* Appendix H
Load and Resistance Factor Design Criteria for Local Flood Protection Project Closure Gates

H-1. Introduction

a. Purpose. This appendix provides structural design guidance for gate closure openings in levees and floodwalls for inland local flood protection projects (LFPP) using the load and resistance factor design method. Load carrying members (including but not limited to: skin plates, intercostals, girders, diagonals, and vertical diaphragms) shall be designed in accordance with the criteria contained in this appendix, as well as criteria in Chapters 1, 2, 3, and 5 where applicable. Gate layout, selection of materials, and assumed member loading shall follow guidance in EM 1110-2-2705 unless otherwise stated herein. Mechanical and electrical items shall be designed in accordance with Chapter 4 and guidance specified in EM 1110-2-2705.

b. Background.

(1) Types of LFPP closure structures. Closure structures for openings in levee and floodwall systems of LFPPs are usually either stoplog or gate type closures. The guidance presented in this appendix is limited to swing, miter, rolling, and trolley gates since these are the most commonly used LFPP gate types. Many gate details are shown in EM 1110-2-2705.

(2) Load combinations and load factors. ASCE (1990) and AISC (1986) specify load factors and load combinations for buildings; however, for LFPP closures, unique loads and load combinations exist. The load factors and load combinations specified in paragraph H-2*a* pertain specifically to LFPP closure gates. Development of the load factors considered variability, definition, and likeness to those loads specified in ASCE (1990) and AISC (1986).

(3) A discussion of the need for using reliability factor α for HSS design is given in paragraph 3-8. LFPP gates are considered hydraulic steel structures; however, the environment they function in is not as severe as other HSS and is more like building environments than the typical HSS environment. Therefore, the reliability factor for LFPP gates shall be 1.0 unless the structural engineer is aware of extenuating circumstances that require a more conservative design.

H-2. Load and Resistance Factor Design

a. Strength requirements. LFPP gates shall have design strengths at all sections at least equal to the required strengths calculated for the factored loads and forces in the following load combinations. The most unfavorable effect may occur when one or more of the loads in a particular load combination are equal to zero.

$$1.4\,Hs + 1.2\,D \qquad \text{(H-1)}$$

$$1.2\,D + 1.3\,(Q \text{ or } W) \qquad \text{(H-2)}$$

The nominal loads are defined as follows:

H_s = hydrostatic load

D = dead load

Q = maximum operating load (draw bar pull or operating equipment capacity)

W = wind load

b. Load considerations. Loads due to thermal effects need not be considered. Earthquake loads need not be considered for the gate members since the probability of an earthquake occurring when the gate is closed is very remote. However, the seismic design for the concrete monolith supporting the open gate must include the inertial effects. This appendix addresses only inland structures; therefore, other special loading conditions may be necessary for gate closures in hurricane flood protection projects. For example, gates could be subjected to large wave loads during closing operations before the main hurricane storm strikes.

(1) Hydraulic loads. Hydrostatic load H_s shall be determined based on water to the top of the gate on the unprotected side and at or below the gate sill elevation on the protected side.

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* (2) Gravity loads. Dead load[1] *D* shall be determined based on site-specific conditions. Ice and mud loads are generally not considered in LFPP gate load combinations.

(3) Wind loads. Wind load *W* shall consist of a wind load of 15 psf when the gate is opening or closing (gate operating). When the gate is in the latched closed or open positions (gate stationary), a wind load as specified in EM 1110-2-2502 shall be used.

(4) Operating loads. Load *Q* shall be the maximum load that can be exerted by the operator (stalling torque of motorized winch, capacity of manually operated winch, etc. This value should be obtained from the mechanical engineer that designed the machinery or other equipment).

c. Load cases. The following load cases shall be considered with the appropriate loading combinations:

(1) Case 1: Gate stationary.

(a) Closed under hydrostatic loads. (Eq. H-1 with $D = 0$ would apply.)

(b) Open or closed, no hydrostatic load. (Eq. H-2, $Q = 0$ would apply.)

(2) Case 2: Gate operating.

(a) Hinge gates. This loading condition results in the maximum torsion load. Hinge gates shall be designed for a uniform wind load of 15 psf (refer to paragraph 9*b*(4) of EM 1110-2-2705) and an equal and opposite reaction load at the operator (usually a draw bar) connection. (Eq. H-2 with $Q = 0$ would apply.)

(b) Wheel gates. The maximum load for determining the localized stresses for designing the operator connection (usually a winch plate) shall be the limiting load for the operator. (Eq. H-2 with $W = 0$ would apply.)

d. Design for individual members. The following paragraphs include a brief description of design assumptions, appropriate LRFD formulas, and load cases for the design of individual gate members. Further design guidance is presented in EM 1110-2-2705.

(1) Skin plate.

(a) Skin plates shall be sized such that the maximum calculated stress is less than the yield limit state of $\alpha\phi Fy$ where α is 1 as per paragraph H-1*b*(3), and ϕ is defined in AISC (1986). Skin plates shall be designed for hydrostatic loading only. Stresses shall be determined on the basis of small deflection thin plate theory using load case 1(a) of paragraph H-2*c*. Deflection shall be limited to 0.4 of the plate thickness to prevent the development of significant membrane stresses. More than one thickness of plate may be desirable for taller gates. The minimum plate thickness shall be 1/4 in.

(b) With requirements of paragraph H-2*d*(1)(a) above, design per paragraph B-2*d*(1)(b).

(2) Intercostals.

(a) Intercostals shall be sized so the maximum calculated moment is less than the nominal bending strength of $\alpha\phi_b M_n$ where α is 1 as per paragraph H-1*b*(3) and ϕ_b is defined in AISC (1986). Intercostals shall be designed for hydrostatic loading only. They may be flat bars or plates, tee sections, or angle sections. Load case 1(a) or paragraph H-2*c* shall be investigated to determine the maximum load effect.

(b) With requirements of paragraph H-2*d*(2)(a) above, design per the applicable requirements of paragraph B-2*d*(2).

(3) Girders. Horizontal girders for LFPP miter gates shall be designed in accordance with the principles discussed in paragraph B-2*d*(3).[2] Horizontal girders for swing gates that support components of the diagonal loads shall be designed for flexure due to hydrostatic loading plus flexure and axial load induced by dead load in the diagonals. Rolling and trolley gate girders shall be designed for flexure due to hydrostatic loading only. For all types of LFPP gates, load case 1(a) of paragraph H-2*c*

[1] Miter gate design includes ice and mud in the dead load. LFPP gates usually do not consider these loads because of their environment. If the designer has an unusual situation and wants to consider these loads, he should refer to paragraph B-2*b*(2).

[2] Paragraph B-2*d*(3) is written with emphasis on built-up sections. LFPP gates generally use rolled sections.

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* shall be investigated to determine the maximum load effect. The maximum design wind loading acting against the exposed gate surface is insignificant when compared with the hydrostatic loading.

(4) Diagonals. Diagonals shall be designed in accordance with the principles discussed in paragraph B-2*d*(4). They shall be designed to resist gate torsion to the dead load as well as the torsion resulting from closing or opening the gate against a 15-psf uniform wind loading. Load case 2(a) of paragraph H-2*c* is applicable.

(5) Vertical diaphragms. Vertical diaphragms for hinge gates shall be designed to resist diagonal loads as well as flexure loads. Vertical diaphragms for wheel gates shall be designed to resist flexure loads only, except those diaphragms in line with wheels or trolley hangars. They shall include axial and bending due to the forces from the wheels or trolley hangars. Load case 1(a) is applicable. The minimum thickness of any diaphragm element shall be 1/4 in.

(6) Stabilizing systems. The hinges, wheels, trolleys, latching devices, closing links, gate tie-down assemblies, gate hooks, or other stabilizing systems for the various types of LFPP gates are shown in the plates in EM 1110-2-2705. Components of the system shall be designed as individual units. The force applied to the units may be from hydrostatic, dead, operating, or wind or a combination of these loads. Components of the gate being used to stabilize the gate in the closed position with hydrostatic load shall be designed using load case 1(a). For example, the gates hooks for the L-frame rolling gate would use this load case. Other gate components that are designed to resist dead, operating, or wind load (depending on the component's function) shall be designed using load case 2.

e. Serviceability requirements. Serviceability requirements shall be as specified in paragraph 3-5. LFPP gates shall be designed for an expected life of 50 years. Limiting values of structural behavior to ensure serviceability (e.g., maximum deflections, details for ease of maintenance, details for ease of operation, ensuring the gate is not damaged in the latched open position, etc.) shall be chosen so that the closure functions properly throughout its design life.

f. Fatigue. Fatigue is not a concern for LFPP closure structures due to the small number of stress cycles over the life of the structure.

g. Fracture. Requirements of paragraph 3-6 shall be applied to fracture critical members (FCM). The designer shall determine which members are fracture critical for the specific gate in question in accordance with paragraph 3-6*b*. Typically, hinges, wheels, trolley gate hangers, and their associated connections are considered to be FCM.

H-3. Connections and Details

Chapter 5 provides general guidance for connection design. Connection details shall be consistent with the design assumptions. For example, Figure B-2 illustrates the details required for consistency in intercostal design for simple or fixed connections. Paragraphs 1-5*a*(6) and 1-5*a*(7) of EM 1110-2-2703 discuss the use of bolts, welds, and fabrication of miter gate leafs, and paragraph 2-1*j*(3) includes a discussion of diagonal connections. Although EM 1110-2-2703 is written for lock gates, the guidance is generally applicable for LFPP gates.

H-4. Design Example

Specific LFPP gate design examples are not included in this appendix. Appendices B and C demonstrate LRFD principles for the design of miter and tainter gate elements, respectively. The calculations are provided to demonstrate LRFD principles; they do not provide comprehensive design for entire gates. Examples in the two appendices are limited to the design of skin plates, intercostals, and girders. Also, design of the diagonals for a horizontally framed miter gate is shown in Appendix B. These examples should be used for guidance when designing similar structural members for LFPP gates.

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