CHAPTER 40
STRUCTURAL DESIGN

40. INTRODUCTION

The technical requirements presented in this chapter are minimum requirements set by MDEQ Dam Safety. The majority of the requirements in this chapter come from ACI 350-06. Additional guidance for structural design can be found in the documents listed below.

AVAILABLE GUIDANCE:

AMERICAN CONCRETE INSTITUTE (ACI)

ACI 318-08 *or most recently adopted edition*: Building Code Requirements for Reinforced Concrete

ACI 350-06 *or most recently adopted edition*: Code Requirements for Environmental Engineering Concrete Structures

PORTLAND CEMENT ASSOCIATION

Rectangular Concrete Tanks

NATURAL RESOURCES CONSERVATION SERVICE (NRCS or SCS)

Technical Release No. 5: Structural Design of Underground Conduits

Technical Release No. 18: Computation of Pipe Joint Extensibility Requirements

Technical Release No. 30: Structural Design of Standard Covered Risers

Technical Release No. 31: Structural Analysis and Design at Low Stage Inlets

Technical Release No. 37: Structural Analysis and Design at Base of Riser with Conduit Openings in Both Endwalls

Technical Release No. 42: Single Cell Rectangular Conduits, Criteria and Procedures for Structural Design

Technical Release No. 45: Twin Cell Rectangular Conduits, Criteria and Procedures for Structural Design

Technical Release No. 50: Design of Rectangular Structural Channels

Technical Release No. 54: Structural Design of SAF Stilling Basins

TRN 54-1: 1981 Update to Wingwall Design

Technical Release No. 63: Structural Design of Monolithic Straight Drop Spillways

Technical Release No. 67: Reinforced Concrete Strength Design

Technical Release No. 74: Lateral Earth Pressures

National Engineering Handbook, Section 6: Structural Dams

National Engineering Handbook, Section 11: Drop Spillways

National Engineering Handbook, Chapter 52: Structural Design of Flexible Conduits

U.S. ARMY CORPS OF ENGINEERS

EM 1110-2-2104: Strength Design for Reinforced Concrete Hydraulic Structures
EM 1110-2-2104: Change 1, 20 Aug 03

EM 1110-2-2902: Conduits, Culverts, and Pipes

EM 1110-2-2100: Stability Analysis of Concrete Structures

AMERICAN IRON AND STEEL INSTITUTE

Welded Steel Pipe Design Manual, 2007 *or most recent edition*

AMERICAN WATER WORKS ASSOCIATION

Steel Pipe-A Guide for Design and Installation (Manual of Water Supply Practices M11)

U.S. BUREAU OF RECLAMATION

Guide to Concrete Repair

Design of Small Dams

Engineering Monograph No. 27: Moments and Reactions for Rectangular Plates

AMERICAN SOCIETY OF CIVIL ENGINEERS

ASCE 7-10: Minimum Design Loads for Buildings and Other Structures

41. CONCRETE REQUIREMENTS

In general, concrete and reinforcement used in spillways and ancillary structures, shall meet the requirements of ACI 350-06, *Code Requirements for Environmental Engineering Concrete Structures* or most recent edition.

___ The minimum compressive strength of concrete used in any part of construction of a dam or outlet works shall be 4,000 psi. Concrete that is to be subjected to abrasion erosion shall meet the requirements of ACI 350-06, Section 4.6.3. Concrete that is subjected to freeze-thaw conditions shall meet the requirements of ACI 350-06, Section 4.2.

___ Reinforcement shall be ASTM A 615 (Billet Steel), Grade 60.

___ The minimum concrete cover for reinforcing steel shall be in accordance with ACI 350-06, Section 7.71.

___ The minimum distance between primary flexural reinforcement shall not exceed the lesser of 12 inches or that determined by the requirements given in ACI 350-06, Section 10.6.5. Minimum flexural reinforcement shall be determined by ACI 350-06, Section 10.5.1.

___ All exposed concrete surfaces shall have a Class C or better finish.

___ Joints shall be designed in accordance with ACI 350.4R-04: Design Considerations for Environmental Engineering Concrete Structures, Chapter 5. Waterstops shall be required in all joints.

___ Minimum shrinkage and temperature reinforcement shall be in accordance with ACI 350-06, Section 7.12.

___ Aggregates proposed for use in concrete structures associated with High and Significant Hazard dams shall be tested for Alkali-Silica Reactivity.

42. RIGID CONDUITS

In general, cast in place conduits should be designed in accordance with EM 1110-2-2104 along with guidance presented in ACI 350-06.

___ Joints in rigid conduits must be designed to be watertight and flexible to accommodate longitudinal and lateral movements. The specifications should contain a requirement that joints be hydrostatically or air tested prior to backfilling around the conduit.

___ Circular concrete pressure pipe should conform to and be installed in accordance with EM1110-2-2902, Chapter 3, Section 3-1 to 3-3 (see Page 94 Conduits through embankment dams). It must also be AWWA 300, 301, or 303 pipe.

___ The outside walls of concrete box culverts shall have a 1H:10V or more side slope for improved compaction of earthfill against the conduit.

___ Concrete cradles are required for circular conduits on all high and significant hazard dams and should be designed in accordance with NRCS Technical Release No. 5 or most recent NRCS guidance. Foundations for conduits shall be reviewed and approved by Geotechnical Engineer.

___ Cast in place conduits shall be constructed in alternating sections with control joints which include water stops that are either dumbbell or ribbed with a centerbulb.

___ Computation of joint extensibility requirements shall be performed and implemented for all conduits constructed on yielding foundations. Guidelines can be found in *NRCS's Computation of Joint Extensibility Requirements* (1969).

___ Cast in place conduits through embankments should be designed and constructed with a camber to allow positive drainage. The camber should be computed based upon the maximum anticipated settlement of the embankment.

___ Filter diaphragms shall be used to limit the potential of piping for any conduit penetrating though the embankment. Guidelines can be found in NRCS's National Engineering Handbook, Part 628 Dams, Chapter 45 Filter Diaphragms.

43. FLEXIBLE CONDUITS

In general, Steel pipe shall be designed and installed in accordance with AWWA M11, *Steel Pipe – A Guide for Design and Installation* and Chapter 52 of the National Engineering Handbook, *Structural Design of Flexible Conduits* and Plastic pipe shall be designed in accordance with FEMA *Technical Manual: Plastic Pipe Used in Embankment Dams* (FEMA P-676) and *Structural Design of Flexible Conduits.*

___ Corrugated Metal Pipe (CMP) is expressly prohibited in all new high and significant hazard dam construction.

___ Computation of joint extensibility requirements shall be performed and implemented for all conduits constructed on yielding foundations. Guidelines can be found in *NRCS's Computation of Joint Extensibility Requirements* (1969).

___ Joints in flexible conduits must be designed to be watertight and flexible to accommodate longitudinal and lateral movements. The specifications should contain a requirement that joints be hydrostatically tested prior to backfilling around the conduit.

44. SPILLWAY SLABS

___ Spillway slabs should be designed to meet applicable factors of safety for uplift, sliding and foundation reaction. Guidelines for stability analyses can be found in USACE EM 1110-2-2100.

___ Spillway slabs should be a minimum of 8" thick with a minimum temperature and shrinkage reinforcement of #4 bars at 12" on center in each face unless additional reinforcement is required by ACI 350-06, Section 7.12 or spacing of reinforcement is limited by ACI 350-06, Section 10.6.5.

___ All spillway slabs on the downstream face of a dam shall be underlain with a sand filter to collect any seepage that may occur behind the slab or leakage through joints. The sand filter should have perforated drain pipes of a minimum of 4" in diameter to collect seepage and convey it downstream of the dam.

___ All joints shall have water stops that are designed in accordance with ACI 350.4R-04: Design Considerations for Environmental Engineering Concrete Structures, Chapter 5. Typically, dumbbell waterstops are utilized for non-moveable joints (i.e. construction joints) and centerbulb waterstops are utilized for moveable joints (i.e. expansion/contraction joints).

45. RISERS

___ All risers should be checked for flotation as follows (from SCS TR 30):

(1) When the riser is located in the reservoir area, the ratio of the weight of the riser to the weight of the volume of water displaced by the riser shall not be less than 1.5. Low stage inlet(s), if any, shall be assumed plugged for this computation.

(2) When the riser is located in the embankment – same as (1), but add to the weight of the riser, the buoyant weight of the submerged fill over the riser footing projections. Take the buoyant unit weight as $w_b = 50$ pcf.

Note: Flexible risers and conduits may need to be embedded in a concrete base to prevent flotation. A spreadsheet for performing this calculation can be obtained from the MDEQ Dam Safety Division.

___ Risers which rise above the water surface at normal pool shall be designed for wind loading as determined by ASCE 7-10 acting over the entire sidewall.

___ Ultimate bearing capacity of foundation soils under risers shall be calculated and the report shall show that a factor of safety of three (3) shall be met under normal loading conditions.

___ The structural and stability analysis for risers on large height high and significant hazard dams constructed North of Hwy 82 shall include an analysis of earthquake forces resulting from the 2% probability of exceedance in 50 years event.

46. MISCELLANEOUS

___ Filter diaphragms designed in accordance with Chapter 45 of the NRCS National Engineering Handbook are required on conduits for all high and significant hazard dams.

___ All drain pipes shall have a minimum of one clean out that is at least 4" in diameter with a metallic cap and no 90° bends. Drain pipes which run longitudinal to the dam shall have clean outs at least every 200'.

___ All new High and Significant Hazard dams must include a low level outlet that is capable of draining the lake.