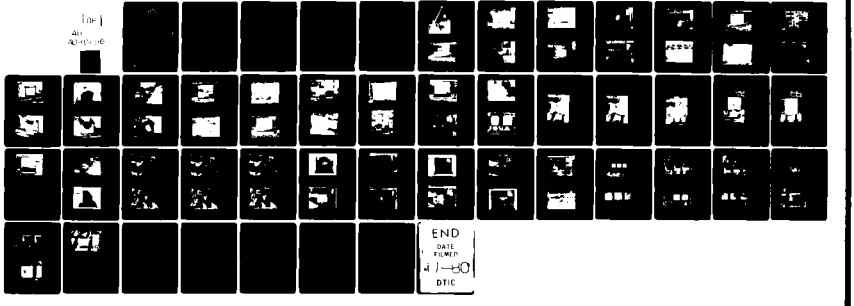
AD-A090 196 CORPS OF ENGINEERS OMAHA NE F/G 13/13
HARDENED WALL TESTS.(U)
APR 78

UNCLASSIFIED NL



LEVEL II

F

20

AD A090196

(6) HARDENED WALL TESTS.

By

Corps of Engineers

Omaha District

(11) 21 April 1978

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I. INTRODUCTION.

Authority and Scope.

This study is authorized by AFRCE-SAC letter dated 22 February 1978 and MRDED-M 1st Ind dated 23 February 1978.

The scope of the study includes testing of various materials to determine their effectiveness in preventing complete penetration of a single 7.62 mm NATO round, fired from a distance of 125 feet. As an added item of interest, additional 4-shot bursts were fired at the same spot to determine what effect this would have on the materials.

Background and Purpose.

The Air Force is currently upgrading their security requirements in the Weapons Storage Areas (WSA) and the Aircraft Alert Areas (AAA) at various Air Force Bases. A portion of this upgrading requires hardening of walls to meet the criteria presented above. Although there are many reports of this type, covering testing of various materials, they do not fit the immediate criteria required for these projects.

The purpose of this report is to determine the adequacy of the hardening criteria furnished by the Air Force, and to produce economies of design where the criteria could be reduced.

II. DISCUSSION.

The wall sections and steel plates used for testing were prepared under the supervision of the Missouri River Division Laboratory. Appendix A indicates the materials and procedures used in preparing the sections and plates. Test samples were delivered to the Eastern Nebraska Gun Club range by Operations Division Maintenance Base of Omaha District, Corps of Engineers.

III. TEST PROCEDURE.

The procedure followed for the tests was as follows:

a. Photograph original wall samples.

b. Fire a single shot at each section.

c. Photograph effect of the shot on the section.

d. Fire additional 4-shot burst at same spot on wall sections.

e. Photograph effect of total of five (5) shots.

A plastic 12" X 12" grid with 1/2" squares was used to record size of hole and spalls. A depth meter was used to measure depth of penetration, where applicable.

IV. SUMMARY.

A. The following materials failed under one shot:

1. 4-inch brick.

2. 4, 6, and 8-inch CMU without grout fill.

3. 8 pieces of glass bonded together to form 2-inch thick (+ or -) sample.

4. 1/4-inch mild steel.

5. 1/4-inch hardened steel (see Appendix A).

6. 3/8-inch hardened steel (see Appendix A).

B. The following materials or wall sections did not fail:

1. 12-inch CMU without fill.

2. 6-2-6 CMU-CMU cavity wall without fill.

3. 4-2-6 brick-CMU cavity wall without fill.

4. 8-inch concrete walls.

5. All wall sections with one or both wythes filled with grout.

6. Two 1/4-inch thick pieces of A-36 steel separated by a 2-inch air space.

7. Two 3/8-inch thick pieces of A-36 steel separated by a 2-inch air space.

8. Two 1/2-inch thick pieces of A-36 steel separated by a 2-inch air space.

9. One 5/8-inch thick piece of A-36 steel.

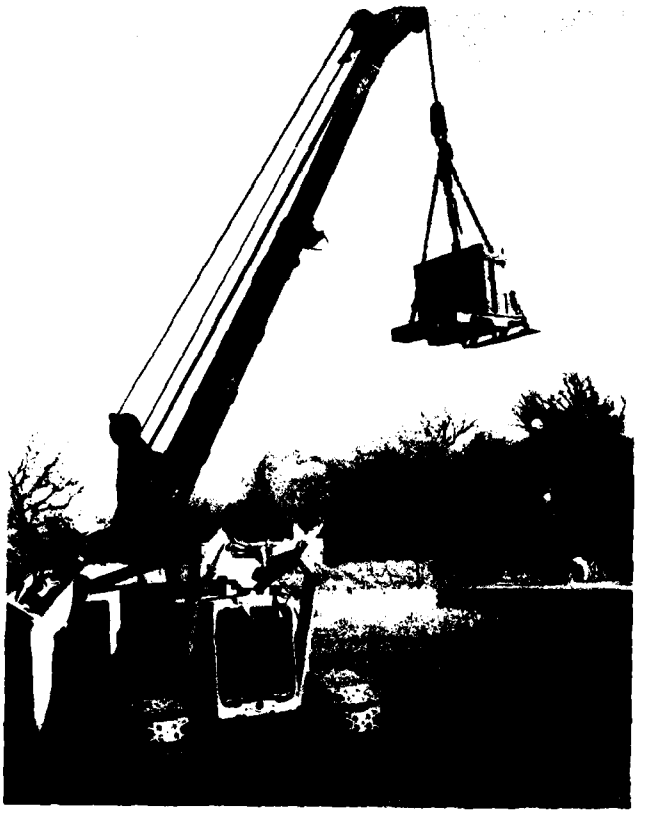
10. One 3/4-inch thick piece of A-36 steel.

11. One 1/4-inch thick piece of hardened steel (Deep Air-Hardened Alloy Steel) manufactured by Astralloy-Vulcan Corporation. Brinell Hardness per MRD Laboratory = 356.

12. One 3/8-inch thick piece of hardened steel (Deep Air-Hardened Alloy Steel) manufactured by Astralloy-Vulcan Corporation. Brinell Hardness per MRD Laboratory = 299.

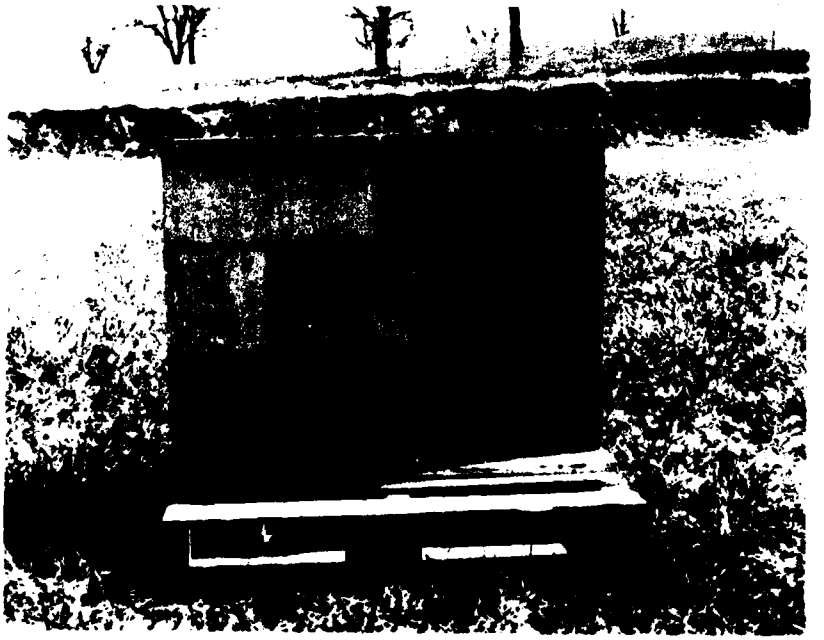
V. PHOTOGRAPHS.

NOTE: Number of picture corresponds to number on back of original photograph.



1-4

1-4. Wall Section being unloaded.



1-6

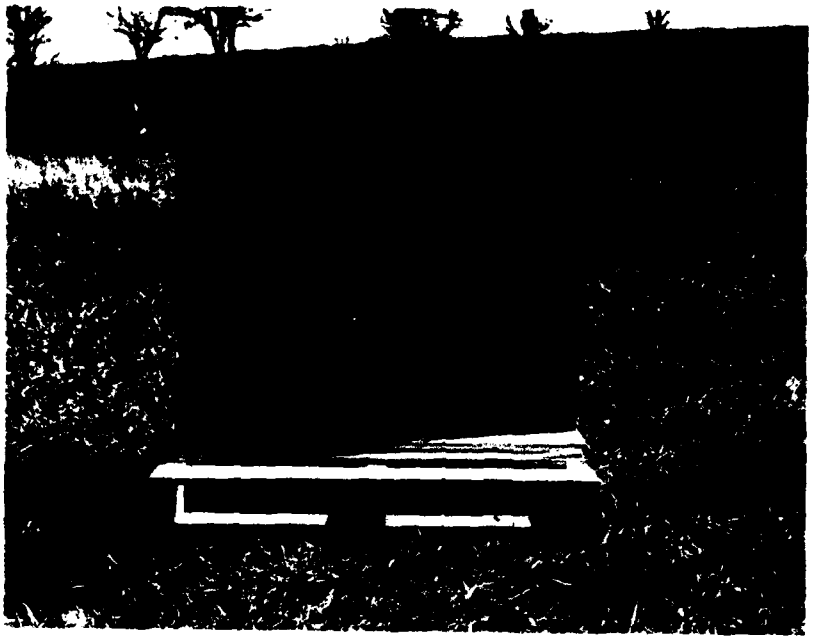
1-6. Wall #6. CMU-CMU cavity without grout fill.

1-16

1-16. Wall #6. First shot penetrated 6-inch CMU. Did not penetrate face shell of second CMU. Spall ± 2-1/2". Hole 1".

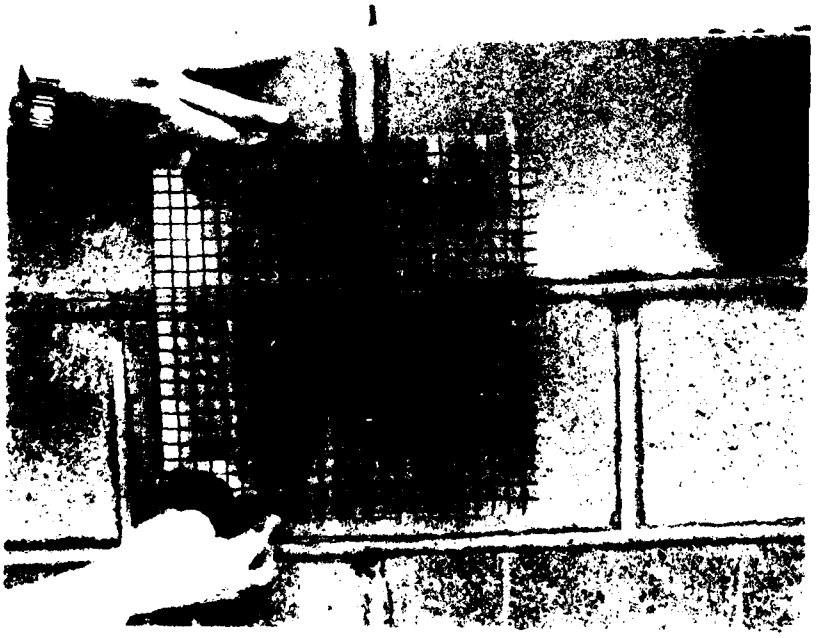
1-17

1-17. Wall #6. Additional 4-shot burst penetrated first CMU and face shell of second CMU. Did not penetrate back shell of second CMU.



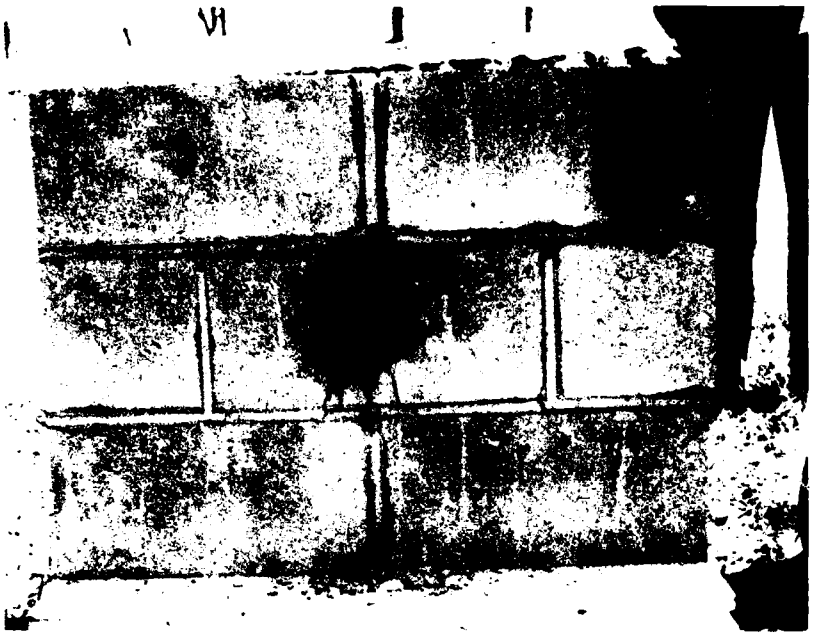
1-7. Wall #8. 6-2-6 CMU-CMU Cavity Wall without grout fill.

1-7



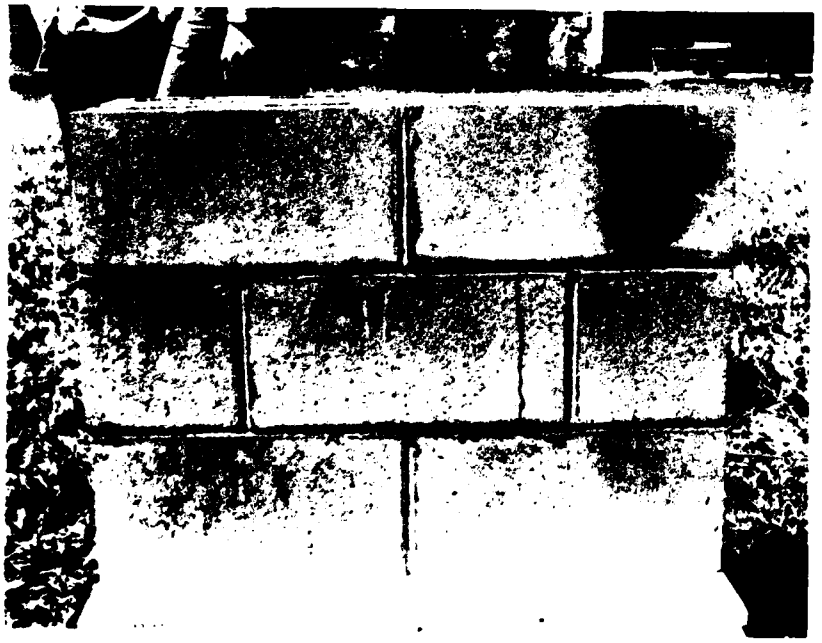
1-18. Wall #8. First shot [see #2-19 and #2-20 also]. Shot hit near web of CMU. Penetrated face shell of first CMU but did not penetrate back shell. Spall 3-1/2 In. Dia. Hole 1 In. Dia.

1-18



1-20. Wall #8. 4-shot burst penetrated first CMU and face shell of second CMU. Did not penetrate back shell of second CMU.

1-20

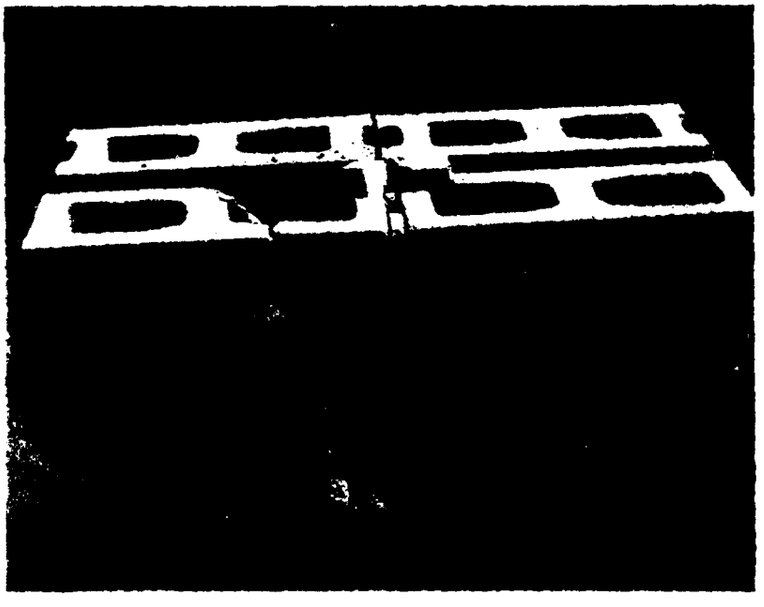


1-19. Wall #8. 4-shot burst shows crack in back shell of second CMU.

1-19

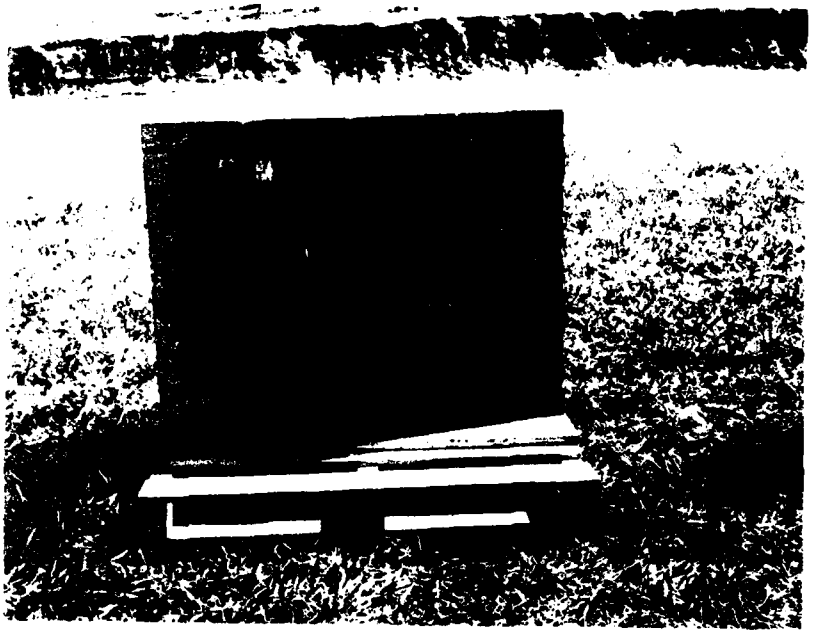
2-19. Wall #8. Single shot after 4-shot burst. [See 2-20.]

2-19



2-20. An additional shot was made at this wall in between webs. Penetrated first CMU but did not penetrate face shell of second CMU.

2-20

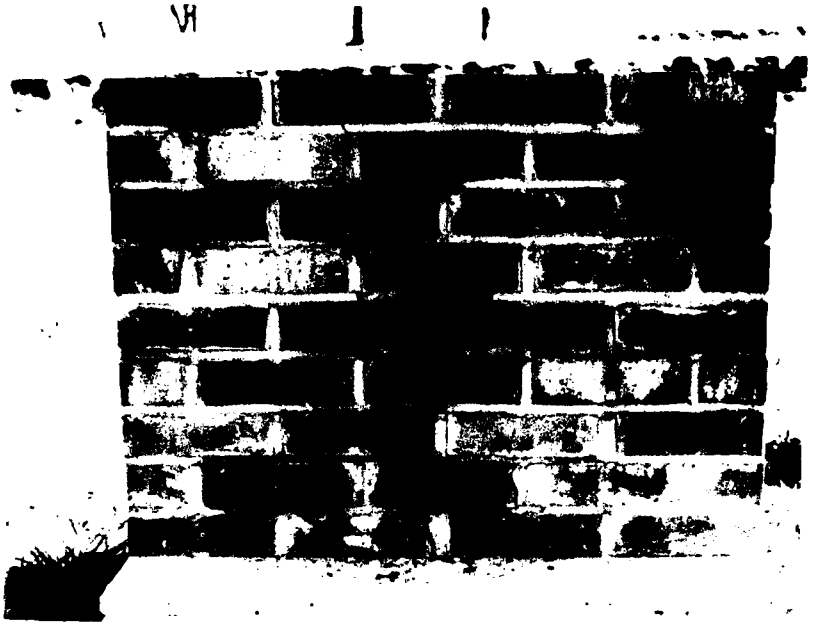


1-8

1-8. Wall #10. 4-2-6 brick-CMU cavity wall without cells filled.

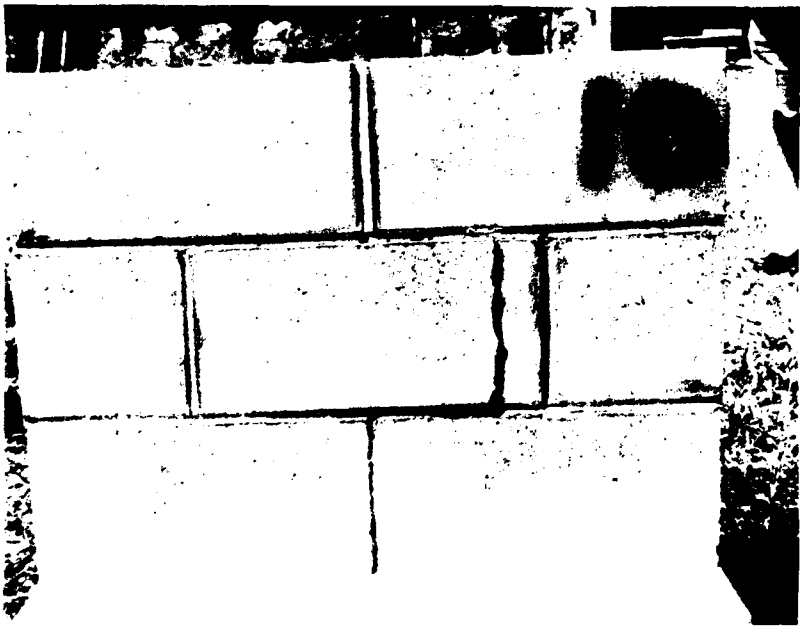
1-20
(colored)

1-20 (colored). Wall #10. First shot penetrated brick causing a 3-inch spall on back face of brick. It did not penetrate face shell of CMU.



2-2. Wall #10. 4-shot burst. [See 2-1.]

2-2

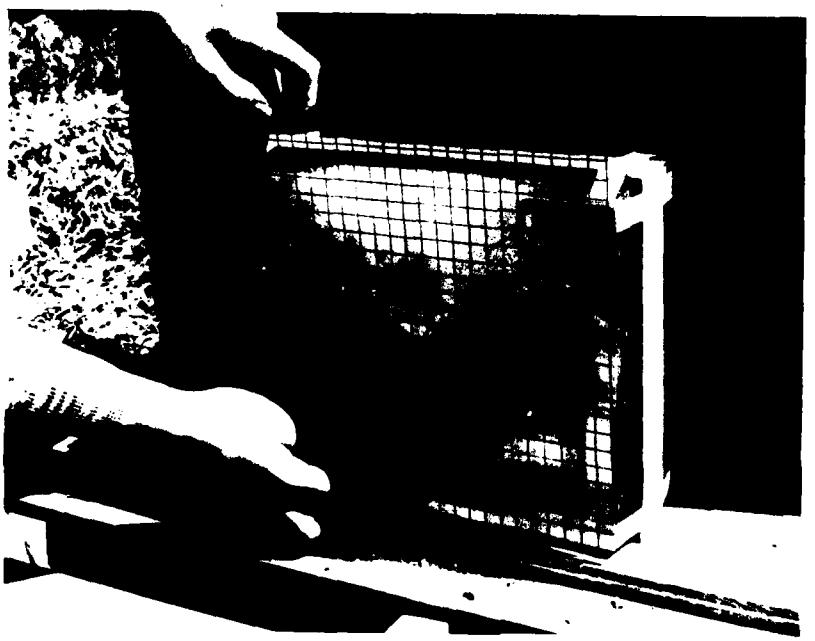


2-1. Penetrated brick and face shell of CMU. Cracked back shell of CMU.

2-1

2-3

2-3 Glass Sample. Sample consists of 7 layers of float glass bound together by means of a transparent polyvinyl butyral plastic sheet between each layer of glass. The glass arrangement is 3/8 X 7/32 X 3/8 X 7/32 X 7/32 X 7/32 X 3/32.



2-4

2-4 Glass Sample. First shot. Penetrated approx. 0.7 inch. Spall, 3-inch. Hole, 2-inch. Back of glass was spalled off.

2-6. Glass sample. First Shot. Back of glass sample.

2-6

2-8. Glass Sample. Second shot at same spot. [See 2-9.]

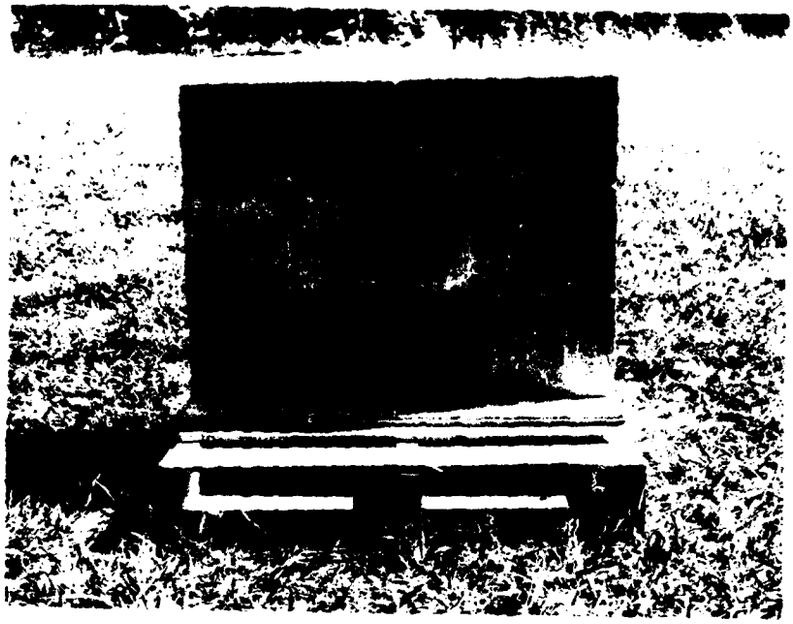
2-8

2-9. Penetrated glass and spalled concrete as indicated by pen.

2-9

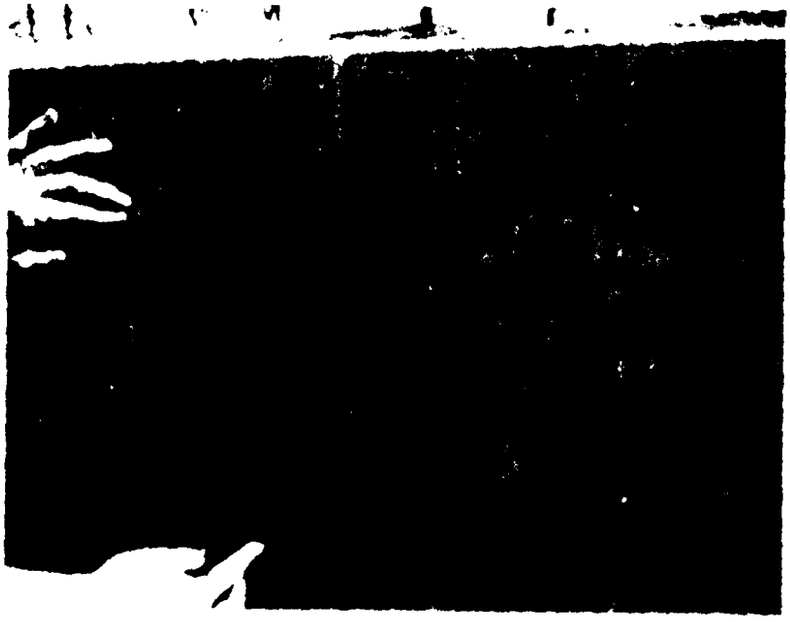
2-10. Glass sample. Second shot. Back of glass sample.

2-10



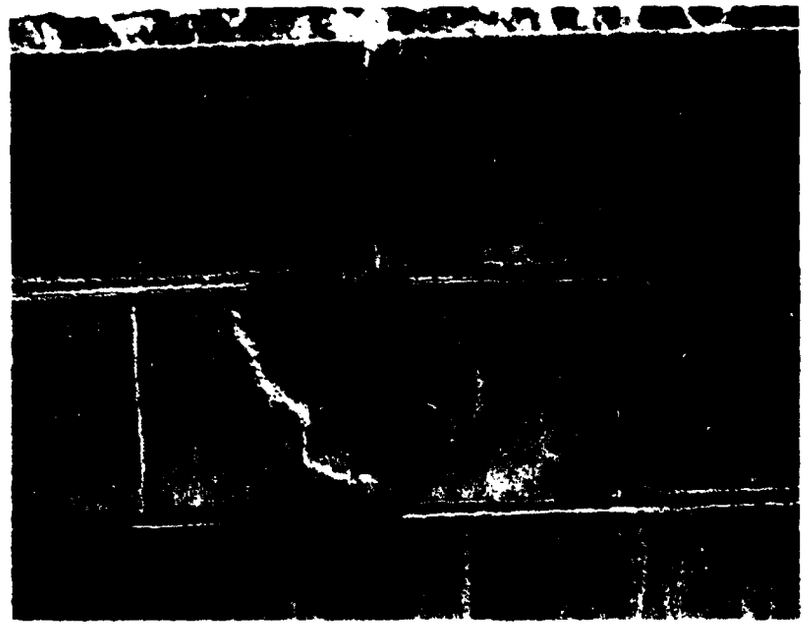
1-9

1-9. Wall #7. 6-2-6 CMU-CMU with both wythes filled with grout.



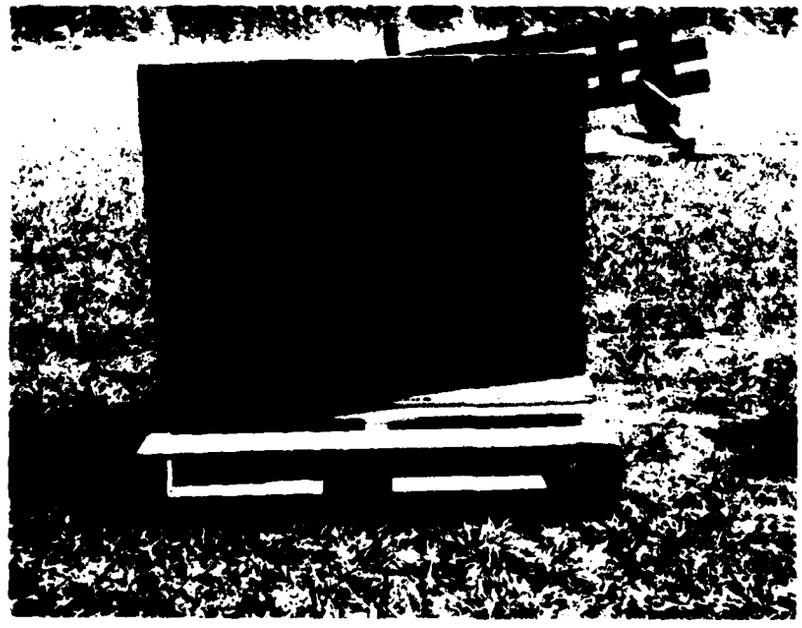
2-5

2-5. Wall #7. First Shot. Did not penetrate first wythe. Spall, 4 inches. Hole, 1 inch. Penetration Depth, 2.025 inches.



2-7. Wall #7.
4-shot burst.
Cracked back face
of first CMU but
did not penetrate.
Spall, 8 inches.
Depth, 2.530 in.

2-7

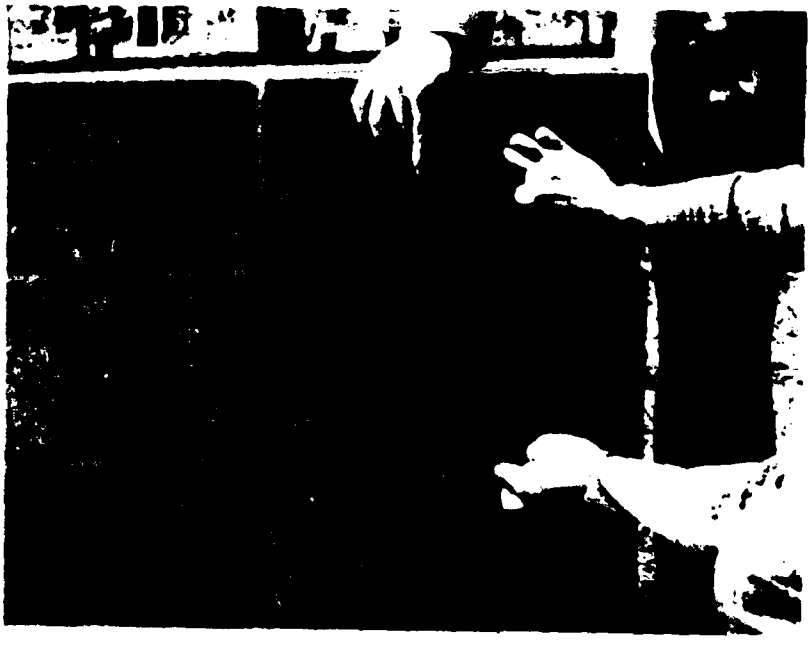


1-12. Wall #12.
4-2-8 brick-CMU.
No grout fill.

1-12

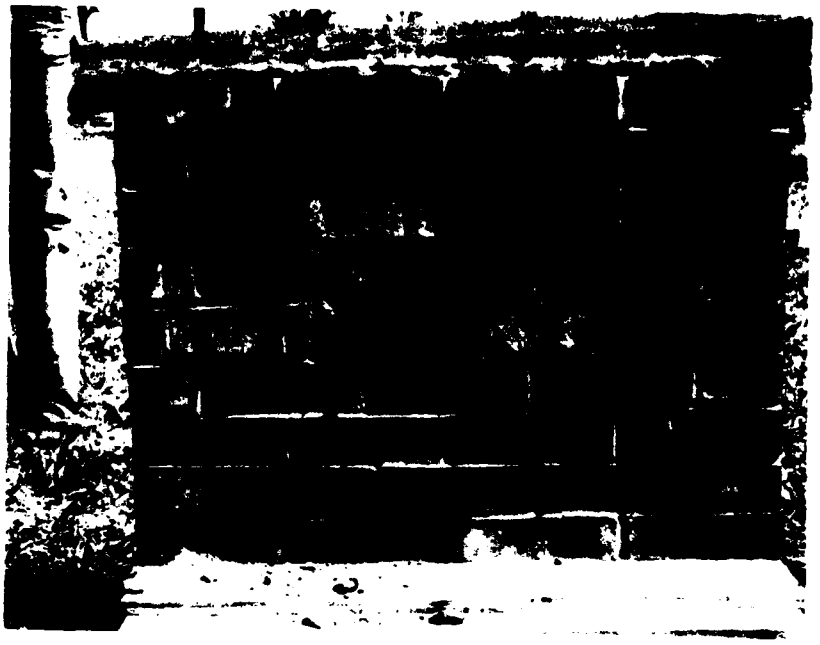
2-12

2-12. Wall #12. First shot. Penetrated brick, spalling off back face. Did not penetrate face shell of CMU. Spall, 3 inches.



2-13

2-13. Wall #12. 4-shot burst. Penetrated entire wall and threw concrete back approximately 10 feet.

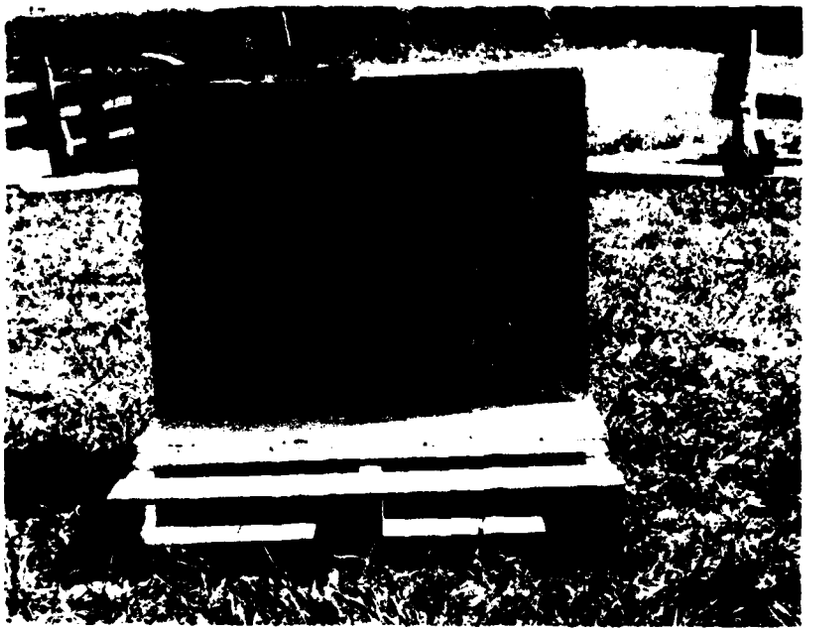


2-14. Wall #12.
4-shot burst.
Back of wall.
Spall, 4-1/2 in.
Shot at wall hit
between webs
which accounts
for difference
in shots at
Wall #6.

2-14

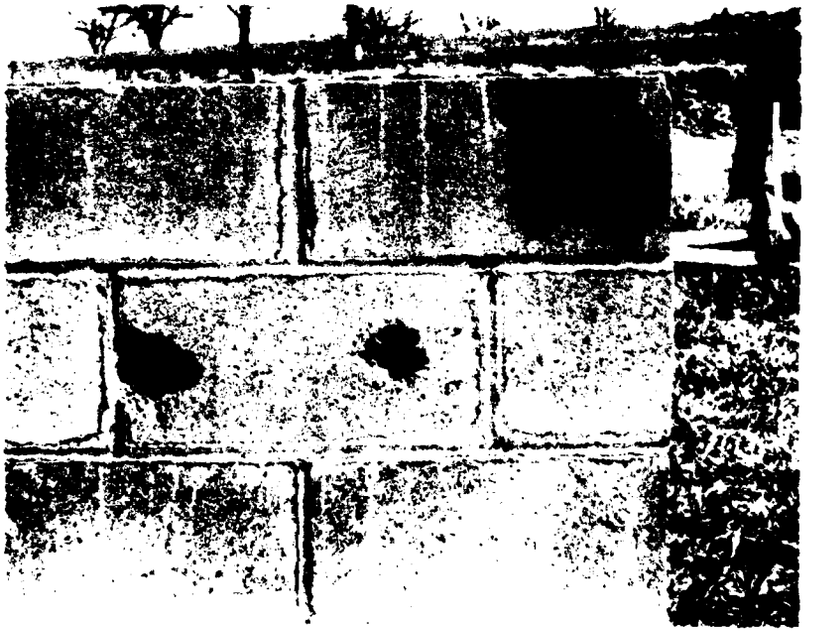
3-17. Wall #12.
Single shot from
75 feet. Hit
near edge and
broke out entire
brick but did not
penetrate face
shell of CMU.

3-17



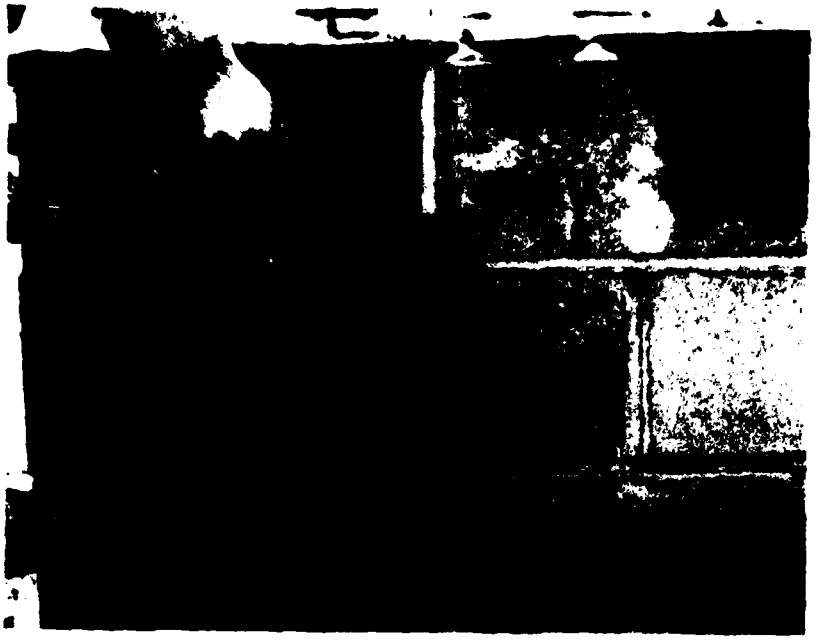
1-14

1-14. Wall #14.
8-inch CMU.
No grout.



2-16

2-16. Wall #14.
Two single shots approximately 8 in. apart. First shot on left penetrated face shell but did not penetrate back shell. This shot hit a portion of the web. Second shot hit between webs and penetrated entire wall.

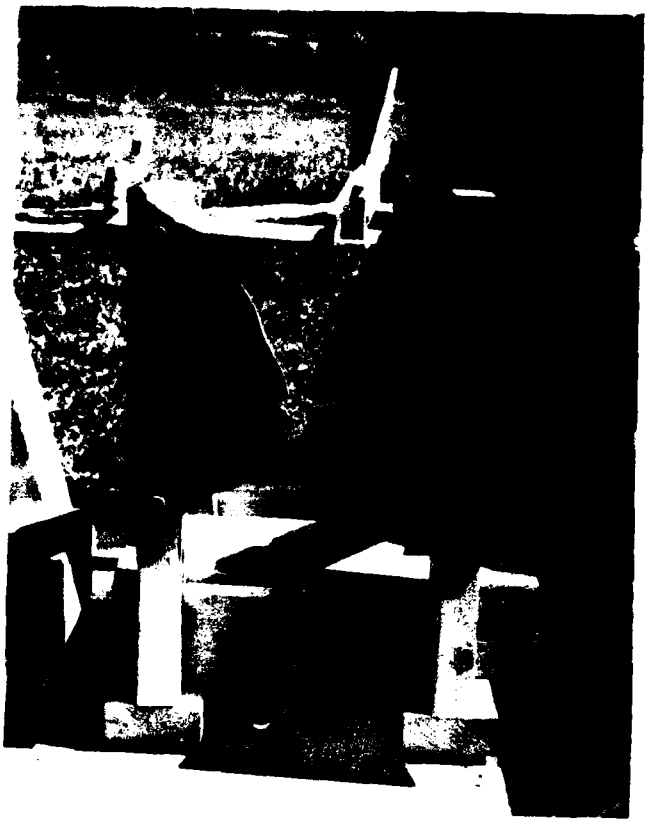


2-15. Wall #14. Shows back side of wall for second shot. Spall 3-1/2 in.

2-15

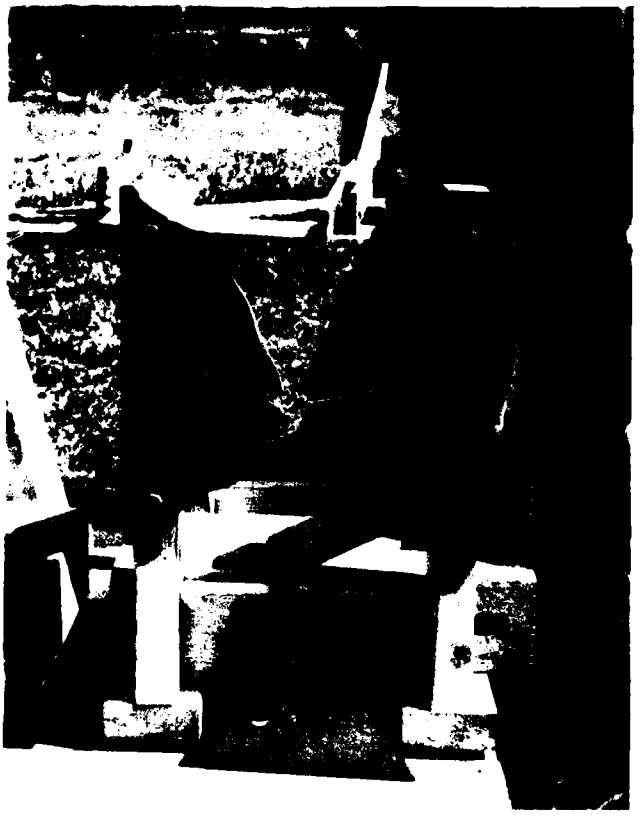
1-15. Steel plates. #20, 3/8" thick hardened steel. #19, 1/4" thick hardened steel.

1-15



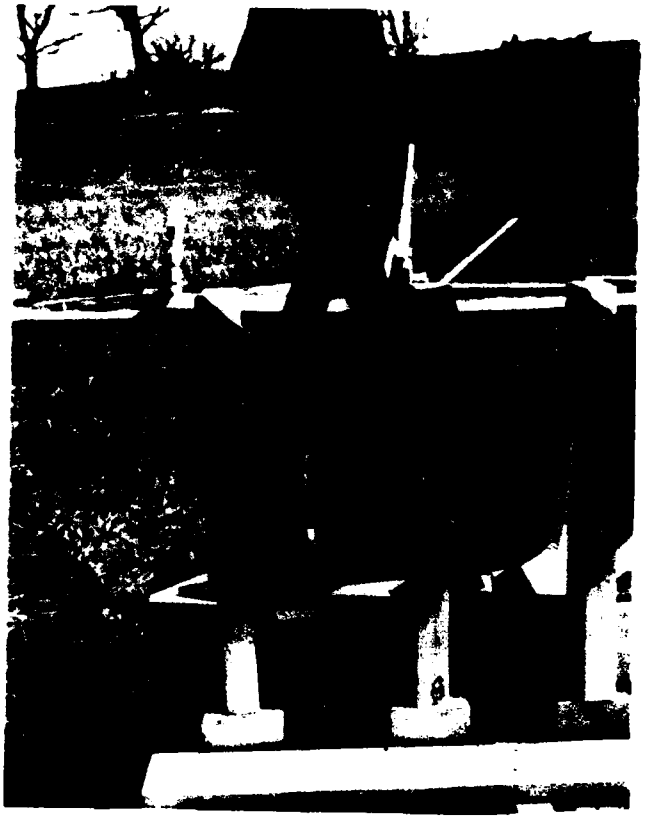
2-17

2-17. #19, piece of steel flew back 11'-7".



2-17

2-17. #19, piece of steel flew back 11'-7".



2-18

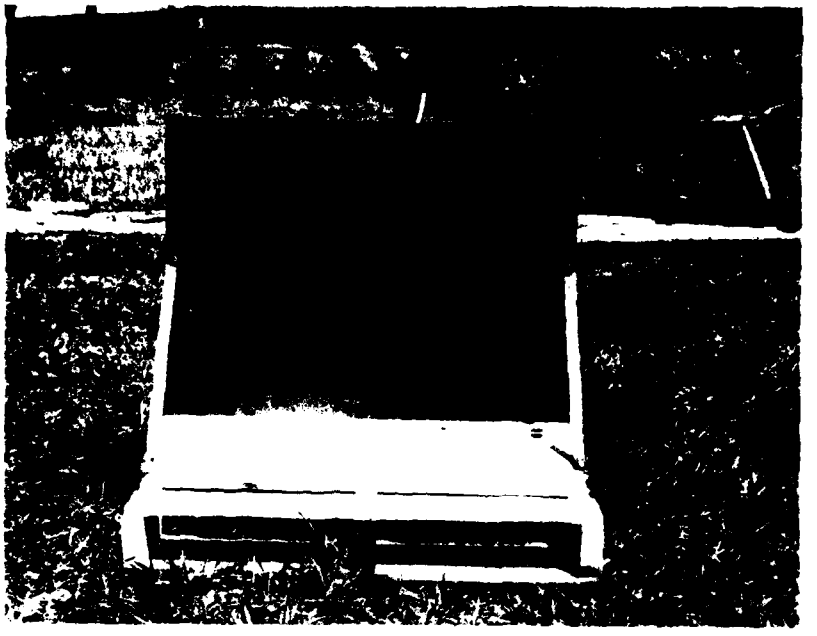
2-18. #20, steel shattered and threw metal back.

1-36
(colored)

1-36 (colored).
#19, shows bullet
went through.

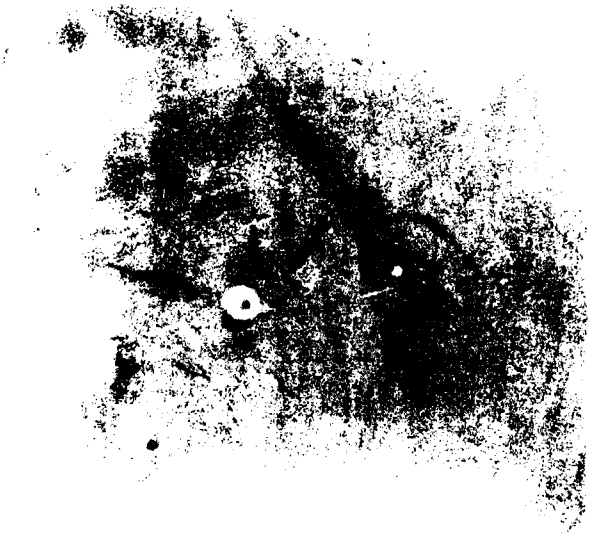
1-37
(colored)

1- 37 (colored).
#20, shows
bullet did not
put hole in plate.



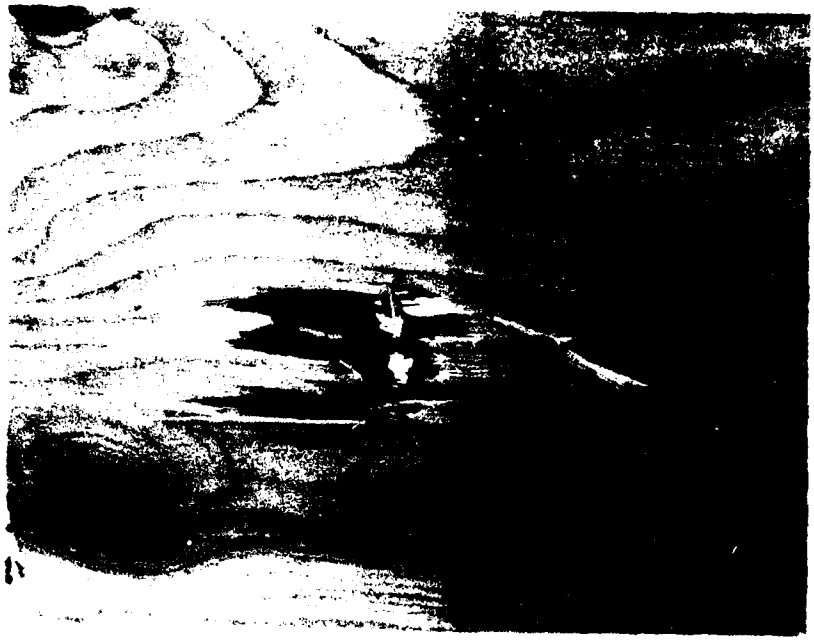
3-1

3-1. 1/4-inch mild steel plate.



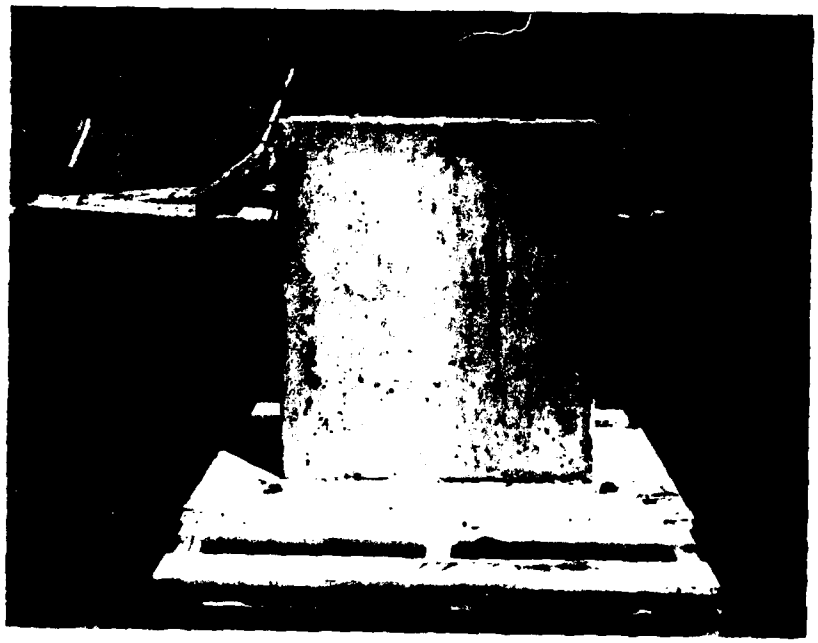
3-5

3-5. 1/4-inch mild steel plate. One shot went right through.



3-15

3-15. Piece of 3/4" plywood placed 12" back of 1/4-inch mild steel plate. One shot went completely through plywood and spalled CMU wall behind.

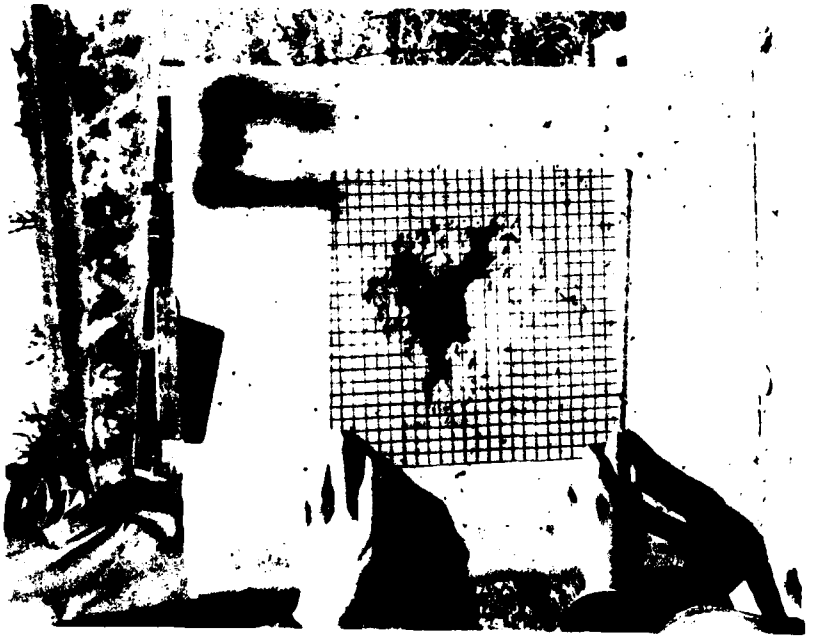


3-2

3-2. Wall #17. 8-inch concrete with 3000 psi compressive strength at 28 days.

3-6

3-6. Wall #17. Single shot. Did not penetrate. Spall, 6 inches. Depth, 1.601 in.

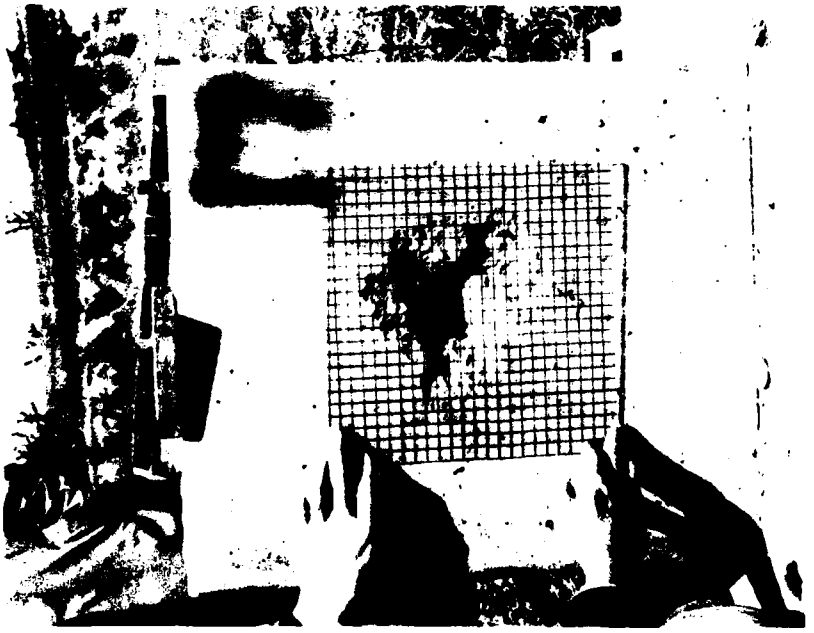


3-7

3-7. Wall #17. 4-shot burst. Did not penetrate. No cracks in rear face. Depth of penetration, 2.775 inches.

3-6. Wall #17. Single shot. Did not penetrate. Spall, 6 inches. Depth, 1.601 in.

3-6

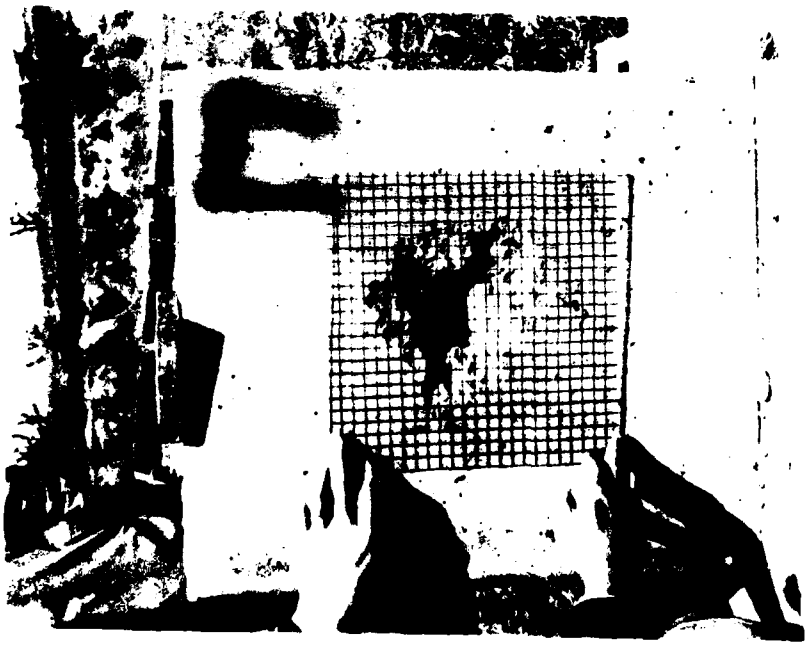


3-7. Wall #17. 4-shot burst. Did not penetrate. No cracks in rear face. Depth of penetration, 2.775 inches.

3-7

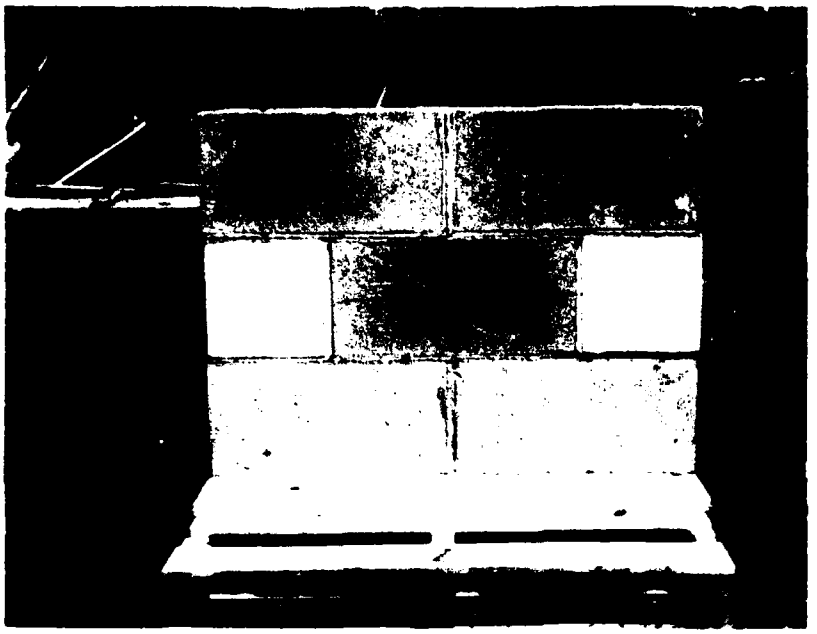
3-6. Wall #17. Single shot. Did not penetrate. Spall, 6 inches. Depth, 1.601 in.

3-6



3-7. Wall #17. 4-shot burst. Did not penetrate. No cracks in rear face. Depth of penetration, 2.775 inches.

3-7



3-3

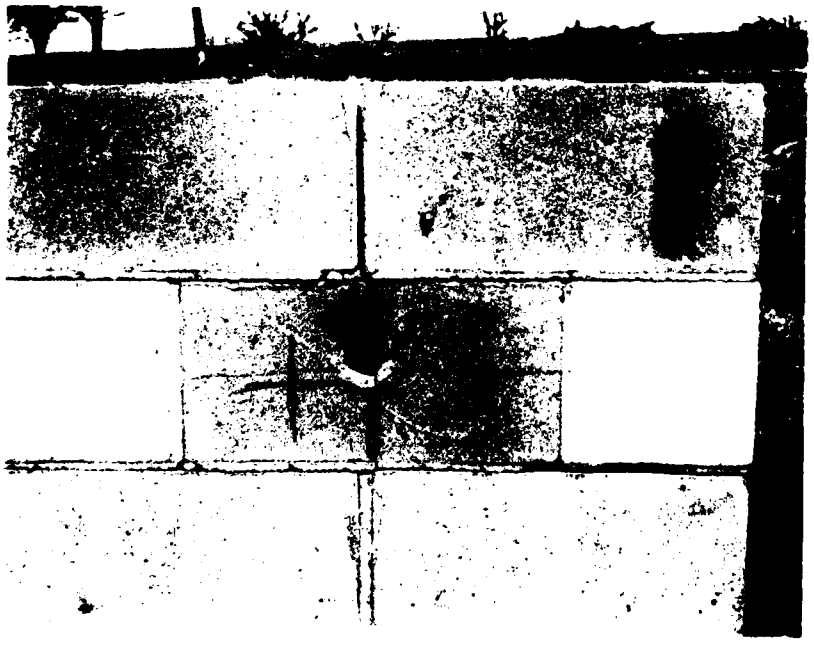
3-3. Wall #1. 4-2-6 CMU-CMU with 6-inch wythe filled with grout.

3-8

3-8. Wall #1. Single shot. Penetrated 4-inch CMU and spalled 6-inch CMU.

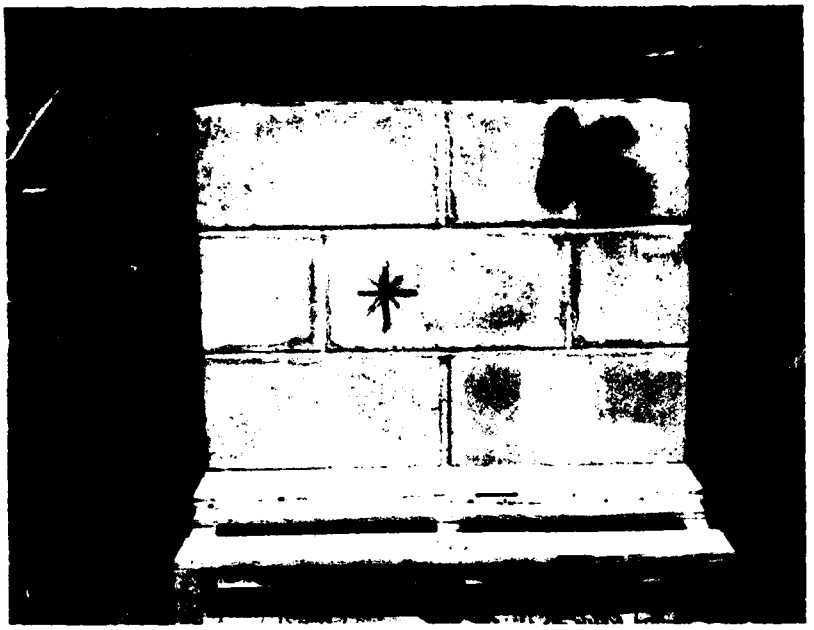
3-9

3-9. Wall #1. 4-shot burst penetrated 4-inch CMU. Did not penetrate 6-inch CMU. Put 7" spall in 6-in. CMU.



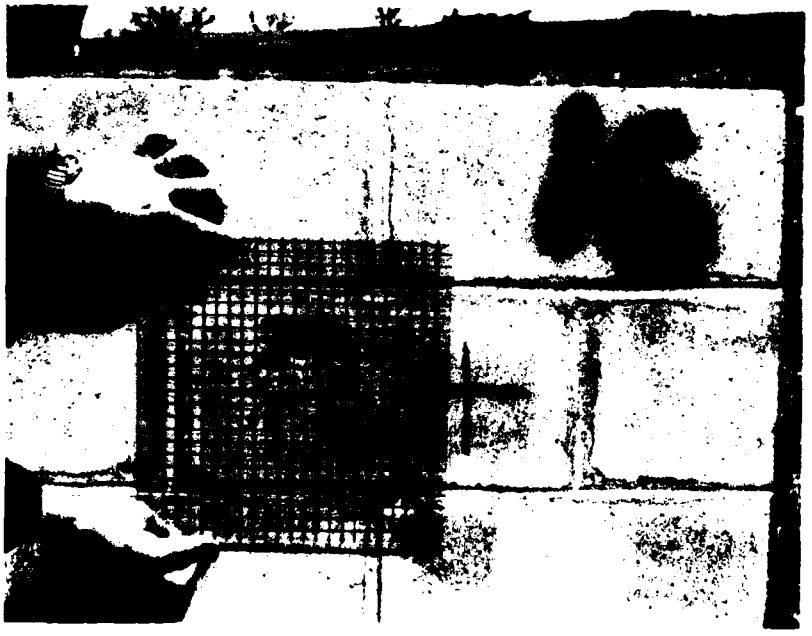
3-10

3-10. Wall #1. 4-shot burst. Crack in back of 6-inch CMU.



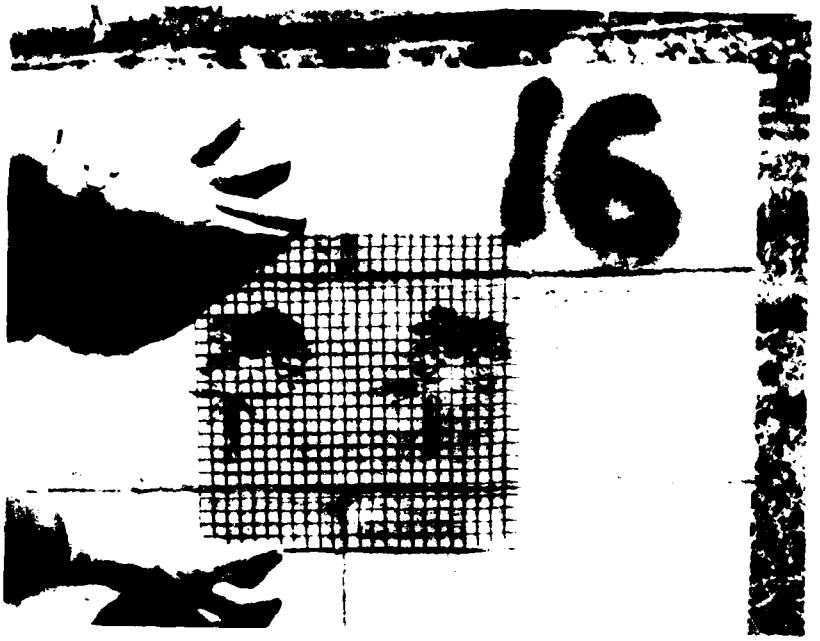
3-4

3-4. Wall #16.
12-inch CMU.
No fill.



3-11

3-11. Wall #16. Single shot. Penetrated face shell. Did not penetrate back shell. No cracks in back of wall.

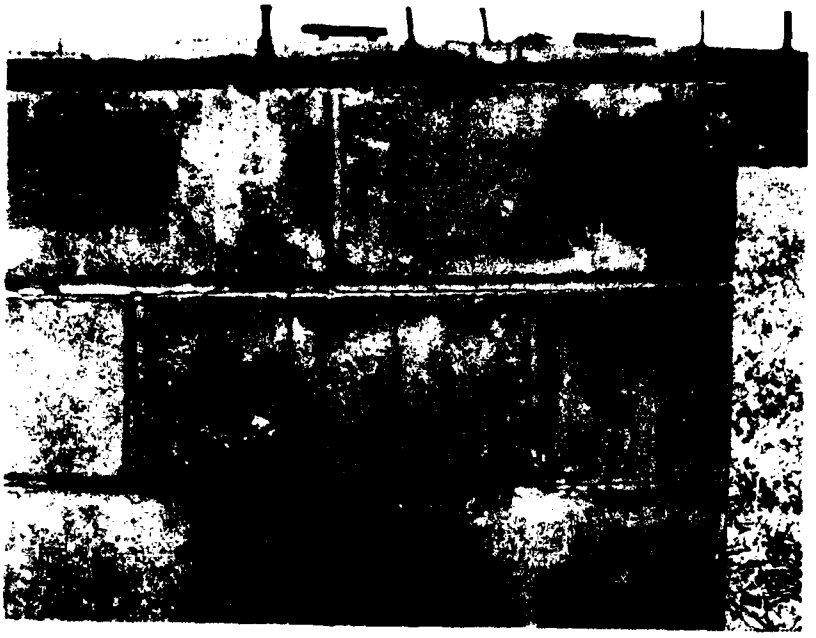


3-12. Wall #16. Single shot approximately 8 inches from first shot. Same results as previous shot.

3-12

3-14. Wall #16. 4-shot burst. Penetrated entire wall.

3-14



3-13. Wall #16. 4-shot burst. Back of wall shots hit web and still penetrated entire wall.

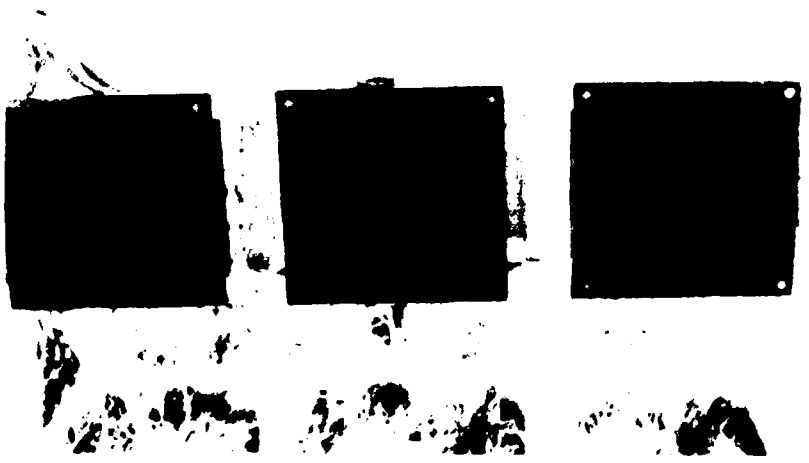
3-13

3-19. View of wall panels in place after tests are completed.

3-19

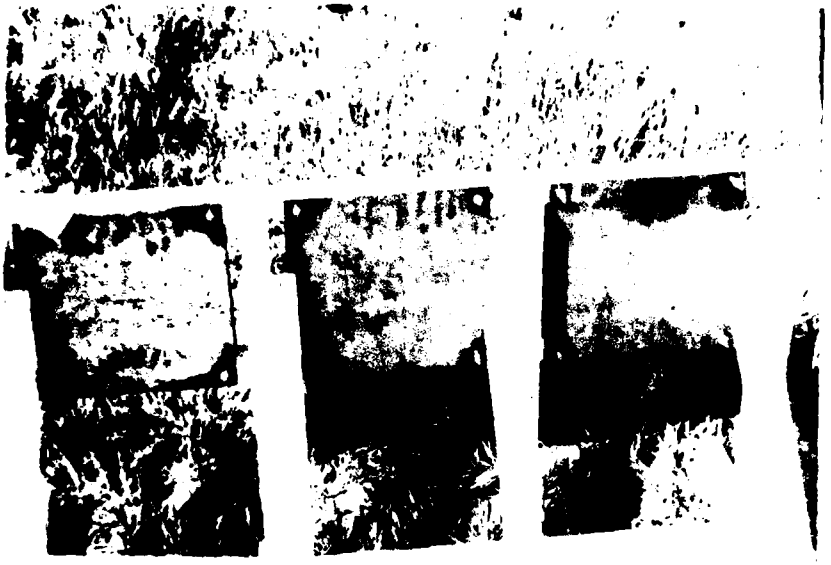
4-1

4-1. Original view of Double Plates and Supports. Construction consists of 2 identical plates separated by a 2-in. air space. Plates are ASTM A-36. Starting from left, the plates are 1/4-in., 3/8-in., and 1/2-in.



4-2

4-2. Shows double plates above with a single shot at each plate. Single shot went through the first plate and did not penetrate the second plate in all cases.



4-3

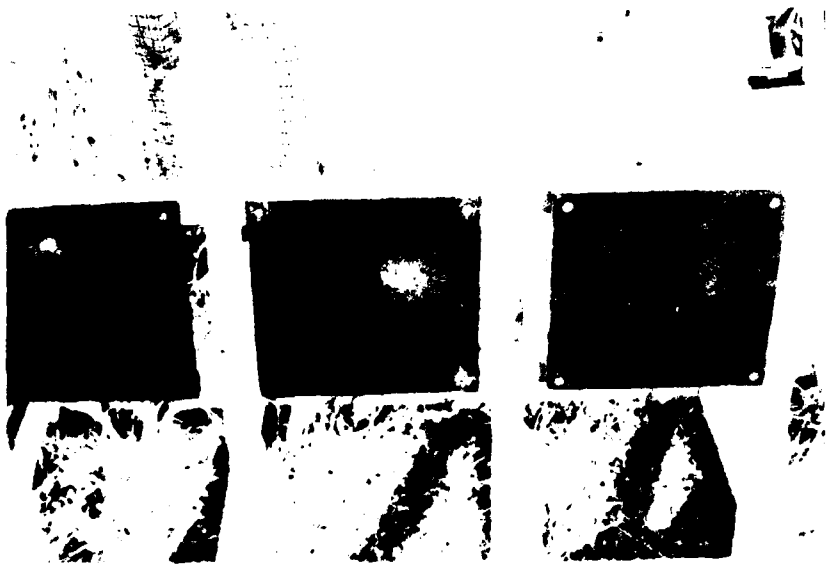
4-3. Back side of Double Plate construction after single shot at each plate. Bulge is shown in the 1/4-in. plate arrangement. A slight bulge could be felt in the 3/8-in. arrangement. There was no bulge in the 1/2-in. plate.

4-4

4-4. Second shot at the 1/4-in. double plate. Same results as first shot. Shots were approximately 2 inches apart.

4-5

4-5. Back side of double 1/4-in. plates after second shot. Same results as first shot.



5-1

5-1. View of single plates with a single shot fired at each. Left-most plate is 1/4-in. hardened steel (Astralloy) Brinell Hardness = 356. Single shot did not penetrate plate. It put a bulge in back side of plate. Center plate is 3/8-in. hardened steel (Astralloy) Brinnell Hardness = 299. It did not penetrate or put a bulge in back side. Right-most plate is 5/8-in. A-36 steel. Single shot did not penetrate, but did put a large bulge in back side of plate. Appeared to come very close to penetrating.

5-2

5-2. Three additional shots at 1/4-in. hardened steel and one additional shot at 3/8 in. hardened steel. Results were the same as the single shot in all cases. Two of the shots at the 1/4-in. were 1-3/4 in. apart. All shots at the 1/4-in. plate had small cracks in the indentation in front face.

5-3

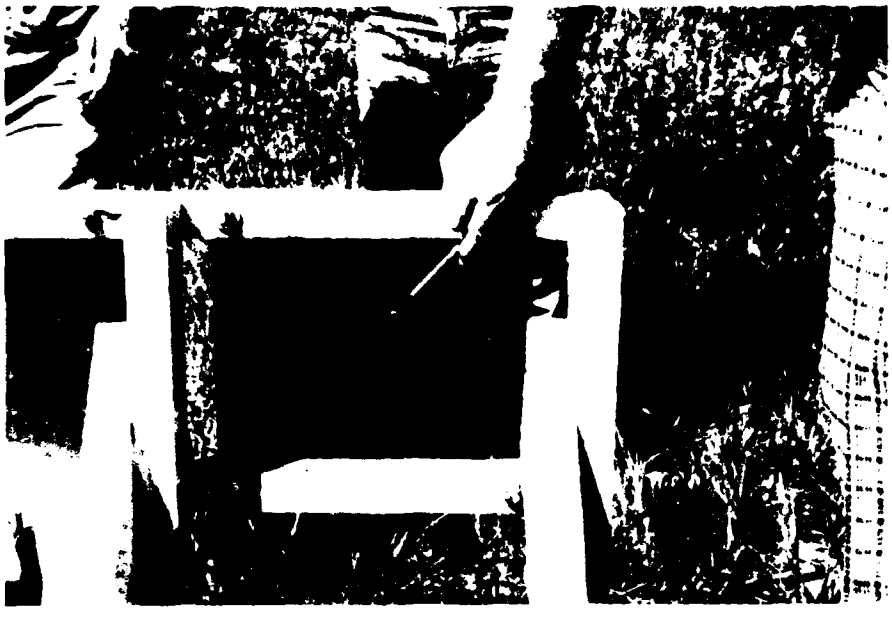
5-3. Back side of 1/4-in. hardened steel after three additional shots. Bulges can be seen for each shot except first shot. It was high and cannot be seen because of top support.

5-4

5-4. Back side of 5/8-in. thick A-36 after two shots. Shows bulge from both shots. Also shows there is no bulge in 3/8-in. hardened steel. A single shot was also made at a 3/4-in. A-36 plate. Results were same as 5/8-in. plate; however, bulge in the back side was not as great.

6-1
(colored)

6-1. (Colored). An additional shot was made at the 1/4-in. hardened plate with a 30-06 round. It did not penetrate but it did put a bulge in the back side and the bulge had a crack in it. This round was fired for information only and is not part of the criteria. The 30-06 is a 150 grain soft-point hunting load with a velocity of 3100 fps.



6-2
(colored)

6.2 (Colored). Back side of 1/4-in. hardened plate showing crack in the bulge resulting from 30-06 round.

VI. ACKNOWLEDGEMENTS.

We wish to express our sincere appreciation to the following Corps of Engineers personnel for their valuable assistance and cooperation in preparing for and conducting these tests:

Missouri River Division Laboratory: Mr. William Coy, Mr. Jerry Calta, and Mr. Gail Rosenbaugh.

Operations, Omaha District: Mr. Millard J. Crouch and Mr. Robert C. Willard.

Photographs, Omaha District: Mr. Robert B. Etzel.

Design Branch, Omaha District: Mr. James L. Ennenga, Mr. Bruce Harris, and Mr. Gaylin Bergers.

Military Branch, Omaha District: Mr. Lawrence R. Leehy.

A special expression of appreciation is made to the following:

Mr. James Ennenga, who furnished the rifle and his expertise in firing at the walls. These tests were conducted on Mr. Ennenga's last official day at work prior to retiring from the Corps of Engineers.

Mr. Bruce Harris, who coordinated the efforts for these tests.

In addition, we wish to express our appreciation to the following Air Force personnel for their participation and help while conducting these tests:

Mr. John Bilyeu, AFRCE-SAC.

Mr. Joe Garro and Captain Jerry Kranzler, HQ SAC/DEEA.

VII. APPENDIX A. APPENDIX A

DEPARTMENT OF THE ARMY
MISSOURI RIVER DIVISION, CORPS OF ENGINEERS
DIVISION LABORATORY
OMAHA, NEBRASKA 68102

MRD Lab. No. 78/30

Sheet 1 of 4

9 MAY 1978

Subject: Preparation of Panels for Tests of Bullet Resistance

Project: Air Force Construction
Intended Use: -
Source of Material: See "Materials"

Submitted by: Chief, Engineering Division, Omaha District
Date Sampled: - , Date Received: 24 February 1978
Method of Test or Specification: As indicated

References: Omaha District Letter Request dated 17 February 1978.

INTRODUCTION

1. Certain structures to be designed by the Omaha District are to have some degree of resistance to penetration by a rifle bullet. In order to find the most economical method of construction, a number of sample panels were prepared by the Laboratory to be used for test firing. In accordance with the referenced request, sixteen wall panels of various masonry configurations, two reinforced concrete panels of different strength concrete, and two hardened steel plates of different thicknesses, were assembled. The work was coordinated with Mr. Harris, Design Br., Engrg Div, Omaha District.

MATERIALS

2. Concrete Masonry Units.

a. Units were made by Ideal Concrete Products of Omaha, Nebraska. Units were normal weight concrete, whole and half block, in widths of 4, 6, 8, and 12-inches. Whole block were 2 core units for all widths.

b. Properties of the CMU, as determined in the Laboratory in accordance with ASTM-C 140, are as follows:

Unit weight, lb./cu. ft.	138.9
Water absorption, lb./cu. ft.	7.1
" " , percent	5.4
Compressive strength, psi	1930

3. Brick. Brick was obtained from Watkins Concrete Block Co., Inc.; Omaha, Nebraska and was manufactured by Cantex Industries of Grimes or Redfield, Iowa. Brick was intended to meet ASTM-C 62, Grade SW. Brick was not tested in the Laboratory.

4. Masonry Joint Reinforcement. Joint reinforcement was obtained from Ideal Concrete Products, Omaha, Nebraska and was truss design, zinc coated, No. 9 wire. Only 8-inch, 2 wire reinforcement was available, and for the cavity wall panels two sections of reinforcement were placed transversely.

5. Masonry Cement. Masonry cement from Ash Grove Cement Co. was used for both mortar and grout.

6. Portland Cement. Portland cement was Type II from Ash Grove Cement Co.; Louisville, Nebraska.

7. Sand. Sand for mortar and grout was from Holliday Sand and Gravel Co.; Edwardsville, Kansas. This is a natural sand used as a laboratory standard.

8. Steel. Steel plates were obtained from Paxton & Vierling Steel Co.; Omaha, Nebraska. Plates were approximately 10 by 12-inches, 1/4-inch and 3/8-inch thick. Plates are Warplis brand oil-hardening, non-warping, tool steel made by Teledyne Pittsburgh Tool Steel; Monaco, Pennsylvania. Analysis is as follows:

Carbon	0.95
Manganese	1.20
Silicon	0.25
Chromium	0.50
Tungsten	0.50
Vanadium	0.15

Plates were heat treated locally to produce a Brinell hardness of approximately 500.

PROCEDURE

9. Masonry Panels. Sixteen masonry panels were assembled on wood pallets. Plywood was nailed to the pallets, and the first course of brick or CMU fastened to the plywood with a cement used for panelling. Panels were 32-inches wide, 24-inches high, and of varying widths.

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a. Panel configurations are as follows:

Panel No.	Exterior Wythe	Cavity, inches	Interior Wythe	Wythe Filled With Grout
1	4-in. CMU	2	6-in. CMU	Int.
2	"	"	"	None
3	"	"	8-in. CMU	Int.
4	"	"	"	None
5	6-in. CMU	"	"	Int.
6	"	"	"	None
7	"	"	6-in. CMU	Int. & Ext.
8	"	"	"	None
9	Brick	"	"	Int.
10	"	"	"	None
11	"	"	8-in. CMU	Int.
12	"	"	"	None
13	-	-	"	Yes
14	-	-	"	No
15	-	-	12-in. CMU	Yes
16	-	-	"	No

b. Mortar was proportioned to comply with ASTM-C 270, Type S. Sand was brought to a moisture condition of 1 percent above saturated-surface dry for all tests. Proportions and properties of the mortar are as follows:

	Volume	Weight
Sand	4 1/2 parts	1321g.
Masonry cement	1 part	181g.
Portland cement	1/2 part	106g.
Water (W/C = 0.54)		155g.

Flow, percent	131
Flow after suction, percent	99
Compressive strength, 28-day moist cured, psi	2950

c. Grout for filling cells in the CMU's was proportioned to comply with ASTM-C 476, Type PM. Sand was brought to a moisture condition of 1% above saturated-surface dry for all tests. Proportions and properties of the grout are as follows:

	Volume	Weight
Sand	6 parts	1321g.
Masonry cement	1 part	136g.
Portland cement	1 part	158g.
Water (W/C = 0.54)		159g.

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Flow, percent	135
Flow after suction, percent	96
Compressive strength, 28-day, moist cured, psi	2400

10. Concrete Panels. Two concrete panels were cast and were identical except for the proportions of the concrete. Dimensions were 24-inches high, 21-inches wide, and 8-inches thick. Panels were cast in plywood forms. Reinforcing consisted of 2-No. 4 bars in each direction spaced 1-foot on centers. The panels were moist cured with burlap and plastic for 7-days after casting, then exposed to laboratory air. The panels were cemented to plywood on pallets in the same manner as the masonry panels. Concrete was proportioned to yield 3000 and 5000 psi at 28-days All materials are laboratory standard. Proportions and properties are as follows:

	3000 psi	5000 psi
Cement, Type II, lb.	100	100
Coarse agg., 1" max., lb.	504	397
Fine agg., lb.	405	282
Water, lb.	61	47
W/C	0.61	0.47
Cement content, cwt./cu. yd.	3.62	4.75
Sand, percent of agg.	45	42
Slump, inches	3 1/2	3 1/2
Air content, percent	6.9	5.7
Compressive strength, psi		
28-day moist cured	3160	4520
7-day moist, 45-day air	3290	4600

11. Steel Panels. The two steel panels were mounted on separate wood stands. Mounting holes were drilled before heat treating.

12. Pallets were loaded on two trucks furnished by the Omaha District Maintenance Base on 20 April 1978.

Submitted by:

R. K. SCHLENKER
Director, MRD Laboratory