

## STRUCTURES

1. General. Critical structures may impact the integrity of a flood control project in several manners such as the excavation for construction of the structure, the type of foundation, backfill materials, and compaction. A critical structure is defined as a structure that functions as part of the flood control works; or a structure which, if it should fail, the failure would lessen the flood control project' level of flood protection. The Corps of Engineers, Local Protection Section and Structural/Civil Section will determine whether or not a structure is classified as critical. Consideration will be given to the flood control structure's height, structure's proximity to the flood control works, structure size and purpose, foundation blanket type and thickness, and foundation aquifer type. Structures that function as part of the flood control works shall be designed in accordance with the applicable Corps of Engineers guidance for the type of structure listed in the references paragraph at the end of this topic. Where the recommended references are not appropriate, or do not cover the type of work, other standards may be used subject to approval of the Geotechnical Design Section or Structural Section. General requirements for critical and non-critical structures are as follows.

1.1. Excavation and backfill for structures should conform to the topic EXCAVATION AND BACKFILL.

1.2. Dewatering of excavations should conform to the topic DEWATERING.

1.3. If the integrity of flood protection will be reduced by excavation in a levee embankment, interim flood protection should be provided as required in the topic INTERIM FLOOD PROTECTION AND CONTINGENCY PLAN.

1.4. If the proposed project location is within the critical area, a contingency plan should be prepared. The contingency plan should conform to the requirements in the topic INTERIM FLOOD PROTECTION AND CONTINGENCY PLAN. The contingency plan should include all information required in the checklist: CONSTRUCTION IN THE CRITICAL AREA OF FLOOD CONTROL PROJECTS CONSTRUCTED BY THE CORPS OF ENGINEERS.

2. Uplift (Flotation) Considerations.

2.1. Uplift analysis should use the hydraulic grade lines for river stages obtained from an underseepage analysis. The underseepage analysis should conform to the topic UNDERSEEPAGE.

2.2. The uplift factors of safety and methods of analysis should conform to the topic UPLIFT.

3. Temporary or Permanent Use of Deep Foundations in and Around Levees. Considerations should include uplift on pile caps, pile negative skin friction, lateral loads on piling, seepage around piling, use of sheet piling for flood walls and retaining walls, and use of temporary or permanent sheet piling.

3.1. Piles such as auger cast piles that leave no void between the concrete and the soil when complete may be used for deep foundations. A minimum diameter of 18 inches should be used for auger cast piles to provide sufficient depth from the outside of the pile to the reinforcing steel to develop the required moment capacity.

3.2. EM 1110-2-2906 - DESIGN OF PILE FOUNDATIONS discusses pile capacity, pile negative skin friction and lateral loads and lists computer programs which can be used in determining lateral loads on piles.

3.3. Seepage around sheet piling cutoffs should be considered as shown in EM 1110-2-2502, RETAINING AND FLOOD WALLS. Due to interlock leakage, sheet piling is only 50% effective in reducing uplift in coarse grained soils.

3.4. Sheet piling for flood and retaining walls should be designed and constructed as shown in EM 1110-2-2502, RETAINING AND FLOOD WALLS, and EM 1110-2-2504, DESIGN OF SHEET PILE WALLS. Cantilevered I-type sheet piles walls should not be used when the differential fill height is greater than 10 feet.

3.5. Permanent sheet piling may be used as cutoff to control underseepage and provide scour protection for foundations. Temporary sheet piling may be used to support excavations. Design of permanent or temporary sheet piling retaining structures must consider the effect of sheet pile lateral deflection.

#### 4. Watertightness of Walls for Reinforced Concrete Structures.

4.1. To insure watertightness, minimum 10-inch thick walls should be used. Two layers of reinforcing steel must be placed with the horizontal steel continuous around the wall corners. Continuity of reinforcement around the corners will prevent wall corners from opening under load and enhance water tightness.

4.2. Horizontal construction joints in walls shall be straight with the surface roughened and vertical steel continuous through the joints. If a waterstop is necessary, a 1/8-inch thick galvanized flat steel waterstop can be used.

4.3. If transverse contraction joints are required in the walls of a structure like a reinforced concrete box culvert, waterstops of a flexible type should be used, as specified in EM 1110-2-2102, WATERSTOPS AND OTHER PREFORMED JOINT MATERIALS FOR CIVIL WORK STRUCTURES.

#### 5. Repair/modification of Existing Flood walls and Retaining Walls.

5.1. Suggestions for repair measures of existing floodwalls or retaining walls within the critical area are contained in EM 1110-2-2502, RETAINING AND FLOOD WALLS and EM 1110-2-2002, EVALUATION AND REPAIR OF EXISTING CONCRETE STRUCTURES.

5.1.1. If an opening needs to be provided in an existing wall, remove an entire monolith section of the wall, if practicable, to avoid modification to the existing adjacent walls.

5.1.2. If only a portion of the wall monolith will be removed, then the modified monolith must meet all applicable criteria.

5.1.3. Existing wall sections should be carefully removed by saw cutting. Use of "headache" balls and blasting are not permitted.

5.1.4. Existing reinforcing steel should be left in place and incorporated into the new work.

5.1.5. Shrinkage compensating concrete next to the existing concrete surfaces having a minimum compressive design strength of 3,000 PSI at 28 days should be used.

5.1.6. The modified structure must be watertight.

## 6. Methods of Abandonment of Structures.

6.1. Proposed method of abandonment and/or removal of structures within the critical area of flood control projects should be described.

6.2. Excavation and backfill for removal and abandonment of structures should comply with the requirements shown in the topic EXCAVATION AND BACKFILL.

## 7. Minimum Depth of Foundations to Prevent Frost Heave.

7.1. Minimum design depths for building foundations below finished grade is detailed in UFC 3-310-01 (previously TI 809-01 & EI 015901), LOAD ASSUMPTIONS FOR BUILDINGS. The following procedures are recommended:

7.1.1. Frost penetration value for project locations are shown in Table 1 of the above referenced UFC 3-310-01.

7.1.2. Using frost penetration values from Table 1 and taking into account whether the structure is heated or not, the bottom of the foundation depth should be determined from Fig. 1 of the above referenced UFC 3-310-01

7.1.3. If erosion potential or moisture desiccation is a concern, the design depth should be adjusted accordingly.

7.1.4. In no instance should the bottom of isolated or strip footings be less than 3 feet below finished grade.

## 8. Structures Located in Corrosive Environments.

8.1. Corrosion effects on vitrified-clay, reinforced concrete, cast iron, steel, flexible metal,

plastic pipes, ductile iron pipes and asbestos cement pipes should be considered as addressed in EM 1110-2-2902, CONDUITS, CULVERTS AND PIPES and in MRD Policy on Installation of Pressurized Water Lines in Existing Dam Embankments (NWDR 1110-1-1).

8.1.2. Required soil resistivity measurements for buried ferrous metal facilities for use in determining the need for cathodic protection should conform to Kansas City District Policy - Cathodic Protection of Buried Facilities, Measurements of Soil Resistivity.

8.2. Concrete protection requirements for reinforcing steel cover are contained in ACI 318-95, ACI 318R-95, Building Code Requirements for Structural Concrete and Commentary. For structures that are classified as hydraulic structures design must follow the guidance provided in EM 1110-2-2104, Strength Design Of Reinforced Concrete Hydraulic Structures. Special requirements for the concrete mix are also covered in the ACI publications.

9. Mechanical Consideration for design and construction of sluice gates are shown in the topic SLUICE GATES.

10. Recommended references. The following references are recommended to be used for design and construction of structures within the levee embankment or in the critical area of flood control projects.

10.1. EM 1110-2-3104, STRUCTURAL AND ARCHITECTURAL DESIGN OF PUMPING STATIONS, describes the following requirements:

- a. Structural loads on pumping plants.
- b. Design stresses, design criteria, and loading conditions for pumping plants.
- c. Design criteria for pressurized lines.

10.2. EM 1110-2-3102, GENERAL PRINCIPLES OF PUMPING STATION DESIGN AND LAYOUT, includes the layout criteria of Pumping Station discharge lines.

10.3. EM 1110-2-2902, CONDUITS, CULVERTS AND PIPES, includes the following:

- a. Methods of Analysis, loadings, materials, installation, joints, and camber for pipes and concrete culverts, through levees or in the critical area of flood control projects.
- b. Loadings on installed pipes, materials and installation for pipe jacking.
- c. Corrosion effects on pipes.

10.4. EM 1110-2-2502, RETAINING AND FLOOD WALLS, contains the following information for walls within the critical areas of flood control projects:

- a. Design and construction considerations and methods for floodwalls and for retaining walls.
- b. Geotechnical investigation requirements.
- c. Repair measures suggestions for existing floodwalls.

10.5. EM 1110-2-2705, STRUCTURAL DESIGN OF CLOSURE STRUCTURES FOR LOCAL FLOOD PROTECTION PROJECTS, includes the following requirements and information:

- a. Selection criteria of closure types.
- b. Structural analysis and design of closure structures.
- c. Gate operating equipment, seal assemblies, embedded materials.
- d. Corrosion protection criteria and requirements.

10.6. TM 5-818-1, AFM 88-3, Chap. 7, SOILS AND GEOLOGY PROCEDURES FOR FOUNDATION DESIGN OF BUILDINGS AND OTHER STRUCTURES (EXCEPT HYDRAULIC STRUCTURES), includes the following information:

- a. Necessary subsurface investigation and laboratory testing to determine the engineering properties of soil and rock for foundation design.
- b. Settlement analysis.
- c. Bearing capacity analysis.
- d. Selection of foundation type.
- e. Stabilization of subgrade soils.
- f. Design analysis for spread footings, mat foundations, deep foundation including drilled piers, and pile foundations.
- g. Foundations in areas of significant frost penetration.

10.7. EM 1110-1-1905, BEARING CAPACITY OF SOILS, contains the following information:

- a. Determination of the engineering properties of foundation soils for bearing capacity analysis.
- b. Bearing capacity analysis for shallow foundation.
- c. Analysis of deep foundations including drilled shafts and driven piles.

10.8. EM 1110-2-2102, WATERSTOPS AND OTHER PREFORMED JOINT MATERIALS FOR CIVIL WORK STRUCTURES, includes requirements necessary to insure watertightness of construction.

10.9. EM 1110-2-2906, DESIGN OF PILE FOUNDATIONS, includes the following:

- a. Geotechnical investigations for design of pile foundations.
- b. Design analysis construction requirements for pile foundations.

10.10. EM 1110-2-2504, DESIGN OF SHEET PILE WALLS.

10.11. NAVFAC DM-7.2, NAVAL FACILITIES ENGINEERING COMMAND - FOUNDATIONS AND EARTH STRUCTURES.

10.12. EM 1110-1-1904, SETTLEMENT ANALYSIS, includes design analysis for settlement

of construction.

10.13. UFGS 03373, CONCRETE FOR CONCRETE CUTOFF WALLS, includes material requirements, construction and testing of cutoff walls.

10.14 NWD POLICY ON INSTALLATION OF PRESSURIZED WATER LINES IN EXISTING DAM EMBANKMENTS, NWDR 1110-1-1, 15 May 1999, contains guidance on corrosion protection for buried metallic lines and casing pipes.

10.15. KANSAS CITY DISTRICT POLICY - CATHODIC PROTECTION OF BURIED FACILITIES, MEASUREMENTS OF SOIL RESISTIVITY, addresses requires soil resistivity measurements for buried ferrous metal facilities for use in determining need for cathodic protection.

10.16. ACI 318, BUILDING CODE REQUIREMENTS FOR STRUCTURAL CONCRETE AND COMMENTARY, addresses concrete reinforcing steel cover requirements and denseness and non-porosity of concrete in corrosive environments.

10.17 UFC 3-310-01, LOAD ASSUMPTION FOR BUILDINGS, addresses frost depth requirements for foundations.

10.18 EM 1110-2-2504 DESIGN OF SHEET PILE WALLS.

10.19 EM 1110-2-2104, STRENGTH DESIGN OF REINFORCED CONCRETE HYDRAULIC STRUCTURES, provides supplemental design guidance, to ACI 318, required of hydraulic structures.

10.20. EM 1110-2-2105, DESIGN OF HYDRAULIC STEEL STRUCTURES, provides guidance for designing hydraulic steel structures and guidance for fracture control.