

Research Article

Ballistic strength of aerated concrete

Gökhan Durmuş a,* 🕞, Sefa Ekinci a 🕞

^a Department of Civil Engineering, Gazi University, 06570 Ankara, Turkey

ABSTRACT

In regional studies conducted by the Law Enforcement Agency and the Armed Forces within the scope of counter-terrorism activities, to ensure peace and security throughout the country and for the police and military personnel to provide security services, the need to produce different solutions has arisen in the face of attacks on the security points established at many important points, especially at the entrance and exit points of the cities. In this context, by changing the direction and angle of the wall types made of aerated concrete used in construction techniques, 7 variations were tested on these wall types with materials formed with adhesive mortar+plaster, monolithic elastomer polyurea, and non-Newtonian fluid, and the strength of these materials were tested with BR6 and BR7 bullets. The main purpose of this study was to determine the most suitable material in terms of security parameters in the shortest time and at a low cost and to create a reliable structure for security cabins. At the end of the study, the best results were obtained with the shots made on the narrow surface of the aerated concrete and the shots made on the platform formed with non-Newtonian fluid.

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1. Introduction

Throughout the history of the world, humanity has made various studies on how to protect itself against the weapons it has invented, while developing more advanced weapon technologies (Bocetta, 2017). Various materials have been developed and used since animal skins were first used for protection. Steel plates come first among them. Soft ballistic armors made of plates were first tested in Korea in 1860 (Henderson, 2008). During World War II, the development of personal protective armors gained momentum. Later, researchers in Arizona and Illinois have developed a fabric made of silk that could stop bullets fired from certain weapons (Bozdoğan et al., 2015).

Ballistics is a field of mechanics concerned with the launching, flight behavior, and impact effects of projectiles, especially ranged weapon munitions such as bullets, unguided bombs, rockets, or the like. It focuses on explaining the complex event between the time the bullet leaves the muzzle and reaches the target in detail. It is also considered as a special division of applied mechanics

(Plummer, 1940). The standards regarding the protection levels of ballistic protective materials are as follows: NIJ (The US National Institute of Justice) (NIJ Standard-0101.06, 2008) and HOSDB (UK Home Office Scientific Development Branch), these standards have proven their national or international validity and are widely accepted. Apart from this, various military standards have been developed by NATO and the Turkish Standards Institute (TSE EN 771, 2015) However, the fact that regional-based armed conflicts contain different threat elements together with the rapidly developing weapon technology makes it almost impossible to establish and use a single international ballistic protective material standard for all regions. For this purpose, ballistic studies are conducted on different materials.

In these studies, the ballistic performance of the material; is related to the response characteristic in the high-velocity impact region and is proportional to the energy it can absorb during the impact (Mousavi et al., 2020). The material thickness also clearly affects the energy absorbed during impact in some cases (Hsieh et al., 1990) Ballistic protective materials are divided into two

classes as hard and soft protective materials (TDIPC, 2021). Hard protective materials are made of glass, ceramic, and metal. These are used in the form of plates, protective helmets, armors/vests, shields. Soft protective materials, on the other hand, are polymer-based materials consisting of fabric and fabric-like structures (Göksel, 2018; Ayten et al., 2020., Feng et al., 2020). In terms of construction, structural forms consisting of armor/vest steel are used in these materials. In particular, such structures are used at the security points provided for the personnel working in the military and security units to provide safety services in public and private buildings. Although these structures consist of important materials in terms of ballistics and have proven themselves, when it comes to the efficiency, they are not yet at the desired level when compared to other materials in terms of time and cost parameters.

With the developments in construction technology. the behavior of steel, concrete, and other building materials under different loads such as impact has gained even more importance (Jin et al., 2017; Naito et al., 2014). In experimental studies on building materials, test elements produced from high-strength concrete were tested and examined with a free-falling (drop) weight impact test (Feng et al., 2020; Oucif et al., 2021). At the end of the foresaid study, different results were obtained. It was found out that the number of drops depends on the concrete's compressive strength, the damage and deformation types under different impact loads differ from each other, the decrease rate in the maximum acceleration value measured from the test elements with normal and high concrete compressive strength is higher than the decrease rate in the minimum acceleration value, etc. (Kantar et al., 2021; Kaymaz et al., 2018) Different methods have been used depending on the material shape and type in the experiments conducted to see the impact effect (Alkayis et al., 2021) One of them is the studies with explosive materials (Özmen et al., 2018; Verhagen, 1978).

In this study, to provide a safer environment for the police and military personnel providing security services, a study has been conducted on the materials that can be used in structures that can be built to provide protection during terrorist attacks on security points established at many important points such as private and public buildings, especially at the entrance and exit points of the cities. Different wall types were formed by placing the unit volume weight of 600 kg/m³ aerated concrete in different directions. According to the European Standard TS EN 1063 (2002), the BR6, BR7 bullets were fired on the walls produced and the ballistic properties of the walls were examined. Evaluations were made on these walls, which are intended to be used at security points where police and military personnel are employed.

2. Materials and Method

In this study, 7.62x51 mm diameter, and armor-piercing type bullets were fired on two different aerated concretes covered with adhesive mortar (used for bonding aerated concrete), monolithic elastomer polyurea coating material, and non-Newtonian liquid to see different effects.

2.1. Materials

2.1.1. Aerated concrete

In this study, aerated concrete conforming to TS EN 771-4 (2015) standards was used. Technical specifications of aerated concrete are given in Table 1. 6 pieces of 200x600x250 mm³ and 10 pieces of 250x600x250 mm³ aerated concrete were combined with adhesive mortar in 2 blocks and formed as shown in Fig. 1.





Fig. 1. Wall applications made of aerated concrete.

Table 1. Technical sr	pecifications	of aerated	concrete.
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Behaviour against fire	Dry unit volume weight average	Compressive strength	Shear tie strength	Water vapor permeability coefficient μ	Drying shrinkage	Thermal conductivity value
A1	600 kg/m ³	5 N/mm ²	≥0,3 N/mm ²	5/10	≥0,2 mm/m	≥0,16 W/mK

2.1.2. Adhesive mortar, plaster and mixing water

Normal hardening cementitious adhesive with higher slip-resistance in accordance with TS EN 12004-1 (2017) standards was used both for building aerated concrete walls and for the plaster on their surfaces. The technical specifications of the mortar used are given in Table 2. Additionally, in accordance with the application instructions of the mortar, it was prepared to have 5.6 liters of mains water per 25-kg material. Paid strict attention to ensure that the applied surface mortar was 0.5 cm thick. For the plaster, 4.47 lt of mains water was added to 9-kg material to ensure a thickness of 2-3 mm.

2.1.3. Monolithic elastomer polyurea

Monolithic elastomer polyurea is a material applied using a high-pressure spray system in the range of 54-98°C. It is basically a combination of 4,4'-Diphenylmethane diisocyanate ($C_{15}H_{10}N_2O_2$) and mostly alpha-(2-aminomethyl)-omega-(2-aminomethylethoxy)-poly[oxy (methyl-1,-2-ethanediyl)]. These are polymer components that act as plasticizers, consisting of a reactive component ($C_8H_{20}N_2O_2$). An elastic coating has been used to cover the applied surface and to protect it against bursting, wear and abrasion, and turns into a thick and hard material after application (Izoline, 2021)(Fig. 2).

Table 2. Technical specifications of adhesive mortar.

Behaviour against fire	A1
Dry powder density	$1.4 \pm 0.1 \mathrm{gr/cm^3}$
Initial tensile adhesion strength	≥0,5 N/mm ²
Tensile adhesion strength after immersion in water	≥0,5 N/mm ²
Tensile adhesion strength after heat aging	≥0,5 N/mm ²
Tensile adhesion strength after freezing – thawing cycles	≥0,5 N/mm ²





Fig. 2. Monolithic elastomer polyurea applied on the aerated concrete surface.

2.1.4. Non-Newtonian fluid

It is a powdered material obtained by separating corn using physical methods as a result of processing corn with the wet-milling method (Wikipedia, 2021). It was prepared with 2 kg corn starch and 4 lt water at a mixing ratio of 0.5. It was used by placing it in a 5 cm platform between two glasses placed on the aerated concrete

surface. Additionally, a shooting test was also carried out on a 16 cm wide platform consisting of a mixture of 2.5 kg of corn starch and 5 lt of water, which was placed on the aerated concrete surface of a different size. It was also aimed to benefit from its properties of behaving like a liquid and solid material when velocity-dependent force is applied to the non-Newtonian fluid mixture (Fig. 3).





Fig. 3. Starch in the platform applied on the aerated concrete surface.

2.1.5. G3 rifle and ballistic bullet

Shooting studies were carried out on the materials conducted by expert personnel using a G3 assault rifle,

which is loaded with 7.62 mm magazine and functions automatically and semi-automatically with the roller-delayed blowback. The characteristics of the firearm are given in Table 3.

Table 3. Technical specifications of the G3 assault rifle.

Cartridge	7.62x51 mm
Length	102 cm
Target range scaling	100-200-300-400 m
Maximum Firing Range	3700 m
Effective Firing Range	400 m
Mass (without magazine)	4.25 kg
Magazine Capacity	20
Muzzle velocity	800 m/s
Rate of fire	500-600 rounds/min

To test the BR6 and BR7 ballistic levels, during the shooting, different numbers of armor-piercing bullets of 7.62x51 mm diameter and type (M61) designed for

lightly armored targets such as steel vests, bulletproof glass and light armored vehicles were used, as shown in Fig. 4.





Fig. 4. G3 assault rifle and armor-piercing bullet.

2.2. Method

Aerated concrete, which have a compressive strength of 5 N/mm² and are used in the construction of exterior and interior infilled walls in construction systems, and also are used as a load-bearing outer and inner wall material in masonry structures, were formed as double row blocks by adhering with cement-based mortar material with a dry powder density of 1.4 gr/cm³ and increased vertical slip resistance. The surfaces and direction of the formed aerated concrete blocks were changed and covered separately by using materials such as mortar-plaster, starch, and monolithic elastomer polyurea that protects against impact and pressure. The aerated concrete

blocks formed with these materials were shot using a G3 assault rifle with a 7,62x51 mm diameter and type (M61) armor-piercing bullet according to the ballistic standards. The ballistic level table of the bullets is given in Table 4.

The shooting test was carried out following the instructions specified in TS EN 1063 (2002) by shooting with a G3 assault rifle (bullet angle of 90 degrees and a shooting distance of 10 m) on aerated concrete of different sizes, coating materials and directions, which was fixed with supporting products. A picture of the shooting range is shown in Fig. 5. The gradual summary of the article work program is shown in Table 5 in accordance with the modellings.

Table 4. Ballistic levels table.

CEN (Committee European Normalization) BS/EN 1063 Strength Standards										
Level	Level Weapon type Calibre Bullet t			Mass (gr)	Shooting distance (m)	Projectile velocity (m/s)	Shots	Distance between shots (mm)		
BR6	Rifle	7.62 x 51mm	FJ1 / PB / SC	9.5 ± 0.1	10.00 ± 0.5	830 ± 10	3	120 ± 10		
BR7	Rifle	7.62 x 51mm	FJ2 / PB / HCI	9.8 ± 0.1	10.00 ± 0.5	820 ± 10	3	120 ± 10		



Fig. 5. Shooting range setup.

Table 5. Shooting experiment modeling.

Experiment	Shooting direction to the wall		Aerated concrete dimensions (mm)		Material applied on surface			Bullet type		Number of shots		
Experiment		Horizontal	Vertical	20x60x25	25x60x25	Mortar +Plaster	Monolithic elastomer polyurea	Starch	BR6	BR7	BR6	BR7
Chapting 1	1-a	\checkmark			✓	✓			✓	\checkmark	3	1
Shooting-1	1-b	\checkmark			✓		✓		✓	\checkmark	3	3
Chartina 2	2-a		✓		✓	✓			✓	✓	1	1
Shooting-2	2-b		✓		✓		✓		✓	✓	1	1
Shooting-3		√		✓		✓			✓	✓	3	1
Shooting-4	4-a	✓			✓	✓		✓	-	✓	-	1
	4-b	✓		✓		✓		✓	-	✓	-	1

The study is structured in 4 sections as indicated in Table 5. Shooting-1: It shows 2 different shooting tests carried out to see the effect of the material applied to the surface of the aerated concretes with the same thickness in the horizontal direction. Shooting-2: It shows 2 different shooting tests carried out to see the effect of the material applied to the surface of the aerated concretes with the same thickness in the vertical direction. Shooting-3: It shows the shooting test carried out to see the effect of the material applied to the surface of the aerated concrete (depending on the thickness) which was formed in a double row. Shooting-4: It shows 2 different shooting tests carried out to see the effect of the material of different thicknesses applied on the surface of 20 cm and 25 cm thick aerated concretes in the horizontal direction.

2.2.1. Shooting tests during the study

In the Shooting-1 part of the study, a total of 10 rounds of BR6 and BR7 bullets were shot on two different walls,

on the horizontal wide surface of the aerated concrete. The schematic representation of the sample coated with adhesive mortar-plaster is shown in Fig. 6a, and the sample coated with monolithic elastomer polyurea is shown in Fig. 6b.

When Fig. 6 is examined: a) 3 rounds of BR6 bullets were shot on the upper zone and 1 round of BR7 bullet was shot on the lower zone; b) 3 rounds of BR6 bullets were shot on the upper zone and 3 rounds of BR7 bullets were shot on the lower zone.

When Fig. 7 is examined; in both Shooting-2a and Shooting-2b, 1 round of BR6 bullet was shot on the upper zone and 1 round of BR7 bullet was shot on the lower zone.

In the Shooting-3 part of the study, a total of 4 rounds of BR6 and BR7 bullets were shot on a double row 20 cm thick aerated concrete wall, on the horizontal wide surface. Its schematic representation is shown in Fig. 8.

In Fig. 8, 3 rounds of BR6 bullets were shot on the upper part of the aerated concrete and 1 round of BR7 bullet was shot on the lower part of the aerated concrete.

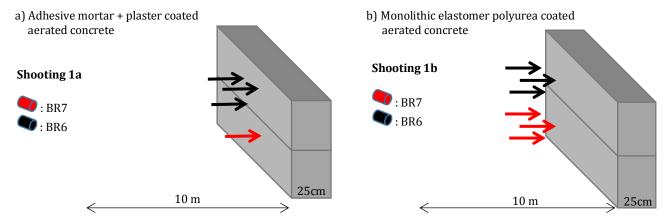


Fig. 6. Schematic representation of the shots fired on the two wide and short surfaces of the aerated concrete wall.

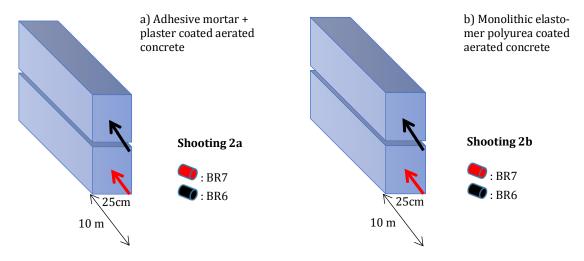


Fig. 7. Schematic representation of the shots fired on the two short surfaces of the aerated concrete wall.

Mortar-plaster coated aerated concrete

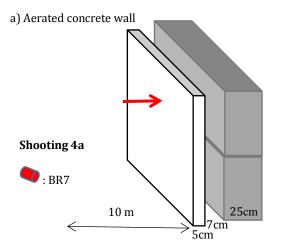
Shooting 3
: BR7
: BR6

10 m
20cm
20cm

Fig. 8. Adhesive mortar + plaster shooting diagram.

In the Shooting-4 part of the study, a total of 2 rounds of BR7 bullets were shot on the starch-filled platforms in front of the horizontal wide surface of the aerated concrete, on the walls made of 20 cm and 25 cm thick aerated concrete. Its schematic representation is shown in Fig. 9.

BR7 bullet was shot on the starch in the platform with a distance of 7 cm to the aerated concrete and a width of 5 cm.



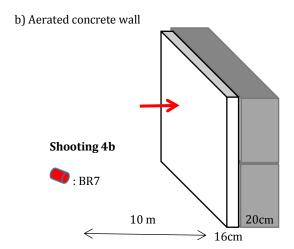


Fig. 9. Shooting diagram of adhesive mortar-plaster and non-Newtonian liquid in front of it.

3. Findings and Discussion

3.1. Shooting test-1

As a result of the shooting tests performed on wide surfaces of aerated concrete coated with different coating materials such as adhesive mortar-plaster and monolithic elastomer polyurea;

- The aerated concrete sample coated with adhesive mortar-plaster was shot with 3 rounds of BR6 bullets and 1 round of BR7 bullet in a controlled manner, according to the bullet exit status. In the examination carried out after the shooting, perforation was observed on the back surface of the aerated concrete as a result of the damage caused by the bullets. To examine the effect of the bullet on the aerated concrete, the aerated concrete was divided into 2 equal parts of 12.5 cm and their measurements were taken. The measurements taken are given in Table 6.
- The aerated concrete sample coated with monolithic elastomer polyurea was shot with 3 rounds of BR6 bullets and 3 rounds of BR7 bullets in a controlled manner, according to the bullet exit status. In the examination carried out after the shooting, perforation was observed on the back surface of the aerated concrete as a result of the damage caused by the bullets. To examine the effect of the bullet on the aerated concrete, the aerated concrete was divided into 2 equal

parts of 12.5 cm and their measurements were taken. The measurements taken are given in Table 6.

In Table 6, the positions of the bullets in both aerated concretes are indicated by measuring the distance they change both in height and horizontally. When this table is examined, it is seen that the BR6 and BR7 bullets do not follow a linear path, and the materials used on the surface affect the movement of the bullets. Especially in aerated concrete coated with monolithic elastomer polyurea material, it was determined that the displacements of the bullets in the shots fired with BR7 bullets were higher than the adhesive mortar-plaster. This can be explained by the resistance of the monolithic elastomer polyurea and the effect of the BR7 bullet. However, the fact that the bullets exited from the back surface in both aerated concrete showed us that such a form could not be built.

3.2. Shooting test-2

As a result of the shooting tests performed on narrow surfaces of aerated concrete coated with different coating materials such as Adhesive Mortar-plaster and Monolithic elastomer polyurea (by changing its direction);

 The aerated concrete sample coated with adhesive mortar-plaster was shot with 1 round of BR6 and 1 round of BR7 bullet in a controlled manner, according to the bullet exit status. In the examination carried out after the shooting, no perforation was observed on the back surface of the aerated concrete as a result of the damage caused by the BR6 bullet. In the shot fired with the BR7 bullet, no perforation was observed and the bullet exited at a distance of 25 cm from the back surface. In order to examine the effect of the bullet on the aerated concrete, the aerated concrete was divided into 4 pieces of 10/15/10/25 cm and their measurements were taken. The measurements taken are given in Table 7.

 The aerated concrete sample coated with monolithic elastomer polyurea was shot with 1 round of BR6 bullet and 1 round of BR7 bullet in a controlled manner, according to the bullet exit status. In the examination carried out after the shooting, it was observed that the bullet advanced up to 41 cm from the surface of the aerated concrete in the shot fired with the BR6 bullet but no perforation occurred on the back surface as a result of the damage done by the bullet. In the shot fired with the BR7 bullet, no perforation was observed and the bullet exited at a distance of 17.5 cm from the back surface. To examine the effect of the bullet on the aerated concrete, the aerated concrete was divided into 4 pieces of 10/15/15/25 cm and their measurements were taken. The measurements taken are given in Table 7.

Table 6. Effect of the bullets on the wide surface of the aerated concrete (measurements were taken from the front surface and left surface).

Surface coating		Adhesive mo	ortar-plaster		Monolithic elastomer polyurea			
Protection level	BI	R6	BI	R7	BR6		BR7	
Measurement (cm)	Front surface	Left surface	Front surface	Left surface	Front surface	Left surface	Front surface	Left surface
	35.0	16.0			37.0	15.0	16.0	25.5
Entrance (surface)	39.0	20.5	23.5	31.5	40.0	25.0	8.5	35.0
(surface)	33.5	33.0			39.5	33.5	19.0	28.5
	33.0	15.0			37.5	14.5	15.0	27.5
Middle (12.5 cm)	38.0	19.5	26.0	32.5	39.5	26.0	10.5	29.5
(12.5 cm)	32.5	32.0			40.0	33.5	20.5	36.0
	31.0	14.0			37.0	13.5	19.0	27.5
Exit (25 cm)	35.0	18.5	26.0	34.5	37.5	26.0	15.5	34.0
(25 cm)	30.5	31.5			39.0	32.5	26.0	40.0

Table 7. The effect of the bullet on the aerated concrete narrow surface (measurements were taken from the front surface and left surface).

Surface coating		Adhesive mo	ortar-plaster		Monolithic elastomer polyurea			
Protection level	ВІ	R6	BR7		BR6		BR7	
Measurement (cm)	Front surface	Left surface	Front surface	Left surface	Front surface	Left surface	Front surface	Left surface
Entrance (surface)	37.5	7.0	15.5	9.0	37.0	12.5	15.5	14.5
10 cm	37.0	7.0	14.5	9.0	37.0	12.5	15.0	14.5
25 cm	38.0	7.0	12.0	5.0	34.0	13.0	13.0	6.5
35 cm	39.0	8.0	10.0	1.5	33.5	11.5	9.5	3.0

In Table 7, the positions of the bullets in both aerated concretes are indicated by measuring the distance they change both in height and horizontally. When this table is examined, it has been determined that the height and displacements on the aerated concrete coated with both materials are higher in the shots fired with BR7 bullets. As a result of the long trajectory of the projectile in shots fired on the narrow surface and the hollow structure of the aerated concrete, BR6 bullets could not exit through the aerated concrete coated with adhesive mortar + plaster and monolithic elastomer polyurea, while BR7 bul-

lets exited from the side surface. The fact that the bullets did not exit from the back surface in both aerated concretes showed that such a structure could be formed, however, it is thought that building a form so that the bullet remains in the aerated concrete and conducting a study in this direction will yield better results.

In the study conducted with both coating materials, it was observed that the studies performed with monolithic elastomer polyurea were better than the adhesive mortar + plaster, but did not yield the desired result, according to the data in Tables 6 and 7.

3.3. Shooting test-3

3 rounds of BR6 bullets and 1 round of BR7 bullet were shot on the surface coated with mortar-plaster, which was obtained by combining 2 rows of aerated concrete with adhesive mortar. In the examination

Entrance

(surface)

Exit

(25 cm)

made after the shooting tests, it was seen that as a result of the damage caused by the bullets, perforation did not occur on the back surface of the aerated concrete in all shots. To examine the effect of the bullet on the aerated concrete, the entrance and exit hole of the bullet were measured. The measurements are given in Table 8.

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	Surface coating	Adhesive mortar-plaster						
	Protection level	ВІ	R6	BR7				
	Measurement (cm)	Front surface	Left surface	Front surface	Left surface			
Ì		23.5	23					

25.5

19.0

32.0

30.0

26.5

39.5

47.5

12.5

33.5

40.5

Table 8. The effect of the bullet on the aerated concrete formed in double rows (measurements were taken from the front surface and left surface).

In Table 8, the positions of the bullets in both aerated concretes are indicated by measuring the distance they change both in height and horizontally. When this table is examined, it is seen that the BR6 and BR7 bullets do not follow a linear path. The fact that the bullets had exited from the back surface in the aerated concrete showed us that such a form could not be built. Although 2 rows of 20 cm thick aerated concrete were formed and the thickness was 40 cm, it was understood that the thickness had no effect on an aerated concrete wall built in such a structure.

3.4. Shooting test-4

As a result of the shooting tests performed on the starch-coated materials placed in front of the adhesive mortar-plaster coated surface on the wide surfaces of the aerated concrete;

• The starch inside the platform with a distance of 7 cm to 25 cm thick aerated concrete and a width of 5 cm was shot with 1 round of BR7 bullet. In the examination made after the shooting, it was observed that the bullet penetrated 13 cm from the moment it entered the surface, and no perforation occurred on the back surface of the aerated concrete. To examine the effect of the bullet on the aerated concrete, the aerated concrete was divided into 2 equal parts from their joints

and their measurements were taken. The measurements are given in Table 9.

37.5

31.5

16.5

25.0

• The material containing starch with a diameter of 16 cm in front of 20 cm thick aerated concrete was shot with 1 round of BR7 bullet. In the examination made after the shooting, it was observed that the bullet penetrated 14 cm from the moment it entered the surface, and no perforation occurred on the back surface of the aerated concrete. To examine the effect of the bullet on the aerated concrete, the aerated concrete was divided into 2 equal parts of 10 cm and their measurements were taken. The measurements are given in Table 9.

In Table 9, the positions of the bullets in both aerated concretes are indicated by measuring the distance they change both in height and horizontally. When this table was examined, in the shots fired with BR7 bullets, it was seen that the heights and displacements on both aerated concretes were in different directions. In structures created with non-Newtonian fluids, the fact that the bullets did not exit from the back surface in both aerated concretes makes it the best choice to build such a form. Compared with other shooting experiments, the fact that it kept the bullet inside showed that this form was successful and it would be appropriate to carry out studies in this direction so that it could be used in structures to be built (Fig. 10).

Table 9. The effect of the bullet on the aerated concrete formed with starch (measurements were taken from the front surface and left surface).

Surface Coating	Platform	Starch	Surface Coating	Platform Starch		
Protection Level	BR7		Protection Level	BR7		
Measurement (cm)	ement (cm) Front surface Le		Measurement (cm)	Front surface	Left surface	
Entrance (surface)	28.0	38.5	Entrance	22.5	25.5	
13 cm	33.0	40.0	10 cm	21.5	22.5	





Fig. 10. Effect of shots fired on starch coated aerated concrete.

4. Conclusions

In the study, to examine the impact effect of aerated concrete and to measure its ballistic resistance against BR6 and BR7 bullets, the effect of thickness, direction, and different materials applied to the surface was examined by using 4 different stages. The evaluations were made as a result of the cuts made on the aerated concrete, the movements of the bullet on the aerated concrete surface, and the entrance-exit hole damages.

- It is very difficult to generalize the results due to the fact that such studies on aerated concrete are conducted for the first time and the studies in this field are extremely limited. However, this study is thought to be a basis for future studies.
- The hollow structure of aerated concrete has affected the path the bullets followed inside the aerated concrete. When the displacement and height changes in the figures were examined, it was seen that there was no linear movement. This situation was effective in the fact that the bullet could not exit through the back surface after entering the aerated concrete, especially in the shots fired on the narrow surface and the shots fired on the starchy surface.
- As a result of the shooting tests, Shooting-1, 1-a, 1-b and Shooting-3 were unsuccessful because the bullets exited through the back surfaces and could not show the desired strength performance. In the 2-a and 2-b shooting tests carried out in Shooting-2, the BR-6 bullets did not perforate, and the shots made with the BR-7 bullets exited from the side surface before reaching the back surface. Compared to Shooting-1 and Shooting-3, it can be said that it was a successful test, but the study can be expanded to further improve this form and keep the bullets inside. Tests carried out on the structures built in Shooting-4, 4-a and 4-b are the most successful ones. It was able to keep the bullet inside and there was no exit from the back surface. This study was more reliable and successful than the other 3 studies.
- In the application of adhesive mortar-plaster applied to the wide surface of the aerated concrete, it was determined that even if the thickness of the aerated concrete was increased, it could not prevent the bullet from exiting. In the aerated concretes created with the application of monolithic elastomer polyurea, it has been observed that, unlike the large bullet entrances and exits in the adhesive mortar-plaster application, the bullet is in the form of small scratches at the entrance and exit points, and the bullet exits when the monolithic elastomer polyurea coating is removed. The monolithic elastomer polyurea absorbed the energy in the parts where the projectile entered and exited the aerated concrete and kept the material together without scattering. It is thought that it would be appropriate to use a material of this nature against explosions, etc., instead of an armed attack.
- In the shots fired on the narrow surface, there was no exit from the back of the aerated concrete. It was observed that BR7 bullets exited from the side surface on both the adhesive mortar-plaster and monolithic elastomer polyurea coated surfaces. In a structure to be formed, in order to provide protection, it will be advantageous to form the direction of the aerated concrete to be used in the narrow surface direction.
- Studies on starch-coated surfaces have been more successful than other materials applied. In particular, the resistance of the oobleck mixture (non-Newtonian fluid) created with a mixture of water and starch on the aerated concrete surface against the impact, and the fact that the BR7 bullets did not exit after the shots fired on the wide surface, showed that a structure formed suitably with this material would be appropriate. Especially in the setup built with the starch platform, the 7 cm gap between the aerated concrete and the setup was also effective. When the displacement and height changes were examined, it was seen that the bullet was displaced more in the starch formed with the platform. This situation can be explained by the fact that the projectile was displaced during the process after hitting the platform, especially in a hollow environment.

Within the scope of this study and the scope of a structure to be formed with aerated concrete, with the direction of the aerated concrete, the gap structure that can be formed in front of the aerated concrete (with building materials such as stone wool, etc.) and a form of starch suitable for building materials, the establishment of police and military security points will be both time and cost-effective.

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