

# EARTH COVERED-MAGAZINES STRUCTURAL INTEGRITY ASSESSMENTS (ECMSIA)

*Author/Presenter: Jeff Coulston, PE, US Army Engineering and Support Center, Huntsville (CEHNC); ATTN: CEHNC-EDC-S (Coulston); PO Box 1600; Huntsville, AL 35807-4301; phone 256-895-1651; E-mail: Jeff. Coulston@usace.army.mil*

Keywords: earth-covered magazine, structural health, assessment, aging infrastructure, risk

## Abstract

An important element of the Department of Defense Explosives Safety Board's (DDESB) Explosives Safety Program is munitions related infrastructure. One of the actions within this element is to determine if aging Earth-Covered Magazines (ECM) have structurally degraded to a point they do not meet current structural designations (e.g. 7-bar, 3-bar, Undefined) criteria which could jeopardize significant quantities of U.S. munitions stockpile if an accidental explosion were to occur. The Army is supporting an assessment of Department of Defense (DoD) military munitions earth covered magazines (ECM) initiated and funded by the DDESB. The purpose of the structural integrity assessment is to determine the ECM type, establish the structural health, assign a structural health rating, recommend needed repairs or replacement and estimate the remaining service life of ECMs at select installations. The output of the assessment will be utilized for development of a Munitions-Related Infrastructure Recapitalization Plan the Army can use to plan and budget for the maintenance and replacement of aging infrastructure.

The structural health rating is an indication of the ECM's capability to adequately perform its intended purpose, considering its structural designation and explosives safety siting environment both as an Exposed Site (ES) and Potential Explosion Site (PES).

## *Introduction/Background*

This paper will present the ECM assessment overall approach and description of the three phases with emphasis on Phase 1 'Earth Covered-Magazine Structural Integrity Assessment'.

There are approximately 25,000 Earth-Covered Magazines (ECMs) in the Department of Defense's inventory, with most built during the World War II era and approaching 75 years of service. The arch shape and flat roof type magazines are two of the most common ECMs in use today. Figure 1 shows a picture of each shape. There are many variations of these two shapes utilized within DoD.

**Figure 1 Earth Covered Magazines Pictures**



Photo credit:  
[http://www.mcaap.army.mil/docs/info/Brochure 4 Internet.pdf](http://www.mcaap.army.mil/docs/info/Brochure%204%20Internet.pdf)



Photo Credit: Jeff Coulston

An important element of the Department of Defense Explosives Safety Board's Explosives Safety Program is munitions related infrastructure. One of the actions within this element is to determine if aging Earth-Covered Magazines (ECM) have structurally degraded to a point they do not meet current structural designations (e.g. 7-bar, 3-bar, Undefined) criteria which could jeopardize significant quantities of U.S. munitions stockpile if an accidental explosion were to occur. The DDESB initiated and is funding a comprehensive study of DoD military munitions ECMs to better understand risks to infrastructure, assess overall "structural health" of ECMs as related to their intended use for storage of explosives and predict the remaining service life of the ECMs. The study will inform a long-term Munitions-Related Infrastructure Recapitalization Plan for the assessment, maintenance, and replacement of AE storage facilities to ensure continued ability to support the mission, manage risk and protect the public. The information gained from ECM assessment can be utilized to manage risk and protect the public while ensuring the continued ability to support the mission. For FY19 to FY23, three installations were selected for the munition related infrastructure evaluation with emphasis on ECM assessments.

Currently an ECM assessment execution plan is under development for the McAlester Army Ammunition Plant (MCAAP), Crane Army Ammunition Activity (CAAA) and the Tooele Army Depot (TEAD). An assessment team consisting of personnel from the USACE Engineering and Support Center, Huntsville (CEHNC), USACE Engineering and Research Center (ERDC), NAVFAC-Atlantic and consultant firm will work with the Joint Munitions Command (JMC) and the installation personnel to execute the assessments. The total summation baseline quantity at these installation are approximately 5,000 ECMs.

In February 2018, the assessment procedures for Phase 1 of the ECM assessment were demonstrated for two typical ECMs located on CAAA. Personnel from various organizations including the U.S. Army Technical Center for Explosives Safety (USATCES) and Naval Ordnance Safety and Security Activity (NOSSA) witnessed the procedures. Initial site visits to present the assessment concept and procedures to the Installation Command were made to MCAAP and TEAD in March 2018. Data gathering also took place at these meetings.

#### ***Earth Covered Magazine General Information***

Explosives safety standards are set forth by the Department of Defense (DoD) in DoD 6055.09-M [1] and Military Service Level explosives safety documents. The DoD explosives safety management policy is to expose the minimum number of people for the minimum time to the minimum amount of explosives consistent with safe and efficient operations. The goal is to provide the maximum possible protection to people and property from the potential damaging effects of DoD military munitions.

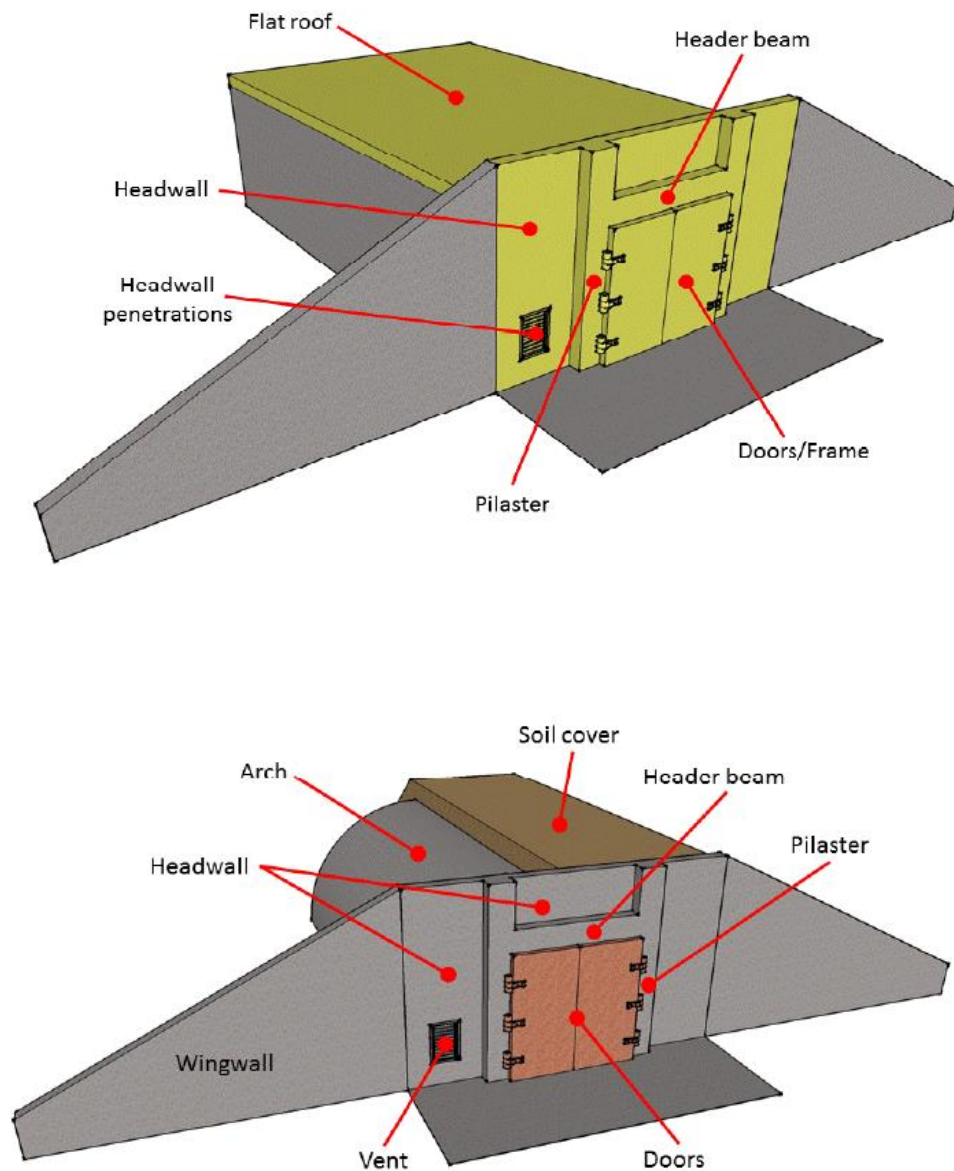
DoD missions require the storage of ammunition and explosives. Earth-covered magazines, or ECMs, are a common form of military structure used to store volatile chemical products, including explosives and sensitive fuels. The Department of Defense Explosives Safety Board (DDESB) published Technical Paper (TP) 15 'Approved Protective Construction' [2] provides a record of historically significant information about the origin and evolution of protective construction designs, including ECMs, that have been built over the past 80 years and the explosives safety criteria associated with them. When an ECM is the Exposed Site (ES), its primary purpose is to protect its'

contents and to prevent propagation of explosion. When the ECM is the Potential Explosion Site, the potential resulting explosives effects of concern are blast, fragments, and thermal hazards.

While there are many types of ECMs on DoD installations, the various structural forms usually arise from variations on a common theme, that of a steel or reinforced concrete structure with either single- or double-curved in its roof (i.e., vaults or domes), flat roof, headwall (including door), and rear wall with earth cover over all components except the headwall. See Figure 2 below for depictions of typical magazines in use today. These depictions illustrate the major components of an ECM.

Earth-covered magazines have been built for decades in the United States, and many of these structures are showing signs of aging.

**Figure 2 Earth Covered Magazines Depictions**



### ***Approach for the Assessments***

The DDESB established a multi-organization team to execute the ECM assessments. This team consists of members from the Department of Defense, Department of Army, Army Materiel Command, Joint Munitions Command, Defense Ammunition Center, U.S. Army Technical Center of Explosives Safety (USATCES), Installation Command and Personnel, U.S. Army Corps of Engineers, Naval Ordnance Safety and Security Activity (NOSSA) and NAVFAC-Atlantic.

The overall approach to accomplish the objective is to utilize three phases over a multi-year effort. The three phases, once completed, will identify the types of magazines at the installation, provide a representative structural health of the installation magazines with a probable remaining service life, establish storage limits and allow planning/accounting for stockpile.

#### **Phase 1: Earth Covered-Magazine Structural Integrity Assessment**

- Part 1 - Facilities Assessment: establish types/quantity of ECMs
- Part 2 - Structural Health Visual Inspection (SHVI): establish 'Structural Health' Rating
- Part 3- Concrete Coring/Testing: project remaining service life

#### **Phase 2: Site Planning**

- Accurate geo-locating and mapping
- Electronic Quantity Distance Analysis utilizing DDESB approved Explosives Safety Siting Software (addresses grandfathering)

#### **Phase 3: Load Plan Analysis**

- Account for stockpile

The three Phases shown above are related and best performed in succession. Parts 1 and 2 of Phase 1 will provide needed information for Phases 2 and 3. Three distinct and related 'Parts' have been identified to accomplish the Phase 1 assessments which is the main emphasis of this paper and are explained further below.

#### ***Phase 1: Earth Covered-Magazine Structural Integrity Assessment***

Phase 1 is the emphasis of this paper and its execution is currently being coordinated with JMC with execution planned to begin in FY 19. This phase is distinctly divided into three related parts. The various types and physical dimensions of each magazine will be determined and documented. This information will be utilized to determine which magazines will receive the structural health visual inspection. It will also be used to determine which magazines will have concrete cores extracted/tested, resulting in determining the probable remaining service life. The intent is to capture the results of Phase 1 in an electronic database.

#### **Sampling Method to Determine Quantity/Types of ECMs for assessment for Phase 1:**

While all ECMs will be accounted for in Part 1, a representative sampling, rather than 100%, of the ECMs will be selected for Parts 2 and 3. The representative sampling will provide the installation with a 'structural health picture' of their ECMs. For the sampling determination, we will utilize the Simple Proportion Sampling Method from Probability and Statistics for Engineers by Miller and Freund. In this method, the criticality of the activity undertaken is considered in determining the percentage of confidence level appropriate. We utilized the guidance and examples by Miller and Freund to develop the percentage of confidence to be used in Parts 2 and 3. A high level of confidence in the results is desired to achieve a true representative sampling of the in situ ECMs. A representative sample for each type (type of ECM will be established/confirmed in Part 1) will be determined and a list of ECM building numbers for Parts 2 and 3 will be generated. In general, the more 'types' of ECMs will increase the number of ECMs required to be assessed to maintain the appropriate level of confidence needed. Initially a list of ECMs for Parts 2 and 3 will be developed using the information provided by the installations. Once Part 1 is completed, a comparison of its results (number of types and quantity of each type) to the initial information provided to CEHNC will be completed and needed adjustments will be made. The overall structural health and remaining expected service life of the ECMs at the three installations will be representative and valid for planning purposes and making decisions related to continued use.

- Part 1 - Facilities Assessment: establish types/quantity of ECMs  
100% of the ECMs at the installation will be assessed.

- **Part 2 (Structural Health Visual Inspection (SHVI)):**  
Use the total quantity of 'Army' ECMs at the Installations as the sample base and develop quantities statistically using a 95% confidence level the results will be representative of the installations ECM. A range of 20% to 30% of the total quantity is expected. The general guidance and examples we found indicate a 95% confidence level is the most common for a high level of confidence, unless the activity is a 'very high risk to health' (then a higher percentage can be used). The visual structural inspection of ECMs does not fall into the 'very high risk to health' category. Even if we find an ECM that we would recommend be taken out of service because we feel it is not adequate for ammo storage, it would not be considered a "very high risk to health".
- **Part 3 (Concrete Core Extractions/Testing):**  
Use the total quantity of 'Army' ECMs at the Installations as the sample base and develop quantities statistically using a 70% confidence level the results will be representative of the installations ECM. A range of 8% to 12% of the total quantity is expected. The criticality of the concrete core extraction testing results is less than the SHVI Part 2 for the objective of obtaining the overall structural health of the ECMs at the installations; therefore, warranting a lower percentage confidence level. A balance of using an adequate percentage confidence level and keeping the impact to the day to day functions at the installations was considered in selecting this level of confidence. The intent is to avoid having to re-warehouse or move ECM content while maintaining the integrity of the sampling. Based on previous ECM assessment efforts, justification of a lower confidence level percentage (than used in Part 2) is warranted since none of the previous concrete core lab testing results lowered the structural health rating assigned during the visual inspections. All efforts in the concrete core extraction task will be coordinated and approved by the installation Explosives Safety Manager.

#### **Parts 1, 2 and 3:**

A more detailed explanation of each 'Part' of Phase 1 is presented below. It is envisioned that a Phase 1 multi-volume report will be developed as a deliverable for this Phase.

- **Part 1: Facilities Assessment**  
Each ECM (100%) at the installation will be visited and undergo activities to determine the type of ECM and to gather physical dimensions and features specific to the ECM. The information will be documented on the Facility Assessment form developed by NAVFAC. See Attachment A for a sample of the form. The types of ECMs and the quantity of each type will be established in this Part of Phase 1. This information will be provided to the installation and any conflicts will be addressed resulting in the baseline (ECM types and quantities of each type) to be used for Parts 2 and 3. No structural health visual inspections or concrete core extractions will be done in Part 1.
- Report:**  
A report will be generated documenting the activities and results of this Part. A spreadsheet will be developed that contains each ECM located on the installation. Information identifying the 'type', physical dimensions, profile and characteristics will be captured.
- **Part 2: Structural Health Visual Inspection**  
A percentage of ECMs will be selected for a structural health visual inspection. The quantity of ECMs to be inspected varies based on the number of different types at the installation. A range of 20% to 30% of the total quantity is expected. The results of the SHVI will be documented on an Earth-Covered Magazine Visual Inspection Form developed by CEHNC. See Attachment B for a sample of the form. This form is continually being updated for completeness and ease of use. The intent is to utilize readily available software to develop a database and utilize approved tablets to record the inspection data real time. Consideration of the forms use DoD wide is recommended to enhance consistency of results. The structural rating criteria and guidance is in accordance with the American Concrete Institute Guide for Conducting a Visual Inspection of Concrete in Service (ACI 201.1R-08 (2008)). A numerical code (ranges from 0-9) based on criteria established by the National Bridge Institute general condition of the bridge and main structural elements will be assigned. The numerical code description has been modified slightly too adequately address ECM components. The numerical code indicates an overall structural health rating for

the ECM. Based on the numerical code, the ECM is assigned an Installation Status Rating of Green, Amber, Red or Black.

- GREEN: continue to use as is, but monitor any minor deterioration noted
- AMBER: continue to use, but noted repairs should be made to prevent further deterioration
- RED: do not continue to use until noted repairs are completed
- BLACK: considered un-repairable, do not use

The ECM assessment team will assign structural health ratings consistent with the above and the Installation's management will make the decision on what action, if any, to take related to the magazines' continued use.

### **Repairs**

During the SHVI, deterioration of ECM structural elements will be documented on the ECM visual inspection form. The location and extent of the deterioration will be captured on the form along with a recommended repair and repair cost.

### **Report:**

A multivolume report will be generated to document the activities and results of this Part. It is envisioned, the report will have an appendix that contains the inspection form for each ECM with various pictures (to document some of the more major deterioration) and recommended repairs. A master spreadsheet will be developed that contains each ECM located on the installation. The master spreadsheet, at a minimum, will contain information such as the type of ECM, structural designation (7-bar, 3-bar, Undefined, other reduced QD criteria), year constructed, year major repairs made, structural health rating, ISR, repair type and repair cost. A color coded site map showing the assigned structural health ratings will be provided.

- **Part 3: Concrete Core Extractions/Testing**

A percentage of ECMs will be selected for concrete core extraction and testing. The quantity of ECMs varies based on the number of different types at the installation. A range of 8% to 12% of the total quantity is expected. A minimum of five extractions per ECM is expected in order to have enough core samples to perform the needed lab testing.

Some of the ASTM tests methods that will be used to obtain, prepare, and examine the concrete cores are listed below. Details and explanations of these test methods and standards are separately published by ASTM as indicated below.

- ASTM C 295, "Standard Practices for Petrographic Examination of Aggregates for Concrete."
- ASTM C 33, "Standard Specification for Concrete Aggregates."
- ASTM C 294, "Standard Descriptive Nomenclature for Constituents of Concrete Aggregates."
- ASTM C 856, "Petrographic Examination of Hardened Concrete."
- ASTM C 42, "Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete."
- ASTM C 39, "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens."
- ASTM C 496, "Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens."

### **Report:**

The results of the testing and remaining service life projections will be documented in technical reports developed by USACE ERDC. A color coded site map showing the probable remaining service life will be provided.

**Conclusion and Recommendations:**

Establishing the structural health of aging DoD earth-covered magazines is essential for understanding the risk to munitions related infrastructure. Undertaking this FY19 - FY23 effort will establish a base line of ECM types and quantities, provide an overall picture of the structural effort and provide probably remaining service life for three major DoD installations. The results of the assessment will inform a long-term Munitions-Related Infrastructure Recapitalization Plan for the assessment, maintenance, and replacement of AE storage facilities to ensure continued ability to support the mission, manage risk and protect the public. The information gained from ECM assessment can be utilized to manage risk and protect the public while ensuring the continued ability to support the mission.

It is recommended that consideration be given and plans made to perform similar assessment at all DoD installations where AE is stored. For consistency in ECM assessment results, it is recommended that DoD adopt a base line ECM inspection form.

Attachment A  
Phase 1, Part 1 AE Facilities Assessment Form



## AE Facility Assessment

Facility Number

**Measurements:**

Interior Length	<input style="width: 60px; height: 15px;" type="text"/>	ft.	<input style="width: 60px; height: 15px;" type="text"/>	in.	(to nearest inch)	
Interior Width	<input style="width: 60px; height: 15px;" type="text"/>	ft.	<input style="width: 60px; height: 15px;" type="text"/>	in.	(to nearest inch)	
Interior Height	<input style="width: 60px; height: 15px;" type="text"/>	ft.	High Point		(to nearest linear foot)	
	<input style="width: 60px; height: 15px;" type="text"/>	ft.	Low Point		(to nearest linear foot)	(Box Type)

**Doors:**

Number	<input style="width: 60px; height: 15px;" type="text"/>	
Height	<input style="width: 60px; height: 15px;" type="text"/>	ft. <input style="width: 60px; height: 15px;" type="text"/> in. (to nearest inch)
Width	<input style="width: 60px; height: 15px;" type="text"/>	ft. <input style="width: 60px; height: 15px;" type="text"/> in. (to nearest inch)
Clear Opening	<input style="width: 60px; height: 15px;" type="text"/>	ft. <input style="width: 60px; height: 15px;" type="text"/> in.
Location from center of headwall	<input style="width: 60px; height: 15px;" type="text"/>	ft.

**Design:**

Single Leaf	<input style="width: 20px; height: 15px;" type="text"/>	Double Leaf	<input style="width: 20px; height: 15px;" type="text"/>
Swing Open	<input style="width: 20px; height: 15px;" type="text"/>	Slide Open	<input style="width: 20px; height: 15px;" type="text"/>

Steel Plates in Thickness

Corbels  Y /  N

Pull-up Door Stops  Y /  N

**Headwall:**

Thickness  ft.  in. (to nearest inch)

Windows/Other Openings

**Columns:**

Number	<input style="width: 60px; height: 15px;" type="text"/>	
Width	<input style="width: 60px; height: 15px;" type="text"/>	ft. (to nearest half-foot)
Height	<input style="width: 60px; height: 15px;" type="text"/>	ft. (to nearest half-foot)
Distance between	<input style="width: 60px; height: 15px;" type="text"/>	ft. (to nearest half-foot)
Column Header	<input style="width: 60px; height: 15px;" type="text"/>	Dimensions <input style="width: 60px; height: 15px;" type="text"/>
Rows	<input style="width: 60px; height: 15px;" type="text"/>	Columns per Row <input style="width: 60px; height: 15px;" type="text"/>

**Photographs:**

Magazine Interior	<input style="width: 20px; height: 15px;" type="text"/>	
Headwall	Interior	<input style="width: 20px; height: 15px;" type="text"/>
	Exterior	<input style="width: 20px; height: 15px;" type="text"/>
Door	Interior	<input style="width: 20px; height: 15px;" type="text"/>
	Exterior	<input style="width: 20px; height: 15px;" type="text"/>

**Miscellaneous:**

Loading Dock	<input type="checkbox"/> Y / <input type="checkbox"/> N	Length <input style="width: 60px; height: 15px;" type="text"/>	Width <input style="width: 60px; height: 15px;" type="text"/>	Area <input style="width: 60px; height: 15px;" type="text"/> SY
Wing Walls	<input type="checkbox"/> Y / <input type="checkbox"/> N	<input style="width: 60px; height: 15px;" type="text"/> LF		
Berm	<input type="checkbox"/> Y / <input type="checkbox"/> N			<input style="width: 60px; height: 15px;" type="text"/> EA
Headwall GPS Coordinates	Left	<input style="width: 60px; height: 15px;" type="text"/>	Center	<input style="width: 60px; height: 15px;" type="text"/>
	Longitude	<input style="width: 60px; height: 15px;" type="text"/>	Right	<input style="width: 60px; height: 15px;" type="text"/>
	Latitude	<input style="width: 60px; height: 15px;" type="text"/>		<input style="width: 60px; height: 15px;" type="text"/>

Attachment B  
Phase 1, Part 2 Earth-Covered Magazine Visual  
Inspection Form

EARTH-COVERED MAGAZINE  
VISUAL INSPECTION FORM

PHOTO	Site Name:			
	ECM No.		Site Label No.	
	Steel Door Tag No.			
	Date of Inspection			
	Inspector's Name(s)			
	ECM Type		If Other:	
	Door Type		If Other:	
	Dates of Construction:		Unknown	
SKETCH	Interior ECM Dimensions		Height (ft)	
			Width (ft)	
			Taken From:	
	Pilasters Adjacent to Doors Dimension (if present):		Height (ft)	
			Width (in)	
			Depth (in)	
	Head Beam at Headwall (if present):		Height (ft)	
			Length (ft)	
			Width (ft)	
<b>REPAIRS:</b> (Describe any known repairs completed to the ECM including dates)				
<b>ADDITIONS:</b> (Describe any known additions completed to the ECM including dates)				
<b>COMMENTS:</b> (Provide any additional observations related to the ECM's rating or condition)				
OVERALL CONDITION RATING	CODE	DESCRIPTION		
	Enter Value			

## VISUAL INSPECTION FORM

INTERIOR WALL SURFACE CONDITION OF CONCRETE								
Item	Surface Condition Type	Location	Distance from Rear/Left (ft.)	Height from Slab (ft.)	Width or Area (in)	Length or Depth (ft.)	Type	Evaluation
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								

**VISUAL INSPECTION FORM**

INTERIOR WALL SURFACE CONDITION OF CONCRETE								
Item	Surface Condition Type	Location	Distance from Rear/Left (ft.)	Height from Slab (ft.)	Width or Area (in)	Length or Depth (ft.)	Type	Evaluation
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								
33								
34								
35								
36								
37								
38								

### VISUAL INSPECTION FORM

FLAT ROOF (UNDERSIDE) SURFACE CONDITION OF CONCRETE								
Item	Surface Condition Type	Location	Distance from Rear/Left	Distance from Side Wall	Width or Area	Length or Depth	Type	Evaluation
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								

## VISUAL INSPECTION FORM

HEADWALL SURFACE CONDITION OF CONCRETE					
<u>PILASTERS ADJACENT TO DOOR:</u>					
<b>Left Pilaster Condition:</b>					
Cracking:	<input type="checkbox"/> None	<input type="checkbox"/> Minor	<input type="checkbox"/> Moderate	<input type="checkbox"/> Significant	<input type="checkbox"/> Major
Spalling:	<input type="checkbox"/> None	<input type="checkbox"/> Minor	<input type="checkbox"/> Moderate	<input type="checkbox"/> Significant	<input type="checkbox"/> Major
Delamination:	<input type="checkbox"/> None	<input type="checkbox"/> Minor	<input type="checkbox"/> Moderate	<input type="checkbox"/> Significant	<input type="checkbox"/> Major
<b>Right Pilaster Condition:</b>					
Cracking:	<input type="checkbox"/> None	<input type="checkbox"/> Minor	<input type="checkbox"/> Moderate	<input type="checkbox"/> Significant	<input type="checkbox"/> Major
Spalling:	<input type="checkbox"/> None	<input type="checkbox"/> Minor	<input type="checkbox"/> Moderate	<input type="checkbox"/> Significant	<input type="checkbox"/> Major
Delamination:	<input type="checkbox"/> None	<input type="checkbox"/> Minor	<input type="checkbox"/> Moderate	<input type="checkbox"/> Significant	<input type="checkbox"/> Major
Pilaster Comments:					
<u>HEAD BEAM COMMENTS:</u>					
Cracking:	<input type="checkbox"/> None	<input type="checkbox"/> Minor	<input type="checkbox"/> Moderate	<input type="checkbox"/> Significant	<input type="checkbox"/> Major
Spalling:	<input type="checkbox"/> None	<input type="checkbox"/> Minor	<input type="checkbox"/> Moderate	<input type="checkbox"/> Significant	<input type="checkbox"/> Major
Delamination:	<input type="checkbox"/> None	<input type="checkbox"/> Minor	<input type="checkbox"/> Moderate	<input type="checkbox"/> Significant	<input type="checkbox"/> Major
Head Beam Comments:					
<u>DOOR CONDITION:</u>					
Operation:	<input type="checkbox"/> Fair	<input type="checkbox"/> Good	<input type="checkbox"/> Excellent		
Door Comments:					

## VISUAL INSPECTION FORM

OTHER STRUCTURAL COMPONENTS SURFACE CONDITION OF CONCRETE					
<u>WING WALL:</u>					
<b>Left Wing Wall Condition:</b>					
Cracking:	<input type="checkbox"/> None	<input type="checkbox"/> Minor	<input type="checkbox"/> Moderate	<input type="checkbox"/> Significant	<input type="checkbox"/> Major
Spalling:	<input type="checkbox"/> None	<input type="checkbox"/> Minor	<input type="checkbox"/> Moderate	<input type="checkbox"/> Significant	<input type="checkbox"/> Major
Delamination:	<input type="checkbox"/> None	<input type="checkbox"/> Minor	<input type="checkbox"/> Moderate	<input type="checkbox"/> Significant	<input type="checkbox"/> Major
<b>Right Wing Wall Condition:</b>					
Cracking:	<input type="checkbox"/> None	<input type="checkbox"/> Minor	<input type="checkbox"/> Moderate	<input type="checkbox"/> Significant	<input type="checkbox"/> Major
Spalling:	<input type="checkbox"/> None	<input type="checkbox"/> Minor	<input type="checkbox"/> Moderate	<input type="checkbox"/> Significant	<input type="checkbox"/> Major
Delamination:	<input type="checkbox"/> None	<input type="checkbox"/> Minor	<input type="checkbox"/> Moderate	<input type="checkbox"/> Significant	<input type="checkbox"/> Major
Wing Wall Comments:					
<u>SLAB-ON-GRADE (INTERIOR):</u>					
Cracking:	<input type="checkbox"/> None	<input type="checkbox"/> Minor	<input type="checkbox"/> Moderate	<input type="checkbox"/> Significant	<input type="checkbox"/> Major
Spalling:	<input type="checkbox"/> None	<input type="checkbox"/> Minor	<input type="checkbox"/> Moderate	<input type="checkbox"/> Significant	<input type="checkbox"/> Major
Delamination:	<input type="checkbox"/> None	<input type="checkbox"/> Minor	<input type="checkbox"/> Moderate	<input type="checkbox"/> Significant	<input type="checkbox"/> Major
Interior Slab Comments:					



## STRUCTURAL RATING CRITERIA AND GUIDANCE

For General ECM Conditions the following descriptions will be used throughout the report to rate the condition of the individual or groups of ECM elements

Rating	Description
Very Good	No problems noted.
Good	Some minor problems.
Satisfactory	Structural elements show some minor deterioration.
Fair	Primary structural elements are sound, but may have minor deterioration, section loss, cracking or spalling
Poor	Advanced deterioration, section loss, cracking or spalling
Serious	Deteriorated condition has seriously affected primary structural components.

The description of the spall and scale defects in the concrete members are based on definitions from the American Concrete Institute (ACI) Guide for Conducting a Visual Inspection of Concrete in Service : ACI 201.1R-08 (2008). The description of crack defects is based on definitions in ACI "Guide for Making a Condition Survey of Concrete in Service" (1984).

Defect	Description
Small Spall	A roughly circular depression not greater than 0.8 inch in depth and 6 inches in any dimension
Large Spall	May be roughly circular or oval, or, in some cases, elongated, and is more than 0.8 inches in depth and 6 inches in greatest dimension.
Light Scale	Loss of surface mortar without exposure of coarse aggregate
Medium Scale	Loss of surface mortar 0.2 to 0.4 in. in depth and exposure of coarse aggregate
Severe Scale	Loss of surface mortar 0.2 to 0.4 inches in depth with some loss of mortar surrounding aggregate particles 0.4 to 0.8 in. in depth.
Very Severe Scale	Loss of coarse aggregate particles as well as surface mortar, generally to a depth greater than 0.8 inches
Fine or Hairline Crack	Less than 0.04" wide
Medium Crack	0.04" to 0.08" wide
Wide Crack	Greater than 0.08" wide

The following descriptions will be used to define the degree of section loss in the steel members. The degree of section loss was estimated from visual inspection.

Section Loss	Description
Minor	No section loss
Moderate	Section loss but not measurable
Severe	Section loss measurable

## STRUCTURAL RATING CRITERIA AND GUIDANCE

Based on the structural rating, the following color categories will be used to indicate recommended status of the ECM for the use of ammunition/explosives storage.

ISR Green	ISR Amber	ISR Red	ISR Black
<b>Ratings:</b> Good, Very Good, Excellent (7, 8, 9)	<b>Ratings:</b> Fair/Satisfactory (5,6)	<b>Ratings:</b> Poor/Serious (3,4)	<b>Ratings:</b> Failed/Imminent Failure/Critical (0,1,2)
<b>Components:</b> -Arch/Roof -Headwall -Side Walls -Rear wall -Door	<b>Components:</b> -Arch/Roof -Headwall -Side Walls -Rear wall -Door	<b>Components:</b> -Arch/Roof -Headwall -Side Walls -Rear wall -Door	<b>Components:</b> -Arch/Roof -Headwall -Side Walls -Rear wall -Door
Structural Health adequate for assigned Structural Designation  No significant deterioration.	Structural Health adequate for assigned Structural Designation  Repairs needed to prevent future deterioration.	Structural Health is NOT adequate for assigned Structural Designation  Repairs needed to continue use.	Structural Health is NOT adequate for assigned Structural Designation  Deemed un-repairable. Do not continue to use.

**Green:** magazines receiving a numerical structural rating of 7 or above. New condition, minor nonstructural issues identified, no significant deterioration. Structural Health is adequate for the assigned structural designation. Continued to use as is.

**Amber:** magazines receiving a numerical rating of 5 or 6. Primary structural components are sound, some minor section loss, cracking and spalling. Structural Health is adequate for the assigned structural designation. Continued use is as is, but needed repairs should be completed to prevent future deterioration.

**Red:** magazines receiving a rating of 2, 3 or 4. Significant deterioration of primary structural components, advanced section loss and spalling. Structural Health is not adequate for the assigned structural strength designation. Do not use until repairs are made.

**Black:** magazines receiving a numerical rating of 0 or 1. Major deterioration or section loss in critical structural components. Beyond repair, do not use for storage of ammunition/explosives.

## ***References***

1. DOD 6055.09-M, DoD Ammunition and Explosives Safety Standards: General Explosives Safety Information and Requirements, February 29, 2008, Administratively Reissued August 4, 2010, *Incorporating Change 2, effective December 29,2017.*
2. DDESB Technical Paper 15 *Approved Protective Construction (Revision 3),May 2010*