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LIGHTWEIGHT COVERS FOR ATTENUATING THE EXPLOSION OF THE CHARGES AND THE METHODOLOGY OF THEIR PROTECTIVE PERFORMANCE ASSAY

Abstract: Various types and parameters of terrorist IEDs were shown in brief. The parameters and properties of cylinder-shaped protective containers "EPISAFE" and Bomb Killer for protection against threat of such bombs' fragments were presented. The results of tests on several versions of multilayered, cylinder-shaped, paraaramide fibrous covers were analyzed with the elaborated methodology of assaying the protective performance of lightweight covers. The tests involved standard fragments and bear balls of various diameters as the pelting elements, propelled with the blast of TNT bar explosion. The resulting depths were listed of pelting elements penetration into various layers of cylinder-shaped covers, fabric screens and the soldier cardboard figures, placed 1 up to 10 m away of the TNT bar. The rate of decrease of results of blast of TNT bars with pelting elements, which have been located inside two lightweight textile covers and inside the big "Episafe" container were assayed.

1. Introduction

The terrorist bombs planted at public places are mainly the IEDs (*improvised explosive devices*) [1÷3]. Depending on the action area of terrorists, gangs, etc. they often use remotely fired bombs of various sizes, usually filled with fragments and of various blast power:

1. small (0,2÷1 kg) - planted in bags, suitcases, baskets and directly attached to the cars' sides of bottoms, etc. (Fig. 1) [3],
2. medium (1÷5 kg) – planted near entrances to buildings, military facilities,
3. big (5÷20 kg) – installed mainly on the roads and by sides of them in order to destroy military vehicles, politicians and authority representatives, supply convoys, etc.

To protect people against effects of potential explosion of dangerous, small power charges located at public places (railway stations, stadiums, airports, subway, public administration buildings, market centres, etc.) the anti-explosion covers are useful, as their function is attenuating the blast energy.

Collecting the data on number, kinds of terrorist bombs used worldwide and precise descriptions of ways of planting them is impossible.

IED bombs of small power are the threat to human life and to the public objects due to blast-propelling various metal objects to high velocities 400÷1700 m/s, excess pressure of shock wave, effect of detonation products and high temperature [4]. The metal elements have strong pelting action horizontally and weaker vertically upwards and potentially downwards bounced from a top surface like ceiling, etc.).

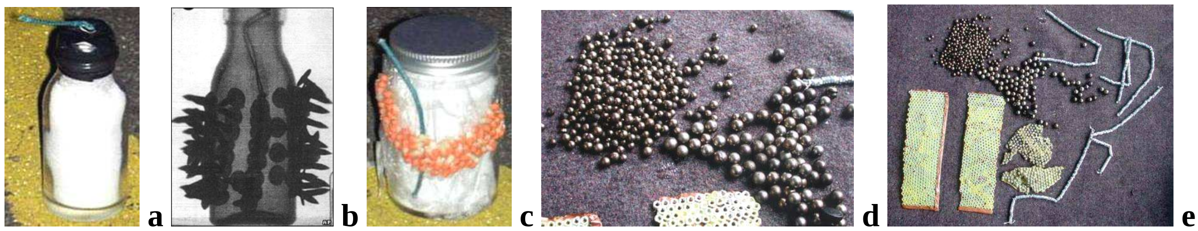


Fig. 1. Terrorist IEDs: a) in a bottle, b) in bottle with nails, c) in a jar, d) bearing balls, e) bearing balls and nuts threaded on strings.

Nowadays there are many kinds of lightweight anti-explosion covers worldwide, stiff and soft, which are designed for restricting the results of small charges explosions. Some of the basic components of such covers are the textile materials, which might be carried and put onto the charge by one or two persons. The examples of such goods are: EPISAFE container for bomb blast attenuating (by Futura Composites B.V – Holland) [5], Bomb Killer (by SEMA WORLD – France) [6], Fibrous covers (by MORATEX Institute - Poland) [3].

2. "Episafe" attenuator

An "Episafe" cylindrical container (Fig. 2) [5] is made of a lightweight polyethylene composite material and its two U-shaped handles of a technical textile belt of high strength are used for carrying and putting the attenuator onto an explosive by a single person. The container is used to attenuate the force of an explosion of:

- high explosive charges of a mass up to about 500 g (e.g. cluster bombs BLU97 and BL755 MK1, pipe bombs, etc.),
- bare explosive charges up to ca. 1000 g (e.g. a plastic high explosive placed in a case, etc.),
- a charge in the form of a 200 g TNT bar, 25x50x100 mm dimensions, with 48 standard fragments of a mass of 1.102$\pm$0.02 g stuck on side surfaces of the bar [7].

The attenuator is offered in two versions: a small one – outside diameter of 475 ± 10 mm, height 300 ± 10 mm and mass including the handles 16 ± 2 kg and a big one - outside diameter of 574 ± 10 mm, height 400 ± 10 mm and mass including the handles 26 ± 4 kg.

3. Bomb killer – a group of protections used for fighting against terrorism on the ground and in the air

They include, among others, patented products: GBK (Ground Bomb Killer), FBK (Flight Bomb Killer) (Fig. 3) and Dirty Bomb Killer [6] made of ballistic fibres and special reinforcements.

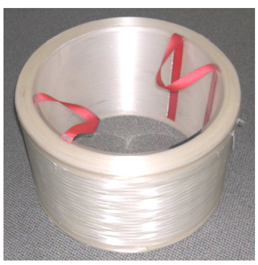


Fig. 2. "Episafe" attenuator [7]

Fig. 3. FBK (Flight Bomb Killer): 1 – "grenade killer", 2 – box, 3 – bag, 4 – cover and 5 "cap"

4. Fibrous protections

Several versions of multilayered cylindrical paraaramid fibrous protections were developed as part of the research project [3]. The cylinder of protection I in the internal chamber has a shock absorbing layer made of a ballistic polyethylene product (Fig. 4a), and the cylinder of protection II (Fig. 4b) has additional strips of ST-3 steel sheet inside the cylinder, paraaramid inserts coated with rubber compounds are placed in the direction of scattering of balls of 3 mm diameter (one on the inside of steel sheets and the other one on the outside of the steel sheets and above them) and a paraaramid insert coated with rubber compounds placed in the direction of scattering of balls of 4 mm diameter and on the outside of the steel sheets. Additionally, layers of aluminized fabric of glass fibres and slow-burning cotton fabric are used in the cylinders.

Cylinders of both the protections have the same dimensions, i.e. outside diameter ~910 mm and height ~450 mm. The mass of protection I and protection II amounts to 31.02 kg and 51 kg respectively.


a


b

Fig. 4. Fibrous protections: a – protection I and b – protection II

5. Methodology for assessing protective effectiveness of lightweight protections

The methodology has been developed by the Military Institute of Armament Technology (WITU) in co-operation with the Institute of Safety Technology „MORATEX" [3, 7] and approved by KGP Police Headquarters. Basing thereon, there was assessed the protective effectiveness of several lightweight protections, including a big "Episafe" attenuator (Fig. 2) and fibrous protections I and II (Fig. 4). A standardized testing methodology of that type products is still lacking, both at home and abroad.

The following was used for testing the protective effectiveness of the above mentioned protections and the big attenuator [3, 7]:

1. A 200 g TNT bar of 25x50x100 mm dimensions with: 48 standard fragments (Fig. 5) stuck on all walls of the TNT bar (Fig. 6) – for "Episafe" attenuator testing (Fig. 2), 100 standard fragments (Fig. 6) on two walls (100x50 mm) of a TNT bar (Fig. 7) – for testing of fibrous protection I (Fig. 4 a), steel bearing balls of the following diameters: 3 mm – 200 pieces and 4 mm – 200 pieces – on two walls (100x50 mm) of a TNT bar (Fig. 8) - for testing of fibrous protection II (Fig. 4 b). The bars were placed inside the cylinders of the attenuator and protections and fired using an ERG electric detonator fed from an exploder.

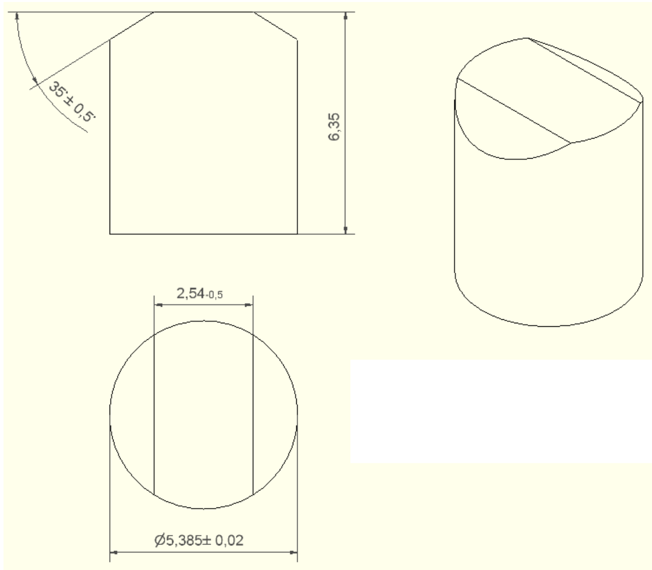


Fig. 5. Parameters of a fragment stuck on a TNT bar

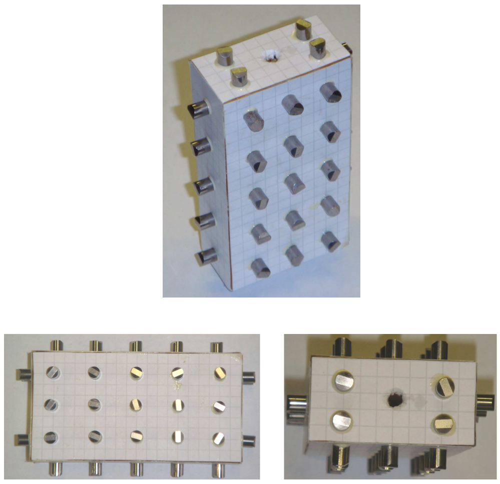
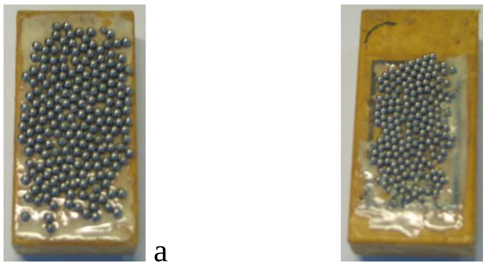


Fig. 6. View of a TNT bar from all sides with 48 standard fragments stuck thereon

Fig. 7. A TNT bar with 100 standard fragments stuck on two 100x50 mm walls of the TNT bar



a b

Fig. 8. A TNT bar with bearing balls stuck on two 100x50 mm walls; a - 200 balls Ø 4, b - 200 balls Ø 3 mm

2. St-3 steel sheet of 1000x1000x3 mm dimensions with an additional 200x200x20 mm steel armour plate placed thereon and TNT bars with fragments or bearing balls on them (Fig. 9, 10). Those sheets eliminated pressing down of an exploding TNT bar into soft ground and, thus, disturbances to fragment driving.

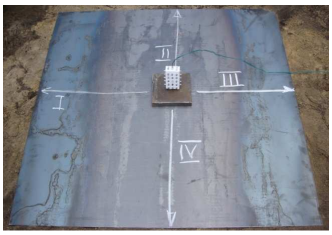
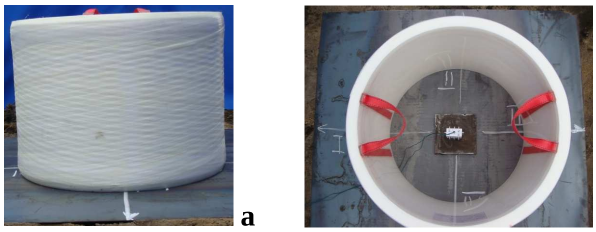


Fig. 9. View prior to the explosion of a TNT bar with fragments, placed on 200x200x20 mm sheet and 1000x1000x3 mm sheet



a **b**

Fig. 10. Side view (a) and top view (b) prior to the explosion of the big Episafe attenuator with a TNT bar, placed on 200x200x20 mm sheet and 1000x1000x3 mm sheet, one after the other

3. Four fabric shields, 2.5 m high, in order to inspect the whole area of scattering of striking elements also beyond the area of the tested protections and attenuator. The shields were arranged around the cylinders at distances of 1 m, 2 m, 3 m and 4 m from their centres in consecutive sectors every 90^{o} (Fig. 11, 12).

4. Additionally, at a distance of about 10 m from the centre of explosion, two soldier figures of corrugated cardboard (Fig. 12) were situated in order to check whether it was a safe distance for people while detonating a terrorist bomb in the attenuator and protections.

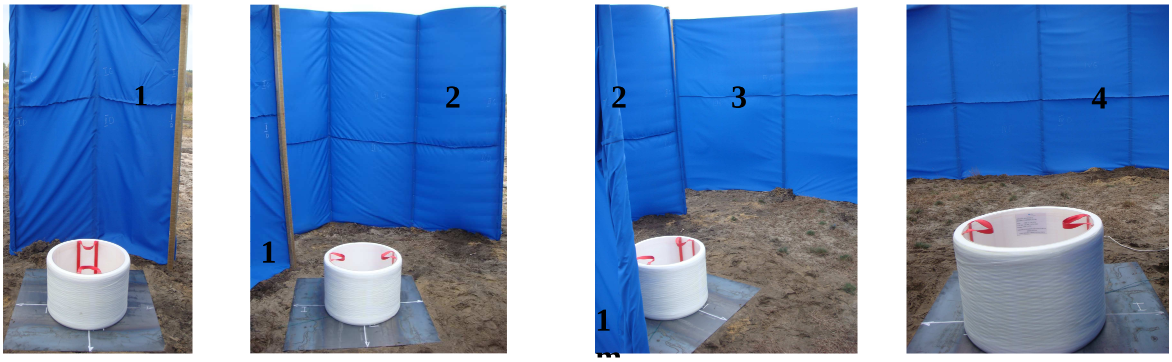


Fig. 11. View of cylindrically shaped fabric shields at various distances of 1÷4 m (marking 1÷4) with the "Episafe" attenuator and TNT bar with fragments before the explosion

Fig. 12. View of fabric shields (a) surrounding the big "Episafe" attenuator with a TNT bar with fragments before the explosion and two cardboard shields in the form of soldier figures (b) located at a distance of 10 m from the place of explosion

5. Reactions of the fibrous protections and the attenuator and all other elements of the testing system to the explosion of charges with fragments and steel balls were recorded with a camera to an accuracy of $\pm$0,01 s.

6. Findings and assessment of protective effectiveness of the protections

Tests of fibrous protections I and II as well as the big "Episafe" attenuator have been carried out at the Military Institute of Armament Technology [3, 7], and their protective effectiveness assessment is shown in Tables 1 and 2.

Figures 13÷24 show examples of fibrous protections and attenuator reactions to the explosion of charges with various steel elements as recorded with the camera.

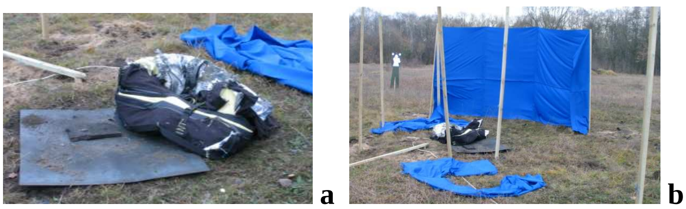


Fig. 13. View of damages to the fibrous protection I and shields after an explosion: a - protection cylinder; b- fabric shields

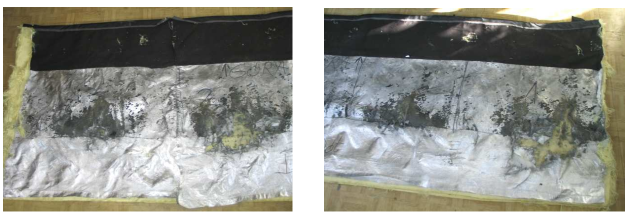


Fig. 14 View of demonstration damages to the surface of protection I cylinder

Fig. 15. View of damages to the shock absorbing layer of protection I (a) and deformed standard fragments

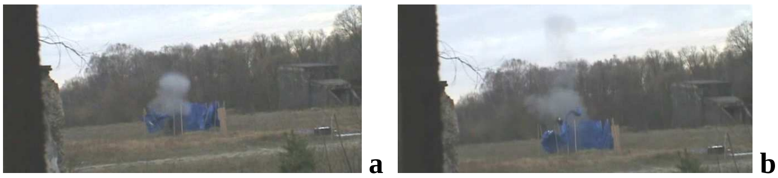


Fig. 16. Cylinder after charge detonation, *t*=0,32 s (a) and *t*=0,88 s (b)

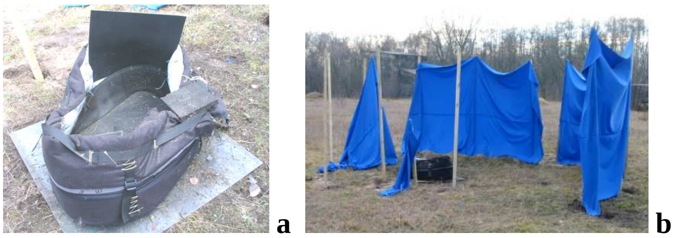


Fig. 17. View after explosion: a – fibrous protection version III; b – fabric shields

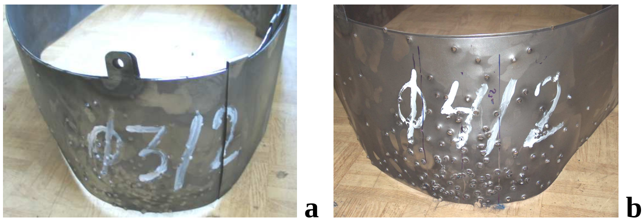


Fig. 18. View of the 2nd sheet from the outside after an impact of fragments of 3 mm diameter (a) and 4 mm diameter (b)

Fig. 19. View of the cylinder outside on the side of action of bearing balls, 3 mm (a) and 4 mm (b) diameters

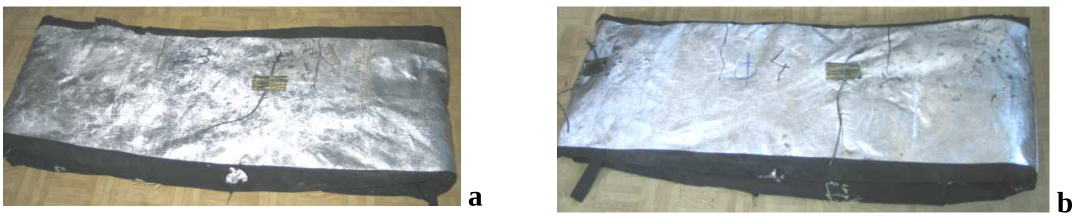
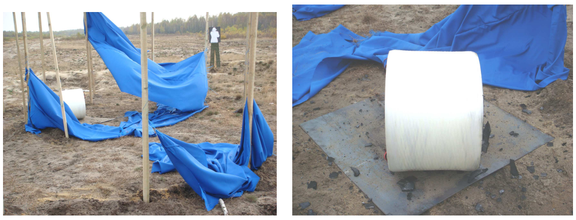
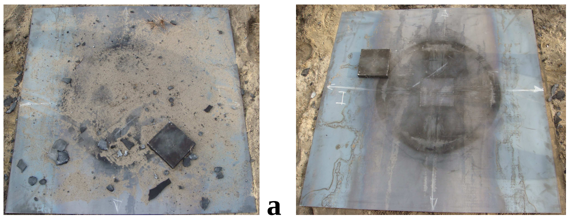


Fig. 20. View of the cylinder inside on the side of action of bearing balls, 3 mm (a) and 4 mm (b) diameters

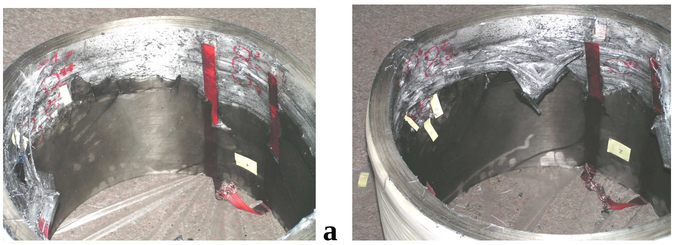




a b

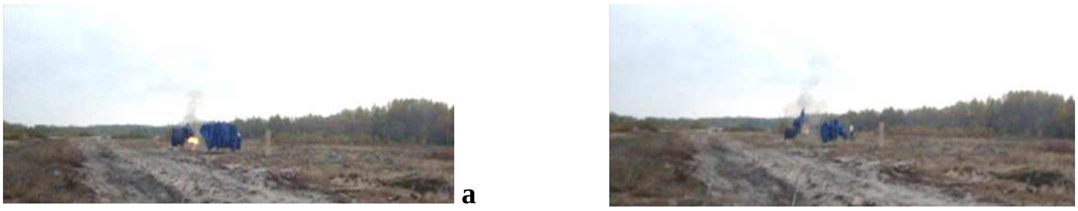
Fig. 21. View of "Episafe" attenuator and shields after detonation of the TNT bar with fragments

Fig. 22. View of sheets after detonation of the TNT bar with fragments in the "Episafe" attenuator, directly (a) and after cleaning sand off (b)



a b

Fig. 23. View of the lower inside part of "Episafe" attenuator: (a) in a place for and near handle 1 - direction I and at the same time between handles 1 and 2 - direction II and (b) in a place for and near handle 2 - direction III and at the same time between handles 2 and 1 - direction IV



a b

Fig. 24. Flight of the attenuator upwards a - *t*=2,61 s and b - *t*=2,77 s

Table 1. Number of holes (perforations) in the fabric shields arisen during tests of fibrous protections I and II and the big "Episafe" attenuator according to the developed testing methodology

Distance of the shield from the charge with fragments (bearing balls), m	Number of holes in the fabric shield		
	Protection I	Protection II	"Episafe" attenuator
	Number of holes	Number of holes / steel ball Ø	Number of holes
1	7	6 / -	6
2	12	109 / 4	1
3	0	0 / -	2
4	25	11 / 3	0
Total	44	126	9

Table 2. Assessment of protective effectiveness of fibrous protections I and II and the big "Episafe" attenuator according to the developed testing methodology

Assessment criterion	Fibrous protection I	Fibrous protection II	Big "Episafe" attenuator
Behaviour of the protection after the charge detonation	The protection did not fly upwards but only moved about 1 m from its original position	The protection did not fly upwards and did not move from its original position and from the sheet surface	The attenuator flew upwards to about 1 m, it turned on to its side and fell down about 0.5 m from its original position but it did not move from the sheet surface
Damages to and perforations of the fabric shields	Partial perforation and break of the shields	Partial perforation and break of the shields	Partial perforation and break of the shields
Damages to and perforations of the cardboard shields	No damages to and perforations of the shields	No damages to and perforations of the shields	No damages to and perforations of the shields
Protection destructions caused by the explosion of the charge with striking elements (fragments, bearing balls)	• On the side of the charge, the cylinder was perforated with the fragments to half the number of its layers • The shock absorbing layer was perforated with one fragment • Outside layers of the cylinder were not perforated	• Irrespective of their diameters, the bearing balls perforated the inside layers of the cylinder and stopped in the sheets • Outside layers of the protection remained intact • Paraaramid inserts inside the cylinder were perforated and those behind the sheets were not perforated	• No perforation of the attenuator wall • 34 pieces of fragments were stopped in the attenuator • Maximum depth of penetration of the attenuator wall of mean thickness of 66 mm amounted to 22/66 mm, i.e. 33 %
Deformation of striking elements	Due to interaction with the cylinder fabric layer, the fragments were deformed - mushroom-shaped	Bearing balls were deformed slightly	Due to interaction with the internal wall of the attenuator, the fragments became mushroom-shaped
Getting of fragments out from under the shield	During explosion a part of the fragments get out from under the cylinder which was proved by traces of their impacts on the sheet	During explosion a part of the bearing balls get out from under the cylinder which was proved by traces of their impacts on the sheet	During explosion a part of the fragments get out from under the cylinder which was proved by traces of their impacts on the sheet
Destruction of the sheet and armour plate	• The armoured plate was not dented • Traces of fragment impacts could be seen on the sheet	• The armoured plate was not dented • Traces of fragment impacts could be seen on the sheet	• The armoured plate was not dented • Traces of fragment impacts could be seen on the sheet

7. Conclusions

1. The elaborated methodology of tests allows for making an assay of protective performance of various lightweight covers upon 200 g TNT bar explosion and various pelting elements (standard fragments and steel balls).
2. The protective performance of the lightweight covers was evaluated on a basis of the analysis of the following criteria: behaviour of the covers upon TNT bar explosion, damage to the textile screens and cardboard figures, covers' destruction caused by the explosion of TNT bar with the pelting elements, the elements deformation and their escape out of the covers and the destruction of metal sheet and armour panel.
3. Three lightweight covers, i.e. I - fibrous and II – fibrous with extra protective elements and the big „Episafe" container do reduce the blast threat to the individuals and environment within 4 m range and minimize the pelting action of blast and blast-propelled fragments within a range of 10 m.
4. On a basic of this methodology the Testing Procedure pr. PBB/ITB:2008 "Assay of protection ability of the lightweight covers attenuating the blast of explosives".

8. References

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LEKKIE OSŁONY DO TŁUMIENIA SIŁY WYBUCHU ŁADUNKÓW I METODYKA OCENY ICH SKUTECZNOŚCI OCHRONNEJ

Streszczenie: Przedstawiono skrótowo różne typy i parametry bomb terrorystycznych typu IED. Do ochrony przed rażeniem odłamkami z tych bomb zaprezentowano parametry i właściwości kontenerów cylindrycznych ochronnych typu „Episafe" oraz Bomb Killer. Z użyciem opracowanej metodyki oceny skuteczności ochronnej lekkich osłon analizowano wyniki badań kilku wersji wielowarstwowych cylindrycznych paraaramidowych osłon włóknistych. W badaniach użyto elementów rażących w postaci odłamków standardowych i kulek łożyskowych o różnej średnicy, napędzanych wybuchem detonującej kostki TNT. Zestawiono wyniki głębokości wnikania elementów rażących w różne warstwy osłon cylindrycznych,

w ekrany z tkaniny oraz w tekturowe figury żołnierzy, umieszczone w odległościach 1÷10 m od kostki TNT. Oceniono stopień zmniejszenia skutków wybuchu kostek TNT z elementami rażącymi, które były umieszczone w dwóch lekkich osłonach włókienniczych oraz w dużym kontenerze „Episafe”.