A simplified method for designing elevated water storage tanks
by John Briscoe*

John Briscoe is Assistant Professor at the Department of Environmental Sciences and Engineering, University of North Carolina, USA, and this technique has already proved its worth in Mozambique, where he developed it while working with the National Directorate of Water.

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 drawing.

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

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

WATERLINES VOL.2 NO.3 JANUARY 1984
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 (0.75D' L): Not to exceed 150 cu m.

Covering slab
Thickness (c) = 8 cm.
Choose the diameter of the reinforcing rods in the slab (v_c, in mm),
depending on the availability of different diameters;
0.8v^2
Distance between the rods, d_v = the lesser of: \( \frac{c}{2} \) and 12 cm.
(If 12 cm is the lesser of the two, it is more economical to use smaller reinforcing rods and re-calculate d_v.)

Walls of the tank
Thickness, h = 10 cm.
Horizontal reinforcing steel:

<table>
<thead>
<tr>
<th>Choose the diameter of reinforcing rods (mm)</th>
<th>Calculate X and Y</th>
<th>Calculate the area of steel (cm²/m)</th>
<th>Distance between reinforcing rods (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>U4 Zone 1 y_1 = 0.061D</td>
<td>X_1 = 1.11D+1.32v</td>
<td>0.8y_1</td>
<td>d_v = the lesser of: ( \frac{0.8v^2}{1.32} ) and 15 cm.</td>
</tr>
<tr>
<td>U4 Zone 2 y_2 = 0.18D</td>
<td>X_2 = 1.11D+1.32v</td>
<td>0.8y_2</td>
<td>d_v = the lesser of: ( \frac{0.8v^2}{1.32} ) and 15 cm.</td>
</tr>
<tr>
<td>U4 Zone 3 y_3 = 0.27D</td>
<td>X_3 = 1.11D+1.32v</td>
<td>0.8y_3</td>
<td>d_v = the lesser of: ( \frac{0.8v^2}{1.32} ) and 15 cm.</td>
</tr>
<tr>
<td>U4 Zone 4 y_4 = 0.36D</td>
<td>X_4 = 1.11D+1.32v</td>
<td>0.8y_4</td>
<td>d_v = the lesser of: ( \frac{0.8v^2}{1.32} ) and 15 cm.</td>
</tr>
</tbody>
</table>

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

| Upper zone | d_v, upper = 15 cm |
| Lower zone | d_v, lower = the lesser of \( \frac{0.8v^2}{1.32} \) and 15 cm. |

Base slab
Thickness, p = the greater of (D x 2 + 0.5L) and (10) cm.
Choose the diameter of the reinforcing rods, v_v (mm).
The distance between the reinforcing rods is d_v where
\( \frac{0.8v^2}{1.32} \) and [1.5p] 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 50 cu m capacity.
Moulds of 3.8 m diameter are available.
The base of the tower is to be 10 m above ground level

| \( \pi x 50^4 \) | 4.4 |
| \( \pi x 3.8^2 \) |

\( L = \) Volume = \( \pi x D^2/4 \)

\( M = 10.0 \)

Checking that design is within the permissible limits:
D = 3.8 which is less than both 6 and 2.5 \( x \) 4.4 = 11 m;
L = 4.4 which is less than both 6 and 2.5 \( x \) 3.8 = 9.5 m;
Capacity is 50 cu m which is less than 150 cu m.

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

Covering slab
Thickness: c = 8 cm
v_c = 6 mm, chosen because of the availability of these rods.
d_v = the lesser of \( \frac{0.8v^2}{1.32} \) = 13.3, and 12.

Walls of the tank
Thickness: h = 10 cm

Vertical reinforcing steel:

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<tr>
<th>Choose the diameter of reinforcing rods (mm)</th>
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<tr>
<td>Zone 1 y_h = 6 mm</td>
<td>X_1 = 1.11D+1.32v</td>
<td>Y_1 = 0.061D</td>
<td>0.8y_1 = ( \frac{0.8v^2}{1.32} ) and 15 cm.</td>
</tr>
<tr>
<td>Zone 2 y_h = 6 mm</td>
<td>X_2 = 1.11D+1.32v</td>
<td>Y_2 = 0.18D</td>
<td>0.8y_2 = ( \frac{0.8v^2}{1.32} ) and 15 cm.</td>
</tr>
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<td>0.8y_3 = ( \frac{0.8v^2}{1.32} ) and 15 cm.</td>
</tr>
<tr>
<td>Zone 4 y_h = 6 mm</td>
<td>X_4 = 1.11D+1.32v</td>
<td>Y_4 = 0.36D</td>
<td>0.8y_4 = ( \frac{0.8v^2}{1.32} ) and 15 cm.</td>
</tr>
</tbody>
</table>

Vertical reinforcing steel:
v_v = 6 mm

Upper zone: This is the zone from the top to 0.25 + 0.15D = 0.35 + 0.15 - 3.8 = 0.9 m from the base.

i.e. d_v, upper = 15 cm

Lower zone: This is the zone of 0.9 m at the bottom of the wall.
d_v, lower = the lesser of \( \frac{0.8v^2}{1.32} \) = 6.6 and 15 cm.

i.e. d_v, lower = 8 cm.

Base slab
Thickness, p = the greater of 3.8 x (2 + 0.5 x 4.4) = 16.0 and 10 cm.
i.e. p = 16 cm.

d_f = the lesser of \( \frac{0.8v^2}{1.32} \) = 6.4 and 1.5 x 16 = 24.

i.e. d_f = 6 cm.

Support tower
Thickness of the walls, t = the greater of 4 x 4.4 + 2 x 10.0 = 23.6 and 12.
i.e. t = 24 cm.

Foundations
The width of the foundation, s = 0.22 x 4.4 + 0.15 x 10 - 0.6 = 1.9 m.
i.e. s = 1.9 m.