



# Structural Design Standards

## I. Background and Overview

- A. The City's Program Standards and Procedures (PSP) are intended to be used in conjunction with the data contained in related standards and procedures. They are not intended to be used as stand alone documents. It is the responsibility of the Designer to become familiar with all the PSP documents and comply with the criteria set forth as a whole.
- B. This standard was developed to provide consistency in design criteria for the design of structures for the City of Salem Willow Lake Water Pollution Control Facility (WPCF). The Structural Design Standards is divided into the following sections:
  - II. Codes and Standards
  - III. Subsurface Exploration and Geotechnical Report
  - IV. General Structural Design Loads for Tanks, Buildings, and Foundations
  - V. Design Criteria for Reinforced Concrete Structures
  - VI. Structural Design Guidelines for Major Facilities
  - VII. Design Criteria for Concrete Rectangular Tanks
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## II. Codes and Standards

- A. This section defines the codes and standards that should be used in the structural design of hydraulic structures and process buildings.



B. Governing Standards and Codes used for the structural design should be as follows.

1. Governing building codes:
  - a. The latest edition of the International Building Code (IBC), supplemented by the most current Oregon Structural Specialty Code.
  - b. Current edition of Minimum Design Loads for Buildings and Other Structures (ASCE-7).
2. The latest edition of Standard specifications for Tolerances for Concrete Construction and Materials (ACI 117).
3. Seismic requirements:
  - a. The latest edition of Seismic Design of Liquid Containing Concrete Structures and Commentary (ACI 350.3).
  - b. The latest edition of Standards for Welded Steel Tanks for Water Storage (ANSI/AWWA D100).
4. Reinforced concrete tanks and structures:
  - a. The latest edition of Code Requirements for Structural Concrete and Commentary (ACI 318), and supplemented by the most current Oregon Structural Specialty Code.
  - b. The latest edition of Code Requirements for Environmental Engineering Concrete Structures and Commentary (ACI 350).
5. Prestressed concrete tanks and structures:
  - a. The latest edition of Design and Construction of Circular Wire and Strand Wrapped Prestressed Concrete Structures (ACI 372).
  - b. The latest edition of Design and Construction of Circular Prestressed Concrete Structures with Circumferential Tendons (ACI 373).
  - c. The latest edition of Code Requirements for Environmental Engineering Concrete Structures and Commentary (ACI 350).
6. Steel tanks and structures:
  - a. The latest edition of the IBC supplemented by the most current Oregon Structural Specialty Code.
  - b. The latest edition of the Steel Construction Manual, American Institute of Steel Construction (AISC).



- c. ANSI Welded Steel Tank for Oil Storage API STD 650, latest edition. API 650 should be used for tanks at atmospheric pressure.
  - d. API recommended rules for the design and construction of large, welded, low pressure storage tanks, API STD 620, latest edition. API 620 should be used for tanks with low internal pressure.
  - e. The latest edition of Standards for Welded Steel Tanks for Water Storage (ANSI/AWWA D100).
7. Reinforced masonry structures:
- a. The latest edition of the IBC supplemented by the most current Oregon Structural Specialty Code.
  - b. The latest edition of Building Code Requirements for Masonry Structures (ACI 530) and Commentary.
8. Timber structures:
- a. The latest edition of the IBC supplemented by the most current Oregon Structural Specialty Code.
  - b. The latest edition of National Design Specification (NDS) for Wood Construction.
  - c. The latest edition of Standard for Load and Resistance Factor Design (LRFD) for Engineered Wood construction (ASCE 16).
9. Aluminum structures:
- a. The latest edition of the IBC supplemented by the most current Oregon Structural Specialty Code.
  - b. The latest edition of the Aluminum Design Manual, Aluminum Association Inc. (AA).
- C. As of October 1, 2004, the State of Oregon adopted the latest version of the International Building Code (IBC). Where the requirements of this standard conflict with this code, the IBC shall take precedence.

### **III. Subsurface Exploration and Geotechnical Report:**

- A. Geotechnical Investigations:
- 1. The Design Consultant should be responsible for securing the services of a licenced geotechnical professional to perform on site subsurface exploration and for preparing a geotechnical report as indicated herein.



2. Geotechnical investigations should be performed for each significant structure or facility proposed for design.
3. The objective of the investigations is to characterize the substrata, determine groundwater levels, and determine engineering properties required for design and construction.

B. Background Information:

The initial phase of investigations should consist of a review of geologic conditions at the site. This includes a paper study of available data including United States Geological Survey (USGS) and State Geological Survey publications, remote sensing imagery, aerial photography, any prior geotechnical borings or reports, and a field reconnaissance. This information should be used as a guide to plan the site specific subsurface investigation program.

C. Geologic Mapping:

The field reconnaissance should include performing detailed geologic mapping of any surface outcrops at the site and along the pipeline alignments identifying strikes, dips and fracture patterns of various rock units; visible faults and/or shear zones. The results of geologic mapping should be used to plan the boring program and presented in the geotechnical report.

D. Borings:

1. Borings are the most common method of subsurface exploration.
2. Borings should be performed using a solid stem auger, hollow stem auger, or rotary wash techniques:
  - a. Only hollow stem auger or rotary wash techniques should be used in granular soils below the water table.
  - b. The drilling program should be designed to provide an accurate description of the materials encountered, defining changes in material characteristics with depths. Samples should be taken at frequent intervals.
  - c. Split barrel and thin walled tube samples should be taken at maximum intervals of five feet and at each change in strata.
  - d. Generally, the cohesionless soils should be sampled using a split barrel sampler (ASTM D1586) and cohesive soils with a thin walled tube sampler (ASTM D1587).



- e. A sufficient number of thin walled tube samples should be taken at selected intervals to provide testable undisturbed samples of significant clay strata:

The remainder of the clays may be sampled by a split barrel sampler.

- f. Soil classification should be in accordance with ASTM D2487 and 2488 procedures.

- 3. No boring should be terminated in soft, compressible or otherwise unsuitable material, but should extend beyond the planned depth to reach firm material or refusal:

- a. Where bedrock is encountered at lower depths, a few borings should be cored to determine properties of the bedrock for foundation design and constructability purposes as appropriate.

- b. The remainder of the borings may generally be terminated at rock refusal.

- 4. Rock coring should be performed in accordance with ASTM D2113 using double tube swivel type, WM-design core barrels. The minimum size of core barrel and bit should be NWM in accordance with ASTM D2113.

- 5. The recovered core should be logged in detail by an experienced geologist, engineering geologist or geotechnical engineer. Recovered core should be boxed, labeled and photographed in color using a digital camera.

#### E. Boring Layout and Depths.

- 1. The boring layout should be governed by the geology of the site, the type of structure or facility being planned, and to suit the problem being investigated:

- a. The borings should be arranged so that geological profiles may be determined at the most useful orientation for design.

- b. When detailed settlement analyses and stability evaluations are required, a minimum of two borings should be included to obtain undisturbed samples of critical strata.

- 2. The borings should be extended to sufficient depths to provide information for design and constructability.

- 3. The following general guidelines should be used in planning the boring program. These are for general guide only. The program should be developed by an experienced geotechnical professional to collect information as required for addressing the necessary items required in the geotechnical report. It is the



responsibility of the Design Consultant to coordinate the boring program with the geotechnical professional to match their design.

- a. For large structures with separate closely spaced footings:
  - 1) Borings should be spaced approximately 50 to 75 feet apart in both directions including borings at possible exterior foundation walls, at machinery locations, and heavily loaded locations.
  - 2) Borings should extend to depth where increase in vertical stress for combined foundations is less than 10 percent of effective overburden stress. Generally, all borings should extend to no less than 25 feet below the lowest part of the foundation unless bedrock is encountered at shallower depth.
- b. For structures with isolated rigid foundations:
  - 1) If the foundations area is 2,500 to 10,000 square feet, a minimum of three borings should be taken around the perimeter.
  - 2) If the foundation area is less than 2,500 square feet, a minimum of two borings should be taken at opposite corners. Additional borings should be taken if erratic conditions are anticipated or encountered.
  - 3) Extend borings to depth where vertical stress decreases to 10 percent of bearing pressure. Generally, all borings should extend to no less than 25 feet below the lowest part of the foundation unless bedrock is encountered at lower depth.
- c. For ground storage circular tanks or basins:
  - 1) If the diameter is less than 100 feet in diameter at least three borings should be taken in a 120 degree pattern around the perimeter. For larger diameters a center boring should be added.
  - 2) For basins and large circular tanks make at least one boring to a depth of 50 feet. The remaining borings should follow the guidelines provided above.
- d. For transmission mains and sewers:
  - 1) Borings should be spaced at a maximum interval of 500 feet unless the conditions are known to be fairly uniform. For short tunneled or trenchless crossings below roads and railroads a



boring should be made at each end of the crossing. Additional borings should be added if the length of the crossing exceeds 250 feet or if the two borings indicate dissimilar conditions.

- 2) Extend borings to at least five feet below the trench bottom. At tunneled and trenchless crossings extend borings to 15 feet below the tunnel pit bottom or to  $\frac{1}{2}$  the depth of the tunnel pit from ground surface, whichever is larger. Water bearing granular soils or very soft cohesive soils may require additional depth for both the pipelines as well as trenchless construction.
  - 3) For earth lagoons and ponds borings should be taken at a maximum interval of 200 feet. Shallow test pits using a small backhoe may be used to investigate potential borrow areas and to obtain bulk samples for testing.
  - 4) In addition, the following criteria should apply to boring depths:
    - (a) No boring should be stopped in soft or unsuitable material and should extend to reach firm material or refusal.
    - (b) For cuts extend borings to five-to-eight feet below the base of the cut.
    - (c) For embankments extend boring to depth between  $\frac{1}{2}$  to  $1\frac{1}{4}$  times the horizontal length of side slope in relatively homogeneous substrata, but extend as necessary to reach hard material.
4. Boring elevations:
- a. Boring locations should be surveyed and ground surface elevation determined at each location.
  - b. It is suggested that the boring locations be staked prior to making the boring. If the surveyed boring locations are revised, the new location and elevation of the relocated borings should be determined.
  - c. Boring logs should report the correct ground elevation at each boring. A drawing showing the as drilled location of the boring should be prepared and included in the geotechnical report.
  - d. The Design Consultant should be responsible for coordinating survey information to provide a topographical map of the site, including all proposed new structures to the geotechnical professional.



5. Groundwater level measurements.
  - a. Groundwater levels should be recorded in each auger boring when the groundwater is first encountered and 24 hours after completion of the boring:
    - 1) If the hole will not remain open a temporary pipe with a perforated bottom section should be left in the hole overnight for water level measurements.
    - 2) Permanent piezometers should be installed for long term groundwater level measurements in selected borings for basin and buried tanks where groundwater levels are critical to the design and construction of the structure.
    - 3) Borings should be backfilled in accordance with the applicable regulatory requirements.
6. Laboratory tests.
  - a. Laboratory tests should be performed on recovered samples as required to complete the geotechnical analyses and interpretations required for preparation of the report.
  - b. The following list provides the type of laboratory tests generally performed for a foundation investigation program. The Design Consultant should be responsible for coordinating the required tests for the geotechnical program with the geotechnical professional:
    - 1) Classification tests on selected samples to confirm field classification of the soil. These will consist of Atterberg limits on cohesive soils and sieve analysis and/or No. 200 test for coarse grained soils.
    - 2) Unconfined compression tests on a representative number of undisturbed cohesive soil samples. Undisturbed samples should be extruded from thin walled tubes in the same direction as driven. Split barrel samples should be considered as disturbed.
    - 3) Unconfined compression tests on a representative number of rock cores, if rock is encountered at shallow depths.
    - 4) Consolidation tests on representative samples of cohesive soils for use in the settlement and time rate computations.
    - 5) Compaction tests on representative samples to be used as backfill or structural fill.



- 6) Natural moisture content and dry density tests on selected undisturbed cohesive soil samples.
- 7) Resilient Modulus ( $M_R$ ) tests for pavement design as described in the Oregon Department of Transportation (ODOT) Pavement Design Guide, July 2002, or most current.
- 8) Swell tests as required if the material appears to be expansive.
- 9) Corrosivity tests, i.e., water soluble sulfate, water soluble chloride, water soluble sulfides, redox potential, lab resistivity and pH on a representative number of soils which will interface with the substructure and piping. Field resistivity tests should be performed at selected intervals along pipeline alignments for design of corrosion protection systems.
- 10) Any other testing considered necessary by the geotechnical engineer to provide the data for the geotechnical report.

7. Other investigations:

Investigations other than borings may be required subject to the local subsurface conditions and the nature of the project. These include geophysical methods, static cone penetration tests, borehole permeability tests, and using special samplers such as a pitcher sampler or a modified California sampler.

8. Boring logs.

- a. Boring logs containing a record of the subsurface conditions and groundwater levels encountered should be prepared and included in the geotechnical report. All field work should be performed under the direct supervision of and field boring logs prepared during drilling and sampling by a qualified geologist, engineering geologist or geotechnical engineer.
- b. The boring logs should contain, as a minimum, the following specific information for each test boring:
  - 1) Actual location.
  - 2) Surface elevation.
  - 3) Descriptions of the classification, consistency, thickness, elevation, and geologic origin of materials encountered.
  - 4) Groundwater information.



- 5) Blow counts from standard penetration test on cohesionless soils. Pocket penetrometer (properly calibrated and maintained) test on thin walled tube samples in cohesive soils as a relative measure of consistency.
  - 6) At least one unconfined compressive strength test should be conducted for each five-pocket penetrometers.
  - 7) Percent recovery of thin walled tube samples.
  - 8) Sample locations.
  - 9) Results of index property tests.
- c. In addition, the boring logs should contain the following specific information for core borings:
- 1) Description of rock fabric.
  - 2) Length of core run, percent recovery, fracture frequency, joint characteristics, and rock quality designation.
  - 3) Location of core loss.
  - 4) Drilling rate including depths of abnormal drill behavior.
  - 5) Drill water return.
  - 6) Casing requirements.
  - 7) Location of core in box.
9. Geotechnical report.
- a. A geotechnical report should be prepared summarizing the findings of the field investigations, laboratory testing, and engineering analysis:
- 1) The report should be prepared as a first draft, second draft, and final report.
    - a) The first draft should include recommendations based on the geotechnical engineer's understanding of the general project description and any preliminary drawings provided in the beginning of the project.
    - b) The second draft should be based on a more refined structure layout, estimates of loads, and bearing levels, to be provided by the design engineer.



- c) The second draft should address all first draft review comments made by the Owner and design engineer.
  - d) The final report should be submitted late in the design phase of the project when the final layout, bearing loads, and levels are available.
  - e) The final report should incorporate any additional comments accumulated by the design engineer during the design phase.
- 2) The Design Consultant should include the final report as part of the construction bid package.
- b. In addition to the factual information such as boring logs, boring location maps and laboratory test results, the geotechnical report should contain the geotechnical engineer's evaluation of the geotechnical aspects of the project. The report should contain the following specific information:
- 1) A discussion of the geotechnical engineer's understanding of the proposed construction including locations, dimensions, bearing elevations and loading conditions, to the extent known.
  - 2) A discussion of the regional and site geology and topography. Engineering interpretations of the drilling and laboratory data. Engineering properties of the soil and rock mass characteristics.
  - 3) Recommendations for site preparation including depth of removal and overexcavation, and improvements of in-situ soils, if applicable.
  - 4) Recommended allowable bearing pressures at the proposed bottom of the foundation elevations.
  - 5) Recommended type of foundations (slabs on grade, shallow spread footings, or deep foundations). Recommended load capacity for piers and piles, if deep foundations are required. Recommended pile driving criteria and methods to verify pile capacity during construction.
  - 6) Recommended minimum depth for foundations based on frost and other considerations.
  - 7) Recommended safe slopes for any permanent cuts or fills.



- 8) Recommended lateral earth pressures for design of substructure and retaining walls. Lateral earth pressures for both active and at rest, and drained and submerged conditions should be provided. Recommended design parameters for retaining structures including friction coefficients and passive pressure (if applicable) for calculating resistance against sliding.
- 9) Seismic design considerations, including local fault characteristics and recent activity, if applicable to evaluation of seismicity at the site; building code related site seismic coefficients and parameters or other building code requirements; an evaluation of seismic hazards including liquefaction potential and recommendations to mitigate; and allowable increases in bearing capacity for transient loading including that from wind forces.
- 10) Recommendations for backfill materials including onsite availability, recommended index properties, grain size distributions, classifications in accordance with ASTM D2487 and moisture and density compaction criteria.
- 11) Compaction characteristics and suitability of onsite soils for use as engineered and other fills and other pertinent earth work recommendations, including shrinkage factors.
- 12) Estimate of total and differential settlements at each structure as well as the duration over which settlements will occur if the settlements are significant. The potential for and magnitude of differential settlement between the proposed and existing structures, if applicable and also between portions of buildings bearing at different levels.
- 13) Modulus of subgrade reaction for design of mat foundations and slabs on grade as applicable.
- 14) The influence of expansive soils, if encountered, on foundation design and recommendations to mitigate harmful effects.
- 15) Recommended Resilient Modulus ( $M_R$ ) value to be used in the design of asphalt and portland cement pavements.
- 16) Constructibility considerations including temporary excavation slopes, sheeting and shoring/cofferdams, trafficability, excavatability, possibility of heave of excavation bottoms, and applicable dewatering problems and methods.
- 17) Recommendations should include lateral pressures for design of excavation support systems.



- 18) Recommendations for protecting existing structures during construction of the proposed facilities.
- 19) Groundwater elevations and their effect upon the proposed design and construction, together with a discussion of underdrain requirements and/or recommendations for resistance to uplift pressures. A design groundwater table should be recommended for buoyancy and lateral earth pressure considerations.
- 20) Recommended corrosion protection for construction materials (metals and concrete) if corrosive soils are encountered.
- 21) Evaluation of applicable tunnel excavation techniques and any associated limitations.
- 22) Recommendations for any changes in pipeline or tunnel grades and alignment for reasons of constructibility and costs.
- 23) Possible effects of pipeline or tunnel construction on the surface and subsurface facilities in the alignment and recommended measures to control detrimental effects or ground subsidence.
- 24) Any other geological or geotechnical recommendations considered by the geotechnical engineer to be pertinent to the project.

## IV. General Structural Design Loads for Tanks, Buildings, and Foundations

- A. Structures should be designed to handle all dead and live loads. These include:
1. Floor and roof loads.
  2. Equipment and process loads.
  3. Vibration loads.
  4. Internal and external hydraulic pressures.
  5. Hydrostatic and hydrodynamic loads.
  6. Air pressures.
  7. Vacuum pressure.



8. Earth backfill loads.
  9. Monorail and crane loads.
  10. Winds and seismic loads.
  11. Thermal forces.
  12. Construction loads.
  13. Truck and railroad loadings, as appropriate.
  14. Additional miscellaneous loads.
- B. Without limiting the generality of other requirements of this criteria, all design loads should conform to or exceed the requirements for the IBC supplemented by the most current Oregon Structural Specialty Code and the applicable requirements of the previously listed codes and standards.
- C. The Structural Designer should consult with the appropriate Project Manager and lead process engineer to establish design criteria such as equipment weight and operating frequencies, for special loads:
1. For liquid holding basins, the hydraulic design criteria, sequence of construction, and method of operation should be determined.
  2. Special construction loads, such as limiting wheel loads for construction equipment, will also need to be considered in the design.
- D. Additional consideration should be given for the type, size, and weight of specific equipment and the maintenance of equipment in determining live load.
- E. Minimum uniform live loads for equipment and control room floors are listed in Table 1:
1. In most cases, these minimum loads will allow the equipment to be moved or additional equipment to be added.
  2. The actual weight of equipment should be obtained during final design to determine if the live load is adequate.
  3. How equipment and future maintenance equipment will get to areas of the plant should be reviewed to be sure areas on the travel path are designed for a sufficient live load.



Table 1: Minimum Live Load Values	
Area	Load
Laboratory areas	100 psf*
Office areas	50 psf
Maintenance garages (check wheel loads)	100 psf
Mechanical areas	100 psf
Equipment floors	300 psf
Auxiliary pump rooms	150 psf
Shaft, duct, or vent floors	100 psf
Pump station and process building floor areas	300 psf
Electrical equipment areas	100 psf
Auxiliary equipment and electrical control room	300 psf
Main generator or motor floor	150 psf
Electrical equipment rooms	200 psf
Unrestricted vehicular access	AASHTO HS 20
Grating, checkered plate, hatch covers, walkways, platforms, and stairs	(Same as adjacent floor area, but not less than 100 psf. Deflection should be no more than 1/4")
* psf = pounds per square foot	

4. Rooms within a building that have a ceiling cover should be designed to support the potential loads of items that could be stored on the cover. Otherwise, the ceiling cover should be sloped so that the area cannot be used for storage.
5. Storage live loads also should be checked by determining the stacking height and unit weight of the materials to be stored. The design live load for each floor area of a building should be developed according to the building code and clearly shown on the drawings. The design live load should also be posted in the constructed facility.
6. Wind speed and design pressures should be determined according to the IBC, supplemented by the latest revision of the Oregon Speciality Code.
7. All hydraulic structures should be designed for hydrostatic forces imposed by the fluid contained in the structure.
8. Hydraulic structures, walls, and base slabs should be designed for the following load combinations:
  - a. Normal operating hydraulic level and maximum overflow level with no backfill against exterior walls. (This case pertains to water leakage tests and considers the impact of adjacent excavation for the repair of pipes, etc. These potential issues should be coordinated with the appropriate Project Manager.)



- b. Empty with backfill in place and normal groundwater levels. (Flood levels should be discussed with the City Project Manager.)
  - c. Empty with backfill in place and groundwater at maximum elevation (with increased allowable stresses).
  - d. Any combination of empty and full adjacent cells with common walls.
  - e. Wind in combination with load combination a or b above (with increased allowable stresses).
  - f. Impact forces due to process operation such as surging fluid should be considered in the design.
  - g. Roof live loads for covered/buried tanks should be 100 psf minimum.
  - h. Certain project conditions, such as those during construction or unusual flooding, may require that Designers consider load combinations different from those shown above.
9. All structures should be designed and checked for uplift, or buoyancy:
- a. Live loads, equipment weight and soil friction or cohesion on the walls should not be used to calculate the resisting dead load of the structure for uplift.
  - b. The minimum floatation factor of safety should be 1.10 for worst case conditions such as flood to top of structure or above.
  - c. The minimum safety factor should be 1.25 for flood levels below the top of the structure.
10. Load combinations for nonhydraulic structures should be dictated by the applicable codes.
11. General roof live loads should include loads due to wind and snow.
12. All forces produced by the equipment or machinery having a tendency to vibrate should be considered in the design of supporting structures:
- a. The magnitude of the force should be obtained from the equipment supplier for use in design.
  - b. The equipment that most often causes vibration problems are centrifugal pumps, fans, centrifuges, compressors, and engine generators. Special precautions should be taken when designing structural supports and grout for this machinery. Impact should also be considered for this equipment.



13. Dead loads of different construction material for use in determining self weight are listed in Table 2.

<b>Table 2</b> <b>Dead Loads of Construction Materials</b>	
<b>Material</b>	<b>Dead Load</b>
Concrete	150 pcf
Steel	490 pcf
Aluminum	169 pcf
Fiberglass	100 to 115 pcf
Wood	40 pcf
Masonry, concrete block, solid grouted	
8 inches wide	75 psf (Lightweight) 84 psf (Normal Weight)
12 inches wide	118 psf (Lightweight) 133 psf (Normal Weight)
pcf = Pounds per cubic foot psf = Pounds per square foot	

14. Fluid densities for use in designing hydraulic structures are listed in Table 3.

<b>Table 3</b> <b>Fluid Densities</b>	
Raw sewage	63 pcf **
Grit	110 pcf
Anaerobic sludge	65 pcf
Thickened sludge	65 pcf
Dewatered sludge	70 pcf
** pcf = pounds per cubic foot.	

15. In addition to the load of the basic structure material, the following concentrated loads should be included:
- a. All equipment and piping permanently attached to and considered part of the structure including anticipated future equipment and piping.
  - b. Fireproofing used on structural steel, vessel skirts, and equipment.
  - c. Equipment including all internals and refractory linings



- d. Structural steel platform framing and floor plate. Heavy beams or girders, such as those required to carry other than platform live loads, should be considered separately.
  - e. Miscellaneous loads of special nature, such as counterweights, spring hangers, and thrusts from expansion joints, should be considered in the design.
  - f. Lifting eyes or other for equipment or piping removal.
16. Craneways should be designed to resist horizontal transverse and longitudinal forces in accordance with ASCE 7.
17. Earthquake loads should be as considered in accordance with the section of this standard entitled “Seismic Design Criteria.” Hydraulic structures should be designed for hydrodynamic forces.
18. All below grade structures or parts of structures should be designed for the following soil pressures:
- a. Active soil pressure for all yielding walls (i.e., cantilever walls).
  - b. At rest soil pressure for all nonyielding walls (i.e., restrained or supported walls).
  - c. A minimum surcharge pressure equal to an additional two feet of soil.
  - d. Seismic soil pressure.
  - e. The values for soil pressure should be in accordance with the geotechnical report.
  - f. Surcharge due to adjacent structures and vehicular wheel load should be considered in the design.
19. Test forces and loads should be taken into account in the design.
20. Minimum thickness and reinforcing for nonhydraulic slabs on grade are listed in Table 4.



<b>Table 4 Minimum Slab-on-grade Thickness and Reinforcing</b>		
<b>Application</b>	<b>Minimum Thickness (inches)</b>	<b>Minimum Reinforcing (each way)</b>
Sidewalks	4	#3 @ 16 inches at center of slab, 1½-inch cover
Office Areas	5	#4 @ 18 inches at center of slab, 1½-inch cover
Process and storage areas, passenger vehicle access, and parking	6	#4 @ 12 inches at center of slab, 2-inch cover
Light truck access and parking (AASHTO H10 or less)	8	#5 @ 12 inches at center of slab, 2½-inch cover
Heavy truck access and parking (AASHTO H15 or greater)	10	#4 @ 12 inches at top and bottom of slab, 1½-inch cover at top and 3-inch cover at bottom



## V. Design Criteria for Reinforced Concrete Structures

These requirements should apply to the design of cast-in-place reinforced concrete environmental engineering structures and process buildings.

- A. Table 5 lists the minimum allowable strength requirements for all structural materials used in the construction of reinforced concrete environmental structures and process buildings.

<b>Table 5 Minimum Material Strength</b>	
<b>Material</b>	<b>Minimum Strength</b>
Concrete	28 days compressive strength of 4,000 psi. Increase strengths for durability per ACI 318, ACI 350 and IBC.
Reinforcing Steel	Yield strength of 60,000 psi per ASTM A615
Prestressing Steel	
Seven Wire Strands (Galvanized)	270,000 psi tensile strength; per ASTM A-416
Galvanized Solid Wires	220,000 psi tensile strength; 180,000 psi yield strength at 1% extension
Steel Bars	150,000 psi ultimate tensile strength conforming to ASTM A-722, Type 1

- B. Structural design of reinforced concrete environmental engineering structures and process buildings should be in accordance with the general requirements of ACI 318 and ACI 350. The structural engineer should establish the design criteria for each specific structure within the limitations of ACI and IBC.
- C. Reinforced concrete structures should be designed for both strength and serviceability. The strength design method and the working stress method (alternative design method) are acceptable methods of design of environmental engineering structures per ACI 350.
- D. The following guidelines should be followed in using the strength design method:
1. All concrete structures for treatment facilities such as administration, operation, and process buildings which are not for the containment, treatment, and transmission of wastewater, or other fluids, should be designed by the strength design method in accordance with ACI 318 and IBC.



2. The load factors prescribed in ACI 318 should be used only in the design of buildings.
  3. The load factors of the ACI 318 should be modified when designing environmental engineering structures in accordance with ACI 350.
  4. Serviceability requirements should be in accordance with the provisions of ACI 318, and the requirements for structures with normal environmental exposure and severe environmental exposure in accordance with ACI 350.
- E. In addition to being strong and durable, concrete structures should be built to minimize crack formation. The allowable design stress for reinforcing steel is an important factor in ensuring a watertight, low maintenance concrete structure. The allowable steel stress is a function of the allowable crack width, the bar spacing, and the concrete cover. Designs should comply with appropriate values of the “s” factor in ACI 318 and the Z factor in ACI 350.

## VI. Structural Design Guidelines for Major Facilities

These requirements should apply to the design of concrete rectangular tanks, reinforced concrete circular tanks, prestressed concrete circular tanks, steel rectangular tanks, and steel circular tanks.

- A. Walls should be designed in accordance with the following:
1. Tank walls restrained at the top should be considered as nonyielding wall, and at rest soil pressures should be used in the design.
  2. For long tanks, where walls are designed as a cantilever, consideration should be given for restraint that is provided at the end or cross walls.
  3. Reinforced concrete walls at least 10 feet high that are in contact with liquid should have a minimum thickness of 12 inches. The minimum wall thickness of any environmental engineering concrete structure should be eight inches.
- B. Foundations should be designed in accordance with the following:
1. Unless groundwater or other geotechnical requirements dictate a raft or a deep foundation, the foundation should consist of a spread footing cast monolithically with the floor slabs:  
  
Floor slabs should be designed as a membrane reinforced concrete slab with a recommended minimum thickness of six inches and a minimum reinforcement in accordance with ACI 350.
  2. Where foundation considerations require continuous concrete slabs that are large in plan, special consideration for shrinkage and thermal movements should be made.



3. Where raft foundation is required, it should be designed as a slab on an elastic foundation or by an accepted rational method.
  4. All joints should be provided with a waterstop.
- C. Joints for Environmental Concrete Structures:
1. Expansion, contraction, and construction joints should be provided in accordance with ACI 350 in order to allow flexibility, to tolerate differential movements, and to resist temperature and shrinkage stress. All types of joints should be provided with waterstops where liquid tightness is required.
  2. The location of all contraction and expansion joints should be indicated on the plan drawings; whereas, construction joints normally do not need to be shown.
  3. Typically, the contractor should submit the construction joint plans to the Engineer for review, however, if the location of the construction joints is critical to the design of the structure, they should be shown on the plans.
  4. Wall sections should show the locations of construction joints and water stops.
  5. At construction joints and at partial contraction joints, a minimum of 48 hours should pass until adjacent concrete can be placed.
  6. Expansion or contraction joints may be used as movement joints to dissipate shrinkage stresses. Where used, contraction spacing should be at intervals not to exceed 30 feet, unless additional reinforcement is provided in accordance with ACI 350.
  7. Expansion joints should be provided at abrupt changes in the structural configuration.
  8. Construction joints should be located to provide logical separation between segments, facilitate construction, limit the size of concrete placement, and not impair the strength, water tightness and serviceability of the structure. Horizontal construction joints should be located at the base of walls, and immediately below and above structural slabs.
  9. All reinforcement should be continued across or through all joints unless designed as a contraction or expansion joint.
  10. At liquid holding structures, plastic or steel waterstops should be used at all construction joints to keep them watertight. They should extend at least 1.5 feet above the maximum water surface, or to two inches below the top end of the wall, whichever is lower. At dry structures, waterstops should be used to at least 1.5 feet above the maximum groundwater table.



11. To minimize shrinkage cracking in the bottom of wall pours placed over thick foundation slabs, three additional horizontal reinforcing bars should be placed at each wall face in the bottom three feet of the wall.
- D. Joint Sealants:
1. Notes to Specifier in the specifications and manufacturer's literature should be consulted for types of sealants to be used. Drawings should not specify the sealant type to be used.
  2. Designers should verify that the joint dimensions shown on the drawings are proper for the type of sealant specified and the total anticipated movement should be verified.
- E. Minimum shrinkage and temperature reinforcing minimum shrinkage and temperature reinforcing parameters for environmental engineering structures should be according to ACI 350 and ACI 318.

## VII. Design Criteria for Concrete Rectangular Tanks

- A. These requirements should apply to the design of cast-in-place reinforced concrete environmental rectangular tanks.

The following documents may be used in the design of rectangular tanks:

1. "Rectangular Concrete Tanks" by PCA.
2. "Moments and Reactions for Rectangular Plates," Engineering Monograph No. 27 by U.S. Bureau of Reclamation.

## VIII. Design Criteria for Reinforced Concrete Circular Tanks

These requirements should apply to the design of circular, cast-in-place, reinforced concrete process units and ground level storage tanks.

- A. The following documents may be used in the design of circular, reinforced concrete tanks and foundations:
1. The latest edition of ACI 350.
  2. "Circular Concrete Tanks without Prestressing" by Portland Cement Association (PCA).
- B. Concrete wall sections should be sized for direct tension; reinforcing steel should be assumed to carry the entire tensile load. Stresses in concrete should not exceed the allowable tensile stress.



- C. Footing Design:
1. Unless the foundation is a raft or otherwise stiffened, the wall-to-footing connection should be considered hinged. If the foundation is a raft, the wall-to-footing connection should be designed for bending continuity.
  2. Outward acting wall base shears or sliding base forces should be resisted by hoop reinforcing in the footing.

## IX. Design Criteria for Circular Prestressed Concrete Tanks

- A. These requirements should apply to the design of circular prestressed concrete process units and ground level storage tanks.
- B. The following documents should be used in the design of circular, prestressed concrete tanks and foundations:
1. ACI 372R, Design and Construction of Circular Wire and Strand Wrapped Prestressed Concrete Structures, latest edition.
  2. ACI 373R, Design and Construction of Circular Prestressed Concrete Structures with Circumferential Tendons, latest edition.
  3. ACI 350, Code Requirements for Environmental Engineering Concrete Structures.
- C. For circular, prestressed concrete tanks, the Contractor should be allowed to use either the circumferentially wrapped prestressed system or the wall encased duct with tendon system.
1. Circular, prestressed concrete tanks should meet the following criteria:
    - a. Minimum residual prestress force should be 200 psi, after application of internal loads and prestress losses, without consideration of backfill pressures, if any.
    - b. Maximum design prestressed concrete compressive strength ( $f_c'$ ) should be 5,000 psi at 28 days for concrete and should be 4,500 psi at 28 days for shotcrete:
    - c. Maximum initial concrete compressive stress should be  $0.55 f_c'$  after prestressing.
    - d. Maximum concrete compressive stress should be  $0.45 f_c'$  under service loads, after prestress losses, without internal pressure.



2. All prestressing steel and anchorages should be hot dipped galvanized.
  3. Strands for horizontal prestressing should be seven-wire, cold drawn, stress relieved, conforming to ASTM A416, Standard Specification for Steel Strand, Uncoated Seven Wire Stress Relieved for Prestressed Concrete, Grade 270, minimum tensile strength after galvanizing 240,000 psi.
  4. Bars for vertical prestressing should conform to ASTM A722, Standard Specification for Uncoated, High Strength Steel Bar for Prestressing Concrete.
  5. Seismic anchorage wall to footing should be made with galvanized prestressing strands, configured to allow free radial movement of the wall at the base.
  6. After prestressing forces have been applied to the wall, an internal curb should be cast to insure that during an earthquake the movement of the wall relative to the footing is within acceptable deformation limits of the waterstop.
  7. No connections should be made to the prestressed wall which would inhibit the free radial movement of the wall, cause stress concentrations, or damage the prestressing system in any way.
  8. Walls designed for the wall encased duct with tendon system should have horizontal tendons installed in the ducts cast into the core wall between thrust anchorages located around the tank periphery.
  9. Tendons should be made up of multiple prestressing strands as required by the design force diagram.
  10. The horizontal ducts should be galvanized ferrous metal, circular in cross section and mortar tight.
  11. The inside cross sectional area of the duct should be at least two times the net area of the prestressing steel.
  12. Each end of the ducts or anchorage assemblies should be provided with steel pipe for the injection of grout after prestressing.
  13. Annular spaces between tendons and duct should be filled with either epoxy or cement grout.
  14. Unbonded tendon systems should not be used.
- D. When appropriate, concrete walls of process units should be designed for through wall differential temperature. Methods referenced in ACI 372R or ACI 373R or other accepted, rational approach should be used.



## X. Design Criteria for Steel Tanks

These requirements should apply to the design and construction of vertical, ground supported, welded circular or rectangular steel tanks, including water storage tanks and process tanks that operate at atmospheric or low internal pressure.

- A. The following standards and codes are references:
1. ANSI Welded Steel Tank for Oil Storage API STD 650, latest edition. API 650 should be used for tanks at atmospheric pressure.
  2. API recommended rules for the design and construction of large, welded, low pressure storage tanks, API STD 620, latest edition. API 620 should be used for tanks with low internal pressure, not more than 15 psig.
  3. AWWA Standards for Welded Steel Tanks for Water Storage ANSI/AWWA D100, latest edition.
- B. In addition to the loads outlined previously, the following loads should also be included:
1. Content loading.
  2. Test loading.
  3. Soil loading.
  4. Process or operating pressure loading.
  5. Thermal loadings.
- C. The following design requirements should apply to both circular process and water storage steel tanks:
1. Fabrication of steel tanks should be by welding.
  2. The tank details should be designed to eliminate wherever possible unwelded joints that will promote corrosion, pockets that will accumulate rainwater, and attachments to the steel which result in excessive localized stresses due to welding or imposed loads.
  3. All welds joining shell plates and wetted roof plates should have complete joint penetration and fusion and should be double welded from both sides.
  4. The use of low hydrogen electrodes is mandatory for manual welding of shell plates, permanent attachments to the shell plates, fittings, and for welds joining the shell plate to the bottom plate.



5. All shell plates should be rolled, regardless of material thickness.
  6. The roof of circular nonburied tanks should be designed for a minimum live load of 20 pounds per square foot and should be sloped for drainage:
    - a. Pressure loading, if specified, should be added to the design.
    - b. Lateral bracing of rafter compression flanges should not be assumed to be provided by friction between roof sheets and rafters.
    - c. Rafters bridging between rafters should be designed for standard structural steel shapes.
  7. Columns should be fabricated from steel pipe sealed at both ends:
    - a. Column bases should be fabricated from steel plate and provided with the necessary gusset plates to distribute the load uniformly.
    - b. The base plates should be designed for a maximum foundation loading as recommended in the geotechnical report, exclusive of the weight of the water.
    - c. The column bases should not be welded to the bottom plates but should be prevented from lateral movement by angle clips welded to the bottom plates.
- D. Structural steel shapes will not be permitted in fabrication of column bases:
1. Freeboard between maximum fluid level and top of shell should be provide to accommodate for the sloshing of fluid induced by the seismic loading so as not to overstress the roof plate and the connections.
  2. The tank bottom (including sketch plates) should be fabricated from steel plate not less than 5/16-inch thickness.
  3. Butt welded annular plate should be provided to resist the seismic overturning moment for an unanchored tank.
  4. Bottom plates other than annular plate should be lap welded unless otherwise noted.
- E. Circular tanks for process applications should be designed for the following additional criteria:
1. Tanks operated at atmospheric pressure should be designed in accordance with the requirements of API 650.



2. Tanks operated at maximum internal pressure of 15 psig or less should be designed in accordance with the requirements of API 620.
3. For tanks operated at internal pressure of 2.5 psig may use either the design procedures in Appendix F (Design Tanks for Small Internal Pressure) API 650 or API 620.
4. Testing or operating pressure should be added to the design loading for roof, shell, and anchorage.
5. For tanks that are totally or partially submerged in fluid or soil, buckling caused by the external loading should be considered:
  - a. A minimum factor of safety of three should be used in calculating required thickness or stiffener spacings to resist buckling.
  - b. A factor of safety of 1.5 should be used in the design against wind or seismic overturning and sliding.
  - c. Corrosion allowance should be specified for each tank if required.
6. Openings in tank roof, shell, and bottom should be indicated on the design plans and any special requirements should be specified. Reinforcement for openings should be designed in accordance with the API 650 or API 620 standard.
7. Flat bottom tanks should be supported by concrete ring wall footing, or mat foundation.
8. Conical or other type of tank bottoms should be supported by concrete slab footings, or a combination of concrete ring wall and slab.
9. Seismic design should be in accordance with the section of this standard titled "Seismic Design Criteria."
10. Circular tanks for water storage should be designed for the following additional criteria:
  - a. Tank's shell, roof, bottom plate, and roof supports should be designed in accordance with ANSI/AWWA D100, latest edition.
  - b. The option of using the design, fabrication, and inspection procedures specified in Appendix C of ANSI/AWWA D100 will be permitted with the following limitation: Only steel complying with ASTM A36 or ASTM A131 may be used.
  - c. The lowest one-day mean temperature should be considered to be 45 degrees F.



- d. A factor of safety of 1.5 should be used in the design against wind or seismic overturning and sliding.
  - e. Corrosion allowance should be specified for each tank as required.
  - f. Openings in tank roof, shell, and bottom should be as specified. Reinforcement for openings should be designed in accordance with the ANSI/AWWA D100, latest edition.
  - g. Foundation should be concrete ring wall.
  - h. Seismic design should be in accordance with the section of this standard titled “Seismic Design Criteria.”
11. Rectangular tanks consist of flat steel plates stiffened with structural shapes to transfer gravity and wind or seismic loads to its supports. Design loads are transferred by the plate and stiffener to the supports or footings. Requirements for rectangular tanks include the following:
- a. The thickness of plate and spacing of stiffeners should be based on the continuous beam analysis with each stiffener acting as a support; support spacing should be equal to the center-to-center spacing of stiffeners.
  - b. When a stiffener is fully or partially submerged in fluid, it should be continuously welded to the plate at both sides.
  - c. When the tank is divided into compartments, the full loading of one compartment while the adjacent compartment is empty should be considered in the design.
  - d. Stiffeners should be designed as simply supported members utilizing a portion of the steel plate as its stiffening element.
  - e. A width of 12 times the thickness of the steel plate may be utilized as a stiffening element at each side of the stiffener.
  - f. The stiffener flange that is welded to the plate should be considered as fully laterally supported, the other flange is unsupported.
  - g. When required, structural members should be used as lateral brace.
  - h. Steel plate and stiffeners should be designed in accordance with the requirements of AISC, with the exception that the allowable bending stress for steel plates should be limited to  $0.66 f_y$ .



- i. Surfaces in contact with the tank contents should be continuously seal welded.
- j. Foundations should be mat footings or concrete piers.
- k. Allowable stresses may be increased by 33 percent for wind and seismic loading.
- l. When the top cover is provided, pressure loading should be taken into consideration in conjunction with other loadings in the design of plates and stiffeners:

The effect of sloshing fluid induced by seismic loading on roof plate and stiffeners should be investigated.

12. Rectangular tanks should be designed for the following loading in addition to that previously discussed:

Process pressure loads, such as operating pressure and pressure setting of relief valves or vents.

- a) Soil and surcharge load if tank is totally or partially below finished grade.
- b) Roof live load for covered tank should be 100 psf unless otherwise noted.

## XI. Design Criteria for Equipment Footings

These requirements should apply to the design of equipment footings.

- A. The following should be included in the design loading:
  1. Equipment dead weight plus contents.
  2. Portion of piping and the contents attached to the equipment.
  3. Operating live load.
  4. Dead load and live load of attached platforms, ladders, and stairs.
  5. Equipment impact, vibration, and torque.
  6. Seismic and wind load.
- B. Equipment footing should be designed for the maximum load under operating or testing conditions. Only 50 percent of platform live load should be combined with



the test loading in the design. Test and seismic loading need not be combined in footing design.

- C. The most unfavorable effects from wind and seismic loads should be considered in the design. Wind and seismic loads are assumed not to be acting on the equipment simultaneously. Factor of safety against wind and seismic overturning and sliding should not be less than 1.5. Piping connecting to the equipment should not be used as a means to resist the wind or seismic loading.
- D. Horizontal vessels should be supported by pedestal(s). In addition to the loadings above, frictional force due to thermal movement should be taken into consideration in the design. Sliding bearings should be provided at one end to reduce the friction loading. Movement and shear acting on footings caused by removing some internal components from the equipment (such as tube bundle) should be considered in the design. The horizontal force should be assumed as two times the weight removed unless specific valves are provided.
- E. The effect of impact, vibration, and torque of the equipment on the footing should be considered. In the absence of equipment data required for the footing or support structure vibration design, preliminary footings should be sized to have three times the weight of the equipment.

## XII. Design Criteria for Miscellaneous Structures

- A. These requirements should apply to the design of platforms, stairs, ladders, minor equipment, and pipe supports.
  - 1. The following standards and codes are referenced:
    - Standard for Occupational Safety and Health Administration (OSHA).
- B. Design loads should conform to the following:
  - 1. Platforms, walkways, stairs, and ladders should be designed for a minimum live load of 100 psf, plus concentrated and distributed loading from equipment or connecting framing members.
  - 2. Minimum concentrated load on ladders and stairs should be in accordance with the requirements of the ASCE 7 and OSHA.
  - 3. Seismic loading as outlined in the section of this standard titled “Seismic Design Criteria.”
  - 4. Steel connected bolts should be ASTM A307.
  - 5. Bolts of stainless steel, Type 304 or 316 should be used for aluminum member connections.



6. Shop connections may be welded or bolted. Field connection should be bolted whenever possible.
  7. Minimum requirements in width and clearance for platforms, stairs, and ladders should be in accordance with the requirements of OSHA.
  8. Long walkways should be provided with access on one end and an emergency escape ladder, as a minimum, at the opposite end from the main stairway or ladder.
- C. For safety, ladders extending more than 30 feet in height should be offset with intermediate landings. When the ladder is over 12 feet in height or originates from a point which is 12 feet or higher above grade, safety cages (originating 7'-0" from the bottom) should be installed. Safety gates should be provided across from all platform openings leading to ladders. Fall prevention devices may be considered instead of cages, and should require the approval of the City Project Manager.
- D. Weight of platform grating or checkered plate segments should be a maximum of 80 pounds.

### **XIII. Seismic Design Criteria**

- A. The following standards and codes should be used to define the seismic design loads to be used in the design of tanks, buildings, and structures foundations:
1. The most current version of the IBC supplemented by the most current Oregon Structural Specialty Code.
  2. Seismic Design of Liquid Containing Concrete Structures and Commentary (ACI 350.3).
  3. ANSI Welded Steel Tank for Oil Storage API STD 650, latest edition. API 650 should be used for tanks at atmospheric pressure.
  4. Standards for Welded Steel Tanks for Water Storage ANSI/AWWA D100, latest edition.
  5. "Nuclear Reactors and Earthquakes," Chapter 6 entitled "Dynamic Pressure in Fluid Containers," Report No. TID7024, by Dr. Housner.
  6. Site specific design recommendations as given by the geotechnical report for each specific project site.



- B. When selecting ground motions for the seismic design of structures, the economic life and requirements for uninterrupted operation after a major earthquake should be considered. The following are basic guidelines for determining the design ground acceleration and seismic forces:
1. A seismic risk analysis for the project site should be performed by developing a probabilistic source model based upon the regional structural geology and the historical seismicity. The result of this study should be presented in the geotechnical report in the form of peak ground acceleration versus probability of exceedance for 150 years' design life and response spectra for the various levels of shaking.
  2. The seismic design should be based on the ground acceleration for two lower level earthquakes with 50 percent probability of occurrence during 50 and 100 years for the structural design life and two upper level earthquakes with 10 percent probability of occurrence during 50 and 100 years' design life.
- C. Response spectra with damping factors of 0.5, 1, 2, and 5 percent should be used for the seismic design for the appropriate level of shaking and type of structure.
- D. For minor isolated structures where a site specific seismic study may not be performed, the appropriate provisions of the IBC should be used to determine seismic forces.
- E. All seismic forces and designs should be performed using the ground acceleration and the appropriate response spectra for a 100 year design life with a probability of exceedance of 50 percent. All structures should be checked against collapse using the ground acceleration and the appropriate response spectra for a 100 year design life with a probability of exceedance of 10 percent using load factors equal to 1.0.

Seismic design of process and non-process structures at the plant shall be designed as critical structures. The designer is responsible for identifying those structures which would add significant construction costs without adding significant structural benefit.

- F. For steel circular tanks used for process liquids, the seismic coefficient as specified by the geotechnical consultant should be used in the design. In the absence of a recommended seismic coefficient from the geotechnical consultant, the seismic coefficient outlined in API 650, Appendix E should be used. For steel circular tanks used for water storage, the seismic coefficient as specified by the geotechnical consultant should be used in the design. In the absence of a recommended seismic coefficient from the geotechnical consultant, the seismic coefficient outlined in ANSI/AWWA D100 should be used.
- G. For concrete tanks, the seismic coefficient as specified by the geotechnical consultant should be used in design. In the absence of a recommended seismic coefficient from the geotechnical consultant, the seismic coefficient outlined in ACI 350.3 should be used.



- H. Seismic soil pressure should be determined in accordance with the recommendations given in the geotechnical report for each specific project site.
- I. Loadings should be calculated for different conditions. As a minimum, the following load combinations should be determined:
  - 1. Tank Full—Hydrostatic loading plus hydrodynamic loading plus seismic forces due to dead loads.
  - 2. Tank Empty—Static soil pressure (active or at rest) plus seismic soil pressure plus seismic forces due to dead loads plus permanent surcharge.
  - 3. Suspended Slabs and Roofs—Dead loads plus seismic dead loads plus percent of live load as required by the provisions of the IBC.
- J. All design should be performed in accordance with the seismic provisions of the following codes and references:
  - 1. The most current version of the IBC supplemented by the most current Oregon Structural Specialty Code.
  - 2. The provisions presented in Chapter 21 of the ACI-318, latest edition.
  - 3. The provisions presented in the ACI 350 and ACI 350.3, latest edition.
  - 4. The latest edition of Recommended Lateral Force Requirements and Commentary by the Seismology Committee of the Structural Engineers Association of California (SEAOC) (commonly known as the “Blue Book”).
  - 5. Detailing of different structural elements to ensure ductility and other requirements should be in accordance with the requirements of the IBC, SEAOC, and ACI.

## XIV. Concrete Requirements

- A. The following mix design considerations impact the design of the structure and should be coordinated with the specifications:
  - 1. All concrete should be air entrained with an air content of four-to-six percent. At interior slabs to be trowel finished, air entraining may be omitted.
  - 2. Type II cement should be used at covered wastewater treatment structures unless high sulphate contents in site soils or groundwater require Type V. Use Type V concrete for all structures containing sanitary sewer liquids.
  - 3. Colored cement should not be used for cast-in-place concrete; however, it may be used for precast concrete panels.



4. Fly ash should be considered on all projects. Fly ash increases the sulfide resistance of the concrete and lessens the impact of the heat of hydration.
5. All concrete for hydraulic, or liquid containing, structures should contain a water reducer and, preferably, a superplasticizer. A superplasticizer allows reduction of water content which makes the concrete less susceptible to shrinkage, more dense, and more resistant to chemical attack.
6. Where walls are to receive coatings, paint, cementitious material, tile, waterproofing, or other similar finishes, or where solvent based coatings are not permitted, only water curing procedures should be used. Current state regulations should be checked to see if a curing compound with solvents is prohibited. A curing compound may be used if it is compatible with the proposed covering or if the curing compound is removed before the covering is placed.

B. Finishes:

1. The various wall and slab finishes are described below. Master Guide Specifications, Division 9 will provide more detailed descriptions of these finishes.
2. Wall finishes:
  - a. Type W-1 (Ordinary Wall Finish)—This finish should be used on walls where appearance is not important, such as on walls to be backfilled, or inside basins that are not publicly viewed and are not difficult to wash down. Projections are knocked off and defective areas are patched.
  - b. Type W-2 (Smooth Wall Finish)—This finish should be used on walls where appearance is more important than required for W-1, such as pump station walls, tunnels, and where painted concrete or waterproofing is desired. Air bubbles are not repaired, however, projections are ground off and rough spots and defective areas are repaired.
  - c. Type W-3 (Grout Cleaned Finish)—This finish should be used for exposed exterior surfaces where a high quality finish is required. A preconstruction meeting should be held to view a sample panel of the finish on a new and/or existing surface. A similar, less expensive finish can be obtained by combining W-2 with a cementitious coating.
3. Slab finishes:
  - a. Type S-1 (Steel Troweled Finish)—This finish should be used on areas such as tunnels and the inside of exposed buildings. Trowel



finishing produces a smooth surface that is easier to wash down than a light broomed finish surface.

- b. Type S-2 (Wood Float Finish)—This finish should be used on slabs that will receive a mortar setting bed for ceramic tile or topping slab.
  - c. Type S-3 (Underside Elevated Slab Finish)—This finish should be used on the underside of concrete slabs that are exposed where appearance is important. If a surface is to be painted, this finish should also be used. Repair of air pockets is not required if appearance is not a problem. If a surface is to receive a coating, the surface should be prepared to receive the coating, as specified.
  - d. Type S-4 (Preparation for Topping Slab)—The surface should be screened with straight edges to leave surface ready for the topping slab.
  - e. Type S-5 (Broomed Finish)—This finish is as specified for Type S-1 finish, except that final troweling should be omitted and the surface should be finished by drawing a fine hair broom lightly across it, providing a nonslip surface such as for stair treads, sidewalks, and pavements.
  - f. Type S-6 (Sidewalk Finish)—This broomed finish should be used on all exterior sidewalks.
4. Concrete finish schedule:
- a. Information pertaining to concrete finishes should be specified in the concrete finish in Master Guide Specification, Division 9. Additional finish types may be required for project specific conditions. The structural engineer and the project architect should both review the schedule to make sure all possibilities are covered, and that the finishing techniques specified are practical, economical, and satisfy the project requirements.
  - b. The above wall and slab finish numbers should not be revised on a project even if some finishes are not used or additional finishes are specified. Additional finishes should receive a number not covered in the finishes indicated above.

C. Tolerances:

- a. The tolerances for the wall and slab finishes described above are covered in Master Guide Specification, Division 9. Applicable areas are indicated in the concrete finish schedule. These limits should be reviewed and any additional limits that may be applicable to specific project conditions should be added.



- b. The floor tolerances are given in inches per foot. For projects for which floor finish tolerances are very important or critical, ACI 117, specifications for Tolerances for Concrete Construction and Materials, should be referred to for the “F Numbers” required. Also, they should be incorporated into the specification.

## XV. Structural Detailing

### A. Concrete Wall Thickness:

1. The wall should be thick enough to provide enough space to properly place and consolidate concrete.
2. Wall thicknesses should be designed in two-inch multiples to simplify form tie systems.
3. One curtain of reinforcing steel should be used in walls less than 10 inches thick; two curtains should be used in walls 10 inches thick and greater.

### B. Structural Concrete Slabs (Elevated):

1. Two layers of reinforcement should be used in structural or elevated slabs.
2. Slab thicknesses sufficient for placing shrinkage and temperature reinforcement near the top and bottom surfaces should be provided. Compression reinforcement should also be provided to limit creep deflection.

### C. Topping Slabs:

Concrete topping slabs should be at least 3½ inches thick. The edges of the concrete topping can not be tapered.

### D. Spacing of Reinforcing Steel:

1. In general, six-inch spacing should be used for primary steel and 12-inch spacing should be used for secondary steel for typical design and detailing of reinforcement. Four-, eight-, nine-, and ten-inch spacing should be considered, when desired, to limit bar size and flexural cracking, or to decrease costs.
2. The spacing of the steel should be reviewed in congested areas. In the past, there have been problems in such areas where steel congestion has made it difficult to place concrete.

### E. Minimum Concrete Cover over Reinforcing Steel:

The IBC requirements should be followed for concrete cover for building structures. For environmental structures, ACI should be followed.



F. Lap Splices and Development Lengths:

Lap splices and development lengths in reinforcing bars should conform to the IBC. Rebar welding should not be detailed or specified.

## XVI. Reinforcement Details

- A. For basin walls, corner bars should be shown on the drawings. Inside horizontal bars should be extended through the intersecting wall and hooked or lapped with horizontal bars on the opposite face.
- B. The dimension should be shown if the vertical dowels project above the base slab on the wall sections. The dowel projection should provide enough splice length for the continuing reinforcement and should be located at the proper cutoff point for the dowels. Dowels should be embedded or lapped with the base slab or footing reinforcement. Ninety degree hooks should be provided where required for embedment length, with adequate slab thickness to develop the 90-degree hook.
- C. Epoxy coated reinforcement should not be used.
- D. Plastic tipped reinforcing chairs should also be used to prevent rusting and staining of the concrete.
- E. For circular structures, the slab reinforcing should be placed in a radial pattern to minimize the number of different reinforcing bar lengths provided.

## XVII. Equipment Pad Details

- A. Equipment pads should be shown and dimensioned on the structural floor plans. The Designer may also choose to show dimensions on the mechanical and electrical plans.
- B. All equipment in potential wash-down areas should be placed on an equipment or housekeeping pad. The mechanical and electrical designers should identify in the design the need for equipment pads. They should also consider the potential need to raise equipment off the floor in areas of potential wash down. Steel support legs should not be placed directly on the floor slabs.

## XVIII. Concrete Anchors

- A. The following concrete anchors should be used as required. The Designer should refer to the specifications for additional requirements:
  - 1. Embedded Anchor Bolts—Embedded or cast-in-place anchor bolts and headed concrete anchors (e.g., Nelson Stud).



2. Wedge Anchors—Drilled wedge anchors (e.g., Hilti Kwik-Bolt, ITW Ramset/Redhead Trubolt Wedge, Molly Parabolt, and Wej-It).
  3. Expansion Anchors—Self drilling, snapoff or flush expansion anchors (e.g., Hilti HDI Drop In Anchor or ITW Ramset/Redhead Self Drilling Anchor). This type of anchor should not be used.
  4. Adhesive Anchors—Drilled epoxy anchors (e.g., Adhesives Technology Anchor It Fastening System, ITW Ramset/Red Head Epcon Ceramic 6 Epoxy Anchor System, Covert Operations CIA Epoxy Anchors, Rawl/Sika Foil Fast Epoxy Injection Gel System, and U.S. Anchor UltraBond). Vinyl ester anchor systems should not be used.
- B. Wedge or expansion anchors should not be submerged or used for anchoring vibrating equipment or machinery, or for overhead pullout loads. Only stainless steel epoxy or adhesive anchors should be submerged.
- C. Epoxy or adhesive anchors should not be used to resist pullout forces in overhead ceiling or wall installations, to support fire resistive construction, or in areas where temperatures will exceed 120 degrees F.
- D. Stainless steel anchors should be used in areas that are submerged or exposed to wet conditions.

## XIX. Testing

A. Water Leakage Tests:

Water leakage tests can be performed on liquid containing structures to determine integrity and water tightness of finished concrete surfaces. These tests should be done before the structure is backfilled so that required repairs can be made if necessary. If leakage tests are used for a project, the testing methods and required repair methods should be incorporated into the project specifications. The need for such tests should be coordinated with the appropriate City Project Manager. This should be identified early on in the project since it will impact the structural design of the structure.

B Field Testing:

The latest policy regarding field testing of concrete should be reviewed with the responsible City Project Manager. Field testing should be coordinated with the specifications.



## XX. Metals

### A. Structural Steel:

Designers should base analysis and design of structural steel systems on the Allowable Stress Design (ASD) Method or the Load and Resistance Factor Design (LRFD) Method, and according to the AISC Manual of Steel Construction.

### B. Connections.

#### 1. Bolted Connections:

- a. ASTM A325 high strength bolted connections should be used for all structural steel framing. Type 1 bolts for high temperatures and Type 3 bolts for atmospheric corrosion resistance should also be used.
- b. Bearing type connections should be used unless the connection will be subjected to vibration or stress reversal or will be carrying shear in a moment resistant connection with welded flanges. If that is the case, slip critical connections should be used.
- c. Different bolt diameters and connection types should not be used on the same project or facility.
- d. For bolted connections of miscellaneous fabricated metal work not meeting the AISC definition of structural steel, ASTM A307 bolts may be used.

#### 2. Welded Connections:

Continuous seal welds should be used in exterior or corrosive environments. Built up members with intermittent welds should not be used in humid or corrosive environments.

### C. Open Web Steel Joists:

1. Open web joists should not be used in areas that are susceptible to high humidity and corrosion. Because of the joint configurations of the truss members, it is difficult to ensure that all steel surfaces will be adequately protected by the specified coating system.
2. Joist design load criteria should be shown on the framing plan or included in the specifications. Along with the uniform dead and live loads, all concentrated loads on the top and bottom chords due to equipment supports and monorails, including anticipated future loads should be shown.



#### D. Steel Deck.

The following guidelines apply to steel deck:

1. All metal deck should be galvanized.
2. The following information should be shown on the drawings if it is not included in the specifications—deck profile type, depth, minimum gauge, and coating. The required diaphragm shear values should be shown on the framing plan. Where diaphragm shear values are large and require extra welding, different minimum values should be shown on the roof plan.
3. For floor deck, the need to shore during concrete placement should be avoided by specifying a section modulus adequate for supporting the wet concrete from the steel framework.

#### E. Grating:

1. The direction of bearing bars should be shown on the framing plan. Also, the type of attachment to intermediate supports should be specified, depending on whether the sections are to be removable. All grating should be fastened to the supports with stainless steel connectors.
2. All grating and openings greater than two inches should be banded. Aluminum grating should have an electrolytic separator if the grating is supported by steel framing. Grating panels should weigh less than 80 pounds per panel. The type of grating and need for nonslip surface should be coordinated with the appropriate City Project Manager.
3. In general, aluminum or galvanized grating is preferred.
4. Fiberglass reinforced plastic (FRP) grating should be used in chemical areas, or other corrosive areas where the use of aluminum or steel is undesirable. The City Project Manager should approve the areas where FRP grating is used.

#### F. Cover Plates:

Removable cover plates generally should be aluminum or should weigh less than 80 pounds per section. The allowable live load for the cover plates should be included on the drawings. Live load should be at least equal to that of the adjacent floor system with a minimum of 100 psf. Maximum deflection should be no greater than one quarter of an inch.



## G. Metal Fabrications.

### 1. Anchors:

- a. Generally, all anchors should be Type 316 stainless steel. Exceptions to this may be those located in noncorrosive, interior areas, such as administrative buildings. Steel anchors should not be used with aluminum or other dissimilar metals. If adhesive anchors are used in a submerged condition, their adequacy should be verified. Their use should require approval from the City Project Manager.

### 2. Stairs:

- a. In the interest of safety, conventional stairs conforming to the IBC should be used. Ships ladders or spiral stairs should not be used. Spaces should be laid out to accommodate a conventional stair, but if space restraints do not allow this (such as in an existing building), an alternating tread ladder (Lapeyre Stair) should be used. The appropriate City Project Manager should be contacted before using anything other than a conventional stair. These requirements also apply to stairs to roofs.
- b. Only aluminum or concrete stairs should be used in exterior applications. All stairs treads, interior and exterior, should be provided with abrasive nosings; grating type treads should be used where materials, such as sludge, could build up and create a slipping hazard.

### 3. Ladders:

Rungs should be slip resistant on the flat portion and should either extend through the side rails or be through bolted; connections depending solely on welded connections should not be used. Safety cages should be used when required by codes and OSHA; safety climb devices may be used but should require approval of the City Project Manager. To simplify floor cleaning and reduce corrosion, ladders should be mounted on walls (off floor), except where they are away from walls. A security door should be provided at the base of ladders in areas that may be accessible to the public.

### 4. Guardrails:

- a. Guard rails and anchors shall be designed for appropriate loading as specified by OSHA and the building code.
- b. Normally, guardrails in process areas, which are not usually accessible to the public, may have a 12-inch open space. Those areas with public access should have rails spaced at four-inch maximum vertical clearance. Public access areas are those areas of the plant subject to public tours.



- c. Exterior guardrails—Exterior guardrails should be those provided on the perimeter of tanks where the walls are not high enough to meet OSHA safety requirements. The standard rail used is a three rail system as specified by OSHA. If small areas of guardrail are being added adjacent to existing rails, the new rail may match the existing rail design. The appropriate City Project Manager should be consulted to determine if this is the case on a particular project. Public access railings will typically not be required for exterior guardrails. Also, toe boards will not be required, but should be added where necessary. Aluminum rails should be used rather than concrete rails.
  - d. Interior guardrails—Interior guardrails should be guardrails located on walkways above basins and other access areas. Interior guardrails are used with and without toe boards, depending on the application. Toe boards should be required where maintenance will be performed from the walkway to prevent tools and other objects from being kicked into the basin or into the areas below. In areas accessible to the public, such as administrative areas, rail designs with a four-inch maximum space should be used. All rails should be aluminum, except galvanized steel may be used in special circumstances when a stronger rail is needed. In noncorrosive administrative type areas, painted steel rails may be used.
- H. Surfaces in contact with concrete or dissimilar metals should be coated with a bituminous coating. Guardrails should be side or surface attached with anchors drilled in the field. Cast-in-place, sleeve type anchorage should not be used because it has a history of having alignment problems.

Bollards should be placed on both the interior and exterior side of door openings subject to forklift or vehicular traffic or around chemical storage tanks. The bollards should be located on the plans such that they will not interfere with operation of doors or access to tanks or equipment should be verified. Bollards should be as shown in the Drawing Library.

## XXI. Waterproofing

- A. All below grade walls and roofs enclosing space should be waterproofed, except spaces such as crawl spaces, where moisture penetration is not a concern. The Designer should determine the appropriate type of waterproofing to be used on a project based on soil type, water table, importance of enclosed space, etc. That the concrete finish specified is adequate to receive specified waterproofing should be verified.
- B. Brush, spray, or roll-on asphalt materials should not be considered as a means of waterproofing. These materials should only be used where water penetration is not a critical factor.
- C. Cementitious/chemical waterproofing can be subject to short term leaking during its initial application and any time a crack develops in the concrete after occupancy.



This type of waterproofing should not be used in areas where short term leaking may be a problem.

- D. A protection board should always be used with waterproofing systems. The only exception to this is Xypex, which may be the manufacturer's standard product or a rigid perimeter insulation. If a rigid perimeter insulation is used, the compressive strength should be adequate to resist loads, especially if used over horizontal surfaces in areas where vehicular traffic is expected.

—End of Section—

