



1.0 INPUT

1.1 Design Options

Design Code **British Standard**
 Design Unit **SI Unit**

1.2 Dimensions

1.2.1 Pit

Breadth $B_p = 1500$ mm
 Length $L_p = 2400$ mm
 Thickness of the Wall $t_{wall} = 250$ mm

1.2.2 Slab

Top Cover **Monolithic**
 Thickness of Top Slab $t_{top} = 250$ mm
 Thickness of Bottom Slab $t_{bot} = 250$ mm
 Projection of Bottom Slab beyond Wallproj = 0 mm

1.3 Levels

Reference Ground Level Elevation GL = 100.5 m
 Top of Top Slab Elevation $W_{ele} = 100.6$ m
 Top of Bottom Slab Level $B_{SL} = 97.2$ m
 Max. Ground Water Level Elevation GWL = 96.2 m

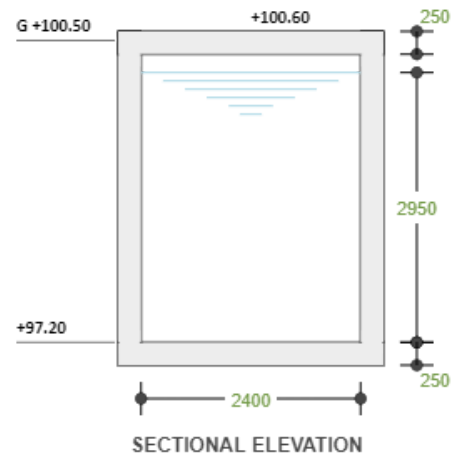
1.4 Contents

Content Inside Tank **Liquid**
 Unit Weight of Content $\gamma_{cont} = 10$ kN/m³
 Weight of Equipment $W_L = 50$ kN
 Volume of Equipment $V_L = 5$ m³
 Free Board FB = 0.2 m

1.5 Reinforcement

1.5.1 Cover

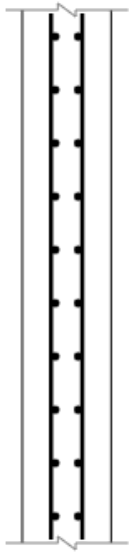
Clear Cover for Wall $C_{wall} = 75$ mm
 Clear Cover for Top Slab $C_{t_{slab}} = 75$ mm
 Clear Cover for Bottom Slab $C_{b_{slab}} = 75$ mm



Content Volume: 10.62 m³

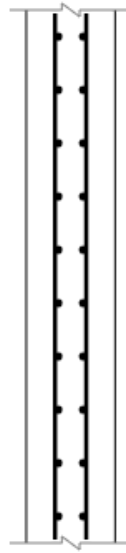


1.5.2 Short Wall Reinforcement



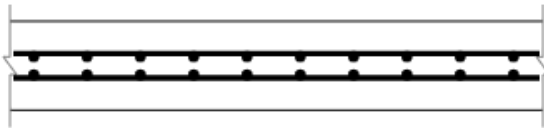
Vertical Reinforcement
 $\phi 12 - 150\text{mm c/c}$ (1507.96 mm² - 0.6%)
Horizontal Reinforcement
 $\phi 12 - 150\text{mm c/c}$ (1507.96 mm² - 0.6%)

1.5.3 Long Wall Reinforcement



Vertical Reinforcement
 $\phi 12 - 150\text{mm c/c}$ (1507.96 mm² - 0.6%)
Horizontal Reinforcement
 $\phi 12 - 150\text{mm c/c}$ (1507.96 mm² - 0.6%)

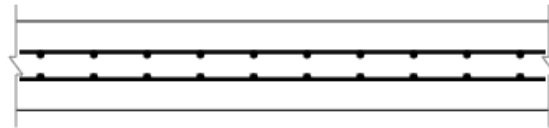
1.5.4 Bottom Slab Reinforcement



Length Direction
 $\phi 16 - 150\text{mm c/c}$ (2680.83 mm² - 1.07%)
Breadth Direction
 $\phi 16 - 150\text{mm c/c}$ (2680.83 mm² - 1.07%)

(Section shown along shorter direction)

1.5.5 Top Slab Reinforcement



Length Direction
 $\phi 12 - 150\text{mm c/c}$ (1507.96 mm² - 0.6%)
Breadth Direction
 $\phi 12 - 150\text{mm c/c}$ (1507.96 mm² - 0.6%)

(Section shown along shorter direction)

1.6 Load Data

Live Load on the Slab	LL	=	6 kN/m ²
Surcharge Live Load	SL	=	0 kN/m ²
Water Testing			Yes

1.7 Soil

Unit Weight of Soil	γ_{soil}	=	17 kN/m ³
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Unit Weight of Submerged Soil	$\gamma'_{\text{soil}} = 7 \text{ kN/m}^3$
Unit Weight of Ground Water	$\gamma_w = 10 \text{ kN/m}^3$
Allowable Safe Bearing Pressure	SBC = 300 kN/m²
Angle of Internal Friction	$\Phi = 32 \text{ Deg}$

1.8 Reinforced Concrete Properties

Strength of Concrete	$f_{\text{cu}} = 35 \text{ N/mm}^2$
Strength of Reinforcement	$f_y = 500 \text{ N/mm}^2$
Density of Concrete	$\gamma_{\text{conc}} = 24 \text{ kN/m}^3$
Modulus of Elasticity of Steel	$E_s = 200 \text{ kN/mm}^2$

1.9 Material Partial Safety Factors

Concrete in Compression	$\gamma_{\text{mc}} = 1.5$
Concrete in Shear	$\gamma_{\text{mcs}} = 1.25$
Reinforcement	$\gamma_{\text{ms}} = 1.15$

1.10 Stability Safety Factors

Uplift	$\gamma_{\text{uplifts}} = 1$
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1.11 Crack Width

Check for Crack Width	No
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2.0 OUTPUT

Content Active Pressure Coefficient	$k_{\text{ac}} = 1$
Soil Active Pressure Coefficient	$k_a = (1 - \sin(\Phi)) / (1 + \sin(\Phi)) = 0.31$
Base Slab Bottom Level	$h_2 = B_{\text{SL}} - t_{\text{bot}} = 96.95 \text{ m}$
Wall Height	$H_{\text{wall}} = W_{\text{ele}} - B_{\text{SL}} - t_{\text{top}} = 3.15 \text{ m}$
Operating Liquid Height	$H_{\text{ol}} = W_{\text{ele}} - B_{\text{SL}} - t_{\text{top}} - \text{FB} = 2.95 \text{ m}$
Test Liquid Height	$H_{\text{tl}} = W_{\text{ele}} - B_{\text{SL}} - t_{\text{top}} = 3.15 \text{ m}$
Unit Weight of Test Water	$\gamma_{\text{water}} = 9.81 \text{ kN/m}^3$

2.1 Load Case

- i. DL - Dead Load
- ii. S - Surcharge
- iii. LL - Live Load
- iv. E - Earth Pressure
- v. O - Content Operating Case
- vi. T - Content Test Case

2.2 Load Combinations

2.2.1 Serviceability Load Combinations

Sl.No	Load Combination
SLS1	DL + E + LL + S

2.2 Load Combinations

2.2.1 Serviceability Load Combinations

Sl.No	Load Combination
SLS2	DL + O + LL + S + E
SLS3	DL + T + LL

2.2.2 Ultimate Load Combinations

Sl.No	Load Combination
ULS1	1.4DL + 1.6S + 1.2E + 1.6LL
ULS2	1.4DL + 1.4O + 1.6LL + 1.6S + 1.2E
ULS3	1.4DL + 1.4T + 1.6LL

2.3 Stability Checks

2.3.1 Uplift Check - Tank Empty Condition

Weight of Wall	$W_{tw} = 2 * \gamma_{conc} * t_{wall} * H_{wall} * (L_p + B_p + 2 * t_{wall})$ = 166.3 kN
Weight of Cover Slab	$W_{tts} = \gamma_{conc} * t_{top} * (L_p + 2 * t_{wall}) * (B_p + 2 * t_{wall}) =$ 34.8 kN
Weight of Base Slab	$W_{tbs} = \gamma_{conc} * t_{bot} * (L_p + 2 * t_{wall} + 2 * proj) * (B_p + 2 * t_{wall} + 2 * proj) =$ 34.8 kN
Pit Empty Weight	$W_{te} = W_{tw} + W_{tts} + W_{tbs} =$ 235.9 kN
Height of Water Table above Pit Base Slab	$h_u =$ 0 m
Soil Load on Projection	$L_{soilpr} =$ 0 kN
Soil Load on Top Slab	$L_{soilts} =$ 0 kN
Total Counteracting Force	$F_{cf} = W_{te} + L_{soilpr} + L_{soilts} =$ 235.9 kN
Uplift Pressure on Pit Base Slab	$P_u = h_u * \gamma_w =$ 0 kN/m²
Uplift Force	$F_u = P_u * (L_p + 2 * t_{wall} + 2 * proj) * (B_p + 2 * t_{wall} + 2 * proj)$ = 0 kN
Factor of Safety	$FOS = F_{cf} / F_u =$ 100

2.3.2 Bearing Pressure Check

Weight due to Surcharge Load (S)	$P_1 = SL =$ 0 kN/m²
Weight due to Live Load (LL)	$P_2 = LL =$ 6 kN/m²
Pressure in Empty Condition (DL)	$P_3 = W_{te} / ((L_p + 2 * t_{wall} + 2 * proj) * (B_p + 2 * t_{wall} + 2 * proj))$ = 40.7 kN/m²
Pressure in Operating Condition (O)	$P_4 = (\gamma_{cont} * ((B_p * L_p * H_{ol}) - V_L) + W_L) / (L_p * B_p) =$ 29.5 kN/m²
Pressure in Test Condition (T)	$P_5 = \gamma_{water} * H_{tl} =$ 30.9 kN/m²
Pressure due to Soil on Slab (E)	$P_6 =$ 0 kN/m²

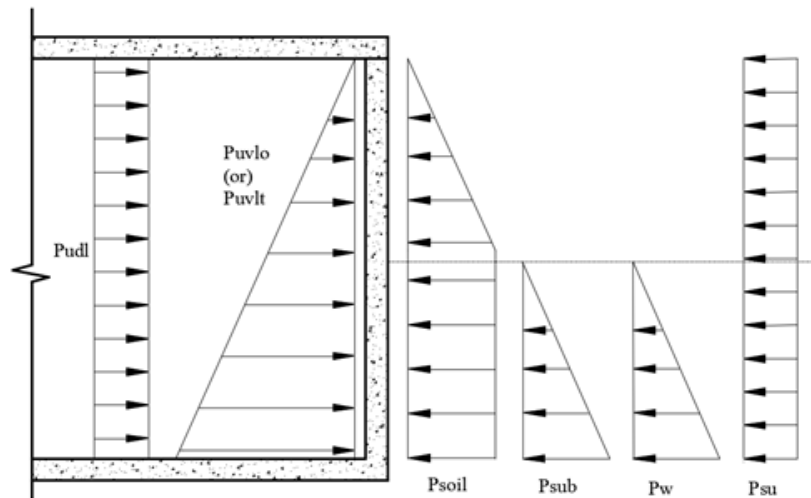
Load Combination	Bearing Pressure (kN/m ²)	Allowable SBC (kN/m ²)
SLS1	46.7	300
SLS2	76.2	300
SLS3	77.6	300

2.4 Wall Design

Pressure due to Operating Content (O)	$P_{uvlo} = H_{ol} * \gamma_{cont} * k_a = 29.5 \text{ kN/m}^2$
Pressure due to Test Content (T)	$P_{uvlt} = H_{tl} * \gamma_{water} = 30.9 \text{ kN/m}^2$
Pressure due to Surcharge Inside Pit (S)	$P_{udl} = 0 \text{ kN/m}^2$
Pressure due to Surcharge Outside Pit (S)	$P_{su} = SL * k_a = 0 \text{ kN/m}^2$

2.4.1 Earth Pressure Components

Pressure due to Saturated Soil (E)	$P_{soil} = \max((GL - h_2) * \gamma_{soil} * k_a, 0) = 18.54 \text{ kN/m}^2$
Pressure due to Submerged Soil (E)	$P_{sub} = \max((GWL - h_2) * \gamma'_{soil} * k_a, 0) = 0 \text{ kN/m}^2$
Pressure due to Ground Water (E)	$P_w = \max((GWL - h_2) * \gamma_w, 0) = 0 \text{ kN/m}^2$



Sign Convention

Tension Outside = +ve Moment

Tension Inside = -ve Moment

Reference

Based on Roark's Formulas for Stress and Strain by WARREN C. YOUNG & RICHARD G. BUDYNAS

2.4.2 Moment & Shear For Load Cases - Short Wall (D/L = 0.48)

Load Case	Vertical Direction (kN-m)		Horizontal Direction (kN-m)		Shear Force (kN)	
	Support Moment	Span Moment	Support Moment	Span Moment	Vertical Direction	Horizontal Direction
Operating Content	-2.9	0	-2.9	0	9	6.9
Test Content	-3.1	0	-3.2	0	9.6	7.4
Surcharge Inside	0	0	0	0	0	0
Surcharge Outside	0	0	0	0	0	0
Submerged Soil	0	0	0	0	0	0
Soil	0	-1.8	0	-1.9	5.7	4.4
Ground Water	0	0	0	0	0	0

2.4.3 Moment & Shear For Load Cases - Long Wall (D/L = 0.76)

Load Case	Vertical Direction (kN-m)	Horizontal Direction (kN-m)	Shear Force (kN)
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	Support Moment	Span Moment	Support Moment	Span Moment	Vertical Direction	Horizontal Direction
Operating Content	-5.8	0	-5.6	0	12.7	9.8
Test Content	-6.3	0	-6.4	0	13.7	10.9
Surcharge Inside	0	0	0	0	0	0
Surcharge Outside	0	0	0	0	0	0
Submerged Soil	0	0	0	0	0	0
Soil	0	-3.8	0	-3.9	8.2	6.6
Ground Water	0	0	0	0	0	0

2.4.4 Design Moment

Element	Load Combination	Vertical Direction(kN-m)		Horizontal Direction(kN-m)	
		Support Moment	Span Moment	Support Moment	Span Moment
Short Wall	ULS1	0	-2.2	0	-2.3
	ULS2	-4	-2.2	-4.1	-2.3
	ULS3	-4.3	0	-4.5	0
Long Wall	ULS1	0	-4.5	0	-4.6
	ULS2	-8.1	-4.5	-7.9	-4.6
	ULS3	-8.8	0	-9	0

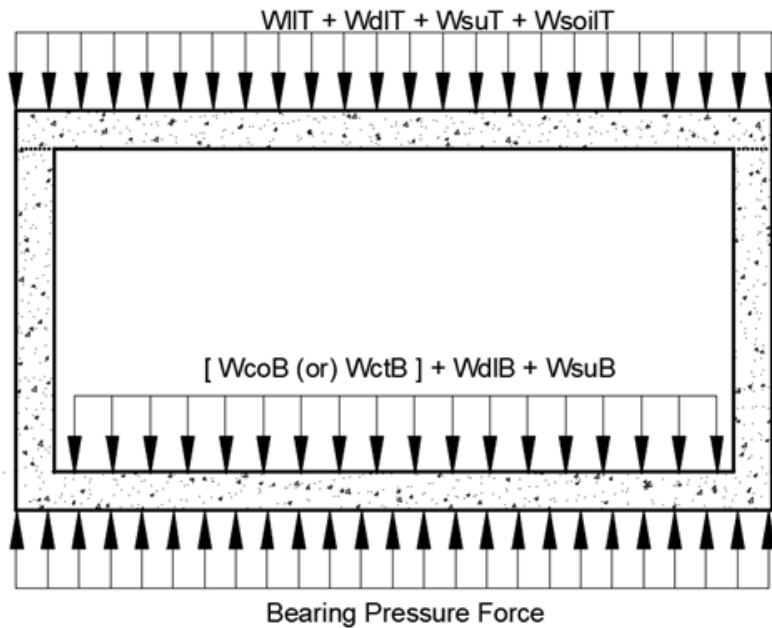
2.4.5 Design Shear

Element	Load Combination	Shear Force (kN)		Design Shear Stress (N/mm ²)	
		Vertical Direction	Horizontal Direction	Vertical Direction	Horizontal Direction
Short Wall	ULS1	6.9	5.3	0.041	0.034
	ULS2	19.4	15	0.115	0.095
	ULS3	13.4	10.4	0.079	0.066
Long Wall	ULS1	9.9	7.9	0.058	0.05
	ULS2	27.7	21.6	0.164	0.138
	ULS3	19.2	15.3	0.113	0.098

2.4.6 Moment & Shear Capacity

Element	Moment Capacity (kN-m)		Shear Strength (N/mm ²)	
	Vertical Direction	Horizontal Direction	Vertical Direction	Horizontal Direction
Short Wall	68.1	68.1	0.67	0.7
Long Wall	68.1	68.1	0.67	0.7

2.5 Slab Design



2.5.1 Top Slab

Live Load on Slab (LL)	$W_{IT} = LL = 6 \text{ kN/m}^2$
Dead Load of Slab (DL)	$W_{dIT} = \gamma_{\text{conc}} * t_{\text{top}} = 6 \text{ kN/m}^2$
Surcharge Load on Slab (S)	$W_{suT} = 0 \text{ kN/m}^2$
Earth Pressure on Slab (E)	$W_{soilT} = 0 \text{ kN/m}^2$

2.5.1.1 Design Moment

Load Combination	Length Direction (kN-m)		Breadth Direction (kN-m)	
	Support Moment	Span Moment	Support Moment	Span Moment
ULS1	0	4	0	6.5
ULS2	0	4	0	6.5
ULS3	0	4	0	6.5

2.5.1.2 Design Shear

Load Combination	Shear Force (kN)		Design Shear Stress (N/mm ²)	
	Length Direction	Breadth Direction	Length Direction	Breadth Direction
ULS1	11.9	15.8	0.076	0.094
ULS2	11.9	15.8	0.076	0.094
ULS3	11.9	15.8	0.076	0.094

2.5.1.3 Moment & Shear Capacity

Moment Capacity (kN-m)		Shear Strength (N/mm ²)	
Length Direction	Breadth Direction	Length Direction	Breadth Direction
68.1	68.1	0.7	0.67

2.5.2 Bottom Slab

Dead Load on Slab (DL)	$W_{dlB} = \gamma_{conc} * t_{bot} = 6 \text{ kN/m}^2$
Surcharge Load on Slab (S)	$W_{suB} = 0 \text{ kN/m}^2$
Operating Content Load on Slab (O)	$W_{coB} = \gamma_{cont} * H_{ol} = 29.5 \text{ kN/m}^2$
Test Content Load on Slab (T)	$W_{ctB} = \gamma_{water} * H_{tl} = 30.9 \text{ kN/m}^2$

* Note1 : Effect of Bearing Pressure also considered

* Note2 : Moment transferred from Slab Projection and Wall is taken into consideration

2.5.2.1 Design Moment

Load Combination	Length Direction (kN-m)		Breadth Direction (kN-m)	
	Support Moment	Span Moment	Support Moment	Span Moment
ULS1	0	-13	0	-20.9
ULS2	4	-9	8.1	-12.9
ULS3	4.3	-8.7	8.8	-12.1

2.5.2.2 Design Shear

Load Combination	Shear Force (kN)		Design Shear Stress (N/mm ²)	
	Length Direction	Breadth Direction	Length Direction	Breadth Direction
ULS1	-38.4	-51.2	0.254	0.306
ULS2	-38.4	-51.2	0.254	0.306
ULS3	-38.4	-51.2	0.254	0.306

2.5.2.3 Moment & Shear Capacity

Moment Capacity (kN-m)		Shear Strength (N/mm ²)	
Length Direction	Breadth Direction	Length Direction	Breadth Direction
96.1	97	0.867	0.817

3.0 SUMMARY

3.1 Stability Checks

Description	Critical Combination	Actual	Allowable	Status
Uplift Check	-	100	1	PASS
Bearing Pressure Check (kN/m ²)	DL + T + LL	77.6	300	PASS

3.2 Short Wall

Description	Critical Combination	Actual	Allowable	Status
Moment - Vertical (kN-m)	1.4DL + 1.4T + 1.6LL	4.3	68.1	PASS
Moment - Horizontal (kN-m)	1.4DL + 1.4T + 1.6LL	4.5	68.1	PASS
Shear Resistance - Vertical (N/mm ²)	1.4DL + 1.4O + 1.6LL + 1.6S + 1.2E	0.115	0.67	PASS
Shear Resistance - Horizontal (N/mm ²)	1.4DL + 1.4O + 1.6LL + 1.6S + 1.2E	0.095	0.7	PASS

3.3 Long Wall

Description	Critical Combination	Actual	Allowable	Status
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3.3 Long Wall

Description	Critical Combination	Actual	Allowable	Status
Moment - Vertical (kN-m)	1.4DL + 1.4T + 1.6LL	8.8	68.1	PASS
Moment - Horizontal (kN-m)	1.4DL + 1.4T + 1.6LL	9	68.1	PASS
Shear Resistance - Vertical (N/mm ²)	1.4DL + 1.4O + 1.6LL + 1.6S + 1.2E	0.164	0.67	PASS
Shear Resistance - Horizontal (N/mm ²)	1.4DL + 1.4O + 1.6LL + 1.6S + 1.2E	0.138	0.7	PASS

3.4 Bottom Slab

Description	Critical Combination	Actual	Allowable	Status
Moment - Length (kN-m)	1.4DL + 1.6S + 1.2E + 1.6LL	13	96.1	PASS
Moment - Breadth (kN-m)	1.4DL + 1.6S + 1.2E + 1.6LL	20.9	97	PASS
Shear Resistance - Length (N/mm ²)	1.4DL + 1.6S + 1.2E + 1.6LL	0.254	0.867	PASS
Shear Resistance - Breadth (N/mm ²)	1.4DL + 1.6S + 1.2E + 1.6LL	0.306	0.817	PASS

3.5 Top Slab

Description	Critical Combination	Actual	Allowable	Status
Moment - Length (kN-m)	1.4DL + 1.6S + 1.2E + 1.6LL	4	68.1	PASS
Moment - Breadth (kN-m)	1.4DL + 1.6S + 1.2E + 1.6LL	6.5	68.1	PASS
Shear Resistance - Length (N/mm ²)	1.4DL + 1.6S + 1.2E + 1.6LL	0.076	0.7	PASS
Shear Resistance - Breadth (N/mm ²)	1.4DL + 1.6S + 1.2E + 1.6LL	0.094	0.67	PASS