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TRI-SERVICE SECURITY ENGINEERING WORKING GROUP (TSSEWG) MANUAL

DOD JOINT COMMERCIAL BUNKER TESTING PROCEDURES

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DoD JOINT COMMERCIAL BUNKER TESTING PROCEDURES

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND

AIR FORCE CIVIL ENGINEER CENTER (Preparing Activity)

Record of Changes (changes are indicated by **1**\ ... /**1**/)

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FOREWORD

This Tri-Service Security Engineering Working Group (TSSEWG) Manual supplements guidance found in other Unified Facilities Criteria, Unified Facility Guide Specifications, Defense Logistics Agency Specifications, and Service-specific publications. All construction outside of the United States, its territories, and possessions is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA). Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable. This manual provides guidance on acceptance testing protocol and limits to identify materials for use in protecting against fragmentation and blast from near-miss indirect fire weapons.

TSSEWG Manuals are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction, maintenance, repair, or operation. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Systems Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of this document. Technical content of this TSSEWG Manual is the responsibility of the Tri-Service Security Engineering Working Group (TSSEWG). Defense agencies should contact the Preparing Activity for document interpretation and send recommended changes with supporting rationale to the Preparing Activity.

TSSEWG Manuals are effective upon issuance and are distributed only in electronic media from Whole Building Design Guide: https://www.wbdg.org/dod.

Hard copies of TSSEWG Manuals printed from electronic media should be checked against the current electronic version prior to use to ensure they are current. Refer to UFC 1-200-01, *DoD Building Code*, for implementation of new issuances on projects.

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CHAPTER 1 INTRODUCTION

1-1 BACKGROUND.

Many bunkers have been designed and built throughout modern history to protect personnel from hostile attack from a variety of munitions. These bunkers must be capable of providing protection from the blast and fragmentation hazards produced by munitions. Often the specific munition threat is not specified, and the level of protection provided by the structures is unknown, so bunkers are built to provide the best level of protection which can be afforded based on cost, time, material, and skill constraints. It is usually not conceivable to design/build bunkers to provide protection from direct hits of munitions due to the effectiveness of modern munitions to breach even substantially constructed bunkers. As a result, bunkers are typically designed to provide protection from "near-miss" munition detonations, and bunker spacing is provided so that at worst case only one bunker is within range of a detonating munition at an installation.

1-2 PURPOSE AND SCOPE.

This manual provides criteria for determining the suitability of government- and commercially-designed and manufactured bunkers for providing protection to personnel in bunkers at installations subjected to hostile attack from munitions. Munitions include classes of rocket, artillery, and mortar (RAM) threat weapons, and free airburst detonations at the designated standoff distance.

The scope of this manual is limited to providing construction requirements, testing procedures, and evaluation criteria for bunkers subjected to the classes of munitions at detonation distances contained in this manual. This will allow installation personnel to select suitable bunkers satisfying requirements based on the required threat class.

1-3 APPLICABILITY.

This TSSEWG Manual applies to manufacturers and designers of force protection facilities and facility components. This manual:

- Provides manufacturers a clear set of standards to facilitate development and acceptance of new and innovative commercial protective bunkers using novel protective materials and techniques.
- Reduces reliance on DoD laboratories to test new protective weapon protection bunkers.

1-4 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, *DoD Building Code*. UFC 1-200-01 provides applicability of model building codes and government-unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, high performance and sustainability requirements, and safety. Use this TSSEWG Manual in addition to UFC 1-200-01 and the UFCs and government criteria referenced in UFC 1-200-01.

1-5 CYBERSECURITY.

All facility-related control systems (including systems separate from a utility monitoring and control system) must be planned, designed, acquired, executed, and maintained in accordance with UFC 4-010-06, *Cybersecurity of Facility-Related Control Systems (FRCS)*, and as required by individual Service implementation policy.

1-6 COMMENTARY.

Limited commentary has been added to the chapters. Section designations for such commentary are preceded by a "**[C]**" and the commentary narrative is highlighted with light gray.

1-7 GLOSSARY.

Appendix A contains acronyms, abbreviations, and terms.

1-8 REFERENCES.

Appendix B contains a list of references used in this manual. The publication date of the code or standard is not included. Unless otherwise specified, the most recent edition of the referenced publication applies.

CHAPTER 2 TECHNICAL REQUIREMENTS

2-1 BUNKER PROTECTION CLASSES.

Design the bunker to meet one of the following bunker protection classes from Table 2-1 based on the TNT-equivalent net explosive weight (NEW) of the explosive fill, the specified threat standoff distance, and the design fragment representing the governing munition in the protection class. Validate the bunker blast protection performance against blast loading using a full-scale arena testing, and the fragment protection using V50 fragment simulating projectile testing as described in this manual.

Table 2-1 Validation Testing Parameters to Determine Protection Classification of Bunkers

Protection Class	FSP for V50 Testing[1]			Blast Pressure Validation Testing Parameters			
						Incident[4]	
	Mass (grain)	Diameter (in.)	Minimum V50 (ft/sec)	Charge Weight (lb)[3]	Standoff (ft)	Pressure (psi)	Impulse (psi-msec)
1	207[1]	0.500	5450	7.8	10	41.1	29.7
2	828[2]	0.79	3753	16.1	10	71.8	47.7
3	828[2]	0.79	5436	242.9	50	14.9	61.3
4	207[1]	0.500	4020	2000.0	50	71.50	237.5

Notes:
[1] The Fragment Simulating Projectile (FSP) for Protection Classes 1 and 4 is the standard 0.50 caliber FSP as described in MIL-DTL-46593B, *Detail Specification: Projectile, Calibers .22, .30, .50, and 20 mm Fragment-Simulating*.
[2] The FSP for Protection Classes 2 and 3 is the standard 20-millimeter FSP as described in MIL-DTL-46593B.
[3] The TNT-equivalent NEW is an estimate based on weapons' effects of a max. weapon within each class. The test engineer determines the amount of TNT or equivalent explosive required to obtain the minimum pressure and impulse.
[4] Incident pressure/impulse values are based on conventional weapons (CONWEP).

2-2 GENERAL TESTING PARAMETERS.

Test bunkers which are being presented for specific protection class certification in accordance with this manual and any referenced standards or criteria. Submit a report summarizing the procedures and results of all blast and fragmentation testing to the TSSEWG Service representatives (see paragraph 2-17) for consideration as an acceptable protection bunker for use by DoD personnel.

A bunker may be certified for a specific protection class by performing bare explosive blast testing on all unique sides of the bunker together with FSP V50 ballistic limit

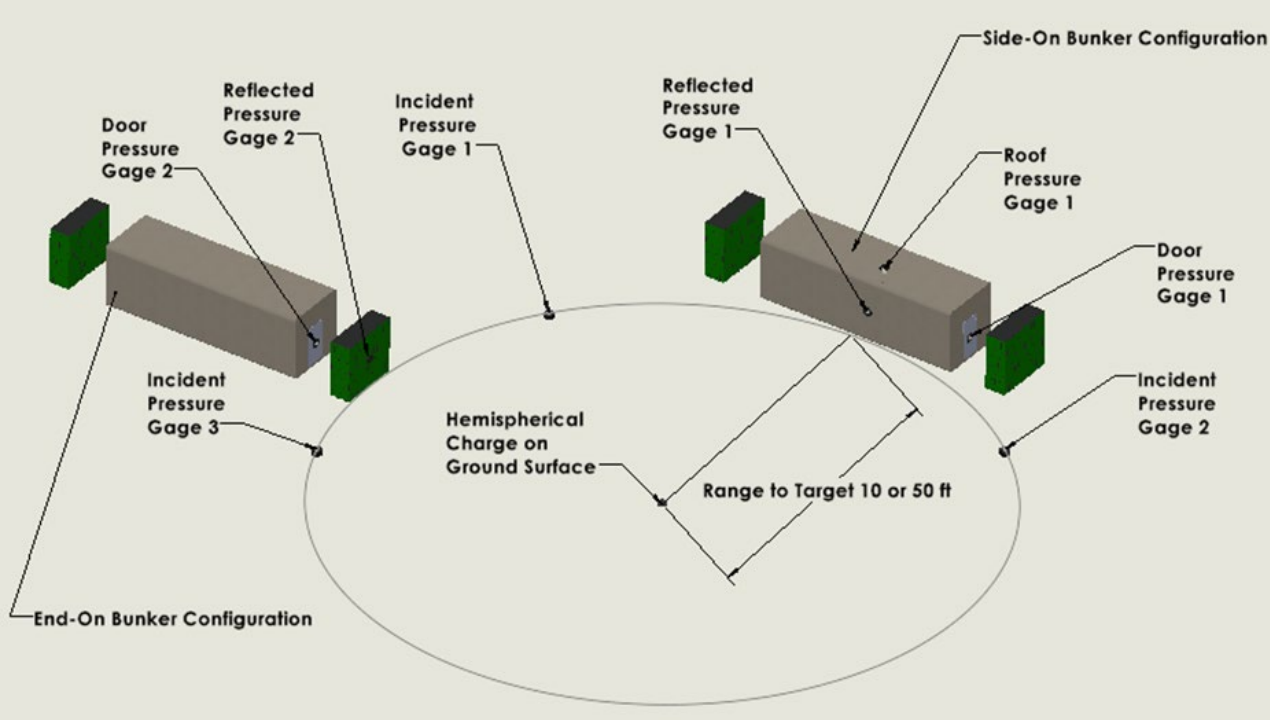
testing on all unique exterior structural components, applying the testing parameters in Table 2-1 and following procedures in paragraphs 2-2.1 through 2-16.

2-2.1 Blast Validation Testing

Construct the candidate bunker as specified in manufacturer's instructions at sites representing real world scenarios at DoD forward operating locations. Figure 2-1 illustrates a typical bunker blast test arena. Each unique bunker vertical surface will be exposed to orthogonal blast pressure, as shown by the side-on and end-on configurations below. Perform blast testing in accordance with ASTM F3664-24, *Standard Practice for Blast Testing*, except as specified in paragraphs 2-2.1 and 2-2.2.

Chose the estimated charge weight based on the desired protection class designation for the bunker (see Table 2-1). Use bare explosives to test the bunker response to blast effects. The explosive used during the verification testing must produce measured peak incident pressure and impulse values equal to or greater than the pressures shown in Table 2-1. Do not combine and average any pressure measurements. Position an incident pressure gage on the left and right of each tested bunker configuration. These values are the expected pressures and impulses resulting from the detonation of the governing munition representing the protection class and the standoff distance specified in Table 2-1.

Figure 2-1 Typical Blast Testing Arena Configuration



2-2.1.1 Charge Placement/Soil Preparation.

[C] 2-2.1.1 Charge Placement/Soil Preparation.

The granulated soil directly beneath the charge placement must be free of secondary debris hazards and compacted to ensure the charge behaves similarly to a surface-detonated hemispherical charge. This is particularly important where multiple previous charge detonations have occurred to prevent extensive loosening of soil under the charge.

American Society for Testing and Materials (ASTM) F3664 recommends the charge be placed at a height representing a vehicle-borne explosive. This procedure requires the bottom of the charge to be placed at ground surface. This paragraph modifies ASTM F3664.

Shape the charge to resemble a hemisphere and place the charge at ground level. Ensure granulated soil directly beneath the charge to a depth of 2 feet and a radius of 5 feet around the charge center is free of any particles exceeding 3/8 inches in diameter. Compact the soil beneath the charge to a California Bearing Ratio (CBR) of 20 percent as measured using a dynamic cone penetrometer (DCP) with results correlated to CBR using standard empirical formulas.

2-2.1.2 Exterior Pressure Measurements.

For the blast pressure validation tests using bare explosive charges, make two surface-level ground (incident) pressure measurements at the same distance as the distance from the center of the charge to the closest point on the structure. Where there are multiple structures, include an additional surface-level ground (incident) pressure measurement for each structure. Place the ground pressure gages at least 10 feet from the bunker to prevent blast reflections from the bunker impinging on the ground pressure transducers. Make surface flush pressure measurements at or near the midspan on all unique exterior surfaces of the structures facing the blast, and on the doors and roof.

2-2.1.3 Exterior Measurement Acceptance Criteria.

Peak incident pressures and impulses measured during validation testing must all meet or exceed the values shown in Table 2-1. Reference incident pressure gages 1, 2, and 3 in Figure 2-1 as the locations at the designated standoff distance for measuring exterior blast acceptance criteria.

2-2.1.4 Interior Pressure Measurements

Record pressure measurements at two locations inside the bunker.

2-2.1.5 Interior Blast Pressure Thresholds.

The peak air blast measured inside the bunker must be less than 1.3 pounds per square inch (psi).

2-2.2 Fragmentation Protection Validation Testing.

The bunkers are intended to provide protection of bunker occupants from the primary fragments resulting from the detonation of theater ballistic missiles (TBM), artillery, mortars, and rockets. This procedure requires that the FSP V50 ballistic limit of each bunker component be determined using ballistic testing standards. The FSP weight for each protection class was determined from the 95% design fragment weight produced during detonation of the governing munition (one with most kinetic energy) in the protection class. The FSP diameter was determined by using the FSP dimension proportions provided in MIL-DTL-46593B. The required minimum V50 was determined based on the striking velocity of the design fragment.

Validate the fragment penetration protection capability based on the intended bunker protection class designation using the procedures outlined in MIL-STD-662, *V50 Ballistic Test for Armor.* Refer to Table 2-1 for the diameter and weight of the FSP used during V50 testing to verify fragment protection for each protection class. FSP dimensions must be scaled to the 0.50 caliber FSP dimensions described in MIL-DTL-46593B. The V50 determined during testing for each unique structural component (including doors) must be less than the minimum allowable V50 ballistic limit value shown in Table 2-1 for the intended protection class.

2-3 STRUCTURAL PERFORMANCE.

The components of the portions of the bunker housing the occupants must remain elastic to ensure that the blast/fragment loaded structures can support the dead weight loads in an undeformed shape to limit injury to occupants and allow unrestricted egress from the bunker. Ancillary parts of the structure such as sand-filled walls, are not required to remain intact but must not prevent access or egress from the occupied portions of the structure. No breach or failure of the interior core/liner is acceptable.

2-4 INTERNAL SPALL LIMITS.

The interior surface of the structure must not experience any harmful concrete spall or flying particles resulting from blast or fragment impact for the threat weapon. Spall or flying particles are harmful if the spall/particle is larger than 0.1 ounces and land further than 2 feet into the protected space.

Note: While it is not practical to require all particles to stay attached to the interior surface of the bunker, larger particle sizes which travel into the protected space further than 2 feet are limited in weight roughly to that of a dime (0.1 ounces). There is no limit to the allowed distance for particles lighter than a dime.

2-5 RIGID BODY GLOBAL TRANSLATION.

Measure the rigid body translation of the core/liner of the structure using any method that accurately provides the relative displacement of the structure from its initial location. The global rigid body translation of the structure must be less than 2 inches, as measured at the corners of the structure. None of the corner translation distance measurements may exceed 2 inches.

2-6 INTERNAL DEFLECTION LIMITS.

Record deflection measurements during blast testing of the bunker. Install deflection measurement devices on the walls and roofs at the horizontal and vertical midspan of the walls and roof, and at the center of the doors. For walls containing doors, install wall deflection measurement devices at the same height as the door measurement and as close to the door opening as practical. The walls and roof of the portion of the bunker housing personnel must remain elastic and the interior surface of the bunker wall and roof must experience less than 2 inches of elastic deflection as measured at the vertical and horizonal midspans of the wall or roof.

2-7 LOCAL DAMAGE.

Local damage visible from the inside is permitted as long as structural performance is acceptable and spall and internal deflection limits are not exceeded.

2-8 RESIDUAL STRUCTURAL CAPACITY.

No plastic deformation of the walls, columns, or beams is allowed, nor is visible damage or cracking of any primary structural connection. The structure’s capacity to support vertical gravity dead loads must not be reduced.

2-9 DOOR OPERATION AND PERFORMANCE.

Provide at least two doors on the bunker placed at opposite sides of the bunker on separate surfaces. The doors must be capable of being secured and opened by personnel located both inside and outside of the structure. After the design level blast event, at least one door must remain operational from both inside and outside the structure without use of additional tools.

2-10 ALLOWABLE DOOR DEFLECTION/DAMAGE.

The door must remain securely in the opening during the blast event, with no door or door frame pieces failing and flying into the protected space. Limited plastic deflection is allowed, but the plastic deflection design limit must be clearly specified in the design/construction documents to ensure that this area around the interior of the bunker is kept clear during occupancy to prevent injury from excessive plastic deformation. After the blast event, the door must be easy to open by a single person and without requiring use of tools, both from the inside and from the outside.

2-11 OPTIONAL CONFIGURATION REQUIREMENTS.

Blast testing must include all optional configuration components which are included in the bunker design.

2-11.1 Lighting.

If bunker lighting is provided, the electrical system must conform to UFC 1-201-01, *Non-Permanent DoD Facilities in Support of Military Operations.*

2-11.2 Ventilation.

There are no ventilation requirements for blast testing. Where vents are installed, internal pressures during blast testing must not exceed 1.3 psi (reference paragraph 2-2.1.5).

2-12 TRANSPORTABILITY.

Design the bunker so that each individual bunker component can be transported within the theater using readily available transport vehicles. Dimensions of each individual bunker component must not exceed 20 feet long by 10 feet wide by 10 feet tall, and a bunker must weigh less than 20,000 pounds.

2-13 USE OF ON-SITE MATERIALS.

Bunker design can include use of on-site materials to provide fill for bunker components as required for blast and/or fragment protection. If on-site material is used, the manufacturer must provide specifications for allowable materials, gradation of materials, and method of placement/compaction of materials.

2-14 BUNKER FOUNDATION PREPARATION.

If specific instructions are not provided by the manufacturer, place the bunker on a flat improved surface such as concrete paving, asphalt paving, or stabilized soil.

If an improved surface (such as concrete paving, asphalt paving, or stabilized soil) will not be used for construction, the foundation area must be prepared. The bunker must be constructed on a flat, level foundation. The foundation must be strong and stable enough to support the structure over its intended life. Blade the area to level the foundation site and remove organic material and loose surface soils. Test exposed foundation material to ensure a stable foundation. Refer to TM 3-34.85/MCRP 3-34.1, *Engineer Field Data,* Table 11-1 for characteristics of specific soils; Figure 11-1, page 11-3, outlines the procedure for field identification of soils.

2-15 ASSEMBLY INSTRUCTIONS.

Provide assembly instructions including complete details for preparing the site for construction and assembling the bunker on-site.

2-16 ACCEPTANCE CRITERIA.

Provide a test report and a certification letter from testing laboratories or agencies documenting the fragmentation and blast testing performed on the bunker and results. Include the protection classification to which the bunker was tested in the certification letter. Within the test report, provide photographs of the before and after condition and the set-up configuration of the structure and the instrumentation. Provide photographs of the damage, deflection and disposition of the structure as part of the report. Record readings of all pressure gages (see Figure 2.1). Record results of acceptance tests and measurements and provide a narrative to accompany the results.

2-17 POINTS OF CONTACT.

Contact information for Service representatives of the Army, Navy, and Department of the Air Force is provided below. Contact the appropriate Service representative for document interpretation and additional guidance to assist with bunker certification. Recommendations for improvements to this TSSEWG Manual are encouraged. Send recommended changes, with supporting rationale, to:

USACE Protective Design Center, 1616 Capitol Avenue, Suite 9000, Omaha, NE 68102-9000, email: PDC.Web@usace.army.mil, https://pdc.usace.army.mil

NAVFAC Atlantic, Lafayette River Complex, 6506 Hampton Boulevard., Norfolk, VA 23508, DSN: 262-8000, commercial (757)322-8000, https://www.navfac.navy.mil/

Preparing Activity: AFCEC/COSC, 139 Barnes Drive, Suite 1, Tyndall AFB, FL 32408-5319, Attention: Antiterrorism Subject Matter Expert, DSN 523-6119, commercial (850)283-6119, email AFCEC.rbc@us.af.mil

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APPENDIX A GLOSSARY

A-1 ACRONYMS.

ASTM	American Society for Testing and Materials
CBR	California bearing ratio
CONWEP	conventional weapon(s)
CUI	Controlled Unclassified Information
DCP	dynamic cone penetrometer
FRCS	facility related control system
FSP	fragment-simulating projectile
ft	foot
ft/s	feet per second
in.	inch
lb	pound
m	meter
mm	millimeter
NEW	net explosive weight
psi	pound(s) per square inch
psi-msec	pound(s) per square inch–millisecond (unit of impulse)
RAM	rockets, artillery, and mortars
TBM	theater ballistic missile
TNT	trinitrotoluene
TSSEWG	Tri-service Security Engineering Working Group
TSSEWG M	TSSEWG Manual
UFC	Unified Facility Criteria
V_{50}	50 percent Ballistic Limit Velocity

A-2 DEFINITIONS OF TERMS.

Near Miss: A near miss of an indirect fire weapon is defined as the effects of the weapon detonated no closer than 10 feet from the surface of the target. See Figure 2-1.

V50 Ballistic Limit: The velocity at which a specific projectile (bullet or FSP) is expected to penetrate the armor or protective component half of the time.

APPENDIX B REFERENCES

UNIFIED FACILITIES CRITERIA

https://www.wbdg.org/dod/ufc

UFC 1-200-01, *DoD Building Code*

UFC 1-201-01, *Non-Permanent DoD Facilities in Support of Military Operations*

UFC 4-010-06, *Cybersecurity of Facility-Related Control Systems (FRCS)*

FEDERAL

MIL-DTL-46593B*, Detail Specification: Projectile, Calibers .22, .30, .50, and 20 mm Fragment-Simulating,* 11 Aug 2008

MIL-STD-662F*, V50 Ballistic Test for Armor,* December 18, 1997

ARMY/MARINE CORPS

TM 3-34.85/MCRP, *Engineer Field Data*

ASTM INTERNATIONAL

https://www.astm.org

ASTM F3664-*24, Standard Practice for Blast Testing, 2024*

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APPENDIX C CONSENSUS PROCEDURES FOR DETERMINING MUNITION PROTECTION CLASSES, AND DESIGN FRAGMENT WEIGHT AND VELOCITY TO REPRESENT EACH CLASS

This appendix is provided for reference only, and is intended to document the consensus methodologies (described herein) that were agreed upon to determine:

- munition classes and the governing munition to represent each munition class
- the design fragment weight and velocity to provide the required level of protection from the governing munition for each protection class.

Additional sections of this appendix contain Controlled Unclassified information (CUI). For access, contact the appropriate Service point of contact listed in paragraph 2-17.

(PDF) Engineer Field Data – United States Marine Corps (Doctrine Announcements: Aug 30, 2024)
https://www.bing.com/ck/a?!&&p=b1a2785f130a37fc4667d4a0997e540a39c3c5abcc7745170b4f575be0dbd598JmltdHM9MTczODcxMzYwMA&ptn=3&ver=2&hsh=4&fclid=26aeb335-b343-6065-027b-a064b24261b2&psq=TM+3-34.85&u=a1aHR0cHM6Ly93d3cudHJuZ2NtZC5tYXJpbmVzLm1pbC9Qb3J0YWxzLzIwNy9Eb2NzL01DRVMvRG9jcy9Eb2N0cmluZS9Eb2N0cmluZSUyMEFubm91bmNlbWVudF8zMCUyMEFVRyUyMDI0LnBkZj92ZXI9VlJwQzZBTEV4TkRkT0FxbTJoMl9kdyUzZCUzZA&ntb=1,

8. Army's Maneuver Support Center of Excellence is developing a new Army-only pub, Engineer Platoon. It'll consolidate information from TM 3-34.85/MCRP 3-34.1, Engineer Field Data, in appendices. Then, Engineer Field Data will be cancelled. MCES was notified of Army's plan and issued a request for feedback (RFF) questionnaire across the Service. Feedback received will be used to determine whether to retain Engineer Field Data as Marine Corps-only pub and decide which information should be retained, revised, eliminated, or added. Evaluation of feedback has been temporarily paused