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PSDC-TR-11

AD817129

ABOVEGROUND CONCRETE MASONRY FAMILY FALLOUT SHELTER

BY

HERBERT C. LAMB

JANUARY 1967

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JUN 14 1967
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FOR

OFFICE OF CIVIL DEFENSE

WORK ORDER PS-65-17

SUBTASK 1618 A

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PROTECTIVE STRUCTURES DEVELOPMENT CENTER

JOINT CIVIL DEFENSE SUPPORT GROUP

OFFICE OF THE CHIEF OF ENGINEERS

DEPARTMENT OF THE ARMY

WASHINGTON, D. C. 20315

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SUMMARY

PSDC-TR-11

ABOVEGROUND CONCRETE MASONRY
FAMILY FALLOUT SHELTER

February 1967

Technical Report Prepared for
The Protective Structures Development Center
Joint Civil Defense Support Group
Office of the Chief of Engineers/Naval Facilities Engineering Command
Fort Belvoir, Virginia

By

Herbert C. Lamb

Sponsored By

Office of Civil Defense
Office of the Secretary of the Army
Washington, D. C. 20310
OCD Work Order OS-63-14-8
Subtask 1618A(b)

Construction plans, details and bill of materials for a 6 person family shelter are presented. Radiation shielding with PF 100 is provided by masonry walls 1'-8" thick and a roof composed of 17 to 20 inches of gravel fill sandwiched between two concrete slabs $4\frac{1}{2}$ " and $2\frac{1}{2}$ " thick. The shelter design was developed for construction by a contractor. It is particularly suitable for locations where below-ground, including basement, structures are not feasible or an above-ground building is desired for non-shelter use. Cost of the basic structure was \$4,210. Alternate designs are discussed which will improve and/or reduce the cost of the shelter. A manual or manual-electric blower, electrical wiring, furnishings and shelter supplies are required to complete the shelter. Dual purpose uses such as general storage, tool shed, garden supply storage or workshop were considered in the design and evaluation of the shelter.

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SUMMARY

Construction plans, details and bill of materials for a 6 person family shelter are presented. Radiation shielding with PF 100 is provided by masonry walls 1'-8" thick and a roof composed of 17 to 20 inches of gravel fill sandwiched between two concrete slabs $4\frac{1}{2}$ " and $2\frac{1}{2}$ " thick. The shelter design was developed for construction by a contractor. It is particularly suitable for locations where below-ground, including basement, structures are not feasible or an above-ground building is desired for non-shelter use. Cost of the basic structure was \$4,210. Alternate designs are discussed which will improve and/or reduce the cost of the shelter. A manual or manual-electric blower, electrical wiring, furnishings and shelter supplies are required to complete the shelter. Dual purpose uses such as general storage, tool shed, garden supply storage or workshop were considered in the design and evaluation of the shelter.

FOREWORD

This report describes the design, construction and evaluation of an aboveground concrete masonry family fallout shelter. Funds were made available for this purpose by the Office of Civil Defense Work Order No. OCD-OS-63-148, dated 24 May 1963 (as amended). The shelter was built in 1964 at the Protective Structures Development Center, Fort Belvoir, Virginia.

Michael M. Dembo
Chief, Protective Structures Development Center

Herbert C. Lamb
Project Engineer

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SECTION 1: INTRODUCTION

Subject and Purpose

1.1 The purpose of this task was to develop, test and evaluate a prototype design for an aboveground, outside type concrete masonry family fallout shelter. The shelter was constructed to obtain detailed cost data, observe construction techniques and provide a test structure for observation, evaluation and for other developmental programs at the Center. This report concerns the design, construction and evaluation of such a prototype shelter, having a capacity of 6 persons, at the Protective Structures Development Center (PSDC), Fort Belvoir, Virginia.

Background

1.2 The shelter which is the subject of this report was designed by the PSDC, adapted from an original concept by the Office of Civil Defense. The contract (No. DA-49-129-ENG-538) for the construction of the shelter and preparation of construction cost data was awarded on 27 September 1964. The structure was completed in December 1964.

SECTION 2: DESIGN

General

2.1 An aboveground, outside type concrete masonry family fallout shelter was designed to accommodate 6 people. The shelter is 14'-8" long and 11'-4" wide outside with a usable shelter space 8'-0" x 7'-8" inside. Additional space is provided in the entranceway which can be utilized for storage of supplies and "non-shelter" uses. Exterior walls are concrete masonry 1'-8" thick composed of inner and outer wythes of 8" concrete blocks having voids filled with grout. Concrete was placed in the wall cavity. The floor is a concrete slab on grade. Overhead shielding is provided by 17 to 20 inch gravel fill sandwiched between two concrete slabs. The lower (i.e. ceiling) slab is 4½" thick reinforced concrete designed to support the weight of the 17 to 20 inch thick gravel layer and the 2½ inch cover slab above plus nominal roof live load.

Structural

2.2 Structural design was in accordance with the ACI building code 318-63. A live load of 20 pounds per square foot was used for the roof design. Concrete having a minimum compressive strength of 3000 psi at 28 days was specified for all work except grout for walls. All reinforcing bars were intermediate grade ASTM A15-62T steel. Drawings are included as Appendix A.

Radiation Shielding

2.3 The shelter was designed for radiation shielding to provide a protection factor of 100. The radiation shielding analysis is included as Appendix C.

SECTION 3: CONSTRUCTION

Construction Sequence

3.1 Construction of the concrete masonry family fallout shelter is illustrated in Figures 3.1 through 3.24. The construction sequence is shown beginning with layout of the structure at the site through final concrete finishing. The completed shelter is shown in Figure 3.24.

Construction Costs

3.2 Total contract cost of the structure was \$4,210. A detailed cost breakdown is included in Table 3.1. Costs shown in the table reflects contractor's profit and overhead of items in place.

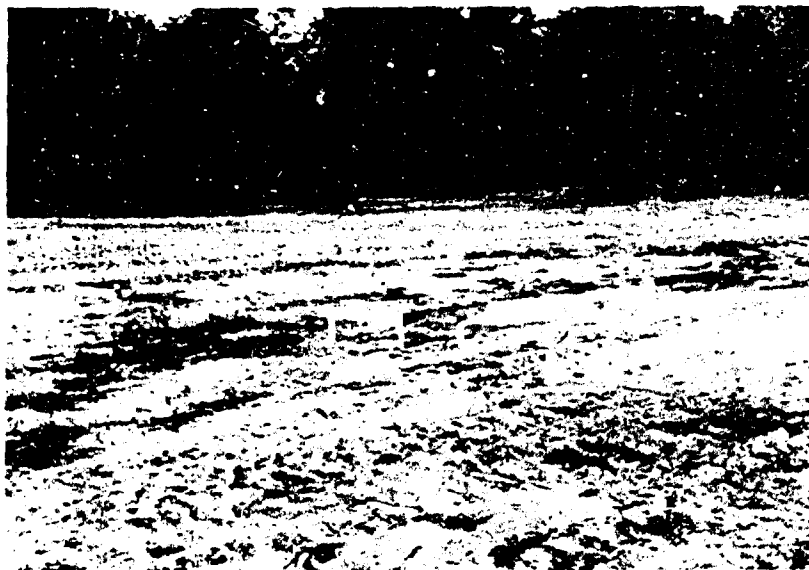


Figure 3.1 Placement of batter boards completed layout of the shelter. No site clearing was required.



Figure 3.2 Excavation for footings was done entirely by hand using picks and shovels.



Figure 3.3 Grades for the top of footings were marked with nails driven into the side of the excavation. No forms were required for footings.



Figure 3.4 Transit mixed concrete was placed using a hand tamper.



Figure 3.5 Concrete was covered with polyethylene sheeting during the curing period.



Figure 3.6 Construction site showing materials and equipment used in the masonry work.



Figure 3.7 Ventilation pipes were installed in the wall cavity. Tooled joints were used on all exposed masonry walls.



Figure 3.8 Alternate courses of 4" high solid blocks and 8" hollow core blocks were used in the outer wythe. Hollow blocks in the outer wythe were filled with mortar as each course was laid.

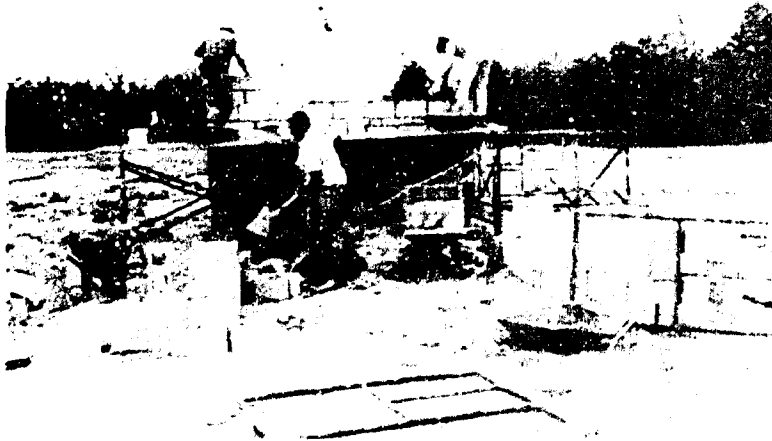


Figure 3.9 Steel scaffolding used in later phase of construction.



Figure 3.10 Joint reinforcement provides ties between the two wythes of the walls.

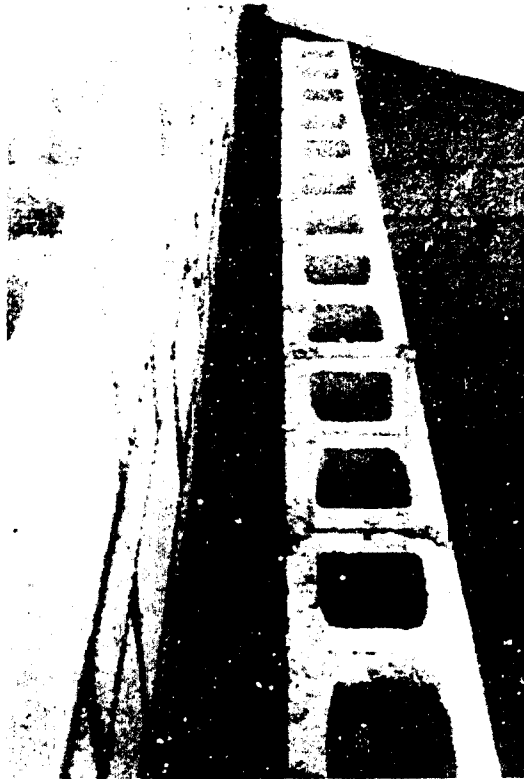


Figure 3.11 Completed wall ready for placement of bond beam reinforcement.



Figure 3.12 Premculded joint filler installed prior to placement of drainage fill and floor slab.

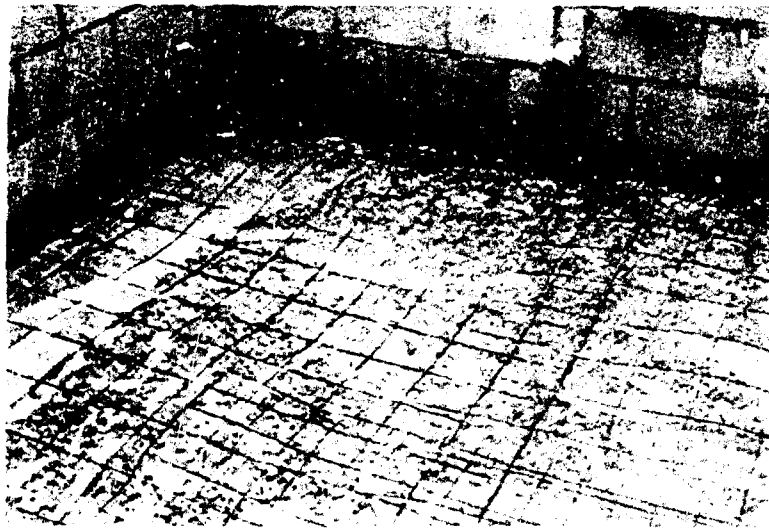


Figure 3.13 Polyethylene vapor barrier in place over gravel drainage fill. Floor slab was reinforced with welded wire mesh.



Figure 3.14 Tamping wall grout into cavity between inner and outer wythes. Block cavities had previously been filled with mortar.

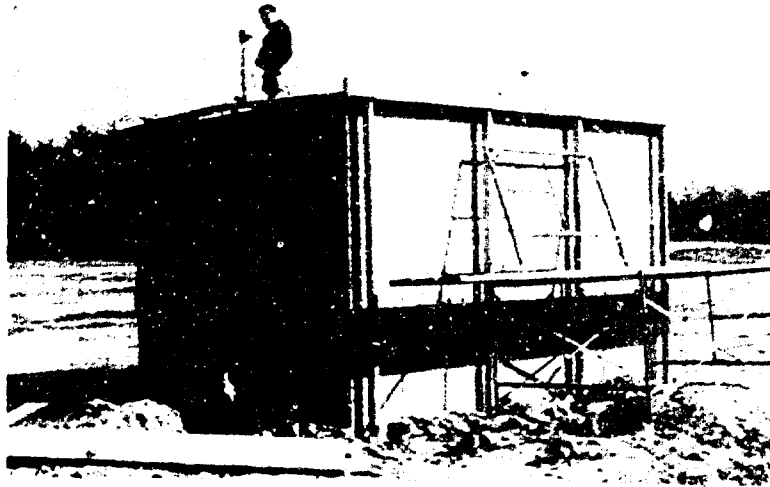


Figure 3.15 Shoring was provided for the roof slab forms.



Figure 3.16 The $4\frac{1}{2}$ " thick roof (i.e. ceiling) slab ready for placement of gravel fill.



Figure 3.17 Clearing gravel from roof overhang forms. Gravel fill has been compacted and screeded to proper contour.

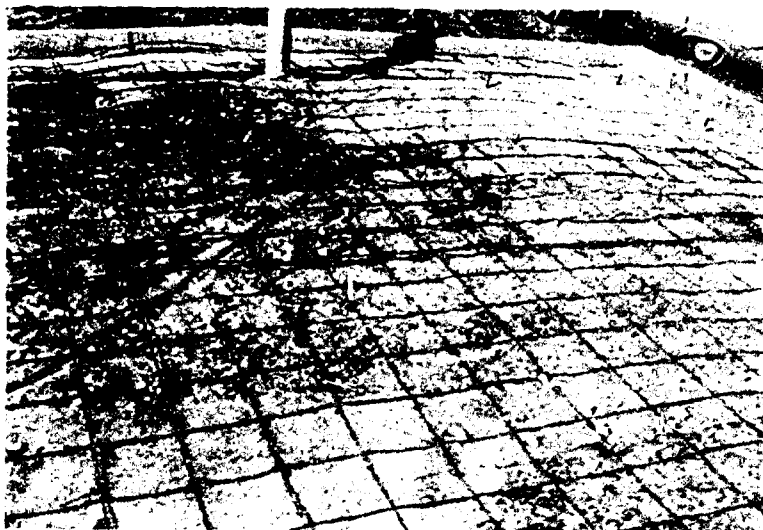


Figure 3.18 Vapor barrier and welded wire reinforcing mesh for 2 $\frac{1}{2}$ " thick roof slab.



Figure 3.19 A trowled finish completes the roof slab.

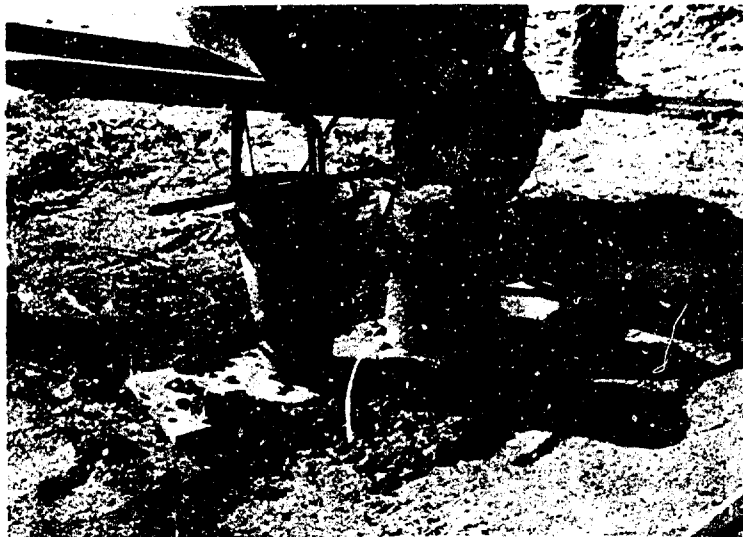


Figure 3.20 Concrete slump was determined using standard cone and tamping rod.



Figure 3.21 Air content of concrete for the $2\frac{1}{2}$ " roof slab was measured using the pressure method in accordance with ASTM Designation: C 231-62.



Figure 3.22 A carpenter installing wood door and frame in shelter entrance.



Figure 3.23 Concrete finisher applies final touches to shelter exterior.



Figure 3.24 View of completed family shelter.

Table 3.1

ESTIMATED CONSTRUCTION COST AND QUANTITY BREAKDOWN

Item No.	Description	Unit	Amount	Unit Cost \$	Cost \$
1.	Excavation & Backfill	C.Y.	50.00	5.00	250.00
2.	Grading	L.S.	-	-	182.00
3.	Drainage Fill	C.Y.	2.00	10.00	20.00
4.	Concrete, Footings	C.Y.	3.00	30.00	90.00
5.	Concrete, Floor	C.Y.	2.00	60.00	120.00
6.	Concrete, 4½" Roof Slab	C.Y.	2.00	80.00	160.00
7.	Air Entrained Concrete, 2½" Roof Slab	C.Y.	2.00	80.00	160.00
8.	Gravel Fill, Roof	C.Y.	8.00	10.00	80.00
9.	Formwork, Roof	S.F.	144.00	2.00	288.00
10.	Reinforcement, Bars	Lb.	200.00	.30	60.00
11.	Reinforcement, Mesh	S.Y.	35.00	1.00	35.00
12.	Reinforcement, Joint	L.F.	450.00	.20	90.00
13.	CMU 8 inch Interior	S.F.	360.00	1.20	432.00
14.	CMU 8 inch Exterior	S.F.	700.00	1.20	910.00
15.	CMU 12 inch Interior	S.F.	32.00	2.00	64.00
16.	Grout, Wall Cavity	C.Y.	6.00	70.00	420.00
17.	Vapor Barrier	S.F.	150.00	.08	12.00
18.	Door	Ea.			100.00
19.	Painting & Caulking	L.S.			150.00
20.	Air Intake & Exhaust Pipes	L.S.			80.00
21.	Air Intake & Exhaust Hoods	L.S.			80.00
22.	Miscellaneous	Lot			<u>427.00</u>
				Total Contract Cost	<u><u>4,210.00</u></u>

SECTION 4: EVALUATION

General

4.1 This shelter design is suitable for locations where below-ground structures are not feasible or an aboveground building is desired for non-shelter uses. Cost of the prototype structure was \$700 per shelter space; however, a long building life at very low maintenance cost can be expected. Considerable savings could be realized if the shelter was built by a homeowner having the necessary skills. Construction of the roof system requires skilled workmen and/or qualified supervision. Some savings can be expected by using all 8" high blocks in a running bond in lieu of the coursed ashlar outer wythe.

Alternate Design

4.2 An alternate design incorporating a solid concrete roof slab in lieu of the system having gravel fill was evaluated. Based upon experience obtained from construction of the shelter it is estimated that a shelter having the solid concrete roof can be built at a lower cost. The estimated net saving of \$80 is due primarily to the following:

- a. Labor costs are reduced since the amount of concrete finishing required for the roof is reduced by nearly one-half and all concrete for the roof can be placed in one day. The existing roof system requires that the $4\frac{1}{2}$ " ceiling slab be placed and allowed to attain sufficient strength before placement of the gravel fill.
- b. Cost of the crane rental is reduced by one-half by placing all roof material in one day.
- c. The height of the exterior CMU wall is reduced by 4" since a 20" solid concrete roof has approximately the same mass thickness as the existing roof.
- d. Weep holes are not required for the alternate design. The alternate design, in addition to being lower in cost, has greater strength and will be more attractive because of the lower silhouette and elimination of weep holes.

Shelter Use

4.3 Additional items required to complete the shelter include a hand cranked blower, electrical wiring, furnishings and shelter supplies. Minimum electrical fixtures should include a wall mounted outlet for lamp holder with pull switch and a duplex convenience outlet. Furnishings can be adapted to suit individual requirements. An arrangement for occupancy based on using four bunks tiered two high and two chairs is shown in Figure 4.1. Supplies should include a minimum of $3\frac{1}{2}$ gallons of water per person, food, sanitation items, flash light, first aid kit, blankets and other items which may be selected for the comfort and well being of the occupants. A blower connected to the air intake pipe will be used to ventilate the shelter. Fresh air may also be allowed to enter through the doorway, if necessary.

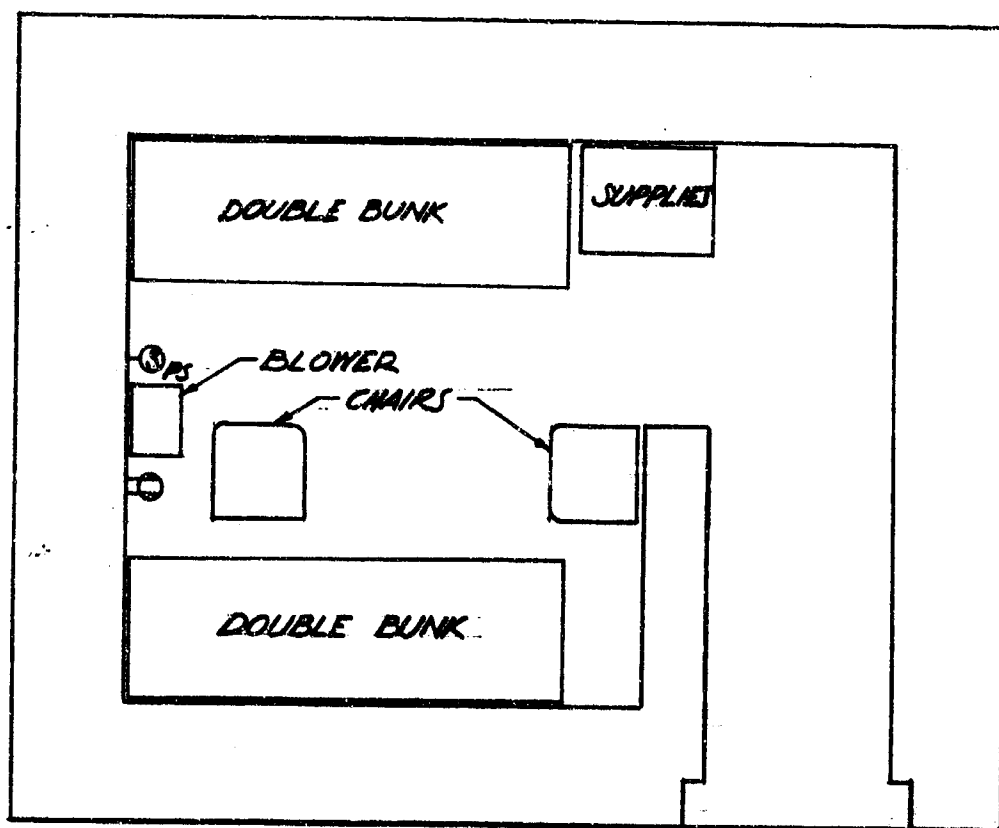
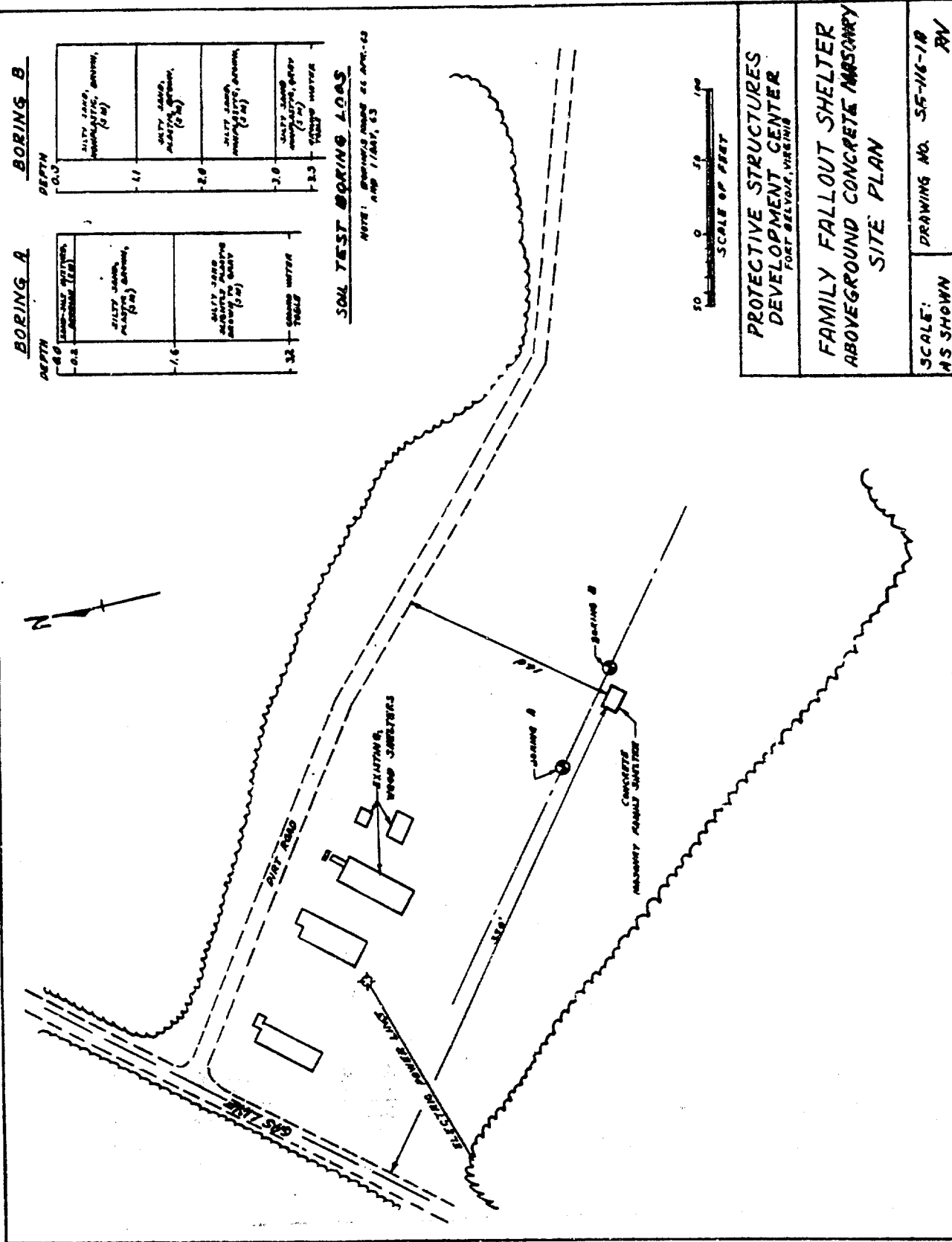


Figure 4.1 Floor plan showing a general arrangement for occupancy.

Dual Purpose Use

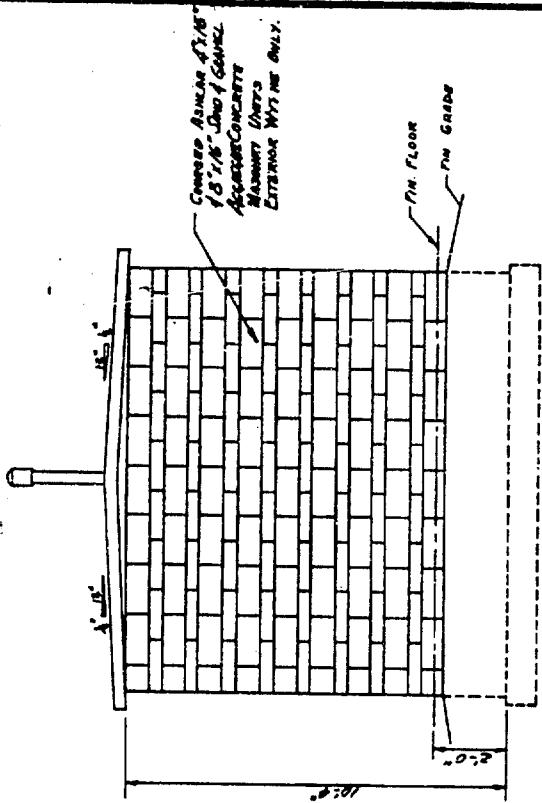
4.4 This family shelter was designed for dual purpose uses. The entranceway was made sufficiently wide (2'-8") to allow large objects to be moved in and out. Examples of normal purpose use include general storage, tool shed, garden supply storage and workshop. Storage should be limited to items which can be quickly removed in an emergency or which may be useful during shelter occupancy. Items such as tools and lawn chairs could supplement the shelter equipment.



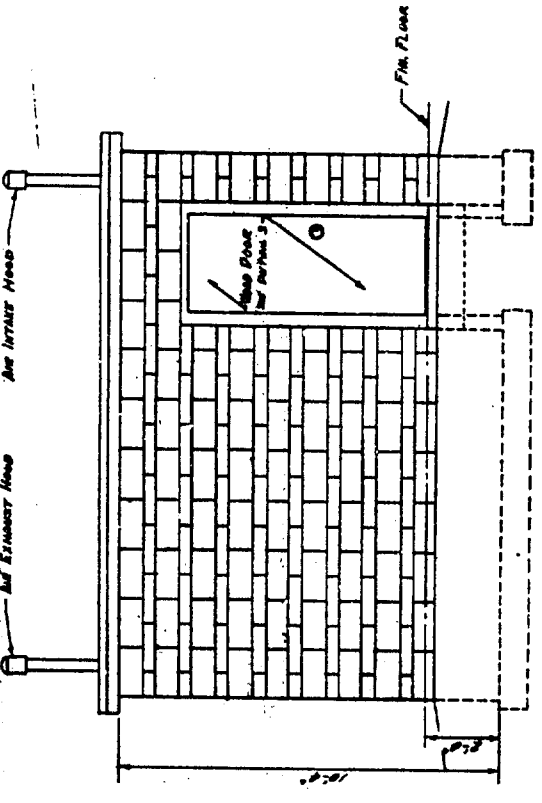
PROTECTIVE STRUCTURES
 DEVELOPMENT CENTER
 FORT BELVOIR, VIRGINIA

FAMILY FALLOUT SHELTER
 ABOVEGROUND CONCRETE MASONRY
 SITE PLAN

SCALE: AS SHOWN
 DRAWING NO. SF-116-1B
 RV

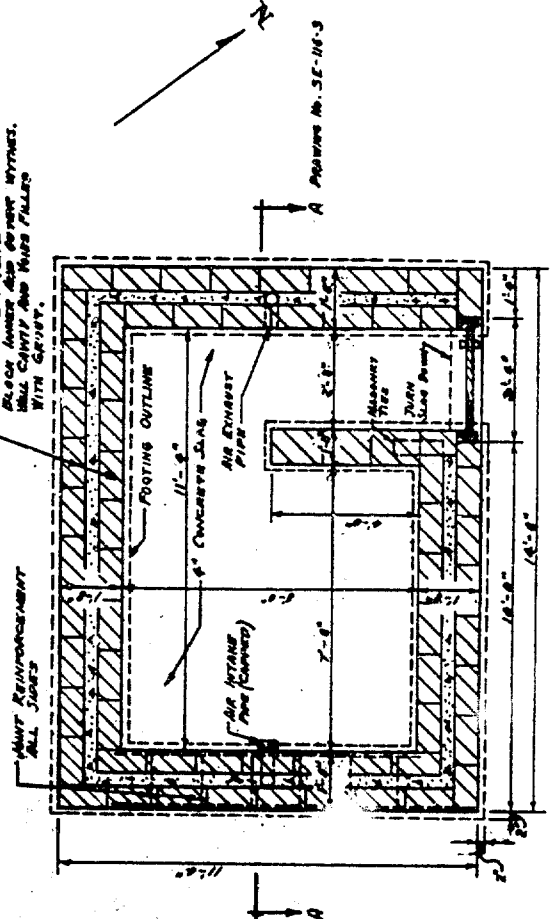


EAST ELEVATION



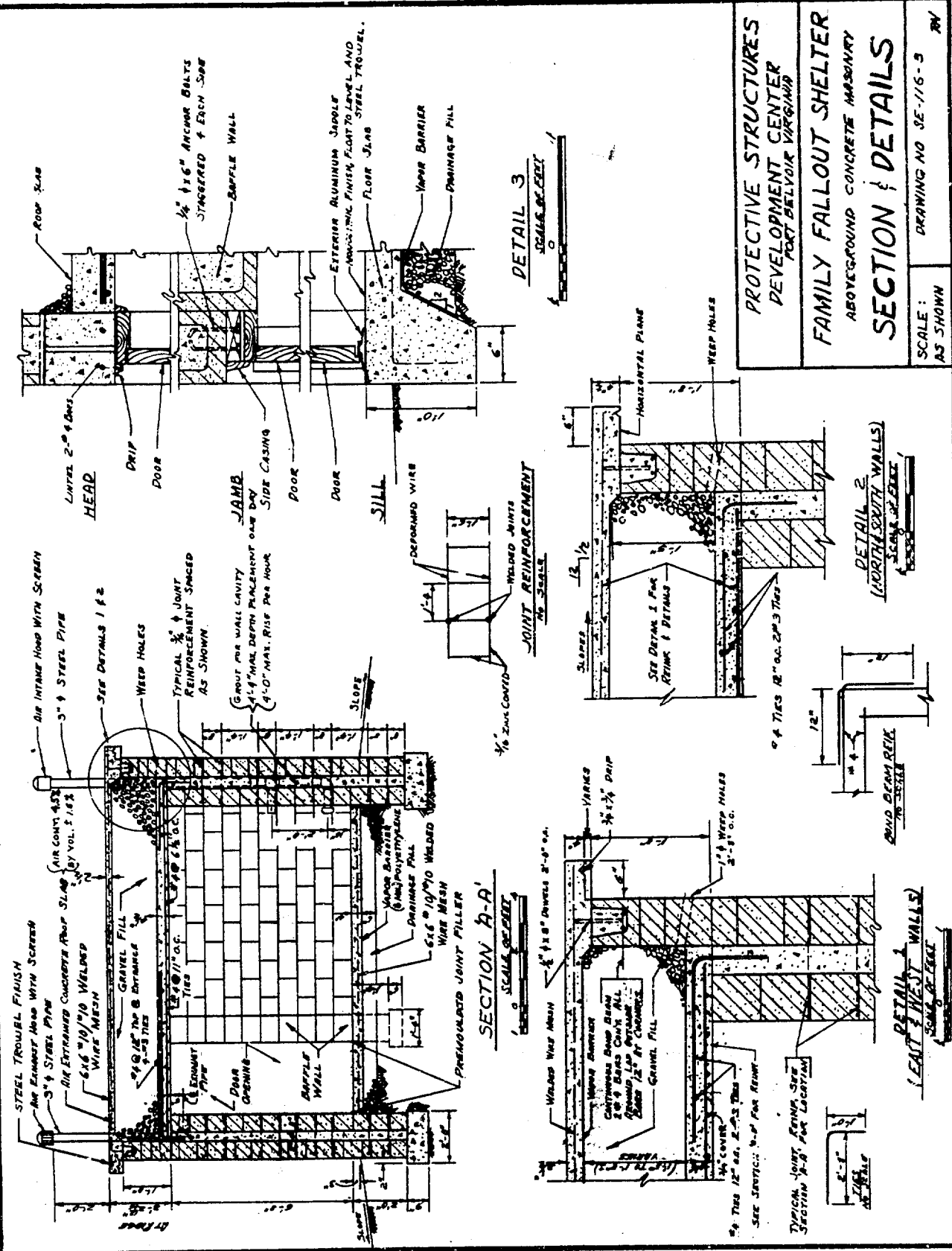
NORTH ELEVATION

8" HOLLOW CONCRETE BLOCK INNER AND EXTERIOR WYTHES. WALL CAVITY AND WEBS FILLED WITH GROUT.



PLAN

PROTECTIVE STRUCTURES DEVELOPMENT CENTER FORT BELVOIR, VIRGINIA	
FAMILY FALLOUT SHELTER ABOVEGROUND CONCRETE MASONRY	
SCALE: AS SHOWN	DRAWING NO. SE-106-2
20	



PROTECTIVE STRUCTURES
 DEVELOPMENT CENTER
 FORT BELVOIR VIRGINIA

FAMILY FALLOUT SHELTER
 ABOVEGROUND CONCRETE MASONRY

SECTION & DETAILS

SCALE: AS SHOWN

DRAWING NO SE-116-3

RV

APPENDIX B

SPECIFICATIONS

Construction of the shelter described in this report will, in most instances, require the services of a professional builder such as a concrete or masonry work contractor.

Sample specifications indicating basis of design rather than complete building specifications are provided. Since the specifications and drawings together define what it is that the owner wants and what the contractor is to provide, they must be complete and unambiguous. It is recommended that the prospective shelter owner retain the services of an architect or engineer to prepare a complete set of specifications.

The following specifications adapted from Supplement to Blueprint for Survival No. 6 (1964) published by the Emergency Measures Organization, Ottawa, Canada, are suitable for contract use. It is recommended that a qualified architect provide appropriate General Conditions to accompany the technical specifications. The General Conditions would, for the type of construction contemplated, define responsibility for protection of existing structures, utilities, vegetation, cleaning up, method of payment, bonds and in general set the legal ground rules for the work.

General Conditions

The General Conditions are to be read with and form part of these specifications.

Excavation and Backfilling

Scope of Work

The work shall include clearing of the site, setting out the work, all excavation, backfilling and grading as shown on the drawings and hereinafter specified.

Setting Out of Work

The Contractor shall accurately set out the structure in the location shown on the site plan and shall establish all lines and levels. The Contractor shall supply all labor and material incidental for the erection of substantial batter boards and lines.

Excavation

The Contractor shall excavate for the structure to the depths as indicated on the drawings.

The Contractor must examine the site and determine the nature and extent of the materials that it will be necessary to remove to reach the depths shown on or required by the drawings.

If blasting is required it shall be done by a competent and fully experienced person and all precautions shall be taken to prevent damage to property or injury to life. The Contractor will be held solely responsible for accidents or injury to life and property.

If it should prove necessary during the prosecution of the work to interrupt or obstruct the natural surface drainage or the flow of drains, the Contractor shall provide for same during the progress of the work in such a way that no damage shall result to either the Owner's property or adjacent property. The bottom of the excavation shall be level and free from all surplus material.

Water in Excavation

The Contractor shall provide and operate any pumping equipment necessary to keep the excavation free from water. Water pumped from the excavation shall be piped away from the excavation in such a manner as to cause no damage to the Owner's or adjoining properties.

Shoring and Bracing and Underpinning

When necessary the Contractor shall provide suitable and sufficient shoring and bracing to prevent the sides of the excavation from falling, slipping or caving in.

Backfilling and Grading

Backfill material may be unfrozen excavated, material providing it does not contain rock or boulders or a high clay content. Otherwise all backfilling shall be done using unfrozen sand fill.

The top 4 inches to bring the fill up to grade shall be topsoiled (if owner desires).

Upon completion of backfilling the site around the structure shall be graded and all surplus material removed from the site.

Concrete Work

Scope of Work

The work shall include the furnishing of all labor, materials, equipment and operations required in the forming, handling, placement, finishing and protection of all concrete as shown on the drawings and specified herein.

The American Concrete Institute Standard ACI 318-63, Building Code Requirements for Reinforced Concrete, shall govern all concrete work except where otherwise specified herein.

Wherever in these specifications methods of tests or standards are referred to the latest American Society for Testing Materials standards shall be used.

Unless otherwise noted, all material used in concrete work shall conform to the current Standard Specifications of the American Society for Testing Materials covering respective materials suitable for the work.

Concrete for all concrete work, except grout for walls, shall have a minimum compressive strength of 3000 psi in 28 days. Maximum aggregate size shall be 3/4 inch. Slump for vibrated concrete shall be 2 to 3 inches.

Concrete for filling wall cavity and vertical cells of wall masonry units shall have a minimum compressive strength of 2500 psi in 28 days. Maximum aggregate size shall be 1/2 inch. Slump for concrete for wall construction shall be 3 to 4 inches if vibrated and 3 to 5 inches if non-vibrated.

Aggregate for all concrete shall be heavy weight.

Forms shall be of sound lumber or steel panels and securely assembled to prevent displacement.

Reinforcement shall be intermediate grade billet steel deformed bars, minimum yield strength 40,000 psi.

Bending, splicing and placing of reinforcement shall conform to American Concrete Institute Standard ACI 318-63.

Concrete shall be placed only when the temperature is at least 35°F and rising.

Grout shall not be placed to a depth exceeding 4'-4" in anyone day or at a rate exceeding a rise of $4\frac{1}{2}$ " per hour in the masonry wall cavity between the inner and outer wythes.

Concrete surfaces not covered by forms shall be protected against moisture loss for not less than 7 days.

Leave all forms in place until safe to remove them. The Contractor shall assume all responsibility in this connection.

Provide and install dowels, ventilation piping, anchor bolts, and metal ties as indicated on the drawings.

Masonry

Load-bearing concrete masonry units shall conform to requirements of the American Society for Testing Materials Standard ASTM C-90 for grade U-I for normal weight aggregate.

Mortar for all masonry shall comply with the property specifications for type N mortar, ASTM Standard C-270.

Reinforcing steel bars and rods shall be as specified in Concrete Work.

Masonry shall not be erected when the ambient temperature is below 35 degrees F. No frozen work shall be built upon. No brick or other unit having a film of water or frost on its surface shall be laid in the walls. Masonry shall be protected from freezing for 48 hours after being laid. Masonry erected during arid weather when the ambient air has a temperature of more than 99 degrees F. in the shade and a relative humidity of less than 50 percent shall be protected from direct exposure to wind and sun for 48 hours after installation. Masonry shall be laid plumb and true to line. Bond pattern corners and reveals shall be kept plumb and true throughout. Spaces around built-in items shall be solidly filled with mortar. Anchors, wall plugs, accessories, and other items required to be built in with masonry shall be built in as the masonry work progresses. Cutting and fitting of masonry required to accommodate the work of others shall be done by masonry mechanics. Units in exposed-to-view walls shall be free from chipped edges or other imperfections detracting from the appearance of the finished work.

Joints in exposed-to-view walls shall be tooled slightly concave.

Unfinished work shall be stepped back for joining with new work. All loose mortar shall be removed and the exposed joint shall be thoroughly cleaned before laying new work. Surfaces of masonry not being worked on shall be properly protected at all times during construction operations. When rain or snow is imminent and the work is discontinued, the tops of exposed masonry walls shall be covered with a strong waterproof membrane well secured in place. Adequate provisions shall be made during construction to prevent damage by wind.

Mortar that has stiffened because of chemical reaction due to hydration shall not be used. Mortar shall be used and placed in final position within 2-1/2 hours after mixing where air temperature is 80 degrees F. or higher, and within 3-1/2 hours after mixing when air temperature is less than 80 degrees F. Mortar not used within these time intervals shall be discarded. In mixing mortar, the maximum amount of water shall be used as necessary to produce the wettest workable consistency possible.

Concrete masonry units: Concrete masonry units shall not be wetted before laying. Mortar joints shall be approximately 3/8-inch wide. Mortar joints in starting courses on footings shall be full bedded under both face shells and webs. Other joints shall have full mortar coverage on horizontal- and vertical-face shells, but mortar shall not extend through the unit on the web edges. Each course shall be bonded at corners. Jamb units shall be of the shapes and sizes required to bond with wall units. No cells shall be left open in face surfaces. Sections of concrete brick work shall be incorporated in the masonry work where necessary to fill out at corners, and elsewhere as required.

Masonry unit grout filled cavity-wall: The space to be grout filled between the inner and outer wythes shall be kept clear and clean of mortar droppings.

Vertical cells shall have vertical alignment sufficient to maintain a clear, unobstructed, continuous vertical cell measuring not less than 2 by 3 inches.

Grout: All vertical cells and spaces between the inner and outer wythes shall be solid filled as specified under SECTION: CONCRETE.

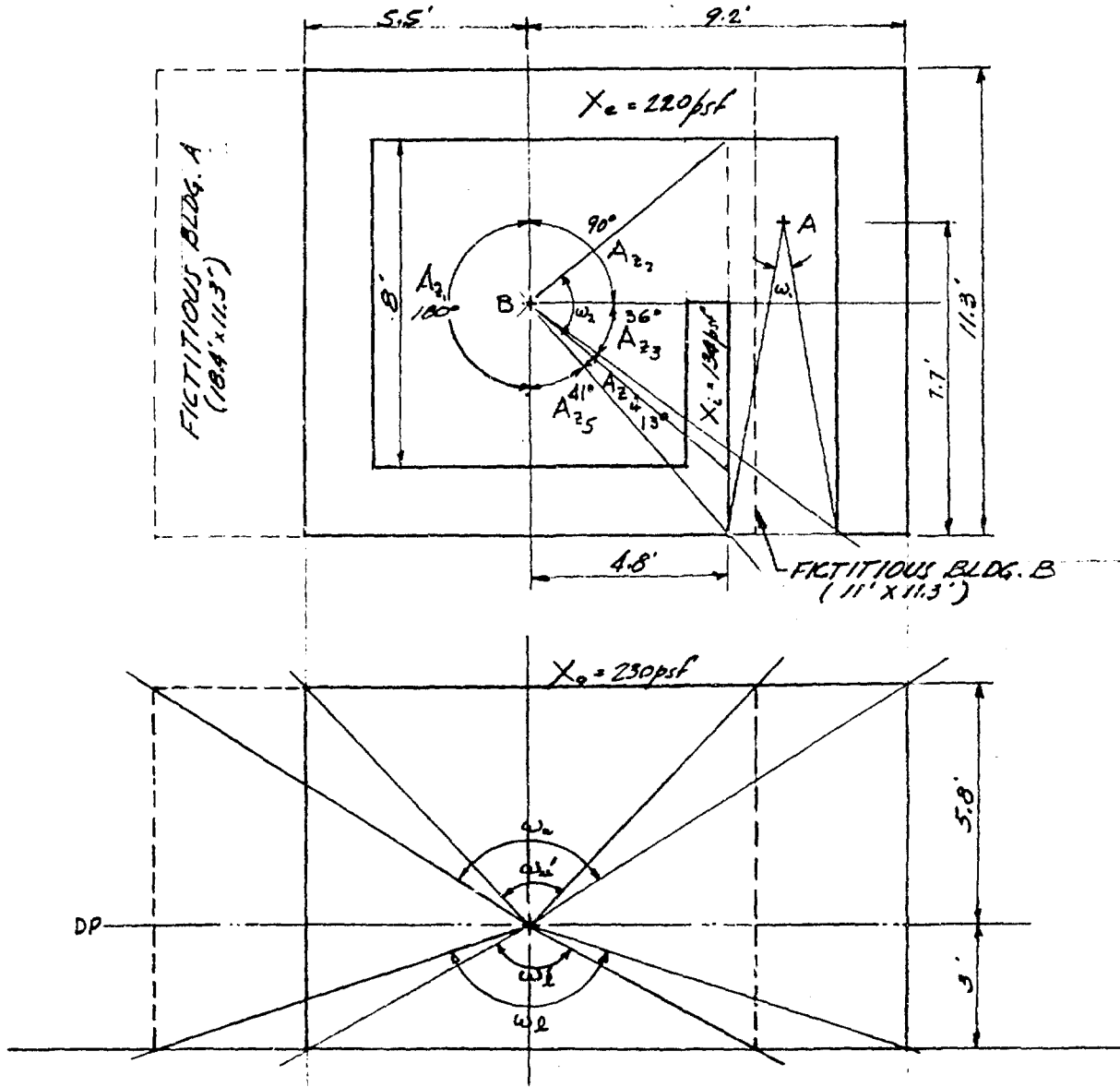
Before completion of the work, all defects in joints of exposed exterior masonry surfaces shall be raked out as necessary, filled with mortar, and retooled. All masonry surfaces shall be left clean, free of mortar daubs, and with tight mortar joints throughout.

APPENDIX C

BY *H. Lamb* DATE *11 Dec 64*
 CHKD. BY DATE

SUBJECT *Aboveground Concrete
 Masonry Family Shelter
 (Shielding Analysis)*

SHEET NO. *1* OF *3*
 JOB NO.



X_0 : Air entrained concrete $11.5 \times 2.5 = 28$
 Gravel $8 \times 10.5 = 148$
 Concrete $12 \times 4.5 = 54$
 230 psf

APPENDIX C

BY H. Lamb DATE 11 Dec 64 SUBJECT Aboveground Concrete Masonry Family Shelter (Shielding Analysis) SHEET NO. 2 OF 3
 CHKD. BY _____ DATE _____ JOB NO. _____

(Continued)

X_e : 8" CMU filled with mortar
 Concrete Grout
 $S_N(X_e) = .87$ $B_c(220) = .0072$ $81.5 \times 2 = 163$
 $12 \times 4.75 = 57$
 220 psl

X_i : 12" CMU filled with grout $\approx 134 \text{ psl}$
 $S_N(134) = .78$ $B_c(134) = .045$, $B_i(134) = .045$

	W	L	Z	$e = \frac{W}{L}$	$n = \frac{2Z}{L}$	w	G_d	G_a	G_s	E
w_u	11.3	18.4	5.8	.614	.63	.40	-	.008	.405	1.37
w_{in}	11	11.3	5.8	.975	1.03	.33	-	.091	.425	1.42
w_L	11.3	18.4	3	.614	.326	.65	.67	-	.315	1.37
w_i	11	11.3	3	.975	.53	.58	.72	-	.345	1.42
w_1	2.7	6.7	7.7	.403	2.30	.028	-	-	-	-
w_2	6.7	8	4.8	.837	1.20	.24	-	-	-	-

Roof contribution: Neglect interior partition.

$$C_o = C_o(w_{in}, X_o) + \frac{C_o(w_u, X_o) - C_o(w_{in}, X_o)}{2}$$

$$C_o = .00078 + \frac{.00081 - .00078}{2} = .00078 + .000015$$

$$C_o = .000795 \text{ say } \underline{C_o = .0008}$$

Ground contribution:

$$G_g = [G_s(w_1) + G_s(w_2)] S_N(X_e) E(e) + [G_d(w_1, H) + G_a(w_2)] [1 - S_N(X_e)]$$

$$G_g = \sum G_g B_c(X_e, H) B_i(X_i, 3) A_i$$

APPENDIX C

BY H. Lamb DATE 11 Dec 44 SUBJECT Aboveground Concrete Masonry Family Shelter (Shielding Analysis) SHEET NO. 3 OF 3
 CHKD. BY _____ DATE _____ JOB NO. _____

(Ground contribution continued)

Wall (1): Fict. Bldg B

$$G_{g1} = [345 + 425] \cdot 87 \times 1.42 + [.72 + .091][1 - .87]$$

$$G_{g1} = .770 \times .87 \times 1.42 + .811 \times .13 = .951 + .105 = 1.056$$

$$C_{g1} = 1.056 \times .0072 \times \frac{180}{360} = .0038$$

Wall (2 & 5): Fict. Bldg. A

$$G_{g2,5} = [.315 + .405] \cdot 87 \times 1.37 + [.67 + .088][1 - .87]$$

$$G_{g2,5} = .720 \times .87 \times 1.37 + .758 \times .13 = .859 + .0985 = .9575$$

$$C_{g2,5} = .9575 \times .0072 \times \frac{90 + 41}{360} = .00251 \quad \text{Say: } .0025$$

Wall (3): Fict. Bldg. A

$$G_{g3} = .9575$$

$$C_{g3} = .9575 \times .0072 \times .045 \times \frac{36}{360} = .000031 \quad \text{Say: } .00003$$

Wall (4): Fict. Bldg. A

$$G_{g4} = [.315 + .405] \cdot 78 \times 1.37 + [.67 + .088][1 - .78]$$

$$G_{g4} = .720 \times .78 \times 1.37 + .758 \times .22 = .77 + .167$$

$$C_{g4} = .937 \times .045 \times \frac{12}{360} = .00152 \quad \text{Say: } .0015$$

$$C_{g \text{ TOTAL}} = .0038 + .0025 + .00003 + .0015 = .00783 \quad \text{Say: } .0078$$

Entrance contribution:

$$R_{fA} = A_r(w_1) = .06$$

$$R_{fB} = R_{fA} \times \frac{0.2 \times w_2}{2} = .06 \times \frac{.2 \times .24}{2} = .00144$$

$$R_f = C_0 + C_{g \text{ TOTAL}} + R_{fB} = .0008 + .0078 + .0014 = .0100$$

Protection Factor: $R_f = 100$