UNIVERSITY OF ASIA PACIFIC
Department of Civil Engineering

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CE 416

PROJECT

Submitted by:

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<u>CONTENTS</u>

CONTRIBUTION OF TEAM MEMBERS

As the last project of our Bachelor program, we enjoyed a lot during the project work. We divided the tasks efficiently and approached the project as a whole team. We enjoyed the process and learned a great deal from working together. Each member's contribution was valuable and integrated seamlessly into the final report. We are grateful for the opportunity to have collaborated on this project. However, a formal table of contributions is given below:

Name	Registration No:	Contribution
Niaz Morshed	20105049	Introduction
Raiyan Ferdous Choudhury	20105052	Design of Top Slab
Usayed Islam	20105062	Design of Sidewalls
Md. Yeamin Hossain	20105079	Software Analysis & Detailing
Lamia Ahmed Sadia	20105084	Design of Base Slab

Design of Underground Water Tank (Reservoir)

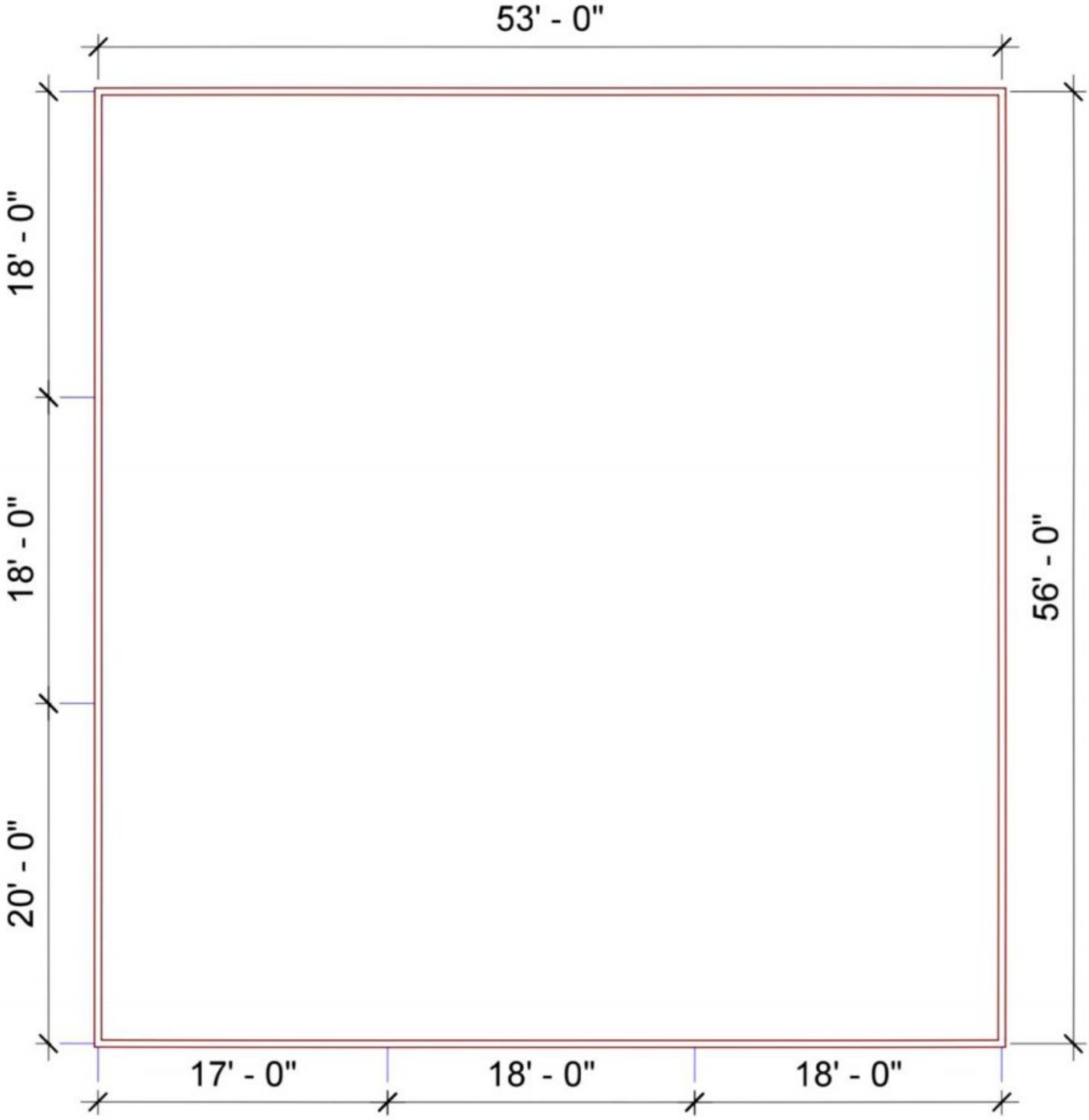


Fig-01 : Typical Floor Plan

1.1: Tank Dimensions:

Total Area for the 6 floors,

= 6*(18+18+20)*(17+18+18)

=16128 ft^2

According to the BNBC 2020, maximum allowable number of people per 1000 ft^2 is 8 persons.

So, Number of residents,

N = 16128*(8/1000)

= 130 Nos people

The daily water requirement per person is 5 ft^3

So, daily water requirement is = (130*5) ft^3

= 650 ft^3

Due to need of pump the water twice a day,

The required volume of the underground water tank is,

= (2*650)ft^3=1300 ft^3

Depth of tank, H = $V^{1/3}$ = 10.92 ft

Freeboard, F.B. = 0.50 ft

Total depth, D = H +F.B. = (10.92+0.50) ft = 11.42 ft

As UGWT slabs are designs as Two-way slab. Where L/B ratio is less than 2,

Assume, L/B = 1.5

Tank Area, A = L*B

1300/10.92 = 1.5B * B

B = 8.91 ft

L= 1.5* 8.91 = 13.365ft

1.2: Loads & Material Properties:

- **Loads** :

$FF = 11.5$ psf

$LL = 21.5$ psf

- **Materials:**

$f_c' = 3.5$ ksi

$f_{t.ult} = 5\sqrt{(f_c')} = 5*\sqrt{(3.5/100)} = 0.30$ ksi

$f_{t.all} = f_{t.ult}/2 = 0.30/2 = 0.15$ ksi

$f_y = f_s = 23$ ksi

$f_c = 0.45f_c' = (0.45*3.5)$ ksi $= 1.575$ ksi

Assume,

$E_s = 29000$ ksi

$E_c = 3500$ ksi

$n = E_s/E_c = 29000/3500 = 8.28 = 9$

$r = f_s/f_c = 23/1.575 = 14.603 = 14$

now,

$k = n/(n+r) = 9/(9+14) = 0.391$

$j = 1-k/3 = 1-(0.391/3) = 0.87$

$R = ½*f_c*kj = ½*1.575*0.391*0.87 = 0.267$ ksi

$R_t = f_{t.all}/6 = 0.15/6 = 0.025$ ksi

For soil, Angle $\Theta = 30^0$

$K_a = (1-\sin\Theta)/(1+\sin\Theta) = (1-\sin 30^0)/(1+\sin 30^0) = 0.333$

1.3: Design Conditions:

The UG water tank has three basic components such as top slab, sidewalls and base slab.

- The top slab will be designed as normal simply supported slab based on the self-weight and superimposed loads
- The design of sidewalls and the base slab will be based on assuming (i) Tank full of water but no soil outside, (ii) No water inside tank but soil pressure from outside

The other more critical condition of no water inside but saturated soil outside is avoided here because it might cause instability of the tank itself. Alternately, a provision must be made that the tank cannot be evacuated when the soil is fully saturated.

2. Design of Top Slab:

This is designed as a simply supported slab with clear spans,

$S_a = 8.91'$

$S_b = 13.365\ '$

$m = 8.91/13.365 = 0.67$

Required slab thickness considering deflection is,

= perimeter/ 15

= 2*(8.91+13.365)/15

=2.97″

Assuming Minimum slab thickness, t = 4″

$W_{total} = (t/12 * 150) + FF + LL$

$= (4/12 * 150) + 11.5 + 21.5$ psf

= 83psf

= 0.083 ksf

For case-1,

$C_a = 0.072$

$M_a^{(+)} = 0.072*0.083*(8.91)^2 = 0.4744\ k'/'$

$C_b = 0.014$

$M_b^{(+)} = 0.014*0.083*(13.365)^2 = 0.2076\ k'/'$

$d_{req} = \sqrt{(M_{max}/R)} = \sqrt{(0.4744/0.267)} = 1.33''$

Here, $t_{provided} = 4''$ so, $d_{provided} = (4-1)'' = 3''$

Here, $d_{required} < d_{provided}$

So the thickness is OK.

$A_{sa}^{(+)} = M_a^{(+)}/f_s jd = (0.4744*12) /(23*0.87*3) = 0.095\ in^2/'$

$A_{sb}^{(+)} = M_b^{(+)}/f_s jd = (0.2076*12) /(23*0.87*3) = 0.041\ in^2/'$

$A_{s(temp)} = 0.03t = 0.15\ in^2/'$

$S_{max} = 2t = 2*5'' = 10''$

Using #3 reber,

Spacing = (0.11/0.15)*12 = 8.8″= 8 ″

Use #3 @ 8 ″ c/c in both directions.

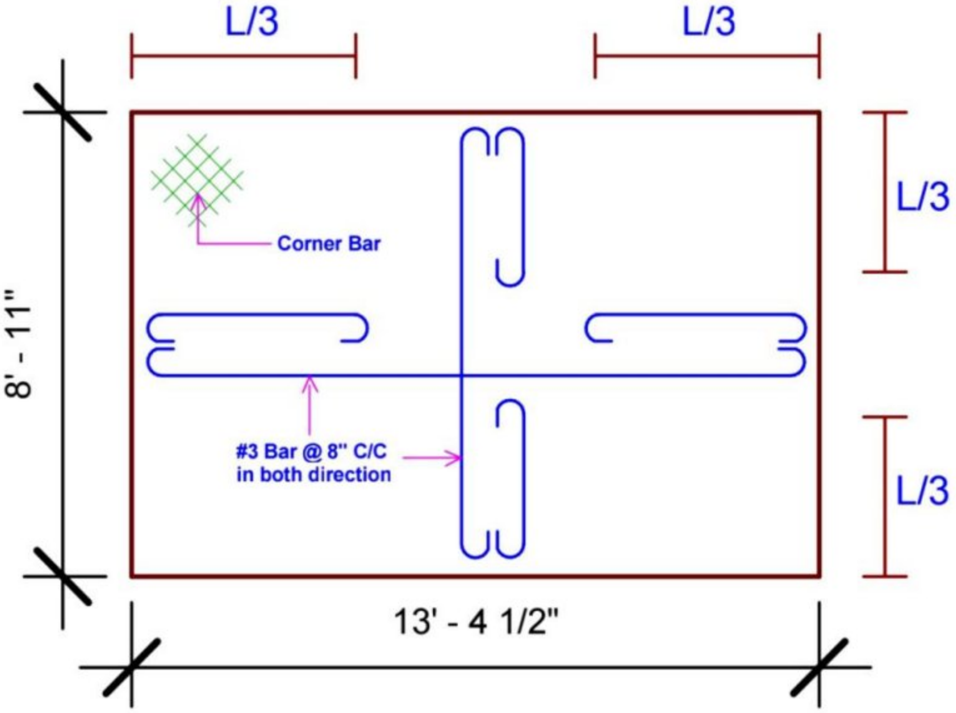


Fig-02: Detailing of Top Slab

3: Design of Sidewalls:

Since both L/H and B/H are within 0.5 and 2.0, sidewalls have both slab and cantilever action. Cantilever action is within the bottom H/4 or 1m height (whichever is greater)

H/4= 10.92 ′/4 = 2.73′

While, 1m = 3.28 ′ > 2.73 ′

3.1 Slab Action:

Case (i)- Tank full of water but no soil outside

In this case, $P_{max} = \gamma_W(H\text{-}h)$

$= 0.0625 * (10.92-3.28)$

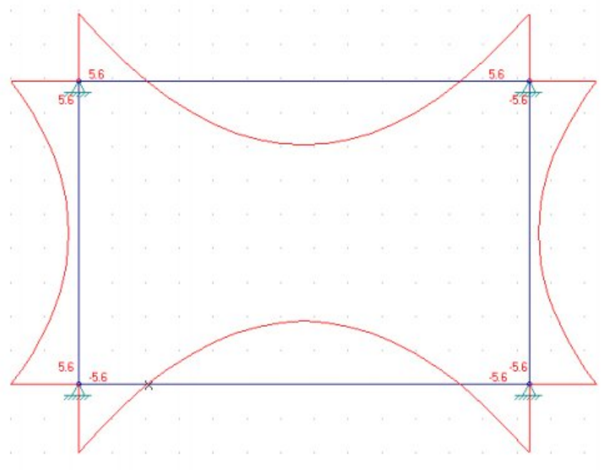
$= 0.48$ ksf

Case (ii)- No water inside the tank but soil pressure from outside.

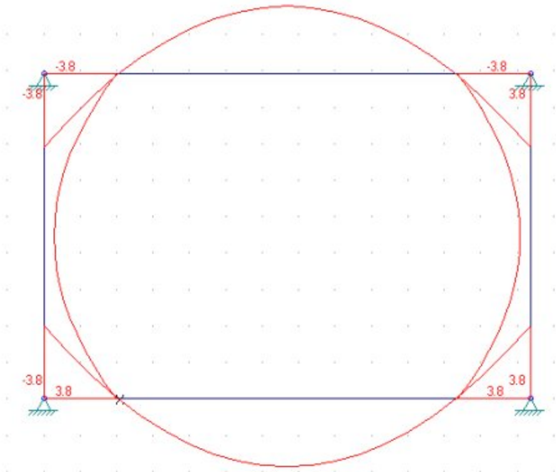
In this case, $P_{max} = K_a\gamma_s(D\text{-}h)$

$= 0.333*0.120*(11.42-3.28)$

$= 0.325$ksf



Case-i



Case-ii

From analysis by GRASP : Case -i: $M_{max} = 5.16k'/'$

Case -ii: $M_{max} = 3.494k'/'$

3.2: Cantilever Action:

Case (i) Tank full of water but no soil outside

In this case, $P_{max} = \gamma_W * H$

$= 0.0625 * 10.92 ksf$

$= 0.6825 ksf$

The maximum bending moment $M_{max} = (P_{max} h^2)/6$

$= (0.6825 * 3.28^2)/6$

$= 1.224\ k'/'$

Case (ii) No water inside the tank but soil pressure from outside.

In this case, $P_{max} = K_a \gamma_s D$

$= 0.333 * 0.120 * 11.42$

$= 0.456 ksf$

Max. Bending Moment, $M_{max} = (P_{max} h^2)/6$

$= (0.456 * 3.28^2)/6$

$= 0.818 k\text{-}'/'$

Required slab thickness, $t_{req} = \sqrt{(M_{max}/R_b)}$

$= \sqrt{(5.16/0.025)}$

$= 14.37''$

$= 15''$; i.e., $d = 13.5''$

Area of steel (max), $A_{s\,(max)} = M_{max}/f_s jd$

$= (5.16 * 12)/(23 * 0.87 * 13.5)$

$= 0.23\ in^2/'$

Area of temperature & shrinkage bar, $A_{s(temp)} = 0.03t = 0.03 * 15$

$= 0.45 in^2/'$

Maximum spacing, $S_{max} = 2t = 30''$

As $A_{s(temp)}$ govern in all cases. So, **Use #3 bar @ 2.5″ c/c.**

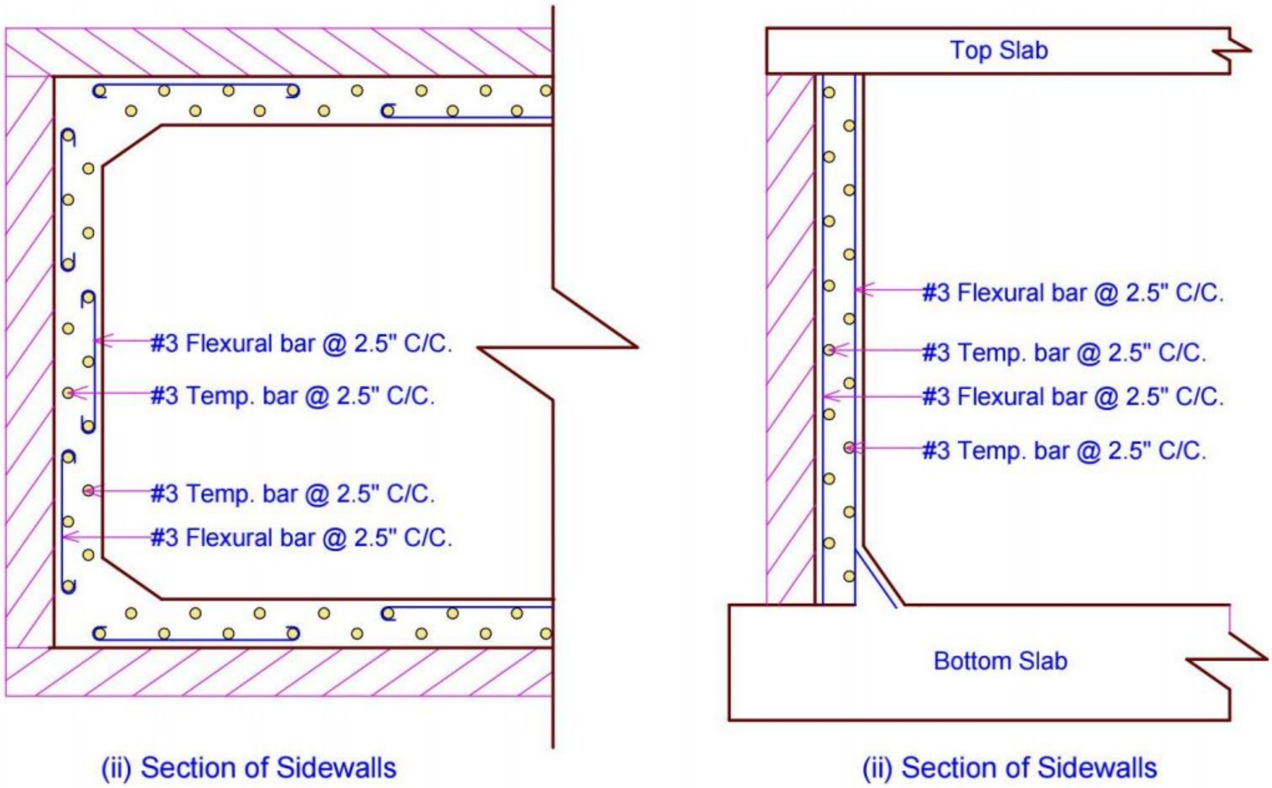


Fig-03: Detailing of Sidewalls

4. Design of Base Slab:

The slab has to carry end moments (1.224k′/′ and 0.818 k′/′) from the cantilever action of the sidewalls; which results in the reduction of mid-span maximum moments.

This is designed as a simply supported slab with clear spans,

$S_a = 8.91'$
$S_b = 13.365'$
$m = 8.91/13.365 = 0.67$

Required slab thickness considering deflection is,

= perimeter/ 15
= 2*(8.91+13.365)/15
=2.97″

However, since the slab carries significant load from water.

The assumed slab thickness, t = 10″

Case (i)- Tank full of water but no soil outside

$W_{total} = \gamma_c t + FF + \gamma_w * H$
$= 150 * 10/12 + 11.5 + (62.5 * 10.92)$
= 819 psf
= 0.819 ksf

<u>Assuming negative moment of 1.224 k′/′:</u>

$C_a = 0.072$; $C_b = 0.014$

$M_a^{(+)} = 0.072 * 0.819 * (8.91)^2 - 1.224 = 3.46$ k′/′

$M_b^{(+)} = 0.014 * 0.819 * (13.365)^2 - 1.224 = 0.824$ k′/′

Case (ii)- No water inside the tank but soil pressure from outside.

In this case the total weight of top slab and sidewalls is

={(13.365+30/12)*(8.91+30/12)*4/12+2*(13.365+8.91+30/12)*11.42*15/12}* 0.150 =115.15k

Net upward pressure from soil, W_{Total} = 115.15/{(13.365+30/12)*(8.91+30/12)}

=0.636 ksf

Assuming negative moment of 0.818 k′/′:

$M_a^{(+)}$ =0.072*0.636*(8.91)^2 -0.818 =2.82 k′/′

$M_b^{(+)}$ =0.014*0.636*(13.365)^2 -0.818 =0.772 k′/′

t_{req}= √(M_{max}/R_tb)

= √(3.46 /0.023)

= 12.3″>t **(Not OK)**

Trial -01: Assume slab thickness is 14″

Case (i)- Tank full of water but no soil outside

W_{total} = γ_ct+ FF + γ_w*H
= 150* 14/12 +11.5 + (62.5*10.92)
= 869 psf
= 0.869 ksf

Assuming negative moment of 1.224 k′/′:

C_a= 0.072 ; C_b= 0.014

$M_a^{(+)}$ =0.072*0.869*(8.91)^2 -1.224 = 3.743 k′/′

$M_b^{(+)}$ =0.014*0.869*(13.365)^2 -1.224 = 0.95 k′/′

t_{req}= √(M_{max}/R_tb)

= √(3.743 /0.023)

= 12.8″<t **(OK)**

Now,

$A_{s\ (Max)}$= $M_a^{(+)}$ /f_s jd = (3.743 *12) /(23*0.87*12.5) = 0.18 in^2/′

$A_{s(temp)}$ = 0.03t = 0.03*14 = 0.42 in^2/′

S_{max} = 2t = 2*14″ = 28″

Using #3 bar; S_{min}= $(0.11*12)/A_{s(temp)} = (0.11*12)/0.42 = 3.14'' = 3''$ c/c

As $A_{s(temp)}$ govern at all cases. So, **Use #3 bar@ 3″ c/c in all directions.**

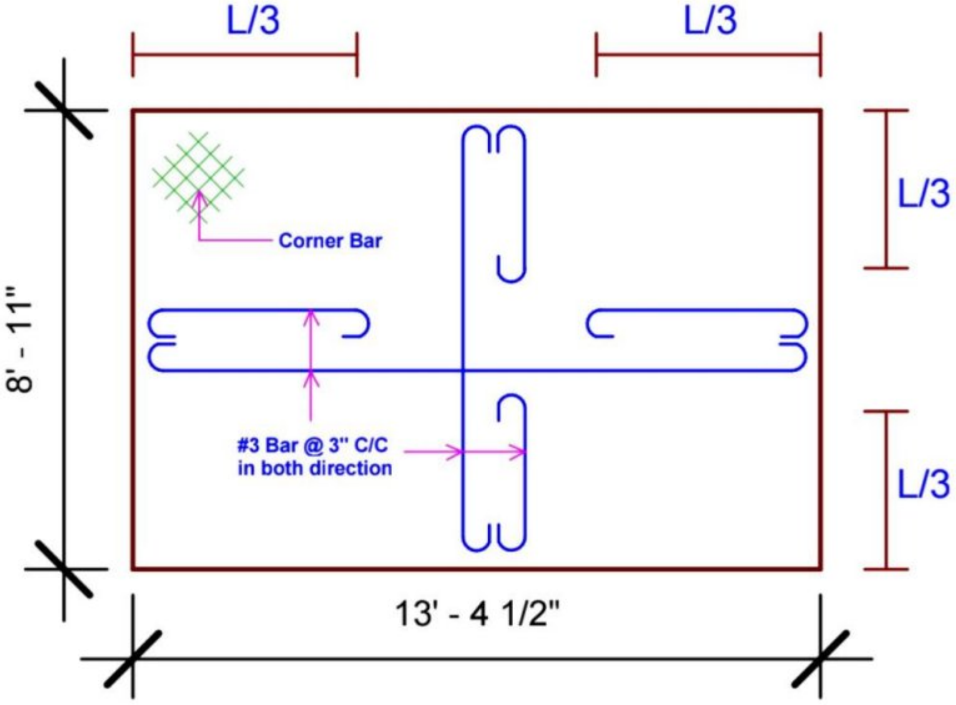


Fig-04: Detailing of Bottom Slab