

DDESB Technical Paper (TP) 15 Update and Standard ECM Designs Approved for New Construction

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Abstract

DDESB Technical Paper (TP) 15, “Approved Protective Construction,” contains information on protective construction used by the DoD for explosives safety purposes, intended to meet the criteria of DoDM 6055.09, “DoD Ammunition and Explosives Safety Standards”¹. The document is currently being updated, and Revision 4 will be published in 2018. The current version of TP 15, Revision 3², is dated May 2010, so there is a considerable amount of information to incorporate in the update. The new revision will be a modernized document incorporating recent protective construction approvals and a reduced list of standard earth covered magazine (ECM) designs approved for new construction. The reduced list of eleven actively maintained 7-Bar ECM designs include various construction types, such as reinforced concrete arch and box, modular precast concrete, and metal arch types. Future revisions of TP 15 will likely see the paper hosted online as a “living document” with support documentation, such as engineering drawings, approval memos, and technical reports, available to registered users.

Introduction

The Department of Defense Explosives Safety Board (DDESB) publishes and maintains a set of technical papers to supplement its set of official explosives safety issuances. These papers typically present topics in greater technical detail than other issuances, serving as guidance related to approved calculation methodologies or preparation of official submissions. One of these papers is DDESB Technical Paper (TP) 15, titled “Approved Protective Construction,” which is a record of historically significant information about the origin and evolution of protective construction designs and the explosives safety criteria associated with them. It documents ammunition and explosives (AE) storage facilities and other protective construction designs currently and previously approved by the DDESB. Its intent is to educate and inform users in the explosives safety community of how criteria were developed and influenced and to serve as a source of approved designs for use in the community.

The current version of TP 15, Revision 3, is dated May 2010. Since the purpose of the paper is to document up-to-date approvals of protective construction designs and relevant criteria, a new revision is clearly needed for accurate and complete information to be communicated to the explosives safety community. The DDESB has recently assigned responsibility for updating the paper to the U.S. Army Engineering and Support Center (CEHNC) Structural Branch. Updates in the draft Revision 4 include incorporating protective construction approvals issued since the last revision, updating information on criteria development, and correcting inaccurate historical information. As of the date of this publication, Revision 4 is in draft final status and undergoing final editing and will subsequently be sent for review by the Services. Issuance is expected in 2018. This paper discusses the history of TP 15’s development, as well as its format and features, the changes expected in future versions, and the updated list of AE storage magazines approved for new construction.

History

TP 15 was originally developed by the DDESB, with Mr. Eric Deschambault leading the development effort, and published in February 2001. This original version was a major effort of collecting, consolidating, and presenting historical information and DDESB approval documentation related to protective construction. A second version of

TP 15 was published in June 2004. Significant updates in this version included expansion of recent testing details and associated conclusions, information related to non-propagating walls (NPW) and substantial dividing walls (SDW), and the addition of sand-filled walls and missile test cells. Also, the lists of approved AE storage magazines were moved to an appendix to allow for more frequent updates than the full TP, a formatting feature that has been maintained to present day.

Revision 3 of TP 15 was published by the DDESB in May 2010. This revision first introduced a new webpage established by the Naval Facilities Engineering Command (NAVFAC) on their Whole Building Design Guide (WBDG) website intended to assist in the planning and design of new AE storage magazines, serving as the first open online source of design documentation and engineering drawings in multiple formats for these facilities. Other updates included: additional guidance on protective construction submittals to the DDESB associated with explosives safety site plans, with direction to utilize a competent DoD blast design agency (e.g. CEHNC and NAVFAC EXWC) for validation of designs; additional information on NPW and prevention of sympathetic detonation (SD); incorporation of updated ECM design considerations and blast loads approved by the DDESB; information on underground AE storage criteria from the North Atlantic Treaty Organization (NATO) Allied Ammunition Storage and Transport Publication (AASTP-1), which is more closely maintained than the DoD underground storage criteria; addition of modified barricade height criteria for intermagazine (IM) protection to prevent prompt propagation; information on NATO Nations testing background for sand-filled, wire-reinforced barricades used to protect forward operating bases (FOB); incorporation of water barricades used to separate combat aircraft for IM protection; expansion of detonation containment vessel content; expanded information on hardened aircraft shelters (HAS) to address missing criteria; incorporation of Noble Eagle F-15 and F-16 reduced maximum credible event (MCE) and quantity-distance (QD) criteria and approvals for AIM-7, AIM-9 and AIM-120 container storage reduced MCE and QD; addition of Chapter 9 for non-storage related protective construction not falling into categories discussed elsewhere in the document; updating of standard AE magazine listings in Appendix AP1; and updated information related to operational/deployed storage and airfield applications, as governed by NATO AASTP-5.

In 2016, acknowledging that a new revision of TP 15 was needed due to time elapsed since the previous version, the DDESB funded CEHNC's Structural Branch to develop an updated version of the paper. Since that time, CEHNC has been assembling and incorporating recent protective construction approvals, coordinating with the Services' explosives safety offices on AE storage magazine standards, and performing miscellaneous edits of the document at the direction of the DDESB in the development of a draft version of Revision 4. These updates are discussed below under "Revision 4 Changes."

Current TP 15 Format

Since the publication of the initial version of TP 15, the format and layout has remained largely consistent. The current format and contents are discussed below, by chapter/appendix:

- **Chapter 1: Introduction**
This chapter is a brief, general introduction to the TP that summarizes general concepts, the content and layout of the paper, relevant points of contact and resources for each DoD Component for background/support documentation (e.g. construction drawings, approval memoranda, Components letters, messages, technical reports, analyses), and guidance for protective construction submittals to the DDESB.
- **Chapter 2: Magazine History**
Chapter 2 is a thorough historical review of AE storage magazines used in the United States. It discusses the origins of the use of explosives safety distances, the evolution of the designs throughout the twentieth century, and the extensive testing programs undertaken for magazines between the 1920s and 1990s. This testing includes the programs commonly referred to as Arco, NOTS, ESKIMO, Navajo, and Hastings, as well as the modular igloo and high performance magazine (HPM) testing. Also discussed are the NPW and sympathetic detonation criteria resulting from the HPM testing or associated with the HPM design.
- **Chapter 3: Earth Covered Magazine (ECM) Descriptions**

This chapter introduces strength designations for ECMs (i.e. 7-Bar, 3-Bar, and Undefined), how they have evolved since their introduction, and the design requirements for each type as specified in DoD standards¹. It also discusses the typical features of an ECM, such as the earth cover and retaining wing walls, blast doors, lightning protection and electrical ground systems, and chamber walls/roofs. Finally, guidance is provided on the use of new or pre-approved ECM designs.

- **Chapter 4: Magazine Listings**

Chapter 4 presents descriptions of the typical ECM shapes/types (e.g. arch, oval-arch, Stradley, box-type) and references the lists of approved standards presented in Appendix AP1.

- **Chapter 5: Underground Ammunition Storage Facilities**

Chapter 5 is a very brief reference to existing underground storage criteria in the DoD and NATO.

Specifics of this criteria are very extensive and beyond the scope of TP 15, in particular due to the rarity of this type of storage in the DoD.

- **Chapter 6: Barricades and Containment Structures**

This chapter briefly presents some of the uses and capabilities of barricade structures, which are primarily used for defeating fragmentation and debris effects in various applications, and it lists the barricade types approved for use by the DDESB. It then discusses other protective construction types that provide a greater degree of containment for blast effects, such as suppressive shields and containment chambers/vessels. This is the location where all DDESB-approved containment vessels for intentional detonation are documented. Finally, this chapter presents historical discussion on the use of Navy Missile Test Cells (MTC) and substantial dividing walls (SDW), with references to testing data and discussion of their current acceptable uses.

- **Chapter 7: Barricaded Module Storage**

Chapter 7 is dedicated to barricaded module storage, which consists of series of connected cells with hard surface pads separated by earthen barricades, intended to prevent propagation between cells. The intended use of these facilities is primarily for temporary open storage of AE. The chapter presents the historical development of this storage type, including the validating test series, Big Papa.

- **Chapter 8: Airfield Associate Protective Construction**

Chapter 8 presents all protective construction and reduced QD or MCE associated with DoD airfields. It contains thorough discussion on the history of the hardened aircraft shelter (HAS) concept and criteria development, including testing history. In addition, it presents all of the currently approved reduced MCE and QD for combat aircraft storage configurations and all-up-round missile storage containers and trailer storage configurations.

- **Chapter 9: Other Non-Storage Related Protective Construction**

Chapter 9 serves to contain information on non-storage related protective construction designs that do not fall into the categories of previous chapters. It contains very little information currently but could potentially expand in future iterations.

- **Appendix 1: Magazine Listings**

Appendix 1 contains the tabular listings of standard AE storage magazines referenced in Chapter 4. The four tables in this appendix are:

- **Table AP1-1: 7-Bar and 3-Bar ECM Approved for New Construction**

This table contains only ECM designs with high structural strength designations that are actively maintained to meet current criteria and are permitted to be site-adapted for new construction

- **Table AP1-2: 7-Bar and 3-Bar ECM No Longer Used for New Construction, But Still in Use**

Those ECM standard designs with high strength designations not included in Table AP1-1 are in this table because they are not actively maintained or have been superseded. These magazines can only be constructed if the designs are updated to meet current criteria and submitted for DDESB approval.

- **Table AP1-3: Undefined ECM**

This table lists the ECM standard designs with the lowest structural strength designation. Many of these designs are very dated and/or obsolete.

- **Table AP1-4: Magazines (Earth-Covered and Aboveground) and Containers with Reduced NEWs and/or Reduced QD**

This table is a list of miscellaneous AE storage magazine designs that do not fall into the categories of the other three tables but afford some degree of reduction to siting requirements.

- **Appendix 2: Operational Field Storage**

Appendix AP2 contains information drawn and consolidated from TP 15 and other sources to assist users who have a need to establish AE storage in deployed locations. A focus in this section is reduction of MCE to address limited availability of real estate in these types of locations. Much of the information in this appendix may be found in other locations in the paper.

Revision 4 Changes and Future Outlook

As mentioned in previous sections of this paper, considerable changes of varying magnitude have been made to Revision 3 of TP 15 in the preparation of a draft final version of Revision 4. These changes are discussed below in greater detail, by chapter.

Chapter 1

Changes to Chapter 1 are limited to minor wording changes for clarity and updates to references for accuracy.

Chapter 2

The content of Chapter 2 had remained mostly consistent through the first three versions of TP 15. However, through additional research of historical records, DDESB staff had identified some omissions and inaccuracies in the early magazine and siting history description. Revision 4 will include the first significant change to this content to correct or clarify this information.

Chapter 3

This brief chapter remains largely unchanged, with exception to the addition of a reference to UFC 4-420-01, “Ammunition and Explosives Storage Magazines”⁴. This document provides more in-depth information on the features of ECMs and additional guidance on the selection and siting of the facilities. Users of TP 15 can reference this UFC for additional assistance in the selection and design process.

Chapter 4

Modular Storage Magazine (MSM) will be added to the list of ECM categories. This is a currently prevalent type of ECM design with precast concrete panels used for the walls and roof to allow for rapid construction and modular assembly. Also, Revision 4 will add updated guidance on the siting of legacy flat-roof earth-covered magazines and the associated restrictions due to inadequate structural strength of the roof components. A limited number of these magazine designs have been addressed through DDESB guidance⁵, but others should be checked on a case-by-case basis if resited or repurposed, as noted in this revision.

Chapter 6

Numerous updates to Chapter 6 consist primarily of background information from new protective construction design approvals. These recently approved designs are as follows:

- Updated content on the use of sandbags to mitigate blast effects at Munitions and Explosives of Concern (MEC) Removal Sites based on the latest amendment to the relevant report
- The permitted use of sand-filled Defencell System Units as an alternative to sandbags for the relevant purposes from the preceding bullet
- Recently approved intentional detonation chambers:
 - Dynasafe DynaSEALR X10 and DynaSEALR X12
 - NABCO Total Containment System models 64-SCS, 64-SCS-GT, 42-SCS, and 42-SCS-GT
 - Mistral Security models ARC 5 GT, ARC 6 GT, ARC 9 GT, and ARC 10 GT
 - DAVINCH USA DV-60

Other updates include:

- Updated content on missile test cells (MTC) to reflect recent documentation and siting restrictions; added a comprehensive list of pertinent MTC documents.

- Updated substantial dividing wall (SDW) content in major revision, including:
 - corrected historical SDW testing information
 - revised content on current status of guidance to reflect reevaluation efforts resulting from recent research

Chapter 8

Updates to the airfield-related protective construction and reduced QD/MCE include:

- Approval for Noble Eagle F-22 missile load MCEs and reduced quantity distance (QD)
- Additional Noble Eagle F-15 and F-16 configurations that were tested and approved since the publication of Revision 3
- Reduced debris IBD for Noble Eagle aircraft configurations in light metal structures
- The recently approved reduced MCE for AIM-120 trailer storage configurations

Appendix 1

Perhaps the most significant change in Revision 4 of TP 15 is the update to the AP1 magazine list tables. The DDESB and Service explosives safety offices have made a concerted effort to consolidate their lists of 7-Bar and 3-Bar ECM designs approved for new construction, as listed in Table AP1-1. The primary driver for this change is to limit the magazines in AP1-1 to those that are truly actively maintained by the Services and commonly constructed, as is the intent of the ECM approvals, while balancing the need for adequate variety in construction options. This is also consistent with the recent initiative within the DoD for all new ECM designs to be true DoD standards that all Services can support and construct rather than being attributed to a single DoD component. In addition to these influences, there is the obvious need for updates to replace the magazines that have been superseded with the information of their successors and corresponding updated design data. Also, several foreign ECM designs have been removed from this list because they were either lacking complete design data or no longer maintained by the nations that developed them. The specific ECM designs in this consolidated list are discussed in further depth below under “Approved 7-Bar and 3-Bar Magazines Approved for New Construction.” It should be noted that the updated designs for some of these standards, including 421-80-01, 421-80-03, and 421-80-05, are in work but are yet to be completed and/or approved.

With ECM designs being removed from Table AP1-1, they have been added to Table AP1-2, as they are no longer approved for new construction but are still in use. Additionally, revisions have been made to AP1-3 to address legacy flat-roof ECM designs that had previously been treated as Undefined ECMs. Several of these smokeless powder and projectile (SP&P) magazines have been relocated from Table AP1-3 to Table AP1-4. They can no longer be treated directly as Undefined ECM, but should be sited in accordance with updated DDESB guidance for SP&P magazines⁵.

Future Updates and Evolution of TP 15

The long-term intent for TP 15 is to develop a “living document” that is hosted online and updated in regular intervals as new approvals are issued and criteria is developed. With this change in format and accessibility, registered users will be able to access up-to-date information, as well as the support documentation associated with the protective construction designs or policy of concern, such as construction drawings, approval memoranda, Component letters, correspondence, and technical reports. It should be noted that there is no set timeline for this format transition, but updates to TP 15 are continuously being worked under the direction of the DDESB.

Additionally, there are intentions to separate the contents of TP 15 into a more logical sequence or to remove certain subsets of the contents for documentation elsewhere. For example, there are considerations to relocate or separate the EOD-related protective construction and the airfield-related reduced QD/MCE approvals to more appropriate or new documents.

Of course, the DDESB continues to request that the explosives safety community provides copies of any documentation that can be used to correct, update, or enhance the document.

Approved 7-Bar and 3-Bar Magazines Approved for New Construction

As discussed above, Revision 4 of TP 15 will include significant updates to the magazine lists of API, including Table AP1-1, 7-Bar and 3-Bar ECM Approved for New Construction. This newly consolidated list includes the following ECM designs:

- 10400001 through 10400027 (Navy Type M)
- 14004689 through 14004720 and 14005091 through 14005122 (Navy Type C)
- 14026988 through 14027031 (Navy MSM)
- 18232899 through 18232936 and 18232939 through 18232978 (Navy Type D)
- 33-15-74 (Korean Version)
- 421-80-01
- 421-80-03
- 421-80-05
- 421-80-07
- 421-80-08
- 421-80-09

Each of these standard designs is presented in further depth on the following pages. Each is presented with its entry from Table AP1-1, along with pertinent details and general background information.

10400001 through 10400027 (Navy Type M)

DRAWING NO. (NOTE 1)	DRAWING DATE	DESCRIPTION (1)	DESIGN AGENT	DDES APPROVAL DATE	ECM DESIGNATION	COMMENTS: (Notes 2 and 3)
10400001 through 10400027	5-Jan-04	RC Box, Type M	NAVFAC	1-Dec-99	7-Bar	Internal dimensions are 81' wide by 124' long by 24' 6" high (measured at interior face at each side wall). The design provides for 2 entrances on the headwall. Each door measures 14' 8" wide by 14' 2" high over 14'0" by 14'0" openings. The design provides for internal magazine access by rail and truck. Sited for 350,000 pounds NEW. This drawing number represents the most recent design of three versions of the Box Type M Magazine that have been constructed. The initial design was approved by DDES-B-KO memo of 9 Apr 93 for construction at NAVWPNSTA Seal Beach. Two subsequent design variations were approved by DDES-B-KO memo of 1 Dec 99, for construction at NAVWPNSTA Yorktown. All new construction of Box Type M ECM will be in accordance with drawings 10400001 through 10400027.

- Type: Reinforced concrete box, Type M
- Dimensions: 124' length x 81' width x 24.5' height
- Door type: 2 separate built-up steel, sliding doors on headwall over 14' x 14' openings
- Design validation is from a 1991 NCEL BODD (Seal Beach) along with 1999 Mason & Hanger calculations (Yorktown)

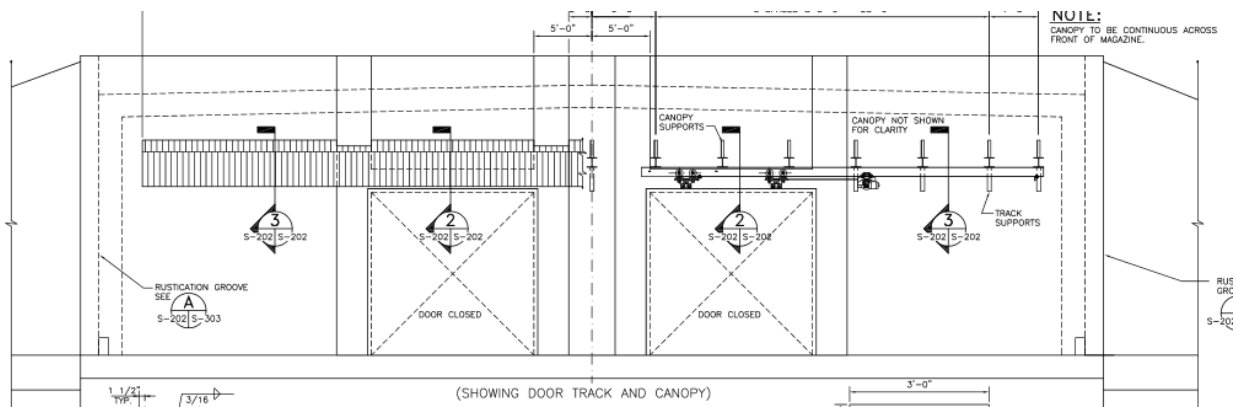


Figure 1: Front Elevation of Type M ECM

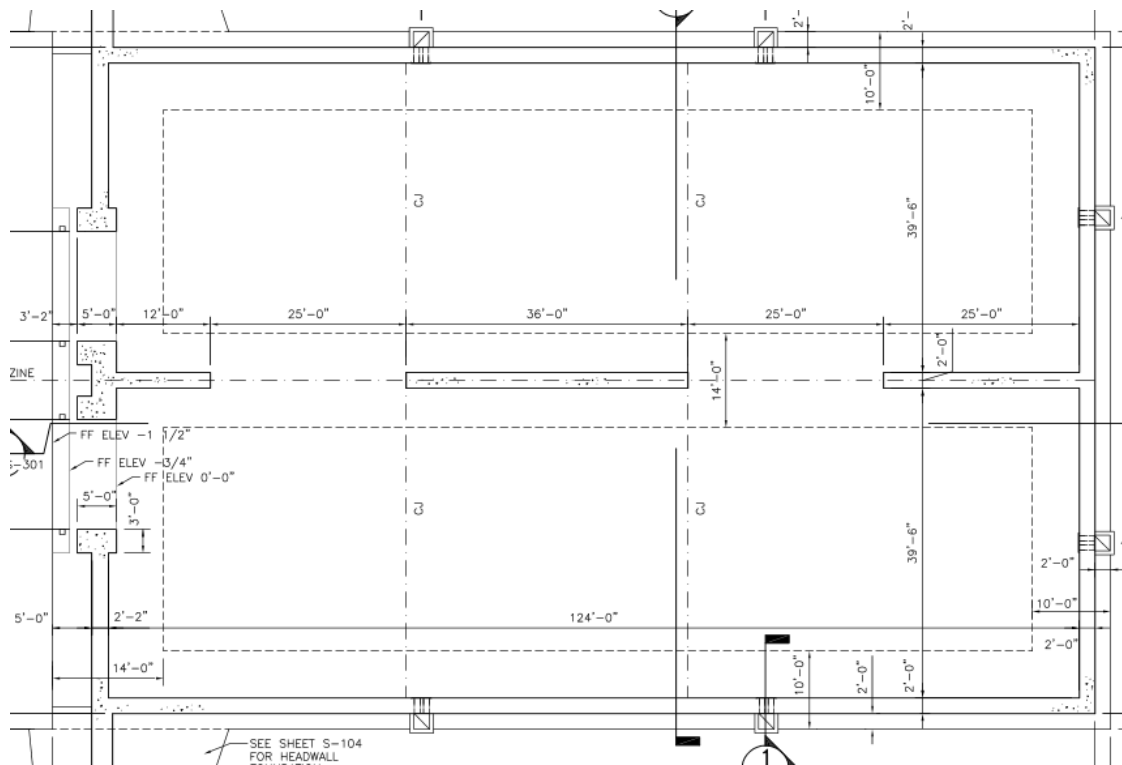


Figure 2: Floor Plan of Type M ECM

14004689 through 14004720 and 14005091 through 14005122 (Navy Type C)

DRAWING NO. (NOTE 1)	DRAWING DATE	DESCRIPTION (1)	DESIGN AGENT	DDES APPROVAL DATE	ECM DESIGNATION	COMMENTS: (Notes 2 and 3)
14004689 through 14004720, (without loading dock) and 14005091 through 14005122, (with loading dock)	10-May-17	RC Box, Type C	NAVFAC	25-Sep-17	7-Bar	This design supercedes the previous version of 14004689 through 14004720 and 14005091 through 14005122 dated 15 December 2010. Revision dates on drawings vary, so the DDES approval memo references the drawing date of 10 May 2017. Internal dimensions are 50' deep by 94' 8" wide by 13' 8" (rear of magazine) to 15' 10" (front of magazine) high. Three (3) entrances are provided on the headwall. Each of the 3 sliding doors measures 26' 6" wide by 12' high over 25'0" wide by 11'0" high openings. Sited for 350,000 pounds NEW. Original DDES approval of the Type C magazine was documented in a memo dated 11 May 85. DDES memo of 2 February 2006 approved an increase of the maximum, allowable NEW to 500,000 lbs of HD 1.1. This revision incorporates lessons learned from recent projects, including increases to rebar splice and development lengths and changing light fixtures to LEDs.

- Type: Reinforced concrete box, Type C
- Dimensions: 50' length x 94'8" width x 13'8" height
- Door Type: 3 separate built-up steel, sliding doors on headwall over 25' x 11' openings
- Design validation include Navy calculations IAW UFC 3-340-02

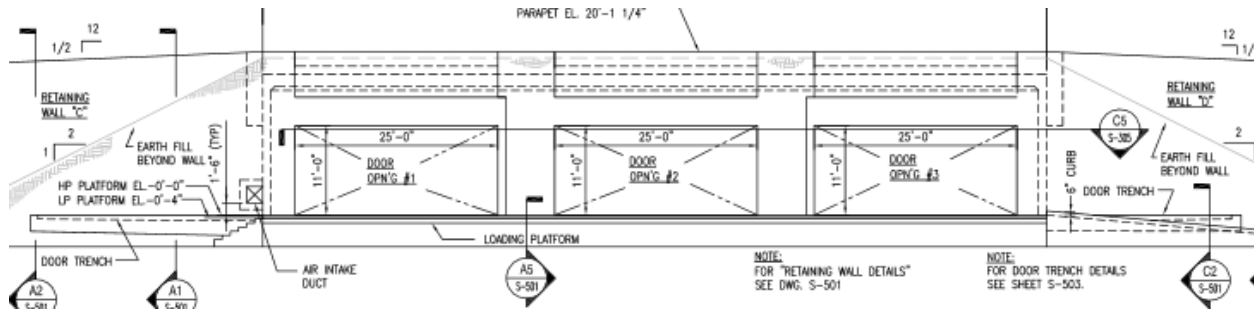


Figure 3: Front Elevation of Type C ECM

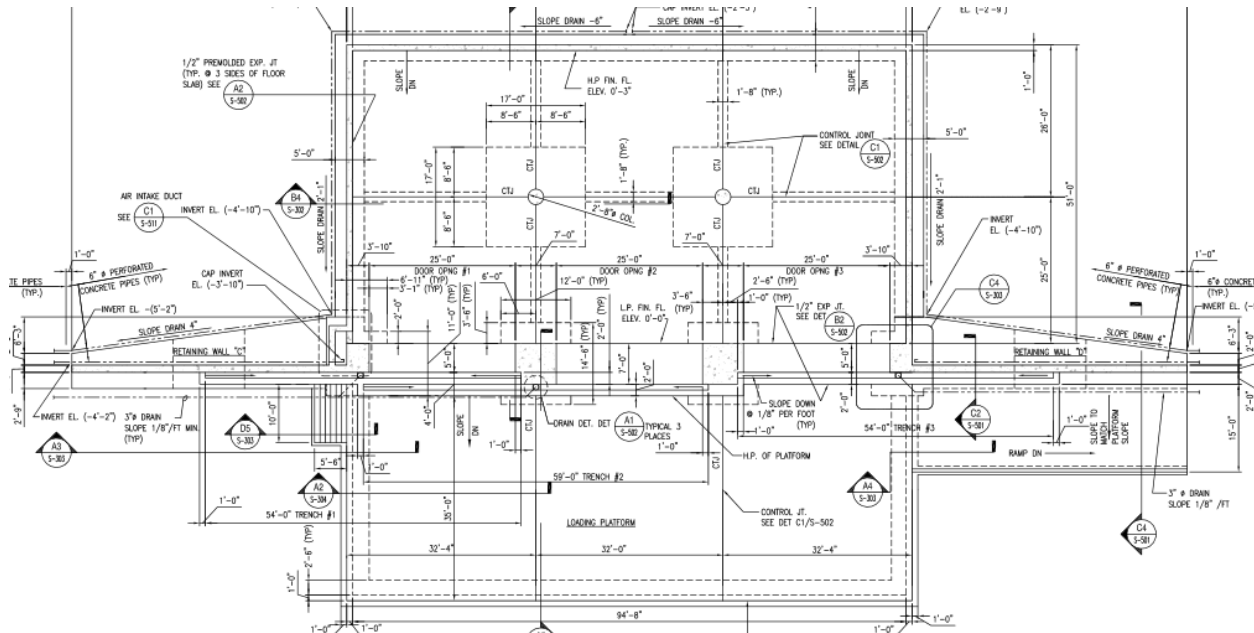


Figure 4: Floor Plan of Type C ECM

14026988 through 14027031 (Navy MSM)

DRAWING NO. (NOTE 1)	DRAWING DATE	DESCRIPTION (1)	DESIGN AGENT	DDESB APPROVAL DATE	ECM DESIGNATION	COMMENTS: (Notes 2 and 3)
14026988 through 14027031	31-May-13	RC Box, MSM	NAVFAC	31-Jul-13	7-Bar	The standard is based on the design of the Hill AFB Munitions Storage Magazine (see Table AP1-2) with the following changes: The new standard includes a sliding door and an option for environmental controls. Internal dimensions are 25'0" wide by 80'0" long by 14'8" high. The allowable HD 1.1 explosive limit is 500,000 lbs. The design is presented in metric units. This magazine has higher seismic limits than other MSMs. It also is equipped with a robust sliding steel door with concrete fill, providing a greater level of physical security. The door opening measures 25'0" wide by 14'8" high. The design includes an optional air conditioning room with associated equipment.

- Type: Precast concrete box, “modular storage magazine (MSM)”
- Dimensions: 80’ length x 25’ width x 14’8” height
- Door Type: Sliding steel door w/ concrete fill (for higher physical security) over 25’x14’8” door opening
- Design validation: Designed IAW UFC 3-340-02 by NAVFAC EXWC
- Other Notes:
 - Greatly increased seismic limits ($S_s=1.95$, $S_1=0.75$)
 - Includes optional air conditioning room/penetrations

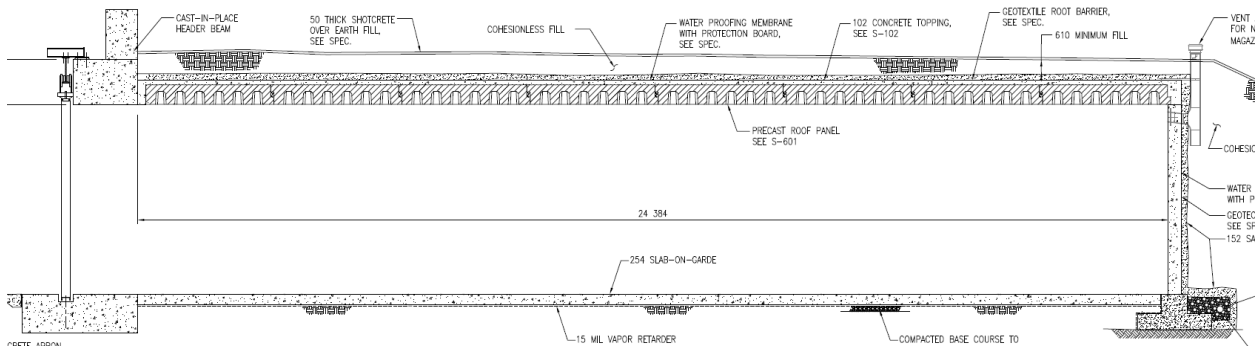


Figure 5: Cross-section of Navy MSM

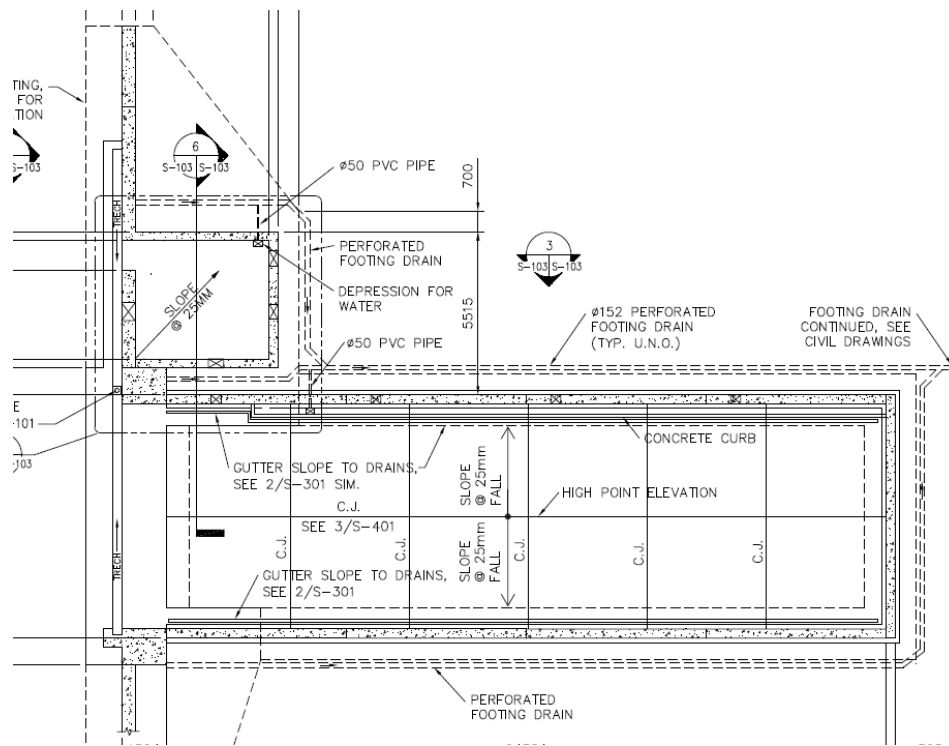


Figure 6: Floor Plan of Navy MSM with HVAC room option

18232899 through 18232936 and 18232939 through 18232978 (Navy Type D)

DRAWING NO. (NOTE 1)	DRAWING DATE	DESCRIPTION (1)	DESIGN AGENT	DDES APPROVAL DATE	ECM DESIGNATION	COMMENTS: (Notes 2 and 3)
18232899 through 18232936. (without platform) and 18232939 through 18232978. (with platform)	May-17	RC Box, Type D, Rev. 1	NAVFAC	19-Jul-17	7-Bar	Superseded NAVFAC 14021368 through 14021404 and 14021406 through 14021444. Internal dimensions are 50' deep by 158' 8" wide by 13' 8" (rear of magazine) to 15' 10" (front of magazine) high. Five (5) entrances are provided on the headwall. Each of the 5 sliding doors measures 26' 3" wide by 120" high over 25' 0" wide by 11' 0" high openings. Sited for up to 500,000 pounds NEW. This revision incorporates lessons learned from recent projects, including increases to rebar splice and development lengths and changing light fixtures to LEDs.

- Type: Reinforced concrete box, Type D
- Dimensions: 50' length x 158' 8" width x 13' 8" height
- Door Type: 5 separate built-up steel, sliding doors on headwall over 25' x 11' openings
- Design validation: Designed by Navy IAW UFC 3-340-02

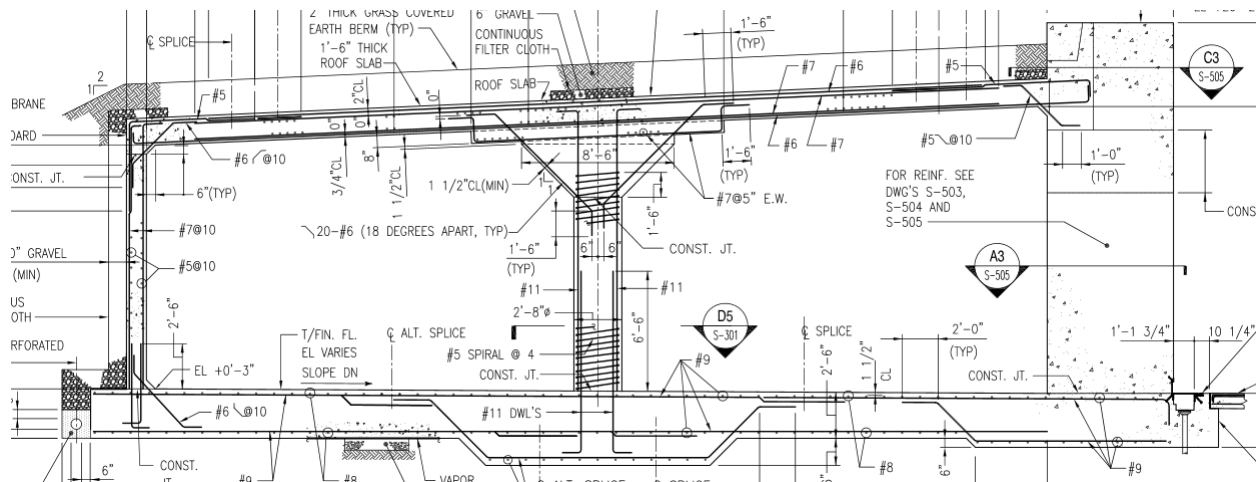


Figure 7: Cross-section of Type D ECM

33-15-74 (Korean Version)

DRAWING NO. (NOTE 1)	DRAWING DATE	DESCRIPTION (1)	DESIGN AGENT	DDESB APPROVAL DATE	ECM DESIGNATION	COMMENTS: (Notes 2 and 3)
33-15-74 (Korean Version)	August 2000/modified March 2006	RC FRELOC Stradley	Korean Ministry of Defense	23 Sep 2003 and 26 July 2006	7-Bar	This design is the approved version of the Republic of Korea Army (ROKA) drawing for 33-15-74, Igloo Type Storage (63 Pyung). The original basis for the Korean version was U.S. Army COE 33-15-74. The Korean drawings assure that all reinforcing steel is electrically continuous. The design specifies the use of a single sliding door which measures 10' 10" wide by 10' 3" high over an opening that measures 10'0" by 10'0". The previous version of this drawing was approved by the DDESB as a 7-Bar magazine on 25 May 2002. DDESB-PD Memorandum of 26 July 2006 approved design changes which added a mechanical room and several penetrations for the addition of air conditioning.

- Type: Reinforced Concrete arch, FRELOC Stradley
- Dimensions: 90' length x 25' width x 14' max height
- Door Type: Built-up steel door (10' x 10')
- Design validation:
 - Predecessor (33-15-13) tested in ESKIMO V (1977)
 - Door & headwall originally from 33-15-73, tested in ESKIMO III (1974)
- Other Notes:
 - 2006 modification added option for air conditioning room/penetrations
 - Metric version of 33-15-74 (predecessor of 421-80-09)

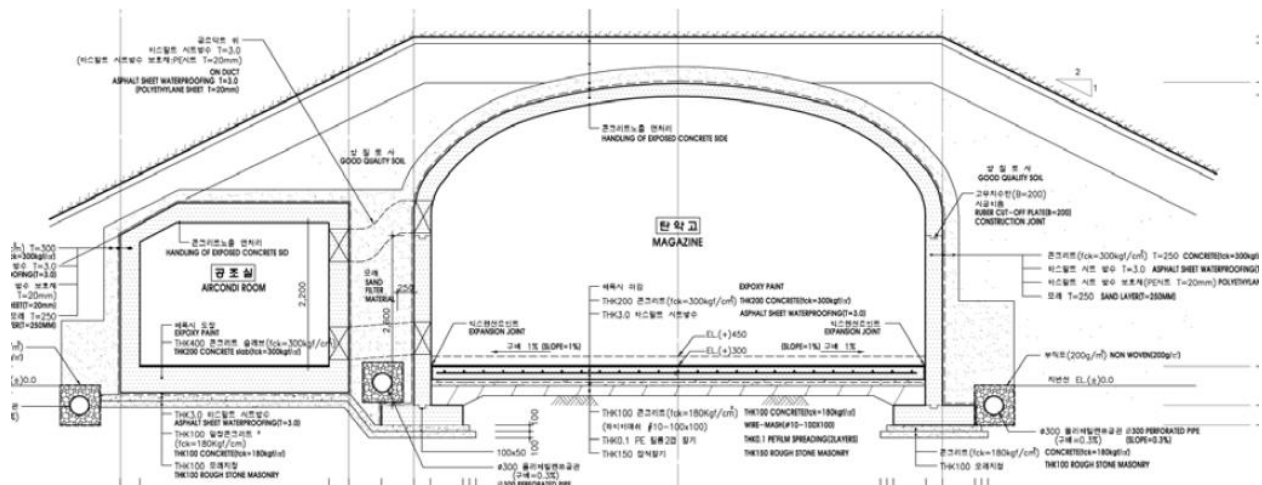


Figure 8: Cross-section of Korean 33-15-74 with HVAC room option

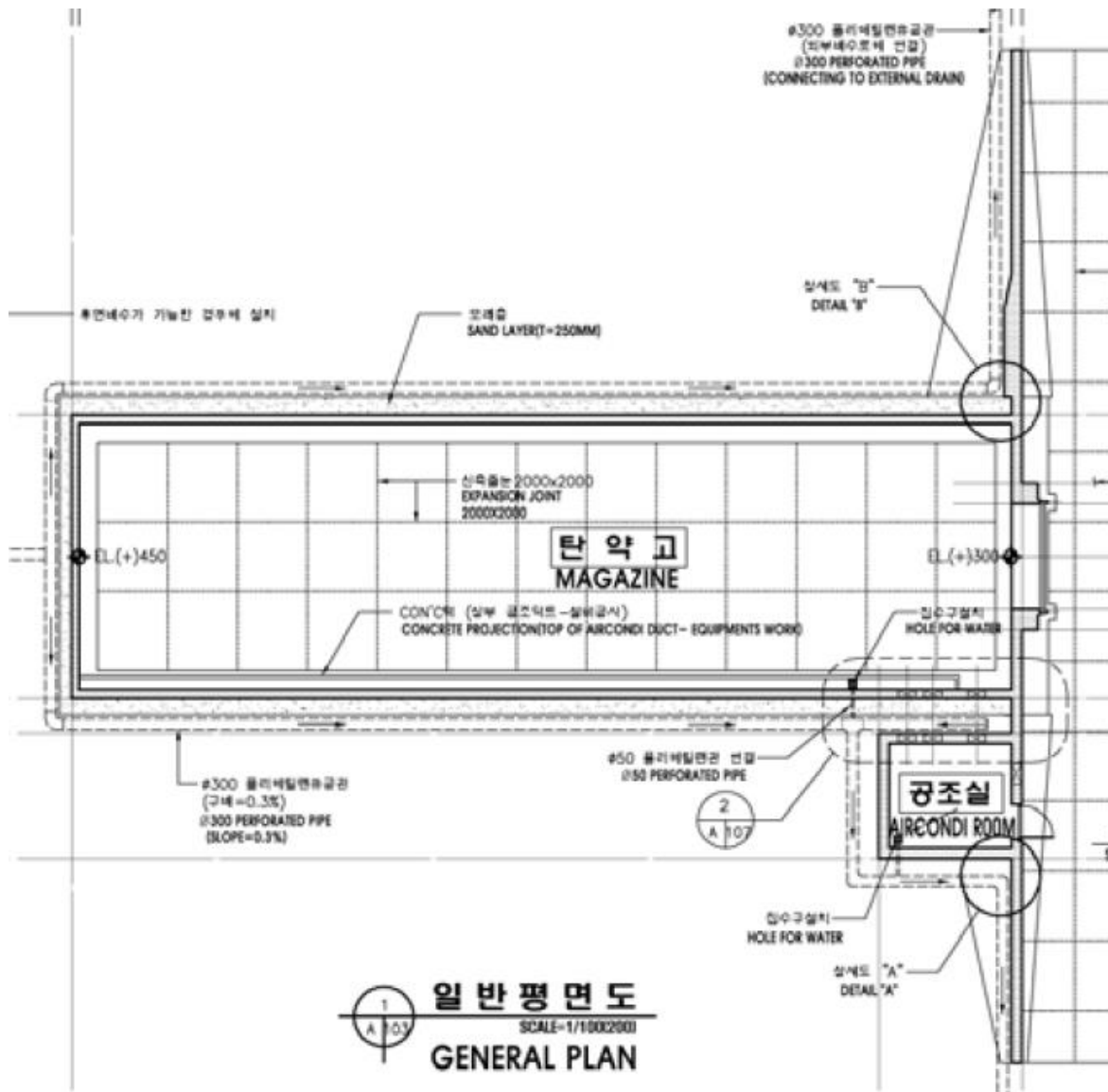


Figure 9: Floor Plan of Korean 33-15-74 with HVAC room option

421-80-01

DRAWING NO. (NOTE 1)	DRAWING DATE	DESCRIPTION (1)	DESIGN AGENT	DDES APPROVAL DATE	ECM DESIGNATION	COMMENTS: (Notes 2 and 3)
421-80-01	5-Feb-88	Steel, Semi-circular Arch	COE	28-Jun-88	7-Bar	Replaced 33-15-64. Drawing permits the use of a 2" deep or 5.5" deep corrugated steel arch. Internal width and height dimensions are approximately 26' wide by 13' 6" high. The minimum internal length is 19', expandable up to the most commonly used magazine length of 89'. The magazine has a single entrance with 2 size options with sliding steel doors: a) 8'0" wide by 8'0" high (8'10" wide by 8'3" high door), or b) 10'0" wide by 10'0" high (10'10" wide by 10'3" high door).

- Type: Steel corrugated arch, semi-circular (2" or 5.5" corrugation)
- Dimensions: 19' to 89' length x 26' width x 13.5' max height
- Door Type: Built-up steel door w/ 2 size options (8' x 8' and 10' x 10')
- Design validation:
 - Predecessor (AW 33-15-64) tested in steel arch test (1962-63) & ESKIMO I (1971)
 - Door & headwall originally from 33-15-73, tested in ESKIMO III (1974)
- Other Notes:
 - Electrical updates at DDESB for review
 - Will be replaced by 421-80-12 in coming months

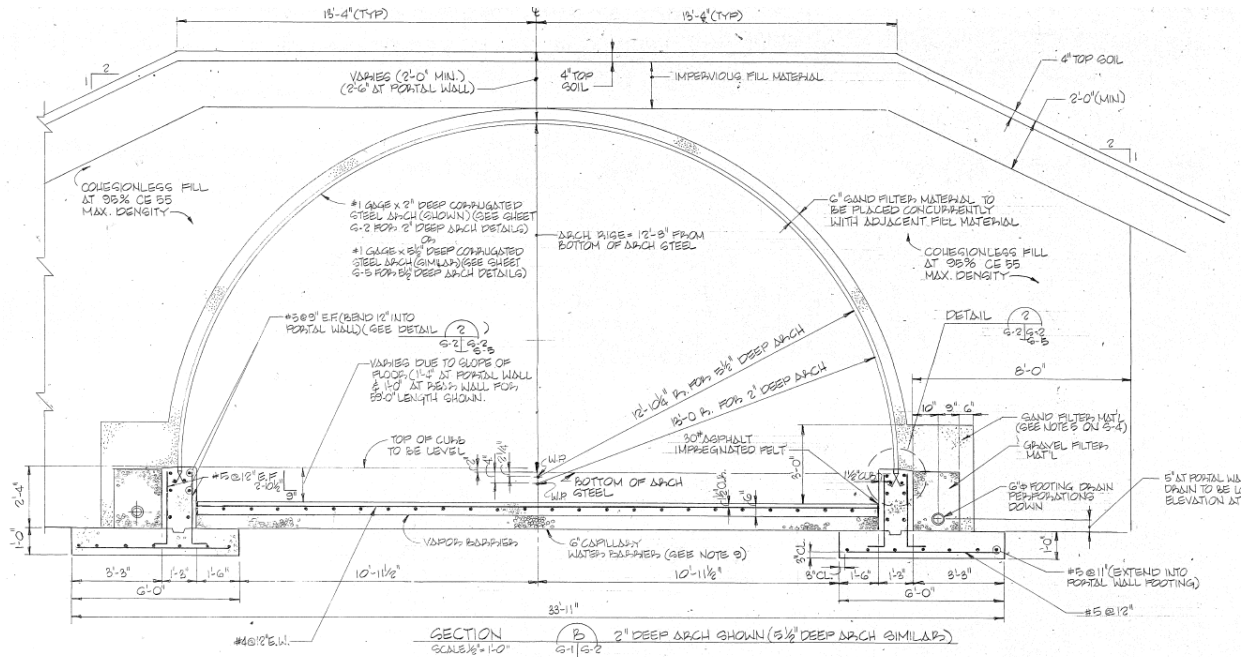


Figure 10: Cross-section of 421-80-01

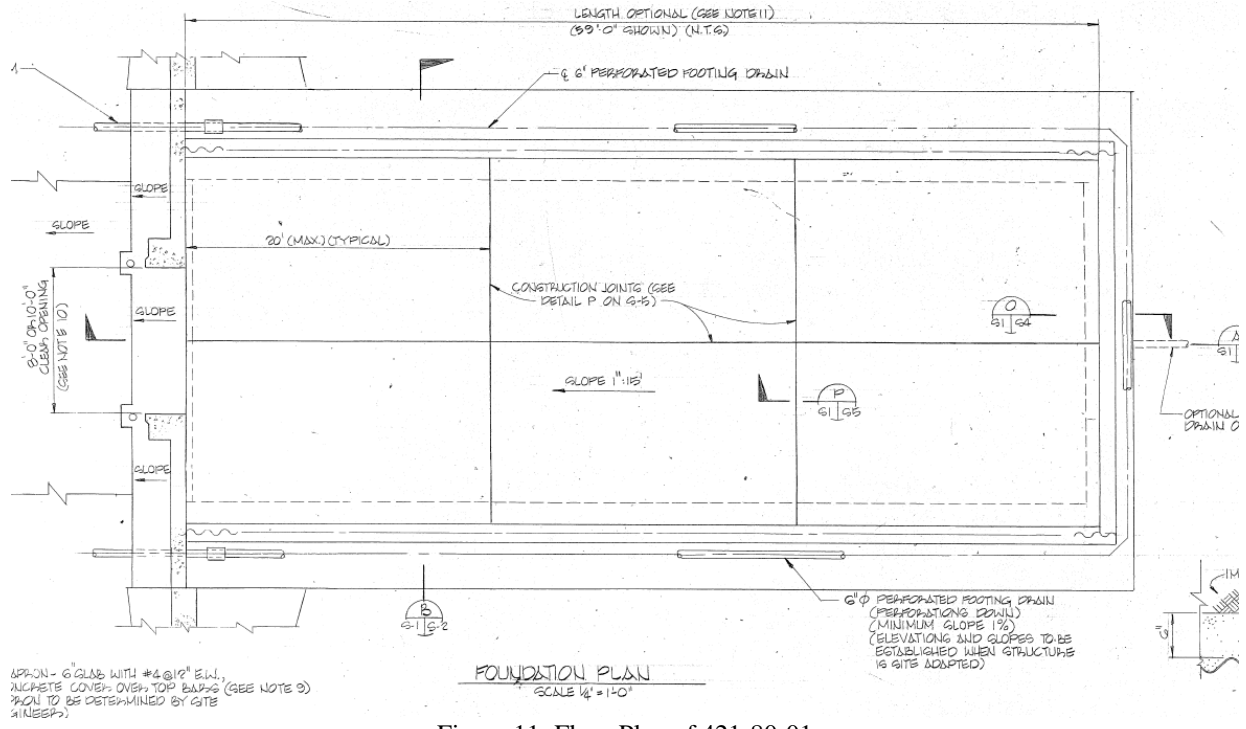


Figure 11: Floor Plan of 421-80-01

421-80-03

DRAWING NO. (NOTE 1)	DRAWING DATE	DESCRIPTION (1)	DESIGN AGENT	DDES APPROVAL DATE	ECM DESIGNATION	COMMENTS: (Notes 2 and 3)
421-80-03	30-Oct-92	Steel, Oval Arch	COE	28-Dec-92	7-Bar	Replaced 33-15-73. Arch design composed of a 1 gage (0.280 inch) corrugated steel arch. Internal dimensions are 24' wide (measured from base of steel arch) by 21' (minimum) to 89' maximum length. Arch height is 14' 5". The magazine has a single entrance with 2 size options with sliding steel doors: a) 8'0" wide by 8'0" high (8'10" wide by 8'3" high door), or b) 10'0" wide by 10'0" high (10'10" wide by 10'3" high door). DDES approval signature of 28 Dec 1992 on drawings. Thirty-nine ECM based on this design drawing were constructed at Camp Leatherneck, Afghanistan, using the CONTECH SUPER-SPAN Mode1102A15-24 High Profile Arch. DDES approval memo DDES-PE of 6 Oct 2010 approved the use of this arch as meeting the arch requirements of 421-80-03, thereby considering the ECM as 7-bar structures.

- Type: Steel corrugated oval-arch
- Dimensions: 21' to 89' length x 24' width x 14.5' max height
- Door Type: Built-up steel door w/ 2 size options (8' x 8' and 10' x 10')
- Design Validation: Predecessor (33-15-73) tested in ESKIMO III (1974)
- Other Notes:
 - Electrical updates at DDES for review
 - Will be replaced by modernized design in near future

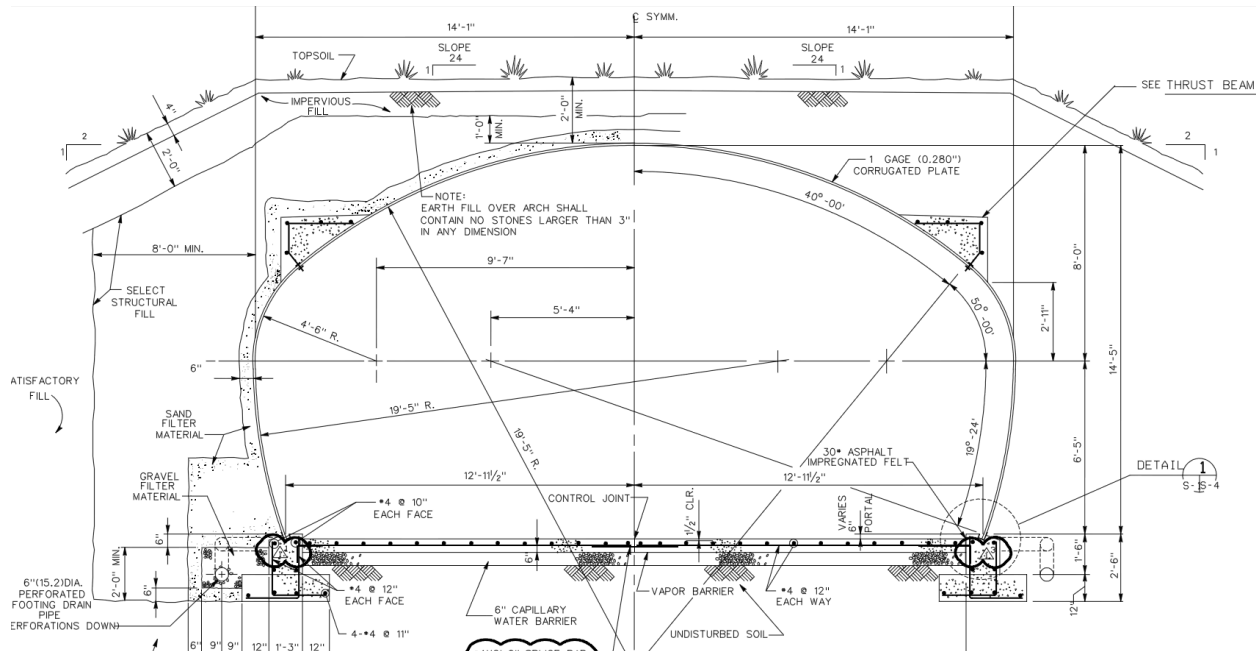


Figure 12: Cross-section of 421-80-03

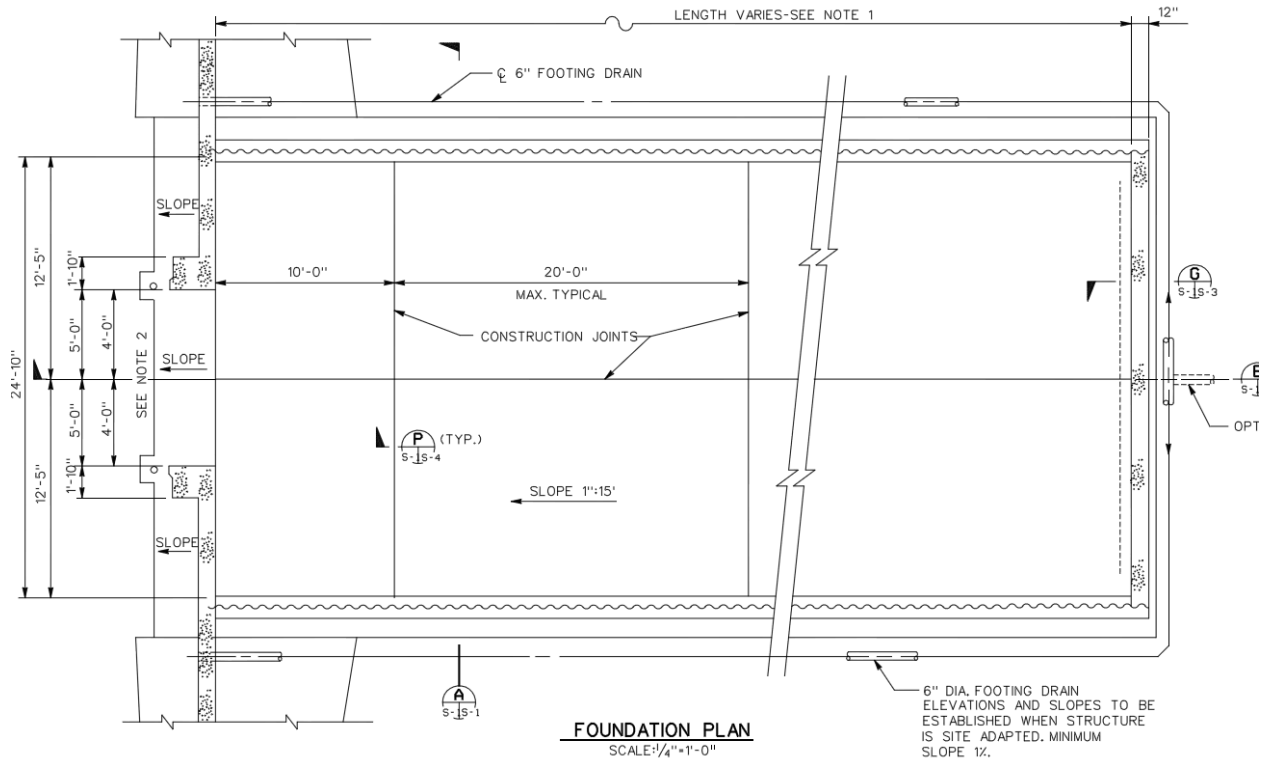


Figure 13: Floor Plan of 421-80-03

421-80-05

DRAWING NO. (NOTE 1)	DRAWING DATE	DESCRIPTION (1)	DESIGN AGENT	DDES APPROVAL DATE	ECM DESIGNATION	COMMENTS: (Notes 2 and 3)
421-80-05	1-Sep-98	RC Arch	COE	8-Sep-98	7-Bar	Constructed using the Techspan Precast Concrete System, developed by the Reinforced Earth Company, for arch construction. The headwall and door are derived from 33-15-74. Internal dimensions are 25' 11" wide by 90" maximum (normally length is 60' or 80') by 14' high (largest clearance at center of magazine). The magazine has a single entrance with 2 size options with sliding steel doors: a) 8'0" wide by 8'0" high (8'10" wide by 8'3" high door), or b) 10'0" wide by 10'0" high (10'10" wide by 10'3" high door).

- Type: Precast concrete arch, semi-circular (Techspan proprietary system)
- Dimensions: 60' to 90' length x 26' width x 14.5' max height
- Door Type: Built-up steel door w/ 2 size options (8' x 8' and 10' x 10')
- Design validation:
 - No direct validation of arches (approval based on previous RC arch testing)
 - Current door & headwall originally from 33-15-73, tested in ESKIMO III (1974)
- Other Note: Will be replaced by 421-80-11 in coming months

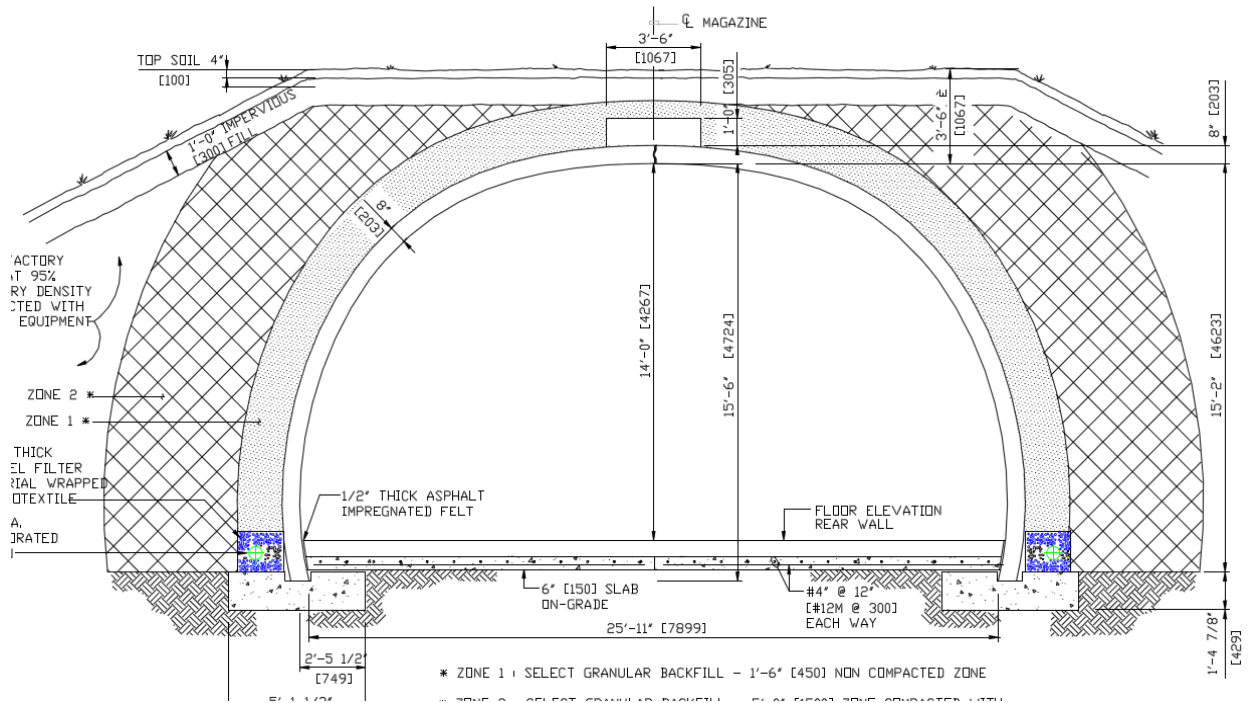


Figure 14: Cross-section of 421-80-05

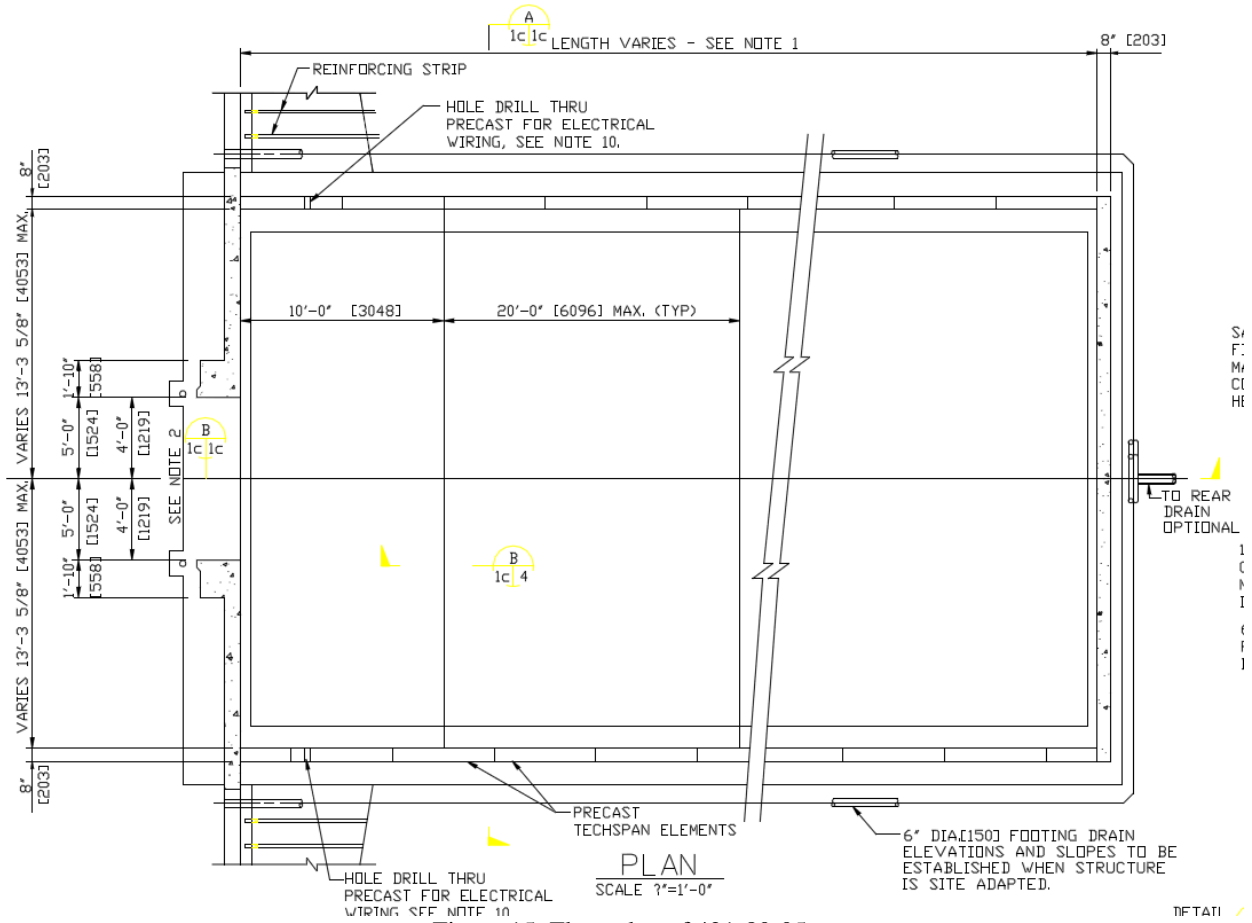


Figure 15: Floor plan of 421-80-05

421-80-07

DRAWING NO. (NOTE 1)	DRAWING DATE	DESCRIPTION (1)	DESIGN AGENT	DDESB APPROVAL DATE	ECM DESIGNATION	COMMENTS: (Notes 2 and 3)
421-80-07	2-Dec-11	RC Box, MSM	COE	27-Dec-11	7-Bar	This design supersedes 421-80-06 (modified). This series updates the drawings to meet current AEC CAD standards, improved plan readability, constructability, and correct omissions within the construction drawings. Internal dimensions are 25'0" wide by 20'0" minimum length to 80'0" maximum length by 11'0" high. The front opening consists of two hinged doors, each measuring 12'2" wide by 10'8" high. The door opening measures 24'0" wide by 10'4" high. The magazine can be sited for 500,000 lbs NEW.

- Type: Precast concrete box, “modular storage magazine (MSM)”
- Dimensions: 20’ to 80’ length x 25’ width x 11’ height
- Door Type: Double swinging door, built-up steel over 24’x10’4” door opening
- Design validation
 - 1988 modular igloo test validated all components but roof
 - Redesigned roof validated in 1992 HEST test
- Superseded 421-80-06 (modified) in 2011

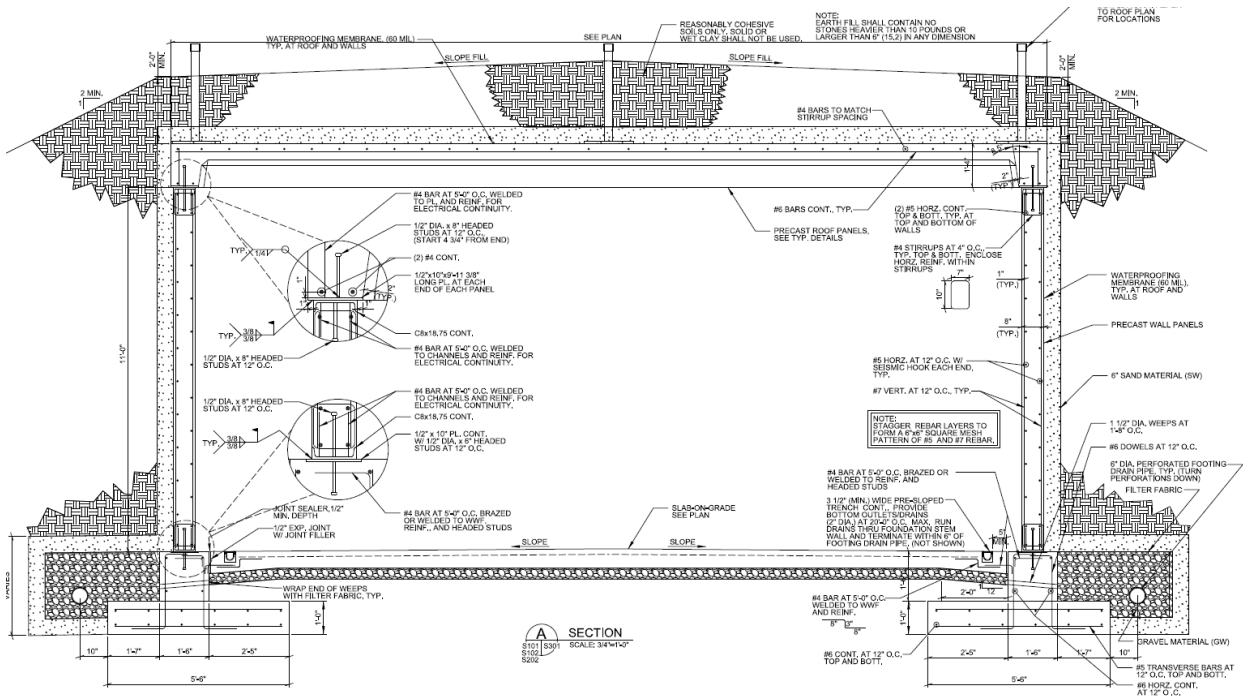


Figure 16: Cross-section of 421-80-07

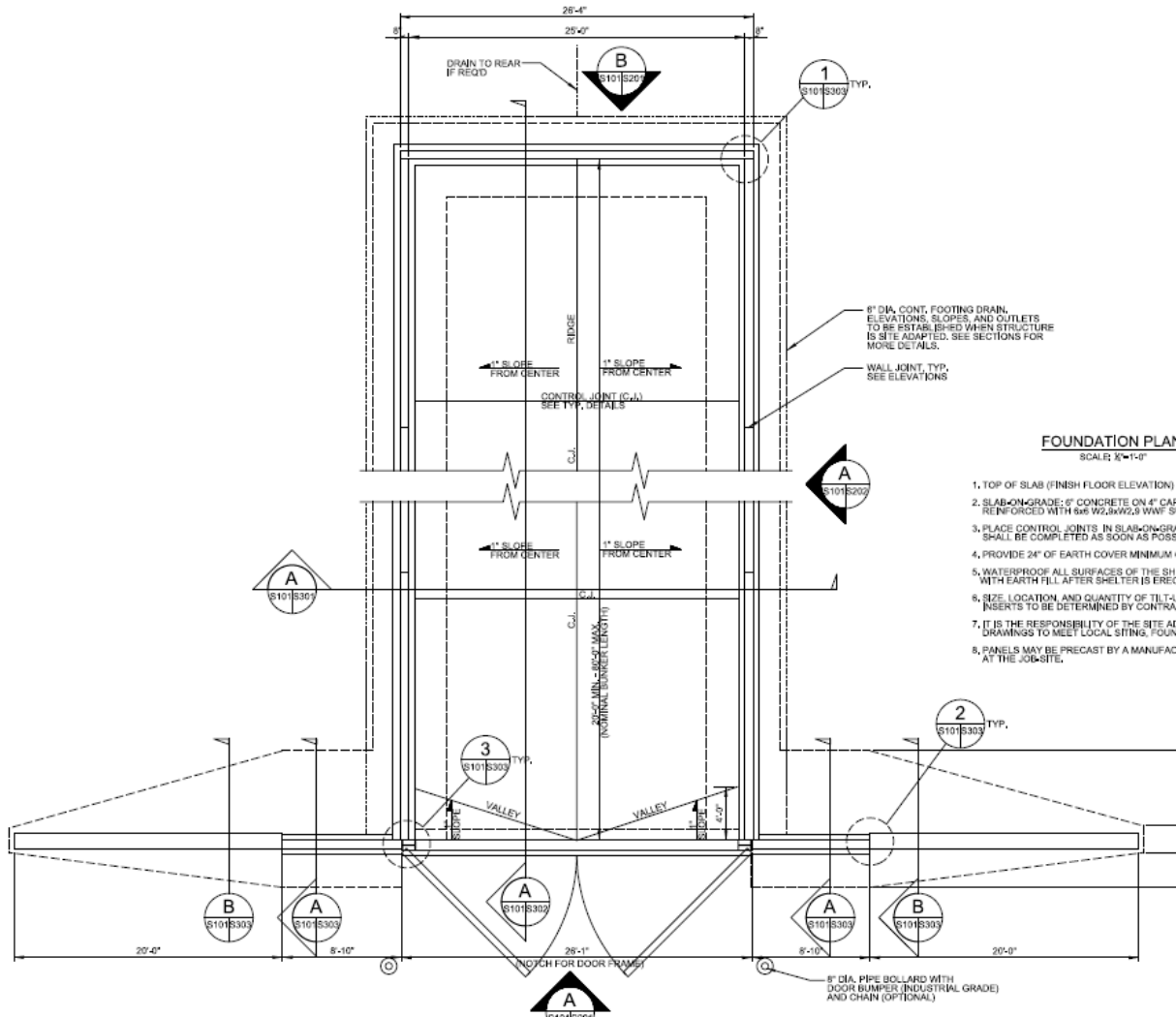


Figure 17: Floor Plan of 421-80-07

421-80-08

DRAWING NO. (NOTE 1)	DRAWING DATE	DESCRIPTION (1)	DESIGN AGENT	DDESB APPROVAL DATE	ECM DESIGNATION	COMMENTS: (Notes 2 and 3)
421-80-08	Jun-13	RC Box MSM	COE	15-Jul-13	7-Bar	This design supersedes the Munitions Storage Magazine (MSM) as designed for Hill AFB. This series updates the drawings to meet current AEC CAD standards, and features improved plan readability, constructability, and corrects omissions within the construction drawings. Internal dimensions are 25'0" wide by 20'0" minimum length to 80'0" maximum length by 14'8" high. The front wall consists of two hinged doors, each measuring 12'-1/4" wide by 13'-1/2" high. The door opening measures 24'0" wide by 13'-11" high. The magazine can be sited for 300,000 lbs NEW.

- Type: Precast concrete box, “modular storage magazine (MSM)”
- Dimensions: 20’ to 80’ length x 25’ width x 14’8” height
- Door Type: Double swinging door, built-up steel over 24’x13’11” door opening
- Design validation
 - 1988 modular igloo test validated all components but roof
 - Redesigned roof validated in 1992 HEST test
 - Analysis of door performed by EASE, Inc. to verify larger door has “at least equivalent strength” as original MSM door
- Superseded Hill AFB MSM in 2013

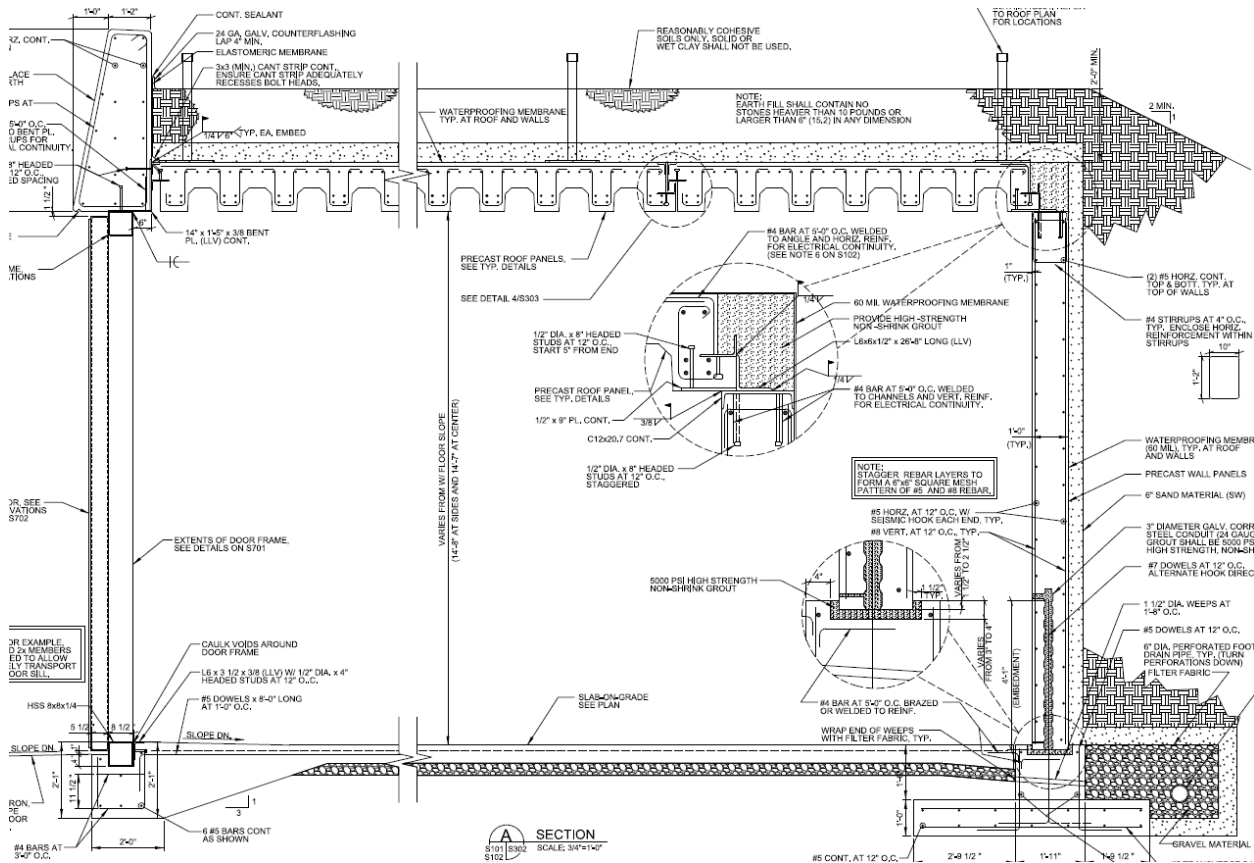


Figure 18: Cross-section of 421-80-08

421-80-09

DRAWING NO. (NOTE 1)	DRAWING DATE	DESCRIPTION (1)	DESIGN AGENT	DDESB APPROVAL DATE	ECM DESIGNATION	COMMENTS: (Notes 2 and 3)
421-80-09	Sep-13	RC FRELOC Stradley	COE	10-Oct-13	7-Bar	This design supersedes 33-15-74. This series updates the drawings to meet current AEC CAD standards, improves plan readability, constructability, and corrects omissions within the construction drawings. Headwall components have been re-analyzed under the 7-bar blast loading from DoD 6055.09-M using the methodology of UFC 3-340-02. The remaining components are as originally designed. Internal dimensions are 25'0" wide by 20'0" minimum length to 90'0" maximum length by 14'0" maximum arch height. The magazine has a single entrance with 2 size options with sliding steel doors: a) 8'0" wide by 8'0" high (8'10" wide by 8'3" high door), or b) 10'0" wide by 10'0" high (10'10" wide by 10'3" high door).

- Type: Reinforced Concrete arch, FRELOC Stradley
- Dimensions: 20' to 90' length x 25' width x 14' max height
- Door Type: Built-up steel door w/ 2 size options (8' x 8' and 10' x 10')
- Design validation
 - Predecessor (33-15-13) tested in ESKIMO V (1977)
 - Door & headwall originally from 33-15-73, tested in ESKIMO III (1974)
- Superseded 33-15-74 in 2013

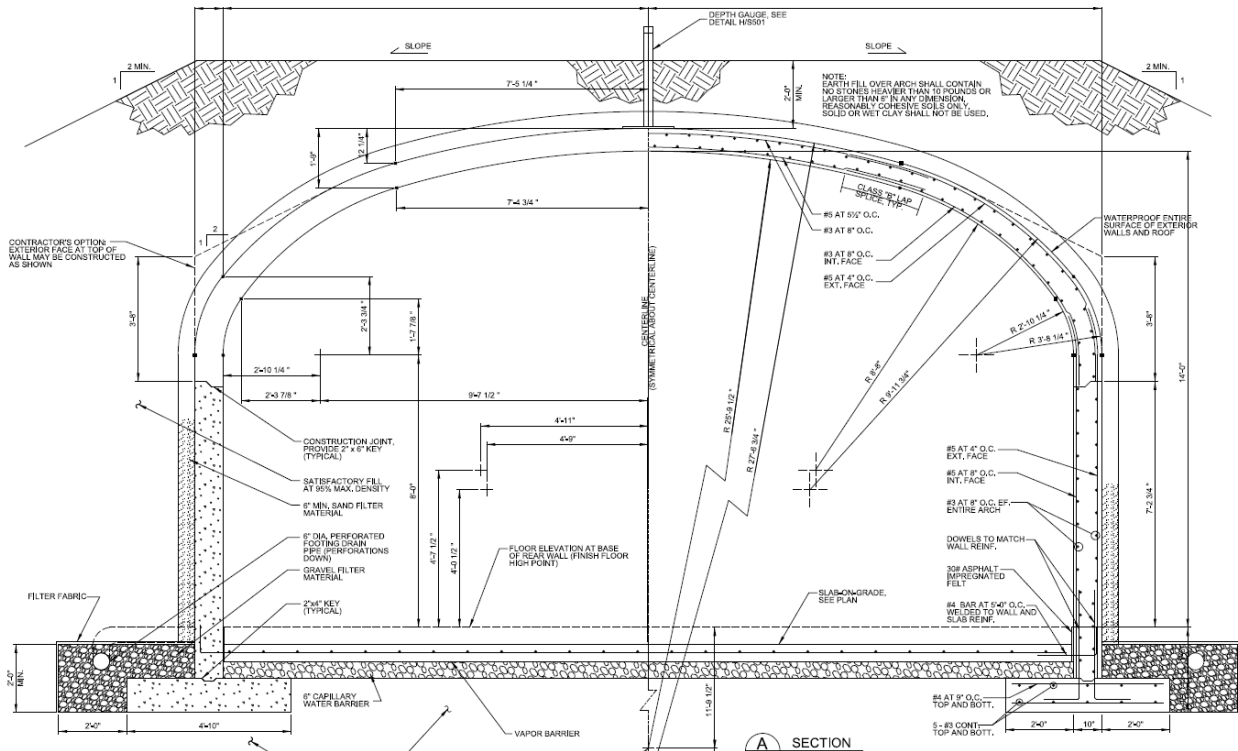


Figure 19: Cross-section of 421-80-09

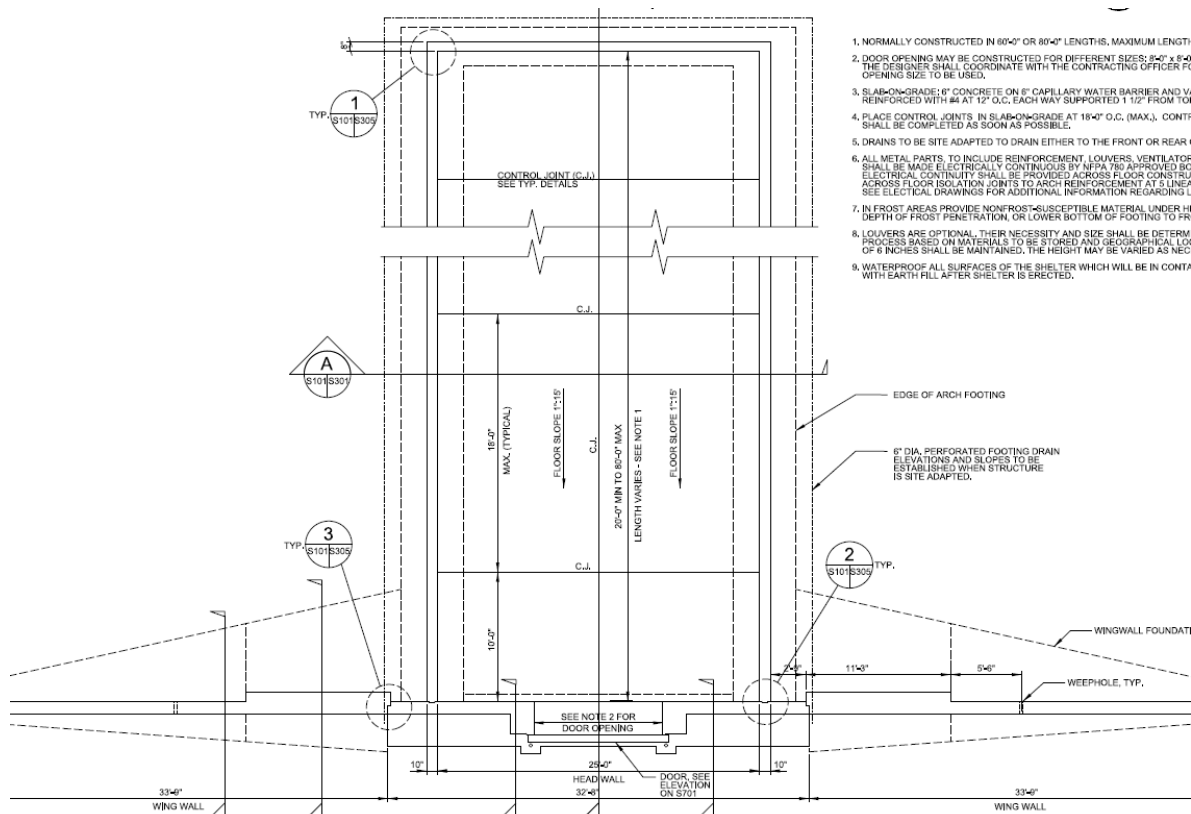


Figure 20: Floor Plan of 421-80-09

References

1. DoDM 6055.09, "DoD Ammunition and Explosives Safety Standards," Volumes 1 through 8, date varies by volume.
2. DDESB Technical Paper 15, "Approved Protective Construction," Revision 3, May 2010.
3. Unified Facilities Criteria (UFC) 3-340-02, "Structures to Resist the Effects of Accidental Explosions," 5 December 2008, Incorporating Change 2, 1 September 2014.
4. Unified Facilities Criteria (UFC) 4-420-01, "Ammunition and Explosives Storage Magazines," 1 May 2015.
5. DDESB-PD Memorandum, Subject: Explosives Safety Quantity-Distances for Type I, Type IIA and Type IIB Smokeless Powder/Projectile Magazines, 8 March 2016.