Masonry Walls That Resist Bullet Penetration

By: Michael Hatzinikolas, Ph.D., P.Eng.
Canadian Masonry Research Institute,

Marc Kuzik, M.Sc., E.I.T.
University of Alberta
and
Scott Kashuba, B.Sc., MA, MBA
Royal Canadian Mounted Police

Masonry structures, by there robust nature, convey a feeling of security. Hence, it is probably by no coincidence that many correctional institutions, law enforcement facilities, and government buildings are effectively constructed with different types of masonry. During the second world war, masonry structures were used to house equipment sensitive to sabotage. Today, terrorist attacks and the increasing occurrences of "drive-by shootings" pose a great threat to public safety. However, for both Engineers and Architects, little information is published on the resistance of exterior walls to bullet penetration. Intuitively, masonry should provide better protection from direct or indirect gun shots than do other forms of typical light construction simply because of the mass available to dissipate the energy from an impact. However, to simply specify a building material based on a hunch is not a rational design methodology. In addition, to blacklist other types of construction materials without performing a scientific comparison between complete wall systems, is simply unprofessional. To address these issues, a research program was initiated by the Canadian Masonry Research Institute (CMRI) and the Royal Canadian Mounted Police (RCMP) to investigate the performance of complete wall assemblies subjected to direct gun shots.

To conduct this study, a total of 16 wall assemblies were constructed using standard construction procedures and in accordance with the applicable building standards. Each wall assembly was built in an "L–shape" as viewed in plan. Figure 1 shows a typical wall specimen. For 13 of the walls, the main framing consisted of 51 mm x 102 mm (2"x 4") wood studs spaced at 400 mm (16") on center. The framing was covered with 13 mm ($^1/_2$") thick wood sheathing and exterior tar paper while fiberglass insulation was placed between the studs. The interior side of each wall was covered with drywall and then painted. The remaining three walls were constructed using standard 150 mm hollow concrete blocks as the backup wall system. These three walls were detailed with a bituminous air barrier membrane and 50 mm (2”) of rigid foam insulation. No paint was applied to the interior side of the concrete block backup walls.

Figure 1 - Concrete Brick with Wood Stud Backup Wall Specimens

The exterior of the wood framed walls was finished with five different systems: concrete brick, clay brick, Tindlestone, vinyl siding, and stucco. Three walls were finished with concrete brick units of which two walls utilized 90 mm (thick) x 57 mm (high) units and one wall utilized 90 mm (thick) x 200 mm (high) units. The nominal strength of the concrete masonry units was 15 MPa. One wall utilized high strength clay bricks as the veneer. These high strength units were almost black in colour and had a compressive strength of 70 MPa. Another single wall specimen utilized Tindlestone from Manitoba as the veneer. The Tindlestone was saw cut on all faces a typical thickness of 90 mm. Standard vinyl siding was placed on two walls and wire mesh with stucco was applied on four walls. The stucco walls were divided into two categories: a two coat stucco having a total thickness of 13 mm, and a three coat stucco having a total thickness of 19 mm.

The remaining three wall assemblies were constructed using standard 150 mm hollow concrete masonry units as the structural backup. Two of these wall specimens were constructed with 90 mm (thick) x 57 mm (high) clay bricks for the veneer and the concrete block backup was not grouted. The last specimen was constructed using a fully grouted backup with concrete brick as the veneer. Type S mortar was used for both the clay brick and concrete block masonry units.

An extensive variety of firearms were used in the testing program. Because literally thousands of different types of firearms exist, the objective was to select a sample of common firearms and ammunition typically available to civilians and police. The following table lists all the firearms along with the corresponding ammunition used.

See Table "Description of Firearms and Ammunition"

The walls were tested in the firing range at the Royal Canadian Mounted Police (RCMP) forensic laboratory located in Edmonton, Alberta, Canada. Testing was performed on one wall at a time due to the physical layout and size constraints of the firing range; however, the test procedure used for each wall specimen was identical.

The walls were positioned at a horizontal distance of 25 m from the location of the riffle. Each wall was then fired upon twice with each caliber of rifle selected. For the first shot, the given wall was positioned such that one leg of the "L–shape" was perpendicular to the trajectory of the bullet. The second was fired with the wall rotated 45 degrees such that the theoretical trajectory of the bullet before impact passed through both faces of the "L–shaped" wall assembly. Figure 2 shows the plan view of the two wall positions used during testing.

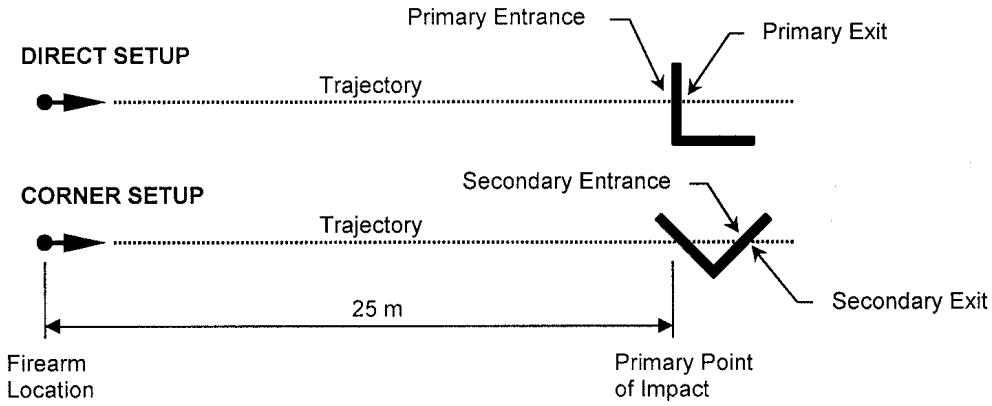

Figure 2 - Plan View of Test Setup

This procedure was repeated once for each caliber, beginning with the .22 caliber and then sequentially increasing the caliber, until the wall was penetrated. A summary of the test results is listed in the following tables.

	VINYL SIDING	
Firearm	**Direct**	**Corner**
.177 Pellet	embedded in plywood	not tested
.22 Revolver	through wall	through both walls
.22 Long Rifle	through wall	through both walls
.223 Remington	through wall	through both walls
.25 Automatic	through wall	through 1 wall
.32 Automatic	through wall	through both walls
.308 Winchester	through wall	through both walls
.40 Smith & Wesson	not tested	through both walls
12 Gauge 0 Buckshot	through wall	not tested

STUCCO SIDING—13 mm

Firearm	Direct	Corner
.22 Revolver	embedded in stucco	not tested
.22 Long Rifle	through wall	not tested
.223 Remington	not tested	embedded in second wall
.25 Automatic	embedded in stucco	not tested
.32 Automatic	embedded in stucco	not tested
9x19mm Pistol	through wall	not tested
12 Gauge Sabot Slug	not tested	through both walls

	STUCCO SIDING—19 mm	
Firearm	**Direct**	**Corner**
.22 Long Rifle	embedded in stucco	not tested
.223 Remington	through wall	embedded in second wall
.308 Winchester	through wall	through both walls
.40 Smith & Wesson	through wall	not tested
9x19mm Pistol	through wall	not tested
9x19mm Sub-machine gun	through wall	through first wall
12 Gauge 0 Buckshot	4/12 pellets embedded in drywall	not tested
12 Gauge Rifle Slug	through wall	not tested
12 Gauge Sabot Slug	through wall	not tested

	Clay Brick—17.5 MPa	
Firearm	**Direct**	**Corner**
.22 Long Rifle	large chip in brick	not tested
.223 Remington	large hole in brick	not tested
.308 Winchester	large hole in brick	large hole in brick (embedded)
7mm Remington Magnum	large hole in brick	not tested
7mm Shooting Times Westerner	through brick to tar paper	not tested
.30-06 Springfield	large hole in brick	not tested
.375 Holland & Holland	through brick to tar paper	not tested

	Clay Brick—70 MPa
Firearm	**Direct**
.22 Long Rifle	small chip in brick
.223 Remington	large hole half way through brick
.308 Winchester	large hole in brick
.50 Browning Machine Gun	through wall

	Concrete Brick
Firearm	**Direct**
.22 Long Rifle	small chip in brick
.223 Remington	hole in brick
7mm Remington Magnum	large hole in brick
.308 Winchester	large hole in brick
.30-06 Springfield	large hole in brick

	Concrete Block (hollow)
Firearm	**Direct**
.22 Long Rifle	large chip in brick
.223 Remington	hole through first face shell
.308 Winchester	hole through both face shells

	Cavity wall—Ungrouted	
Firearm	**Direct**	**Corner**
.50 Browning Machine Gun	through wall	through first wall and embedded in second

	Cavity wall— Fully Grouted	
Firearm	**Direct**	**Corner**
.50 Browning Machine Gun	3 successive shots required to penetrate wall	not tested

	Manitoba Tindlestone
Firearm	**Direct**
.22 Long Rifle	small chip in brick
.223 Remington	large diameter surface chip
.308 Winchester	large deep chip
.50 Browning Machine Gun	through wall

The results of this project were somewhat unexpected. The ability of a .22 Long Rifle bullet to easily travel completely through the corner of a typically constructed vinyl sided house was as unforeseen as the clay and concrete brick walls stopping all but the bullet with the greatest velocity. Standard 13 mm or 19 mm stucco finishing does not significantly reduce life-threatening situations for people inside or outside a wall that is subjected to most centerfire bullet impacts. This danger increases with the velocity and energy of the bullet fired. A person struck by one of these projectiles would be at risk of serious bodily injury or death. Secondary projectiles (wood, lathe, stucco, etc.) produced by a bullet travelling through one of these walls would also present a risk to a person. Walls finished with either a clay brick, concrete brick, or Tindlestone veneer prevented all but the .50 Browning from completely penetrating the wall assembly.

The ability of the both the high strength (70 MPa) and low strength (17.5 MPa) clay brick walls to prevent bullet penetration was very similar. However, the localized behaviour of high and low strength bricks was substantially different. Upon impact, the low strength brick was turned into powder in the localized region of the bullet impact. Figure 3 shows the impact zone caused by the .308 Winchester on the low strength clay brick.

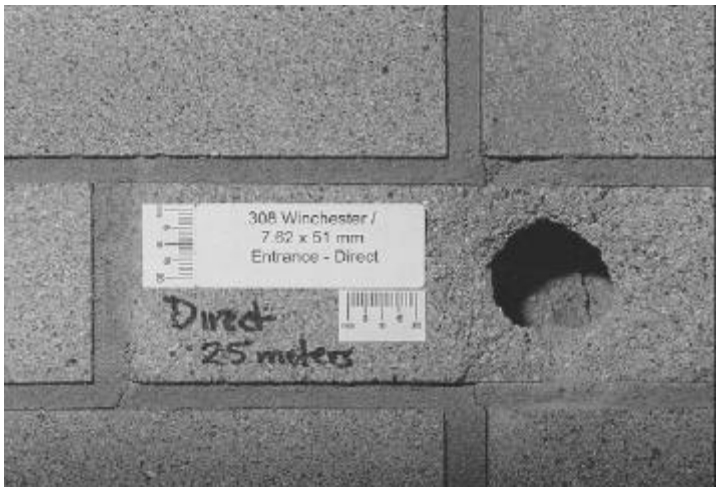

Figure 3 - Damage to Low Strength Clay Brick Caused by .308 Winchester

Very little flying debris was observed and the bullet typically came to rest inside the wall. For the high strength brick, a more brittle type of behaviour was observed. Rather than turning to powder upon impact, many small chips were formed which scattered as far as 10 m from the impact zone. Figure 4 shows the impact zone caused by the .308 Winchester on the high strength clay brick.

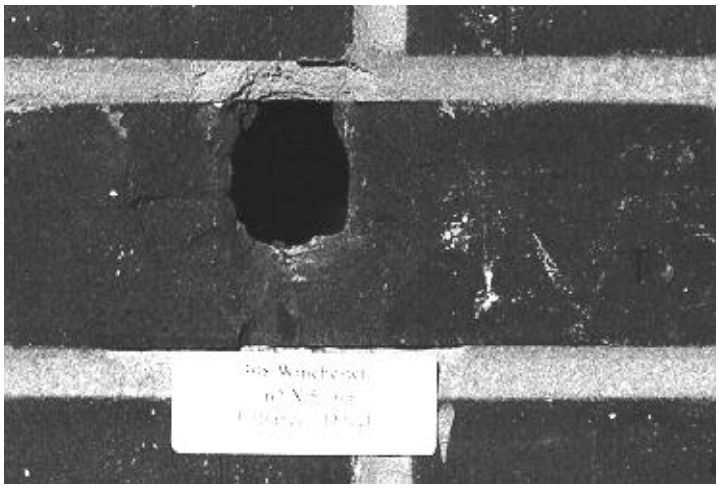

Figure 4 - Damage to High Strength Clay Brick Caused by .308 Winchester

Similar characteristics were exhibited by the Tindlestone wall with fragmented pieces travelling as far as 20 m. Figure 5 shows the chipped region caused by the .223 Remington.

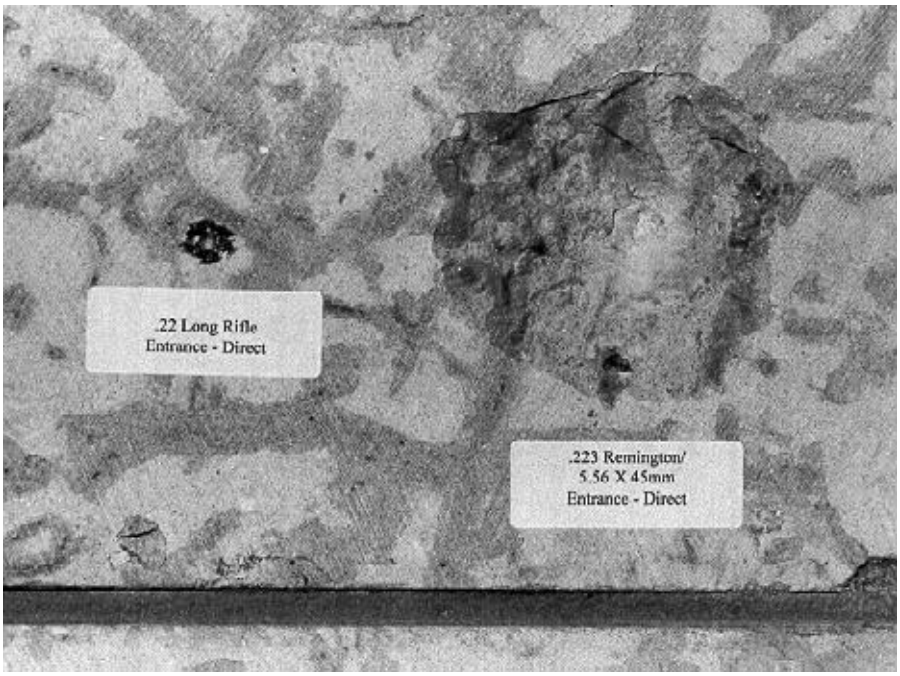

Figure 5 - Damage to Tindlestone Caused by .223 Remington

These tests have provided valuable forensic firearms information regarding the type of damage expected to buildings after they have been struck by gunfire. Certain inferences about velocities and caliber can be made by observing the damage found on primary and secondary targets. The results provide members of law enforcement with the knowledge of what consequences they can expect in situations where firearms are being used by and/or against them. These results will also provide builders and architects of high risk projects with the knowledge of what finishes can be used in specialized or high risk applications.

This project was funded by CMRI and the RCMP. The authors wish to thank the management of the RCMP Crime Laboratory for without their support and cooperation, this project could not have been undertaken.