UFC 3-220-01
1 November 2012
Change 1, 3 November 2021

UNIFIED FACILITIES CRITERIA (UFC)

GEOTECHNICAL ENGINEERING

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

GEOTECHNICAL ENGINEERING

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

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

Change No.	Date	Location
1	11/03/2021	Update to referenced International Building Code 2018 (IBC 2018) as implemented by UFC 1-200-01. Clarifications to requirements not addressed by the current Building Code. Appendix A, B, C, and D updated links.

This UFC supersedes UFC 3-220-01, dated 1 November 2012.

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States 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.

UFC 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. 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 the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale may be sent to the respective DoD working group by submitting a Criteria Change Request (CCR) via the Internet site listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://www.wbdg.org/ffc/dod.

Refer to UFC 1-200-01, *DoD Building Code*, for implementation of new issuances on projects.

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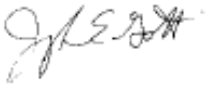

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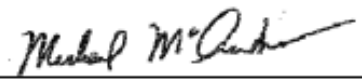

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UNIFIED FACILITIES CRITERIA (UFC)
REVISION SUMMARY SHEET

Document: UFC 3-220-01, *Geotechnical Engineering*

Superseding: UFC 3-220-01, *Geotechnical Engineering,* dated 1 November 2012.

Description of Changes: This UFC adopts and modifies the provisions of the International Building Code 2018 (IBC 2018) consistent with the scope of current military requirements and procedures.

Reasons for Changes:

- The updated UFC is designed to be consistent with and to supplement the guidance contained in the 2018 IBC as modified and implemented by UFC 1-200-01.

- Clarification of requirements not addressed by IBC 2018 are added and use additional industry standards.

Impact: Changes to this document further reduce interpretation and ambiguity that could potentially lead to design and construction conflicts. Increase to costs of DoD facilities are not expected as a result of these changes.

Unification Issues: There are no unification issues.

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CHAPTER 1 INTRODUCTION

1-1 BACKGROUND.

UFC 1-200-01, “General Building Requirements” adopts and modifies \1\ International Building Code 2018 (IBC 2018) /1/ as the building code for DoD. This UFC adopts the updated International Building Code 2018 (IBC 2018) as the basis for use in geotechnical engineering design requirements. Chapter 2 of this UFC further modifies the IBC for specific geotechnical engineering design requirements and is organized by the IBC chapter that each section modifies. The required IBC 2018 section modifications are one of four actions, according to the following legend:

[Addition] – New section added, includes new section number not shown in IBC 2018.

[Deletion] – Delete referenced IBC 2018 section.

[Replacement] – Delete referenced IBC 2018 section or noted portion and replace it with the narrative shown.

[Supplement] – Add narrative shown as a supplement to the narrative shown in the referenced section of IBC 2018.

Effort has been made to adopt non-government standards to the greatest practical extent when they appear to cover the topics and/or the information contained in the former manuals, or when they provide new and innovative methods for geotechnical engineering practices. When non-government criteria does not exist or there is insufficient coverage of the topic in the non-government criteria and where there are unique Department of Defense (DoD) requirements, the existing government criteria from DoD publications are either referenced or have been inserted totally in the document.

1-2 PURPOSE AND SCOPE.

This Unified Facilities Criteria (UFC) provides technical guidance and minimum technical requirements for geotechnical engineering and design of DoD facilities worldwide for all service elements. This guidance and the technical requirements are based on the IBC 2018 and the requirements in UFC 1-200-01. This UFC shall be used by geotechnical engineers to develop military construction contract documents for design and construction of DoD facilities. Project conditions may dictate the need for designs that exceed these requirements. This document shall not supersede higher level mandates such as Public Laws (PL), Executive Orders (E.O.), Regulations (CFR), DoD Directives (DoDD) and DoD Instructions (DoDI) unless a specific exemption has been obtained. If a condition or application occurs for which guidance is not provided, the *registered design professional* shall obtain guidance from the *building official* at the earliest stage of design and prior to commission of any act not easily revise without cost to the Government.

1-3 APPLICABILITY.

This UFC applies to all service elements and contractors involved in the planning, design and construction of DoD facilities worldwide. For construction outside of the U.S., the design shall comply with the more stringent of the UFC and the Host Nation requirements and regulations.

1-4 GENERAL BUILDING REQUIREMENTS.

UFC 1-200-01, "General Building Requirements", provides applicability of model building codes and government-unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, sustainability, and safety. Use this UFC in addition to UFC 1-200-01 and the UFCs and government criteria referenced therein. In addition comply with all contract documents specific requirements.

1-5 REFERENCES.

Appendix A contains a list of references used in this document. The publication date of the code or standard is not included in this document. In general, the latest available issuance of the reference is to be used.

1-6 BEST PRACTICES.

Appendix B identifies background information and practices considered by the DoD as being acceptable for accomplishing certain geotechnical design and engineering services. The Engineer of Record (EoR) or Designer of Record (DoR) is expected to review and interpret this guidance as it conforms to criteria and contract requirements, and apply the information according to the needs of the project. If a Best Practices document has guidelines or requirements that differ from the UFGS or Unified Facilities Criteria, the UFGS and the UFC shall prevail.

1-7 SUPPLEMENTAL RESOURCES.

Appendix C provides a list of reliable sources for information on subjects related to geotechnical engineering, design and construction. These resources are valuable tools to the geotechnical engineer for additional information on topics pertinent to and affiliated with geotechnical engineering.

The glossary in Appendix D contains acronyms, abbreviations, and definitions for terms used in this document.

CHAPTER 2 MODIFICATIONS TO IBC

2-1 CHAPTER 2 DEFINITIONS

2-1.1 Section 202 DEFINITIONS [Replacement]

Replace the

\1\ Registered Design Professional: A registered design professional, as referred to in this document, is an individual licensed to practice engineering in the project area, knowledgeable in soil mechanics and experienced with the geotechnical conditions and construction practices in the project vicinity. This is the individual referred to as the Engineer of Record or Designer of Record for the geotechnical portion of the design in other Department of Defense construction requirement documents./1/

2-2 CHAPTER 16 STRUCTURAL DESIGN.

2-2.1 Section 1613 EARTHQUAKE LOADS.

2-2.1.1 1613.1 Scope. [Supplement]

Insert the following after the first sentence:

Unless approved by the building official, the assessment of liquefaction potential must be based on the Summary Report and supporting documentation contained in NCEER-97-0022, Proceedings of the NCEER Workshop on Evaluation of Liquefaction Resistance of Soils. An acceptable factor of safety associated with liquefaction potential shall meet or exceed those listed in TABLE 2-1 below or conform to local code requirements, whichever is greater. Risk Category is as indicated in Table 1604.5 of IBC 2018.

TABLE 2-1 MINIMUM FACTOR OF SAFETY FOR LIQUEFACTION

Risk Category	Factor of Safety
I & II	1.0
III & IV	1.1

Factor of safety values stated for risk categories I & II are to prevent structural collapse. Factor of safety values stated for risk categories III & IV are to prevent major non-repairable structural damage. Factor of safety values stated are minimums for an extreme event and some structures or conditions may require a factor of safety in excess of those indicated.

2-2.1.2 1613.3.2 Site class definitions. [Replacement]

Replace the following sentence:

"Where the soil properties are not known in sufficient detail to determine the site class, Site Class D, subjected to the requirements of Section 1613.2.3, shall be used unless the *building official* or geotechnical data determines that Site Class E or F soils are present at the site."

With:

If the *building official* does not provide an assumed site class, or where the soil properties are not known in sufficient detail to determine the site class, Site Class D shall be assumed for preliminary purposes. However, the registered design professional shall be responsible for verification of the site class used for design. \1\ Verify the site class by assessing the strength and stiffness of the subsurface profile to a depth of 30.5 m (100 ft) using one or more methods specified in ASCE 7. Use applicable data to assess liquefaction potential.

Further, the new 'requirements' of IBC 2018 Section 1613.2.3, read "Where Site Class D is selected as the default site class per Section 1613.2.2, the value of Fa shall be not less than 1.2. Where the simplified design procedure of ASCE 7 Section 12.14 is used, the value of Fa shall be determined in accordance with ASCE 7 Section 12.14.8.1, and the values of Fv, SMS and SM1 need not be determined." These requirements should be included in the replacement./1/

2-3 CHAPTER 17 SPECIAL INSPECTIONS AND TESTS. [REPLACEMENT]

Replace all paragraphs in this chapter relating to soils and foundations with the following:

All special inspections and testing shall be performed and documented as prescribed in the contract documents.

2-4 CHAPTER 18 SOILS AND FOUNDATIONS.

2-4.1 Section 1801 GENERAL.

2-4.1.1 1801.1 Scope. [Replacement]

Replace the current paragraph with the following:

The provisions of this chapter shall apply to Geotechnical Engineering for construction of military facilities. All exceptions must be approved by the *building official* (as defined in UFC 1-200-01). NAVFAC projects shall also conform to the provisions contained in UFC 1-300-09N, Design Procedures. If conflicts occur with the requirements in this document, the requirements of this document shall take precedence.

2-4.2 Section 1803 GEOTECHNICAL INVESTIGATIONS

2-4.2.1 1803.1 General. [Supplement]

Add the following after the first sentence:

In addition: All site work, including topographic/hydrographic and soil surveys, shall be coordinated with representatives of the Public Works, Utilities and Energy team, base engineering and other design personnel. During execution of field investigation work, the *registered design professional* shall be responsible for obtaining necessary permits, and complying with applicable laws, codes, and regulations, including OSHA regulations. \1\The exact location of the geotechnical excavation, whether by drilling or digging, shall be approved by the appropriate authorities, be it the local utility service or by a company hired by the geotechnical engineering firm to locate or “scope” utilities./1/ The *registered design professional* shall be responsible for all damages to persons and property that occur as a result of their fault or negligence. The *registered design professional* shall take proper safety precautions to protect all persons and property from physical hazards and unsafe conditions. Upon completion of field investigation, return the property to its original condition except as released in writing by the client activity.

Add the following to the end of the paragraph:

The qualifications of the geotechnical testing laboratory and personnel shall meet ASTM D3740, “Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction”. Adherence to the requirements in the ASTM D420, “Standard Guide to Site Characterization for Engineering Design and Construction Purposes” shall be required for all foundation and soils investigations. See IBC 2018, Section 1613 for requirements and procedure to determine site class. \1\ Follow IBC revisions contained within this UFC document./1/

2-4.2.2 1803.2 Investigations required. [Supplement]

Add the following to the end of the paragraph:

Investigations and evaluations (including soil borings, test pits, ground penetrating radar surveys, seismic refraction surveys, and electrical resistivity testing, laboratory testing) shall be in accordance with ASTM D420 and other applicable ASTM standards to the fullest practical extent. The soil classification and investigation shall be supervised by a registered professional engineer. Where ASTM methods are not applicable, procedures and apparatus used shall be in accordance with generally accepted engineering practice.

2-4.2.3 1803.3.1 Scope of Investigation. [Supplement]

Add the following to the end of the paragraph:

Architecture and engineering firms preparing, planning or designing documents shall contact the *building official* to determine if there are files pertaining to the existing geotechnical and seismic conditions or past design approaches for facilities, structures, or pavements that are applicable to the current project. For Design-Build contracts, any relevant Government provided geotechnical or pavement information that is available will be furnished in the Design-Build RFP. Unless approved otherwise by the building official, Cone Penetration Test (CPT) holes shall be performed in accordance with ASTM D5778, “Standard Test Method for Electronic Friction Cone and Piezocone Penetration Testing of Soils” and the soil classification shall be substantiated by visual and laboratory testing of samples recovered from ASTM D1586, “Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils” \1\ and ASTM D1587, "Standard Practice for Thin-Walled Tube Sampling of Fine-Grained Soils", ASTM D3550, “Thick Wall, Ring-Lined, Split Barrel, Drive Sampling of Soils” soil borings. SPT tests and tube samples must be conducted continuously to a depth of 3.7m (12 ft), or 3.7m (12 ft) below the lowest floor elevation, foundation, whichever is greater. Investigate to a depth of 6.2m (20 ft) below the lowest anticipated deep foundations or deeper as determined by the registered design professional. /1/ If geophysical methods including seismic (sonic) methods, electrical and electro-magnetic procedures, gravitational field techniques, and magnetic field methods, are contemplated; then a site visit is required by the *registered design professional* early in the site characterization process.

2-4.2.4 1803.5.4 Ground-water table. [Replacement]

Replace the paragraph with the following:

When encountered, provide the stabilized groundwater elevation with the anticipated variation with the local causes for variation (e.g., seasonal, tidal, etc.). The stabilized groundwater elevation will be measured after 24 hours unless determined otherwise by the *registered design professional*. If drilling techniques are used that prevent the measurement of the water table levels, the Contractor shall install at least two piezometers per drilling site to more accurately measure the depth to the water table. A sufficient number of readings (locations) shall be obtained to establish a representative groundwater depth profile for the project site. Piezometers are required for storm water pond investigations. Piezometers are not required if the ground water levels can be accurately measured during drilling operations or there is good evidence that the water table is not within the depth of the borings or zone of influence for the foundation or structure.

2-4.2.5 1803.5.6 Rock strata. [Supplement]

Add the following to the end of the paragraph:

Limestone areas suspected of containing solution channels or cavities or other areas suspected to have karsts topography or subsurface voids shall be investigated by boring, probing or test pits as determined by the *registered design professional*. A sufficient number of borings, probes and/or test pits shall be performed to verify the subsurface conditions as being adequate to support foundations. Unless specified otherwise in the contract requirements, the investigation shall determine, (a) the depth

of overburden in areas of foundations and excavations; (b) the type and hardness of material encountered; and (c) the degree of difficulty expected to be encountered in excavation. Design of foundations in rock shall include bearing capacity, settlement, sliding stability analyses and consideration of the effects of seepage and grouting to prevent seepage. Rock- Mass Classification shall be determined by one of the systems proposed in ASTM D5878, “Standard Guides for Using Rock-Mass Classification Systems for Engineering Purposes”.

2-4.2.6 1803.5.11 Seismic Design Categories C through F. [Supplement]

Add the following to the end of the paragraph:

\1\ Refer to UFC 3-301-02 for Risk Category V structures, and to UFC 3-301-01 for all other structures. /1/

2-4.2.7 1803.5.12 Seismic Design Categories D through F. [Supplement]

Add the following to the end of the paragraph:

\1\ Refer to UFC 3-301-02 for Risk Category V structures, and to UFC 3-301-01 for all other structures. /1/

2-4.2.8 1803.6 Reporting. [Replacement]

Replace the first paragraph with the following:

A geotechnical report must be provided to the *building official* by the registered design professional on all contracts unless waived by the building official. Unless directed otherwise, provide the report electronically in PDF format and two (2) print copies of the report. The PDF copy of the report shall be produced directly from the report’s authoring software. All Geotechnical Reports shall be signed and sealed by the *registered design professional*. \1\ Include in-situ testing data source files with the electronic submittal of the geotechnical report. /1/

Replace item 1 with the following:

Plot(s) indicating the location of all testing, samples or investigations. The plot(s) shall be to scale and shall clearly indicate the location of each test, etc. on the project site as well as the location of the project on the facility.

Replace item 4 with the following:

When encountered, provide the stabilized groundwater level and identify any factors that influence the groundwater elevation (i.e., tidal or seasonal variation, etc.) and any potential influence of groundwater on the project during both design and during construction.

2-4.2.9 1803.6 Reporting. [Supplement]

Add the following to the end of the section:

11. Seismic site classification and liquefaction potential.
12. Global Positioning System (GPS) coordinates, with an accuracy of at least 3 feet (1 m) for each soil boring, coring or test pit location, referenced to the datum and stated in coordinates required by the *building official*. Reference WGS84 and state in degrees of latitude and longitude for Navy projects.
13. Gradation, moisture content and/or Atterberg tests results per stratum exceeding 1.5 m (5 ft) thickness.
14. Soil corrosivity test results with recommended mitigation construction practices.
15. Observed indication of soil or groundwater contamination.
16. Structural properties tests (i.e. hydraulic conductivity, consolidation, shear strength, triaxial shear, collapse/swell potential, etc.) and dynamic tests (cyclic loading, resonant column, ultrasonic pulse, etc.) when required to support particular design problems.
17. The professional seal and signature of the *registered design professional*.
18. For Cone Penetration Tests (CPT), presentation of results shall include soil stratigraphy in a manner discernable in black and white prints, similar to those provided for soil borings, unless otherwise stated in the contract documents. Include tabulated CPT data.
19. Report the occurrence of permafrost and the accommodations that must be made for the design of the project.
20. When rock is encountered, classify rock in accordance with ASTM D5878, “Standard Guide for Using Rock-Mass Classification Systems for Engineering Purposes” and report the characteristics determined for the specific engineering purpose of the investigation.
21. Provide hammer type used for SPT testing (i.e. manual or automatic) and corrected “N” values with uncorrected values in parenthesis. Supporting information must include energy ratio and supporting calibration data.
22. Provide written and graphic subsurface profiles. Profiles must indicate the elevation of features and based on the report data. Profiles must provide soil and rock stratigraphy, groundwater data, penetration resistance data and all other pertinent data.
23. Site preparation recommendations with any special precautions (e.g., soft soil conditions, high groundwater, etc.) including any equipment limitations and any special requirements (e.g., over-excavation and replacement) and any special precautions.
24. Recommended pavement section(s) with a discussion of the variables (e.g. subgrade CBR and modulus k) used to determine the pavement section(s).

25. \1\ Calculations to support all conclusions, recommendations, and analyses. Include references, factor of safety used, soil model, etc. /1/

2-4.3 Section 1804 EXCAVATION, GRADING AND FILL.

2-4.3.1 1804.1 Excavation near foundations. [Supplement]

Add at the end of this paragraph:

There shall be no excavation in the proximity of an existing foundation without approval of the *building official*. Prior to excavation, provide calculations verifying there will be no loss of support for all excavations closer than the excavation depth to an existing foundation.

2-4.4 Section 1805 DAMPPROOFING AND WATERPROOFING.

2-4.4.1 1805.1.3 Ground-water control. [Replacement]

Replace the first sentence with the following:

Where the ground-water table is lowered and maintained at an elevation 12 inches (304 mm) or more below the bottom of the lowest floor or working level, the floor and walls shall be dampproofed in accordance with Section 1805.2.

Add the following to the end of the paragraph:

Since permanent groundwater control systems must operate continuously without interruption, they shall be conservatively designed and mechanically simple to avoid the need for complicated control equipment subject to failure and the need for operation personnel. When temporary dewatering is required during construction, the dewatering shall be in accordance with UFC 3-220-05, “Dewatering and Groundwater Control” and the groundwater shall be maintained a minimum of 12 inches below the working level or base of the excavation. The *registered design professional* shall provide all documentation required by the *building official* to insure the dewatering procedure does not cause damage to any existing structures, utilities or pavements and insure the process complies with applicable safety requirements.”

2-4.4.2 1805.4.3 Drainage discharge. [Supplement]

Add the following to the end of the paragraph:

Sedimentation and erosion control shall be incorporated in all new construction projects.

2-4.5 Section 1806 PRESUMPTIVE LOAD-BEARING VALUES OF SOILS.

2-4.5.1 1806.1 Load combinations. [Supplement]

Add to the beginning of the paragraph:

Unless otherwise provided or required in the contract documents, load bearing values shall be based on site specific analysis determined by a *registered design professional* as a result of a geotechnical investigation for all structures except minor construction such as equipment or storage sheds less than 55.75 sq m (600 sf). Use the factors of safety provided in Tables 2-2 and 2-3 in developing the allowable bearing values for site specific designs.

TABLE 2-2 MINIMUM FACTORS OF SAFETY (FS) FOR FOUNDATIONS IN ROCK

LOADING CONDITION		FACTOR OF SAFETY (FS)
Bearing		
	Structural Foundations (DL+LL)	3.0
Sliding		
	Dams, Basin Walls	2.5
	Static Loading	2.0
	Seismic Loading	1.3
	Retaining Walls on Rock	1.5
Rock Slopes		
	Severe Consequence of Failure	2.0
	Minor Consequence of Failure	1.3
	Seismic Loading	1.1
Rock Anchorage		
	Based on Unit Weight of Rock Mass	1.5
	Based on Rock Mass Cohesion Intercept	4.0
\1\Pile Foundations Anchored in Rock /1/		
	For pile groups, end bearing piles resting in bedrock may have an efficiency of 1. Buoyancy should be considered in tensile resistance to pull out. The possibility of buckling below the mudline should be evaluated for high capacity piles driven through soft soils to bedrock.	3
\1\ Drilled Shafts/Piers/ Caissons Anchored in Rock /1/		
	Socket into the rock effects the load transfer. Inspection of the bottom of the hole may be needed to ensure the bearing stratum is what was anticipated. For piers extending into Rock assume no load transfer takes place along the soil pier interface. For piers likely to be subjected to tensile loads, reinforcement should be continued for the entire length of the pier.	2.5-4 Depending on uncertainties in loading, stratification, and verification testing.

TABLE 2-3 MINIMUM FACTORS OF SAFETY (FS) FOR FOUNDATIONS IN SOIL

STRUCTURE		FACTOR OF SAFETY (FS)*
Retaining		
	Walls	3.0
	Temporary Braced Excavations	>2
Bridges		
	Railway	4.0
	Highway	3.5
Buildings		
	Silos	2.5
	Warehouse	2.5*
	Apartments, Office	3.0
	Light Industrial, Public	3.5
Footings, Other		3
Mats		>3
\1\ Deep Foundations /1/		
	With static load tests	2
	With dynamic pile analysis including signal matching	2.25 (Compression) 3.0 (Tension)

Notes for Table 2-3:

* Use FS >3 for projects that require extreme limitations on total and differential movements such as super-flat warehouse floors that are needed to accommodate modern transport equipment.

These FS's are conservative and will generally limit settlement to acceptable values, but economy may be sacrificed in some cases.

FS selected for design depends on the extent of data available on subsoil characteristics and their variability. A thorough and extensive subsoil investigation and extensive testing may permit use of a smaller FS. Use of a FS less than the minimum listed above requires formal approval by the Building Official.

FS should generally be $\geq$ 2.5 and never less than 2.

2-4.5.2 1806.2 Presumptive load-bearing values. [Deletion]

Delete the exception statement at the end of this paragraph.

2-4.6 Section 1807 FOUNDATION WALLS, RETAINING WALLS AND EMBEDDED POSTS AND POLES.

2-4.6.1 1807.1.3 Rubble Stone Foundation Walls. [Replacement]

Replace the paragraph with the following:

Rubble stone foundation walls are not allowed.

2-4.6.2 1807.1.4 Permanent Wood Foundation Systems. [Replacement]

Replace the paragraph with the following:

Permanent wood foundation systems are not allowed. \1\Timber piles are allowed where deemed appropriate by the *registered design professional* and approved by the *building official*. /1/

2-4.6.3 1807.2.3 Safety factor. [Replacement]

Replace last sentence in paragraph with the following:

The factor of safety against sliding, calculated as the ratio of forces resisting movement to the horizontal component of earth plus water pressure on the back wall, whether in soil or rock shall be not less than 2.0. In rock, the sliding seismic loading factor of safety is 1.3.

2-4.6.4 1807.3.2.3 Vertical load. [Replacement]

Replace the paragraph with the following:

The resistance to vertical loads shall be determined by the *registered design professional* based on an analysis of the site soil conditions. The presumptive allowable soil-bearing pressures set forth in Table 1806.2 may be used for preliminary design purposes and for minor construction (e.g., non-critical equipment pad or shed, etc.) where a site investigation is not warranted.

2-4.7 Section 1808 FOUNDATIONS.

2-4.7.1 1808.2 Design for capacity and settlement. [Supplement]

Add the following at the end of this paragraph:

The ultimate bearing capacity shall be evaluated using the results from the geotechnical investigation and appropriate in-situ and laboratory analyses.

\1\ Foundation settlements shall be estimated using deformation analyses based on the results of laboratory or in situ testing. The soil parameters used in the analyses shall be chosen to reflect the loading history of the ground, the construction sequence and the effect of soil layering. Both total and differential settlements, including time effect, shall be considered. Ultimate bearing capacity and settlement analysis shall be performed

using a minimum of three (3) widely accepted methods of analysis. The guidance provided in Appendix B shall be utilized for the determination of widely accepted methods of analysis. /1/ Foundations shall be designed such that the net allowable bearing capacity of the soil is not exceeded, and that total and differential settlement is limited to acceptable values, as defined below. Except for minor construction (e.g., equipment sheds, storage sheds, etc. less than 55.75 sq m (600 sf)) minimum width of individual column or pier foundations shall be 610 mm (24 inches) and continuous footings shall be 457 mm (18 inches) wide or 203 mm (8 inches) wider than the supported wall, whichever is greater.

Design of foundations in rock shall include bearing capacity, settlement and sliding stability analyses, and consider the effects of seepage and grouting to control seepage.

Using statistical analyses, compute total settlement at a sufficient number of points to establish the overall settlement pattern. In no case shall total settlement be computed at less than two (2) points. Determine the greatest difference in settlement between adjacent foundation units from this pattern. Designs shall incorporate measures that limit total and differential settlement to levels that prevent structural or cosmetic damage or impairment of the serviceability and function of the facility or structures, including affected drainage and utilities.

\1\ Unless approved by the *building official*, total post construction settlement may not exceed tolerable limits based on building type and dimension, or 25.4 mm (1 in.), whichever is less. Differential settlements shall not result in an angular distortion in excess of 1/500. The angular distortion is defined as the difference in settlement between two points divided by the distance between the points. Acceptable values for total and differential settlement shall give consideration to the purpose and design life of the facility, the materials used for construction, the conditions (environmental, subsurface and external forces) that the facility will be exposed to, and any project-specific requirements. Reference guidance in Appendix B-3.6 for typical limits based on building type and materials. /1/

Slab-on-grade concrete floors shall be designed so that any settlement of the floor shall not result in harmful distortion of the floor or misalignment of the floor with any other building components (such as doorways, trenches or structural elements) or building utilities.

2-4.7.2 1808.3 Design loads. [Supplement]

Add the following to the end of the paragraph:

Consideration of possible future events such as dewatering and flooding due to storms is also required.

2-4.7.3 1808.4 Vibratory loads. [Supplement]

Add the following to the end of the paragraph:

Design foundations in accordance with ACI 351.3R, “Foundations for Dynamic Equipment” and ACI 350.4R, “Design Considerations for Environmental Engineering Concrete Structures”.

2-4.7.4 1808.6 Design for expansive soils. [Supplement]

Add the following to the end of the first paragraph:

Surface soils shall be examined for gilgai whenever expansive soils are suspected.

2-4.7.4.1 1808.6.2 Slab-on-ground foundations. [Supplement]

Add the following at the end of this paragraph:

Structurally supported slabs cast on the ground or above ground shall provide support for all under slab utilities to accommodate their in-service dead and live load using structurally supported trenches and/or stainless steel hangars.

2-4.7.4.2 1808.6.4 Stabilization. [Supplement]

Add the following to the end of the paragraph:

Construction techniques that promote a constant moisture regime in the foundation soils during and following construction shall be used.

2-4.7.5 1808.7.5 Alternate setback and clearance. [Replacement]

Replace the paragraph with the following:

Alternate setback and clearances are permitted subject to the approval of the *building official*. For consideration, the contractor must provide the recommendation of a *registered design professional* substantiated with the results of an investigation that demonstrates the intent of this section has been satisfied.

2-4.7.6 1808.8.6 Seismic requirements. [Deletion]

Delete exceptions at end of paragraph.

2-4.7.7 1808.8.7 Concrete reinforcement. [Addition]

For footings over 0.914 m (3 ft) thick, the minimum ratio of reinforcement area to gross concrete area in each direction shall be 0.0015, with not less than one-half nor more than two-thirds of the total reinforcement required placed in any one face. Minimum bar size shall be #13M (No. 4) with a maximum spacing of 305 mm (12 inches).

2-4.8 Section 1809 SHALLOW FOUNDATIONS.

2-4.8.1 1809.4 Depth and width of footings. [Replacement]

Replace the paragraph with the following:

The minimum depth of footings below the finished ground surface shall be 457 mm (18 inches). Spacing between footings shall be at least 1.5 times the width of the larger foundation to minimize any reduction in bearing capacity due to overlapping zones of influence. The most appropriate foundation types shall be designed, in a preliminary manner and foundation type selection based on a detailed cost comparison of these designs. The minimum footing size shall be as indicated in paragraph 1808.2.

2-4.8.2 1809.5 Frost Protection. [Deletion]

Delete the exception statements at the end of this paragraph.

2-4.8.3 1809.5 Frost Protection. [Replacement]

Replace the last sentence of the paragraph with the following:

Shallow foundations shall not bear on frozen soil unless such frozen condition is of a permanent character and specifically allowed by the contract documents.

2-4.8.3.1 1809.5.1 Frost line depth. [Addition]

Depths to the frost line at specific locations within the United States, its territories and possessions, and at specific locations outside of the United States are identified in UFC 3-301-01, “Structural Engineering”. At locations where frost depths are not provided, use the more stringent of the nearest listed location and the local building code requirement. Conflicts shall be brought to the *building official*’s attention at the earliest stage of design. Additional guidance on frost depth determination and design can be found in Appendix B.

2-4.8.4 Masonry-unit footings. [Replacement]

Replace this subsection paragraph with the following sentence:

Masonry-unit footings are not permitted.

2-4.8.5 1809.11 Steel grillage footings. [Replacement]

Replace this subsection paragraph with the following sentence:

Steel grillage footings are not permitted.

2-4.8.5.1 1809.12 Timber footings. [Replacement]

Replace this subsection paragraph with the following sentence:

Timber footings are not permitted. \1\ Treated timber piling is allowed. /1/

2-4.9 Section 1810 DEEP FOUNDATIONS.

2-4.9.1 1810.1 General. [Supplement]

Add the following to the end of this paragraph:

Applied loads shall not cause excessive vertical and lateral displacements of the pile or drilled shaft. See IBC 2018, Section 1808.2 including revisions in this UFC.

2-4.9.2 1810.2 Analysis. [Supplement]

Add the following to the end of this paragraph:

Applied loads shall not cause excessive vertical and lateral displacements of the pile or drilled shaft. See IBC 2018, Section 1808.2 including revisions in this UFC.

2-4.9.3 1810.2.5 Group effects. [Supplement]

Add the following at the end of this paragraph:

See IBC 2018, Section 1808.2 including revisions in this UFC.

2-4.9.4 1810.3.2.1 Concrete. [Supplement]

Insert the following statement at the end of this paragraph:

Material specifications shall conform to ACI 543R, “Guide to Design, Manufacture, and Installation of Concrete Piles”.

2-4.9.5 1810.3.2.5 Protection of materials. [Replacement]

Replace the first sentence of the paragraph to read:

Where boring records or site conditions indicate possible deleterious action on the materials used in deep foundation elements because of soil constituents, changing water levels or other factors, the *registered design professional* and/or the *Designer of Record* shall evaluate materials, methods or processes to adequately protect these foundation materials and provide recommendations for approval by the *building official*.

2-4.9.6 1810.3.3.1.6 Uplift capacity for grouped deep foundation elements. [Supplement]

After “. . . largest single element”, add the following:

“with the optimum pile spacing being 3 to 3.5B (Vesic 1967) or greater than 0.02L + 2.5B, where L is the pile length in feet and B equals the least horizontal dimension of the largest single deep foundation element.”

2-4.9.7 1810.4.4 Pre-excavation. [Replacement]

Replace first sentence in the paragraph to read:

The use of jetting, auguring or other methods of pre-excavation shall be evaluated by the *registered design professional* and subject to the approval of the *building official*.

2-4.9.8 1810.4.13 Noise. [Addition]

The entire matter of allowable noise disturbance is subjective and shall be carefully evaluated before seeking special methods to reduce its effect.

2-1.1.1.1 1810.4.14 Airfield Clearance. [Addition]

Cranes and other tall equipment used to install deep foundations or site improvement features (e.g., wicks, sand drains, etc.) shall comply with the requirements of UFC 3-260-01, “Airfield and Heliport Planning and Design” including equipment height, clearance and marking requirements.

2-4.10 Section 1811 SLOPE STABILITY [Addition].

2-4.10.1 1811.1 General. [Addition]

Slopes shall be designed and constructed in accordance with Section 1811.2.

2-4.10.2 1811.2 Geotechnical Investigations and stability analyses. [Addition]

Follow guidelines established in Section1803 as modified herein and with special emphasis on ground water and seepage site information. Liquefaction is a major concern for slope stability and shall be investigated thoroughly. Several methods of stability analyses shall be employed to insure greater accuracy and safety in final design. Structural properties testing shall be accomplished for slopes where consequences of failure endanger human life and/or high value structures. Safety factors used in design of new construction or evaluation of existing conditions shall be evaluated by the *registered design professional* and subject to the approval of the *building official* at the earliest stages of the design/evaluation. Acceptable values for factors of safety shall be derived from guidance in Best Practices document EM 1110-2-1902, “Slope Stability”, and evaluation of the conditions (environmental, subsurface and external forces) that the facility will be exposed to, and any project-specific requirements.

2-4.11 Section 1812 GEOSYNTHETICS [Addition].

2-4.11.1 1812.1 General. [Addition]

Applications using geosynthetics shall be designed and constructed using the most current industry accepted practices and standards, along with applicable guidance from Best Practices document UFC 3-220-08FA, “Engineering Use of Geotextiles”. Safety factors shall be applied as stated herein for the type of structure being designed.

2-4.11.2 1812.2 Geosynthetics design and use in construction. [Addition]

Geosynthetics functions include pavement reinforcement, separation, filtration (water and gases), drainage, reinforced embankments, impermeable liners, railroads, erosion and sediment control, and earth retaining walls. \1\ For landfill design and construction, follow guidance from applicable Environmental Protection Agency (EPA) and Geosynthetic Research Institute (GRI) publications. /1/

Geosynthetics must be manufactured for the purpose intended, whether woven, non-woven, method of bonding, whether made from polypropylene, polyester, polyethylene, polyamide (nylon), polyvinylidene chloride, fiberglass or bonded with clay. Strength considerations vary from very low as in non-woven fabrics to very high tensile strength as geogrids. Durability must be considered in exposure to sunlight, ground water, chemicals (landfill liners), asphalt (pavement applications), and temperature of the environment. In drainage design the apparent opening size is important in maintaining drainage and filtration. In construction, important factors are making connections whether in overlapping edges and ends or sewing seams at these intersections and the exposure to sunlight before and after installation.

2-5 CHAPTER 33 SAFEGUARDS DURING CONSTRUCTION.

2-5.1 Section 3304 SITE WORK. [Replacement]

Replace this section with the following:

All site work shall be performed and documented as prescribed in the approved contract documents.

\1\ Designer must consider the differential settlement of the site in relation to the structure or critical areas to ensure that utility connections will not fail. /1/

APPENDIX A REFERENCES

AMERICAN CONCRETE INSTITUTE

www.concrete.org

ACI 543R, Guide to Design, Manufacture, and Installation of Concrete Piles

ACI 350.4R, Design Considerations for Environmental Engineering Concrete Structures

ACI 351.3R, Foundations for Dynamic Equipment

AMERICAN SOCIETY OF CIVIL ENGINEERS (ASCE)

ASCE 7, Minimum Design Loads for Buildings and Other Structures

ASCE 32-01, Design and Construction of Frost-Protected Shallow Foundations

ASCE 41, Seismic Evaluation and Retrofit of Existing Buildings

ASTM INTERNATIONAL

http://www.astm.org/

ASTM D420, Standard Guide to Site Characterization for Engineering Design and Construction Purposes

ASTM D1586, Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils

ASTM D3441, Standard Test Method for Mechanical Cone Penetration Tests of Soil

ASTM D3740, Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

ASTM D5778, Standard Test Method for Electronic Friction Cone and Piezocone Penetration Testing of Soils

ASTM D5878, Standard Guides for Using Rock-Mass Classification Systems for Engineering Purposes

INTERNATIONAL CODE COUNCIL

http://www.iccsafe.org/

International Building Code –2018 Edition

NATIONAL CENTER FOR EARTHQUAKE ENGINEERING RESEARCH

http://www.buffalo.edu/mceer/catalog.host.html/content/shared/www/mceer/publications/NCEER-97-0022.detail.html

NCEER-97-0022, Proceedings of the NCEER Workshop on Evaluation of Liquefaction Resistance of Soils

UNIFIED FACILITIES CRITERIA

http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4

UFC 1-200-01, General Building Requirements

UFC 1-300-09N, Design Procedures

UFC 3-220-05, Dewatering and Groundwater Control

UFC 3-220-08FA, Engineering Use of Geotextiles

UFC 3-260-01, Airfield and Heliport Planning and Design

UFC 3-301-01, Structural Engineering

U.S. ARMY CORPS OF ENGINEERS

https://www.publications.usace.army.mil/USACE-Publications/Engineer-Manuals/?udt_43544_param_page=1

EM 1110-2-1902, Slope Stability

VESIC, A.S.

Ultimate Loads and Settlements of Deep Foundations in Sand, Proc., Symposium on Bearing Capacity and Settlement of Foundations, Duke University, Durham, N.C. 1967, p. 53

APPENDIX B BEST PRACTICES

B-1 INTRODUCTION.

This appendix identifies background information and practices considered by the DoD as being acceptable for accomplishing certain geotechnical design and engineering services. The Designer of Record (DoR) is expected to review and interpret this guidance and apply the information according to the needs of the project. If a Best Practices document has guidelines or requirements that differ from the UFGS or Unified Facilities Criteria, the UFGS and the UFC shall prevail.

B-2 WHOLE BUILDING DESIGN GUIDE.

The Whole Building Design Guide provides additional information and discussion on practice and facility design, including a holistic approach to integrated design of facilities.

The WBDG website provides access to all Construction Criteria Base (CCB) criteria, standards and codes for the DoD Military Departments, National Aeronautics and Space Administration (NASA), and others. These include, Unified Facilities Criteria (UFC), Unified Facilities Guide Specifications (UFGS) and other construction criteria. For approved Government employees, it also provides access to non-government standards.

B-3 GEOTECHNICAL ENGINEERING RELATED GUIDANCE.

The following documents provide guidance on the specific topics indicated. Obtain the indicated UFC documents from the WBDG, the EM documents from http://publications.usace.army.mil/publications/ and ETL documents from https://www.publications.usace.army.mil/USACE-Publications/Engineer-Technical-Letters/

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B-3.1 UFC 3-130-04 FOUNDATION FOR STRUCTURES: ARCTIC AND SUBARCTIC CONSTRUCTION

B-3.2 UFC 3-130-06 CALCULATION METHODS FOR DETERMINATION OF DEPTH OF FREEZE AND THAW IN SOIL: ARCTIC AND SUBARCTIC

B-3.3 UFC 3-220-04FA BACKFILL FOR SUBSURFACE STRUCTURES

B-3.4 UFC 3-220-05 DEWATERING AND GROUNDWATER CONTROL

B-3.5 UFC 3-220-08FA ENGINEERING USE OF GEOTEXTILES

B-3.6 USACE EM 1110-1-1904 Engineering and Design: SETTLEMENT ANALYSIS

B-3.7 USACE EM 1110-1-1905 Engineering and Design: BEARING CAPACITY OF SOILS

B-3.8 USACE EM 1110-1-2907 Engineering and Design: ROCK REINFORCEMENT

B-3.9 USACE EM 1110-1-2908 Engineering and Design: ROCK FOUNDATIONS

B-3.10 USACE EM 1110-2-1421 Engineering and Design - GROUNDWATER HYDROLOGY

B-3.11 USACE EM 1110-2-1901 Engineering and Design: SEEPAGE ANALYSIS AND CONTROL FOR DAMS CH 1

B-3.12 USACE EM 1110-2-1902, Engineering and Design: SLOPE STABILITY

B-3.13 USACE EM 1110-2-2502 Engineering and Design: RETAINING AND FLOOD WALLS

B-3.14 USACE EM 1110-2-2503 Engineering and Design: DESIGN OF SHEET PILE CELLULAR STRUCTURES COFFERDAMS & RETAINING STRUCTURES

B-3.15 USACE EM 1110-2-2504 Engineering and Design: DESIGN OF SHEET PILE WALLS

B-3.16 USACE EM 1110-1-3500 Engineering and Design: CHEMICAL GROUTING

B-3.17 USACE EM 1110-1-1802 Engineering and Design: GEOPHYSICAL EXPLORATION FOR ENGINEERING AND ENVIRONMENTAL INVESTIGATIONS

B-3.18 USACE EM 1110-1-1804 Engineering and Design: GEOTECHNICAL INVESTIGATIONS, ENG 1836, ENG 1836A

B-3.19 USACE EM 1110-1-2909 Engineering and Design: GEOSPATIAL DATA AND SYSTEMS

B-3.20 USACE EM 1110-2-1908 Engineering and Design: INSTRUMENTATION FOR EMBANKMENT DAMS AND LEVEES

B-3.21 USACE EM 1110-2-1909 Engineering and Design: CALIBRATION OF LABORATORY SOILS TESTING EQUIPMENT

B-3.22 USACE EM 1110-2-1911 Engineering and Design: CONSTRUCTION CONTROL FOR EARTH AND ROCK- FILL DAMS

B-3.23 USACE ETL 1110-2-352 Engineering and Design: STABILITY OF GRAVITY WALLS, VERTICAL SHEAR

B-3.24 USACE ETL 1110-2-544 Engineering and Design: GEOTECHNICAL ANAYLSIS BY THE FINITE ELEMENT METHOD

B-3.25 USACE ETL 1110-2-547 Engineering and Design: INTRODUCTION TO PROBABILITY AND RELIABILITY METHODS FOR USE IN GEOTECHNICAL ENGINEERING

B-3.26 American Society of Civil Engineers, SEI/ASCE 32-01 Design and Construction of Frost-Protected Shallow Foundations and ASCE 20-96, Standard Guidelines for the Design and Installation of Pile Foundations

B-3.27 Transportation Research Board, NCHRP Program Report VOL. 343, Engineering Manual for Shallow Foundations, Driven Piles, Drilled Shafts, Retaining Walls, and Abutments.

B-3.28 A Study of Bearing Capacity of Deep Foundations, Georgia Institute of Technology, Atlanta, 1967

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APPENDIX C SUPPLEMENTAL RESOURCES

INTRODUCTION

The following references are reliable sources for information related to geotechnical engineering and design. These sources provide direction for specific geotechnical applications not addressed in this UFC or provide additional information to guide or aid the designer in the various phases of the design. This list is provided for the convenience of the designer and may not include references for all specific applications relevant to all projects. The designer is responsible for insuring the design conforms to all criteria relevant to the project.

UNIFIED FACILITIES CRITERIA

http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4

UFC 3-220-06. GROUTING METHODS AND EQUIPMENT

UFC 3-250-11, SOIL STABILIZATION FOR PAVEMENTS

ARMY CORPS OF ENGINEERS PUBLICATIONS

http://publications.usace.army.mil/publications/

https://discover.dtic.mil/

USACE EM 1110-2-2300 Engineering and Design: GENERAL DESIGN AND CONSTRUCTION CONSIDERATIONS FOR EARTH AND ROCK-FILL DAMS

USACE EM 1110-3-136 Engineering and Design: DRAINAGE AND EROSION CONTROL-MOBILIZATION CONSTRUCTION

USACE EM 1110-3-137 Engineering and Design: SOIL STABILIZATION FOR PAVEMENTS-MOBILIZATION CONSTRUCTION

USACE ER 1110-1-261 Engineering and Design: QUALITY ASSURANCE OF LABORATORY TESTING PROCEDURES

USACE ETL 1110-1-138 Engineering and Design: STANDARD PENETRATION TEST

USACE ETL 1110-1-185 Engineering and Design: GUIDELINES ON GROUND IMPROVEMENT FOR STRUCTURES

USACE ETL 1110-2-282 Engineering and Design: ROCK MASS CLASSIFICATION DATA REQUIREMENT FOR RIPPABILITY

NON-GOVERNMENT INDUSTRY PUBLICATIONS

ADSC: The International Association of Foundation Drilling, 8445 Freeport Parkway, Suite 325, Irving, TX 75063, Telephone: 469-359-6000, Website: www.adsc-iafd.com

Caterpillar Tractor Company, Handbook of Ripping, 8th Edition, Peoria, IL

Cambridge University Press, The Edinburgh Building, Cambridge, CB2 8RU, UK Rock Mechanics and Engineering, by C. Jaeger

Center for Geotechnical Research, Virginia Tech, Blacksburg, VA 24061, Dr. George Filz, Director, E-mail: filz@vt.edu, Phone: 540-231-7151 Website: https://cgpr.cee.vt.edu/

Deep Foundations Institute, 326 Lafayette Avenue, Hawthorne, NJ 07506 Telephone: 973-423-4030, Website: www.dfi.org

Elsevier Publications, The Boulevard, Langford Land, Kidlington Oxford, Engineering Rock Mechanics (Pt. 1, 2) by J.A. Hudson, J.P. Harrison

Geosynthetics Specifiers Guide, Geosynthetics Magazine, Geosynthetic Materials Association,1801 County Road B, West, Roseville, MN 55113, Telephone: 651-222-2508, Website: http://geosyntheticsmagazine.com/

The Geotechnical Directory website: www.geotechnicaldirectory.com

The Geotechnical and Geoenvironmental Software Directory, Website http://www.ggsd.com/

ISEE Blasters' Handbook, International Society of Explosive Engineers, 30325 Bainbridge Road, Cleveland, OH 44139, Telephone: 440-349-4400, Website: http://www.isee.org

Pile Buck, Inc., P.O. Box 64-3929 Vero Beach, FL 32964, Telephone: 772-492-1056, Website: http://www.pilebuck.com/

Transportation Research Board, NCHRP Program Report VOL. 343, Engineering Manual for Shallow Foundations, Driven Piles, Drilled Shafts, Retaining Walls, and Abutments, Website: http://www.trb.org/Publications/PubsNCHRPProjectReportsAll.aspx

APPENDIX D GLOSSARY

ACRONYMS

AFCEC	Air Force Civil Engineering Center
BIA	Bilateral Infrastructure Agreement
DoD	Department of Defense
DoR	Designer of record – The responsible designer whose seal is placed on the design documents (Navy, Marine Corps)
EoR	Engineer of Record – Same as DoR (Army, Air Force)
ft	foot
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HNFA	Host Nation Funded Construction Agreements
NAVFAC	Naval Facilities Engineering Command
SOFA	Status of Forces Agreements
sq m	square meter
sf	square foot
TBD	To Be Determined
UFC	Unified Facilities Criteria
U.S.	United States
USACE	United States Army Corps of Engineers