Additional Structural Design Notes

CVEN 4830/4434
University of Colorado, Boulder
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<u>Moments in Walls</u>

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 $M_u = w_u L^2/8$ 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.
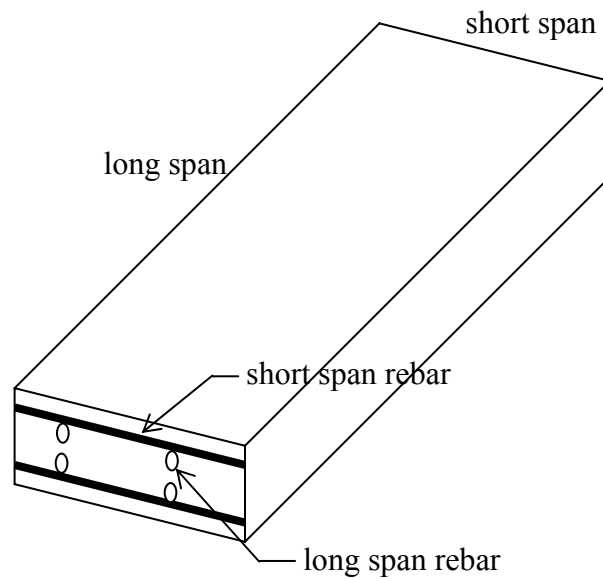
The slab beneath the circular tank will be a slab-on-grade only. Any considerations for slab-on-grade in the soils report should be adhered to. If there are no recommendations in the soils report, use the minimum thickness of the slab specified in ACI 350 § H.3. It is recommended that two layers of reinforcing 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 = gross area of concrete = 1′ ht. × wall thickness   (in^2)

A_s = TOTAL area of steel in the 1′ high section   (in^2)

f'_c = concrete compression strength   (psi)

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

$E_s = 29,000,000$ psi

$n = E_s/E_c$

T = <u>unfactored</u> 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.

<u>Flexural Cracks</u>

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 = <u>unfactored</u> moment   (lb-in)

A_s = area of tension steel for the flexural section (flexure steel only, not total steel)   (in^2)

ρ = steel ratio = $A_s/b_w d$

$n = E_s/E_c$

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

$j = 1 - k/3$

d = distance from the extreme concrete surface in compression to the center of the flexural steel.   (in)

$$f_s = \frac{M}{A_s j d} \quad \text{(psi)}$$

d_c = distance between extreme concrete surface in tension and center of the flexural steel. (this is NOT the same as clear concrete cover)   (in)

b_w = width of section being analyzed, usually taken as 12″

$A = 2 \cdot d_c \cdot b_w$ (in^2)

$$z = \frac{f_s \sqrt{d_c A}}{1000}$$

$z \leq 95$ 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.clowvalve.com/products/index.php?id=24&show=overview

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

Anderson Greenwood PRV:

http://www.andersongreenwood.com/

<u>Gravel Below Slabs</u>

It is common to designate gravel below the tanks. It is suggested that a minimum of 6″ of ¾″ gravel be placed before pouring all slabs and footings. In addition, 24″ of gravel should be placed at locations of pressure relief valves.

Pressure Relief Valve

slab

3/4″ gravel

6″

soil

24″

24″
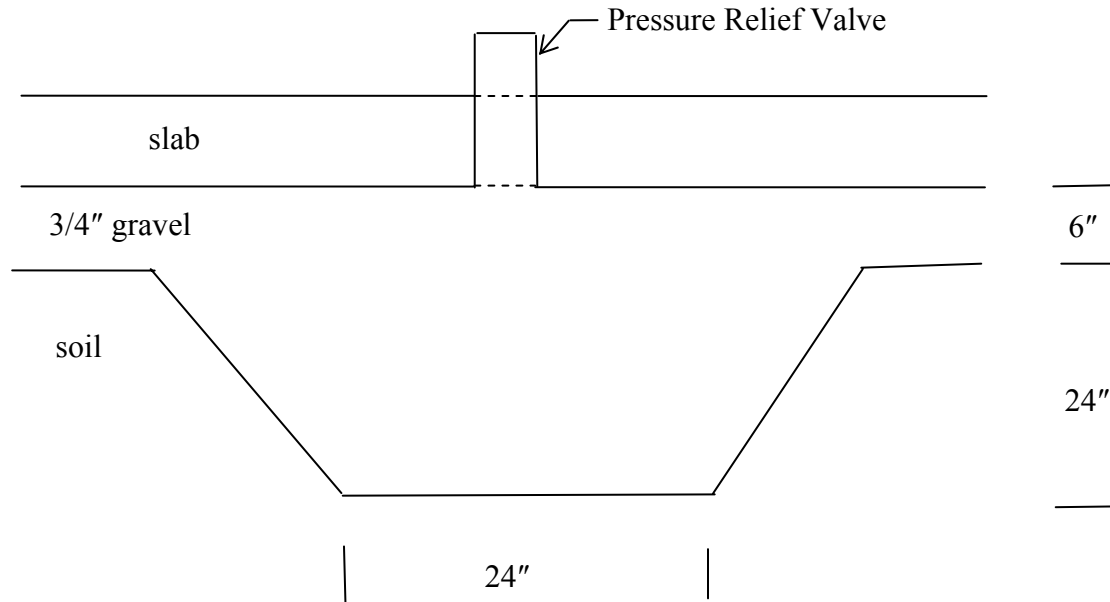
Waterstops

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
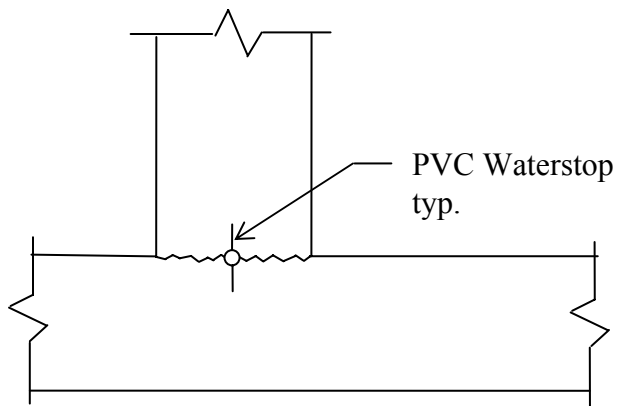waterstop products. This is not a complete listing.

http://www.adeka.com/

http://www.jpspecialties.com/home.html

http://esvc000298.bne102u.server-web.com/Documents/TrelleborgWaterStops.pdf

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

PVC Waterstop
typ.

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.

<u>Rectangular Tank Design Considerations</u>

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