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# Steel Box Earth-Covered Magazine

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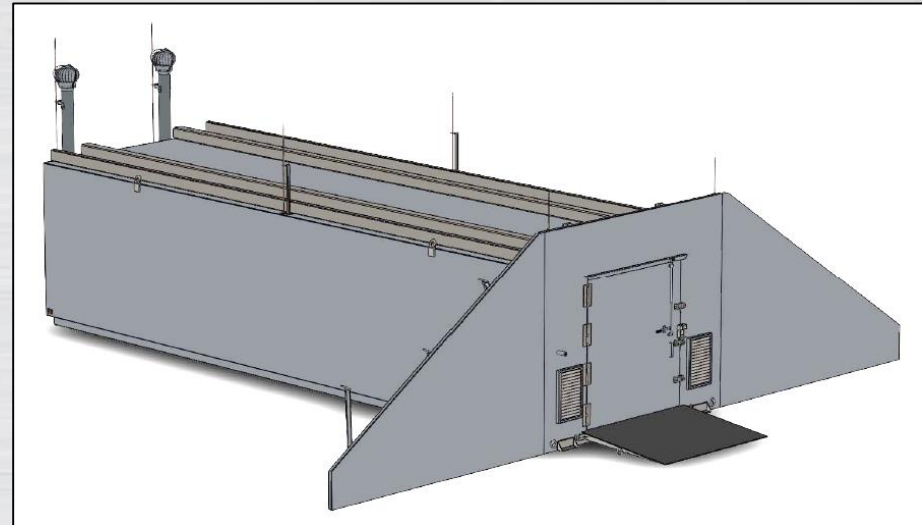
Joseph Haydon – ARMAG Corporation

# Overview

- Introduction
- Purpose and Uses
- Basis of Design
- Magazine Design
  - ▶ Vertical Loading
  - ▶ Horizontal Loading
- Conclusions

# Introduction

- Currently seeking formal approval for the design of a steel-box earth-covered magazine (ECM)
- Seeking incorporation into DDESB TP-15
- Passed review of U.S. Army Corps of Engineers as well as the U.S. Army Technical Center for Explosives Safety (USATCES)
- Seeking 3-bar headwall designation



# Purpose and Uses

- Provide a cost-effective, expedited method to utilize reduced ECM criteria for explosives storage
- Other current ECM designs have significant drawbacks
  - ▶ Significant cost (\$1M+ for an arch ECM and \$3-5M for a box-type ECM)
  - ▶ Lengthy on-site construction
- The ARMAG pre-fabricated ECM solves these issues
  - ▶ Anticipated cost of \$325,000 including concrete pad, delivery, and earthwork
  - ▶ On-site construction involves only a concrete pad and earthwork
- Acquisition can also potentially be simplified in that the ARMAG ECM may be able to be purchased using equipment funds, if applicable acquisition procedures allow

# Purpose and Uses

- The ARMAG ECM provides an explosives storage option that can also alleviate limitations within existing storage facilities
  - ▶ In many locations, limited existing facilities are used to store Hazard Division (HD) 1.1 materials as well as less-restrictive HD 1.3 and 1.4 materials
  - ▶ Existing facilities can be prioritized to store the HD 1.1 materials if desired, whereas the ARMAG ECM is well-suited to store material from any HD
- Storage space for large munitions (e.g., containerized missiles) is usually at a premium at storage locations
  - ▶ When smaller palletized material also requires storage, it often is required to utilize space within limited magazines
  - ▶ The ARMAG ECM is ideal for storing palletized materials, alleviating critical space within larger magazines for larger munitions



# Basis of Design

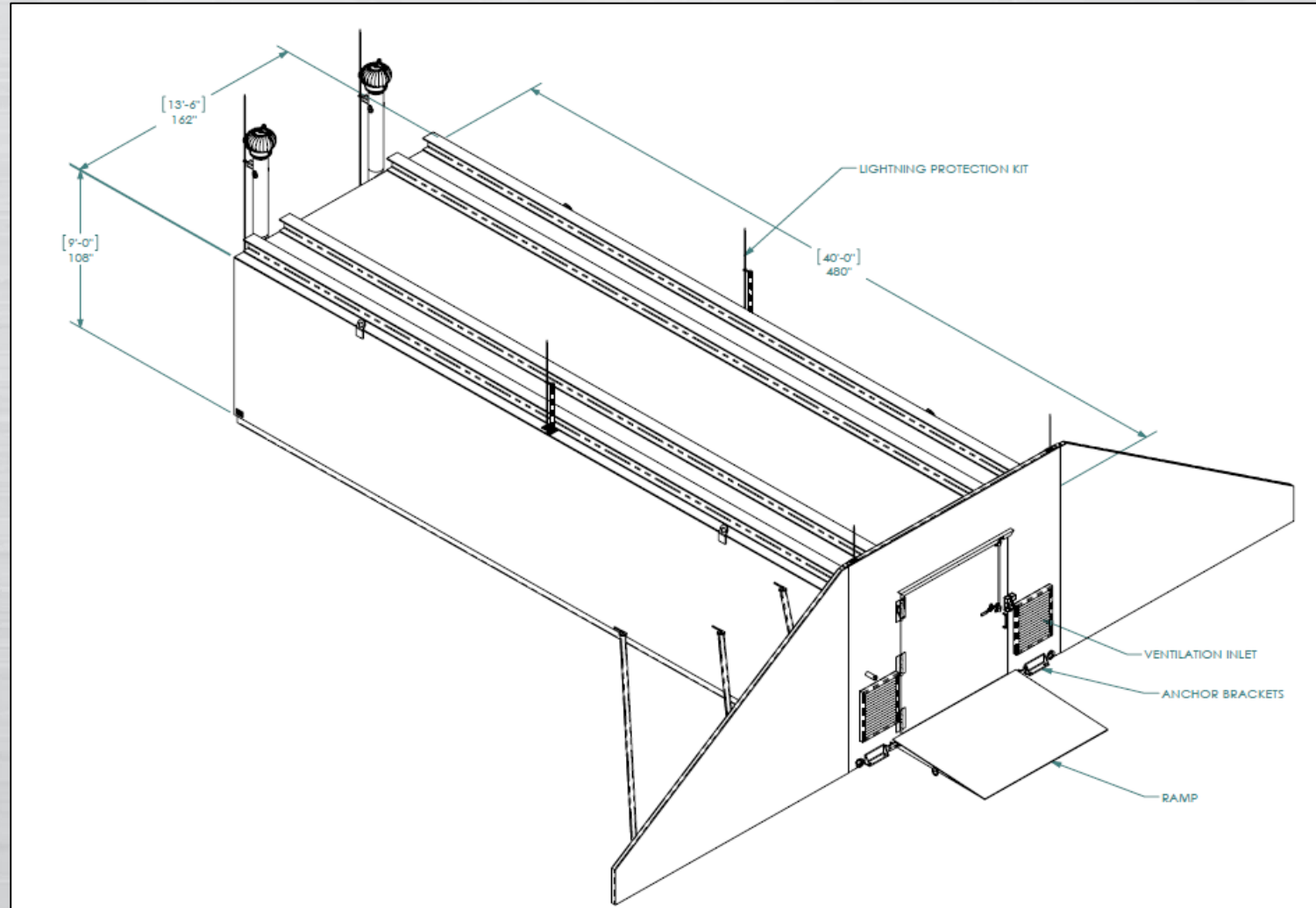
- Designed as a mid-level storage capacity magazine
- 3-bar headwall designation
- Design NEW limit of 50,000 lb HD 1.1
- Design loads obtained from DoD 6055.09-M
  - ▶ Flat roof design load
    - 108 psi
    - Calculated impulse of 700 psi-ms (duration of 13 ms)
  - ▶ 3-bar headwall loading
    - 43.5 psi
    - Calculated impulse of 416 psi-ms (duration of 19 ms)

# Basis of Design

- Headwall is 5/8<sup>th</sup> inch steel plate supported by various beam/column members
- The steel plate headwall is comparable to the large steel doors of currently approved ECM types

Magazine	Headwall size	Door size	% Door (approximate)	Thickness of Steel
33-15-74	25 ft x 14 ft (arched)	10 ft x 10 ft	33%	5/8 <sup>th</sup> inch
RC Box Type C	95 ft x 16 ft	(3) 26 ft x 12 ft	62%	13/16 <sup>th</sup> inch
RC Box Type D	159 ft x 16 ft	(5) 25 ft x 11 ft	54%	13/16 <sup>th</sup> inch
421-80-07 (MSM)	25 ft x 11 ft	24 ft x 10 ft	87%	3/8 <sup>th</sup> inch

# Magazine Design





# Magazine Design

- Box-shaped, 40 feet in length, 13.5 feet wide, and 9 feet tall
- Headwall plate and wing-walls extend above the ECM roof and to the sides to support the soil backfill
- Magazine door is a single-leaf design, 7 feet in width
- Lightning protection system and ventilation stacks
- For additional views and sections of the magazine, please refer to the ARMAG ECM drawings

# Magazine Design

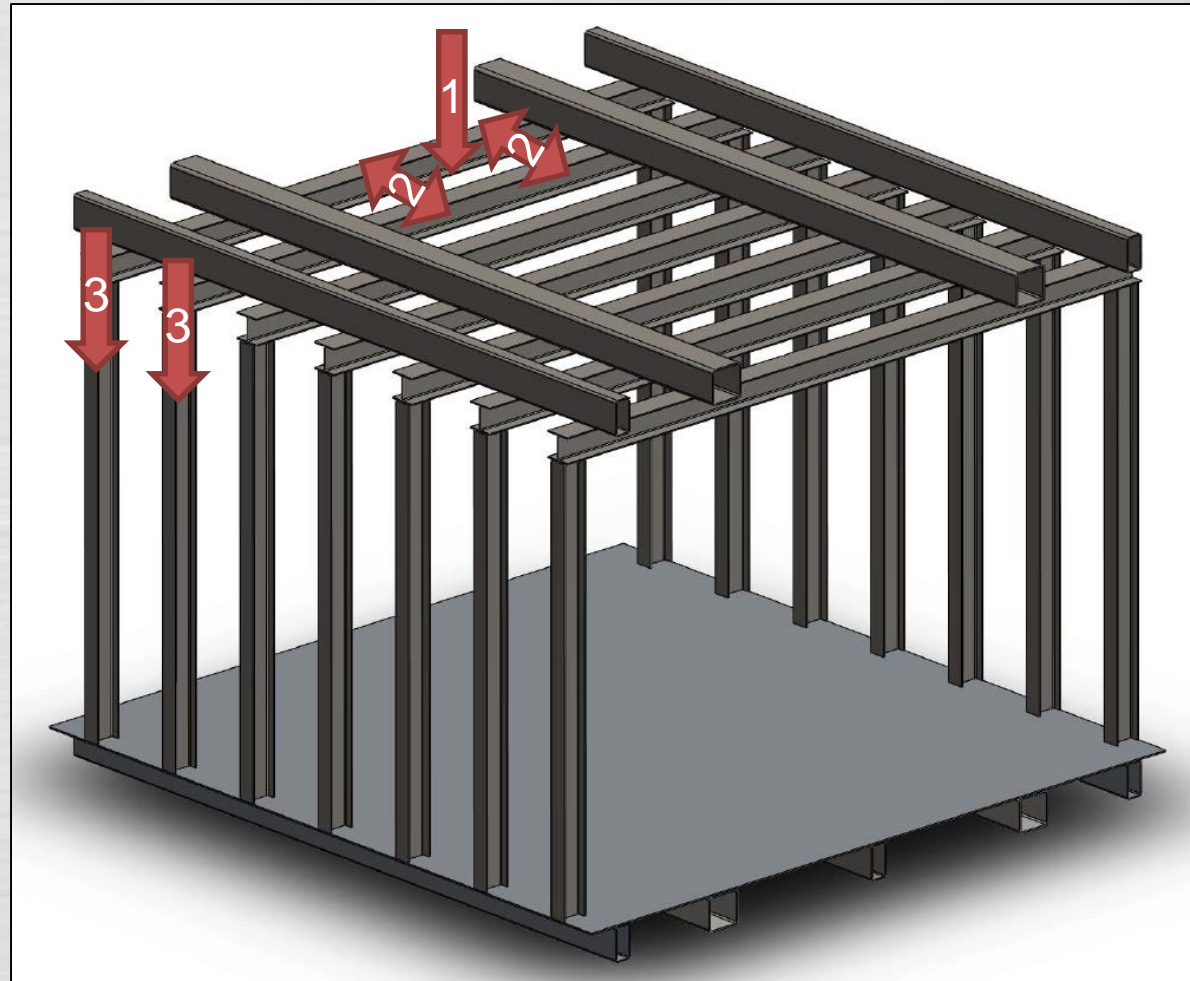
- The blast-resistant structural system has two focus areas:
  - ▶ Vertical roof load
  - ▶ Horizontal headwall load
- The magazine is designed in accordance with United Facilities Criteria (UFC) 3-340-02, “Structures to Resist the Effects of Accidental Explosions”
- Each beam or column component is welded to an adjacent steel plate in 6-inch intervals along the length of the member, though the added flexural capacity is conservatively neglected
- Connections are designed to be simple bearing connections wherever possible to avoid moment transfer
- Rebound loads for all elements and connections are considered

# Vertical Loading

- Blast loading of 108 psi
- Additional loads totaling 519 lb/ft<sup>2</sup>:
  - ▶ Dead load of 2.5 ft of wet soil (456 lb/ft<sup>2</sup>)
  - ▶ Combined live and snow load (63 lb/ft<sup>2</sup>)
- Dynamic analyses for the vertical loads consider two scenarios:
  - ▶ Maximum dead load of 519 lb/ft<sup>2</sup>
  - ▶ Minimum dead load of 240 lb/ft<sup>2</sup> (2 ft of dry soil in order to minimize the dynamic effect of the soil)
- Shear loads were verified for all cases
- Dynamic analysis shows that the worst-case scenario for deflection is the minimum dead load

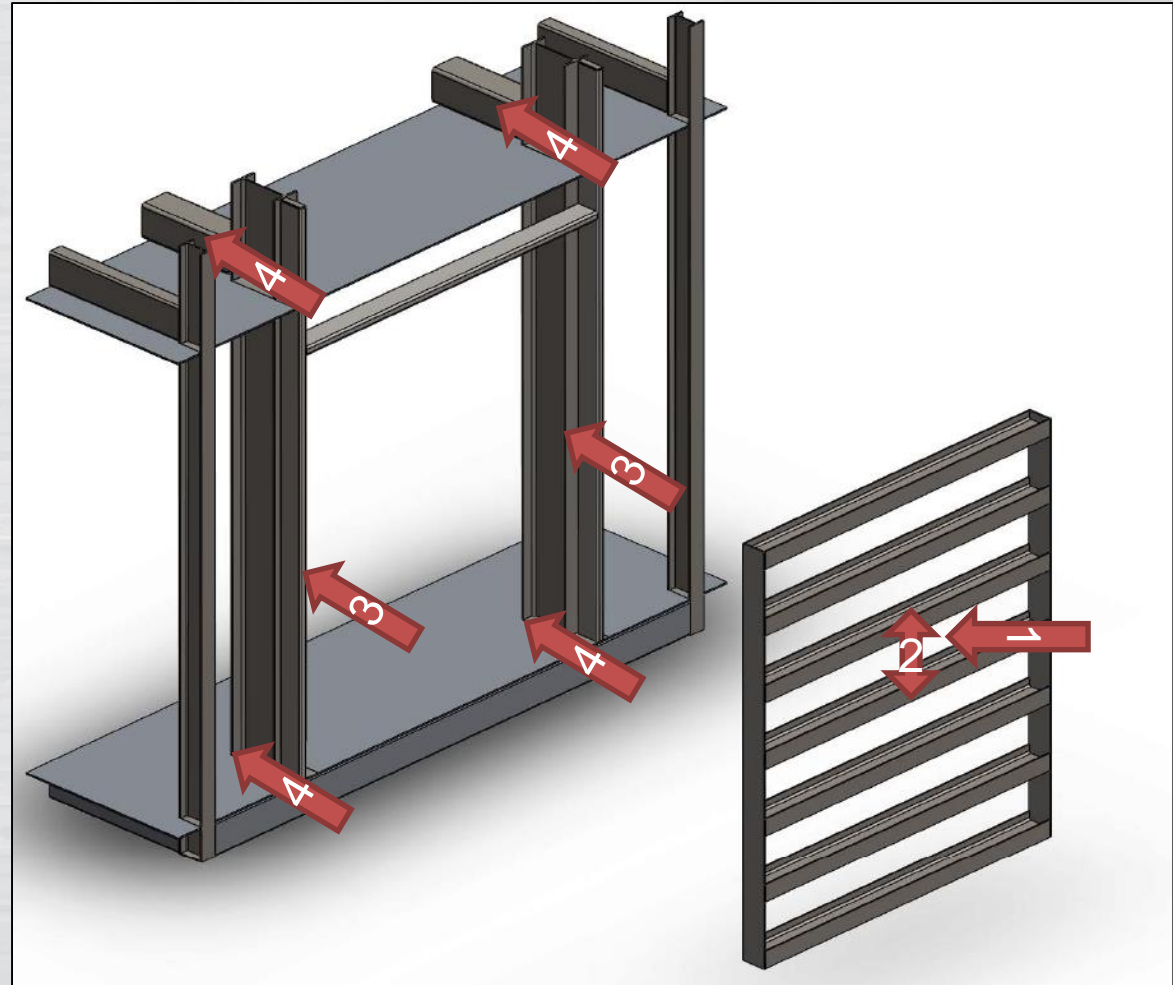
# Vertical Loading

1. Load bears on 3/8<sup>th</sup> inch steel roof plate (not shown)
2. Transfers to W6x20 roof beam (24 inch on center)
3. Bears on W6x12 sidewall column; minimum moment transfer between roof beam and sidewall column



# Horizontal Loading - Door

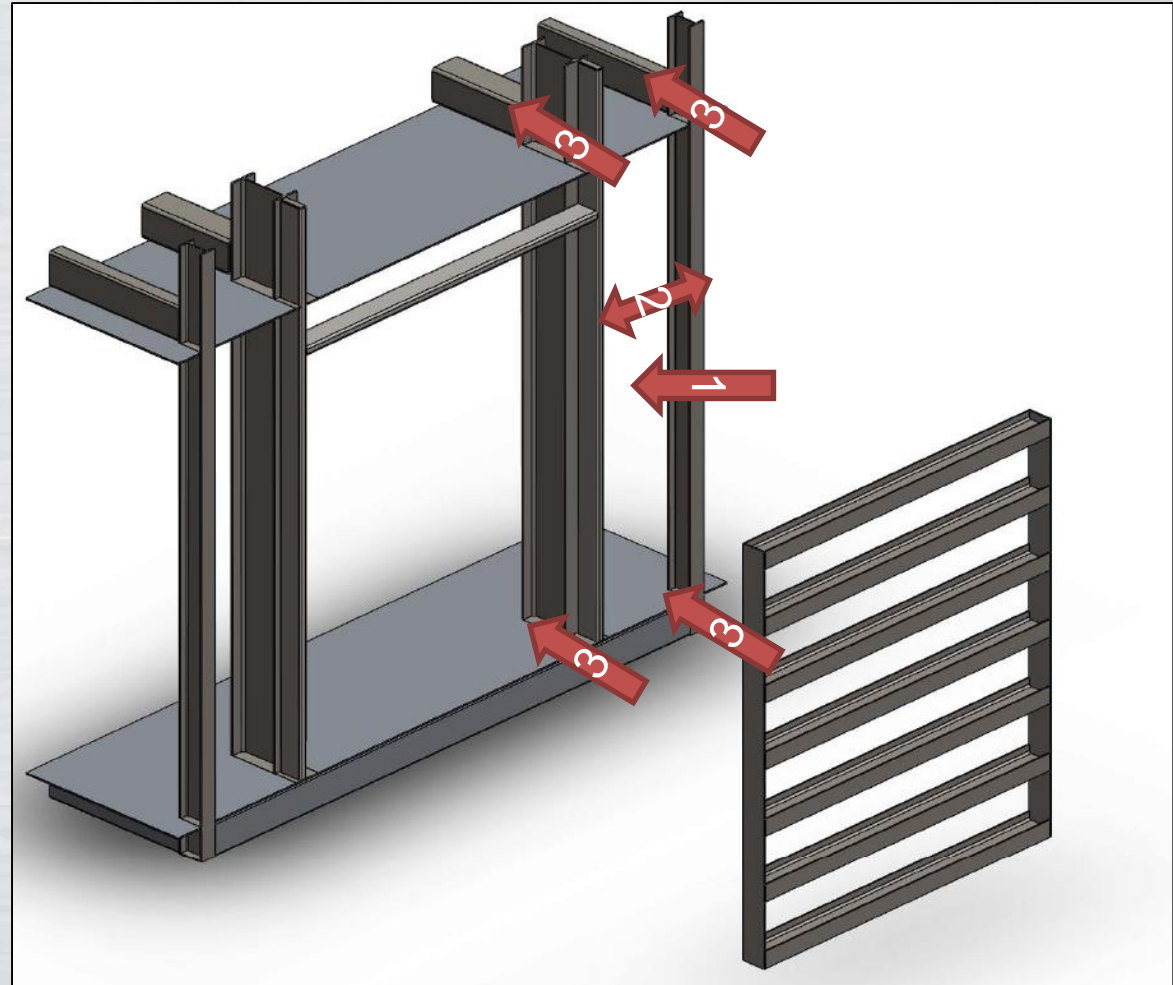
1. Load bears on 5/8<sup>th</sup> inch steel door plate (not shown)
2. Transfers to W6x12 door beams
3. Bears on W12x35 door frame column
4. Bears on longitudinal hollow structural steel (HSS) 8x8x3/8 roof & floor beams





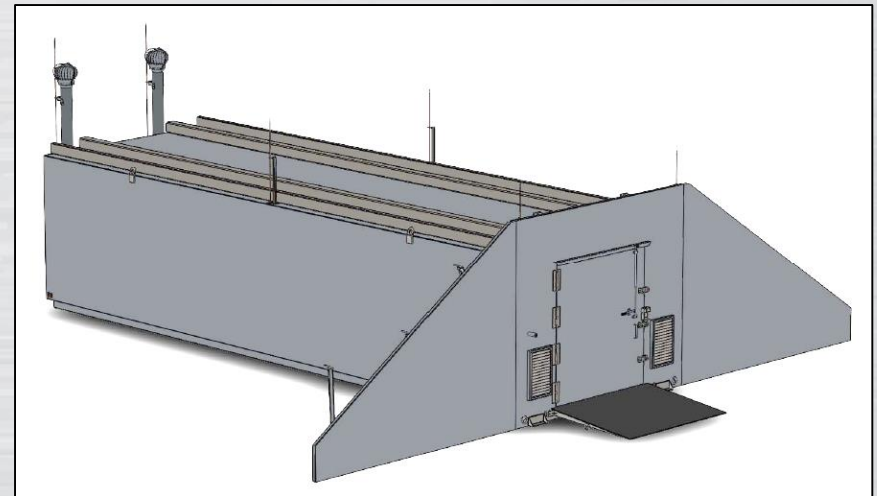
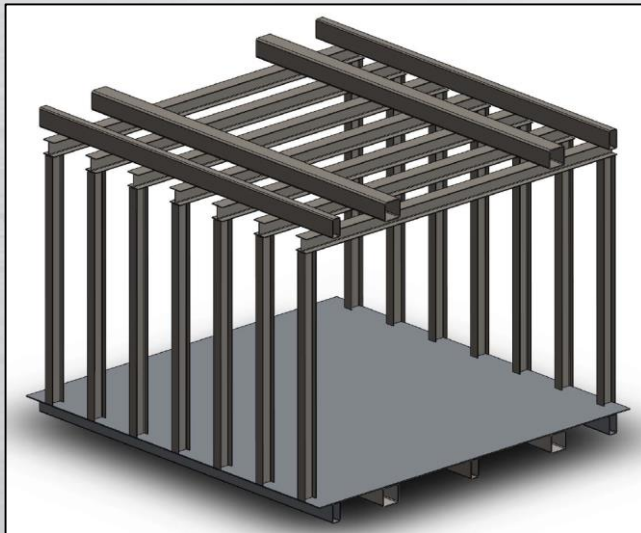
# Horizontal Loading - Headwall

1. Load bears on 5/8<sup>th</sup> inch steel headwall plate (not shown)
2. Transfers to W12x35 door frame column and W6x16 headwall column
3. Bears on longitudinal HSS 8x8x3/8 and HSS 8x4x1/4 roof & floor beams



## Horizontal Loading – Longitudinal Beams

- Specially designed steel HSS compression members running the 40-foot length of the magazine roof and floor
  - ▶ Welded to the magazine roof providing a path for the headwall loads to transition into the structure over the entire length
  - ▶ Connection is a simple pinned/bearing connection
  - ▶ Ensures that the roof acts as a one-way transverse element



# Conclusions

- The ARMAG ECM provides a convenient, cost-effective option for storage of practical quantities of explosives articles utilizing reduced separation criteria for ECM structures
- The design of the ARMAG ECM meets and exceeds UFC 3-340-02 requirements
- Additional details will be available as the design progresses through the DoD review process
- Contact ARMAG for additional details

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