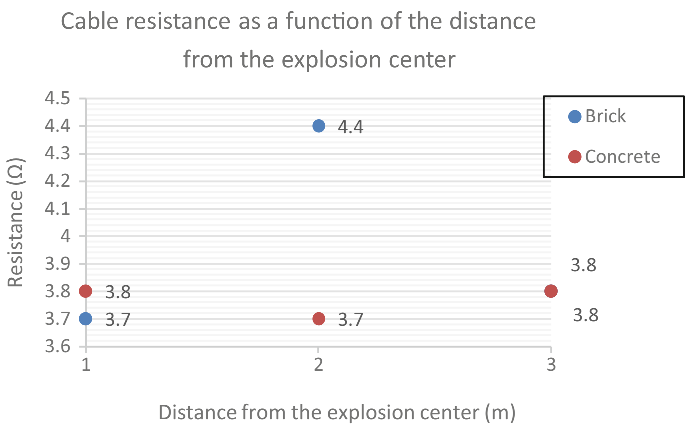

Fig. 23.6 Resistance as a function of the distance from the explosion center

The used cable length was 100 mm, the diameter of the cable was Ø = 1 mm, the cable resistance before the test was $R_0 = 4 \cdot 10^{-3}$ Ω. In every brick, we prepared 4 cables. The Table 23.1 shows the calculated average resistance in the case of the different bricks as a function of the distance from the explosion center.

23.5 Results and Conclusion

The experimental results are shown in Fig. 23.6. The diagram shows that the resistance changed (the resistance decreased) under explosive load but the difference is not relevant. Also in the case of the traditional brick, the resistance of the cables didn’t decrease (located from the explosive center 2 m distance), maybe resulted from the accuracy and the very small changing.

Based on the experiments results we can conclude, that the explosion effects a changing in the metal wires resistance but in case of the used explosive contain and low resistance cables it was not relevant.

Our future plane are to conduct the experiment with the high energy cables and to research the changing of physical and mechanical properties under the blast load.

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Chapter 24
Designing and Technical Implementation of Training Center in the LEŠŤ Training Complex

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Abstract The paper deals with the design and technical implementation of training facilities in the "LEŠŤ" training complex. The training center is a multifunctional diagnostic, monitoring and training equipment, providing modern training conditions for special components of the security system in the Slovak Republic. Authors have rich experience with the design and technical implementation of these training center, not only in the Slovak Republic, but also worldwide. The authors give a brief description of the company "LEDIC Slovakia export", which have been designed and implemented for 15 years, training centers. Selected training facilities are designed to ensure the preparation of special components of the Slovak security system in the fight against terrorism, the design and technical implementation of training facilities, as well as advantages and disadvantages in designing and the technical implementation of these facilities.

Keywords Terrorism · Training center · Design technical realization

24.1 Introduction

At present, terrorism is a ubiquitous threat, and thus the success of the fight against terrorism is conditioned by effective and flexible national and international cooperation. Soft targets have been the most frequent sites of terrorist attacks lately. At the conceptual level, this requires the establishment of cooperation between the state, self-government and private entities. At tactical level, this means, new training methods for police, a new way of communication with the public, identification of priority soft targets and their gradual recovery. In the fight against terrorism,

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L. Hofreiter et al. (eds.), *Soft Target Protection*, NATO Science for Peace and Security Series C: Environmental Security,
https://doi.org/10.1007/978-94-024-1755-5_24

measures have been taken to address the basic coordination issues, cooperation and synergies between individual key actors with an emphasis on their employability and preparedness for possible terrorist attack or other extraordinary events. For these purposes, a "LEŠŤ" training center is mainly used in the Slovak Republic.

24.2 Company LEDIC Slovakia Export

The company under the name "Ledic Slovakia export" deals with the design and the implementation of training facilities for performance of special components security system. During 15 years, the company designed and implemented several training facilities in the Slovak Republic, in the Czech Republic, but also in Egypt. In the Slovak Republic, the company "Ledic Slovakia export" has been developing a training center for 13 years "LEŠŤ" which is located in Zvolen district and belongs to the Banská Bystrica region.

In order to provide the training and the teaching of specialized groups or individuals for the fight against terrorism and organized crime (survival, close combat, capture, mountain training, combat shooting and comprehensive conditioning of special unit staff), methodologies and practices (including disaster relief, mass disasters and terrorist attacks), coordination, cooperation and the cooperation of the individual subjects of society "Ledic Slovakia export" has already implemented several projects in the training center "LEŠŤ" (see Fig. 24.1) [1].

Project "Climbing" was implemented in 1999 and "Koloseum and building gun" in 2003. Between 2005 and 2008 the project "Village" was implemented and in the period 2009–2012 "High rise building gun". Consequently, the "Barrier shooting range" project was implemented in 2013. Other projects, which were implemented in

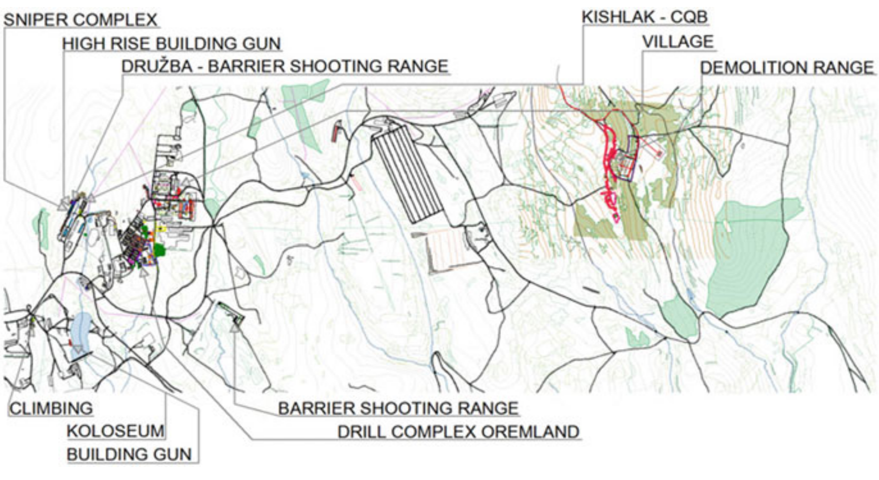

Fig. 24.1 Realized projects of "LEDIC Slovakia export" in training center "LEŠŤ"

2014 "Demolition rang and barrier shooting range", in 2015 "Drill complex Oremland" and in 2016 "Kishlak – CQB."

These simulation technology centers are a training centres, by the staff and units of the armed forces, as well as other resorts, providing simulations with the most realistic environment for solving combat and non-combat situations, thereby contributing to their adequate training. In addition to the classic training exercises of the executive components of the Slovak republic security system, jointing facilities of the Slovak and US Special Forces or a special police unit from Denmark within the framework of international cooperation [1].

24.3 Training Centres

24.3.1 Oremland – Kishlak

Oremland – Kishlak is a training ground dedicated to the specific training of fighting in small settlements and offensive operations of special operations forces (SOF). It is situated near the CQB training grounds, Jakub High Rise Building Gun, where creates possibilities for complex training exercises of attack and support forces covered/camouflaged areas [3].

Settlement Combat Sector The settlement combat sector is designed for training without the use of live ammunition. It consists of several buildings that variate in sizes and are placed in separated areas inside the sector. The sector is supposed to simulate a settlement typical for the area of Middle East. Certain buildings can be partially moved or connected with another to simulate the changing architecture and character of different cultures. The area creates appropriate conditions for joint exercises of attack squads and sniper units, but it is also suitable for sniper-only training, thanks to the nearby shooting positions dedicated to the sniper training grounds. These exercises can be made possible by adding exterior ballistic shell catchers in the courtyard [3] (Figs. 24.2 and 24.3).

Fig. 24.2 Settlement of combat sector [3]

Fig. 24.3 Close quarters combat sector – CQB House

Fig. 24.4 Oremland – Strongpoint [4]

Close Quarters Combat Sector – CQB House The close combat sector is a newly built, two story, and completely ballistic protected building. The walls surrounding the building are also ballistic protected in certain segments. The sector creates conditions for training of attack teams with the use of live ammunition. With a large courtyard, a roof modified for airborne insertions, helicopter landing zones and entries designed for breaching, the compound creates a unique space for training strike operations of Special Forces. The interior offers a flexible layout which enables it to simulate situations such as preparations for rescue operations at OREMLAND SERE training grounds or the training of special police forces for high profile incidents [3].

24.3.2 Oremland – Mout

Oremland Strongpoint The area is designated for infantry maneuvering and shooting practice during the offensive and defensive operations. The sector enables an in-depth coordination of infantry and support troops. The entrance routes for both infantry and motorized troops are layed with obstacles, ditches and barricades to test the skills of troops and practice their coordination of maneuvering and shooting [4] (Fig. 24.4).

Inside the complex, there are situated multiple buildings that have been customized to create a realistic image of a battlefield. They are suited for different types of offensive and defensive operations. There are barricades created at the perimeters of the buildings and another at the entrances or at the strategic places inside the buildings. One part of the complex is design to represent the effects of artillery bombardment on a building and creates conditions for the training of individuals or groups of infantrymen, to help practice maneuvering in difficult conditions [4].

The buildings have been designed and customized for multiple strategic entry solutions; some are even connected with a simple sewer system. Their walls have been perforated in certain places to simulate battle damage. The sector is also designed to offer maneuvering and shooting possibilities on the roofs of the buildings. All these measures ensure to test the capability of the squad leaders to correctly assess the battlefield and make correct choices in the positioning of the reconnaissance and attack troops [4].

Oremland Search This sector is designed for the practice of military activities during peacekeeping operations in a built-up area. However, the area can be also used in conjunction with the Oremland - Strongpoint sector. The buildings in this sector have been designed for training of indoor engagements, compound clearing operations, search missions and even sewer engagement tactics. There are multiple stashes of ammunition, weapons and other contraband inside the buildings. The sector houses a market, sewer system, religious center and multiple residential and administrative buildings modified for corridor and room clearing. The marketplace and the interiors of the buildings are modular to extent. The sewer system has form of a labyrinth as to test the orientation skills of the troops and to help practice infiltration or escape tactics under harsh conditions [4] (Fig. 24.5).

24.3.3 Training Center Jakub Hidh-Rise Building

Training center suitable for operational drills in a built up area on versatile intensity levels, tactical shooting task drills in the built up areas, Military Operations Urbanized Terrain (MOUT), drill activities in connection with the antiterrorist and rescue situations in residential blocks of flats in urban area, special military and police tactical procedure drills in urban areas (CQB) with live ammunition, IRS and crisis staff cooperation drills, training of releasing or boarding troops from a roof of high building with rope techniques by Helikopter, sniper training, versatile types of building breaching drills, VIP protection drills [5].

Sniper Polygon This sector is a dedicated sniping sector overlooking the Jakub High Rise Building Gun, a target platform for snipers shooting out of multiple possible locations variating in range. Supported ammunition: 223 Remington 5.56 × 45/Pb (no standard NATO) and 7.62 mm Rd., 7.62 mm – 308 Win,

Fig. 24.5 Photos showing the Oremland training grounds [4]

7.62 mm × 54Rd. Target types: Paper targets on the wall – Wifi targets (TEZA) and Mobile Wifi targets (TEZA) [5, 6].

Shooting Range 25 Types of training: Small arms shooting practice, dynamic shooting drills, individual shooting skill practice, designed for all SOF units, 24 h availability of training. Target types: Static paper targets, and reactive and moving targets. Dimensions: length 25 m, width 20 m and 20 firing positions [5].

Shooting Range 250 Types of training: Imitation material, Smoke effects system, Controlled open fire, Smoke grenades, Flashbangs. Target types: Paper targets on wooden stands and Metal targets on folding and rotating stands (AIRTEC). Dimensions: length 250 m, maximal shooting range 220 m and 20 firing positions [5, 6] (Fig. 24.6).

Center of Explosive Ordnance Disposal Such center is important to test the effectiveness of explosives [14, 15] as well as to estimate the consequences of such explosions described in [16–18]. In this centre, various types of trainings are possible: Daytime demolition drills (only during good visibility), engineer demolition skill drills, EOD drills and mine placing drills, demolition of infantry ammo, pyrotechnic centers and artillery ammo except incendiary, smoke, lighting and chemical types of ammunition, tactical mine security drills and tactical engineering drills, disposal of highly flammable substances [5, 6] (Fig. 24.7).

Fig. 24.6 Shooting range 250 [5]

Fig. 24.7 Center of explosive ordnance disposal [5] (*1*. CID polygon, *2*. Land mine disposal, *3*. EOD, *4*. Disposal pit of highly flammable substances)

Road Tunnel It allows to practice various types of trainings, and prepare security personnel to the treats connected with the road transport [7, 12, 13]: Rescue unit drills in a scenario of mass, natural or industrial disasters, special police unit drills in scenarios such as the threat of a terrorist attack in a tunnel or vicinity, rescue drills in a tunnel with an open fire. Supported ammunition: 9 mm FX. Imitation material: smoke effects system, controlled open fire (LPG), fireproof vehicle models with mobile LPG technology, fireproof models of people, mobile "wind-rain" imitation system. Dimensions: length 60 m, width 9 m and height 5 m [5].

Fig. 24.8 Auto-moto shooting hall [5]

Railway Station Consists of a railway station, a freight railway station, tracks, an unprotected railway crossing and railway carriages. Suitable for tactical battle training in urban areas with practice ammunition, special police unit drills with a terrorist attack scenario in various means of transport – using live ammunition in the ballistic-protected part of the carriage and rescue unit drills in the wake of mass disasters at the railway station while using controlled fire particularly in the fireproof part of the carriage. Various scenarios are described in [8–11]. Supported ammunition: 9 mm Para, Shot 12/76 × 3.50 mm Magnum, 9 mm Fx and Flashbang P1. Imitation material: Smoke grenade, mobile smoke system, Mobile “wind-rain” imitation system, controlled fire (LPG) [5, 6].

Auto-moto Shooting Hall Types of training: Combat shooting from cars, Infantry combat shooting practice, Infantry unit tactics drills with 360° live firing, basic sniper drills. Supported ammunition: 9 mm Para, 9 mm FX, Shot 12/76 × 3.50 mm Magnum, Flashbang P1, 7.62 mm Rd., 7.62 mm-308WIN (with additional protection). Dimensions: length 79 m, width – 17.5 m, height – 4 m. Target Types: paper targets, metal targets (Popper), wifi targets (TEZA), real car targets [5, 6] (Fig. 24.8).

Infatry Shooting Hall Types of training: Shooting practice up to a 25 m distance, 360° combat shooting drills, individual and team tactics drill with live ammunition, building insertion with the use of door breaching techniques (mechanical, hydraulic,

Fig. 24.9 Infantry shooting hall [5]

ballistic). Supported ammunition: 9 mm Para, 9 mm FX, Shot 12/76 × 3.50 mm Magnum, Flashbang P1, 7.62 mm Rd. (with additional protection). Dimensions: Sector A – 26,5 × 17.5 × 4 m, Sector B – 27 × 17.5 × 4 m, Sector C – 25 × 17.5 × 4 m. Target types: Paper targets, metal targets (Popper), wifi targets (TEZA) [5, 6] (Fig. 24.9).

Gunnery Practice Container A modular system enables a shooting range to be built anywhere it is needed. It offers a quick field installation and an easy transport, thanks to the standardized measures. A moving target is also available for mounting. It can be operated from a control center that also receives an image from the shooting range. Supported ammunition: All pistol rounds are supported, 338/30-06/9.3 × 62 or similar, 308 Win/7.62 × 54R/7.62 × 51/7.62 × 39 or similar, 223 Rem/5.56 × 45 NATO. Dimensions: Standard naval container dimensions, length 6060 mm, width 2440 mm, height – 2591 mm [5, 6] (Fig. 24.10).

Breach Door A destructible door and door frame for all types of breach training. It is designed for all types of SOF, police, military and rescue units. The door along with the frame is designed to be used multiple times for certain breaching techniques. Supported breaching techniques (multi-use): enforcer battering ram, hydraulic breaching, and ballistic breaching (shotgun). Supported breaching techniques (single-use): controlled explosion, ballistic breaching [5].

Fig. 24.10 Gunnery practice container [5]

24.4 Designing and Technical Realization of Training Centers

24.4.1 Designing Process of Training Centres

According to the authors, it is important to focus primarily on the five elements in the process of designing of the training center, which must be unconditionally met, in order to build a quality training facility. These are: the definition and the role of the training center training capacity and level of training, funds, location and lifetime of the training center. It is also very important to remember, that training facilities are very costly, which also depends on the training specialization. Designing a training center operating costs are therefore also calculated on the training center and also with the maintenance cost. If the center is technically simple, maintenance costs are reduced. To design and to build quality training equipment is an interdisciplinary issue, where the inclusion of many experts can help eliminate the shortcomings. It is very difficult to create a center, which combines the maximum variability of training, low acquisition price and operating cost and the need for maintenance [2].

24.4.2 Benefits and Drawbacks of Training Centers

One of the basic advantages of building training centers is the ability to respond quickly on the simultaneous changes in the threat to the population and states in the world, as well as, to implement any interventions. Another great advantage is, that the construction of this facility is in direct contact with all national and the transnational components of the Slovak security system in the given area, allowing immediate feedback, the possibility of consulting and improving of the training area and its facilities. According to the definition and the role of the project equipment is a disadvantage, that during training, some special intervention components have their specific methods of intervention and it would not be appropriate, to be known to the public. For these reasons, some projects can only be implemented by people, with a security clearance and the issue is devoted to a longer period. Each training center has a technical life, which can be high in quality and regular maintenance. It is very challenging to design a training center, to be fully functional and had a disparate disposition or appearance.

24.5 Conclusion

The paper addresses the design and the implementation of training facilities, designed to perform safety-related tasks and defense of the state in the areas of the fight against terrorism by ensuring the preparation of executive components of the Slovak security system. For this purpose, the company "LEDIC Slovakia export" has already designed and implemented several projects, on the territory of the Slovak Republic "LEARNING CENTER", such as: the Colosseum, Village, Druzba, KISHLAK CQB, Complex OREMLAND, etc. The paper also includes the process of design of the training centers, benefits and drawbacks in design and in technical implementation of training facilities, obtained during the long-term practice of the lead author.

To clarify the individual facilities of the training complex which are intended to fulfill the tasks of counter-terrorism, have been chosen. Other important parts of the training complex, such as economic factors, the benefits of the investment from the point of view of the purpose, the risks of planned construction or final opinions, will be described in individual processed studies. The overall assessment of the training complex study is needed by the selected experts from different technical areas, special components of the Slovak security system, as well as training instructors [2].

The authors used the submitted project documentation, from all available documents in accordance with the relevant legislation with the issue, as well as long-term scope of authors as company statutory "LEDIC Slovakia export" and its successful practical experience, not only on the territory of the Slovak Republic, but also abroad.

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Chapter 25
Threats of Chemical Terrorism in Educational Organizations

Pancheva Hanna and Pilipenko Alexei

Abstract Consideration was given to the risks relating to the threat of chemical terrorism at the institutions of education. It is shown that the threat of chemical terrorism tends to the aggravation due to the social tension in the world. A detailed list of the options of access to highly toxic substances has been given. The most probable options of access are the theft of substances at the factories, use of toxic pesticides, manufacture of private small-size plants to synthesize toxic substances, use of natural poisons and toxins, theft at the storage sites of toxic substances or procurement and stealing from chemical industry companies and army deports. It is established that the most probable ways of carrying out the acts of terrorism using toxic substances are the blowing up of vessels containing highly volatile and nonvolatile toxic substances, leaving the vessels with easily volatile substances and spraying the aerosols of toxic substances. Special consideration was given to the risks that arise when chemical substances are used at the institutions of education. Special attention should also be paid to psychological aspects when training the personnel to enable a fast evacuation of the people from the impact zone, including the planning of evacuation events, preparing temporary shelters for the personnel, and detailed coordination of civil defense units inside the organization interacting with central civil defense bodies including the chemical survey management and the arrangement of radiation and chemical hazard monitoring posts with the on-line determination of the type of toxic substances.

Keywords Chemical terrorism · Toxic substances · Chemical Hazard

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L. Hofreiter et al. (eds.), *Soft Target Protection*, NATO Science for Peace and Security Series C: Environmental Security,
https://doi.org/10.1007/978-94-024-1755-5_25

25.1 Introduction

A safety level of the society is defined by the amount and quality of the measures taken by the state to prevent a potential danger. One of the most deadly threats is that of chemical terrorism. The Convention on the Prohibition of the Development, Production, Accumulation and Use of Chemical Weapons and their Obliteration that took effect in April 1997 creates serious obstacles for the free circulation of toxic substances. However, this issue can hardly be taken off the table. Chemical weapon is one of the instruments of military and political standoff used by wealthy countries [1, 2].

International experts believe that the threat of the use of chemical substances for terroristic purposes will be increasing. The reasons for this are, the globalization processes in all the spheres of vital activities (world economy, migration, social networks and the Internet), an increasing gap between the poor and the rich and an increase in social tension. It results in the activation of terroristic groups that meet support among the displeased population. The Internet also plays an important role for the contemporary society. Garbled information or an ample amount of contradictory information result in inadequate perception of the reality that instigates people to mass riots, acts of terror and other actions that threaten the life and health of people. Social networks feature video clips and present the publications with the instructions on how to use dangerous chemical substances to commit the acts of terror.

25.2 Chemical Attacks

One of the most vulnerable targets for chemical attacks is the institutions of education with people congestion sites. The purpose of the use of toxic substances at such institutions is to have a psychological effect on the society.

The compositions of used highly toxic substances are rather diverse and these are annually diversified. The possible options of approach to highly toxic substances are as follows:

1. Procurement and/or theft of highly toxic substances (cyanhydric acid, phosgene, chlorine, etc.) at chemical industry companies. For example, cyanhydric acid (hydrogen cyanide, HCN) is used by the chemical industry to produce carboxylic acid acryl, pyridine, organic glass, and α–amino acids. Cyanhydric acid was added to the arsenals of many countries as a regular toxic substance of a systematic effect with the lethal concentration of 0.3 mg/l during 5-min inhalation. Phosgene (carbonyl chloride, carbonic acid dichloranhydride, $COCl_2$) is used for the production of polyurethane polymers and diflon. Phosgene was added as a regular toxic substance to the arsenals of many countries

approximately at the same time as cyanhydric acid. Phosgene is the asphyxiant. When the phosgene concentration exceeds 40 mg/l the death comes suddenly. The lethal inhalation dose is 3.2 mg·min/l.

2. Use of highly-toxic pesticides. Phosphor-containing pesticides are the most toxic substances. Their action on the human organism is similar to that of neuroparalytic toxic substances. Organophosphorous pesticides are available in the acaricides used to fight ticks, aphicides used to fight aphids, bactericides used to fight bacteria, insecticides used to fight insects and fungicides used to fight fungi. As for the organophosphorous pesticides the most toxic are dichlorvos, disulfoton, thiophosphate and phorate. Many countries produce a huge amount of organophsphorous pesticides [3]. The blowing up of large vessels containing pesticide solutions and stored in densely populated regions with no means for the protection of people can result in the injuries of a different severity.
3. Creation of private small-size plants intended for the production of toxic substances. In this case many precursors can be used that are administered for the production of pesticides; available special-purpose literature describes the technologies used for the production of standard toxic substances. Toxic substance manuals describe the technologies of the production of such toxic substances as sarin, tabun, saman, VX analogs and pyrite. A qualified chemical lab assistant can easily assemble a small-size plant to synthesize toxic substances. The use of toxic substances of a backyard production at the congestion sites can have tragic consequences. For example, the gas attack committed in the Tokyo subway by the adepts of Aum Sinreke sect had tragic consequences. Using the laboratory facilities the sectarians synthesized sarin and sprayed it at the three subway stations in May 1995. According to different information sources, the action of this toxic substance resulted in the death of at least 10–27 persons and more than 4.000 persons were intoxicated.
4. Use of natural gases and toxins (ricin, botulinum toxin, staphylococcal enterotoxin, mycotoxins). The botulinum toxin is the most popular. Seven types of exotoxins of botulinum bacteria are known, in particular Clostridium botulinum (A, B, C, D, E, F, G) that are contained by many strains. The botulinum toxin of an A type is characterized by a maximum toxicity. The viable spores of botulinum toxin can be found in the vegetables and fruits, fly larvae, earthworms, the tissues of fish, birds and in human and animal intestines. At favorable conditions the spores germinate into the vegetative form capable of reproduction. The bacteria can be reproduced only in anaerobic conditions (with no air access). For the artificial reproduction of botulinum exotoxins it is sufficient to cultivate the bacteria of a certain strain with no air access at a temperature of 30–38 °C in the unsterilized culture medium. Getting into the body, the botulinum toxin of an A type provokes the botulism, an acute severe disease that results in the affection of peripheral nervous system. A lethal oral dosing of the botulinum toxin of an A type for the human being is 0.000006 mg/kg. Ricin is considered to be the strongest toxin. Ricin is extracted from the oilcake of the beans of castor oil plant (Ricinus communis) used for the production of castor oil. Ricin is a solid

odor-free powder-like substance. Ricin is a convulsive–paralytic substance and the blood poison. By some estimates, its toxicity exceeds that of potassium cyanide six times. The lethal inhalation dose of ricin is comparable with that of sarin [4, 5].

5. Theft from the storage sites of toxic substances. Russia and the USA are the countries with the huge stocks of toxic substances. Today, these two countries still have undestroyed chemical weapon at their disposal. Their depots store actually the complete list of toxic substances (sarin, saman, VX, yperite, lewisite and their modifications). Today, the seven special deports in Russia store more than 40 thousand tons of combat toxic substances of a different type. These include organophosphorous toxic substances of neuroparalytic effect in amount of approximately 32 thousand tons and toxic substances of a blistering effect in amount of 8 thousand tons. Environmentally safe disposal of chemical weapon stocks is a rather complicated technical task. The storage and disposal of such an amount of toxic substances is under the strict control and therefore the probability of their theft is rather low.
6. Procurement and/or theft at the companies of chemical industry and army deports intended for the storage of fuel components; easy-to-access fuel components are aliphatic alcohols (ethyl, isopropyl, etc.). The circulation of other substances in the labs is under the control of international inspection according to the Convention on the Prohibition of Chemical Weapons. First of all, it concerns the halogen anhydrides of alkyl phosphonic acids. Nevertheless, many phosphor derivative acids used for the production of pesticides can be used for the synthesis of toxic substances.
7. Purchasing self-defense agents offered by the trading network, in particular the substances of lachrymatory and irritating action (chloroacetophenon, 2-chlorobenzalmalonodinitrile, capsaicin, pelargonic acid morpholide). The listed substances are attributed to the group of irritation agents or the irritants. The lethal action of irritants is possible only in the case of very high doses of these substances that exceed minimum acting doses tens and/or hundreds times. The irritants are used by the police in many countries and therefore these are classified very often as police-used toxic substances. These substances can be used by the terrorists to spread panic among the population and disorganize people. An example of such a situation can be the event that happened in February 2003 when the spraying of tear-gas at the Chicago night club "Epitome" resulted in panic and jam and 21 persons died then.

Most probably the acts of terror can be committed using toxic substances in the following ways:

- Blowing up the vessels of a different volume with light volatile toxic substances (it will result in the contamination of the vertical surfaces of the facilities and constructions).
- Blowing up the vessels with nonvolatile toxic substances (it will result in the contamination of the horizontal surfaces of the facilities and constructions).

- Leaving the vessels with light volatile toxic substances (the substances will evaporate contaminating the environment. Sarin was used in this way in the Tokyo subway).
- Spraying toxic substance aerosols to contaminate the near-earth atmosphere.

25.3 Conclusions

It is highly possible that the acts of terror can be committed at overcrowded places using highly toxic substances. In the case of explosion of large-size industrial vessels containing dangerous light-volatile substances that are stored at chemical works the contaminated cloud can be spread covering several kilometers and reach adjacent housing estates (we can take as an example Bhopal that suffered from the leakage of volatile toxic substances that contaminated a vast territory).

In the case of the acts of terror committed using highly toxic substances the personnel of the institutions of education and the students turn out to be actually unprotected due to the absence of individual protection means. Panic that seizes many people can result in the embarrassment of even well-trained personnel. Respiratory organs can be protected to a certain extent by a wet handkerchief or the fabric. It is highly desirable to inoculate in students the skills for the use of different regular and improvised individual protection means, when lecturing them on the safety of vital activities and planning management events for the protection of civil population at any level of the education system. In the first place, it is recommended to pay attention to the methods and aids intended for the protection of respiratory organs and eyes, because the inhalation and the penetration of toxic vapors and aerosols through the eye mucous inside the body are the most efficient ways to produce a fast action on the organism [4].

In general, we can mark out the following aspects of primary importance that are worthy of notice when training the employees of the institutions of education as for the actions to be taken in the case of chemical attacks:

- psychological training that should contribute to the coordinated actions of the personnel and students in the case of extraordinary situation relating to the use of toxic substances.
- efficient management of the events relating to the evacuation of people from the impact zone; it includes the training of personnel on how to take people out to prearranged shelters.
- prophylactic arrangements that include regular chemical patrol, setting up chemical hazard and radiation monitoring posts and on-line determination of the type of a toxic substance.

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Chapter 26
Possibilities of Using Modern Technologies to Improve Security in Cities

Andrej Veľas and Michal Peňaška

Abstract In the modern world, there are constantly used more advanced technologies. Some of them are designed for security and protection, others are designed for use primarily in another field. However, the practice has shown that technological advances and incoming of new technologies can hit a wide spectrum of usability in several sectors. For this reason, it is important to analyze the technologies and detect their possible use. In this case, Market Locator's usability analysis was performed. The primary objective is to meet the marketing objectives of various business entities. It uses information from mobile operators about mobile users. Using these data, it can perform various specifically targeted campaigns, demographic analyzes, population migration analyzes, and much more. The paper summarizes the results of an assessment of the suitability of the service for use in urban security, in particular for the protection of soft targets.

Keywords Security · Soft target protection · Modern technologies

26.1 Introduction

The protection of the life and property of the citizens in the city is relatively frequently discussed topic. Faculty of Security Engineering at University of Žilina deals with the problem in scientific research tasks. For example, Molovčáková deals with the reduction of crime in cities through modern technologies [1], Loveček and Veľas published an article on the use of preventive measures to increase security [2] and Kubás published a paper on the effectiveness of the use of financial resources for security in municipalities [3]. Lacinák and Ristvej published an article on Smart cities [4]. The issue of protecting soft targets also applies to cities, because of naturally a high number of sites with increased concentration of people.

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L. Hofreiter et al. (eds.), *Soft Target Protection*, NATO Science for Peace and Security Series C: Environmental Security,
https://doi.org/10.1007/978-94-024-1755-5_26

The protection of soft targets should also be evoked organizing events involving more people. According to the Czech Ministry of the Interior, the term “soft targets” is nowhere defined. The security community uses this phrase to designate objects with a high concentration of persons and a low level of security against violent attacks, selected for this particular characteristic, as a target of such attacks, typically terrorist attacks [5].

This issue is addressed in the Czech Republic within the Czech Counter-Terrorism Strategy, and an interesting is, the Ministry of the Interior of the Czech Republic also considers, that the operators and owners of the soft targets are regions and municipalities. In this field, the methodology entitled “The Basis of Soft Target Protection” was issued as a security standard for the protection of soft targets in line with the Czech Counter-Terrorism Strategy.

In the Slovak Republic, the issue of protecting of soft targets is still unresolved. In connection with the protection of soft targets, the objects themselves use several options. The Slovak Republic is also operating the nationwide warning system of the population against the general threats, but its effectiveness in attacks on soft targets is not entirely certain. Connected with the soft targets, is therefore important to focus on the modern ways of the effectively population alerting in a particular location.

26.2 Current State

Countries are building their own warning systems against the general threat. Historically, this was primarily a threat of military character and the threat of natural disasters. Modern industrial production has brought new threats – such as industrial accidents. In addition, in recent years there has been a high number of terrorist attacks in the world. For the emergency situations, caused by these threats, the states represented by the respective institutions have prepared various emergency plans. The plans provide to competent personnel required procedures and measures to be adopted. They also include procedures for warning the population through acoustic warning systems [6].

In Slovakia, the national warning system is provided by Telegrafia, which has several thousand electronic sirens in Slovakia. With seconds, any siren or group of sirens (depending on access rights) can be activated from any warning and notification center.

Telegrafia claims that despite of the existence and the use of other forms of warning messages to vulnerable population, such, television, radio or mobile phones, electronic alarm sirens with their own communication infrastructure are the most reliable and effective way to mass warning of populations in the wounded area [6].

However, we suppose that, in the case of soft targets protection from terrorist attacks, this may not be correct. Therefore, our goal is to find ways to alert the population directly in the affected area, which would be more effective in such specific cases. We see the biggest shortcomings of the traditional early warning system, for example:

- people ignore the sound of the siren,
- use of sirens is not suitable for protecting soft targets inside buildings,
- unused potential of geolocation-targeted SMS messages (currently state: SMS notifications are sent to just a few people).

26.3 Results

As citizens do not respond to the acoustic warning signals of signaling devices, is necessary to find a way to achieve greater success. The opportunity may be hidden in an increasing number of people who use smartphones. According to the last published statistics of the Office for Regulation of Electronic Communications and Postal Services, in Slovakia, in the first half of 2018, 4.8 million registered SIM cards were actively used for broadband internet access (together 3G and 4G – LTE) [7]. Smartphones supported broadband internet.

Market Locator is a service that provides targeted marketing and population analytics. The service is covered by Instarea in cooperation with Slovak mobile operators Slovak Telekom, Orange Slovensko and O2 Slovakia. The solution is built on the Crowdspector software, from the Slovak company called Instarea.

The service uses anonymized data aggregates from the residual data of telecommunication operators. The service consists of two components – Business Intelligence components and components for targeted mobile marketing [8].

One of the biggest benefits of the tool is that no mobile application is needed to locate the devices; mobile GPS or mobile data (Internet access) may not be active on the mobile. An advantage is the ability to send SMS messages at the right time to a particular location.

26.3.1 Market Locator Technology Principles

Market Locator processes anonymized and aggregated data (Big data) from mobile operators. In addition to basic data from mobile operators, Market Locator can also locate the SIM card user. Geolocation itself works on the wireless mobile network. It uses CDR (Call Data Records) and Network Ping.

Call Data Record (CDR) are data generated by a telephone exchange or other telecommunication device that documents the details of a phone call or other event, made by SIM card users (SMS, MMS…). With network pings, network availability is regularly checked by the network. Both serve to locate the mobile device [9].

The CDR data contains information that describes a specific event of a telecommunications transaction but does not contain the content of that transaction. It can include the phone numbers of both the calling and receiving parties, the start time and the duration of the call. In modern practice, however, call records are much more detailed and contain attributes such as [10, 11]:

- the phone number of the calling party (caller – page A),
- recipient's phone number (called party – page B),
- call time (date and time),
- call duration,
- the billing phone number charged to the call,
- identification of a telephone exchange or transmitter,
- a unique serial number identifying the record,
- the result of the call (whether the call was connected or not),
- the type of transaction (voice call, SMS, etc.),
- any malfunction that occurred and others.

The latest technology of mobile data transmission that is currently in Slovakia is the 4G/LTE. However, its coverage is not 100%. Mobile devices choose the data transfer technology automatically based on the availability of the signal. Signal quality depends on the existence and direction of nearby transmitters that have appropriate technological attributes. Individual mobile operators are also publicly reporting on this availability through the coverage maps.

26.3.2 Map Analytics and Accuracy of Geolocation

Market Locator also allows you to send SMS messages when someone arrives in a chosen location – LBS (location-based services) or geolocation campaign. This is the most appropriate when we need to reach people near a specific location. For Market Locator, the availability of modern data technologies is important, especially for the device positioning accuracy. The more modern mobile data transfer technology is used, the higher accuracy of geolocation is. According to the Market Locator, the accuracy is approximately the following:

- 2G Network – Accuracy in kilometers
- 3G Network – Accuracy in hundreds of meters
- 4G Network – Accuracy 100 m + (150 × 150m in Market Locator)

Market Locator also states that with regard to the technical solution for providing mobile services, accuracy in cities is higher (up to approximately 150 m), the accuracy out the city, is lower (often more than 1 km) [12].

Market Locator presents a "heat-map" (see Fig. 26.1) in clear visual form, i.e. distribution of the population with the ability to filter the information based on the filtering criteria. The data are presented in anonymous and aggregated form so that sensitive customer information cannot be leaked and the privacy of the

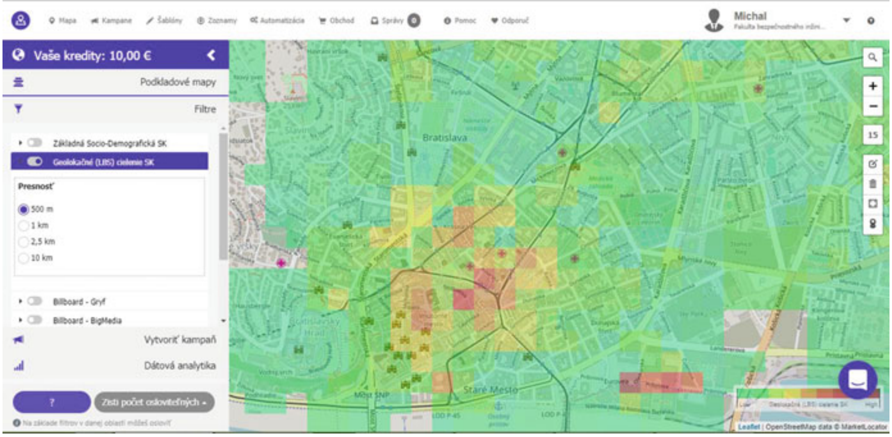

Fig. 26.1 Market Locator work interface

population is fully preserved. This solution is ideal for business people even when we think about how and where to place a business or a new branch; where to place promotional materials and billboards, or when we need to understand the typology of people who live, sleep or work in a certain location [13].

We choose a place in the map and define the target group in the filters. The map is overlaid with heat-maps. They show where the target group is the largest. We can reach out to this target group as well. We can count the number of people in that section of the map with the filters. The reach means about the number of people in that filter that can be targeted. This number can be multiplied by about 7 times for an extended data layer so we can extrapolate it to the entire population [13].

26.3.3 Reach of Market Locator

Market Locator currently operates in Slovakia, in the Czech Republic and in Saudi Arabia. There are more than 2.7 million people in Slovakia (see Fig. 26.2) who have agreed to receive targeted SMS campaigns for the three most important operators in Slovakia. Market Locator also allows to build an own mailing list, an own registration form, or log in to the SMS list. The custom contacts can be uploaded at any time in the CSV format and use them in SMS campaigns.

26.3.4 Market Locator and Privacy

Market Locator processes data about the SIM card holders, who have given the consent, to the all mentioned mobile carriers. For example, processes data such as

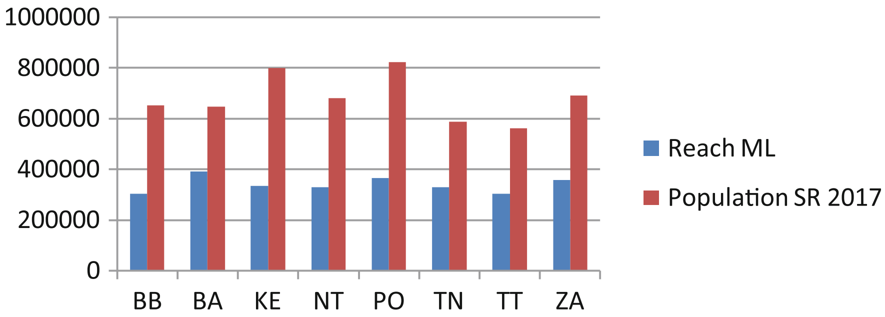

Fig. 26.2 Market locator reach vs. Population in regions of the Slovak Republic in 2017

gender, age, billing address, correspondence address, etc. It is important to note that Market Locator works with anonymized and aggregated data. The SMS messages are sent in the name of the mobile carrier and on the phone numbers the owners have given to the operator for the consent or have given it to another entity that offers subscription to such SMS messages. So, if messages are sent to their own phone number list, the obligation to request permission to process personal data is on the sender's side [14].

26.3.5 Market Locator Use in Cities

For example, Market Locator can use cities to send SMS about water or electricity shutdowns, or local council meetings, as well as information about cultural and sporting events, around. Market Locator also offers a new tool for the modern city office, so-called "SMS Radio". Thanks to this, the local government can reach inhabitants and gradually, create own list for further regular communication with citizens [15].

With regard to the Smart City concept, Market Locator can be useful in areas such are: geolocation analysis, informing and motivating for permanent residence, communication with defaulters, invitations and instructions for city events, registration for city events, feedback and surveys, losses and findings, general notices, hazard warnings, municipal infrastructure planning, optimization of public transport, understanding of behavior/travel, urbanism (development plans, schools, etc.) [15].

26.3.6 Market Locator Use in Security

On the basis of the analysis we can conclude that the use for security is particularly appropriate:

For municipal police and municipalities. Distribution charts and population profile analysis, assessment of the location of municipal police buildings, planning of police traffic or its motorized units, rapid overview of population density and composition, targeted communication of information to the public in order to meet the objectives of preventive programs, sending alert SMS messages, finding unlisted residents in the site, distributing other information, etc.

For the Ministry of the Interior of the Slovak Republic, the Ministry of Defense of the Slovak Republic and other central state administration bodies in the field of security. The same use as for municipal police and self-government, but also as a tool for searching missing persons, applications for the registration of potential witnesses of a crime scene in time, analysis of the profile of a large group of people (e.g. demonstrations), warnings of various threats, crashes, limitations, rapid communication with the public in case of extraordinary events (within the Act No. 42/1994 Coll., on Civil Protection of the Population as amended, defining it as a natural disaster, a technological accident, a terrorist attack or the accumulation of its effects – a disaster),

For business entities. Internal alert SMS messages, as a complementary channel with employees or interested public, for example in case of industrial accidents or security threats.

26.3.7 Market Locator Use in Soft Target Protection

The use of this service could also be useful in protecting of soft targets, in particular in protecting people in public areas, large commercial centers, major transport hubs, etc. Sending a locally targeted alert message, even in the case of terrorist attacks, can avoid significant losses on human lives and property. The advantage can also be reduction of the chaos and disorientation of people and organization.

In the first example (see Fig. 26.3) we can see the possibility of using Market Locator in case of an attack in the open public area. The epicenter is a point in the city where there has been, for example, a terrorist attack. Subsequently, we assume

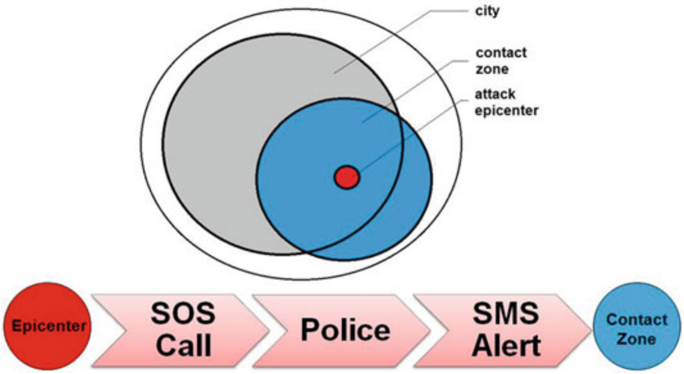

Fig. 26.3 Example 1 – Attack in city (public area)

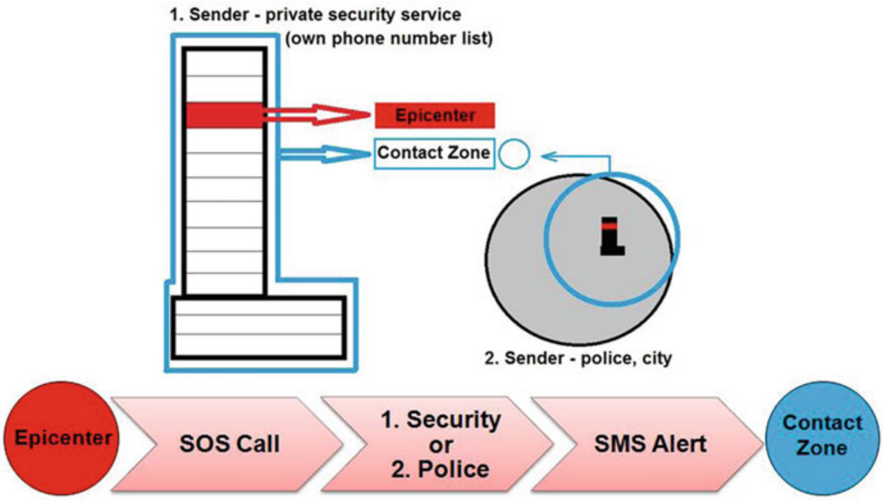

Fig. 26.4 Example 2 – Attack in big building

that someone on the epicenter, will make a phone call to the emergency line and report this fact. The police verify this event and send an alert SMS message to the location. The contact zone of the sent SMS will not be a whole city, but only the epicenter and the selected circle around the epicenter. This alert message will alert residents to leave the epicenter, to find safe shelter and to wait for further instructions.

In the second example, (see Fig. 26.4) is illustrated the possibility of using Market Locator in the case of terrorist attack on a large building with offices. Epicenter is a space in the building on the selected floor. In this case, the event can be reported not only to the police but also to the private security service that provides protection of the building. The police can send an alert SMS message to the neighborhood of the building based on the locality, as in the first example. However, a private security service may also send such alert message, from the own list of telephone numbers, for example, staff from the building.

In both cases, is questionable how people respond to the message and if we achieve the desired result, i.e., immediate transfer of persons to a safe area. The opposite and unwanted outcome could be, that the SMS draws attention and attracts curious citizens closer to the epicenter and in such way to endanger themselves. However, we conclude that comparing with early warning systems based on acoustic sirens, we can expect a higher chance of receiving and understanding the alert.

The advantage of this service compared to other communication channels is mainly targeting according to various criteria, locations, high probability of reading SMS, approximately 50% population coverage within the Slovak Republic and the possibility of own extension of the telephone number database.

Sending an SMS campaign usually takes 1–2 h (maximum 24 h) since launching. However, for the purpose of security and protection of soft targets, it would be possible to ensure immediate notification of alerts. The sender of such SMS would be the Ministry of the Interior of the Slovak Republic, so it would be “Government SMS”. Such message would be prioritized to regular SMS so immediate delivery would be secured. Another advantage is that, the people could also be contacted without the previous consent according to the GDPR.

26.4 Discussion

One of the biggest questions remains, if it is possible, thanks to such service, to actually save human lives. A number of internal and external variables affect terrorist attacks. Our expectations are primarily based on the advantage gained in the form of targeted and timely SMS alerts for residents directly in the threatened area. Figure 26.5 shows an example based on the time. The time of arrival of police is considered decisive in stopping of attackers and preventing further losses on human lives or property.

In the first case, we suppose a terrorist attack without the use of SMS alerts. From the start of the attack, it takes 5 min and someone in the epicenter contacts the emergency line. The police will arrive in 15 min and will eliminate the attacker. We expect that people’s ignorance around the epicenter to cause greater loss of life and property.

In the second case, we assume that the same process is complemented by sending an alert SMS to a threatened area that is sent before the arrival of police forces. This scheme assumes that if an SMS alert is sent to this area, life losses will be lower as well as the number of injured people, ensuring a higher number of saved lives.

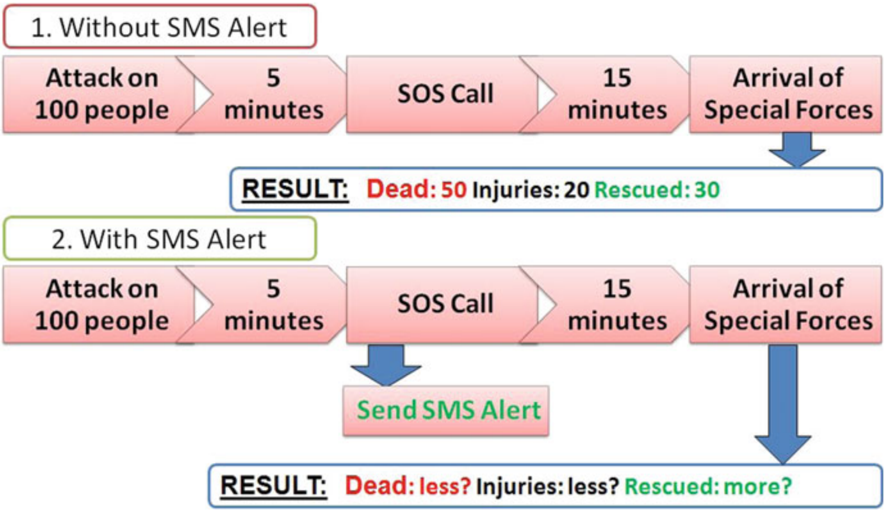

Fig. 26.5 Example of timing during a terrorist attack

In this study, there is a Market Locator utilization of model for sending alerts to the city residents. These proposals need to be verified in practice on a suitable polygon (municipality or city).

26.5 Conclusion

Modern technologies are increasingly being used in all areas of our lives. Local governments are gradually introducing various “smart” solutions to simplify or automate city operations. Such cities can then be called “smart cities”. Various modern solutions can also be applied to security management. In this study, we suggested a usage of the existing Market Locator tool for important security issues in cities, especially for protection of soft targets. The tool can be used for quickly alert of people via SMS. The proposed solutions resulting from the study need to be verified and testing in practice.

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Chapter 27
Sophisticated Drones: New Dangerous Tools for Potential Radiological Attack on Selected Soft Targets

Jozef Sabol

Abstract The paper discusses the present situation regarding the potential use of drones, usually referred to as Unmanned Aerial Vehicles (UAVs), for terrorist attacks of soft targets. An overview of currently available drones and their capabilities to carry out such an attack are also outlined. Since UAVs may play a dangerous role especially in striking selected soft targets, prevention measures are developing in order to mitigate the threats which may be associated with the use of CBRNE materials or weapons transported by these vehicles to attack the selected overcrowded sites. Special attention is paid to the use of drones to carry out radiological attack including the specification of relevant radionuclides.

Keywords Drone · UAV · CBRNE · Terrorist attack · Radioactive sources

27.1 Introduction

Usually, "soft targets" are referring to civilian sites where unarmed people gather in large numbers. The typical soft targets include national monuments, hospitals, schools, sporting arenas, hotels, cultural centres, movie theatres, schools, libraries, hospitals, cafés, and restaurants, places of worship, nightclubs, shopping centres, transportation sites (railway station, buses, rail systems, and ferries) [1].

Contrary to soft targets, the hard targets are well-protected and the access for members of the public is strictly regulated. These targets include such facilities and installations as airports, government buildings, military facilities, foreign embassies, oil or petroleum storage tanks, and nuclear power plants. For terrorists, attacks on soft targets are sometimes more attractive, and obviously much easier, than the

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L. Hofreiter et al. (eds.), *Soft Target Protection*, NATO Science for Peace and Security Series C: Environmental Security,
https://doi.org/10.1007/978-94-024-1755-5_27

attacks on most hard targets. At the same time, such attacks have for the average citizen a higher terror value than other attacks since they trigger panic, fear, and chaos.

One of possible ways in attacking soft targets is the use of UAVs (drones) defined as powered, aerial vehicles without a human operator, able to fly autonomously (also in large groups) or be piloted remotely, and carrying a lethal payload containing CBRNE or other agents and weapons. Originally, drones were used only in military operations, but now some of them can be easily commercially available without any special permission.

27.2 Characteristic of Soft Targets

The soft target usually represents a place which is vulnerable to an easy attack due to the lack of its security or protection measures. Such a location is often populated by large groups of people. It is always important to realize what makes these targets vulnerable in order to take appropriate preventive safety measures. Sometimes, even an individual person may be considered a soft target.

27.2.1 Individual Persons

A soft-target may also be persons who, due to their actions and a lack of appropriate protection, is at the mercy of existing risks and thus represents an easy target. Hard-target persons are persons who can minimize existing risks and thus probably not considered by terrorists as attractive targets. In addition, some officials, leaders or politicians may be attracted by terrorists to attack them despite their protection by bodyguards. The attacks on these persons are in most cases carried out in the open space and during their travelling. An example that the drones were able to get so close to a world leader at a public outdoor event was recently demonstrated in Venezuela, where two drones were to assassinate the president, but the attack was not successful [2].

In order to reduce the danger to be attacked, one should behave in a way that he/she is not susceptible and attractive to potential terrorists. The following hints may discourage terrorists to attack a person who is:

- Alert, confident and walk with purpose; Aware of what is happening around us;
- Positioning in relation to others and in relation to structure;
- Distancing – not letting anyone into his/her personal space;
- Not displaying items of value (jewellery, mobile phone, tablets);
- Locking the car once inside, locking doors and windows of your home;
- Being prepared with keys in hand to unlock front door entry to house and car.

27.2.2 Hardening Soft Targets

For an individual person, it is almost impossible to harder of a soft target location. This can only be done by law enforcement, community officials, employers, event coordinators, and public citizens alike [3]. In some cases, however, a soft target may be upgraded into a hard target. The airport becomes a hard target location to travellers only once they have made it past the point of security. The standard airport security process commonly includes full-body scanners and/or metal detectors. In some airports, a thorough search of all traveller belongings is carried out using a special computer tomography scanner [4].

27.3 Types of Drones

Generally, during the last 10–20 years military UAVs have been considered as rather controversial means for terrorist attacks. This was especially highlighted following 9/11 counterterrorism strategy. They are high-performance aerial vehicles that can operate at high altitude, can reach high speed, can carry enough payloads, and can reach considerable ranges [5]. Relative cheap and easily accessible commercial drones have already attracted attention of potential terrorists and it is expected that in the near future they would try to use this technology for their attacks. This is why more strict control has to be introduced to prevent an easy access to relevant drones.

Small drones are relatively easy accusable and cheap, they can operate anonymously by persons who may not be easily identified. The latest technology provides unprecedented access virtually to any site in open air and even inside buildings. The UAVs may also serve for the assassination of politicians.

In principle, the wings of drones can be fixed or rotary. Fixed-wing UAVs are remotely piloted airplanes. They can be either hand-launched or launched by means of catapults.

27.3.1 Wing Drones

There are some advantages of a fixed-wing drones mainly because they consist of a much simpler structure in comparison to a rotary wing. In addition, the fixed-wing UAVs require air moving over their wings to generate lift and they cannot stay stationary in the same position which may be their disadvantage in contrast to rotary wing UAVs. Fixed-wing UAVs are usually remotely piloted airplanes which can be either hand-launched or launched by means of catapults (see Fig. 27.1).

Fig. 27.1 Wing drones essentially remind the design of conventional aircraft

Fig. 27.2 Some examples of rotary drone versions. A nightmare scenario is the use of a small drone to deliver chemical or biological agents

27.3.2 Rotary Drones

Rotary-wing UAVs generate lift through the rotation of an aerodynamic surface (see Fig. 27.2). In the presence of multiple rotors, they are usually referred to as "multirotor" (e.g. tricopter, quadcopter, hexacopter, and octocopter).

The main advantage of rotary-wing UAVs lies in their hovering capabilities and in their capability to take off and land vertically without the need for any extra equipment.

27.4 Attacks of Drones on Specific Soft Targets

Everything suggests that a new era of terrorism by unmanned aircraft is about to become another malicious threat for the civilian population and another sensitive target including selected overcrowded places and specific objects considered soft targets. The use of weaponized drones by lone individuals and well-organized terrorist groups is no longer just a concern for the future, but very much for the present.

Fig. 27.3 Drones can attack soft or other targets in large groups where individual drones may communicate among themselves and do not require remote control.

27.4.1 Individual Drones

The barrier to gain access to commercial off-the-shelf technology that can be used to lethally target individuals is very low since this domain is still not sufficiently regulated in most countries. Extraordinary threat present lone actors usually referred to as lone wolves, who act on their own and prepare and commit violent acts alone, without receiving any orders or assistance from outside. These terrorists may be influenced or motivated by the ideology spread in mass media and beliefs of external militant groups.

27.4.2 Drones Attacking in Swarms

The use of a swarm attack demonstrates a militant capability, which was previously limited to states, to simultaneously control and coordinate several commercial drones at one time using a GPS unit. This development should prompt professional militaries to double down on countermeasures, specifically the creation of electronic jamming tech. As nations invest in drone research, it is paramount that in addition to drone development, researchers continue to emphasise counter-technologies.

A swarm of armed drones is like a flying minefield (see Fig. 27.3). The individual elements may not be that dangerous, but they are so numerous that they are impossible to defeat. They can be disabled one by one, but the cumulative risk makes it safer to avoid them than to try to destroy them all. While minefields on land may be avoided; the flying minefield goes anywhere. When it strikes targets on the ground the swarm can overwhelm any existing opposition by pure numbers of intelligently-targeted warheads. Future drones will be able to draw energy from the environment and recharge themselves, and thousands of them will operate as a single swarm requiring just one operator – or none. New developments in smart weaponry make swarms of small drones more lethal than anything currently available.

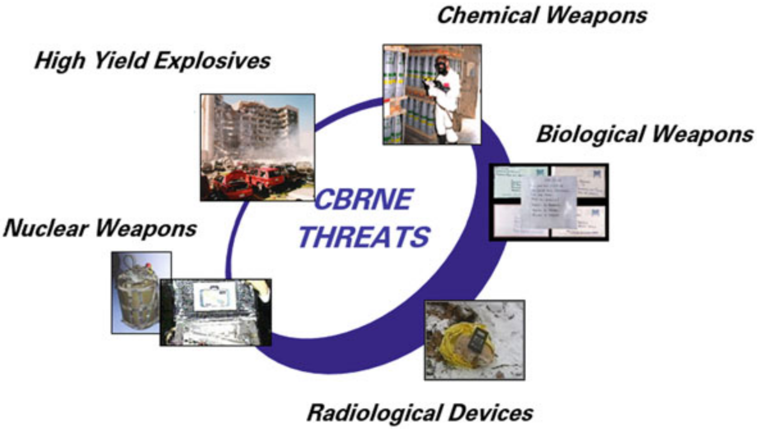

Fig. 27.4 The potential use of drones to deliver CBRNE weapons to the remote target selected for the attack

27.4.3 Drone CBRNE

Emergent technologies are likely to have major implications with regards to chemical, biological, radiological, nuclear and explosive (CBRNE) terrorism. Commercially available drones will become cheaper, more sophisticated, and capable of carrying larger payloads and reach further distance. The error groups will continue capitalize on this technology, using drones to disrupt military operations and attempt to harm civilian populations. In this respect, the use of all CBRNE agents/weapons is expected (see Fig. 27.4).

As mentioned above, drones offer an attractive vehicle for various kinds of terrorism. Complete drones or their parts can be easily transported into the country without much difficulties. In terms of CBRNE defence assignments, unmanned systems can perform a wide variety of tasks that range from inspection and surveillance to detection and decontamination. CBRN devices installed on a UAV platform can perform their functions independent of ground circumstances, thus reducing hazards of human loss and long-lasting health harms to first responders, rescue teams and soldiers. Drones can detect and also, to certain extent identify, radioactive, chemical, and biological substances, as well as explosives while reducing human effort and increasing protection of rescue personnel.

Following the Fukushima Daichii nuclear disaster, which occurred in 2011, the use of UMVs allowed wide-area radiation monitoring in high-radioactively contaminated areas. Later on, in 2015, scientists in Japan constructed a drone which was able to enter inside the nuclear reactor buildings guided by sophisticated laser technology. Such drones can not only avoid obstacles, but they are capable to function in areas without GPS signal [6]. Besides monitoring functions in contaminated areas, these drones could also be deployed in remote areas to detect and identify infectious agents and other dangerous agents.

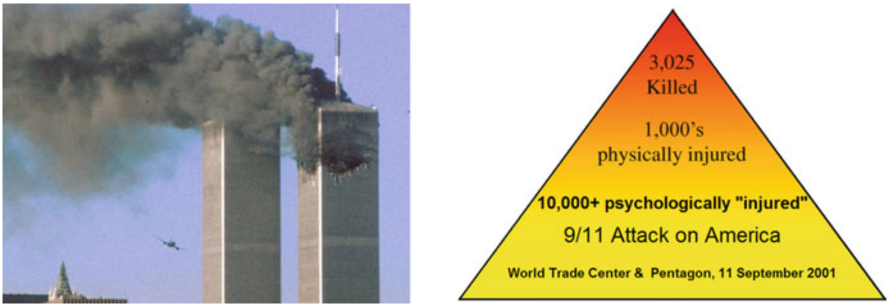

Fig. 27.5 The 9/11 WTC attack and its consequences

Methods to reduce consequences of any radiological attack include equipping and training first responders such as police, fire, and hazardous material response forces, developing and deploying more effective methods to clean up radioactive materials and decontaminate buildings, creating better crisis management strategies for all levels of government, developing better means for crisis management leaders to coordinate with first responders, decontamination crews, and medical personnel, and communicating with the public about measures that they need to take in the event of an act of nuclear or radiological terrorism.

The devastation inflicted by the 9/11 terrorist attacks in 2001 on World Trade Center's Twin Towers in New York highlighted the tactical value of aircraft as means of terror and not just targets, a trend which continued afterward. Originally, the terrorists considered to attack one of the US nuclear power plants but later decided to choose WTC mainly because of larger publicity and high concentration of people in these buildings several thousands of which died (see Fig. 27.5). Next time, similar attacks aimed at the prominent public, commercial or government building are expected to be carried out by weaponized drones.

27.5 Radiological Attacks: Exposure of Persons, Contamination and Decontamination

While a drone carrying a full-scale nuclear weapon is highly unlikely for several reasons, the potential for a UAV to deliver an explosive containing radioactive material is entirely possible (see Fig. 27.6). The direct consequences of an attack using drones as delivery means of high-activity radioactive sources to the target include external and internal exposure of affected people on the site and radioactive contamination of the area of the attack which would require costly decontamination in order to make it safe again.

Radionuclides which may be "candidate" for their use in a dirty bomb or another radioactive dispersal device (RDD) are given in Table 27.1.

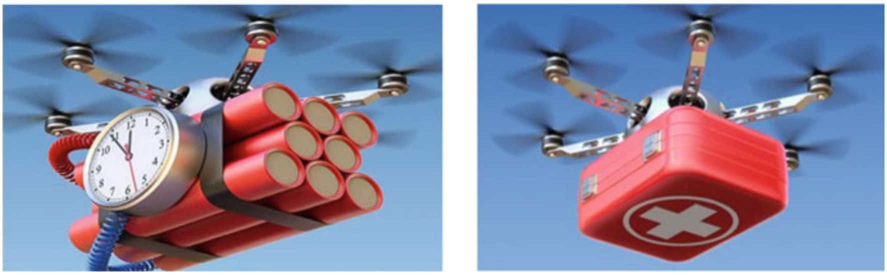

Fig. 27.6 In principle, drones may perform a dangerous mission, but they may also be very useful

Table 27.1 Radioisotopes "useful" for radiological weapons

Radiation emitted	Radionuclides	Where they are used
Pure alpha emitters	Plutonium-238 (^{238}Pu) Americium-241 (^{241}Am) Radium-223 (Ra-223)	Research and well logging, radioisotope thermoelectric generators (RTGs) for space missions Industrial gauges and well logging Cancer treatment of bone metastases
Pure beta emitters	Strontium-99 (^{99}Sr)	RTGs to produce electricity in remote areas
Pure gamma emitters	Technetium-99 m (^{99m}Tc)	Diagnostic imaging in nuclear medicine
Beta/gamma emitters	Cobalt-60 (^{60}Co) Cesium-137 (^{137}Cs) Iridium-192 (^{192}Ir) Iodine-131 (^{131}I)	Cancer therapy, industrial radiography, food irradiation Same uses as ^{60}Co and well logging Industrial radiography, medical implants for cancer therapy Nuclear medicine

Appropriate measures should always be applied to ensure reliable assessment of the radiation exposure using hand-held radiation monitors or/and personal dosimeters as well as specific monitors to evaluate radioactive contamination.

Immediate health effects from exposure to radiation emitted during a radiological attack would be essentially determined by the following factors: (1) the radiation energy absorbed by the body organs and tissues; (2) the type and properties of radiation involved (gamma, beta, alpha, neutrons); (3) the distance from the radioactive sources to an endangered person; (4) the means of exposure, i.e., external and/or internal (absorbed by the skin, inhaled, or ingested); and (5) the time an individual is exposed to radiation.

Basic protective actions which are related to the above-mentioned factors aimed at the reduction of radiation effects include minimizing the time exposed to radioactive materials; maximizing the distance from the source of radiation; shielding from external exposure as well as the protection against inhaling

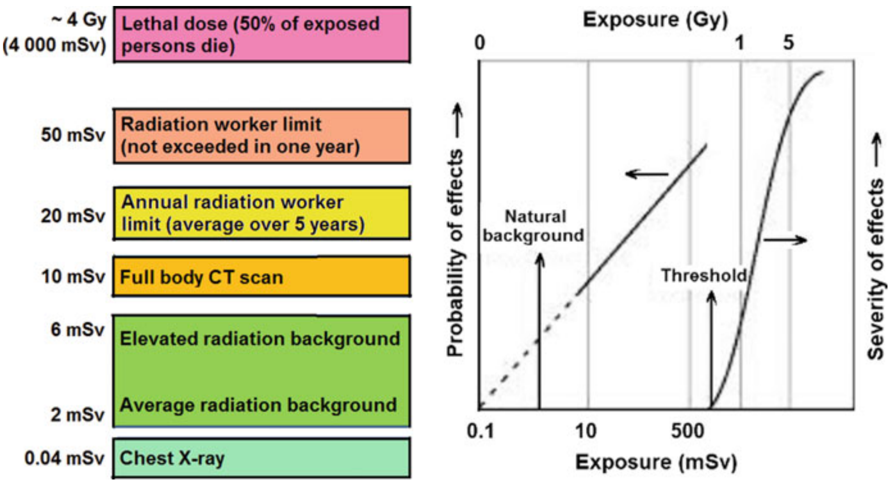

Fig. 27.7 Radiation exposure levels and biological effects

radioactive material. The illustration of the range of typical radiation exposures related to various situations and the characterization of stochastic (probabilistic) and deterministic effects is in Fig. 27.7.

27.6 Conclusion

It is well-known that both UAVs and associated technology can be acquired without any big problem and thus available to anybody including terrorists. The probability that sophisticated drones fall into the wrong hands present grave danger for the next years.

One of alarming scenario generally feared by police and other law enforcement agencies is the use of drones to deliver CBRNE components or weapons in attacking important targets of national critical infrastructure. The likelihood that drones could to disperse lethal agents, viruses or radioactive material over a sports stadium or public crowded place is a disturbing outlook.

The drones, furnished with small explosives, can attack troops and massacre or wounding large number of soldiers. The current terrorist drones are usually remotely navigated, but there are also available drones which are becoming increasingly autonomous. The latest prototypes can find a fixed target on their own, evade obstacles, and independently identify and shadow moving objects. In addition, a drone equipped with facial recognition technology could hypothetically be used to pursuit for and destroy selected persons or specific objects.

It has been recognized that existing research largely overlooked the dangers drones pose to soft targets. Therefore, it is so important to pay more attention to drone countermeasures, which typically include two major categories: kinetic or cybernetic. A kinetic countermeasure is aimed at incapacitating a targeted drone by physically damaging or immobilizing one or more components required to keep the drone in the air. The use of “anti-drone” drones presents one of the most widely practiced drone countermeasures. On the other hand, cybernetic countermeasures involve an assortment of tactics including electronic manipulation of a drone’s communication and guidance system. For the time being, however, in most countries many drone countermeasures remain illegal and would require prior approval or specific permission. This should change soon since the introduction of appropriate international standards is expected soon.

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Chapter 28
Normalization of the Magnetic Fields of Electrical Equipment in Case of Unauthorized Influence on Critical Information Infrastructure Facilities

Sergey Sukach, Dmitry Riznik, Natalya Zachepa, and Vladimir Chenchevoy

Abstract It is proved that the construction of charts of the distribution of the magnetic field of the installed electrical equipment allows us to assess the electromagnetic environment, to develop means and methods of protection against electromagnetic interference, side electromagnetic radiation and induction, as well as to reduce the probability of malfunctions in the work of IT equipment, electronics and electrical equipment. It has been established that as engineering and technical means of protection from side electromagnetic radiation and induction from induction motors, which allows to remove confidential information, interfere with work, listen to negotiations or destroy data from switching and technological systems of objects of critical infrastructure, it is expedient to use screens of a mesh structure.

Keywords Critical information infrastructure facilities · Magnetic fields · Side electromagnetic radiation and interference · Induction motors · Mesh screens

28.1 Introduction

During the last decade, terrorist organizations have changed their vector of attacks. Damage to the population and material damage to infrastructure objects is carried out mainly with the use of hacker attacks. So, in Ukraine, in December 2015, the world's first successful hacker attack on energy facilities was launched. At that time, cybercriminals de-energized three energy supplying organizations, about 30 substations were affected, and almost 230,000 homes and factories stayed without light until 6 h. And every year the number of cyberattacks is constantly increasing [1, 2].

At the same time, negligent attitude, not desire, and quite often, simply lack of information for leaders of many industrial factories on the need for the introduction

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L. Hofreiter et al. (eds.), *Soft Target Protection*, NATO Science for Peace and Security Series C: Environmental Security,
https://doi.org/10.1007/978-94-024-1755-5_28

of technical means of protection to ensure the safety of their own resources are the main causes of maximum losses. For example, the services of the Ministry of Emergency Situations of Ukraine in the open access had published communications schemes of communication cables of "Energoatom", documents on access to the territory of the nuclear power plant, information on the remote water supply station and water channel. This information allows terrorists to carry out their attacks without difficulties.

In recent years, terrorist organizations are often perform their attacks with the use of special equipment [1–3], which uses side electromagnetic radiation (SER) of the electronic devices [4], electrical equipment and power supply, allows to remove confidential information from servers, interfere with the work of information and process systems, listen to talks or destroy data. In addition, due to the dense disposition of the installed electrical equipment, the problems of electromagnetic compatibility arise, which leads to malfunctions in the work of IT-equipment, electronics and electrical equipment. The concept of information security is complex, and its implementation consists of many parts, such as specialized software, hardware protection, human factor, regulatory support, and so on. In our work, we consider a small but very important part of this complex.

Taking into account current conditions the most effective, durable, absolutely harmless and reliable way to protect against these types of threats, is a special shielding of computer rooms, electronic equipment installations and electrical equipment [5, 6].

Thus, the hybrid war, declared by cyberterrorists, forces the scientific community to develop modern, both computer and technical means of protecting the automated control systems of technological processes of critical infrastructure objects.

28.2 Technical and Technological Solution for Soft Target Protection of the Magnetic Fields

28.2.1 Analysis and Justification of the Choice of Effective Protection Against Side Low-Frequency Electromagnetic Radiation and Induction of the Electrical Equipment

The term SER, appeared in the latest 60's and earlies 70's of the last century during the development of methods for preventing information leakage through various kinds of hidden and side radiation of electronic and electromechanical equipment, radio equipment, electrical devices. In Europe and Canada uses the term "compromising emanation" – compromising radiation. In America, the term "TEMPEST" is used [3]. Protection of information from leakage through SER is carried out using passive and active methods and tools. One of the most effective passive methods of protection from SER is shielding. Processes and phenomena forming SER, in ways of occurrence can be divided into four types: unpredictable functions of radio equipment and electric devices converting external acoustic signals into electrical signals; parasitic signals and inductance; indirect high-frequency radiation and low-frequency radiation.

The first three types are characterized by equipment, which is located in the server, negotiation and premises where installed automated control systems. And in these conditions, as active methods of protection (creating masking spatial electromagnetic interference, etc.), and passive, the main of which is the special shielding of computer rooms. Analysis of literature has shown that these types of protections have been poorly explored [1–4].

The greatest threat to the safety of information create by-products of radio and electrotechnical means of low-frequency electromagnetic fields, which contain the information inherent in most electrotechnical equipment. Radiation sources can be chains containing static or dynamic charges (electric current), in which information parameters one way or another protected information records. Protected information in the form of static or dynamic charges, can fall into these circuits directly, if these chains are involved in the processing, transmission and storage of protected information, or the elements of the chains themselves have the properties of acousto-electric converters, or indirectly, when dangerous signals penetrate into the chains that emit through parasitic bonds [7].

In turn, electromechanical equipment, which is characterized by low-frequency magnetic fields, is mainly installed in technical premises (compressors, pumps, ventilators) [7], where the application of active methods of protection and the use of general shielding is quite problematic from the technical side and financially costly in relation to a large area.

Chains that have an output beyond the control zone and which can receive dangerous signals through parasitic bonds of any kind, also belong to power supply chains. And if the cable lines of power in the technological premises are laid in insulation boxes that reduce the probability of information leakage, then this probability is significant in the places of connection to, for example, anti-dust ventilation, emergency drainage and other safety systems. The main element of these systems are induction motors. To date, induction motors (IM) occupy up to 80% of the total set of electric machines, which, in turn, are very serious source of the appearance of the SER [7]. Therefore, preventing the leakage of information through this chains is one of the tasks of engineering and technical protection of information. That is why, it is necessary to conduct experimental research on the distribution of low-frequency magnetic fields from induction motors of different power, to conduct an analysis of the efficiency of the use of mesh shields, on the basis of which will be developed a mathematical model that allow with the use of the graphoanalytic method to select the most effective shield installation distance in order to weaken the SER.

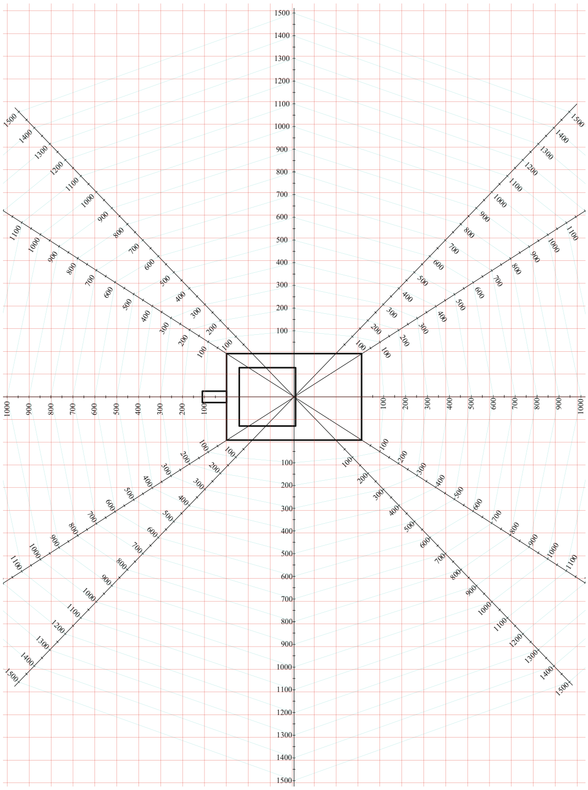

Fig. 28.1 Map of measurement of the magnetic field induction of the IM

28.2.2 Materials and Research Results

In measurements of SER, it is required to determine the boundaries of a controlled area, where the means of technical intelligence may intercept the SER with the help of an ideal or quasi-ideal receiver and the subsequent decryption of the information contained therein. Due to the fact that the decrease of low-frequency magnetic field (MF) of an IM at least twice reduces the SER of an IM, for the convenience of conducting experimental and computational studies, in order to reduce the information leakage zone for the SER, the magnetic field induction (MFI) was chosen as measured parameter. The measuring device TES-1394 was used to measure the MFI, which accurately measures the indicators in the region of ultralow and low frequencies. The measuring device is moved according to the map (Fig. 28.1) with a step of 0.05 m. Several studies of different kinds of an IM have been carried out, which are used at the factories of the Kremenchug region, Poltava region, Ukraine.

On the basis of the obtained results, the dependence of the change of the MFI according to distance and frequency of the supply voltage of an IM is constructed (Fig. 28.2).

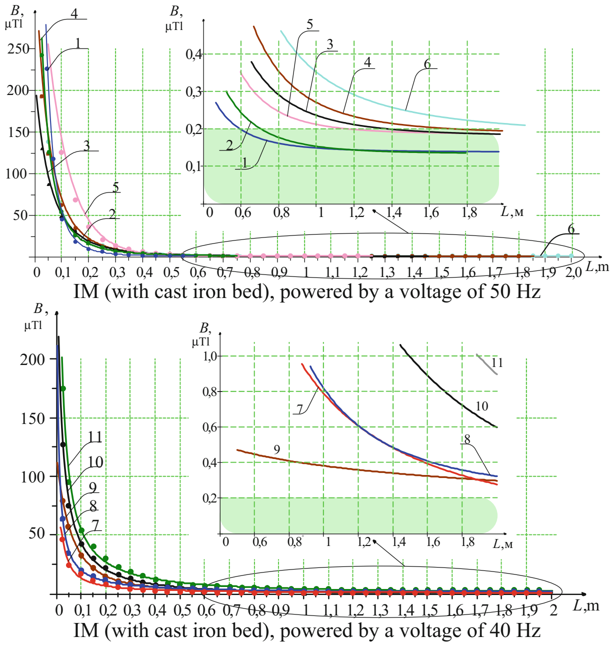

Fig. 28.2 Dependences of the change in the induction of the magnetic field from the distance and frequency of the supply voltage: 1 – $P_н$ = 5,5 kW; 2 – 15 kW; 3 – 22 kW; 4 – 22 kW; 5 – 30 kW; 6 – 45 kW; 7 – 110 kW; 8 – 132 kW; 9 – 160 kW; 10 – 250 kW; 11 – 315 kW

According to the results of the experiments using mathematical methods, an approximation of data was made, which allowed to determine the required level of MFI for the given power of the IM:

$$B(L,P) = (A(P) + C(P)L)^{-1/D(P)}, \tag{28.1}$$

where B – induction of a magnetic field, μT; L – distance from the IM to the metering point, m; $A(P)$, $C(P)$, $D(P)$ – coefficients of approximation, depending on the power of the IM.

To fully carry out the whole program of research at the factory is not possible, due to the impossibility of stopping technological equipment and the large accumulation of technological tools. Therefore, a laboratory research stand (LRS) was developed, the scheme and exterior of which is shown in (Figs. 28.3 and 28.4).

During the research, the surface of the complex with a grid of 50 × 50mm was covered. The device TES-1394 moves through the nodes of the grid and records the values of the MFI. A tripod was used for accurate positioning of the measuring device. According to the methods of measurement and processing of experimental studies, we have obtained pictures of the distribution of the magnetic field around the electrical equipment of the LRS (see Fig. 28.5). It should be noted that the IM

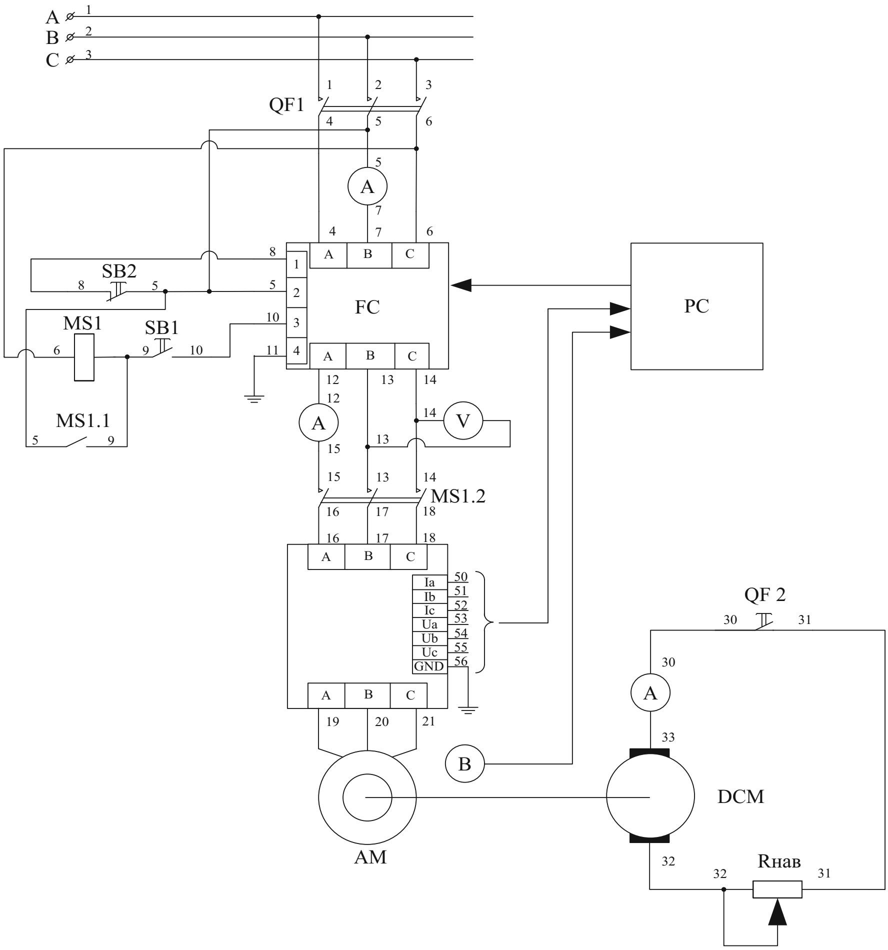

Fig. 28.3 Scheme of research facility

operates in non-load mode with the following characteristics: voltage supply – 220 V; frequency of supply voltage – 50 Hz; frequency of pulse-width modulation of the FC – 4 kHz.

The analysis of experimental data showed that the greatest value of the MFI is observed in three zones: Zone 1 (Fig. 28.5) – in the control panel near the ammeters – is at an elevation of 1.30 m from the floor level. The level of MFI reaches a mark of 6.79 μT; Zone 2 (see Fig. 28.5) – on the control panel under the frequency converter (FC) – is at an elevation of 0.95 m from the floor level. The MFI reaches a mark of 9.98 μT; Zone 3 (see Fig. 28.5) – near the terminal block of an IM – at an altitude of 0,25 m from the floor level.

Fig. 28.4 Exterior of the research facility

The analysis of the performed experimental research (see Fig. 28.5) showed that for the reliable operation of electrical equipment at modern factories, an accurate assessment of the electromagnetic environment (EE) is required, and the assessment of the electromagnetic environment requires an individual approach. And, as a rule, EE is worse with increasing of energy-consuming of factory. Therefore, the installation of integrated digital, electronic and mechanical equipment requires a very careful approach to protection from both electromagnetic disturbances (ED) and from the SER. As noted above, it is not always possible to use active methods to reduce SER. Therefore, passive ones should be used to install protective shields. Conducted analysis of the current trend of protection shows that the most widespread mesh shielding, because it has a number of advantages over solid shields. Namely, the reduction of the additional stress that occurs in solid shields [6], the visual contact with the technological equipment and the lack of the ability to touch the conductive and rotating parts of the equipment. Thus, a series of screens was investigated. The conducted experimental researches have shown, that the best result is given by metal, uninsulated grounded mesh 6 × 6 mm.

The dependence of the values of the MFI of an IM on the type of shield and mode of operation is shown in (Fig. 28.6), where the characteristics are marked accordingly: (1) without a shield; (2) with a shield of metal insulated mesh, 50 × 50 mm; (3) with a shield made of metal insulated mesh, 25 × 25 mm; (4) with a shield from a metal non-insulated grounded mesh, 25 × 25 mm; (5) with a shield from a metal non-insulated grounded mesh, 12,5 × 12,5 mm; (6) with a shield of metal non-insulated grounded mesh, 6 × 6 mm.

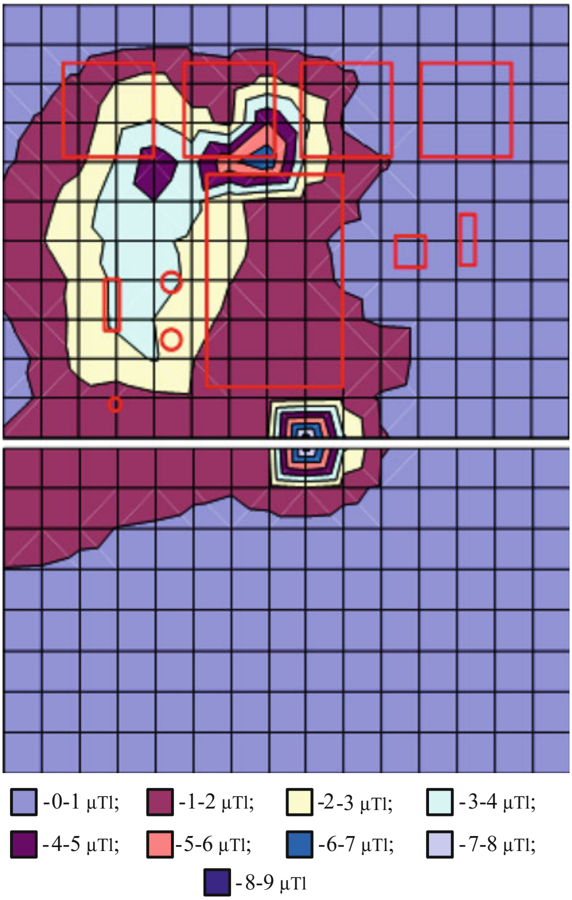

Fig. 28.5 Measurement of magnetic field induction on the front panel of the laboratory research stand

To analyze the results and to automate the calculation procedure, in the work the method of mathematical planning of the experiment was used in accordance with the scheme of rotatable central composite planning (RCCP). As a result of calculations the dependence regression equation of MFI of an IMwas obtained:

$$B = 2,11 + 6,61P - 2,83L - 5,70 \cdot 10^{-2}K_E + 7,08 \cdot 10^{-6}P^2 - 2,91 \cdot 10^{-3}PL - \\ - 4,06 \cdot 10^{-4}K_EP + 0,96L^2 + 4,68 \cdot 10^{-2}LK_E - 3,38 \cdot 10^{-4}K_E^2, \quad (28.2)$$

where B – induction of a magnetic field, μT; P – power of an induction motor, kW; L – distance to an induction motor, m; K_E – shielding factor, dB.

The adequacy of the model is confirmed by the high determination coefficient R2, which equal to 0,96. The coefficients that positioned before the factors indicate the

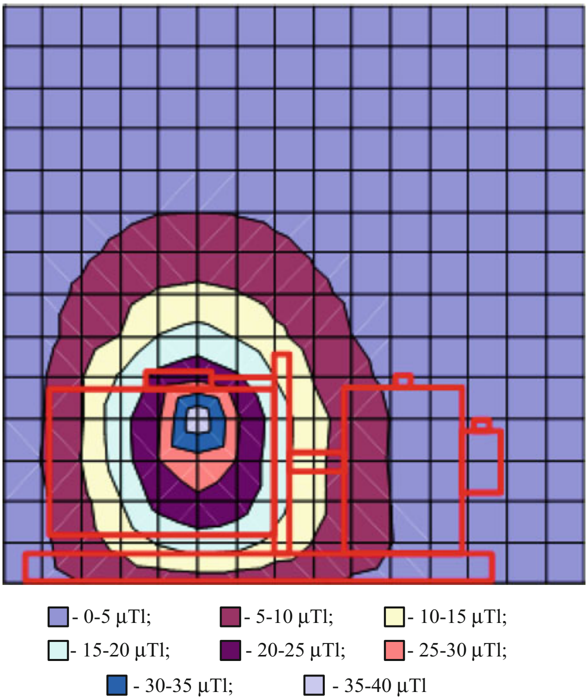

Fig. 28.6 Measurement of magnetic field induction in the frontal plane at a distance of 0.15 m from the induction motor

significance of the input parameters and their effect on the investigated size, as well as their pair interaction. The verification of the static significance of factors using the standardized Pareto map showed that the greatest influence on the level of the MFI are the power P, distance L, shielding factor KE and the quadratic distance value L2.

According to the calculations made in mathematical packages, the (Eq. 28.2) mathematical (Eq. 28.3) and graphic dependences of the change in distance to the IM taking into account the level of magnetic field induction and the shielding factor of the mesh shield were obtained, (Figs. 28.7 and 28.8).

$$L(K_E, B, P) = \frac{-b(P) \pm \sqrt{b(P)^2 - 4ac(P)}}{2a} \tag{28.3}$$

where $a = 0,96$, $b(P) = -2,83 - 2,9 \cdot 10^{-3}P + 4,68 \cdot 10^{-2}K_E$,

$$c(P) = 2,11 + 6,61 \cdot 10^{-3}P - 5,7 \cdot 10^{-2}K_E + 7,08 \cdot 10^{-6}P^2 - \\ - 4,06 \cdot 10^{-4}PK_E - 3,38 \cdot 10^{-4}K_E^2 - B$$

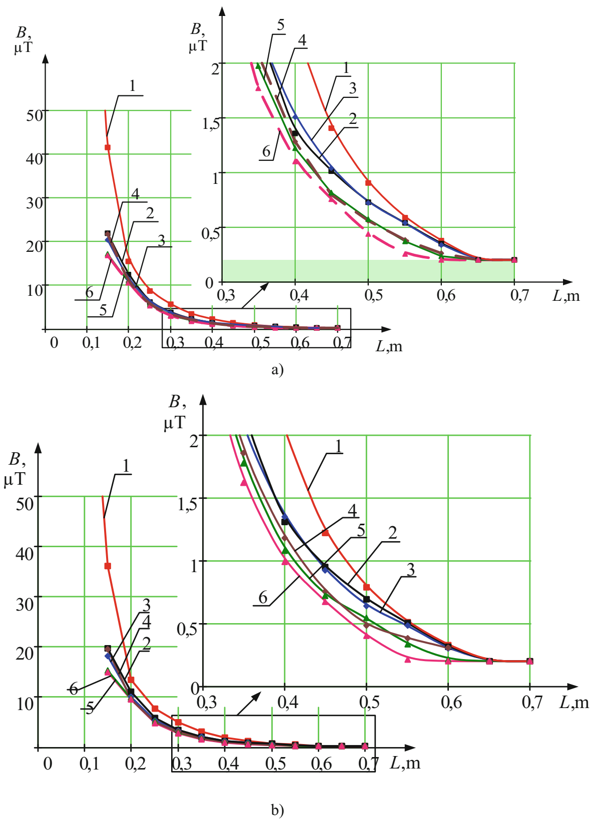

Fig. 28.7 MFI dependence after screen installation: (**a**) non-loadmode, (**b**) underload

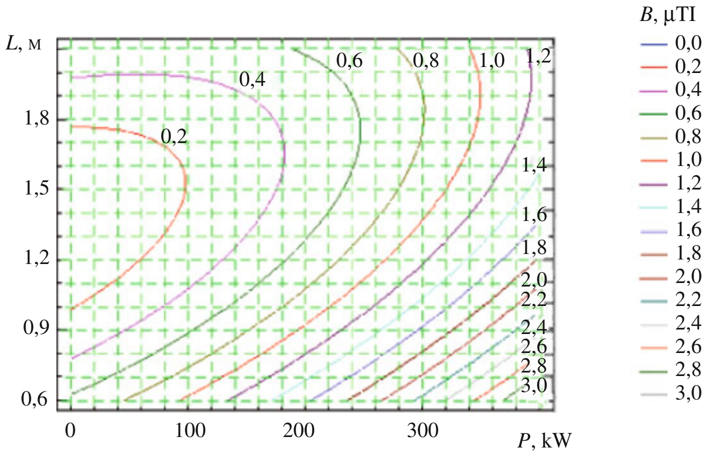

Fig. 28.8 Distance to an induction motor with a fixed value of the magnetic field induction B and a shielding factor $K_E = 4$ dB

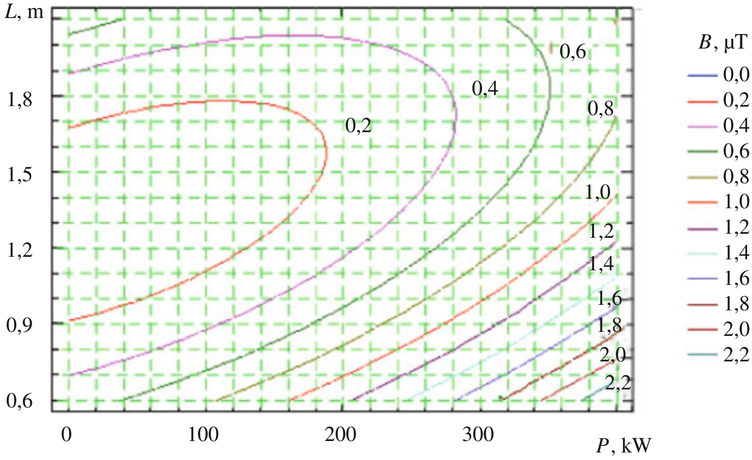

Fig. 28.9 Distance to an induction motor with fixed value of magnetic field induction Band coefficient of screening $K_E = 7{,}5$ dB

Based on the obtained model it is possible to determine the distance and coefficient of shielding, which allows with the use of the graph-analytical method to determine exactly which protective shield should be used in certain operation conditions of the technological object and will allow to choose the necessary shielding factor, which determines the type of screen to provide a minimum level of the MFI and, consequently, the SER, thereby significantly decreases area sufficient for receiving signals and extracting information with the help of special equipment.

The result of the processing of the obtained graphic materials (Figs. 28.8 and 28.9) or analytical dependencies (Figs. 28.2 and 28.3) are the comparative picture of the spatial distribution of the magnetic field induction around the IM without installation and with the installation of a protective shield (Fig. 28.10). The protective shield from a metal wired mesh which is grounded and mounted on along the contour of an IM. The walls of the protective shield are installed at distance of 0.15 m from the motor.

Studies have shown (Fig. 28.10) that, at low consumption power, an almost small change in distance is required to the provision of a minimum MFI. Contrary for higher-power motors, where the distance is reduced from 7.7% to 55%. Thus, the use of screens of mesh structure up to 80% reduces the boundaries of the interception zone of useful information using the means of technical intelligence that use ER.

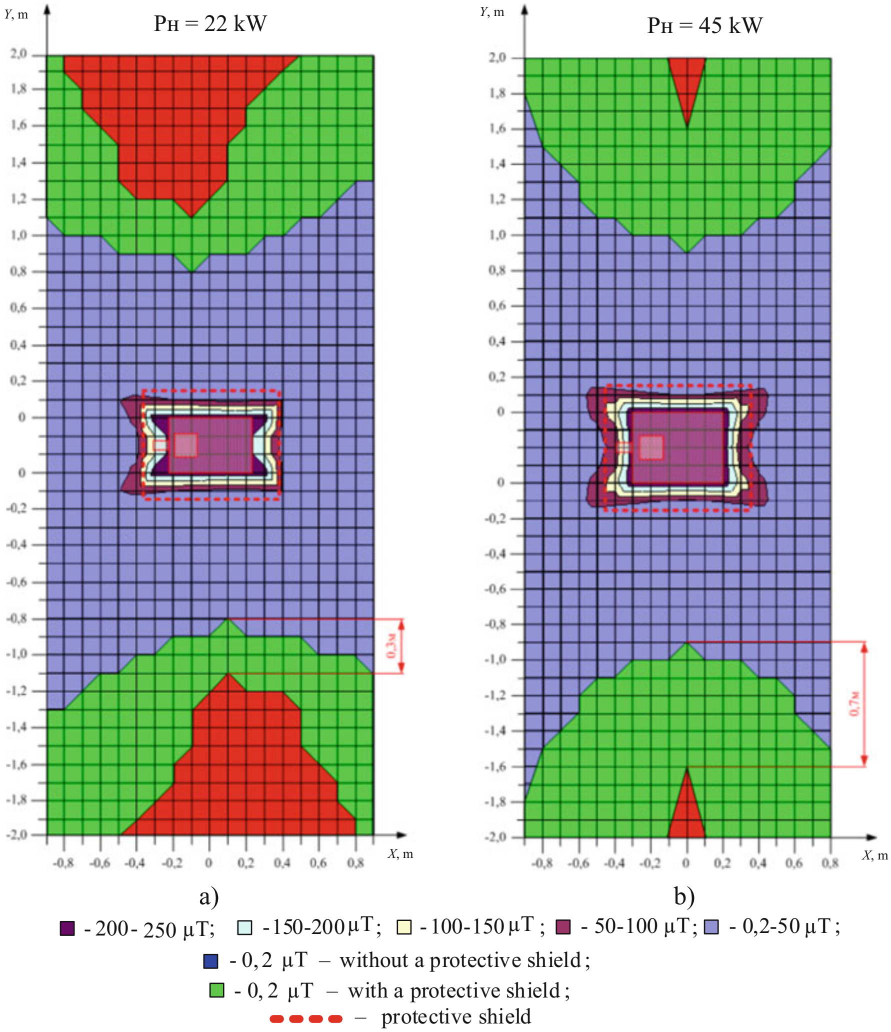

Fig. 28.10 The pattern of the magnetic field induction distribution around induction motor type M3BP180ML4, without and with the use of a protective screen

28.3 Conclusions

It has been proved that in order to ensure the electromagnetic safety and minimize the risks associated with the leakage of information through the side electromagnetic radiation of electrical equipment critical infrastructure facilities, it is necessary to plan, develop and integrate the approach to the implementation of organizational measures and technical means.

Approximation of the experimental data was conducted and the spatial dependence of the propagation of the magnetic field induction of an induction motor was obtained. Such approach allows us to determine the distance with the minimum values of magnetic field depending on the power of the electric motor and its mode of operation.

Studies of magnetic field propagation have shown that in the presence of several sources of the magnetic fields induction in the room, there is a redistribution of magnetic fields, which can lead to unstable operation of electronic and electrical equipment.

Obtained the analytical dependence of the levels of the magnetic field induction of an induction motor, which takes into account the shielding factor, power and distance to the induction motor, allows us to establish the necessary parameters for protection against the hazardous effect of the side electromagnetic radiation. The use of mesh screens can reduce the level of magnetic field by 55% and by 80% – the SER around working induction motor, reduce the radius of the required safety zone, thereby significantly reducing the probability of useful information leakage.

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Chapter 29
Soft Target Protection by Using Blast Resistant Trash Receptacles

Jovan Trajkovski and Robert Kunc

Abstract Many terrorist attacks in the last decade around the world have exposed the vulnerability of citizens in public places. The Migrant crisis in Europe additionally increased the intolerance among different ethnic groups leading to increased number of terrorist attacks at public places. Among others, explosive devices are often used at crowded public areas as in the case in Boston marathon 2013. Therefore blast protection of soft targets is very important issue in today's world. Consequently the response evaluation of civilian objects, equipment and properties to this kind of loads becomes also important. For that purpose, this paper presents the results comparison between two different trash receptacles (non-blast resistant and improved design of blast resistant trash receptacle) taking into account the human injury criteria of the numerical HYBRID III 50% dummy by using the explicit code LS-DYNA.

Keywords Blast response · Soft target protection · SPH method · Blast loading

29.1 Introduction

Terrorist attacks in the last decade have exposed the vulnerability of citizens in public places. Since 2014 more than 65 terrorist attacks have been carried out causing more than 350 deaths and 2400 injured [1]. Besides using vehicles, melee weapons and firearms, explosives are also disposed in public trash cans to attack the unprotected citizens in public places like city centers, metro stations, stadiums, cinemas, banks, embassies, governmental buildings and etc. Public trash receptacles can be easily abused as well-covered places in which Improvised Explosive Devices (IED) can be simply left and then remotely activated, like in the case of Boston

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L. Hofreiter et al. (eds.), *Soft Target Protection*, NATO Science for Peace and Security Series C: Environmental Security,
https://doi.org/10.1007/978-94-024-1755-5_29

marathon terrorist attack [2]. Therefore, blast resistance and possibility of blast loads redirection are very important characteristics of trash receptacles placed at public areas.

Evaluation of the blast response of civilian structures and equipment is of great importance in today's globalized world with high probability of terroristic attacks. For this reason, it is very important to improve the response of such structures and equipment to withstand these high-intensity short-duration loads with little consequences. Since blast loading experiments involving high explosives are very expensive even for small scale experiments performed in laboratory conditions, the numerical analysis represents the most valuable examination tool.

The empirical ConWep method [3, 4], the Multi Material Arbitrary Lagrange Euler method (MM-ALE) [5–10], Smooth Particle Hydrodynamics (SPH) method [11–13] and the Corpuscular Particle Method (CPM) [14, 15] are the most useful methods available today for numerical evaluation of blast loaded structures. In this study, the combined SPH-FE method [16–18] was used since it has been proved as an efficient and precise method for modelling the blast response of military and civilian structures [11–13, 19–21]. Numerical simulations presented in this paper were performed using the explicit code LS-DYNA.

In this paper, the results comparison is presented for two different trash receptacles (non-blast resistant and blast resistant) taking into account the human injury criteria of the numerical HYBRID III dummy. The results have shown that a considerable effect can be achieved by using blast resistant receptacles, thus reducing the possibility of deaths and injuries. A thickness optimization study can also be performed, based on the previously defined size and properties of the explosive.

29.2 Numerical Model

The SPH method is a computationally efficient and reliable method for modelling the blast response of different structures and vehicles [11–13, 19–21]. It surpasses the Multi Material Arbitrary Lagrange Euler (MM-ALE) method, especially when irregular and complicated geometries are examined. The SPH method does not require the surrounding air to be represented in the model (Fig. 29.1), which greatly reduces the computational time required to solve the model. The drawback of the SPH method is that it does not allow the user to track the blast wave loading parameters at a certain point in space as a function of time [19]. However, this study is focused on the response of trash receptacles and HYBRID III dummy to blast loading, considering that proper blast wave loading characteristics are satisfied following the procedure previously described in [22–24]. Therefore, the SPH method was used in a combination with the well-known Finite Element Method (FEM).

HYBRID III dummy (see Fig. 29.1) is successfully validated [25–27] and used particularly in crash analysis [28–30]. Its validation under blast loading is performed only for underbody blast loading conditions [31, 32] to examine the response of lower extremity of HYBRID III dummy while validation of its response under direct

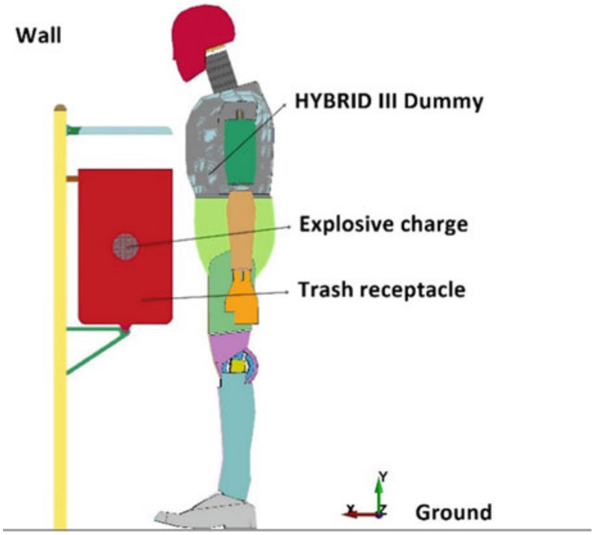

Fig. 29.1 Numerical model presentation

blast wave loading is still missing. For the purpose of the study HYBRID III dummy was placed at a distance of 50 mm between its chest and the nearest point of the trash receptacle (see Fig. 29.1).

29.2.1 Geometry and Mesh

Figure 29.2a shows non-blast resistant trash receptacle, while Fig. 29.2b shows the blast resistant trash receptacle made of armour steel PROTAC 500. The armour steel PROTAC 500 is represented with Johnson-Cook material model [33, 34] and 48,500 Lagrangian shell elements with one integration point. Since underintegrated elements were used, the hourglass energy of the receptacle was carefully controlled to be under 3% of the internal energy. The explosive charge was modelled with 14,628 SPH particles in the form of sphere representing a mass of 0.5 kg (see Fig. 29.1). In order to simplify the analyses, all the surrounding parts in the model were represented as rigid.

The default automatic surface-to-surface or tied surface-to-surface contacts were used between different parts in order to better approximate the real case. The contacts between the receptacle and the SPH particles were modelled as automatic nodes to surface penalty based contact available in LS-DYNA. The 50% male HYBRID III dummy in the model was represented with 143 parts, 5239 elements and 8865 nodes. HYBRID III has defined numerous sensors at the same places as they are mounted on the experimental HYBRID III dummy. A more detailed description of the models‘geometry can be found in [35].

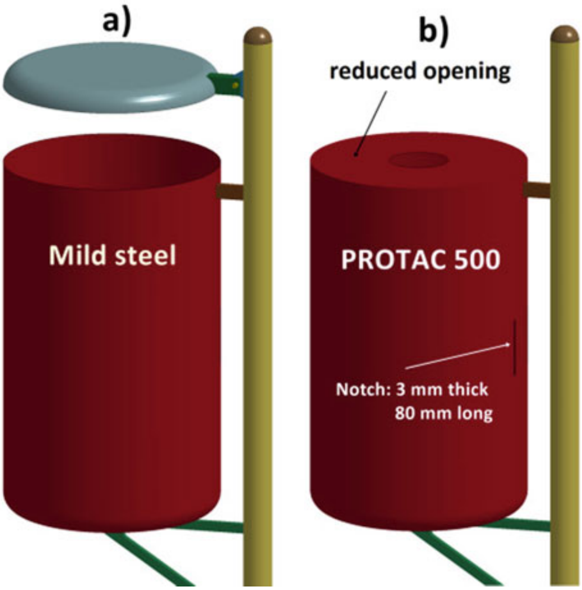

Fig. 29.2 Trash receptacle model: (**a**) non blast resistant (**b**) blast resistant

29.2.2 Blast Injury Classification

Blast injury is generally classified as; Primary, Secondary, Tertiary or Quaternary. Primary (blast) injury is caused by the blast wave causing damage to the surrounding tissues of hollow organs, including the lungs, intestines and ears, and subsequent hemorrhage and edema. Secondary injury is due to the impact and penetration of structural fragments and debris. Tertiary injury can be caused by the displacement of the whole body or body parts. Quaternary injury includes other effects such as burns, gas and dust inhalation, and structure collapse [36].

29.2.3 Material Models and Material Parameters

Explosive Charge The explosive charge in the model is presented with ∗MAT_HIGH_EXPLOSIVE_BURN in combination with the Jones-Wilkins-Lee (JWL) equation of state (EOS)

$$p = A\left(1 - \frac{\omega}{R_1 v}\right) exp^{\,-R_1 v} + B\left(1 - \frac{\omega}{R_2 v}\right) exp^{\,-R_2 v} + \frac{\omega E}{v} \tag{29.1}$$

Table 29.1 Material properties and JWL parameters for TNT [37]

ρ(kg/m^3)	D(m/s)	P_{CJ}(GPa)	A(GPa)	B(GPa)	R_1(−)	R_2(−)	ω(−)	E(J/m^3)
1590	6930	21.0	3.712	3.231	4.15	0.95	0.3	$7*10^9$

Table 29.2 J-C model parameters for PROTAC 500

J-C strength parameters	A (MPa)	B (MPa)	n (−)	C (−)	m (−)
	1380	948	0.2351	0.0035	1.087
J-C fracture parameters	D_1 (−)	D_2 (−)	D_3 (−)	D_4 (−)	D_5 (−)
	0.0001	1.586	−1.718	0.00695	3.247

which calculates blast pressure as a function of relative volume $v = \rho_0/\rho$ and internal energy E, for an explosive element. In this equation, A, B, R_1, R_2, and ω are parameters related to the explosive material and can be found in most of the explosive textbooks. They were taken from reference [37] for TNT high explosive and are given in Table 29.1.

PROTAC 500 PROTAC 500 is a low carbon high-strength steel which is complexly alloyed with Si (1.01 m. %), Cr (0.69 m. %), Mo (0.33 m. %), and microalloyed with Ti (0.027 m. %) and B (0.002 m. %) [38, 39]. The ballistic test performed at the NATO (North Atlantic Treaty Organization) accredited Beschussamt institute in Ulm, Germany, showed that PROTAC 500 can be successfully used for military and civil applications where high protection is needed [39].

For the purpose of numerical representation of PROTAC 500, the Johnson-Cook (J-C) model was used. The material parameters used for PROTAC 500 regarding the J-C strength as well as fracture model are given by Trajkovski et al. [40], as shown in Table 29.2.

29.3 Results

Although much more detailed comparison can be made including the injury parameters of particular body parts, for the purpose of this analysis only the chest deformation is presented. Figure 29.2 shows the results comparison for chest deformation from non-blast resistant model and blast resistant model. It can be seen that chest deformation of around 25 mm is achieved for the non-blast resistant model while no chest deformation is present using the blast resistant receptacle. Figure 29.3 shows the visual representation of the results comparison between the

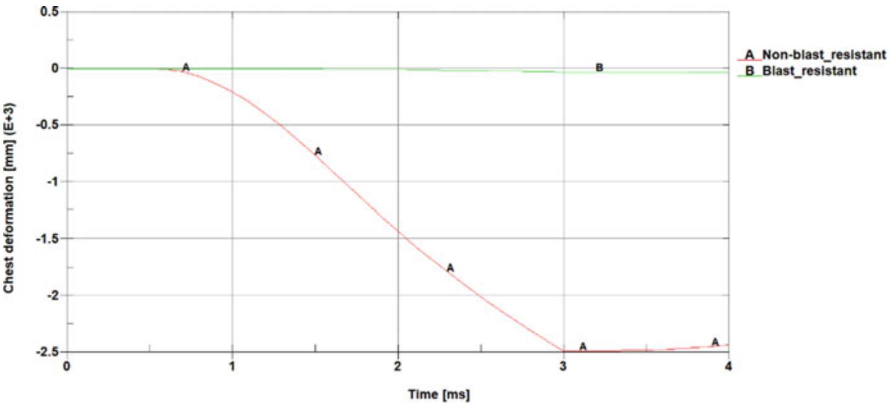

Fig. 29.3 Results comparison: chest deformation of HYBRID III 50%

non-blast resistant model and blast resistant model. It can be seen that the non-blast resistant trash receptacle (see Fig. 29.3 right) has broken into small fragments moving radially with initial velocity of around 270 m/s [35], while blast resistant model shows much more improved response to blast loads almost without fracture (Fig. 29.3 left). Since no fragmentation occurred in the blast resistant model, the HYBRID III dummy does not suffer injury by flying debris while in the case of non-blast resistant model the dummy suffers combined primary injury by the blast wave as well as the secondary injury by the flying debris (Fig. 29.4).

29.4 Conclusion

In this paper comparative numerical analysis of non-blast resistant and blast resistant trash receptacles was presented with the respect of human injury assessment by using the numerical HYBRID III dummy. The results comparison showed that blast resistant trash receptacles greatly reduces the injury of HYBRID III dummy. The use of blast resistant trash receptacles in dense pedestrian areas can save people's lives or reduce the severity of injuries.

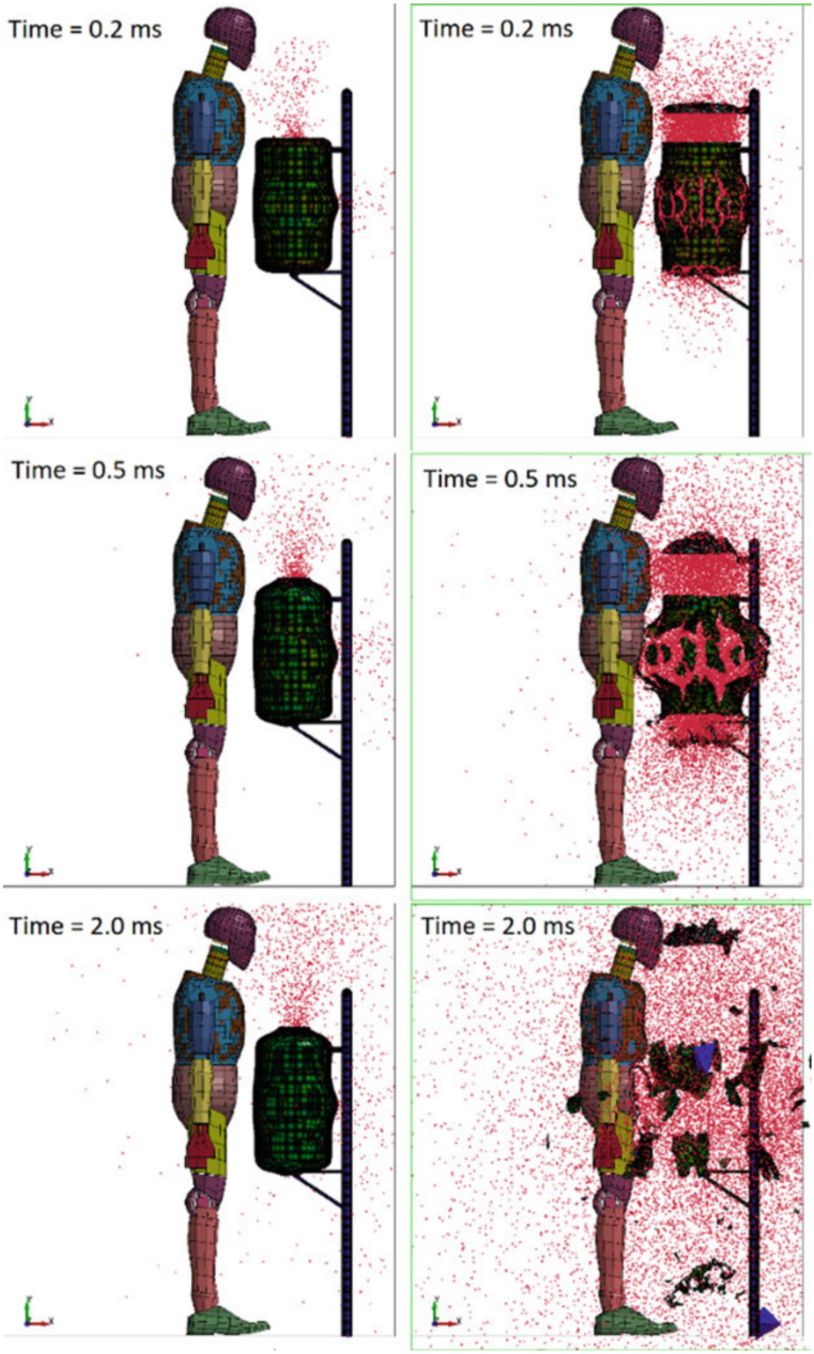

Fig. 29.4 Results comparison of HYBRID III response: blast resistant (left) non-blast resistant model (right)

Acknowledgement The research presented in this article has been partly funded by the Slovenian Research Agency as part of the "Modelling in technics and medicine" (code P2-0109 (C)) research programme.

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Chapter 30
Hazard Analysis and Risk Assessment Methodology for Safety and Security Problem Solving

Oleksandr Zaporozhets and Boris Blyukher

Abstract Safety is not defined as a total absence of hazards, it is a state in which hazards and conditions leading to physical, psychological or material harm are controlled in order to preserve (protect) the health and well-being of individuals and the community. Civil aviation sector is a huge system, contributing essentially in global and any national GDP, and any harmful event inside the system may decrease such a contribution sufficiently. Analytical modeling of the system safety is used to describe the relationships between the causes, dangers and effects of system states in its various operational scenarios. For activities, which characterized with a significant quantitative risk assessment, an approach can suggest for assessing the acceptability of risk. Risk is assessed according to the hazard identification, associated with the probability of adverse events and their consequences. The approach uses two types of risk: individual and societal. A number of events must occur if a main stressor should take place with conditional probability of their realization. Framework for risk assessment and reduction is considered also.

Keywords Risk · Aviation · Assessment and control

30.1 Introduction

Safety is not defined as a total absence of hazards and its objects are not to eliminate all the risks. Generally speaking the concept of safety is complex and difficult to understand in all its entire dimensions, physical, social, psychological, and, therefore, difficult to promote. Safety is a *state* in which hazards and conditions leading to physical, psychological or material harm are controlled in order to preserve (protect)

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L. Hofreiter et al. (eds.), *Soft Target Protection*, NATO Science for Peace and Security Series C: Environmental Security,
https://doi.org/10.1007/978-94-024-1755-5_30

health and well-being of individuals and the community. Risks can come from various sources – uncertainty in financial markets, threats from project failures (during their design, development or production), legal liabilities, financial credit, accidents, natural causes and disasters – and can cause a heavy damage. Safety is the result of a complex *process* where humans interact with their environments, including the physical, social, cultural, technological, political, economic and organisational environments, inside which the sources of hazard appear and exist (sometimes permanently) and, of course, should be controlled to limiting the risk for humans and communities at appropriate level. The effective safety (considering as a state or a process) improvement requires an integrated management approach, which takes into account several aspects in its framework that allows them to be viewed complicated and intelligibly [1].

Major accident investigations, particularly in transportation or/and energy sector, have identified a poor safety culture as a causal factor that increases the probability and severity of occurrence of the accidents and their consequences. A positive safety culture means first of all the readiness of the object under the risk to control personal or community vulnerability to the hazard(s) at appropriate level. Currently a proactive approach to integrate a safety culture at the organizational level of any kind of activities is required (focusing on troubleshooting just before the problems have a chance to emerge) in order to protect all safety-related functions against developing behaviors and practices that show themselves appropriate before an emergency happens. The safety culture explains conceptually and very pragmatically - how the vulnerability of an object at risk, especially defined by the lack of necessary knowledge and skills of as well as the priority placed on risk and safety among managers and employees can contribute to disasters that may expected in case of inadequacy of any element of the safety culture as such.

Transportation sector is one of the examples where terrorist attacks were found as a problem of highest sectoral importance, terrorist attacks on soft targets at airports, rail stations, seaports have increased during the last decade unfortunately. Transportation security, as a system, has been a major focus of transportation security policy since the terrorist attacks of September 11, 2001 involving the aviation. The events in New York World Trading Center exposed deep vulnerabilities in providing security of the aviation sector. As a result, the USA government adopted concrete policies and procedures to prevent aircraft hijackings in future and to keep prohibited items from getting into aircraft. However, since 2011, 14 airport attacks have occurred worldwide. The increase in attacks at airports demonstrates that rivals are continuously seeking new targets and not only in aviation sector. At the same time, a general increase in passenger travel has led to larger crowds at airports, rail stations, seaports, etc. Any attack on soft targets in their environment could cause not only the damage (mortality) in place, but even a significant disruption of the particular industry, leading to a large negative effect on the national economy, not to mention the social and psychological health of this nation's citizens. For example, a specific Annex 17 "Aviation Security" was adopted by ICAO (International Civil Aviation Organization) to its Chicago Convention on International Civil Aviation, which introduces the rules for protection of the people in airports and in aircraft from unlawful interference (hijacking). Originally, two terms – soft-target (a person who, due to specific vulnerability, provided by any actions and/or simply a lack of appropriate protection, is under the influence of existing risks and consequently turns into an *easy* target for terrorists) and hard-target (a person who, due to their specific actions and/or appropriate protection, is able to eliminate the existing risks and therefore most likely represents an *unattractive* target for terrorists) come from the military and relate to protected and unprotected targets. A glance at the world of people shows that most of them obviously defined as a category of soft targets. Such a category is largely characterized by the lack of personal security awareness and associated careless behavior.

Security awareness itself is not enough in usual case. In most of the cases, people also demand on necessary tools and measures to be able to realize any activity safely. In fact, soft targets mean a great threat for society – however, the problem is mostly local. If a person does not prepare himself/herself in a qualified way and does not take appropriate preventive measures, it contributes to the uncertainty of themselves, affects others, and increases the probability of an emergency. The problem in reality is much more complex than a simple lack of funding (for preventive measures). Contemporary terrorism does not consider any moral limits. The rate of violence and mortality resulting from the crimes appears to be rising. We're all human, we're all vulnerable – it is an important condition, which needs to be considered everywhere and every time. Obligation from the states and from any person exists – to transform the soft targets to be "harder" and to diminish their vulnerability [2]. For that the States should establish a specific safety policy and safety objectives and facilitate the promotion of a positive safety culture in a community, for example like aviation security or/and aviation safety policy must be declared State, any airline and/or airport to promote security and safety inside the area of their responsibility.

30.2 Safety First

30.2.1 Safety as a State and a Process

Transportation is critical to the lives of people and the global economy. The aviation sector has been among the most frequent targets of terrorist attack and the level of aviation security should be used to assess the *state* and ability of the sector to be protected and kept safe. As demonstrated by number of case studies, airport (aircraft) attacks disrupt the aviation system network as a whole and cause cascading effects inside the system and sometime even going outside. Such attacks may cost for airport and/or airline millions of dollars in lost airline revenues, business continuity operations, emergency response, infrastructure damage/renovation, crowd management, injuries, and deaths. For example, aviation alone accounts for more than 5% of USA GDP contributing over $1.6 trillion to the total market economy [3]. The attacks impact both the local and national economy. An airport attack could result in damage up to $17 billion in GDP from lost air travel [4]. In Brussels for example, the attack cost the Belgian economy an estimated four billion Euros [5]. To progress with the emerging threat, a specific national systematic approach is required and should be launched as a specific *process* to address the protection of people in the airport environment.

30.2.2 Risk Methodology in General

In accordance with the UN International Strategy for Disaster Reduction (UNISDR) terminology [10] the risk is defined as the probability of harmful consequences, or expected losses (any damage to human health, livelihoods or property, injuries, fatality, economic activity disrupted or environment damaged, etc.) resulting from interactions between natural or human-induced hazards and vulnerable conditions.

Under the standard [11] the definition of "risk" is no longer a "chance or probability of loss", but an "*effect of uncertainty on objectives*". The purpose of risk assessment is to provide evidence-based information and analysis to make informed decisions on how to treat particular risks and how to select between options to provide an activity. Principal benefits of a performing risk assessment include a wide set of positive outcomes for person, group or/and community. In general the risk (R) and hazard (H) ratio can formally be expressed in simple form as:

$$R = f\ (H \times E) \tag{30.1}$$

where H – hazard, in our case terroristic attack against soft target, which may lead to a number of effects, E – type and value of exposure of the hazard (depending on number of terrorists involved, their level of training for that, their type of arms and tactics against violent people used, etc.) on subject of impact (for example, on population), f – function of their interdependence.

This simple conceptual dependence between risk and hazard in Eq. (30.1) does not consider the contribution of vulnerability of the object-at-risk (or elements-at-risk) to the hazard under consideration – "the conditions determined by physical, social, economic and environmental factors or processes, which increase the *susceptibility* of a community to the impact of hazards" [6]. Elements-at-risk has a certain level of vulnerability usually, which can be defined in a number of different ways. The general definition is that vulnerability describes the *characteristics* and *circumstances* of a community, system or asset that make it susceptible to the damaging effects of a hazard [7]. There are many aspects of vulnerability exist, related to a number of inter-related conditions (see for example [8]), which may increase the susceptibility of a community to the impact of any hazard under consideration, they can be generally classified as shown in Table 30.1.

In relation to hazard (H), vulnerability (V) and amount of elements-at-risk ($A_{\text{elements-at-risk}}$) (or consequences to them from hazard impact) the risk (R) can be presented conceptually with the following basic equation:

Table 30.1 General classification of vulnerability, modified from [9]

	Human – social	Physical	Economic	Cultural/ environmental
Direct losses	Fatalities Injuries Annoyance Activity (for example sleep, rest, learning) disturbance and/or disruption Loss of income or employment Homelessness	Structural damage or collapse to buildings Non –structural and damage to contents Structural damage infrastructure(especially critical infrastructures)	Interruption of business due to damage to buildings and infrastructure Loss of productive workforce through fatalities, injuries and relief efforts Capita costs of response and relief	Destruction of cultural heritage/ Sedimentation Pollution Endangered species Destruction of ecological zones
Indirect losses	Diseases Permanent disability Psychological impact Loss of social cohesion due to disruption of community Political unrest	Progressive deterioration of damage buildings and infrastructure which are not repaired	Economic losses due to short term disruption of activities Long term economic losses Insurance losses weakening the insurance market Less investments Capital costs of repair Reduction in tourism	Loss of cultural diversity/ Loss of biodiversity

$$R = H * V * A_{elements-at-risk} \tag{30.2}$$

or taking into account the capacity (C_c) (opposite term to vulnerability) to cope the hazard consequences [10]:

$$R = H * V * A_{elements-at-risk}/C_c. \tag{30.3}$$

All these Eqs. (30.1, 30.2, and 30.3) would not be taken literally as a mathematical formula in most of the cases, but rather a model to demonstrate a concept. The first part of the formula for risk, Hazard (or somewhere Threat) x Vulnerability, can also be looked at as a probability [10]. This likelihood is a rough measure that describes the chances a given vulnerability will be discovered and used by a hazard actor. The last part of the formula ($A_{elements\text{-}at\text{-}risk}$) describes the consequences, or impact to elements-at-risk itself, of an impacting attack by hazard actor. The combination of the likelihood and the impact describes the severity of the risk, Fig. 30.1.

Recently, various disciplines investigated the concept of interaction of danger, vulnerability and coping capacity for risk assessment and control, it has considerably

Risk=	Hazard	xVulnerability	/Capacity	x Impact	Conceptual formulation
Risk =	Probability of Hazard Event	x Likelihood of impact		x Severity of consequences	Mathematical formulation
Data sources:	Statistics of historical data for exposure analysis and assessment	Description of the factors of vulnerability and coping capacity		Individual risks, social risks, monetary values, etc	Data presentation for analysis and assessment

Fig. 30.1 Scheme for risk calculation

expanded to a number of new applications. Its conceptual risk assessment formula has changed over time as follows [10]:

$$R = f[H(V, C_c).V(H, C_c)/C_c(H, V)], \tag{30.4}$$

where a number of complex interactions between attributes hazard (H), vulnerability (V) and capacity (C_c) is considered for any possible kind of element-at-risk. For example, the response of the human ear to acoustic spectral frequency of noise event may be considered as vulnerability property of the humans under the risk of noise impact or as it is used currently – to correct the noise exposure level on a value of human ear response, in such way to change the impacting exposure (or hazard) of this disturbing noise including human susceptibility to sound frequency.

If the humans will be provided with ear plugs to prevent them from disturbing noise (for example during their sleep) or if the disturbing noise source will be outside of the sleeping room and a simply closed windows may provide less vulnerable conditions – once again a complex interdependency between H, V and C_c will take place (for example, closed windows in a room may be considered as coping capacity of the location for noise protection purposes or as vulnerability conditions of this location), their account on noise impact will be quite complicated. As a result any kind of community engagement may influence a problem of aircraft noise impact assessment dramatically due to such complex interdependency between H, V and C_c, as shown in general scheme in Fig. 30.2.

In general case the severity of the hazard impacts depends strongly on the level of exposure and vulnerability in the affected area, and evidence indicates that risk has increased worldwide largely due to increases in the exposure of population and its assets, so understanding vulnerability and exposure are fundamental to our understanding of risk [6]. But the given above Eqs. (30.1, 30.2, 30.3, and 30.4) are not only conceptual ones, sometimes they can also be actually calculated (for example, with spatial data in a GIS to quantify risk from geo-distributed hazards [6]). First, while the concepts of “threats” and “vulnerabilities” are clearly relevant to determining the probability of a possible outcome of an event, they are not equivalent to the probability of a possible outcome of an event.

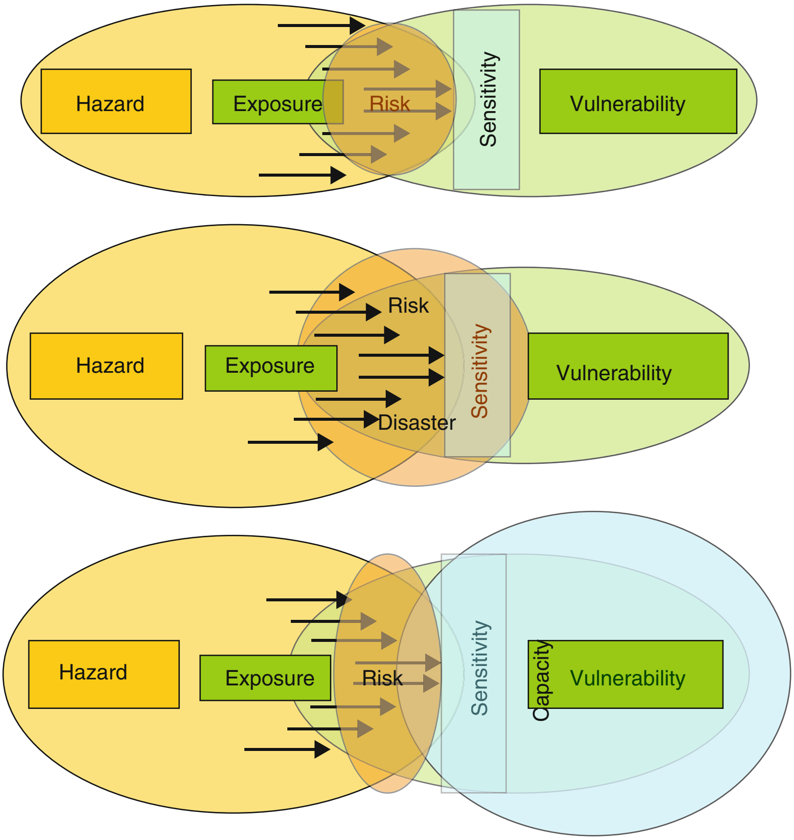

Fig. 30.2 General scheme for hazard, vulnerability and coping capacity inter-influence in risk assessment and control [10]

Mathematically the risk is proportional to a measure for the probability (P) of an event (frequency, likelihood) and the consequences (C) of an event (impact, effect on objectives), Fig. 30.1:

$$R = P * C. \tag{30.5}$$

For individual risk this basic condition may be expressed by the formula [11]:

$$R = P_f * P_{d/f}, \tag{30.6}$$

where P_f – the probability of harmful event (eg, aircraft accident); $P_{d/f}$ – the likelihood of the consequences (effect or damage), particularly the fatal consequences caused to individuals in the absence of protection from (or resistance to) a danger.

Individual risk R_i is an averaged over the year probability of death, injury and illness for an individual who may be located (lives or performs any kind of activities) near the source of hazard (eg airport or power plant or any other critical object), as a result of hazard existence/occurrence/exposure (eg, airplane crash into power plant or into residential area) and regardless presence of the people at all. The purpose of R_i estimating is to ensure that individuals, who may be affected by a threat from critical object (source of hazard), are not exposed to excessive risks. It is a characteristic of the source of hazard or property of lands around this object (which is location specific, for example like Noise Zone around the airport in accordance with aircraft noise levels or Public Safety Zone around the airport in accordance with Third Party Risk assessment), thus R_i may be shown by contours around the object on a map and to be used further for land use planning and corresponding zoning purposes to control the impact of this hazard on population.

Also a societal risk R_S may be used for assessment, which represents the risk to a (large) group of people. It is an annual probability that N or more people may die, being injured and/or ill due to the danger occurrence/exposure. R_S is not person and location specific, but usually used for national and international normative limits and standard values for any kind of hazard control and safety promotion. Societal risk is difficult to apply to the task of risk reduction, specifically because it is multidimensional. It is therefore adequate to look at both R_S and R_i to achieve a full risk picture to be effective with risk management in following steps.

Severity of a hazard (risk of consequences of a danger, Fig. 30.1) is combined with an estimate of its probability (or consequence). First needs to be determined, how often there may be a danger. Usually a function of probability combinations of causes (factors) should be considered. Then a likelihood of the worst state of the system must be assessed. This evaluation can also be quantitative or qualitative (if statistical data for quantity assessment is absent or not enough). Inaccuracy of the data used (Fig. 30.1) and confidence intervals of the results are the same important results of assessment for the following analysis and decision making, because their values often the same as for main results of risk assessment.

Calculation of individual risk R_i basically involves the multiplication of the probability of hazard event and the damage given by this event. As the damage fraction is never larger than 1, it is therefore logical that R_i can never become larger than the probability of hazard event inside a system. By integrating the individual risk R_I and the population density m the expected value of the number of people with damages for their health $E(N)$ inside population N can be determined:

$$E(N) = \iint_A R_j(x, y)\, m(x, y)\, dxdy, \tag{30.7}$$

where all the contributing values are defined at location (x,y) and number of damaged people inside area A per year. The number of people exposed (N_{EXP}) to a certain event can be found by integrating the population density over the exposed area A:

Table 30.2 General classification of damage, modified from [12]

Damage	Tangible	Intangible
Direct	Residences Airport/transportation facilities and inventory Vehicles Agriculture grounds Industrial/occupational facilities Infrastructure and other public facilities Business interruption (inside effected area) Evacuation and rescue operations Clean up costs	Fatalities Injuries and illnesses Annoyance of the humans Animals Utilities and communication Historical and cultural losses Environmental losses
Indirect	Damage for business outside effected area Substitution of business/production outside effected area Temporary housing of evacuees	Societal disruption Societal depression Damage to government

$$N_{EXP} = \iint_A m(x, y)\, dxdy. \tag{30.8}$$

In more general form probability of harmful event P_f may be divided to the probability of scenario p_{Sc}, leading to such event, and the probability of hazard exposure p_{Ex} due to this scenario:

$$P_f = p_{Sc}\, p_{Ex}. \tag{30.9}$$

The effects are usually described in terms of various type of damage k (eg, fatality, injury, physical damage, environmental losses, loss of income, etc. depending what are the elements-at-risk and what type of assessment is under consideration) and their vulnerability v_k (for example, describing a third party risk around the airport in case of aircraft accident a person's vulnerability can be defined as mortality):

$$P_{d/f} = k\, v_k. \tag{30.10}$$

An overview of different types of consequences due to technological accident is given in Table 30.2. The damage is divided into tangible and intangible types, depending on whether or not the losses can be assessed in monetary values. Another distinction is made between the direct damage, for example caused by physical contact with aircraft crash just on site of the accident, and damage indirectly following from the crash (fire, air or ground surface pollution outside the accident site, so on). Indirect damage can be defined as damage that occurs outside the affected area [12]. For example any kind of business can lose supply and demand from the affected area.

Risk assessment needs to be used in framework of its regulation [13]. To investigate the effects of hazards correctly there are important factors of vulnerability – physical, social, economic, cultural and environmental conditions and processes that

Risk management	**Hazard exposure** management: monitoring and control	**Vulnerability factors** management: detection and preparedness	**Protection measures** management: policy, measures and procedures	**Response and emergency** management: response and emergency plans	Management
Risk=	**Hazard**	**xVulnerability**	**/Capacity**	**x Impact**	Conceptual formulation
Risk =	**Probability of Hazard Event**	**x Likelihood of impact**		**x Severity of consequences**	Mathematical formulation
Data sources:	Statistics of historical data for exposure analysis and assessment	Description of the factors of vulnerability and coping capacity		Individual risks, social risks, monetary values, etc	Data presentation for analysis and assessment

Fig. 30.3 Scheme for risk calculation and management [9]

tend to increase the damage from the effects of the hazards impact on the person or society as a whole (Fig. 30.3). There is necessary a *coping capacity* – capabilities of a human, system, society, nature to confront the consequences of emergencies, dangers and threats, i.e. resources are needed that may reduce the negative effects.

For activities which characterized with a significant quantitative risk assessment a framework can suggested for assessing the acceptability of risk. Limit of risk acceptability is determined by the level above which the risk cannot be justified except of extraordinary circumstances. Below the limit of acceptability a risk may be allowed only in response to the advantages associated with the activity, but it should be analyzed for the requirements of ALARP (As Low as Reasonably Practicable). With the improvement of risk management practices it can reach the point at which the cost associated with further risk reduction is high enough to justify the further advantage of its reduction.

30.3 Conclusions

The widespread use and important advantages of risk assessments does not mean that they are the sole determinants of management decisions; risk managers are considering a number of factors. Although risk assessments provide critical information to managers, it is only a part of the decision making process. Reducing the risk to the lowest level can be very expensive or technically unfeasible.

The field of education offers numerous advantages for giving more explicit attention to hazard reduction awareness. Other side – lack of knowledge and skills is a subject of human vulnerability, especially in case of emergencies. Their appropriate level is a subject of coping capacity of the people under the impact of hazard. At higher levels of education and in professional training, more efforts are needed to integrate risk management into other subjects related to the environment, natural resources and sustainable development [14]. Teachers are widely recognized leaders; learning and educational facilities are highly valued in local communities around the world. However, specific disaster risk issues have been incorporated into curricula slowly, and explicit programmes of risk education remain the exception rather than the norm in most countries. A gap exists between the growing recognition of the importance of teaching about disaster risks and actually doing it.

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Chapter 31
Responsibilities of Security Services in the Soft Target Protection

Zuzana Zvaková and Štefan Jangl

Abstract Security services are one of the mechanisms for the provision of soft target protection. Security services complete the object protection system, e.g. protection of the persons or assets from the special category of soft target, mainly it is about the physical protection and the intelligence service. Type of security service is chosen by the owner or operator of the assets (e.g. shopping centre, school, campus, airport, etc.) or by the event organizer (e.g. concert, festival, march, sports event etc.). A special group of security services are private security services. Private security services constitute a part of a market economy providing security. At the same time aims to make a profit. The biggest benefit of this kind of security service is its professional competence and its interest to satisfy the client. The paper is focused on responsibilities and competencies of private security services in the soft target protection as well as the content of the terms of private physical protection and private intelligence services and the ways of its use in the soft target protection.

Keywords Security services · Soft target protection · Private security services

31.1 Security Services

Security services are one of the tools for implementation of the state security policy. The primary role of security services is to protect people's life and health, property, environment, and to supervise the fulfilment of rights. The basic categorization of security services is based on their relationship with the government or their founder. So we know state and non-state security services. The area of security services is detailed in [1–3].

State security services in Slovakia are:

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L. Hofreiter et al. (eds.), *Soft Target Protection*, NATO Science for Peace and Security Series C: Environmental Security,
https://doi.org/10.1007/978-94-024-1755-5_31

- Armed Security Corps – Police Force, Corps of Prison and Court Guard,
- Police Service – Military Police,
- Intelligence Service – Slovak Information Service, Military Intelligence Service,
- National Security Authority,
- Guards – Nature Protection Guard, Fishing Guard, Hunting Guard etc.
- Financial Offices – Customs Office and Tax Office.

Non-state security services in Slovakia are:

- Territorial Police Force – Metropolitan Police [4],
- Services in the Area of Private Security also known as Private Security Services [2].

The system of security services is similar in all European countries, however, the most resembling systems have Visegar Group countries.

Each of the security services carries out the tasks and fulfils the obligations arising from the national legislation, each service have its own regulation or transcripts that regulate its activity in detail. Naturally, the fact that the activities of each security service are regulated separately, does not mean that they can contravene other legislation. Security services must respect national and supranational laws, e.g. international contracts with priority by law and legally binding acts of the European Communities and the European Union.

A special category of security services is an area of private security services. These companies provide security, they want to satisfying the customers and they want to making a profit.

Private security services, in relation to the state, are business entities that carry out their activity under a special permit, licenses to operate a particular type of private security service, or perform their business as private entrepreneurs or business companies. Modifying the relationship between the state and the private security service, as well as, regulating the operation of private security services is a matter of national legislation.

The main legislation in the Slovak Republic is the private security act – Act 473/2005 Coll. about the provision of services in the field of private security and about the amendment of certain laws (the Private Security Act). The private security act is amended by regulations of the Ministry of the Interior of the Slovak Republic and Ministry of Health of the Slovak Republic. Activities of the private security services in the area of cross-border transport of euro cash by road among the euro-area member states is regulated by the regulation of the European Parliament and The Council [1]. The four regulations are the basis for activities of the private security services in Slovakia.

Activities of the private security services, as a special type of business, are regulated in Slovakia by the national law from 1997. The first law about private security services was amended eight times, from its adoption in 1997. The law was replaced by the Private Security Act in 2005. The law was amended 11 times from its adoption in 2005 and the last amendment is valid since 1st of January 2019.

31.2 Private Security Services

Private security services can provide five basic types of services. The types are:

- Technical services as design, installation, maintenance, revision and repair of CCTV [5] or alarm systems [6].
- Security services (physical protection) or guards focused on protection of property (in public and non-public space), protection of persons known also as bodyguards, protection of transit or protection of persons and property in transit, the operation of CCTV or alarm systems, preparation of protection plans, etc. [2, 7].
- Private intelligence services or spy services focused on searching of persons, property and information about person condition, activity, threats to business secrets and sensitive information, etc. This type of private security service is also known as private investigate service.
- Training and counselling in the area of private security involving the training of security staff.
- Professional cross-border transport of Euro cash by road was added to the law by the amendment in 2013 [1].

With the area of the soft target protection is connected mainly, private technical services, private security services and private intelligence services.

31.2.1 Rights of Private Security Services Applicable in the Area of Soft Target Protection

Physical protection is the protection of persons, property or processes performed by a person or it is a systematic human activity with the aim to ensure the security of a protected assets by persons and available legal means (communication tools, vehicles, weapons, various defensive and protective tools [8, 9], etc.) (Table 31.1).

Private intelligence services have a special position from the point of view of private security. We must recognize and understand differences between private intelligence or private investigation and the investigation activities of the state security services, e.g. armed security corps. The common features of the two activities are:

1. Both activities are confident. Classification must be perceived in context, e.g. the confidence of a police corps differs from confidence of private detectives (acting based on a contract concluded between the private intelligence service and the organization).
2. The content of both activities is to prevent, to detect and to document of subject the interest and to detect person responsibilities for the subject of interest.
3. The purpose of both activities is to ensure the protection of persons and property.

Table 31.1 Rights of persons performing physical protection

Right	Point of application	Content
Check	Entry/exit	If the person does not have any tools from an unlawful activity related to the protected area or person or does not have the equipment for any illegal activity (related to the protected area or person). Guards may these tools and equipment detain.
Check	Entry/exit	If any tools or animals from an unlawful activity related to the protected area or person are not in the checked vehicle. Guards may these tools and animals detain.
Check	Entry/exit	If checked persons are not under the influence of alcohol (or drugs).
Ban	Entry	To ban the entry of unauthorized persons.
Ban	Entry	To ban the entry of persons with a weapon (if it is forbidden to enter in the protected area with the weapon).
Register	Entry/exit	To evidence information about persons and vehicles.
Check identity or membership to the army or type of state security service.	Entry/exit	To evidence information about persons.
Check identity	Protected area	If a person was caught in a banned activity (e.g. unauthorized entry).
Record	Entry/exit	To evidence information about persons and vehicles.

The security service operator and its employees are required to respect the honour, the seriousness and the dignity of the person. They are obliged to observe confidentiality.

Private detective cannot search for information about:

- political, trade union or religious beliefs of persons,
- personal race, ethnic group or nationality,
- the health of the person and his/her sexual inclinations [1].

31.2.2 Sources of Intelligence

For the successful application of private detectives, is critical to master the issue of obtaining and processing information in accordance with the applicable law. The following methods [10] shall be used by the detective:

- Human Intelligence – HUMINT – is the oldest and the basic method of collecting information. Information comes directly from people. The use of informants can be combined with this method.
- Imagery Intelligence – IMINT – information is collected from an image analysis in this method (satellite imagery, maps, drawings, photographs, schemes, etc.). The method is used to detect, to classify and to identify objects, people, phenomena and events in the image.
- Open-source Intelligence – OSINT – today the most widely used search and collecting data method. Containing search, collection, processing and analysis of data from publicly available sources. OSINT uses media, literature, websites – personal, corporate, social networks, discussion forums, chat, wiki, blogosphere, audiovisual content, catalogues, databases, registers, etc.
- Measurement and Signature Intelligence – MASINT – is a method where information is obtained by qualitative and quantitative analysis of data from the measurement.
- Counter Intelligence – CI –is protection from foreign intelligence.
- Technical Intelligence – TECHINT – is a method, focused on weapons and technical equipment in the armed forces of foreign states in the military context. In the field of private security, it can be used in a modified form, in competitive intelligence.
- Signals Intelligence – SIGINT – is the method where information is obtained from communication data, CCTV, alarm systems data, etc.

The work of a private detective is not just about knowing methods, procedures, and means. Each step of the detective must be performed in accordance with applicable regulations and law [2, 11]. Careless action of a detective, or its action in violation of the applicable law, may cause that the whole detective task to be diminished and a detective will be compromised.

31.3 Conclusion

Private security services are part of the object protection system, applicable in the soft target protection. Security services are able to verify the alarm state, take action, to act preventively and reprehensively or create an information system through the physical protection and private investigation. The intelligence service gains importance in soft target protection in relation to a number of freely available information.

Private intelligence services constitute only a fraction of all activities performed in the area of private security in Slovakia. Over the past 10 years, licenses to operate intelligence services have formed between 15% and 23% from the number of licenses required the operation private physical protection and private intelligence. Detectives make up only 2% from a number of people performing physical protection and private intelligence in Slovakia.

The article focuses primarily on private security services, which are part of the market economy and are used for the soft target protection. However, the activity of private security services is given to the owner of the protected assets and its requirements. In the area of soft target protection, a lower degree of private intelligence activity (e.g. hotel detectives) is now relatively use in common. Physical protection, in the area of soft targets, is mainly used to protect mass sports and social events. Naturally, protection of soft targets is also ensured with CCTV and alarm systems.

The future of soft target protection is, from a prevention perspective, largely connected with private security services. Developments in the area of private security, as well as, the emphasis on the professional, physical and psychic capability of security staff, indicate the trend towards to the security and the protection not only soft targets.

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