

30% BASIS OF DESIGN REPORT – SHERMAN STREET CSO STORAGE TANK

APPENDIX H HYDRAULIC STRUCTURES DESIGN CRITERIA



1.1 STRUCTURAL

This section of the Preliminary Design Report presents a summary of the structural codes and design criteria that will be used for the Sherman Street CSO Storage Tank project. These requirements will be incorporated in all new structures design.

1.1.1 Structural Design Codes, Standards, and References

1.1.1.1 Governing codes and Design Standards

Structural design will be performed in accordance with the Tenth Edition Massachusetts State Building Code 780 CMR based on the 2021 Edition of the International Building Code except where other applicable codes are more restrictive.

1.1.1.2 Design References and Standards

Structural design will be in accordance with the following references and standards. Where the version is not listed, use the version listed under Referenced Standards in International Building Code (IBC) 2021.

- American Society of Civil Engineers (ASCE) 7-16 - Minimum Design Loads for Buildings and Other Structures
- American Concrete Institute (ACI) 318-19 - Building Code Requirements for Structural Concrete
- ACI 350-20 – Code Requirements for Environmental Engineering Concrete Structures
- ACI 350.1-22 – Tightness Testing of Environmental Engineering Concrete Structures
- ACI 350.3-20 – Code Requirements for Seismic Analysis and Design of Liquid-Containing Concrete Structures
- ACI 350.4R-04 – Design Considerations for Environmental Engineering Concrete Structures
- American Institute of Steel Construction 325-17 (AISC) – Steel Construction Manual, 15th Edition (includes AISC 360-16 Specification for Structural Steel Buildings and AISC 303-16 Code of Standard Practice for Steel Buildings and Bridges)
- American Welding Society (AWS) D1.1-15 – Structural Welding Code – Steel
- AWS D1.2-14 – Structural Welding Code – Aluminum
- Aluminum Association Aluminum Design Manual (AA ADM) 2020
- American Society of Testing and Materials (ASTM) – Standards and Specifications

1.1.2 Materials of Construction

1.1.2.1 Reinforced Concrete

The reinforced concrete for this project will be designed in accordance with ACI 350 to satisfy the strength, durability, and crack-control requirements for environmental engineering concrete structures. Portland cement conforming to ASTM C150 is anticipated to be used in the hydraulic structures. Concrete mixes will be developed based on the anticipated exposure conditions and soil corrosivity test results from geotechnical investigation.

Cement	ASTM C150 Type II
Pozzolans	No pozzolans (including fly ash) will be used in concrete for hydraulic concrete structures.
Admixtures	A combination of water-reducing admixtures may be used in all concrete mixes for ease of pumping and placement, to achieve the lowest possible water/cement ratios to minimize shrinkage and control cracking. Admixtures containing calcium chloride will not be used.
Reinforcement	ASTM A615 Grade 60 unless otherwise noted Welded wire reinforcement - ASTM A1064
Concrete	Structural Concrete = 4,500 psi or 5,000 psi Lean Concrete (unreinforced applications) = 2,000 psi

1.1.2.2 Stainless Steel

Submerged or corrosive areas	Type 316
All other uses	Type 304

1.1.2.3 Aluminum

All applications, except as noted	Alloy 6061 T6
Railing and grating	Alloy 6061 or 6063

1.1.2.4 Waterstops

New construction	Polyvinyl chloride (PVC) flat strip waterstops, unless noted otherwise. Use center-bulb-type waterstop at movement/expansion joints.
Retrofit	PVC or preformed hydrophilic waterstops.

1.1.3 Design Category and Design Loads

Design category and loads for the structures are summarized in the following paragraphs.

1.1.3.1 Risk Category

The Risk Category for the structures is determined in accordance with the IBC 2021 as Risk Category III.

1.1.3.2 Dead Loads (D)

Dead load includes the weight of the structure and all fixed equipment.

Weights of materials:	
Reinforced concrete	150 pcf
Steel	490 pcf
Stainless Steel	500 pcf
Aluminum	170 pcf
Soil vertical load	135 pcf

1.1.3.3 Soil Loads (H)

Buried structures will be designed for lateral earth pressure, groundwater pressure and hydrostatic uplift loads resulting from groundwater. The buoyant weight of the overburden soil above the structure will be considered when evaluating resistance to uplift.

EARTH PRESSURES	ABOVE GROUNDWATER	BELOW GROUNDWATER
At-rest	56.4 pcf	89.47 pcf

1.1.3.4 Fluid Loads (F)

Structures will be designed to resist hydrostatic and hydrodynamic loads corresponding to the maximum operating water level. Unbalanced fluid loads will be considered wherever they may occur. The maximum possible water level under the worst-case flooding scenario will be evaluated in accordance with ACI 350 load combinations.

Common Fluids	Unit Weights
Water	62.4 pcf
Raw Sewage	63 pcf

1.1.3.5 Live Loads (L)

The underground structures will be designed for HL-93 truck load where subject to vehicular traffic, or a 300 psf live load where no vehicular traffic is permitted.

1.1.3.6 Flood Loads

Flood loads and the design groundwater elevation will be based on the projected 2070 100-year flood plain elevation of El 24.4.

1.1.3.7 Snow Loads (S)

Snow loads will be determined in accordance with ASCE 7, Chapter 7. For structures with roofs at or below grade in this project, ground snow load will be used as the snow load. The following parameters

will be used to determine the snow loads:

Description	Parameter	Value
Ground Snow Load, psf	P_g	40
Importance Factor	I_s	1.10
Exposure Factor	C_e	1.0
Thermal Factor	C_t	1.2

1.1.3.8 Seismic Loads (E)

Seismic loads for design of the seismic force-resisting systems and nonstructural components will be determined in accordance with the requirements of the IBC and ASCE 7, Chapters 11 through 22. The combined effects of both vertical and lateral loads, where required by ASCE 7-16, will be considered in the design. The following parameters will be used to determine the seismic loads:

Description	Parameter	Value
Importance Factor	I_e	1.25
Mapped spectral response acceleration – short period	S_s	0.278
Mapped spectral response acceleration – 1-second period	S_1	0.066
Site Class		D
Design spectral response acceleration – short period	S_{DS}	0.293
Design spectral response acceleration – 1-second period	S_{D1}	0.106
Seismic Design Category		B

Seismically induced hydrodynamic loads will be determined in accordance with ACI 350.3.

Seismic soil loads shall be determined in accordance with 1610.2 of 780 CMR as included below:

$$F_w = 0.100(S_s)(F_a)(\gamma_t)(H)^2$$

1.1.3.9 Wind Loads (W)

Wind loads will be determined in accordance with the requirements of IBC and ASCE 7, Chapters 26 through 31. Because the tops of the structures are at or below grade. Wind loads are not applicable and will not be considered in the structural design. The applicable wind design parameters are provided below for reference.

Description	Parameter	Value
Ultimate design wind speed (3-second gust)	V_{ULT}	128 mph
Nominal design wind speed (3-second gust)	V_{ASD}	99 mph

1.1.4 Load Combinations

1.1.4.1 Hydraulic Concrete and Buried Structures

Concrete environmental engineering structures will be designed considering an environmental durability factor (S_d) in accordance with ACI-350 to limit effective reinforcing steel stress under service load conditions and satisfy the crack control requirements. For unusual or unlikely load cases, durability factors need not be applied to the design of the reinforcing steel.

The below grade hydraulic structures will be designed in accordance with ACI 350, with the following load combinations considering dead load (D), live load (L), soil/backfill lateral pressure (H), liquid load (F), earthquake (E) and wind load (W), where applicable:

1. $U = 1.4 (D + F)$
2. $U = 1.2 (D + F) + 1.6 (L + H) + 0.5 (L_r \text{ or } S \text{ or } R)$
3. $U = 1.2 D + 1.6 (L_r \text{ or } S \text{ or } R) + 1.0 L \text{ or } 0.5 W$
4. $U = 1.2 D + 1.0 W + 1.0 L + 0.5 (L_r \text{ or } S \text{ or } R)$
5. $U = 1.2 D + 1.2 F + 1.0 E + 1.6 H + 1.0 L + 0.2 S$
6. $U = 0.9 D + 1.2 F + 1.0 W + 1.6 H$
7. $U = 0.9 D + 1.2 F + 1.0 E + 1.6 H$
8. $U = 1.4 (D + F) + 0.6 H$

Where fluid loads (F) are present, they will be included with the same load factor as dead load (D) in load combinations 1-5 and 8. Where H loads are present, a factor of 0.6 will be used where the effect of H resists the primary load and 1.6 where H adds to the primary load.

The design strength reduction factors are given in ACI 350 as follows:

- $\Phi = 0.90$ Tension Only Controlled Sections
- $\Phi = 0.75$ Compression Controlled Sections with Spiral reinforcing
- $\Phi = 0.65$ Compression Controlled Sections with other reinforcing
- $\Phi = 0.75$ Shear and Torsion
- $\Phi = 0.65$ Bearing on Concrete

1.1.4.2 Stability

Structures will be designed to provide adequate stability against sliding, overturning, and flotation using the following criteria and factors of safety and applicable load combinations. The design groundwater level is 7 feet below ground surface for against flotation check under operation condition

Factors of safety:	
Against sliding	
Usual	FS = 1.5
Unusual	FS = 1.33
Seismic/Wind	FS = 1.1
Against overturning (minimum base area in compression)	
Usual	100%
Unusual	75%
Earthquake	Resultant Within the base
Against flotation	
Extreme (100-year flood water level)	FS = 1.1
Operation (design ground water level EL 17)	FS = 1.25

Concrete weight of 145 pcf will be used for dead loads resisting flotation. Resistance to uplift of structures due to high groundwater levels will be provided by the dead load of the structure and the weight of soil above the structure. For structures supported on drilled shafts, uplift resistance may also be provided by the drilled shafts with rock sockets, where recommended by the geotechnical engineer. Connection between the drilled shafts and the foundation slab will be designed to transfer the resulting tensile and lateral forces.

1.1.4.3 Deflection Criteria

The following maximum deflection criteria, under service live load only, will be used:

Top Slabs	L/240
Elevated Floor Slab	L/240