Winnipeg

The City of Winnipeg

Winnipeg Sewage Treatment Program

Structural Design Guideline

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1 INTRODUCTION

This document identifies the standard design requirements that are applicable to any structural work within the City of Winnipeg wastewater treatment facilities.

1.1 Scope of the Standard

These design requirements will apply to the following facilities:

- Wastewater treatment plants

1.2 Application

The scope and intent of this document is to convey general design guidance and expectations regarding structural design. This document does address specifics related to design type, selection, and configuration; however the indicated requirements are presented without knowledge of the specific building implementation. It is not within the scope of this document to provide detailed design direction, and it will be the responsibility of the respective structural designers to fully develop the structural details with general conformance to the concepts presented herein. This standard shall not be construed as comprehensive structural engineering design requirements or negate the requirement for professional engineer's involvement. Any design must be executed under the responsibility and seal of the respective engineer in each instance, and must be performed in conformance with all applicable codes and standards, as well as good engineering practice.

Existing facilities do not necessarily comply with this standard. The expectations regarding application of this standard to maintenance and minor upgrades at existing facilities must be assessed on a case-by-case basis; however general guidelines for application are presented as follows:

- All new buildings are expected to comply with this standard.
- All major upgrades to a building are expected to comply with this standard; however in some cases, compromise with the configuration of the existing facility design may be required.
- All minor upgrades should utilize this standard as far as practical for new work; however in some cases, compromise with the configuration of the existing facility design may be required.

1.3 Deviations from Standard

It is expected that there will be occasional situations where a deviation from this design guideline could be considered. The rationale for potential deviations from the design guideline may include:

- Evolution of technology,
- Updates to standards and regulations,
- Practical limitations due to existing conditions on site, or
- Significant cost benefits to the City due to specific project constraints.

For each proposed deviation from this standard, fully complete a *WSTP Standards Deviation Form* and submit to the WSTP Project Manager for approval. Do not proceed with the proposed deviation unless approval is received from the WSTP Project Manager.

1.4 Acronyms and Abbreviations

ACI	American Concrete Institute
AISC	American Institute of Steel Construction
AISI	American Iron and Steel Institute
ASTM	American Society of Testing and Materials
CAC	Cement Association of Canada
CISC	Canadian Institute of Steel Construction
CSA	Canadian Standards Association
NACE	NACE International
NBC	National Building Code
QC/QA	Quality Control / Quality Assurance
SSPC	The Society for Protective Coatings
WSTP	Winnipeg Sewage Treatment Program

1.5 Definitions

Contractor	The entity responsible for constructing the design. In a design-build procurement methodology, this is the design-builder.
Design Team	The entity responsible for providing the detailed design of a project. In a design-bid-bid procurement methodology, this is typically the consultant. In a design-build procurement methodology, this is the design-builder.
Structural Engineer of Record	The professional engineer ultimately responsible for the structural design, in accordance with Section 2.5.

2 GENERAL

2.1 Design Codes and Standards

All designs shall comply with municipal, provincial, and national codes and bylaws. This includes but is not limited to:

- National Building Code of Canada (NBC) with Manitoba Amendments
- CSA A23.3, Design of Concrete Structures
- ACI 350M, Code Requirements for Environmental Engineering Concrete Structures
- CSA S16, Limit States Design of Steel Structures
- CSA S136, North American Specification for the Design of Cold-Formed Steel Structural Members
- CSA S157, Strength Design in Aluminum
- CSA S304.1, Design of Masonry Structures
- Concrete design shall be in accordance with CSA A23.3, except for facilities or portions of facilities that are considered hydraulic structures. Design hydraulic structures in accordance with ACI 350M.
- Design steel structures in accordance with CSA S16.
- Masonry shall be designed in accordance with CSA S304.1.

Note: This design guideline is based upon the current version of the above documents in effect at the time of preparation. All designs shall comply with the latest version of the codes and standards. Where this document conflicts with the latest codes and standards, advise the City along with a recommendation for resolution.

2.2 References

The following list of references shall be used in the design:

- CAC Concrete Design Handbook, latest edition (currently Third Edition)
- CISC Handbook of Steel Construction, latest edition (currently Tenth Edition)
- NRC-CNRC User's Guide – NBC 2010 Structural Commentaries
- ACI 350.1M Specification for Tightness Testing on Environmental Engineering Concrete Containments Structures and Commentary
- ACI 350.4R Design Considerations for Environmental Engineering Structures
- ACI 350.5M Specification for Environmental Concrete Structures
- ACI 515.2 Guide to Selecting Protective Treatments for Concrete.
- NACE 6 / SSPC-SP 13 Surface Preparation of Concrete
- NACE Standard Practice SP0188 Discontinuity (Holiday) Testing of New Protective Coatings on Conductive Substrates
- NACE Standard Practice SP0288 Inspection of Lining Application in Steel and Concrete Equipment

- NACE Standard Practice SP0892 Coatings and Linings Over Concrete For Chemical Immersion and Containment Service
- PCA Circular Concrete Tanks without Prestressing
- PCA Rectangular Concrete Tanks, Revised Fifth Edition, By Javeed A. Munshi
- PCI Design Handbook Precast and Prestressed Concrete, 7th edition, MNL-120-10
- AISC Design Guide 27, Structural Stainless Steel
- Aluminum Association AA ADM 1-05 Aluminum Design Manual
- Canadian Foundation Engineering Manual, 4th edition, Canadian Geotechnical Society, 2006
- SSPC The Society for Protective Coatings

2.3 Other City Standards

1. While not exclusive, ensure that the following City Standards are adhered to:
   1.1 Water and Waste Department Identification Standard

2.4 Units

All drawings and documentation shall use the International System of Units (SI units). Imperial units will be provided in parenthesis after the metric unit, where requested or appropriate. Specific requirements are as follows:

1. All structural dimensions are to be in millimeters.
2. All elevations are to be in meters, in the format EL. ###.### (example EL. 273.520).
3. All loads are to be expressed in kPa, N, or kN.
   - Crane or hoist loads may be expressed in kg.

2.5 Engineer of Record

2.5.1 Responsibilities

1. The Structural Engineer of Record will have responsibility for the structural design of all structural elements and connections to the structures, whether existing or new.
2. All speciality structural engineers or supporting registered professionals for the design of components, and connections shall be under the direction of and coordinate with the Structural Engineer of Record. All designs by the specialty structural engineers or supporting registered professionals shall be signed and sealed and sealed by the specialty structural engineers or supporting registered professionals, as applicable; and the Structural Engineer of Record.
3. The Structural Engineer of Record shall ensure and certify that loadings and reactions of all equipment are identified and addressed in the design. This includes:
   3.1 Anchorage, deflection, natural frequency of the structure, vibration and thermal expansion and seismic (as applicable).

3 DESIGN LOADS

3.1 General

1. Classify all structures and facilities as post-disaster buildings except those not directly associated the wastewater treatment process or in any way critical to the wastewater treatment process. For example, an electrical building providing power to the wastewater treatment process would be a post-disaster building, while a storage shed for non-critical parts would not be required to be a post-disaster building.
2. Use climatic data for the City of Winnipeg.
3. Numerous loads indicated in this section are indicated with minimum values. Ensure that the actual design values used are appropriate and current, but not less than the minimum values.

3.2 Dead Loads

Reference shall be made to CISC Handbook of Steel Construction, Part 7. The following typical values from the CISC Handbook for mass of materials are to be considered as minimum requirements:

Table 3-1 : Dead Loads

Description	**Minimum Value (See Note 1)**
Roof Dead Loads	
4-ply asphalt and gravel:	0.32 kPa
Insulation:	0.21 kPa (assuming 300 mm thick)
Tiled ceiling:	0.20 kPa
Floor Dead Loads	
Additional concrete due to floor slope	1.5 kPa (assume 50 mm thick)
Wall Dead Loads	
300 mm CMU:	2.9 kPa
200 mm CMU:	2.1 kPa
100 mm Brick:	1.9 kPa

Notes:

1. Confirm that actual dead loads with appropriate safety margins are utilized.

3.3 Collateral Loads

Collateral loads are dead load allowances for suspended utilities such as small piping, ducts, lights, conduit, cable trays, and sprinklers. Minimum values are listed below.

Table 3-2 : Collateral Load Values

Description	Minimum Value (See Note 1)
Roof Collateral Load:	1.0 kPa
Floor Collateral Load:	1.0 kPa

Notes:

1. *Confirm that actual dead loads with appropriate safety margins are utilized.*

3.4 Live Loads

Table 3-3 : Live Load Values

Description	Minimum Value (See Note 1)
Roof Live Load (not including snow):	1 kPa
Electrical Rooms:	12 kPa (see Note 2)
Grating, Checkered Plate and Hatch Covers:	Same as surrounding floor area or 5 kPa, whichever is greater
Mechanical Rooms:	10 kPa (see Note 2)
Process Areas (slabs, beams, and girders):	15 kPa (see Note 2)
Process Areas (columns and foundations):	10 kPa (see Note 2)
Office and Laboratory Areas:	4.8 kPa
Stairs, Landings, Platforms, and Corridors:	4.8 kPa
Storage Areas:	Actual maximum stored weight or 10 kPa, whichever is greater
Unrestricted Vehicular Areas:	HS 20-44
Forklift Wheel Loading	See Note 4

Notes:

1. *Confirm that actual live loads with appropriate safety margins are utilized.*
2. *Design the structure to support actual equipment and tank loads in addition the minimum uniform load indicated. Where this minimum uniform load is not possible (i.e., in existing spaces), the maximum allowable load shall be noted on drawings.*
3. *See Impact Loads and Other Machinery Loads for other equipment related live loads.*

4. Design forklift wheel loading utilizing 120% of the loading associated with the rated full load of the largest specified or currently utilized forklifts allocated for the area. The additional 20% is utilized to account for potential future changes in forklift requirements or sizing.

3.5 Seismic Loads

Per Manitoba amendments to the NBC, specifically pertaining to Section 4.1.8.1, the value of $S_a(0.2) = 0$. Therefore, the seismic loads may be ignored, unless newer codes prevail.

3.6 Wind Loads

The minimum values for wind parameters utilized shall be as per Table 3-4.

Table 3-4 : Hourly Wind Pressure Loads

Description	Minimum Design Value
Hourly Wind Pressures:	
1/10	0.35 kPa
1/50	0.45 kPa
Exposure Factor	Calculate for open terrain

3.7 Snow Loads

The following are the snow parameters for the City of Winnipeg to allow for calculation of the snow load as per the NBC.

Table 3-5 : Snow Loads

Description	Minimum Design Value
S_s:	1.9 kPa
S_r:	0.2 kPa

3.8 Rain Loads

Consider rain loads associated with blockage of the primary roof drainage system where applicable or due to ponding. Utilize the following rain parameters for the City of Winnipeg as a minimum:

- One Day Rain Fall: 108 mm

3.9 Ice Loads

Design items such as exterior exposed wires and cables, piping, ductwork, support structures, process covers, etc. for ice loads where applicable.

Ice parameters as follows:

- Minimum Design Ice Thickness: 10 mm or as required by CSA S37 or other applicable codes

3.10 Impact Loads

Confirm equipment loading, including any impact loads due to equipment, with data sheets requested from the manufacturers.

Table 3-6 : Impact Loads

Description	Minimum Design Value
Light machinery (shaft or motor driven):	Increase load by 20 percent minimum or manufacturer's recommendation for impact, whichever is greater.
Reciprocating machinery or power-driven unit:	Increase loads by 50 percent minimum or manufacturer's recommendations for impact, whichever is greater.
Torsional and thrust force:	Obtain maximum torsional and thrust forces from vertical turbines from equipment manufacturer. Identify any other torsional and thrust forces.
Vertical impact due to lifting devices:	The maximum wheel loads of the crane shall be increased by the following percentages: • Cab operated, or radio-operated cranes (powered): 25 percent • Pendant or hand-operated cranes: 10 percent
Lateral force due to cranes:	The lateral force applied perpendicular to the crane runway beams shall be calculated as 20 percent of the sum of the rated capacity of crane and the weight of the hoist and trolley.
Longitudinal force due to cranes:	The longitudinal force on crane runway beams shall be calculated as 10 percent of the maximum wheel loads of the crane.

3.11 Thermal Loads

1. Consider thermal loads for facilities with structural members that will be permanently exposed or partially exposed to exterior condition.
2. Design temperature range for the City of Winnipeg is shown in Table 3-7.

Table 3-7 : Thermal Loads

Description	Design Value
Temperature Range	-35 °C to +30 °C

3. Thermal loading shall also consider the effects of direct heating from the sun, or process heating that may occur because of process heat exposure. Thermal loading shall also be considered as a differential loading situation

3.12 Liquid Loads

1. Define groundwater and flood levels in the geotechnical report. Consider wall loads and uplift pressures due to groundwater levels. Weight of the structure shall be used to counteract uplift.

    1.1 Any design where non-structural weight (i.e. tank fill) is used to counteract buoyancy or uplift forces is not acceptable, unless specific approval is provided by the City.

2. The factor of safety for buoyancy shall be 1.1 against 100-year flood levels. The factor of safety for buoyancy shall be 1.25 against typical high groundwater levels.

    2.1 Where the weight of the structure is insufficient, such as for empty tanks, provide a weeping tile system to an appropriate drain.

3. Tanks shall be designed for maximum liquid levels at overflow. Where there is no overflow, tanks shall be designed for maximum liquid level at top of the walls.

    3.1 Overflows shall be static and not rely on gate position or actuation. Consider cases where downstream situations may prevent the overflow from acting as intended.

3.13 Earth Loads

1. Define lateral design loads due to earth pressure and other geotechnical design. Basement and below grade tank walls shall be designed using the At-Rest earth pressure (Ko).

2. Surcharge loads, as recommended by the geotechnical report, are to be applied to the design of buried walls.

3.14 Test Loads

1. Ensure complete test loads are incorporated into the design and commissioning specifications, including the following:

    1.1 Ensure all liquid-containing tanks are tested for water-tightness.

        a) Adjacent tanks shall be tested independently.

    1.2 Ensure all gas-containing structures are tested for gas leakage.

    1.3 Concrete liquid holding structures will be tested to requirements of ACI 350M.1.

    1.4 Ensure testing of liquid containing structures is to the full hydraulic capacity, including overtopping.

2. Tanks and channels shall be designed for hydrostatic testing prior to backfilling.

3. Determine test loads for foundation support elements from geotechnical recommendations.

4. Design structure taking into consideration test loads for equipment and piping.

3.15 Blast Loads

1. Include blast loads as part of the design where appropriate.

2. Assess blast or overpressure loads based on a process risk assessment, following accepted best practices.

3. Ensure continuously occupied spaces are outside blast or deflagration areas.

3.16 Insurance Load Requirements

1. There are no known insurance load requirements that exceed loads listed above.

3.17 Load Combinations

1. Building Structures:
    - Limit states design - NBC, Division B, Part 4
2. Hydraulic Structures:
    - ACI 350M Chapter 9 using the environmental factor (Sd) from Section 9.2.6.
    - Overflow liquid level with no backfill (water-tightness test condition), as per Section 3.12.
    - Empty basin with backfill in place.

3.18 Deflection Criteria

1. The deflection criteria indicated in Table 3-8 apply to all structural elements.
2. Ensure concrete structures meet the most stringent of deflection requirements of CSA A23.3 ACI 350M and Table 3-8.

Table 3-8 : Deflection Criteria

Description	Load Type	Design Value (Maximum)
Roof Members	Dead + Live	L/240
	Live Only	L/360
	Snow Only	L/360
Floor Members	Dead + Live	L/240
	Live Only	L/360
Steel Floor Plates and Grating	Live	L/360
Crane Suspension Systems		
Monorail Crane	Dead + Live	L/800
Bridge Crane	Dead + Live	L/1000
Beams and Lintels Supporting Masonry		
Vertical Support	Dead + Live	Lesser of L/720 or 8 mm
Structural Members bracing out-of-plane loads	Dead + Live	L/360
Concrete Tanks and Channels differential settlement	Dead + Live + Liquid	L/400
Exterior Walls and Interior Partitions	Live, Snow, or Wind	L/240
Beams supporting vibrating equipment	Dead + Live	L/800

3.19 Vibration Design Criteria

1. Consult equipment manufacturers for vibration-related information such as frequencies, unbalanced loads, use of vibration isolators or dampeners, and support requirements.
2. Mount all rotating equipment that produces vibrations of sufficient magnitude on suitable foundations or support systems to control the energy transfer to the structure.
3. Design the concrete support and surrounding structure such that the natural frequency shall be less than 0.5 times or more than 1.5 times the normal operating frequency of the equipment. Special consideration shall be given to variable frequency equipment.
4. Where vibration is significant, anchorage to concrete foundations shall be by cast-in-place embedded anchors, not post-installed anchors
5. The following references provide a guide and example for design of foundations and supporting structures for vibrating equipment:
    - *Canadian Foundation Engineering Manual*, Chapter 14, Canadian Geotechnical Society 2006
    - *Soil Mechanics*, Chapter 15, T. William Lambe and Robert V. Whitman
    - *Foundation Engineering Handbook*, Chapter 24, Hans F. Winterkorn and Hsai-Yang Fang
    - *Foundation Analysis and Design.* Chapter 20, Joseph E. Bowles.

- *Standard Handbook for Civil Engineers,* Section 6, Fredrick S Merritt
- *Department of Defense Handbook Soil Dynamics and Special Design Aspects,* MIL-HDBK-1007/3.
- *Design Considerations for Environmental Engineering Concrete Structure*, ACI350.4R-05 Section 4.5.4-Foundations at grade.
- *Foundations for Dynamic Equipment,* ACI 351.3R-04
- *Principles of Soil Dynamics, Chapter 5, Braja M. Das and Zhe Luo*

3.20 Structural System Requirements

1. The requirements indicated in this section are minimum requirements for typical wastewater application and are subject to the material meeting the required design life specified for the specific service conditions. Some environments may require different material selection and the designer is responsible for selecting the appropriate material for the environment and application, but in no case shall the selected material have lower performance, including durability, maintenance and corrosion considerations, than the indicated material. Where the indicated materials will not meet this requirement, provide alternate materials that will meet this requirement without degrading any other requirement.

2. Handrail / Guardrails

   2.1 Provide aluminum handrails / guardrails, except as follows:

   a) Utilize fibreglass in areas with chemical exposure; and

   b) Galvanized steel may be utilized in non-process areas with no exposure to corrosive liquids or gasses.

3. Grating / Floor Plates

   3.1 Provide aluminum grating / floor plates, except as follows:

   a) Utilize fibreglass in areas with chemical exposure;

   b) Galvanized steel may be utilized in non-process areas with no exposure to corrosive liquids or gasses; and

   c) Utilize heavy-duty galvanized steel grating in areas with traffic loading while ensuring that corrosive liquids and gasses do not corrode the grating.

4. Structural Elements

   4.1 Dry building with no corrosive elements

   a) Provide concrete, galvanized steel; or coated/painted steel.

   4.2 Exterior stairs / platforms (not in highly corrosive environments)

   a) Aluminum (preferred); or

   b) Galvanized steel, minimum thickness of 6mm.

   4.3 Walkways and structure over influent and other channels and process equipment until and including the primary clarifiers

   a) Aluminum;

   b) Stainless steel; or

   c) FRP (where the above alternatives are not suitable).

   4.4 Bolts and anchor bolts in wastewater or exposure to splashing

   a) Stainless steel (AISI Type 316)

   4.5 Provide pipe racks constructed out of galvanized steel.

4.6 Tank covers where the tank has a potential for H_2S:

a) Construct covers out of fibreglass / plastic. Plastic coated steel may be utilized for support of covers.

4.7 Walkways and structure over secondary clarifiers and associated channels:

a) Coated carbon steel; or Stainless steel.

5. Process Equipment

5.1 Construct structural elements of secondary clarifiers utilizing:

a) Coated carbon steel; or

b) Stainless steel.

5.2 Construct structural elements in areas subject to H_2S utilizing:

a) 316 Stainless steel;

b) Fibreglass; or

c) Plastic.

6. Process Tanks

6.1 Wastewater process tanks shall be constructed out of concrete to meet the required service life.

Table 3-9 : Structural System Requirements

Description	Requirement
Concrete	To CSA A23.1 with mix designs in accordance with specifications. Concrete shall have minimum compressive strength as required based on CSA Exposure Class and ACI 350 requirements Concrete Exposure Class based on CSA requirements for wastewater A-1, A-2, and A-3 and sulfate exposure S-1, S-2, S-3.
Concrete Masonry	CSA A165
Reinforcing Steel (unless otherwise noted)	CAN/CSA G30.18, Grade 400(R)
Structural Steel (unless otherwise noted)	CAN/CSA G40.21, Grade 350W
Anchor Bolts	ASTM A 307 or ASTM F1554
Structural Bolted Connections	ASTM A 325
Stainless Steel	Exposed to wastewater, salts, or chemicals: AISI Type 316/316L Other exposure: AISI Type 304/304L
Aluminum	Alloy 6061-T6 or 6351-T6

Notes:

1. Ensure that all materials utilized are compatible with the specific environment within the building or process area, including consideration for all chemicals utilized, to achieve the required design life of the facility.

3.21 Erosion Prevention

1. Falling or rapidly moving water through channels or conduits can cause erosion of concrete surfaces. The maximum allowable hydraulic velocity to prevent erosion of concrete shall be assessed by the design engineer and shall not exceed:
   1.1 9.14 m/s for continuous flows (one or more events per day). Note that water falling 4.25 m will reach a velocity of 9.14 m/s
   1.2 15.24 m/s for Intermittent flow (three to four events per month). Note that water falling 9.14 m will reach a velocity of 15.24 m/s
2. Utilize stilling basins as required to prevent erosion.
3. When exposed to cavitation and high flow rates, the embedded reinforcing bar or element closest to the concrete surface should be placed parallel to the direction of flow.
4. Consider the use of armor protection to prevent erosion. Stainless steel plates or micro-silica concrete (70 MPa to 85 MPa) with sound aggregates should be considered.

3.22 Concrete Coatings & Liners

1. Protect against chemical deterioration or corrosion in accordance with requirements and recommendations of ACI 350M Chapter 4-Durability Requirements and ACI 515.2R Guide to Selecting Protective Treatments for Concrete.
2. Evaluate the chemical and physical properties of the liquids, gases and other environmental parameters to which the structure will be exposed and determine if coating or liner systems will be required for the structure to achieve the desired service life.
3. Design concrete surfaces requiring protective coatings or liners assuming severe environmental exposure.
4. Identify coating and liner products that are compatible with service condition, the substrate, and any materials used to clean, repair and patch concrete surfaces prior to the installation of coatings or liners, through consultation with the coating or liner manufacturers.
5. Specify for any concrete surfaces requiring protective coatings or liners are to be prepared in accordance with NACE 6 / SSPC-SP 13 Surface Preparation of Concrete. Provide for QC/QA inspection and testing of the concrete surfaces as required by the standard, including any owner specified or requested conditions noted therein.
6. Specify protective coatings and linings for concrete surfaces are to be installed in accordance with NACE SP0892 and NACE SP0288. Provide for the QC/QA inspection and testing of the coating and liner installations as required by the standards, including any owner specified or requested conditions noted therein, and discontinuity testing in accordance with NACE SP0188.

3.23 Structural Steel Coatings

1. Design and select structural steel coatings to meet the design life of the structure in the given application and environment.

4 DESIGN REQUIREMENTS

4.1 Concrete Design

4.1.1 Requirements

1. Provide cast-in-place concrete design in accordance with the following:
   - 1.1 Design all concrete building elements in accordance with CSA A23.1, CSA A23.2 and CSA A23.3;
   - 1.2 Design all process tanks and liquid holding structures and structures with spaces to be dry flood-proofed to be watertight in accordance with ACI 350M, ACI 350.4R, and AWWA D110;
   - 1.3 Provide concrete formwork, constituents, proportions, and maximum water-cement ratios in accordance with CSA 23.1;
   - 1.4 Provide reinforcing steel for structural concrete in accordance with CAN/CSA-G30.18 Billet-Steel Bars for Concrete Reinforcement, A National Standard of Canada and RSIC “Reinforcing Steel Manual of Standard Practice”;
   - 1.5 Provide concrete cover of reinforcing steel to meet service life but not less than requirements of CSA 23.1, CSA 23.3, AWWA D110, and ACI 350M, whichever is more stringent for the exposure; and
   - 1.6 Provide concrete mix designs to resist deterioration from applicable elements including, but not limited to hydrogen sulfide and wastewater, to provide the required service life and provide certification verifying that the concrete mix designs will provide the service life for the exposure conditions, design and construction.
     - a) Where the concrete cannot meet the service life requirements, provide appropriate coating or lining to meet the service life requirements.

4.1.2 Liquid Holding / Waterproof Structures

1. Ensure crack control is assessed and controlled. Ensure that the design accounts for shrinkage of the concrete, differential settlement, operating and “under construction” thermal regimes, concrete mix design, strain relief restraints, stresses, and construction.
2. All liquid holding structures must pass leakage test with no visible leakage through walls or floor slabs within a 24-hour static condition at ambient air conditions. Where floor slabs are not accessible to assess leakage, test duration should be extended to assess seepage from drains or from well points adjacent to the structure.
3. All leaks shall be sealed and repaired.

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5 MAINTENANCE AND SAFETY

5.1 Maintenance

1. Provide appropriate lifting devices to allow for maintenance and removal of equipment. Coordinate with other disciplines as required.
2. All permanent lifting devices shall be designed and detailed on the design drawings.
3. Design responsibility shall not be deferred to the Contractor except when using a design-build procurement model.
4. All structural components will be designed for a minimum service life of 80 years, unless otherwise indicated.

5.2 Safety

1. Provide systems to accommodate safe access to all areas of the facility, including tanks, conduits, and channels. Minimum requirements include, but are not limited to the following:
    - 1.1 Where physically practical, provide embedded safety davit bases to accommodate a portable safety davit to allow for safe personnel access to tanks, conduits, and channels.
    - 1.2 Surface mount davits may be utilized where embedded davit bases are not acceptable.
    - 1.3 Provide permanent ladders where portable ladders are not effective or where personnel access is frequent (> once per month).

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6 STRUCTURAL DESIGN TEAM RESPONSIBILITIES

6.1 General

1. Responsibility for deliverables:

   1.1 All drawings and other deliverables related to a design are the responsibility of the Design Team.

   1.2 The responsibility for deliverables shall not be passed on to other entities. For example, in a design-bid-build procurement environment, the Design Team (consultant) shall not pass responsibility for items indicated in this section to the Contractor.

2. Ensure all structural design deliverables are sealed by a qualified professional structural engineer.

3. Completeness of drawings:

   3.1 All drawings shall be comprehensive in nature to allow for effective use in construction.

4. Update of existing drawings:

   4.1 If the project is an addition, expansion, upgrade or modification to an existing site or facility, existing drawings may require updating. Update existing drawings as required to ensure that the City has a comprehensive set of as-built drawings.

5. Design reviews:

   5.1 Arrange internal reviews of all design documents (including drawings) by a structural engineer qualified and experienced in design of equivalent structures before submitting to the City.

   5.2 Issue the design documents to the City for review at appropriate intervals in accordance with Contract requirements.

   5.3 Incorporate City comments into the design. Where a City comment is not accepted by the Design Team, provide a complete response, including rationale, to the City.

6. As-built drawings:

   6.1 Update all structural design deliverables to “as-built” status at the end of the project. The “as-built” documents shall incorporate Contractor mark-ups, inspections performed by the design team, change orders, RFIs, and other communication between the Contractor and Design Team.

   6.2 Unless otherwise specified in the Contract, as-built drawings are not required to be sealed.

7. External, 3rd Party Consultants:

   7.1 Expertise and assistance may be required, from external 3rd party specialized consultants, outside of the primary structural design team.

   7.2 The design team shall be responsible for monitoring the activities and progress of each 3rd party consultant.

   7.3 The design engineer is responsible for ensuring that the deliverables follow all City standards and guidelines.

8. Site Visits:

    8.1 The design team is responsible for ensuring that a sufficient number of site visits occur to facilitate the understanding of specific field conditions or status of existing facilities and buildings.

9. Demolition Requirements

    9.1 The Design Team is responsible for associated demolition works required to implement the scope of work. Clearly indicate all demolition requirements on the drawings and in the specifications.

    9.2 Where demolition requirements are significant, create dedicated demolition drawings.

6.2 Drawings

Provide a comprehensive set of drawings to detail the structural construction requirements. The drawings indicated in this section are minimum requirements for new construction.

6.2.1 General Requirements

1. All structural drawings are to be produced on a standard A1 size drawing.
2. All structural drawings shall be to scale.
3. All dimensions required for construction shall be shown.
4. Indicate north direction on all plan drawings.
5. Provide scale bars on drawings to allow for simplified scale takeoff on the drawings.
6. Differentiate new work from existing work via bold lines.

6.2.2 Legend

1. Provide a legend drawing showing the symbols and abbreviations utilized. Ensure that the legend is consistent with the City's Water and Waste Dept. practices and other disciplines working in the project.

6.2.3 General Notes Drawing

1. Requirements
   - 1.1 Provide a general notes drawing for each type of structure.
2. Content
   - 2.1 General construction notes;
   - 2.2 Building design criteria including key design loads;
   - 2.3 Foundation design criteria;
   - 2.4 Concrete requirements;
   - 2.5 Concrete reinforcing requirements;
   - 2.6 Masonry requirements as applicable; and
   - 2.7 Structural steel and metal fabrication requirements.
3. Format
   - 3.1 Prepare drawings to communicate the design requirements in a clear, concise and unambiguous manner. Ensure that drawings are not unnecessarily congested or complicated.

6.2.4 Pile Layout Plans

1. Requirements

   1.1 Provide pile layout drawings for all designs where piling is employed.

2. Content

   2.1 The position of piles relative to grid lines;

   2.2 A reference identifier (number) for each pile shown on the drawing, corresponding to the pile schedule as per Section 6.2.5;

   2.3 Grid lines and grid line dimensions;

   2.4 Estimated pile lengths and capacities, or a source for this information; and

   2.5 The approximate location of existing services and foundations, or any other relevant site information made known to the Design Team, that may conflict with the proposed piles; however, service locates are still the responsibility of the Contractor.

3. Format:

   3.1 Scale:

   a) Recommended: 1:100

   b) Maximum: 1:150

6.2.5 Pile Schedule and Details

1. Requirement

   1.1 Provide pile schedule and detail drawings where piling are utilized.

2. Content

   2.1 Pile schedule including:

   a) Pile identifier (number);

   b) Member size;

   c) Safe working load of pile;

   d) Imposed moment;

   e) Imposed horizontal force;

   f) Finished pile cut-off elevation (geodetic); and

   g) Angle of rake.

   2.2 The layout, sections and details of all foundation works showing:

   a) Types of piles or foundation and specification of material to be used;

   b) Location of piles or foundation;

   c) Pile or foundation founding depth or pile minimum embedment into competent stratum for each pile or foundation;

   d) Unit shaft friction, pile base resistance or foundation bearing pressure;

   e) Pile positional tolerances;

   f) Allowable foundation capacity before and after accounting for negative skin friction where applicable, allowable tension, and lateral load;

   g) Details of pile reinforcements, pile joints, connection with pilecaps are considered minimum requirements for shop drawings; and

h) Number, type of pile or foundation tests, structural integrity tests and location of preliminary test pile or ultimate load tests and site investigation for the tests.

6.2.6 Foundation Drawings

1. Requirement

   1.1 Provide detailed foundation drawings comprehensive of all new and modified areas.

2. Content

   2.1 Layout of foundations;

   2.2 Grid lines and grid line dimensions, as well as overall dimensions and structurally derived dimensions;

   2.3 The types, sizes, locations and details of foundations for columns, walls, piers, equipment, and any other structural load bearing components;

   2.4 The position of each foundation relative to the grid lines. Provide the width, length and depth and the elevation level of the foundation component;

   2.5 Indicate a distinguishing letter for each foundation that will serve as a cross-reference for foundation details detailed elsewhere. Note the maximum allowable safe ground bearing pressure, the blinding thickness (plain, non-reinforced concrete) and concrete classification type on the drawing;

   2.6 The anticipated bearing elevations for foundations;

   2.7 Any drainage or dewatering system or requirements;

   2.8 The foundation system installation sequence, if the sequence is required by the structural design;

   2.9 Sub-grade preparation for slabs-on-grade, as well as the thickness, reinforcing and elevation of the slabs-on-grade;

   2.10 Estimated pile lengths and capacities, or a source for this information;

   2.11 Frost-safe soil cover or equivalent insulation requirements for shallow foundations;

   2.12 The approximate location of existing services and foundations, or any other relevant site information made known to the Design Team, that may conflict with the proposed foundations, however, service locates are still the responsibility of the Contractor; and

   2.13 Allowable SLS and ULS soil or rock bearing capacity, pile capacities and lateral earth pressures for retaining structures with reference to pertinent geotechnical reports.

3. Format:

   3.1 Scale:

      a) Recommended: 1:50 to 1:100

      b) Maximum: 1:150

6.2.7 Structural Plan Drawings

1. Requirement

   1.1 Provide detailed structural plan drawings comprehensive of all new and modified areas.

2. Content

   2.1 Provide sufficient details and notes to indicate the loads and the structural system to resist those loads and sufficient information to allow the design to be independently checked.

   2.2 Provide locations, sizes, reinforcement and details of structural elements at appropriate scales, to enable the fabrication, installation, and connection of the elements in a reasonable sequence by a reasonably competent contractor who is familiar with the techniques of construction for the specified materials.

   2.3 Provide drawings for concrete structures consisting of dimensional data necessary for the setting out and construction of the concrete formwork, i.e.

      a) Setting out of the concrete structure on site;

      b) Plans, sections and elevations where appropriate showing layout, dimensions and levels of all concrete members within the structure; and

      c) Locate key chases, pockets, fixings and items affecting the concrete work

   2.4 Reinforcement drawings that describe and locate the reinforcement in relation to the outline of the concrete work and to relevant holes and fixings. Generally, circular holes up to 150 mm diameter and rectangular holes up to 150x150 mm in slabs or walls need not be indicated on the reinforcement drawings. All other holes should be indicated on the reinforcement drawing and should be trimmed, where necessary, by suitable reinforcing bars.

   2.5 Separate drawings or plans for top and bottom layers of reinforcement that should be used only for fabrication and in exceptional cases, e.g. voided decks and box girders with four layers of reinforcement.

   2.6 Provide north arrow.

   2.7 Provide scale bar.

3. Format:

   3.1 Scale:

      a) Recommended: 1:50

      b) Maximum: 1:100

6.2.8 Structural Section Drawings

1. Requirement

   1.1 Provide detailed structural section and detail drawings comprehensive of all new and modified areas to completely define the required work.

2. Content

   2.1 Elevations, sections, and details are to be at an appropriate scale to portray the relationship of structural elements to each other and their interconnection(s). Sections and details are to be in sufficient number to show all non-typical conditions, their locations and extent.

   2.2 For concrete, show conceptual reinforcing steel design.

   2.3 Use typical details where appropriate, however, care should be taken to determine that details noted as “typical” are applicable to the condition being portrayed and that their locations and extent are explicit.

   2.4 Include on the structural drawing set, graphically or by notes:

   a) Grid line dimensions and structurally derived dimensions

   b) Expansion, construction and control joint locations and details

   c) The lateral load resisting system

   2.5 Cross-sections provide a general impression of the entire vertical structure. Show all major dimensions and levels. Complicated profiles etc. may remain undimensioned; these are shown by local section prepared with the main plan layouts. The elevation of background walls and columns are often included to increase impression.

   2.6 Show elevation of the key components.

3. Format:

   3.1 Scale:

   a) Recommended: 1:20

   b) Maximum: 1:50

6.2.9 Concrete Reinforcing Drawings

1. Requirement

   1.1 Provide structural detail drawings to fully portray the required structural work and in sufficient detail in order for the Contractor's Reinforcing Steel Detailer to prepare detail reinforcing steel fabrication Shop Drawings.

   1.2 Standard details may be utilized to represent structural features, elements, hooks and laps used on a repetitive basis. Details used in this way must be carefully worked out, depicted in sufficient detail in order to provide the Contractor's Reinforcing Steel Detailer the Designer's intent and totally applicable to each location where they are to be specified. Standard details may apply to concrete profiles or reinforcement arrangements, and shall be drawn to a large scale.

2. Content

   2.1 Elevations, sections, and details are to be at an appropriate scale to portray the relationship of the reinforcing steel, reinforcing steel orientation, hooks and laps to each other and their interconnection(s). Sections and details are to be in sufficient number to show all non-typical conditions, their locations and extent.

   2.2 Use typical details where appropriate, however, care should be taken to determine that details noted as "typical" are applicable to the condition being portrayed and that their locations and extent are explicit.

   2.3 Include on the structural drawing set, graphically or by notes:

   a) Reinforcing steel size, spacing and define top upper layer, top lower layer, bottom upper layer, and bottom lower layer.

   b) Define the concrete cover for the concrete components in the General Notes.

   c) Define the reinforcing steel grade for the concrete components in the General Notes.

   d) Define the reinforcing steel minimum lap development lengths and hook lengths for the concrete components in the General Notes.

   2.4 Cross-sections provide a general impression of the entire vertical structure. Show all major reinforcing steel design intents in order for the Contractor's Reinforcing Steel Detailer to prepare detail reinforcing steel fabrication shop drawings.

   2.5 Show elevation of the key components.

3. Format:

   3.1 Plan Scale:

   a) Recommended: 1:50 to 1:100

   b) Maximum: 1:150

   3.2 Detail Scale:

   a) Recommended: 1:20

   b) Maximum: 1:50

6.2.10 Structural Detail Drawings

1. Requirement

   1.1 Provide structural detail drawings to fully portray the required structural work.

   1.2 Standard details may be utilized to represent structural features and elements used on a repetitive basis. Details used in this way must be carefully worked out, fully detailed and totally applicable to each location where they are to be specified. Standard details may apply to concrete profiles or reinforcement arrangements, and shall be drawn to a large scale.

2. Content

   2.1 Elevations, sections, and details are to be at an appropriate scale to portray the relationship of structural elements to each other and their interconnection(s). Sections and details are to be in sufficient number to show all non-typical conditions, their locations and extent.

   2.2 Use typical details where appropriate, however, care should be taken to determine that details noted as “typical” are applicable to the condition being portrayed and that their locations and extent are explicit.

   2.3 Include on the structural drawing set, graphically or by notes:

      a) Grid line dimensions and structurally derived dimensions

      b) Expansion, construction and control joint locations and details

      c) The lateral load resisting system

   2.4 Cross-sections provide a general impression of the entire vertical structure. Show all major dimensions and levels. Complicated profiles etc. may remain undimensioned; these are shown by local section prepared with the main plan layouts. The elevation of background walls and columns are often included to increase impression.

   2.5 Show elevation of the key components.

3. Format:

   3.1 Scale:

      a) Recommended: 1:20

      b) Maximum: 1:50

6.2.11 Miscellaneous Component Detail Drawings

1. Requirement

   1.1 Detail drawings shall include, but not be limited to:

      a) Access hatch configuration, including dimensions, direction of swing and handle location, sill configuration, and materials

      b) Concrete embeds such as studded anchor plates and angles to support masonry veneers, beams, slabs and girders. Provide top of studded anchor plate elevations for all locations.

      c) Monorail hoists, bridge cranes, large diameter piping supports, structural steel stair cases in stairwells, etc.

      d) Guardrail, ladder, and gate details including dimensions and detailed layout

2. Content

   2.1 Check that:

   a) The information agrees with the general arrangement and other associated drawings and reinforcing steel schedules, with particular reference to dimensions, termination of reinforcement, construction details, and notes.

   b) The details shown can, in practice, be constructed.

   c) Where standard drawings are used they should be checked to ensure they represent the actual structure correctly, and when alterations are made check to ensure that the original design intentions are valid.

6.2.12 3D Model

1. When 3D design is required by the Contract, or proposed by the Design Team, this section shall be complied with in its entirety. 3D models and associated drawings are required for all projects that meet one or more of the following criterion:

   1.1 Any work exceeding $5M in construction costs; and

   1.2 Any substructure or superstructure with a building footprint exceeding 10 m².

2. The 3D model shall include key structural elements (other than concrete reinforcing) to allow for full representation of the entire facility, including all other disciplines.

3. In addition to the 3D model provide:

   3.1 3D elevation and section drawings to convey the complete structural configuration.

4. The use of a 3D model does not eliminate any other requirements of this document. While some of the drawings may incorporate elements generated from the model, the type, number, or content of the drawings shall in no way be reduced through the use of the model.

6.2.13 Drawing Checking

1. Prior to submitting drawings, ensure that the following checklist is confirmed. The below checklist is not to be construed as comprehensive.

   a) Is general presentation and orientation correct?

   b) Are titles, scales, drawing numbers correct?

   c) Are revision letters correct and their location shown?

   d) Are sufficient sections and details given?

   e) Are general notes complete and convey requirements clearly and concisely?

   f) Is spelling correct?

   g) Have all standards and codes of practice been complied with?

   h) Are layout dimensions correct?

   i) Do running dimensions agree with overall dimensions?

   j) Can the materials specified be obtained?

   k) Do numbers, sizes and reinforcement agree with the relevant calculations and other drawings?

   l) Has cross-referencing to other drawings been provided?

   m) Are chamfers, fillets and drips and similar features shown?

   n) Are all projections reinforced?

   o) Is concrete cover specified and correct?

p) Are splices and laps in correct position?
q) Do splices suit construction joints?
r) Is the right water bar being used?
s) Is there congestion of reinforcement?
t) Are cranks required where bars cross?
u) Is spacing and orientation of reinforcement correct both on plan and section?
v) Is reinforcement required for anti-crack or fire resistance?
w) Do hooks foul other reinforcement?
x) Where required are the spacers and chairs shown/specified?

6.3 Structural Design Calculations

1. Provide detailed design calculations in accordance with the relevant codes and authorized local and national bodies taking into account the most unfavorable condition of dead load, live load, wind load, construction load etc. for all structures. Design calculations shall be submitted with the design drawings as part of the review cycle to allow for parallel review. At minimum, the following calculations shall be submitted to the City for review:
   1.1 Design criteria:
      a) Table of content for the calculations
      b) Building codes used with edition dates
      c) Discussion and description of design basis including all assumptions
      d) Listing of live loads, water levels, earth loadings, snow loading, and wind loads, and other special loadings
      e) Structural material materials and strengths
      f) Geotechnical report information and design criteria
      g) Deflection limits of the structural elements and systems
   1.2 Sketch of the overall structure and elements with applied loadings
   1.3 Analysis and design calculations for all structural elements for applied loading
      a) Roof structures
      b) Walls
      c) Floors structures
      d) Columns
      e) Foundations
   1.4 Special studies and analysis (example, but not limited to dynamic, vibration, crack control, thermal, etc.)
   1.5 All calculation sheets will be signed by the Structural Engineer of Record and design check engineer.
2. Submit draft design calculations to the City when the design calculation is performed, such that the calculation can be referenced during the review stage.
3. Provide final calculations, updated to include any modifications during design and construction, as part of the final as-built package.
4. Where applicable, provide listing of all structural components to be designed by the Contractor. The final responsibility of all structural design is the responsibility of the Structural Engineer of Record.