Moments in Walls

Rectangular Tanks:

If the wall has an aspect ratio not exceeding 4:1 between supports, including interior walls, baffles, and weirs, use the two-way moment tables in PCA-R pages 2-17 thru 2-22.

If the aspect ratio is outside of the range of these tables, analyze the wall as a vertical cantilever beam, designing a 1’ wide strip is the common practice. This will yield a moment for the vertical strip, designated as $M_x$ in the PCA-R tables. For the horizontal moments the tables for an aspect ratio of 4:1 could be used, which would [conservatively] result in higher moments $M_y$ than the wall actually would experience.

Circular Tanks:

Moments are considered on vertical strips only. The PCA-C table on page A-2 should be used to determine the moments.
Moments in Slabs

For the rectangular tank the slab will span in the short direction as a continuous beam over several supports. The formula $M_u = w_uL^2/8$ can be used for the short span direction, where $L$ is the length of the short span. This is only slightly conservative compared to more rigorous calculations for the maximum moment in continuous beams. The short span rebar should be located at the top and bottom of the slab, taking the concrete cover into consideration. The long span rebar should be located inside of the short span rebar, as illustrated below. For the long span rebar it is conservative to use the same reinforcing as the short span. The maximum moments in the long span direction will generally be less than 75% of the maximum moments in the short span direction, depending on the aspect ratio and the assumed boundary conditions.

The slab beneath the circular tank will be a slab-on-grade only. Any considerations for slab-on-grade in the soils report should be adhered to. If there are no recommendations in the soils report, use the minimum thickness of the slab specified in ACI 350 § H.3. It is recommended that two layers of reinforcing be used, for a minimum thickness of 6″. Generally radial and circular reinforcing patterns are detailed for the slab of a circular tank. These details will take into consideration the minimum reinforcing and maximum rebar spacing for the slab.
Ring Stress Tensile Cracks

PCA – Circular Concrete Tanks §4 eq.1

This should be included in the ring stress (hoop stress) calculations in circular concrete tank analysis, it is designed to limit the tensile cracking in the concrete.

\[ C = 0.0003 \] (don’t confuse this with \( \varepsilon_c = 0.003 \))

\[ A_g = \text{gross area of concrete} = 1' \times \text{wall thickness (in}^2) \]

\[ A_s = \text{TOTAL area of steel in the 1' high section (in}^2) \]

\( f'_c = \text{concrete compression strength (psi)} \)

\[ E_c = 57,000 \sqrt{f'_c} \] (psi)

\[ E_s = 29,000,000 \text{ psi} \]

\[ n = \frac{E_s}{E_c} \]

\[ T = \text{unfactored hoop tensile force in 1' high strip of wall (lb)} \]

\[ f_c = \frac{C \cdot E_s \cdot A_s + T}{A_g + n \cdot A_s} \] (psi)

\[ f_c < 0.1 \cdot f'_c \] must be satisfied

If the above requirement is not met, increase \( A_g \) by increasing the wall thickness.
Flexural Cracks

PCA – Rectangular Concrete Tanks page 1-8

PCA – Circular Concrete Tanks §6 eq.3

This provision should be included in all flexure section calculations, it limits the concrete flexural cracking.

\[ M = \text{unfactored moment} \quad \text{(lb-in)} \]

\[ A_s = \text{area of tension steel for the flexural section (flexure steel only, not total steel)} \quad \text{(in}^2\text{)} \]

\[ \rho = \frac{A_s}{b_w d} \]

\[ n = \frac{E_s}{E_c} \]

\[ k = \sqrt{2 \cdot \rho \cdot n + (\rho \cdot n)^2} - \rho \cdot n \]

\[ j = 1 - k/3 \]

\[ d = \text{distance from the extreme concrete surface in compression to the center of the flexural steel.} \quad \text{(in)} \]

\[ f_s = \frac{M}{A_j d} \quad \text{(psi)} \]

\[ d_c = \text{distance between extreme concrete surface in tension and center of the flexural steel.} \quad \text{(this is NOT the same as clear concrete cover)} \quad \text{(in)} \]

\[ b_w = \text{width of section being analyzed, usually taken as 12”} \]

\[ A = 2 \cdot d_c \cdot b_w \quad \text{(in}^2\text{)} \]

\[ z = \frac{f_s \sqrt{d_c A}}{1000} \]

\[ z \leq 95 \quad \text{must be satisfied} \]
Pressure Relief Valves

Pressure relief valves should be specified for all tanks. These allow groundwater to enter the tank under conditions of low water inside the tank. This relieves pressure on the bottom of the slab and reduces or eliminates flotation of the tank. It is recommended that the number of pressure relief valves specified be twice as many as the minimum number calculated. The hydraulics specialists should be responsible for the design of the pressure relief valves. There are many references available on the internet, listed below are three:

Clow PRV:


http://www.clowcanada.com/english/p_inplantvalves_ftprv.html

Anderson Greenwood PRV:

http://www.andersongreenwood.com/
Gravel Below Slabs

It is common to designate gravel below the tanks. It is suggested that a minimum of 6" of \( \frac{3}{4} \)" gravel be placed before pouring all slabs and footings. In addition, 24" of gravel should be placed at locations of pressure relief valves.
Waterstops

Waterstops are needed for all concrete construction joints. The “design” of the waterstop consists of selecting the particular brand and model from a manufacturer, and including it in the detail drawings and specification sheet. Below are a few websites advertising waterstop products. This is not a complete listing.

http://www.adeka.com/
http://www.jpspecialties.com/home.html
http://www.gamcoform.com/pvcwaterstop-rcb.html
http://www.whitecapdirect.com/products/483GS701
http://www.speconcepts.com/catalog/WaterStops.html
http://www.wrmeadows.com/wrm00016.htm
Circular Tank Design Considerations

Ring Tension
- rebar tension capacity
- ring stress concrete tensile cracks
- minimum horizontal reinforcing for walls
- minimum reinforcing for temperature and shrinkage
- maximum rebar spacing

Ring Compression
- concrete compression capacity
- minimum wall thickness

Vertical Strip of Wall
- flexure capacity of reinforced concrete section
- flexural crack limit for concrete
- minimum vertical reinforcing for walls
- minimum reinforcing for flexure sections
- minimum reinforcing for temperature and shrinkage
- maximum reinforcing for flexure section
- shear capacity of concrete
- minimum wall thickness
- maximum rebar spacing

Footing Design
- Flexure capacity of reinforced concrete section
- flexural crack limit for concrete
- minimum reinforcing for flexure sections
- minimum reinforcing for temperature and shrinkage
- maximum reinforcing for flexure section
- shear capacity of concrete
- maximum rebar spacing

Slab-on-Grade
- minimum slab thickness
- minimum steel for slabs
- maximum rebar spacing

An alternative is to use the Army TM 5-809-12 “Concrete Floor Slabs on Grade Subjected to Heavy Loads”, available on the class website.
Rectangular Tank Design Considerations

Vertical Strip of Wall
  flexure capacity of reinforced concrete section
  flexural crack limit for concrete
  minimum vertical reinforcing for walls
  minimum reinforcing for flexure sections
  minimum reinforcing for temperature and shrinkage
  maximum reinforcing for flexure section
  shear capacity of concrete
  minimum wall thickness
  maximum rebar spacing

Horizontal Strip of Wall
  flexure capacity of reinforced concrete section
  flexural crack limit for concrete
  minimum horizontal reinforcing for walls
  minimum reinforcing for flexure sections
  minimum reinforcing for temperature and shrinkage
  maximum reinforcing for flexure section
  shear capacity of concrete
  minimum wall thickness
  maximum rebar spacing

Footing Design
  Flexure capacity of reinforced concrete section
  flexural crack limit for concrete
  minimum reinforcing for flexure sections
  minimum reinforcing for temperature and shrinkage
  maximum reinforcing for flexure section
  shear capacity of concrete
  maximum rebar spacing

Slab Design
  flexure capacity of reinforced concrete section
  flexural crack limit for concrete
  minimum reinforcing for flexure sections
  minimum reinforcing for temperature and shrinkage
  maximum reinforcing for flexure section
  shear capacity of concrete
  minimum slab thickness
  maximum rebar spacing