A simplified method for designing elevated water storage tanks

by John Briscoe*

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MANY developing countries are committed to extending water services to rural communities and small towns. In many instances it is possible and desirable to provide such services using simple technology such as dug wells fitted with handpumps or gravity supplies fed by protected springs. There are, nevertheless, many hydrological, geological, social and economic circumstances which necessitate pumped supplies with elevated water storage tanks.

The design of an elevated water storage tank is not a trivial task for a civil engineer. For the technicians and technical assistants who are frequently the only water sector personnel in the provinces of developing countries, the design of such a tank is an impossible task.

One way out of this problem is to develop a set of standard drawings for different tower heights and storage capacities and distribute these standard drawings widely. In practice, however, the standard drawings never quite fit the bill: the tower may have to be a metre or two higher than the one in the standard drawing; the circular shutters available may not be of the diameter required by the drawings.

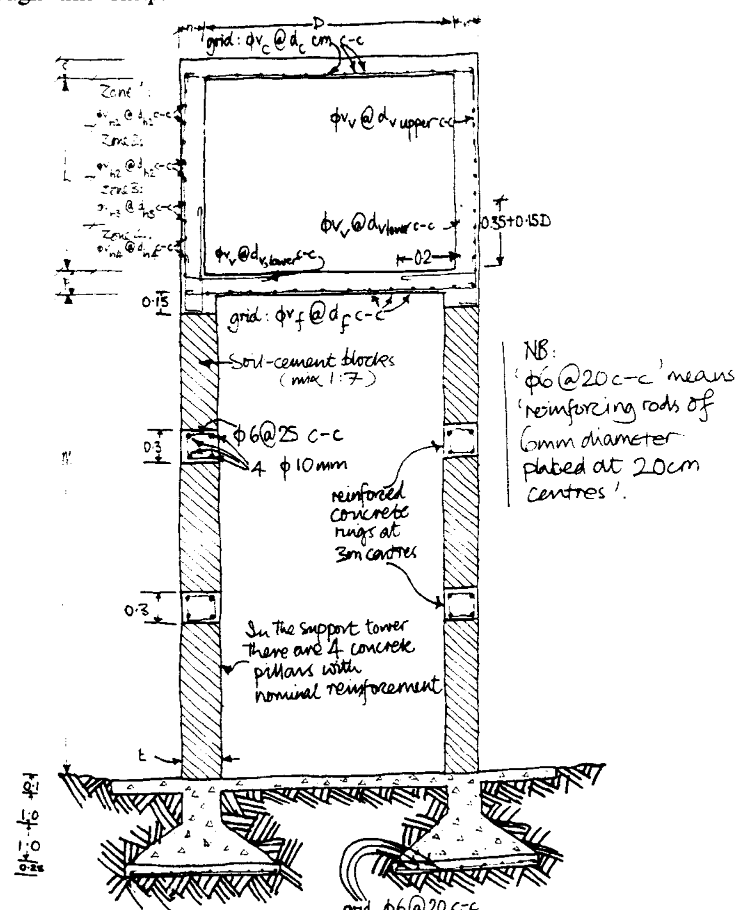
The simplified method for the design of elevated water storage tanks which is presented here was developed by the author in Mozambique, an African country which is committed to a rapid expansion of the supply of drinking water. But there is an almost complete lack of university-trained engineers in Mozambique's provincial water services. The cadres in these provincial water services typically have about six years of formal schooling followed by a six to nine month course in the elements of water supply technology. The design method presented here was tailored for the particular requirements of this group of people (square roots or logarithms could not be used, for instance) and was easily understood and used by them.

In developing the designs wind velocities were assumed to be low, and the bearing pressure of the soil, the quality of raw materials and the quality of workmanship adequate. The designs have been checked against standard designs for the permissible range of parameters. The designs arrived at through this simplified method are very similar to those derived through the much more complicated method followed by structural engineers.

Along with the design guide presented in this paper, an accompanying set of master working drawings was distributed to all who knew how to use the guide and wished to prepare a set of working drawings. The dimensions calculated by using the guide were transposed onto the working drawings. These were then presented to a foreman for construction of the tank.

The design procedure was publicized through direct instruction of technicians in the use of the method and through publication of the method in the Mozambique's journal for the construction industry. Both engineers and technicians used the method to design water storage tanks without experiencing any serious difficulties either with use of the method or with the structural performance of the tanks.

This experience with the simplification of procedures for designing elevated water storage tanks suggests that the capabilities of the critical



Schematic water tank: all terms are used in the calculation opposite

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middle-level cadres can be greatly improved by developing simplified but correct procedures for the design of structures commonly used in water and wastewater systems. It is an approach which could well be applied to many situations to maximize the potential of technicians for the Water Decade and beyond.

Calculation procedure

Limitations on the Application of this Guide

Height of the support tower (M): Not to exceed 18 metres;
Diameter (D): Not to exceed 6 metres or 2.5 times the diameter.
Depth (L): Not to exceed 6 metres or 2.5 times the diameter (D);
Capacity ($0.79D^2L$): Not to exceed 150cu m.

Covering slab

Thickness (c) = 8cm.
Choose the diameter of the reinforcing rods in the slab (v_c, in mm), depending on the availability of different diameters;

Distance between the rods, d_c = the lesser of: $\frac{0.8v_c^2}{0.15D^2}$ and 12cm.

(If 12cm is the lesser of the two, it is more economical to use smaller reinforcing rods and re-calculate d_c.)

Walls of the tank

Thickness, h = 10cm.
Horizontal reinforcing steel:

		Choose the diameter of reinforcing rods (mm)	Calculate X and Y_k	Calculate the area of steel (cm^2/m)	Distance between reinforcing rods (cm):
L/4	Zone 1	v_{h1}	X=1.11D+ 1.33L-5.72 Y_1=0.09DL	A_{h1}=the lesser of X and Y_1	d_{hl}= the lesser of: $\left[\frac{0.8v_{h1}^2}{A_{h1}}\right]$ and 15cm.
L/4	Zone 2	v_{h2}	X=1.11D+ 1.33L-5.72 Y_2=0.18DL	A_{h2}=the lesser of X and Y_2	d_{h2}= the lesser of: $\left[\frac{0.8v_{h2}^2}{A_{h2}}\right]$ and 15cm.
L/4	Zone 3	v_{h3}	X=1.11D+ 1.33L-5.72 Y_3=0.27DL	A_{h3}=the lesser of X and Y_3	d_{h3}= the lesser of: $\left[\frac{0.8v_{h3}^2}{A_{h3}}\right]$ and 15cm.
L/4	Zone 4	v_{h4}	X=1.11D+ 1.33L-5.72 Y_4=0.36DL	A_{h4}= the lesser of X and Y_4	d_{h4}= the lesser of: $\left[\frac{0.8v_{h4}^2}{A_{h4}}\right]$ and 15cm.

Vertical reinforcing steel:

Choose the diameter of the reinforcing rods, v_v (mm).

L	Upper zone	$d_{v,upper}$=15cm
0.35+ 0.15D	Lower zone	$d_{v,lower}$=the lesser of $\left[\frac{0.8v_v^2}{0.2DL}\right]$ and 15cm.

Base slab

Thickness, p = the greater of [D(2+0.5L) and [10] cm.
Choose the diameter of the reinforcing rods, v_f (mm).

The distance between the reinforcing rods is d_f where

$$d_f = \text{the lesser of } \left[\frac{0.8v_1^2(p-2.5)}{3.8D^2L}\right] \text{ and } [1.5p] \text{ cm}$$

Support tower

Thickness of the walls, t = the greater of [4L+2M-14] and [12] cm.

Foundations

The width of the foundation, s = 0.22L+ 0.15M-0.6m.

An example of the calculations

(The values necessary on the drawing are presented in italics.)

Problem: Design an elevated water tower of 50cu m capacity. Moulds of 3.8m diameter are available. The base of the tower is to be 10m above ground level

i.e. $L = \frac{\text{Volume}}{\pi \times D^2/4} = \frac{50 \times 4}{\pi \times 3.8^2}$ 4.4

i.e. *L = 3.8, M = 10.0*

Checking that design is within the permissible limits:

M = 10.0 which is less than 18;
D = 3.8 which is less than both 6 and 2.5 x 4.4 = 11m;
L = 4.4 which is less than both 6 and 2.5 x 3.8 = 9.5m;
Capacity is 50cu m which is less than 150cu m.

The method can therefore be used to design the water tank.

Covering slab

Thickness: *c = 8cm*

v_c = 6mm, chosen because of the availability of these rods.

d_c = the lesser of $\frac{0.8 \times 6^2}{0.15 \times 3.8^2}$ = 13.3, and 12.

i.e. *d_c = 12cm.*

Walls of the tank

Thickness: *h = 10cm*
Horizontal reinforcing steel:

	Choose the diameter of reinforcing rods (mm)	Calculate X and Y_k	Calculate the area of steel (cm^2/m)	Distance between reinforcing rods (cm)
Zone 1	*v_{h1}=6mm*	X=1.11x3.8+ 1.33x4.4- 5.72 =4.3 Y_1= 0.09x4.4 x3.8=1.5	A_{h1}=the lesser of 4.3 and 1.5 =1.5	d_{h1}= the lesser of: $\frac{0.8 \times 6^2}{1.5}$= 19 and 15 i.e. *$d_{h1}$=15cm*
Zone 2	*v_{h2}=6mm*	X=4.3 Y_2= 0.18x4.4 x3.8=3.0	A_{h2}=the lesser of 4.3 and 3.0 =3.0	d_{h2}= the lesser of: $\frac{0.8 \times 6^2}{3.0}$=19 and 15 i.e. *$d_{h2}$=9cm*
Zone 3	*v_{h3}=8mm*	X=4.3 Y_3= 0.27x3.8x 4.4=4.5	A_{h3}=the lesser of 4.3 and 4.5 =4.3	d_{h3}= the lesser of: $\frac{0.8 \times 8^2}{4.3}$=11.8 and 15 i.e. *$d_{h3}$=11cm*
Zone 4	*v_{h4}=8mm*	X=4.3 Y_4= 0.36x3.8x 4.4=6.0	A_{h4}=the lesser of 4.3 and 6.0 =4.3	d_{h4}= the lesser of: $\frac{0.8 \times 8^2}{4.3}$=11.8 and 15 i.e. *$d_{h4}$=11cm*

Vertical reinforcing steel:

v_v = 6mm

Upper zone: This is the zone from the top to 0.35+0.15D = 0.35+0.15+3.8 = 0.9m from the base.

i.e. *$d_{v,\ upper}$ = 15cm*

Lower zone: This is the zone of 0.9m at the bottom of the wall.

$d_{v,lower}$ = the lesser of $\frac{0.8 \times 6^2}{0.2 \times 3.8 \times 4.4}$ = 8.6 and 15cm.

i.e. *$d_{v,lower}$ = 8cm.*

Base slab

Thickness, p = the greater of 3.8x(2+0.5x4.4)=16.0 and 10cm.

i.e. *p = 16cm.*

d_f = the lesser of $\frac{0.8 \times 12^2 \times (16-2.5)}{3.8 \times 3.8^2 \times 4.4}$ = 6.4 and 1.5x16 = 24.

i.e. *d_f = 6cm.*

Support tower

Thickness of the walls, t=the greater of 4x4.4+2x10.0=23.6 and 12.

i.e. *t = 24cm.*

Foundation

The width of the foundation, s = 0.22x4.4+0.15x10-0.6=1.9m.

i.e. *s = 1.9m.*