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FUNCTIONAL REQUIREMENTS AND NEW CONCEPTS FOR AMMUNITION STORAGE--ETC(U)
MAR 81 P A HOWDYSHELL
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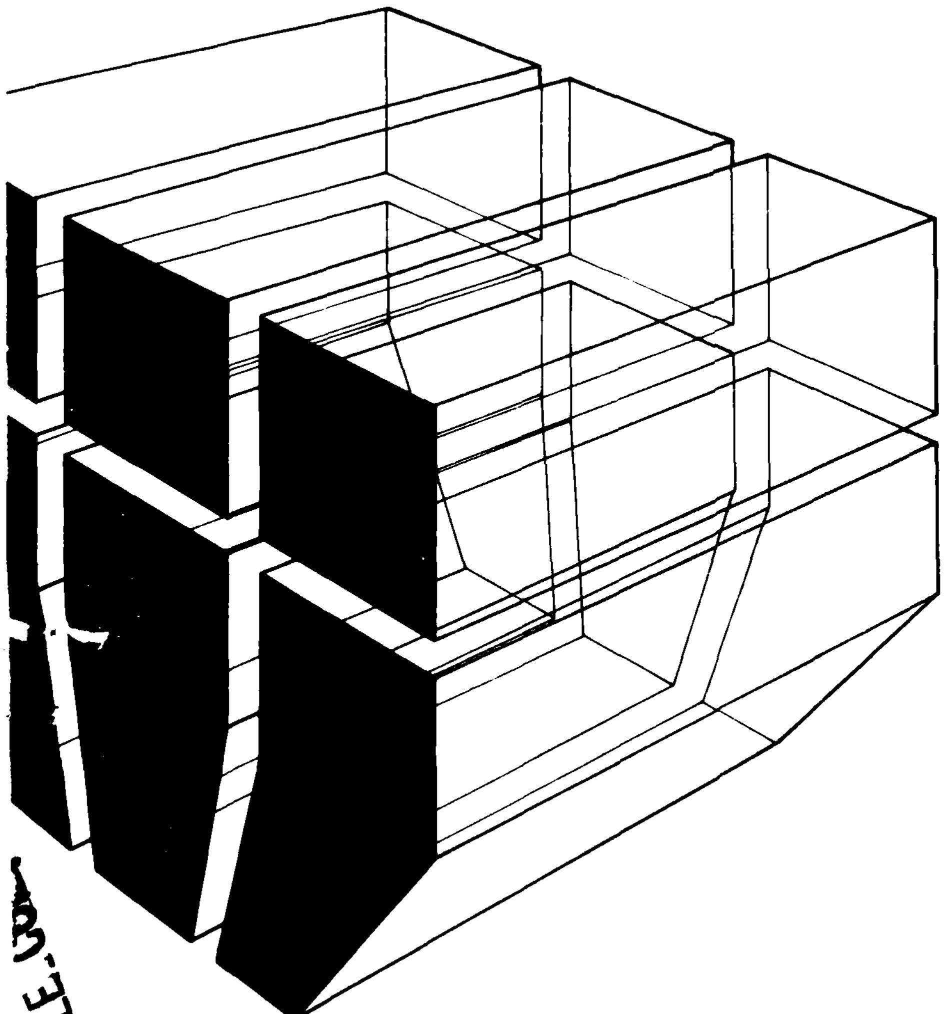
TECHNICAL REPORT M-289
March 1981
Ammunition Storage Concepts

FUNCTIONAL REQUIREMENTS AND NEW CONCEPTS FOR AMMUNITION STORAGE FACILITIES



by
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The Army is scheduled to spend $200 to 300 million constructing about 1700 new ammunition storage magazines between 1981 and 1986. Such facilities are not only cost intensive, they are real estate intensive because of the land area required to meet safety standards. This land area requirement is a particularly severe problem in Europe, where a large share of the new ammunition storage magazines will be built.

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Block 20 continued.

This report describes research to identify innovative ammunition storage facilities that are functional, life-cycle cost effective, and have substantially fewer real estate requirements than existing designs. To do this, functional requirements for existing ammunition storage magazines were developed in four categories: shelter, safety, security, and operations. It was found that safety is the functional requirement which has received the heaviest emphasis in existing designs, often at the cost of less effective shelter and operational characteristics.

Research indicated that magazines with smaller net equivalent weight (NEW) capacities are a promising way of reducing storage real estate requirements, especially where total facility capacity is less than 10 million lb (4.5 million kg) NEW. The study also identified a promising new storage concept: a reinforced earth side wall system with a prestressed concrete roof deck.

FOREWORD

This research was conducted for the Directorate of Military Programs, Office of the Chief of Engineers, under Project 4A762731AT41, "Military Facilities Engineering Technology"; Task C, "Construction Operations in T/O"; Work Unit 025, "Ammunition Storage Concepts." The Technical Monitor was COL P. J. Theuer.

The work was performed by the Engineering and Materials (EM) Division of the U.S. Army Construction Engineering Research Laboratory (CERL). Dr. R. Quattrone is Chief of CERL-EM.

COL Louis J. Circeo is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

CONTENTS

FUNCTIONAL REQUIREMENTS AND NEW CONCEPTS FOR AMMUNITION STORAGE AND FACILITIES

1 INTRODUCTION

Background

Since the military first began using explosives and ammunitions, their storage has been a major concern. The Department of Defense Explosive Safety Board (DDESB) was established to develop storage safety standards, and to assure user compliance through design review and onsite surveillance. The Corps of Engineers and the Naval Facilities Engineering Command, in conjunction with the DDESB, have developed and tested a series of earth-covered arch magazines to empirically determine safe storage capacities, intermagazine spacing, and distance criteria for occupied structures and public highways. The reinforced concrete and steel oval arch magazines that are currently specified and built are improved modifications of the World War II circular arch magazine. The oval arch magazines are not significantly different from the World War II circular arch magazines, other than having straight or bulging side walls and more slender concrete arches.

In recent years, the Army's ammunition storage requirments have expanded, particularly in Europe because of the Prepositioned Overseas Material Configured to Units Sets (POMCUS) program. Thus, the construction and rehabilitation of ammunition storage facilities is a significant item in the Corps of Engineers' construction budget. The 5-year (FY82 to FY86) Military Construction-Army (MCA) construction plan, as of February 1980, calls for $200 million to be spent on ammunition facilities. Of this total, 1600 to 1700 new magazines are scheduled for construction at a cost of $200 to 300 million.

Not only are ammunition storage facilities relatively cost intensive, they are also real estate intensive. This problem is especially severe in Europe, where most of the Army's expanded storage requirement exists. The lack of available real estate may soon impact construction schedules and significantly delay the completion of the POMCUS storage facilities.

Objective

The objectives of this study are (1) to identify functional requirements for ammunition storage facilities, and (2) to use those requirements to develop innovative ammunition storage facilities that are functional and have minimum real estate requirements.

Approach

Before new storage concepts were evaluated, the costs, functional requirements, and real estate needs of magazine designs were analyzed. Based on these findings, several alternative concepts were identified and evaluated. Both the design of individual magazines and magazine layout alternatives were considered and evaluated relative to construction and real estate costs.

Scope

This study did not make detailed design or cost estimates.

Mode of Technology Transfer

The information contained in this report will impact on the proposed Design Guide for Ammunition Storage Facilities. Approved alternative concept recommendations will impact on AR 385-64, *Safety, Ammunition and Explosive Safety Standards* (Department of the Army [DA], March 1972); DOD Manual 5154.4S, *DOD Ammunition and Explosives Safety Standards* (Department of Defense [DOD], January 1978); and TM 9-1300-206, *Ammunition and Explosive Standards*, (DA, August 1973).

2 FUNCTIONAL REQUIREMENTS

This chapter lists general functional requirements for ammunition storage. They are grouped under four categories—safety, security, shelter, and operations. All functional requirements included here were developed by CERL, representatives from DDESB, the Army Ammunition Center and School, and Office of the Chief of Engineers. These requirements are intended to supplement—not supercede—published standards (see Appendix A).

It should be noted that many of the requirements stated here had to be inferred since existing guidance is oriented predominantly toward a solution, and requirements are only implied.

Safety Requirements

Ammunition storage facilities should protect property, equipment, and personnel not directly involved in ammunition handling against blast, fragments, and fire caused by an accidental ammunition detonation. It is specifically required that:

1. An accidental detonation within one magazine not propagate detonations to adjacent magazines.

2. The public and operations and maintenance personnel not directly involved in ammunition handling be protected against injury from accidental explosions and related toxicity.

3. Blast, fragments, and fire associated with an accidental detonation at a storage facility not significantly damage occupied structures and public traffic routes.

Security Requirements

Ammunition storage facilities should prevent the loss of material and/or information to enemies, subversives, vandals, or indigenous animals. Security requirements are:

1. Stored material should be protected against damage from direct hits with small arms, and near misses with large arms.

2. Stored materials should be completely protected against damage from indigenous animals.

3. The site should inhibit access to stored material by intruders.

4. A consistent design should support the security requirement (no weak links); e.g., a security system integrated into the design.

5. Storage facilities should have controlled multiple access.

Shelter Requirements

Storage shelters should be able to maintain ammunition in usable condition for 20 years or more. Shelter requirements are:

1. The shelter should protect the material (and its packaging) from moisture-induced degradation.

2. The shelter should protect the stored material from extreme temperatures and large time/temperature gradients.

3. The shelter should protect its contents from natural catastrophies such as external fire, lightning, and high winds.

Operational Requirements

Ammunition storage facilities must be able to move material in and out of storage efficiently and allow operation and maintenance to be done on material while it is in storage. Other specific operational requirements are:

1. The structure should be able to accommodate the maximum type of explosives and ammunition.

2. The structure should be designed to maximize storage efficiency, including: (a) no interior beams or columns to interfere with storage operations, and (b) ceilings high enough above the *entire* floor area to allow material to be stacked up to 16-ft. (4.9-m) high.

3. Doors should be large enough to accommodate the largest item stored and the equipment required to transport that item. Doors should be placed so fork lift operating areas have a minimum impact on storage space. Foul weather should not interfere with the use of the door. Transition from apron to interior should be smooth.

4. The interior of the structure should be of a light color; lighting should be recessed or protected. Ventilation should be sufficient to remove noxious fumes.

5. Access roads should be all-weather and able to withstand the heaviest axle loads.

6. Each structure should have a hard, open surface area in front of the door for material-handling and transport equipment.

3 ANALYSIS OF STANDARD MAGAZINES

Standard Magazines vs Functional Requirements

The Corps of Engineers has approved four standard large sized magazine designs. All four designs are earth-covered arches with a minimum of 2 ft (0.6 m) of earth cover at the crown and massive reinforced concrete head walls. The older designs are circular arches and the newer are oval. Both use either reinforced concrete or corrugated steel arch barrels. Nominal magazine dimensions are 25-ft (7.6-m) wide with depths up to 100 ft (30 m). Depending on arch type, midspan ceiling heights vary from about 12 to 15 ft (3.6 to 4.5 m). Approved capacities for these standard magazines have been set at 500,000 lb (226 796 kg) net explosive weight (NEW).

The earth-covered arch magazines have been extensively tested under full-scale and model conditions to determine their safety characteristics and to establish a complex set of quantity/distance criteria for intermagazine spacing, distance to occupied building, and public trafficway. The intermagazine spacing is selected to prevent donor/receiver propagation of a full capacity detonation in the donor. The quantity/distance criteria for occupied buildings and public trafficways are based on the prevention of significant damage to the structure or vehicle (minor damage such as breakage of window glass is accepted and anticipated).

The four standard magazines are an integral part of the prescribed security requirements listed in DOD Manual 5100.76-M. But the actual level of security provided by the structures is unknown and depends on the intrusion techniques used. Thus, it is recognized that storage structures are only delay devices and are not intended to constitute complete security, unless supported by a means to detect and assess intrusion and to nullify its effect. In addition to the standard magazines, security regulations normally require various combinations of barrier fences, intrusion detection systems, security lighting, and surveillance.

The existing family of standard magazines is most frequently criticized for failing to meet shelter requirements. Both the reinforced concrete and corrugated steel magazines have experienced moisture intrusion and condensation problems. Many of the existing magazines leak either through bolt holes and lap joints in the corrugated steel arches or cracks in the concrete arches. Normally, leaky magazines are repaired by removing the earth cover and applying a one- or two-ply built-up roof membrane. Such repairs are effective, but very expensive. Recent efforts have indicated interior patching may be a cost-effective alternative if a high level of workmanship can be maintained.[1]

Condensation problems in earth-covered magazines are much more difficult to control; they can occur any time that the dew point of the circulating air is above the temperature of the inside surface of the structure. Under certain conditions, sprayed-on insulation may lessen the severity of the condensation by making the surface temperature of the structure more compatible with the circulating air temperature.

Clogged and/or improperly designed french drains can also be a problem.

The earth-covered magazines have two main operational shortcomings:

1. The basic arch shape is not efficient. Ideally, storage structures should have straight, vertical side walls. Much storage space is lost in the old circular arch magazines.

2. Many of the older magazines have doors that are too small to allow fork lifts or other loading equipment to operate efficiently and do not have hard surface areas immediately outside the door large enough to load and unload material.

Beyond these specific magazine deficiencies, many of the existing storage sites have inadequate access roads and other operational and security shortfalls. But it should be remembered that the primary magazine design consideration has historically been safety, with the other functional requirements receiving only secondary consideration.

Economics of Conventional Magazine Construction

Construction and maintenance cost estimates on various standard magazines were developed as a baseline to evaluate the cost effectiveness future of new concepts. Table 1 lists the 1978 to 1979 United States construction cost for the four standard Corps magazines; it also lists cost estimates for a European version of the concrete oval arch. The European estimates are significantly less than the equivalent United States estimates, but are based on quotations for 30 or more structures per construction site. A major proportion of the cost difference is associated with the effective and efficient use of reusable concrete forms.

Table 1 indicates that the per square foot construction cost for ammunition storage is high; however, Table 2 shows that the real property maintenance for ammunition storage facilities is significantly less than that for military buildings in general.

Besides the total cost of the various magazines, Table 1 indicates that the cost of the magazine barrel for a

[1] Stanley M. Kanarowski, *Investigation of Materials for Waterproofing Leaky Concrete Ammunition-Storage Bunkers from the Inside*, Special Report M-256/ADA064731 (U.S. Army Construction Engineering Research Laboratory [CERL], January 1979).

Table 1
Standard Storage Magazines–Comparative Analysis

Magazine Type	Estimator	Year	Total Cost (\$K)	Cost of Barrel (\$K)	Total Volume cu ft (m^3)	Total Cost/ Volume (\$/cu ft)	Barrel Cost/ Volume (\$/ft²)	Total Cost Floor Area (\$/ft²)
Concrete circular arch	OCE	78-79	147	--	21,397 (605)	6.87	--	73.5
Steel circular arch	OCE	78-79	161	--	23,165 (655)	6.95	--	80.5
Concrete oval arch (I reloc)	OCE	78-79	171	57.093	25,446 (720)	6.72	2.24	85.5
Concrete oval arch (I reloc)	EUD *	May 78	71.8	23.984	25,446 (720)	2.82	0.94	35.9
Concrete oval arch (I reloc)	EUD *	Nov 78	92.8	30.978	25,446 (720)	3.65	1.22	46.4
Steel oval arch	OCE/Black & Veatch	75	116.693	38.633	20,711 (586)	5.63	1.86	76.5
Steel oval arch	OCE	78-79	179	60.799	27,162 (769)	6.59	2.24	89.5

*Cost estimates are based on quotations for 30 or more magazines per construction site.

Table 2
Real Property Maintenance Cost
For Buildings Army-wide (FY78)

Buildings	Unit of Measure*	Base Unit Quantity	Total Cost (\$)	Unit Cost (\$)
All	K sq ft	1,012,794	505,242,487	498.86
Ammunition storage	K sq ft	47,868	5,281,242	110.33

* 1 sq ft = 0.092 903 m

standard 80-ft (24-m) magazine is about one-third the cost of the entire structure. Thus, efforts directed at reducing the cost of the arch barrel have only a minor impact on the cost of the entire magazine.

4 NEW CONCEPTS FOR AMMUNITION STORAGE

Ammunition storage design involves both the design of the magazine, and the intermagazine and site layout. Thus, in evaluating new concepts, both innovative layouts and structural/material concepts were considered.

Site Layout Considerations

Site layout criteria are given in the various Ammunition and Explosive Safety Standards listed in Appendix A. For earth-covered magazines, two levels of criteria ar involved: (1) intermagazine spacing, and (2) the distance to occupied structures. Both the intermagazine and distance-to-occupied-structured criteria are based on the NEW quantity/distance criteria.

Current DDESB criteria for intermagazine spacing vary between $1.25W^{1/3}$ to $11W^{1/3}$, depending on magazine-to-magazine orientation and whether barricades are used.* The quantity/distance criteria for magazine-to-occupied structure vary from 40 to $50W^{1/3}$. Thus, a

*Intermagazine spacing is listed in feet; the W equals NEW in pounds.

major factor in evaluating total storage capacity vs real estate requirement for a given depot, or site, is the maximum allowable quantity of explosives to be stored in each magazine.

Figure 1 shows the relationship between real estate requirements based on the DDESB distance-to-occupied structure and intermagazine criteria for class 7 (mass-detonating) hazard, as a function of site NEW storage capacity for standard 500,000, 250,000, and 125,000 lb (226 796, 113 398, and 56 699 kg) NEW magazines arranged in a compact square or rectangular pattern. Specifically, the real estate involves (1) the area of the magazines, all assumed to be 25 ft by 80 ft, (2) the intermagazine spacing of $1.25\ W^{1/3}$ (100, 80, and 65 ft, respectively, for the 500,000, 250,000, and 125,000 lb NEW magazines), and (3) the perimeter area based on the distance-to-occupied structure criteria of $50W^{1/3}$ (3,970, 3,150, and 2,115 ft, respectively, for the 500,000, 250,000, and 125,000 lb NEW magazines). Appendix B contains an example calculation. The figure indicates that the real estate savings for a given site capacity is predominantly a function of magazine NEW capacity and is not significantly related to total depot or site capacity. About 400 acres (161 ha) can be saved by reducing the allowed NEW capacity from 500,000 to 250,000 lb (226 796 to 113 398 kg); an additional 250 to 300 acres (101 to 121 ha) can be saved by limiting the magazine NEW capacity to 125,000 lb (56 699 kg).

The reduction of the magazine NEW capacity is a viable design consideration in areas where total site storage NEW requirements are reasonably small (less than 10 million lb [4.5 million kg] NEW), or where real estate cost or real estate availability are significant factors. This is true even if magazine cost is constant regardless of NEW capacity. But if smaller NEW capacity magazines can be constructed at some cost savings per magazine, or can approach a constant cost per square foot of storage area, the reduced capacity NEW concepts would be viable even for larger capacity storage sites or depots.

Another alternative for large depot layouts is to surround the full-capacity magazines with magazines of reduced NEW capacity, thus using available real estate effectively within occupied building quantity/distance criteria.

Structure Design Variations

The dominant magazine design since World War II has been some form of earth-covered arch structure with a massive reinforced concrete head wall where earth cover is not provided. However, the Navy has developed rectangular earth-covered, flat-roofed structures. Large-scale explosive model tests indicate that this flat roof design can perform satisfactorily.[2]

One new concept that is very promising involves such a flat-roof, rectangular earth-covered structure. The unique aspect of this system is that all side, rear, and wing walls would be built from Reinforced Earth® concrete panels with soil-friction, metallic tie-back strips (Figure 2). The roof deck could be of hollow-core precast, prestressed concrete panels; the portal (or front) wall could either be conventional cast-in-place or precast concrete, depending on its relative size. The advantage of the reinforced earth precast roof deck system is that, with the exception of the portal wall, foundation and floor slab, the system would be built from precast concrete units. This would virtually eliminate the need for expensive and time consuming form work. The economic feasibility of this concept has not yet been determined, but based on its relative merits as an economic alternative for bridge abutments and retaining walls, the potential for the system's exonomic feasibility is good reinforced earth has been accepted as a viable alternative for earthen baricades used for blast protection.[3]

In addition to the reinforced earth, precast roof deck system, Marwais International of Luxembourg has proposed a steel arch magazine similar to the current magazines, but with significantly deeper corrugations. Included in their design is a steel-concrete-steel sandwich panel for the portal headwall. Recent discussion with representatives of Marwais would indicate some potential for this system, particularly if certain NATO design criteria are revised.[4]

New Materials and Composites

Conventional earth-covered ammunition storage magazines are made from reinforced concrete and or reinforced concrete and corrugated steel (arch barrel). All concrete currently specified is conventional cast-in-place construction. An alternative construction system previously demonstrated at CERL is an inflation-

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[2] P. E. La Foya, "Eskimo VI-Preliminary Test Results" *Minutes of the Nineteenth Explosives Safety Seminar*, vol 1, 9-10-11 Sept. 1980.

[3] Private communication between Dr. Paul Howdyshell of CERL and Dr. Tom Zaker of DDESB (5 September 1980).

[4] Private communication between Dr. Paul Howdyshell of CERL and Mr. D. V. Palan of Marwais International, SA, Luxembourg (21 July 1980).

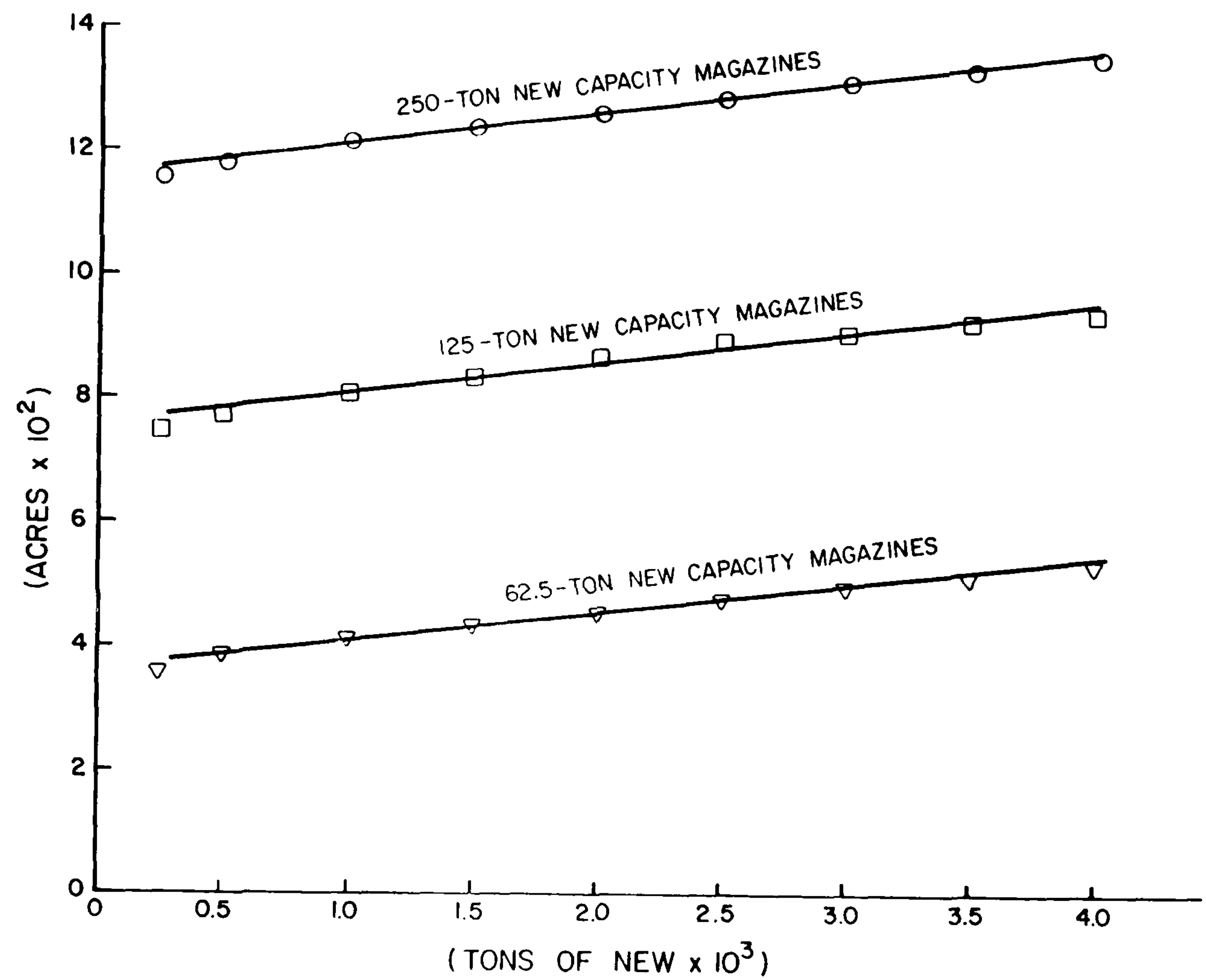

Figure 1. Site storage capacity verses real estate requirements for 250-, 125-, 62.5-Ton NEW capacity magazines.

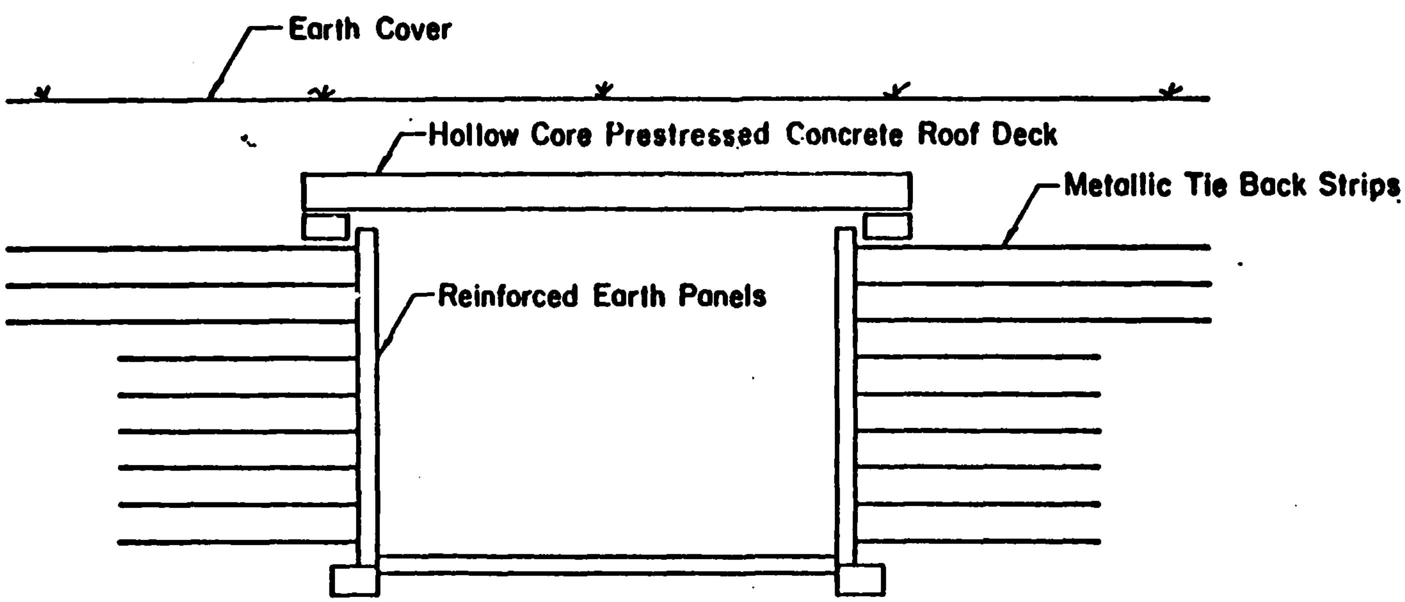

Figure 2. Reinforced earth ammunition storage concept.

formed foam-shotcrete system.[5] The advantage of this system is that it is relatively simple to erect. Its major disadvantages are shotcrete quality control, the slowness of placing concrete with shotcrete equipment, and the amount of concrete waste caused by rebound. Economic analysis has indicated that an earth-covered, foam-shotcrete arch magazine, is equivalent structurally to the conventional cast-in-place concrete magazines, and is cost competitive with single-unit conventional magazine construction. But the successful construction of a large (25-ft [7.6-m] wide) foam shotcrete arch has never been demonstrated because of construction process loads impacting the shape and structural integrity of the resulting structure. It is assumed that a detailed structural analysis of the various construction process loads and appropriate design changes could overcome these process problems.

Two other materials concepts should also be considered: (1) random fibrous concrete and (2) the steel-concrete-steel sandwich panel. Both systems may provide additional hardening for the critical portal wall. Both techniques significantly improve the spall characteristics of concrete and should be considered as alternatives for portal wall design.

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[5] M. Woratzeck, *Inflation/Foam/Shotcrete System for Rapid Construction of Circular Arches*, Special Report M-262/ADA069578 (CERL, May 1979).

5 CONCLUSIONS

1. Based on its flexibility and its economic feasibility for other applications, the reinforced earth, hollow-core prestressed concrete roof deck is a promising new concept for earth-covered ammunition storage.

2. The use of smaller NEW capacity magazines is an effective way of reducing real estate requirements for ammunition storage facilities. This is particularly true for small (less than 10 million lb [4.5 million kg] NEW) facilities (p 16). Limiting the NEW capacity of large facility perimeter magazines can also reduce real estate intensity.

3. It proved to be impossible to identify functional requirements based on existing guidance, therefore, requirements were developed as part of this study (p 8).

4. The analysis of standard magazines relative to functional requirements indicated that safety has been the dominant design consideration; thus, the performance of these magazines relative to shelter and operational requirements is often less than completely satisfactory.

APPENDIX A:

PUBLISHED AMMUNITION STORAGE STANDARDS

Safety, Ammunition and Explosive Safety Standards, AR 385-64 (DA, March 1972).

DOD Ammunition and Explosives Safety Standards, DOD Manual 5154.4S (DOD, January 1978).

Ammunition and Explosive Standards, TM 9-1300-206 (DA, August 1973).

Safety Manual, DARCOMR 385-100 (DARCOM, April 1970).

Security Requirements for Weapons, Ammunition and Explosives, DOD Manual 5100.76-M (1979).

Manual on NATO Safety Principles in the Storage of Ammunition and Explosives, AC/258-D/258 (North Atlantic Treaty Organization [NATO], 1976).

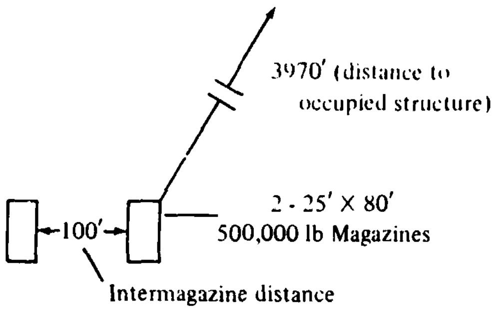
Of the standards listed above, the best information on blast load design parameters for earth-covered magazines is in Part II, Chapter 3, Secion III of NATO AC/258-D/258.

Structures to Resist the Effects of Accidental Explosions, TM 5-1300 (DA, 15 June 1969) contains analysis information and procedures applicable to the design of blast-resistant structures; however, TM 5-1300 does not consider blast loads greater than 20,000 lb (9071 kg) NEW.

APPENDIX B:

EXAMPLE CALCULATION OF REAL ESTATE REQUIRED FOR 1 MILLION LB OF STORAGE

A. 2 - 500,000 lb Magazines



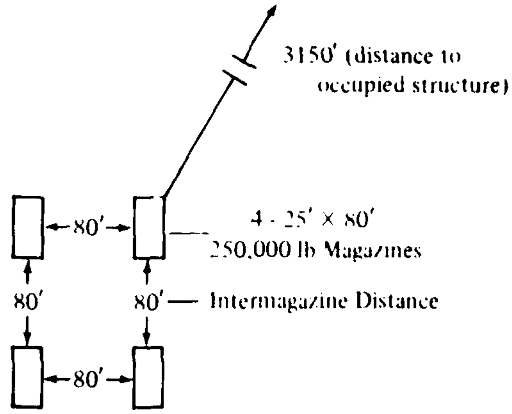
$$\text{Area} = \text{Magazine Area} + \text{Intermagazine Area} + \text{Distance to occupied structure}$$

$$= 50 \times 80 + 100 \times 80 + 150\,(2 \times 3970) + 80\,(2 \times 3970) + \pi\,(3970)^2$$

$$= 49$$

$$= 1179 \text{ Acres}$$

B. 4 - 250,000 lb Magazines

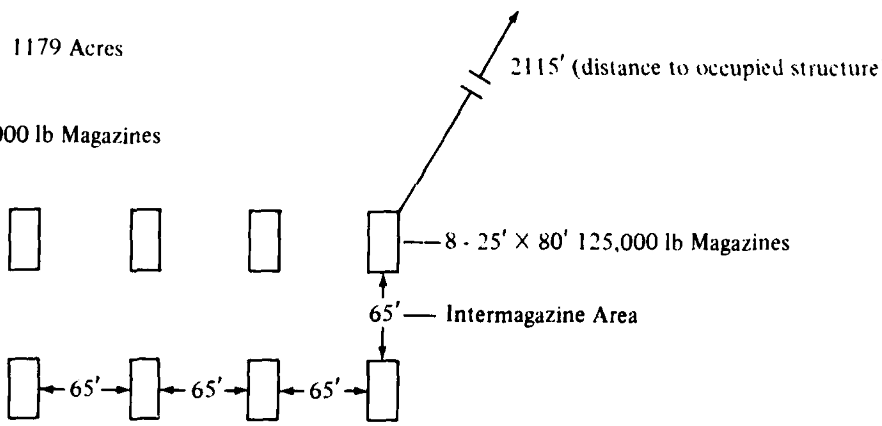


$$\text{Area} = 240 \times 130 + (130 + 240)\,2\,(3150) + \pi\,(3150)^2$$

$$= 33{,}534.6 \times 10^3 \text{ ft}^2$$

$$\cong 769.8 \text{ Ac.}$$

C. 8 - 125,000 lb Magazines



$$\text{Area} = (295 \times 225) + (295 \times 2 \times 2115) + (225 \times 2 \times 2115) + \pi\,(2115)^2$$

$$= 16{,}777.2 \times 10^3 \text{ ft}^2$$

$$\cong 385 \text{ Ac.}$$

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ATTN: Facilities Engineer
Fort Belvoir
Fort Benning
Fort Bliss
Carlisle Barracks
Fort Chaffee
Fort Dix
Fort Eustis
Fort Gordon
Fort Hamilton
Fort Benjamin Harrison
Fort Jackson
Fort Knox
Fort Leavenworth
Fort Lee
Fort McClellan
Fort Monroe
Fort Rucker
Fort Sill
Fort Leonard Wood

INSCOM - Ch, Instl. Div.
ATTN: Facilities Engineer
Vint Hill Farms Station
Arlington Hall Station

WESTCOM
ATTN: Facilities Engineer
Fort Shafter

MDW
ATTN: Facilities Engineer
Cameron Station
Fort Lesley J. McNair
Fort Myer

HSC
HQ USAHSC, ATTN: HSLO-F
ATTN: Facilities Engineer
Fitzsimons Army Medical Center
Walter Reed Army Medical Center

USACC
ATTN: Facilities Engineer
Fort Huachuca
Fort Ritchie

MTMC
HQ, ATTN: MTMC-SA
ATTN: Facilities Engineer
Oakland Army Base
Bayonne MOT
Sunny Point MOT

US Military Academy
ATTN: Facilities Engineer
ATTN: Dept of Geography & Computer Science

USAES, Fort Belvoir, VA
ATTN: ATZA-DTE-EM
ATTN: ATZA-DTE-SU
ATTN: Engr. Library

Chief Inst. Div., I&SA, Rock Island, IL

USA ARRCOM, ATTN: Dir., Instl & Svc
TARCOM, Fac. Div.
TECOM, ATTN: DRSTE-LG-F
TSARCOM, ATTN: STSAS-F
NARAD COM, ATTN: DRDNA-F
AMMRC, ATTN: DRXMR-WE

HQ, XVIII Airborne Corps and Ft. Bragg
ATTN: AFZA-FE-EE

HQ, 7th Army Training Command
ATTN: AETTG-DEH (5)

HQ USAREUR and 7th Army
ODCS/Engineer
ATTN: AEAEN-EH (4)

V Corps
ATTN: AETVDEH (5)

VII Corps
ATTN: AETSDEH (5)

21st Support Command
ATTN: AEREH (5)

US Army Berlin
ATTN: AEBA-EN (2)

US Army Southern European Task Force
ATTN: AESE-ENG (5)

US Army Installation Support Activity, Europe
ATTN: AEUES-RP

8th USA, Korea
ATTN: EAFE
Cdr, Fac Engr Act (8)
AFE, Yongsan Area
AFE, 2D Inf Div
AFE, Area II Spt Det
AFE, Cp Humphreys
AFE, Pusan
AFE, Taegu

DLA ATTN: DLA-WI

USA Japan (USARJ)
Ch, FE Div, AJEN-FE
Fac Engr (Honshu)
Fac Engr (Okinawa)

ROK/US Combined Forces Command
ATTN: EUSA-HHC-CFC/Engr

416th Engineer Command
ATTN: Facilities Engineering

Norton AFB
ATTN: AFRCE-MX/DEE

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