Low Cost Underground Water Tanks

By

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DECLARATION

I herewith declare that the work included in the thesis in part or whole, has not been submitted for any other academic qualification at any institution

....06.11.2001.......... ....

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ABSTRACT

There is a great need to construct low cost underground water tanks in the dry zone of Sri Lanka to enable rain water harvesting .A research is conducted to introduce the said tanks with the use of low cost materials. Mainly brickwork and ferro-cement were considered in the study.

The approach is based on analytical results obtained from a computer program and experimental investigation of properties of the construction materials. The computer program was developed to analyse shell type tanks by incorporating the linear elastic theory of shells. Mainly two types of cylindrical tanks with spherical domed roofs were analysed; viz. "Normal type" and "Advanced type". The difference between the two types is the bottom shape. The normal type tanks are having a flat bottom and the advanced type tanks with an inverted spherical domed bottom. Both fully underground and partially underground tanks were analysed.

A parametric study was carried out by using the computer program. The results revealed that the maximum tank diameter that can be achieved by using brickwork for the spherical roof and the cylindrical wall of the tanks is only about 2.0 –2.4 m which resulted in an approximate tank capacity of 10 m^3. The governing factor in deciding the capacity is the flexural strength of brickwork. Hence, brickwork reinforced with wire mesh is considered for the cylindrical wall. The experimental investigations revealed that the flexural strength could be increased dramatically with this new composite construction material. The new composite material is named as "Brickwork Reinforced with Wire Mesh (*BRWM*)".

According to the results of the parametric study maximum tank diameter that can be achieved for a partially underground advanced type tank having a ferro-cement spherical roof, BRWM cylindrical wall and a ferro-cement inverted spherical bottom is about 6 m which resulted in an approximate capacity of 100 m^3. The structural design for a 66 m^3 tank having the above-mentioned specifications was completed.

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NOTATIONS

The following is a list of symbols, which are common in various chapters of the thesis. All symbols are defined in the text when they first appear. The notations are arranged in the alphabetical order.

ϕ_1	=	Angle between the axis of the shell and the shell normal at the edge of the opening of an open spherical shell on the middle surface of the shell
ϕ_E	=	Angle between the axis of the shell and the shell normal at the ground surface level of a spherical shell on the middle surface of the shell
δ	=	Displacement at boundaries due to edge restraining forces M = 1 and H = 1. First subscript d, c, i, p, R denotes the spherical dome, cylindrical shell, inverted spherical shell, circular plate, ring beam respectively. Second subscript M, H denotes the edge restraining moment, edge restraining horizontal force respectively.
ω	=	Displacement at boundaries due to edge restraining forces M and H. First subscript d, c, i, p, R denotes the spherical dome, cylindrical shell, inverted spherical shell, circular plate, ring beam respectively. Second subscript M, H denotes the edge restraining moment, edge restraining horizontal force respectively.
P_θ	=	External load in the hoop direction
P_ϕ	=	External load in the meridianal direction
P_r	=	External load normal to the middle surface of the shell
ϕ_b	=	Limiting angle at bottom (angle between the axis of the shell and the shell normal at the edge of an inverted spherical shell on the middle surface of the shell)
ϕ_0	=	Limiting angle at top (angle between the axis of the shell and the shell normal at the edge of a spherical shell on the middle surface of the shell)
β	=	Rotation at the boundaries due to edge restraining forces M = 1 and H. = 1. First subscript d, c, i, p, R denotes the spherical dome, cylindrical shell, inverted spherical shell, circular plate, ring beam respectively. Second subscript M, H denotes the edge restraining moment, edge restraining horizontal force respectively.
γ_{sat}	=	Saturated specific weight of soil.
θ	=	Angle between r and any defined line ξ.
ϕ	=	Angle between the axis of the shell and the shell normal at the point under consideration on the middle surface of the shell.
μ	=	Poisons ratio
λ	=	Shell constant for a spherical shell, cylindrical shell

$\varepsilon_{lateral}$ = Difference in lateral strain between a basic loading level and an upper loading level.

$\varepsilon_{longitudinal}$ = Difference in longitudinal strain between a basic loading level and an upper loading level.

Δ_{ε} = Difference in strain between a basic loading level and an upper loading level.

Δ_{σ} = Difference in stress between a basic loading level and an upper loading level.

Δ = Membrane displacement at the boundaries of shells. Subscripts d, c, i, p, denote the spherical dome, cylindrical shell, inverted spherical shell, circular plate.

ϑ = Rotation at the boundaries due to edge restraining forces M and H. First subscript d, c, i, p, R denotes the spherical dome, cylindrical shell, inverted spherical shell, circular plate, ring beam respectively. Second subscript M, H denotes the edge restraining moment, edge restraining horizontal force respectively.

B = Membrane rotations at the boundaries of shells. Subscripts d, c, i, p, denote the spherical dome, cylindrical shell, inverted spherical shell, circular plate

d = Depth of ring beam. Subscripts 1, 2, and 3 denotes the ring beams 1, 2 and 3 respectively

e = Eccentricity. For subscripts - Ref. Fig. 4.2 and Fig. 4.3.

E = Modulus of elasticity

H = Edge restraining horizontal force

h = Height of cylinder

H_R = Resultant horizontal force

k = Cylinder stiffness

M = Edge restraining moment

$M_{\phi\theta}$ = Twisting moment

M_{θ} = Bending moment in the hoop direction.

M_{ϕ} = Bending moment in the meridianal direction.

$M_{\theta\phi}$ = Twisting moment

M_r = Radial moment of a circular plate

M_R = Resultant moment

M_t = Tangential moment of a circular plate

$N_{\phi\theta}$ = Inplane shear force in the hoop direction.

N_{θ} = Normal inplane force in the hoop direction

N_{ϕ} = Normal inplane force in the meridianal direction

N_X = Normal inplane force in the meridianal direction of a cylindrical shell

$N_{\theta\phi}$ = Inplane shear force in the meridian direction

Q_{ϕ} = Transverse shear force

Q_{θ} = Transverse shear force

R = Radius of curvature of meridian of a spherical shell

R = Radius of curvature of parallel (with respect to the geometry of any shell)

r_1 = Radius of curvature of meridian (with respect to the geometry of any shell)

r_2 = Distance from any point on the middle surface to the axis of rotation along the normal to the meridian.

		Radius of cylinder, ring beam 1 and ring beam 3 (with respect to the geometry of a tank)
		Radius of entrance hole opening, ring beam 2 (with respect to the geometry of a tank)
t	=	Thickness of shell, ring beam. The subscripts s, c, p and i denotes the spherical roof, cylindrical wall, circular plate and inverted spherical bottom respectively. Subscripts 1, 2, and 3 denotes the ring beams 1, 2 and 3 respectively
W	=	Weight of ring beam