16. Design of Pipeline Structures.

a. General.

1) The following guidelines are for the design of structures for water and sewer pipelines including structural concrete and miscellaneous metals design. These include cast in place or precast concrete structures such as valve vaults, manholes, junction chambers, air release/vacuum valve vaults, metering vaults, entry port vaults, etc. Whenever possible, provide concrete structures in accordance with the Standard Details. Structures other than those shown in the Standard Details are considered special design and will require the structure to be designed and shown on the drawings using the guidelines in this section. For all special designs, provide structural calculations performed, signed and sealed by a Professional Engineer registered in the State of Maryland.

b. Abbreviations for References.

AASHTO	American Association of State Highway and Transportation Officials.
ACI	American Concrete Institute.
AISC	American Institute of Steel Construction, Inc.
ASTM	American Society for Testing and Materials.
BOCA	Buildings Officials Codes Administration International, Inc.

c. Design Loads for Pipeline Structures.

1) Dead loads:

a) Soil: Use actual soil parameters from Soil Report. see Soil Data or Soil Report, Part Three, Section 20 (Geotechnical and Corrosion Submittals). If Soil Report is not available, use a soil unit weight of 120 lb/ft^3.

b) Water Table: Assume 4'-0" below ground surface if no other information is available.

c) Concrete: 150 lb/ft^3.

d) Aluminum: 175 lb/ft^3.

2) Hydrostatic: 62.4 lb/ft^3.

3) Live loads: 300 lb/ft^2 minimum.

4) Traffic loads: AASHTO H20 wheel load with appropriate impact factor.

5) Surcharge load: Assume 2 feet of earth cover, unless other information is available.

6) Lifting loads: Design precast structures for lifting loads.

7) If the structure is located within the limits of the one hundred (100) year flood plain, use the appropriate loading due to the one hundred (100) year flood.

d. Design Criteria (Codes and Standards) for Pipeline Structures.

1) Design pipeline structures according to the following codes and standards:

a) BOCA Building Code.

b) ASTM C890 (Standard Practice For Minimum Structural Design Loading for Monolithic or Sectional Precast Concrete Water and Wastewater Structures).

c) ACI 318 (Building Code Requirements for Reinforced Concrete Structures).

d) ACI 350 (Environmental Engineering Concrete Structures).

e) AISC Code (Specification for the Design, Fabrication and Erection of Structural Steel Buildings).

f) AASHTO Code.

g) Aluminum Association (Aluminum Design Manual).

e. Concrete Structures.

1) Design methods. Use one of the following two methods for the structural design of reinforced concrete cast in place and precast structures: Strength Design Method and Working Stress Design Method (Alternate Design Method, ACI 318, Appendix A). Use the special limitations for both methods, in accordance with ACI 350, Environmental Engineering Concrete Structures. These methods are described in detail in ACI 318.

2) Design of the structures. When the design requires a structure, if possible use the structures provided in the Standard Details. If a special design structure is required, provide a design for a cast in place structure, with the option for the contractor to submit design for a precast structure, in accordance with the Specifications.

3) Buoyancy design. When groundwater is present, consider the effects of flotation for below ground structures. Size the structure with a flotation safety factor of 1.1 minimum. Assume in the flotation calculations that the structure is empty, the top slab is removed, and neglect the weight of any equipment, piping, etc.

4) Concrete strength. Use the following concrete compressive strengths (f'_c) when designing concrete structures. Indicate the concrete compressive strengths on the drawings.

a) Cast in place structures: f'_c = 4000 psi @ 28 days.

b) Precast structures: f'_c = 5000 psi @ 28 days.

5) Steel reinforcement. Use ASTM A615, grade 60 (yield strength, f_y = 60,000 psi). Indicate the reinforcing bar size and spacing on the drawings.

6) Precast lifting inserts. Design the lifting inserts for precast structures/members for four (4) times the maximum load transmitted to the inserts.

7) Structure components. Design underground concrete structures for the minimum loads indicated in ASTM C890 as modified in this section and include the following load combinations:

a) Top slab design. Consider the cumulative effect of the dead loads including the weight of earth backfill, access openings/covers, loads due to equipment if any lifting eye bolts or hooks are provided on the underside of the slab, etc. and AASHTO H20 live load, unless the top slab is located in a confined area or at least one (1) foot above the ground surface. Also see Design Loads for Pipeline Structures, in this section.

Note: A confined area is defined as an area enclosed by a fence or an area that will have absolutely no H20 loading in the future. For confined areas, use 300 lb/ft^2 live load in lieu of H20 loading.

(1) Provide removable top slabs for either the entire slab (preferable) or portions of the slab to allow the removal of the largest object in the vault.

(2) If the top slab is fixed with the ratio of each side less than two (2), analyze as a two-way slab, otherwise, analyze as a simply supported one-way slab.

(3) Span length: Center of wall (support) to center of wall (support).

(4) Traffic load: Design in accordance with AASHTO.

(5) When depth of fill is less than 2 feet, use exact method considering wheel contact area, or simplified formulas for bending moments as per AASHTO.

(6) When depth of fill is two (2) feet or more, consider concentrated load or loads as uniformly distributed over a square area with the sides equal to 1-3/4 times the depth of fill, see AASHTO Specifications, Section 6, for more information.

(7) Removable slab: Limit size of slab to a maximum of 15,000 lbs and provide off-set key at edge to prevent movement.

(8) Slab openings: Use net cross section of slab for shear and bending moment.

b) Wall design. Include the cumulative effects of the maximum external hydrostatic load, maximum lateral earth pressure and lateral surcharge load. Base the unit lateral earth pressure upon information obtained from the Soil Report, see Part Three, Section 20 (Geotechnical and Corrosion Review Submittals).

(1) When soil borings are not available, assume the at rest earth pressure coefficient $K_0 = 0.5$. Design the walls for ground water pressure in addition to the earth pressure when indicated in the Soil Report. When the Soil Data or Soil Report is not available, assume the ground water level is at four (4) feet below the surface, unless the structure is located in a flood plain area. In this case, design the structure for flooded conditions with an allowable stress increase of 1.33.

(2) When a valve vault is designed as a thrust vault, design the walls for the full closed valve thrust force and size the vault against sliding with a minimum safety factor of 1.5.

(3) Where traffic can come within a horizontal distance from the structure equal to one half the depth of the structure, apply a lateral surcharge pressure to the walls. In most cases, the live

load can be converted to an equivalent depth of earth fill, and the horizontal pressure computed on the basis of the earth depth. The effect of this surcharge can be considered as a rectangular loading diagram for the full height of the wall, up to a depth of eight (8) feet below grade.

(4) Additional wall design requirements.

(a) Walls can be either one box shape or two-box shapes with upper and lower sections for precast members.

(b) For a one box shape wall, consider top wall hinged and three (3) sides fixed for a wall with a width to height ratio between 0.5 and 2, and for other ratios, consider one way slab in short direction.

(c) For a two (2) box shape wall, design the upper box as a one-way element (horizontal) and the lower box as a one box shape wall as indicated above.

(d) Soil load to be trapezoidal distribution as recommended in the Soil Report.

(e) If the vault is to be designed for thrust, consider the thrust force as either: effective width of concentrated thrust force or other accurate method such as finite element analysis, etc.

(f) If the vault is to be designed as a thrust vault, consider the punching shear due to the thrust force.

(g) No shear keys at horizontal joints in concrete structures, unless there is an extraordinary reason; submit to WSSC for review and approval. Instead provide shear reinforcement, if required. Construction joint between the base slab and walls to be located at the junction of the walls and base slab.

c) <u>Bottom slab</u>. Design as fixed end with 2-way slab if ratio between two sides is less than two (2), otherwise consider one way slab. Consider all live loads and dead loads as a uniform load.

f. Miscellaneous Metals.

1) <u>Steel structures</u>. The Working Stress Design Method by the AISC manual is preferable, but Load and Resistance Factor Design (LRFD) may be used.

a) <u>Gratings</u>. Design or select gratings for 300 lb/ft^2 loading, unless given other specific loading conditions or a higher load is expected. Show the span direction of the grating bearing bars on the drawings. Follow the manufacturer's recommendations and limit the deflection to 1/4" or span length L/360, whichever is smaller, at the design load. Provide removable sections with anchoring devices.

b) <u>Frame Structures</u>. Steel frames, wide flange, angle or channel members and designed for the load tributary area. Allowable stress to be in accordance with AISC manual.

c) <u>Hatches</u>. Design hatches in open areas (outside of road) or areas that are not subjected to high density traffic for H20 loading. Design hatches located in confined areas or where the hatch is at least one (1) foot above ground, for 300 lb/ft^2. Limit the maximum deflection to L/150. Use frame and cover in lieu of hatches when opening is located in existing or future roadways or location is subjected to high density traffic.

(1) When hatches are provided, design the hatch drain as follows:

(a) When the top slab is set above grade, design the hatch drain to discharge outside the vault.

(b) When the hatch is set to grade, design the hatch drain to discharge in the vault.

d) Pipe thrust restraint system. Design tie rods for the full thrust tensile force. Design lugs or thrust rings for the full thrust force and shear. Bending moment and deflection must also be checked. Check stress on the pipe due to welded-on thrust rings or lugs.

2) Aluminum Structures.

a) Gratings. Design or select gratings for 300 lb/ft^2 loading, unless given other specific loading conditions or a higher load is expected. Show the span direction of the grating bearing bars on the drawings. Follow the manufacturer's recommendations and limit the deflection to 1/4" or span length L/360, whichever is smaller, at the design load. Provide removable sections with anchoring devices, see Standard Details M/22.0 and M/22.1.

b) Frames. Aluminum frames are to be wide flange, angle or channel members and designed for the load tributary area. Allowable stress of aluminum members to be in accordance with the Aluminum Association Specifications. Design connections and provide details on the drawings using stainless steel bolts. Design anchor bolts or expansion bolts embedded in concrete for shear and tension forces.

c) Hatches. Design hatches located in open areas (outside road) not subjected to high density traffic for an H20 loading. Design hatches located in confined areas or at least one (l) foot above ground, for 300 lb/ft$^{2.}$ Limit the maximum deflection to L/150. Do not use hatches on roadway locations subject to high density traffic.

(1) When hatches are provided, design the hatch drain as follows:

(a) When the top slab is set above grade, design the hatch drain to discharge outside the vault.

(b) When the hatch is set to grade, design the hatch drain to discharge in the vault.

d) Ladders. Design ladders for a 300 lb concentrated load at the middle of the ladder rung. Use solid bar rungs with serrated surface and a minimum of 3/8" thick stringer. Provide a bracket support for the stringers at four (4) foot spacing, see Standard Detail M\16.0.