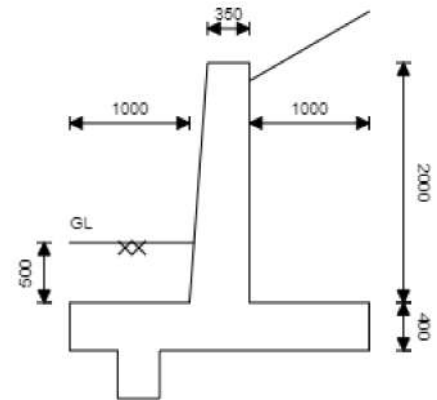




1.0 INPUT

1.1 Stem

Height of Stem	h_s	=	2000 mm
Wall Type			Varying Outside
Top Wall Thickness	T_{tw}	=	350 mm
Bottom Wall Thickness	T_{bw}	=	500 mm



1.2 Base

Length of Toe	L_t	=	1000 mm
Length of Heel	L_h	=	1000 mm
Base Thickness	T_b	=	400 mm

1.3 Shear Key

Depth of Shear Key	S_d	=	400 mm
Shear Key Thickness	T_{sk}	=	350 mm
Position of Shear Key from Toe	S_p	=	400 mm

1.4 Construction

Angle of Soil Surface	β	=	30 Deg
Depth of Water Table	h_{water}	=	1500 mm
Depth of Ground Cover	d_c	=	500 mm
Minimum Ground Cover	d_{mn}	=	200 mm

1.5 Surcharge Loads

Surcharge Dead Load on Plan	P_d	=	2 kN/m²
Surcharge Live Load on Plan	P_l	=	2 kN/m²
Line Dead Load	W_d	=	2 kN/m
Line Live Load	W_l	=	1 kN/m
Distance of Line Load from Wall	V_l	=	0 mm

1.5.1 Direct Loads on Wall

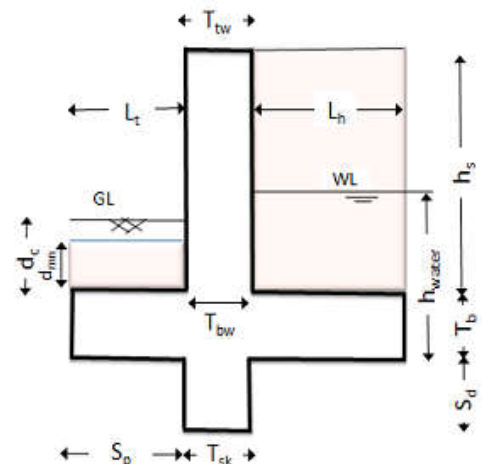
1.5.1.1 Vertical Load on Wall

Dead Load	V_{dl}	=	0 kN/m
Live Load	V_{ll}	=	0 kN/m
Wind Load	V_{wl}	=	0 kN/m

1.5.1.2 Horizontal Load on Wall

Dead Load	F_{dl}	=	0 kN/m
Live Load	F_{ll}	=	0 kN/m
Wind Load	F_{wl}	=	0 kN/m

1.5.1.3 Moment on Top Wall



Dead Load	M_d	=	0 kNm
Live Load	M_l	=	0 kNm
Wind Load	M_w	=	0 kNm

1.6 Soil Properties

Allowable Bearing Pressure	SBC	=	100 kN/m²
Angle of Friction (Retained Material)	δ	=	30 Deg
Angle of Friction for Base Material	δ_b	=	30 Deg
Cohesion of Base Material	c_b	=	0 kN/m²
Co-efficient of Friction (Base & Soil)	μ	=	0.4

1.6.1 Density

Density of Retained Material	γ_m	=	18 kN/m³
Density of Base Material	γ_{mb}	=	18 kN/m³
Submerged Density of Retained Material	γ_s	=	12 kN/m³

1.7 Material Properties

Concrete Grade	f_{cu}	=	40 N/mm²
Main Reinforcement Grade	f_y	=	500 N/mm²
Density of Concrete	γ_{conc}	=	24 kN/m³
Density of Water	γ_w	=	9.86 kN/m³
Modulus of Elasticity of Steel	E_s	=	200 kN/mm²

1.8 Factor of Safety

F.O.S against Sliding	γ_{slide}	=	1.5
F.O.S against Overturning	γ_{over}	=	1.5

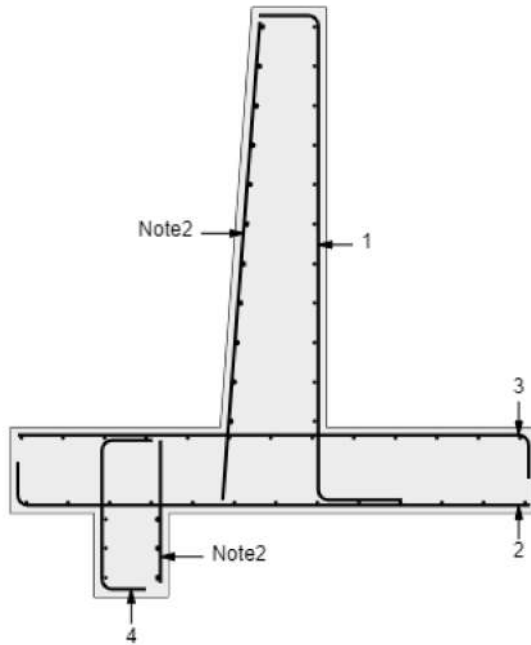
1.9 Material Partial Safety Factor

Concrete in Compression	γ_{mc}	=	1.5
Reinforcement	γ_{ms}	=	1.15
Concrete in Shear	γ_{mcs}	=	1.25

1.10 Crack Width

Maximum Allowable Crack Width	W_k	=	0.3 mm
-------------------------------	-------	---	---------------

1.11 Reinforcement



1. Stem Main:
 $\phi 12 - 150\text{mm c/c} (754 \text{ mm}^2 - 0.15\%)$
2. Base Bottom Main:
 $\phi 12 - 150\text{mm c/c} (754 \text{ mm}^2 - 0.19\%)$
3. Base Top Main:
 $\phi 12 - 150\text{mm c/c} (754 \text{ mm}^2 - 0.19\%)$
4. Shearkey Main:
 $\phi 12 - 150\text{mm c/c} (754 \text{ mm}^2 - 0.19\%)$

Note1: Long. reinforcement is indicative
 Note2: Optional and shown indicative

1.11.1 Clear Cover

Clear Cover for Reinforcement $C_c = 30 \text{ mm}$

2.0 OUTPUT

2.1 Dimension

Overall Length of Base	$l_{\text{base}} = L_t + L_h + T_{\text{bw}} = 2500 \text{ mm}$
Height of Retaining Wall	$h_{\text{rtn}} = h_s + T_b = 2400 \text{ mm}$
Height of Submerged Fill Above Base	$h_{\text{sub}} = \max(h_{\text{water}} - T_b, 0) = 1100 \text{ mm}$
Effective Height at Virtual Back of Wall	$h_{\text{eff}} = h_{\text{rtn}} + (L_h + (T_{\text{bw}} - T_{\text{tw}})) * \tan(\beta) = 2977.35 \text{ mm}$
Angle of Wall at Retaining Face	$\alpha = 90 - \tan^{-1}(h_s / (T_{\text{bw}} - T_{\text{tw}})) = 0 \text{ Deg}$

2.2 Co-efficient of Earth Pressure

Active Pressure	$K_a = (1 - \sin(\delta)) / (1 + \sin(\delta)) = 0.333$
Passive Pressure	$K_p = (1 + \sin(\delta_b)) / (1 - \sin(\delta_b)) = 3$
Cohesion Passive Pressure	$K_{\text{pc}} = 2 * K_p^{1/2} = 3.464$

2.3 Load Cases

2.3.1 Dead Load (D)

Self-Weight of Base	$W_{\text{base}} = \gamma_{\text{conc}} * T_b = 9.6 \text{ kN/m}^2$
Surcharge Load on Base	$W_{\text{surd}} = P_d = 2 \text{ kN/m}^2$
Lateral Pressure due to Surcharge	$F_{\text{surd}} = P_d * K_a * \cos(\alpha) = 0.577 \text{ kN/m}^2$
Self-Weight of Stem (Straight)	$W_{\text{wall1}} = \gamma_{\text{conc}} * T_{\text{tw}} * h_s = 16.8 \text{ kN/m}$
Self-Weight of Stem (Sloped)	$W_{\text{wall2}} = 0.5 * \gamma_{\text{conc}} * (T_{\text{bw}} - T_{\text{tw}}) * h_s = 3.6 \text{ kN/m}$
Total Self-Weight of Stem	$W_{\text{wall}} = W_{\text{wall1}} + W_{\text{wall2}} = 20.4 \text{ kN/m}$
Self-Weight of Shear Key	$W_{\text{sk}} = \gamma_{\text{conc}} * T_{\text{sk}} * S_d = 3.36 \text{ kN/m}$
Direct Load on Stem (Vertical Direction)	$W_{\text{vd}} = V_{\text{dl}} = 0 \text{ kN/m}$

Direct Load on Stem (Lateral Direction)	$F_{hd} = F_{dl} = 0 \text{ kN/m}$
Line Load on Base	$W_{lined} = W_d = 2 \text{ kN/m}$
Lateral Load due to Line Load	$F_{lined} = W_d * K_a * \cos(\alpha) = 0 \text{ kN/m}$

2.3.2 Live Load (L)

Surcharge Load on Base	$W_{surl} = P_l = 2 \text{ kN/m}^2$
Lateral Pressure due to Surcharge	$F_{surl} = P_l * K_a * \cos(\alpha) = 0.577 \text{ kN/m}$
Direct Load on Stem (Vertical Direction)	$W_{vl} = V_{ll} = 0 \text{ kN/m}$
Direct Load on Stem (Lateral Direction)	$F_{hl} = F_{ll} = 0 \text{ kN/m}$
Line Load on Base	$W_{linel} = W_l = 1 \text{ kN/m}$
Lateral Load due to Line Load	$F_{linel} = W_l * K_a * \cos(\alpha) = 0 \text{ kN/m}$

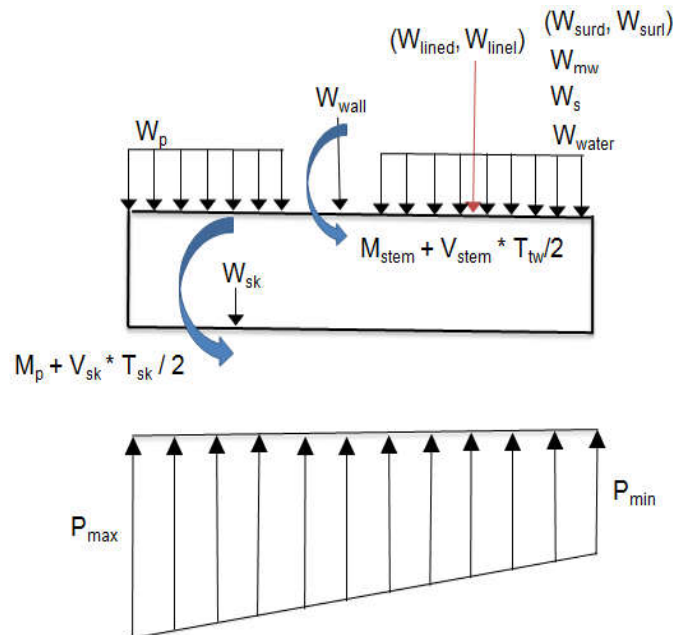
2.3.3 Earth and Water Pressure (E)

Backfill above Water Table (Vertical Dir.)	$W_{mw} = \gamma_m * (h_s - h_{sub}) = 16.2 \text{ kN/m}^2$
Sloped Backfill Above Top of the Wall (Vertical Direction)	$W_{ms} = \gamma_m * L_h * \tan(\beta) = 10.392 \text{ kN/m}^2$
Submerged Backfill (Vertical Direction)	$W_s = \gamma_s * h_{sub} = 13.2 \text{ kN/m}^2$
Water (Vertical Direction)	$W_{water} = \gamma_w * h_{sub} = 10.846 \text{ kN/m}^2$
Soil in front of Wall	$W_p = \gamma_{mb} * d_{mn} * L_t = 3.6 \text{ kN/m}$
Lateral Pressure due to Soil above Water Table	$F_{ma} = \gamma_m * (h_{eff} - h_{water}) * K_a * \cos(\alpha) = 7.677 \text{ kN/m}^2$
Submerged Backfill (Lateral Direction)	$F_s = \gamma_s * h_{water} * K_a * \cos(\alpha) = 5.196 \text{ kN/m}^2$
Water (Lateral Direction)	$F_{water} = \gamma_w * h_{sub} = 14.79 \text{ kN/m}^2$
Passive Resistance of Soil (Lateral Direction)	$F_p = 0.5 * K_p * (T_b + S_d + d_{mn})^2 * \gamma_{mb} + c_b * K_{pc} * (T_b + S_d + d_{mn}) = 27 \text{ kN/m}$

2.3.4 Wind (W)

Direct Load on Stem (Vertical Direction)	$W_{vw} = V_{wl} = 0 \text{ kN/m}$
Direct Load on Stem (Lateral Direction)	$F_{hw} = F_{wl} = 0 \text{ kN/m}$

2.4 Load Summary



2.4.1 Notation Description

P_{max} - Maximum Bearing Pressure

P_{min} - Minimum Bearing Pressure

M_{stem} - Moment on Stem

V_{stem} - Shear on Stem

M_p - Moment on Soil in front of Wall

V_{sk} - Shear on Shear Key

2.5 Distributed Loads (Vertical Direction)

Description	Forces (kN/m ²)		Location (m) *	
	Start	End	Start	End
W_{base}	9.6	9.6	0	2.5
W_{surd}	2	2	0	1
W_{surl}	2	2	0	1
W_{mw}	16.2	16.2	0	1
W_{ms}	0	10.392	0	1
W_s	13.2	13.2	0	1
W_{water}	10.846	10.846	0	1

2.6 Concentrated Loads (Vertical Direction)

Description	Forces (kN/m)	Location (m) *
W_{wall}	16.8	1.175
W_{wall2}	3.6	1.4
W_{sk}	3.36	1.925
W_{lined}	2	1
W_{linel}	1	1
W_{vd}	0	1.175
W_{vl}	0	1.175
W_{vw}	0	1.175

Note * : Distance from Heel

2.7 Distributed Loads (Horizontal Direction)

Description	Forces (kN/m ²)		Location (m) *	
	Start	End	Start	End
F_{surd}	0.577	0.577	0	2.977
F_{surl}	0.577	0.577	0	2.977
F_{ma1}	0	7.677	0	1.477
F_{ma2}	7.677	7.677	1.477	2.977
F_s	0	5.196	1.477	2.977
F_{water}	0	14.79	1.477	2.977

2.8 Concentrated Loads (Horizontal Direction)

Description	Forces (kN/m)	Location (m) *
F_{lined}	0	0
F_{linel}	0	0
F_{hd}	0	0
F_{hl}	0	0
F_{hw}	0	0

Note * : Distance from Top of Wall

2.9 Load Combination

2.9.1 SLS Combinations

SLS1 1D + 1L + 1W + 1E
SLS2 1D + 1E
SLS3 1D + 1W + 1E
SLS4 1D + 1L + 1E

2.9.2 ULS Combinations

ULS1 1.4D + 1.6L + 1.4E
ULS2 1.4D + 1.4W + 1.4E
ULS3 1.2D + 1.2L + 1.2W + 1.2E

2.10 Serviceability Condition for SLS Combinations

2.10.1 Check for Overturning

Load Combination	Overturning Moment (kNm)	Resisting Moment (kNm)	FOS
SLS1	34.345	160.67	4.678
SLS2	31.788	155.17	4.881
SLS3	31.788	155.17	4.881
SLS4	34.345	160.67	4.678

2.10.2 Check for Sliding

Load Combination	Sliding Force (kN/m)	Resisting Force (kN/m)	FOS
SLS1	35.612	67.081	1.884
SLS2	33.894	65.881	1.944
SLS3	33.894	65.881	1.944
SLS4	35.612	67.081	1.884

2.10.3 Check for Bearing Pressure

Load Combination	Maximum Pressure P_{max} (kN/m ²)	Minimum Pressure P_{min} (kN/m ²)	% Contact
SLS1	41.11	39.051	100
SLS2	40.685	37.076	100
SLS3	40.685	37.076	100
SLS4	41.11	39.051	100

2.10.4 Crack Width

Load Combination	Stem (mm)	Base Bottom (mm)	Base Top (mm)	Shear Key (mm)
SLS1	0	0	0	0
SLS2	0	0	0	0
SLS3	0	0	0	0
SLS4	0	0	0	0

2.11 Ultimate Design

2.11.1 Moment and Shear Capacity

2.11 Ultimate Design

2.11.1 Moment and Shear Capacity

Capacity	Stem	Base Bottom	Base Top	Shear Key
Moment - M_c (kNm)	149.076	118.067	118.067	99.902
Shear - v_c (N/mm ²)	0.393	0.402	0.402	0.417

2.11.2 Stem

Load Combination	Moment M_{stem} (kNm)	Shear Force V_{stem} (kN/m)	Shear Stress v_s (N/mm ²)
ULS1	29.034	22.207	0.052
ULS2	25.965	20.254	0.047
ULS3	24.56	18.826	0.044

2.11.3 Base Slab Top

Load Combination	Moment M_{bt} (kNm)	Shear Force V_{bt} (kN/m)	Shear Stress v_{bt} (N/mm ²)
ULS1	8.039	13.02	0.036
ULS2	7.627	11.616	0.032
ULS3	6.847	11.011	0.03

2.11.4 Base Slab Bottom

Load Combination	Moment M_{bb} (kNm)	Shear Force V_{bb} (kN/m)	Shear Stress v_{bb} (N/mm ²)
ULS1	9.713	16.94	0.047
ULS2	8.297	15.129	0.042
ULS3	8.175	14.327	0.039

2.11.5 Shear Key

Load Combination	Moment M_{sk} (kNm)	Shear Force V_{sk} (kN/m)	Shear Stress v_{sk} (N/mm ²)
ULS1	5.242	24.192	0.077
ULS2	5.242	24.192	0.077
ULS3	4.493	20.736	0.066

3.0 SUMMARY

3.1 Stability Check

Description	Combination	Required	Actual	Status
Bearing Pressure (kN/m ²)	SLS1 1D + 1L + 1W + 1E	100	41.1	PASS
Sliding	SLS1 1D + 1L + 1W + 1E	1.5	1.9	PASS
Overturning	SLS1 1D + 1L + 1W + 1E	1.5	4.678	PASS

3.2 Crack Width (mm)

Description	Combination	Required	Actual	Status
Stem	SLS1 1D + 1L + 1W + 1E	0.3	0	PASS
Base Bottom	SLS1 1D + 1L + 1W + 1E	0.3	0	PASS
Base Top	SLS1 1D + 1L + 1W + 1E	0.3	0	PASS
Shear Key	SLS1 1D + 1L + 1W + 1E	0.3	0	PASS

3.3 Moment Capacity (kNm)

Description	Combination	Required	Actual	Status
Stem	ULS1 1.4D + 1.6L + 1.4E	29.034	149.076	PASS
Base Bottom	ULS1 1.4D + 1.6L + 1.4E	9.713	118.067	PASS
Base Top	ULS1 1.4D + 1.6L + 1.4E	8.039	118.067	PASS
Shear Key	ULS1 1.4D + 1.6L + 1.4E	5.242	99.902	PASS

3.4 Shear Resistance (N/mm²)

Description	Combination	Required	Actual	Status
Stem	ULS1 1.4D + 1.6L + 1.4E	0.052	0.393	PASS
Base Bottom	ULS1 1.4D + 1.6L + 1.4E	0.047	0.402	PASS
Base Top	ULS1 1.4D + 1.6L + 1.4E	0.036	0.402	PASS
Shear Key	ULS1 1.4D + 1.6L + 1.4E	0.077	0.417	PASS