Construction of

220 kV Loop in Loop out Paliastomi- into Ozurgeti Substation and

110 kV Double Circuit (D/C) Overhead Line from Ozurgeti Substation to Zoti HPP

Foundation Design Calculations of Tower Type "12B-LC"

(for all soil types)

1	20/10/2022	Revised as per Consultant Comments	D. Nezamolmolki	H.O.Bulut	K. Karagoz
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Document Title	Scale	Sheet of Sheets
Foundation Design Calculations of Tower Type "12B-LC" (for all soil types)	**n.a.**	Page **1** of 52

Soils and Foundations Specifications

Soil Type & Designation	Ground Water Presence	Foundation Type	Density (kN/m3)	Angle of Frustum [°]	Bearing Capacity (kN/m2)
Type 1-Sound Rock	No	Rock Anchor	25	25	1000
Type 2-Deleterious Rock	No	Rock Anchor	20	25	500
Type 2-Deleterious Rock	No	Semi-Auger	20	25	500
Type 3-Good Soil	No	Semi-Auger	17	22	300
Type 3-Good Soil	No	Pad & Chimney	17	22	300
Type 4-Normal Soil-Dry	No	Pad & Chimney	18	15	200
Type 4-Normal Soil-Submerge	Yes	Pad & Chimney	10	15	200
Type 5-Poor Soil-Dry	No	Pad & Chimney	16	0	150
Type 5-Poor Soil-Submerge	Yes	Pad & Chimney	8	0	80

Soil Type: Type 1-Sound Rock
Foundation Type: Rock Anchor
Tower Type: 12B-LC

Maximum Loads on Stub				
Description	*Load Combination*	*Stub Force Components*		
		Shear Force Transversal component	*Shear Force Longitudinal component*	*Axial force*
		kg	kg	kg
Maximum Axial Force, Compression	0° C5,C NA+	44	905	-80,978
Maximum Axial Force, Uplift	0° C5, Min. WS,C NA+	455	568	71,478

Maximum Loads on Foundation				
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	0° C5,C NA+	-12,480	13,429	-78,881
Maximum Axial Force, Uplift	0° C5, Min. WS,C NA+	-10,616	11,638	69,725

Design Standard: EN 1992:2004

Inputs:

Factor of Safety for Loads F.S.= 1.1 Tech. Spec. Clause 2.5.3.4

Foundation Dimensions	Width of Pad	bp =	1.2	m	
	Height of Pad	hp =	0.7	m	
	Width of Chimney	bc =	0.6	m	
	Height of Chimney above ground level	hc1 =	0.3	m	
	Height of Chimney under ground level	hc2 =	0.6	m	
	Total Height of Chimney	hc =	0.9	m	
	Depth of Pad	H =	1.3	m	
	Inplane Slope	β =	9.02	Degree	
	Eccentricity (Bottom of Pad)	e =	0.25	m	
Soil Specifications	Soil Type	Type 1-Sound Rock			
	Density	γ_s =	2.55	ton/m3	Tech. Spec. Section C1 4.1
	Bearing Capacity	q_{all} =	10.19	kg/cm2	Tech. Spec. Section C1 4.1
Concrete	Compressive Strength(28 days of Cylindrical Sample)	f 'c =	20	Mpa	
	Strength Reduction Factor	φc =	0.67		Tech. Spec. Section C1 3.2.2
	Allowable Compressive Strength	f 'c =	13.33	Mpa	
	Density	γ_c =	2.5	ton/m3	
	Pad Cover Thickness	cp=	0.075	m	
	Chimney Cover Thickness	cc=	0.075	m	
Steel	Yield Strength of Rebar	Fy =	500	Mpa	
	Strength Reduction Factor	φs =	0.83		Tech. Spec. Section C1 3.2.2
Bond Stress	Grout and Steel Bond Stress	τ_{gs} =	2	Mpa	Ref. Pile Design in Construction Practice by Tomlinson Page 217
	Grout and Rock Bond Stress	τ_{gr} =	0.9	Mpa	Ref. Pile Design in Construction Practice by Tomlinson Table 6.1
	Concrete and Rebar Bond Stress	τ_{cr} =	2.3	Mpa	EN 50341 2012 Table K.2

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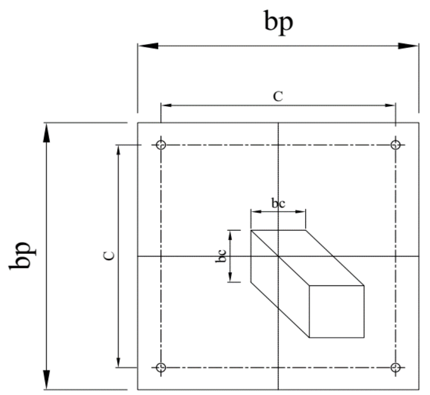
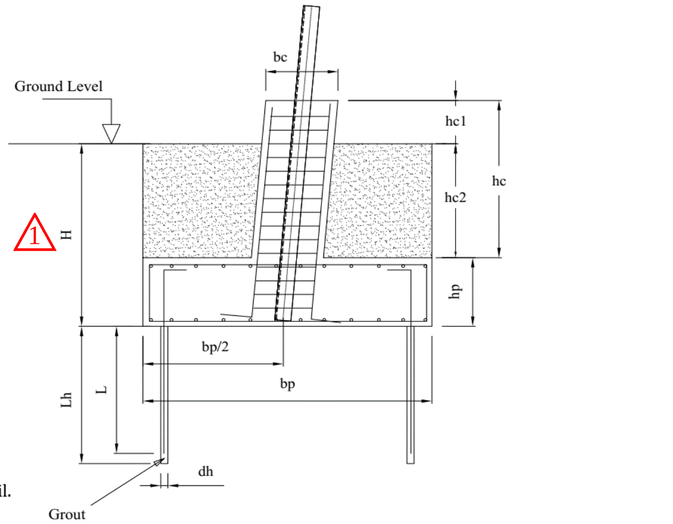




1 * The foundation is in direct contact with undisturbed soil.

MİTAŞ ENERGY

Ultimate Loads:

On Foundation	Compression	C =	86.77	ton
		Vcx =	-13.73	ton
		Vcy =	14.77	ton
	Tension	T =	76.70	ton
		Vtx =	-11.68	ton
		Vty =	12.80	ton

On Stub	Compression	Cs =	89.08	ton
		Vscx =	0.05	ton
		Vscy =	1.00	ton
	Tension	Ts =	78.63	ton
		Vstx =	0.50	ton
		Vsty =	0.62	ton

Design of Anchors:

Volume of chimney above ground level V1 = 0.11 m3
Volume of chimney under ground level V2 = 0.22 m3
Volume of pad, V3 = 1.01 m3
Total volume of foundation , Vf = 1.33 m3

Total weight of foundation, Wf = Vf * γc = 3.33 ton

Uplift Force, U = 76.70 ton

Design force for anchors, U net = U - Wf = 73.37 ton

Required anchor area for uplift, Asu = U net / (φs * Fy) = 17.27 cm2

Anchor arrangement:

No. of anchor rows, n = 2 Distance from hole center to pad edge = 0.2 m

Central Holes to be Ommited = No

Total No. of anchors holes, i = 4

Distance between anchor rows C = 80.0 cm

Distance of the last row to center, c = 40 cm

$\Sigma\ di^2$ = 6400

Anchor diameter, da = 2.0 cm

No. of Anchor in one hole m = 2 The effect of rebars boundle on embedded lenghts would be considered!

Total anchor area in one hole = 6.28 cm

Total area of anchors, As =	25.13	cm2	>	17.27	OK

Uplift Force, T = 76.72 ton
Bending Moment about x axis, Mx = 1.00 ton.m
Bending Moment about y axis, My = 0.80 ton.m

Required Modulus of Section at x direction Wx = Mx / (φs * Fy) = 23.53 cm3
Required Modulus of Section at y direction Wy = My / (φs * Fy) = 18.84 cm3

Required anchor area for bending moment about x axis, Asmx = n * m * Wx * c / (Σ di ^{2}) = 0.59 cm2

Required anchor area for bending moment about y axis, Asmy = n* m * Wy * c / (Σ di ^{2}) = 0.47 cm2

Total Required Area for Anchors, Astot = Asu + Asmx + Asmy =	18.33	cm2	<	25.13	OK

Bearing Capacity:

Compression Force, C = 86.92 ton
Bending Moment about x axis, Mx = 1.59 ton.m
Bending Moment about y axis, My = 0.08 ton.m

Over Load of Concrete, Wf = 3.33 ton

Volume of the Soil directly above foundation Vsl = (H * bp^2) - V2 - V3 = 0.65 m3

Over Load of Soil directly above foundation Wsl= Vsl * γs = 1.65 ton

Overall Bearing Pressure = σp = ((C + Wf + Wsl)/A) =	6.38	kg/cm2	<	10.19	kg/cm2	OK

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) + (6*My)/(bp3) =$ 6.96 kg/cm2

Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) - (6*My)/(bp3) =$ 6.91 kg/cm2

Compression Stress at corner 3, $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) + (6*My)/(bp3) =$ 5.86 kg/cm2

Compression Stress at corner 4, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) - (6*My)/(bp3) =$ 5.80 kg/cm2

Max. Toe Pressure =	6.96	<	q_{all} =	12.74	OK
Min. Toe Pressure =	5.80	>	0		OK

Bond of Anchor and Grout Check :

Max. force of one anchor hole Pa = 19466 kg

Required embedded length of anchor in Rock, Lmin= Pa / (m * τ_{gs} * π * da) = 77.5 cm

Design embedded length of anchor in Rock, L= 180 cm

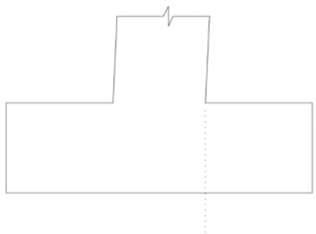
Bond of Grout and Rock Check :

Anchor Hole Diameter, Dh = 7.5 cm

Resisting bond force of the Grout and Rock, $F\tau_{gr} = \tau_{gr} * L * Dh * \pi =$	38170	kg	>	19466	OK

Structural Design of Pad:

Longitudinal Rebar:



Moment Control Section For Pad

Compression Stress at section of Max. bending moment, σm = 6.66 kg/cm2

Mu = 361269 kg.cm = 36127 N.m

Effective Depth, dp = hp - cp = 0.625 m

$K = Mu / f'c * bp * dp^2 =$ 0.00578 < 0.167 OK

Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp

Z max = 621.80 > 593.75 ==>>> Zmax=0.95 dp = 593.75 mm

As = Mu / φs * fyr * z = 146

ρmin = 0.26*(0.3*(f'c^(2/3))/Fyr > 0.0013 >>> 0.0013 EN 1992-1-1:2004 9.1N

ρmax = 0.040 EN 1992-1-1:2004 9.2.1.1

As min = 1092 mm2

As max = 33600 mm2

As = 1092

Rebar Diameter = 16 mm =====> QTY = 6 =====> 6 =====> 6 Ø 16

Rebar Quantity = 6

Rebar Spacing = 21.0

===> As= 1206 mm2

One Way Shear:

Compression Stress at critical section of shear , σv = 7.23 kg/cm2

Vu = -27035 kg = -270355 N Not defined since Theorical shear check distance is more than pad width!

k = 1 +(200/dp)^0.5 < 2.0 >>> k = 1.57 EN 1992-1-1:2004 6.2

ρ_1 = 0.0016

$\sigma_{cp} = N_{ED}/A_C$ = 0 No Axial Force!

$C_{Rd,c} = 0.18/\gamma_c$ = 0.12

k1 = 0.15

$v_{min} = 0.035 * k^{3/2} * f'c^{1/2}$ = 0.250 Mpa EN 1992-1-1:2004 6.3N

Vr = 187783 N

Vr	>	Vu	OK

F.S= Not Defined!

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 6.38 kg/cm2

Vpunch = -425374 kg = -4253742 N

Resisting Shear of Concrete,

Vr = 1604600 N

Vr	>	Vu	OK

F.S. = Not Defined!
Theorical shear check section distance is more than pad width!

Structural Design of Chimney:

Design of Longitudinal Reinforcement for Uplift :

A) Moment at the bottom of chimney about x axis

Mx max = 0.57 ton.m = 5691 N.m

Rebar arrangement:

No. of Rebar rows, n = 3

Total No. of Rebars = 8

Distance of the last row to center, c = 22.5 cm

Σ Ai * di^2 = 3037.5

φs * fy = M * c /I >>>>> Σ Ai * di^2= M * c / φs * fyr

>>>>> A = M * c / (φs * fyr *Σ di^2)

As1= 0.8 cm2

B) Moment at the bottom of chimney about y axis

My max = 0.46 ton.m = 4557 N.m

>>>>> A = M * c / (φs * fyr *Σdi2)

As2= 0.6 cm2

C) Axial required rebar area, As3 = Ts / (φs*Fys) = 9.3 cm2

How Much of Uplift Force to be considered = 50 % of Uplift force is considered because Long Stub transfers 50 % of the force itself!

Total Longitudinal rebar area Ast =As1+As2+As3 = 10.7 cm2

As min = max (0.1*Cs/Fy , 0.002*Ac) = 7.2 cm2 9.12 N

As max = 0.04 *Ac = 144.0 cm2 9.5.2.3

As = 10.7

Rebar Diameter = 16 mm =====> QTY = 6 =====> 8 =====> 8 Ø 16

===>> As final= 16.1 cm2

Rebar Quantity of One Row = 3

Rebar Spacing = 22.5

Check for Compression :

$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a <= 1$ EN 1992-1-1:2004 5.39

$M_{Ed,x} = M_{0Ed,x} + e * N_{Ed} > e_0 * N_{Ed}$

$e = l_0 /400 = 2*(hc)/400 =$ 4.5 mm

$N_{Ed} =$ 89.08 ton

$M_{0Ed, x} =$ 0.91 ton.m

$e_0 = h /30 > 20$ mm ==> $e_0 =$ 20 mm

$M_{Ed,x}$ =	1.78	ton.m

$M_{Ed,y} = M_{0Ed,y} + e * N_{Ed} > e_0 * N_{Ed}$

$M_{0Ed,y}$=	0.04	ton.m
$M_{Ed,y}$ =	1.78	ton.m
As * F yr / bc^2 * f'c =	0.112	
N_{ED}/ f'c * bc^2 =	0.121	
d2 =	131	mm
d2 / bc =	0.22	

Interaction Chart Gives ===> MRd / f'c * bc3 = 0.075 ===> $M_{Rd,x} = M_{Rd,y}$ = 33.03 ton.m

N_{Rd} = Ac * f'c + As * Fyr = 557.62 ton

N_{Ed} / N_{Rd} = 0.16 ===> a = 1.05

$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a$ = 0.093 < 1 OK

Stirrup Rebar : EN 1992-1-1:2004 9.5.3.3

Max Spacing of links =	320	mm	
Rebar Space =	150	mm	==>> Ø8 @ 150 mm
Link Rebar Diameter =	8	mm	

Soil Type: Type 2-Deleterious Rock
Foundation Type: Rock Anchor
Tower Type: 12B-LC

Maximum Loads on Stub				
Description	*Load Combination*	*Stub Force Components*		
		Shear Force Transversal component	*Shear Force Longitudinal component*	*Axial force*
		kg	kg	kg
Maximum Axial Force, Compression	0° C5,C NA+	44	905	-80,978
Maximum Axial Force, Uplift	0° C5, Min. WS,C NA+	455	568	71,478

Maximum Loads on Foundation				
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	0° C5,C NA+	-12,480	13,429	-78,881
Maximum Axial Force, Uplift	0° C5, Min. WS,C NA+	-10,616	11,638	69,725

Design Standard: EN 1992:2004

Inputs:

Factor of Safety for Loads F.S.= 1.1 Tech. Spec. Clause 2.5.3.4

Foundation Dimensions	Width of Pad	bp =	1.4	m	
	Height of Pad	hp =	0.7	m	
	Width of Chimney	bc =	0.6	m	
	Height of Chimney above ground level	hc1 =	0.3	m	
	Height of Chimney under ground level	hc2 =	0.6	m	
	Total Height of Chimney	hc =	0.9	m	
	Depth of Pad	H =	1.3	m	
	Inplane Slope	β =	9.02	Degree	
	Eccentricity (Bottom of Pad)	e =	0.25	m	
Soil Specifications	Soil Type	Type 2-Deleterious Rock			
	Density	γ_s =	2.04	ton/m3	Tech. Spec. Section C1 4.1
	Bearing Capacity	q_{all} =	5.10	kg/cm2	Tech. Spec. Section C1 4.1
Concrete	Compressive Strength(28 days of Cylindrical Sample)	f 'c =	20	Mpa	
	Strength Reduction Factor	φc =	0.67		Tech. Spec. Section C1 3.2.2
	Allowable Compressive Strength	f 'c =	13.33	Mpa	
	Density	γ_c =	2.5	ton/m3	
	Pad Cover Thickness	cp=	0.075	m	
	Chimney Cover Thickness	cc=	0.075	m	
Steel	Yield Strength of Rebar	Fy =	500	Mpa	
	Strength Reduction Factor	φs =	0.83		Tech. Spec. Section C1 3.2.2
Bond Stress	Grout and Steel Bond Stress	τ_{gs} =	2	Mpa	Ref. Pile Design in Construction Practice by Tomlinson Page 217
	Grout and Rock Bond Stress	τ_{gr} =	0.6	Mpa	Ref. Pile Design in Construction Practice by Tomlinson Table 6.1
	Concrete and Rebar Bond Stress	τ_{cr} =	2.3	Mpa	EN 50341 2012 Table K.2

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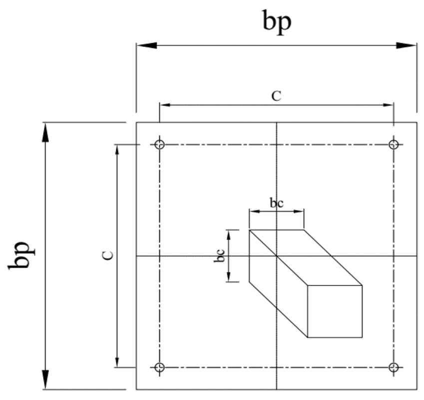
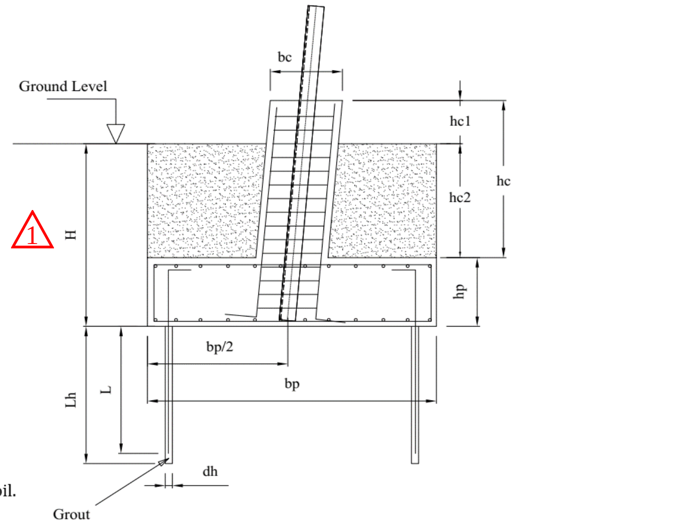




1 * The foundation is in direct contact with undisturbed soil.

Ultimate Loads:

On Foundation	Compression	C =	86.77	ton
		Vcx =	-13.73	ton
		Vcy =	14.77	ton
	Tension	T =	76.70	ton
		Vtx =	-11.68	ton
		Vty =	12.80	ton

On Stub	Compression	Cs =	89.08	ton
		Vscx =	0.05	ton
		Vscy =	1.00	ton
	Tension	Ts =	78.63	ton
		Vstx =	0.50	ton
		Vsty =	0.62	ton

Design of Anchors:

Volume of chimney above ground level V1 = 0.11 m3
Volume of chimney under ground level V2 = 0.22 m3
Volume of pad, V3 = 1.37 m3
Total volume of foundation , Vf = 1.70 m3

Total weight of foundation, Wf = Vf * γc = 4.24 ton

Uplift Force, U = 76.70 ton

Design force for anchors, U net = U - Wf = 72.46 ton

Required anchor area for uplift, Asu = U net / (φs * Fy) = 17.06 cm2

Anchor arrangement:

No. of anchor rows, n = 2 Distance from hole center to pad edge = 0.25 m

Central Holes to be Ommited = No

Total No. of anchors holes, i = 4

Distance between anchor rows C = 90.0 cm

Distance of the last row to center, c = 45 cm

Σ di ^{2} = 8100

Anchor diameter, da = 2.0 cm

No. of Anchor in one hole m = 2 The effect of rebars boundle on embedded lenghts would be considered!

Total anchor area in one hole = 6.28 cm

Total area of anchors, As =	25.13	cm2	>	17.06	OK

Uplift Force, T = 76.72 ton
Bending Moment about x axis, Mx = 1.00 ton.m
Bending Moment about y axis, My = 0.80 ton.m

Required Modulus of Section at x direction Wx = Mx / (φs * Fy) = 23.53 cm3
Required Modulus of Section at y direction Wy = My / (φs * Fy) = 18.84 cm3

Required anchor area for bending moment about x axis, Asmx = n * m * Wx * c / (Σ di ^{2}) = 0.52 cm2

Required anchor area for bending moment about y axis, Asmy = n* m * Wy * c / (Σ di ^{2}) = 0.42 cm2

Total Required Area for Anchors, Astot = Asu + Asmx + Asmy =	18.00	cm2	<	25.13	OK

Bearing Capacity:

Compression Force, C = 86.92 ton
Bending Moment about x axis, Mx = 1.59 ton.m
Bending Moment about y axis, My = 0.08 ton.m

Over Load of Concrete, Wf = 4.24 ton

Volume of the Soil directly above foundation Vsl = (H * bp ^{2}) - V2 - V3 = 0.96 m3

Over Load of Soil directly above foundation Wsl= Vsl * γs = 1.96 ton

Overall Bearing Pressure = σp = ((C + Wf + Wsl)/A) =	4.75	kg/cm2	<	5.10	kg/cm2	OK

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) + (6*My)/(bp3) =$ 5.12 kg/cm2

Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) - (6*My)/(bp3) =$ 5.08 kg/cm2

Compression Stress at corner 3, $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) + (6*My)/(bp3) =$ 4.42 kg/cm2

Compression Stress at corner 4, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) - (6*My)/(bp3) =$ 4.39 kg/cm2

Max. Toe Pressure =	5.12	<	q_{all} =	6.37	OK
Min. Toe Pressure =	4.39	>	0		OK

Bond of Anchor and Grout Check :

Max. force of one anchor hole Pa = 19114 kg

Required embedded length of anchor in Rock, $L_{min} = Pa / (m * \tau_{gs} * \pi * da) =$ 76.1 cm

Design embedded length of anchor in Rock, L= 250 cm

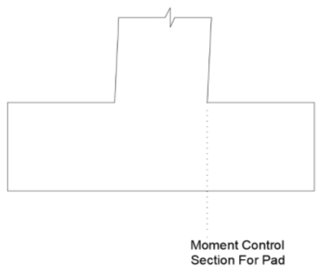
Bond of Grout and Rock Check :

Anchor Hole Diameter, Dh = 7.5 cm

Resisting bond force of the Grout and Rock, $F\tau_{gr} = \tau_{gr} * L * Dh * \pi =$	35343	kg	>	19114	OK

Structural Design of Pad:

Longitudinal Rebar:



Compression Stress at section of Max. bending moment, σm = 4.90 kg/cm2

Mu = 549986 kg.cm = 54999 N.m

Effective Depth, dp = hp - cp = 0.625 m

$K = Mu / f'c * bp * dp^2 =$ 0.00754 < 0.167 OK

Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp

Z max = 620.81 > 593.75 ==>>> Zmax=0.95 dp = 593.75 mm

As = Mu / φs * fyr * z = 222

ρmin = 0.26*(0.3*(f'c^(2/3))/Fyr > 0.0013 >>> 0.0013 EN 1992-1-1:2004 9.1N

ρmax = 0.040 EN 1992-1-1:2004 9.2.1.1

As min = 1274 mm2

As max = 39200 mm2

As = 1274

Rebar Diameter = 16 mm =====> QTY = 7 =====> 7 =====> 7 Ø 16

Rebar Quantity = 7

Rebar Spacing = 20.8

===> As= 1407 mm2

One Way Shear:

Compression Stress at critical section of shear , σv = 5.21 kg/cm2

Vu = -15854 kg = -158537 N Not defined since Theorical shear check distance is more than pad width!

k = 1 +(200/dp)^0.5 < 2.0 >>> k = 1.57 EN 1992-1-1:2004 6.2

ρ_1 = 0.0016

$\sigma_{cp} = N_{ED}/A_C =$ 0 No Axial Force!

$C_{Rd,c} = 0.18/\gamma_c =$ 0.12

k1 = 0.15

$v_{min} = 0.035 * k^{3/2} * f'c^{1/2} =$ 0.250 Mpa EN 1992-1-1:2004 6.3N

Vr = 219080 N

Vr	>	Vu	OK

F.S= Not Defined!

MİTAŞ ENERGY

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 4.75 kg/cm2

Vpunch = -292005 kg = -2920052 N

Resisting Shear of Concrete,

Vr = 1604600 N

Vr	>	Vu	OK

F.S. = Not Defined!
Theorical shear check section distance is more than pad width!

Structural Design of Chimney:

Design of Longitudinal Reinforcement for Uplift :

A) Moment at the bottom of chimney about x axis

Mx max = 0.57 ton.m = 5691 N.m

Rebar arrangement:

No. of Rebar rows, n = 3

Total No. of Rebars = 8

Distance of the last row to center, c = 22.5 cm

Σ Ai * di^2 = 3037.5

φs * fy = M * c /I >>>>> Σ Ai * di^2= M * c / φs * fyr

>>>>> A = M * c / (φs * fyr *Σ di^2)

As1= 0.8 cm2

B) Moment at the bottom of chimney about y axis

My max = 0.46 ton.m = 4557 N.m

>>>>> A = M * c / (φs * fyr *Σdi2)

As2= 0.6 cm2

C) Axial required rebar area, As3 = Ts / (φs*Fys) = 9.3 cm2

How Much of Uplift Force to be considered = 50 % of Uplift force is considered because Long Stub transfers 50 % of the force itself!

Total Longitudinal rebar area Ast =As1+As2+As3 = 10.7 cm2

As min = max (0.1*Cs/Fy , 0.002*Ac) = 7.2 cm2 9.12 N

As max = 0.04 *Ac = 144.0 cm2 9.5.2.3

As = 10.7

Rebar Diameter = 16 mm =====> QTY = 6 =====> 8 =====> 8 Ø 16

===>> As final= 16.1 cm2

Rebar Quantity of One Row = 3

Rebar Spacing = 22.5

Check for Compression :

$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a <= 1$ EN 1992-1-1:2004 5.39

$M_{Ed,x} = M_{0Ed,x} + e * N_{Ed} > e_0 * N_{Ed}$

$e = l_0 /400 = 2*(hc)/400 =$ 4.5 mm

N_{Ed} = 89.08 ton

$M_{0Ed,x}$ = 0.91 ton.m

$e_0 = h /30 > 20$ mm ==> e_0 = 20 mm

$M_{Ed,x}$ = 1.78 ton.m

$M_{Ed,y} = M_{0Ed,y} + e * N_{Ed} > e_0 * N_{Ed}$

$M_{0Ed,y}$= 0.04 ton.m

$M_{Ed,y}$ = 1.78 ton.m

$As * F yr / bc^2 * f'c$ = 0.112

$N_{ED} / f'c * bc^2$ = 0.121

d2 = 131 mm

d2 / bc = 0.22

Interaction Chart Gives ===> MRd / f'c * bc3 = 0.075 ===> $M_{Rd,x} = M_{Rd,y}$ = 33.03 ton.m

$N_{Rd} = Ac * f'c + As * Fyr$ = 557.62 ton

N_{Ed} / N_{Rd} = 0.16 ===> a = 1.05

$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a$ = 0.093 < 1 OK

Stirrup Rebar : EN 1992-1-1:2004 9.5.3.3

Max Spacing of links = 320 mm
Rebar Space = 150 mm ==>> Ø8 @ 150 mm
Link Rebar Diameter = 8 mm

Soil Type: Type 2-Deleterious Rock
Foundation Type: Semi-Auger
Tower Type: 12B-LC

Maximum Loads on Stub				
Description	*Load Combination*	*Stub Force Components*		
		Shear Force Transversal component	*Shear Force Longitudinal component*	*Axial force*
		kg	kg	kg
Maximum Axial Force, Compression	0° C5,C NA+	44	905	-80,978
Maximum Axial Force, Uplift	0° C5, Min. WS,C NA+	455	568	71,478

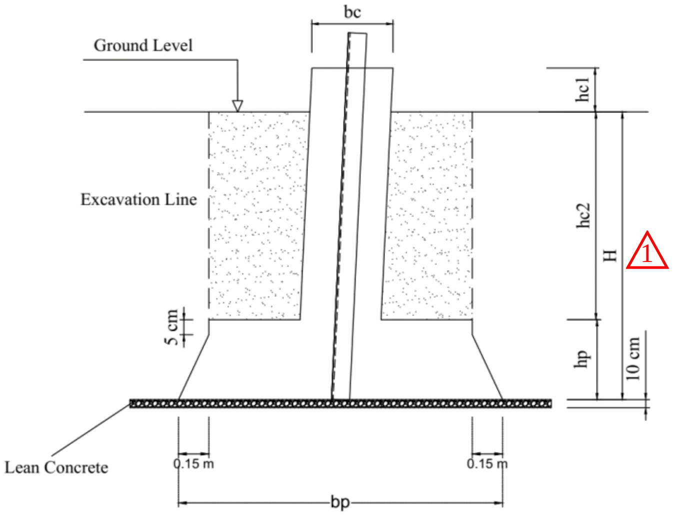
Maximum Loads on Foundation				
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	0° C5,C NA+	-12,480	13,429	-78,881
Maximum Axial Force, Uplift	0° C5, Min. WS,C NA+	-10,616	11,638	69,725

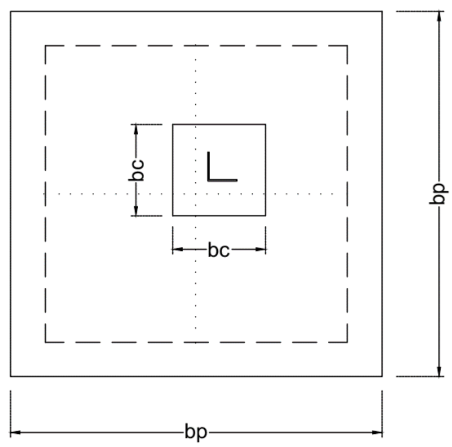
Design Standard: EN 1992:2004

Inputs:

Factor of Safety for Loads F.S.= 1.1 (As per Technical Specifications)

	Width of Pad	bp =	1.8	m	
	Height of Pad	hp =	0.4	m	
	Width of Chimney	bc =	0.7	m	
	Height of Chimney above ground level	hc1 =	0.3	m	
	Height of Chimney unedr ground level	hc2 =	3	m	
	Depth of Pad	H =	3.4	m	
	Inplane Slope	β =	9.02	Degree	
	Diagonal Slope	γ =	12.63	Degree	
Soil Specifications	Soil Type	Type 2-Deleterious Rock			
	Natural Soil Density	γ_s =	2.04	ton/m3	
	Backfill Density	γ_b =	2.04	ton/m3	Tech. Spec. Section C1 4.1
	Bearing Capacity	q_{all} =	5.10	kg/cm2	Tech. Spec. Section C1 4.1
	Frustum Angle	Θ =	25	Degree	
	Internal Friction Angle	ϕ =	35	Degree	EN 50341 Table M.4
	Friction Coefficient Between Soil and Concrete	μ =	0.4		
Concrete	Compressive Strength(28 days of Cylindrical Sample)	f 'c =	20	Mpa	
	Strength Reduction Factor	φc =	0.67		Tech. Spec. Section C1 3.2.2
	Allowable Compressive Strength	f 'c =	13.3	Mpa	
	Density	γ_c =	2.5	ton/m3	
	Pad Cover Thickness	cp=	0.075	m	
	Chimney Cover Thickness	cc=	0.075	m	
Steel	Yield Strength of Rebars	Fyr =	500	Mpa	
	Strength Reduction Factor	φs =	0.83		Tech. Spec. Section C1 3.2.2





* The foundation is in direct contact with undisturbed soil. 1

MİTAŞ ENERGY

Ultimate Loads:

On Foundation	Compression	C =	86.77	ton
		Vcx =	-13.73	ton
		Vcy =	14.77	ton
	Uplift	T =	76.70	ton
		Vtx =	-11.68	ton
		Vty =	12.80	ton

On Stub	Compression	Cs =	89.08	ton
		Vscx =	0.05	ton
		Vscy =	1.00	ton
	Uplift	Ts =	78.63	ton
		Vstx =	0.50	ton
		Vsty =	0.62	ton

Soil Passive Pressure Coefficient $Kp = \tan 2\,(45+\varphi/2) =$ 3.69
Passive Force on chimney, $Fp1 =$ 23.70 ton
Passive Force on pad, $Fp2 =$ 17.33 ton

Uplift:

Volume of chimney above ground level $V1 =$ 0.15 m3
Volume of chimney under ground level $V2 =$ 1.47 m3
Volume of pad, $V3 =$ 1.09 m3
Total volume of foundation , $Vf =$ 2.71 m3

Total weight of foundation, $Wf = Vf * \gamma c =$ 6.77 ton

Cone volume, $Vcone = (H/3)*(\pi*H^2*\tan^2\Theta + 3*bp^2 + 6*bp*H*\tan\theta) =$ 39.37 m3

Soil volume above foundation, $Vsoil = Vcone - V2 - V3 =$ 36.81 m3
Soil weight above foundation, $Ws = Vsoil * \gamma b =$ 75.05 ton

Total resistance force against uplift, $Ru = Ws + Wf =$ 81.82 ton
Uplift Force, $U =$ 76.70 ton

81.82	>	76.70	OK	S.F.= 1.07

Bearing Capacity:

Compression Force, $C =$ 86.92 ton
Bending Moment about x axis, $Mx =$ -3.73 ton.m
Bending Moment about y axis, $My =$ 0.18 ton.m

Over Load of Concrete Wf= 6.77 ton

Volume of the Soil directly above foundation $Vsl = (H * bp^2) - V2 - V3 =$ 8.46 m3

Over Load of Soil directly above foundation $Wsl = Vsl * \gamma b =$ 17.24 ton

Average Bearing Pressure = $\sigma p = ((C + Wf + Wsl)/A) =$	3.42	kg/cm2	<	5.10	kg/cm2	OK

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 3.06 kg/cm2
Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 3.02 kg/cm2
Compression Stress at corner 3, $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 3.83 kg/cm2
Compression Stress at corner 4, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 3.79 kg/cm2

Max. Toe Pressure =	3.83	<	q_{all} =	6.37	OK	S.F.= 1.67
Min. Toe Pressure =	3.02	>		0	OK	

Top Surface Pressure due to Uplift:

Uplift Force, $T =$ 76.72 ton
Bending Moment about x axis, $Mx =$ -2.09 ton.m
Bending Moment about y axis, $My =$ 1.67 ton.m

Pressure due to Uplift at top surface at corner 1, $\sigma u1 = ((T-Wf)/A) + (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 2.12 kg/cm2
Pressure due to Uplift at top surface at corner 2, $\sigma u2 = ((T-Wf)/A) + (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 1.77 kg/cm2
Pressure due to Uplift at top surface at corner 3, $\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 2.55 kg/cm2
Pressure due to Uplift at top surface at corner 4, $\sigma u4 = ((T-Wf)/A) - (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 2.20 kg/cm2

Overturning:

Overturning Moment, Mo= Ts * ((((bp/3)+((hp) * tan β)*cos β) + (Vstmax * (((hc1+hc2+hp)/cos β)- (((bp/3)+(hp) * tan β)* sin β))

Mo = 53.80 ton.m

Resisting Moment, Mr = (Ws/2)*(5*bp/6)+Wf*(bp/3)

Mr = 60.35 ton.m

Mr	>	Mo	OK

S.F.= 1.12

Sliding:

Sliding force, Fo = Vmax

Sliding force, Fo = 12.80 ton

Effective weight of foundation and soil at uplift case, Weff = 5.12 ton

Resisting force, Fr = Weff * μ + Fp1 + Fp2 =

Fr = 43.08

Fr	>	Fo	OK

S.F.= 3.37

Structural Design of Pad:

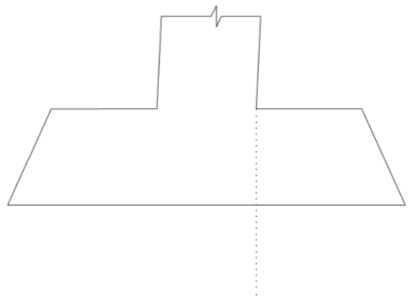
Longitudinal Rebar:

Compression :

Compression Stress at section of Max. bending moment at Pad , σmc = 3.57 kg/cm2

Uplift :

Compression Stress at section of Max. bending moment at Pad , σmu = 2.24 kg/cm2



Max. bending moment at Pad, **(Compression)**

Muc = 848782 kg.cm = 83266 N.m

Max. bending moment at Pad, **(Uplift)**

Muu = 634394 kg.cm = 62234 N.m

Effective Depth of pad , dp = hp - cp = 0.325 m

Compression :

K = Mu /f 'c * bp *dp^2 = 0.033 < 0.167 OK

Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp

Z max = 315.3 > 308.75 ==>>> Zmax=0.95 dp = 308.75

As = Mu / φs * fyr * z = 647.2 mm2

Uplift :

K = Mu /f 'c * bp *dp^2 = 0.025

Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp

Z max = 317.8 > 308.75 ==>>> Zmax=0.95 dp = 308.75

As = Mu / φs * fyr * z = 483.8 mm2

Top of Pad :

As2t= 483.8 mm2

Rebar Diameter= 12 mm =====> QTY = 5 ==>> 7 =====> 7 Ø 12 =====> 792 mm2

Rebar Quantity = 7

Rebar Spacing = 225.0 mm

Bottom of Pad :

As2b= 647.2 mm2

Rebar Diameter= 12 mm =====> QTY = 6 ==>> 8 =====> 8 Ø 12 =====> 905 mm2

Rebar Quantity = 8

Rebar Spacing = 235.7 mm

Min. Rebar Check:

Ast = 1696.5 mm2

ρst = 0.0029 >

ρmin = 0.26*(0.3*(f'c^(2/3))/Fyr > 0.0013 >>> 0.0013 EN 1992-1-1:2004 9.1N

ρmax = 0.040 EN 1992-1-1:2004 9.2.1.1

ρst > ρmin OK

ρst < ρmax OK

One Way Shear:

Compression Stress at critical section of shear at Pad , σv = 3.71 kg/cm2

Vu = 12749 kg = 127488 N

k = 1 +(200/dp2)^0.5 < 2.0 >>> k = 1.78 EN 1992-1-1:2004 6.2

ρ_1 = 0.0029

$\sigma_{cp} = N_{ED}/A_C$ = 0

$C_{Rd,c} = 0.18/\gamma_c$ = 0.12

k1 = 0.15

$v_{min} = 0.035 * k^{3/2} * f'c^{1/2}$ = 0.373 Mpa EN 1992-1-1:2004 6.3N

Vr = 225070 N

Vr	>	Vu	OK

F.S= 1.77

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 3.42 kg/cm2

To check if punch shear section is defined in Pad ==> bp1 - (bc + 4dp2) = -0.2 < 0 ==> Not Defined

Vpunch = No Defined kg = Not Defined N

Resisting Shear of Concrete,

Vr = Not Defined N

Vr	<	Vpunch	Not Defined

F.S.= Not Defined

Structural Design of Chimney:

Design of Longitudinal Reinforcement for Uplift :

A) Moment at the bottom of chimney about x axis Mx max = 2.09 ton.m = 20869 N.m

Rebar arrangement:

No. of rebars rows, n = 4

Total No. of rebars = 12

Distance of the last row to center, c = 27.5 cm

$\Sigma Ai*di^2$ = 6386.1

φs * fyr = M * c /I >>>>> $\Sigma Ai*di^2$ = M * c / φs * fyr

>>>>> A = M * c / (φs * fyr *Σdi^2)

As1= 2.5 cm2

B) Moment at the bottom of chimney about y axis My max = 1.67 ton.m = 16710 N.m

φs * fyr = M * c /I As2= 2.0 cm2

C) Axial required rebar area, As3 = Ts / (φs*Fyr) = 9.3 cm2

How Much of Uplift Force to be considered = 50 % of Uplift force is considered because Long Stub transfers 50 % of the force itself!

Total Required Longitudinal rebar area	Ast =As1+As2+As3 =		13.8	cm2			
As min =	max (0.1*Cs/Fy , 0.002*Ac) =	9.8	cm2		9.12 N		
As max =	0.04 *Ac =	196.0	cm2		9.5.2.3		
As =	13.8						
Rebar Diameter =	16 mm	=====>	QTY =	7	=====>	12	=====> 12 Ø 16
===>> As final=	24.1 cm2						
Rebar Quantity of One Row =	4						
Rebar Spacing =	18.3						

Check for Compression :

$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a <= 1$ EN 1992-1-1:2004 5.39

$M_{Ed,x} = M_{0Ed,x} + e * N_{Ed} > e_0 * N_{Ed}$

$e = l_0 /400 = 2*(hc)/400 =$	16.5	mm
$N_{Ed} =$	89.08	ton
$M_{0Ed, x} =$	3.33	ton.m
$e_0 = h /30 > 20$ mm ==> $e_0 =$	23	mm
$M_{Ed,x} =$	4.80	ton.m

$M_{Ed,y} = M_{0Ed,y} + e * N_{Ed} > e_0 * N_{Ed}$

$M_{0Ed, y} =$	0.16	ton.m
$M_{Ed,y} =$	2.08	ton.m
$As * F yr / bc^2 * f'c =$	0.123	
$N_{ED}/ f'c * bc^2 =$	0.089	
d2 =	136	mm
d2 / bc =	0.19	

Interaction Chart Gives ===> $M_{Rd} / f'c * bc^3 =$ 0.1 ===> $M_{Rd,x} = M_{Rd,y} =$ 46.62 ton.m

$N_{Rd} =$ Ac * f'c + As * Fyr = 768.47 ton

$N_{Ed} / N_{Rd} =$ 0.12 ===> a = 1.01

$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a =$ 0.143 < 1 OK

Stirrup Rebar :

Max Spacing of links =	320	mm	EN 1992-1-1:2004 9.5.3.3
Rebar Space =	150	mm	==>> Ø8 @ 150 mm
Link Rebar Diameter =	8	mm	

Soil Type: Type 3-Good Soil
Foundation Type: Semi-Auger
Tower Type: 12B-LC

Maximum Loads on Stub				
Description	*Load Combination*	*Stub Force Components*		
		Shear Force Transversal component	*Shear Force Longitudinal component*	*Axial force*
		kg	kg	kg
Maximum Axial Force, Compression	0° C5,C NA+	44	905	-80,978
Maximum Axial Force, Uplift	0° C5, Min. WS,C NA+	455	568	71,478

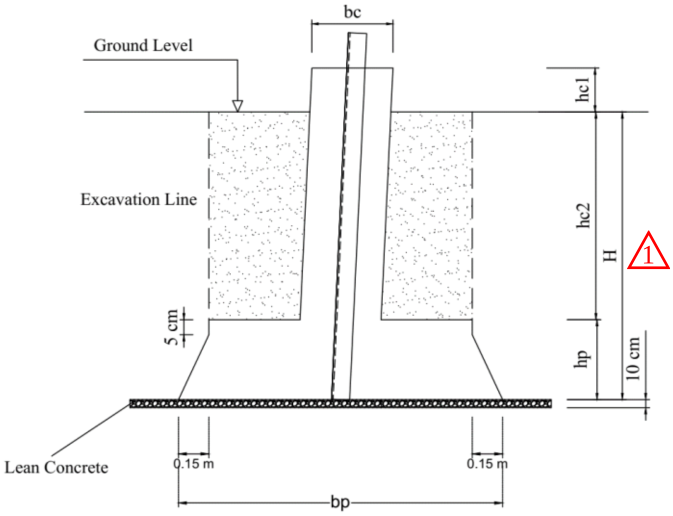
Maximum Loads on Foundation				
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	0° C5,C NA+	-12,480	13,429	-78,881
Maximum Axial Force, Uplift	0° C5, Min. WS,C NA+	-10,616	11,638	69,725

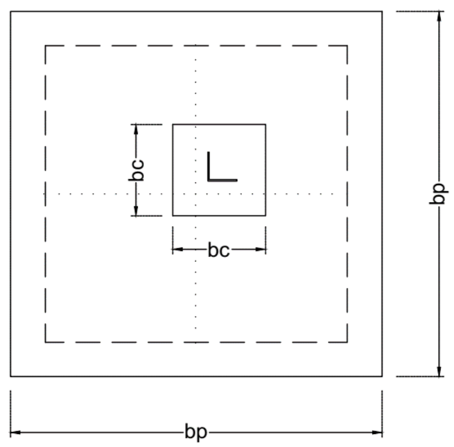
Design Standard: EN 1992:2004

Inputs:

Factor of Safety for Loads F.S.= 1.1 (As per Technical Specifications)

	Width of Pad	bp =	2.2	m	
	Height of Pad	hp =	0.4	m	
	Width of Chimney	bc =	0.7	m	
	Height of Chimney above ground level	hc1 =	0.3	m	
	Height of Chimney unedr ground level	hc2 =	3	m	
	Depth of Pad	H =	3.4	m	
	Inplane Slope	β =	9.02	Degree	
	Diagonal Slope	γ =	12.63	Degree	
Soil Specifications	Soil Type	Type 3-Good Soil			
	Natural Soil Density	γ_s =	1.73	ton/m3	
	Backfill Density	γ_b =	1.73	ton/m3	Tech. Spec. Section C1 4.1
	Bearing Capacity	q_{all} =	3.06	kg/cm2	Tech. Spec. Section C1 4.1
	Frustum Angle	Θ =	22	Degree	
	Internal Friction Angle	ϕ =	35	Degree	EN 50341 Table M.4
	Friction Coefficient Between Soil and Concrete	μ =	0.4		
Concrete	Compressive Strength(28 days of Cylindrical Sample)	f 'c =	20	Mpa	
	Strength Reduction Factor	φc =	0.67		Tech. Spec. Section C1 3.2.2
	Allowable Compressive Strength	f 'c =	13.3	Mpa	
	Density	γ_c =	2.5	ton/m3	
	Pad Cover Thickness	cp=	0.075	m	
	Chimney Cover Thickness	cc=	0.075	m	
Steel	Yield Strength of Rebars	Fyr =	500	Mpa	
	Strength Reduction Factor	φs =	0.83		Tech. Spec. Section C1 3.2.2





* The foundation is in direct contact with undisturbed soil. 1

Ultimate Loads:

On Foundation	Compression	C =	86.77	ton
		Vcx =	-13.73	ton
		Vcy =	14.77	ton
	Uplift	T =	76.70	ton
		Vtx =	-11.68	ton
		Vty =	12.80	ton

On Stub	Compression	Cs =	89.08	ton
		Vscx =	0.05	ton
		Vscy =	1.00	ton
	Uplift	Ts =	78.63	ton
		Vstx =	0.50	ton
		Vsty =	0.62	ton

Soil Passive Pressure Coefficient Kp = tan 2 (45+φ/2) = 3.69
Passive Force on chimney, Fp1 = 20.14 ton
Passive Force on pad, Fp2 = 18.01 ton

Uplift:

Volume of chimney above ground level V1 = 0.15 m3
Volume of chimney under ground level V2 = 1.47 m3
Volume of pad, V3 = 1.68 m3
Total volume of foundation , Vf = 3.30 m3

Total weight of foundation, Wf = Vf * γc = 8.25 ton

Cone volume, Vcone = $(H/3)*(\pi*H^2*\tan^2\Theta + 3*bp^2 + 6*bp*H*\tan\theta)$ = 43.73 m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 = 40.57 m3
Soil weight above foundation, Ws = Vsoil * γb = 70.31 ton

Total resistance force against uplift, Ru= Ws + Wf = 78.56 ton
Uplift Force, U= 76.70 ton

78.56	>	76.70	OK

S.F.= 1.02

Bearing Capacity:

Compression Force, C = 86.92 ton
Bending Moment about x axis, Mx = -3.73 ton.m
Bending Moment about y axis, My = 0.18 ton.m

Over Load of Concrete Wf= 8.25 ton

Volume of the Soil directly above foundation Vsl = $(H * bp^2)$ - V2 - V3 = 13.31 m3

Over Load of Soil directly above foundation Wsl= Vsl * γb = 23.06 ton

Average Bearing Pressure = σp = ((C + Wf + Wsl)/A) =	2.44	kg/cm2	<	3.06	kg/cm2	OK

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) + (6*My)/(bp^3)$ = 2.24 kg/cm2
Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) - (6*My)/(bp^3)$ = 2.22 kg/cm2
Compression Stress at corner 3, $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) + (6*My)/(bp^3)$ = 2.66 kg/cm2
Compression Stress at corner 4, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) - (6*My)/(bp^3)$ = 2.64 kg/cm2

Max. Toe Pressure =	2.66	<	q_{all} =	3.82	OK
Min. Toe Pressure =	2.22	>		0	OK

S.F.= 1.44

Top Surface Pressure due to Uplift:

Uplift Force, T = 76.72 ton
Bending Moment about x axis, Mx = -2.09 ton.m
Bending Moment about y axis, My = 1.67 ton.m

Pressure due to Uplift at top surface at corner 1, $\sigma u1 = ((T-Wf)/A) + (6*Mx)/(bp^3) + (6*My)/(bp^3)$ = 1.39 kg/cm2
Pressure due to Uplift at top surface at corner 2, $\sigma u2 = ((T-Wf)/A) + (6*Mx)/(bp^3) - (6*My)/(bp^3)$ = 1.20 kg/cm2
Pressure due to Uplift at top surface at corner 3, $\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp^3) + (6*My)/(bp^3)$ = 1.63 kg/cm2
Pressure due to Uplift at top surface at corner 4, $\sigma u4 = ((T-Wf)/A) - (6*Mx)/(bp^3) - (6*My)/(bp^3)$ = 1.44 kg/cm2

Overturning:

Overturning Moment, Mo= Ts * ((((bp/3)+((hp) * tan β)*cos β) + (Vstmax * (((hc1+hc2+hp)/cos β)- (((bp/3)+(hp) * tan β)* sin β))

Mo = 64.14 ton.m

Resisting Moment, Mr = (Ws/2)*(5*bp/6)+Wf*(bp/3)

Mr = 70.50 ton.m

Mr	>	Mo	OK

S.F.= 1.10

Sliding:

Sliding force, Fo = Vmax

Sliding force, Fo = 12.80 ton

Effective weight of foundation and soil at uplift case, Weff = 1.86 ton

Resisting force, Fr = Weff * μ + Fp1 + Fp2 =

Fr = 38.90

Fr	>	Fo	OK

S.F.= 3.04

Structural Design of Pad:

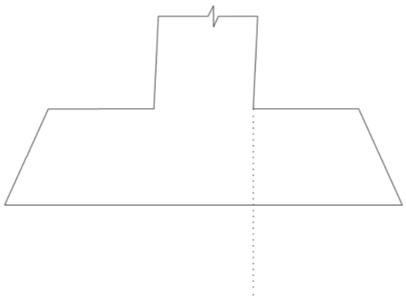
Longitudinal Rebar:

Compression :

Compression Stress at section of Max. bending moment at Pad , σmc = 2.51 kg/cm2

Uplift :

Compression Stress at section of Max. bending moment at Pad , σmu = 1.45 kg/cm2



Max. bending moment at Pad, **(Compression)**

Muc = 1290189 kg.cm = 126568 N.m

Max. bending moment at Pad, **(Uplift)**

Muu = 931665 kg.cm = 91396 N.m

Effective Depth of pad , dp = hp - cp = 0.325 m

Compression :

$K = Mu / f'c * bp * dp^2 =$ 0.041 < 0.167 OK

Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp

Z max = 312.8 > 308.75 ==>>> Zmax=0.95 dp = 308.75

As = Mu / φs * fyr * z = 983.8 mm2

Uplift :

$K = Mu / f'c * bp * dp^2 =$ 0.029

Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp

Z max = 316.3 > 308.75 ==>>> Zmax=0.95 dp = 308.75

As = Mu / φs * fyr * z = 710.4 mm2

Top of Pad :

As2t= 710.4 mm2

Rebar Diameter= 12 mm =====> QTY = 7 ==>> 8 =====> 8 Ø 12 =====> 905 mm2

Rebar Quantity = 8

Rebar Spacing = 250.0 mm

Bottom of Pad :

As2b= 983.8 mm2

Rebar Diameter= 12 mm =====> QTY = 9 ==>> 10 =====> 10 Ø 12 =====> 1131 mm2

Rebar Quantity = 10

Rebar Spacing = 227.8 mm

Min. Rebar Check:

Ast =	2035.8	mm2				
ρst =	0.0028		>			
ρmin = 0.26*(0.3*(f'c^(2/3))/Fyr > 0.0013	>>>		0.0013		EN 1992-1-1:2004	9.1N
ρmax =			0.040		EN 1992-1-1:2004	9.2.1.1
		ρst	>	ρmin	OK	
		ρst	<	ρmax	OK	

One Way Shear:

Compression Stress at critical section of shear at Pad , σv = 2.57 kg/cm2

Vu = 19563 kg = 195632 N

$k = 1 + (200/dp2)^{0.5} < 2.0$ >>> k = 1.78 EN 1992-1-1:2004 6.2

$\rho_1 =$ 0.0028

$\sigma_{cp} = N_{ED}/A_C =$ 0

$C_{Rd,c} = 0.18/\gamma_c =$ 0.12

k1 = 0.15

$v_{min} = 0.035 * k^{3/2} * f'c^{1/2} =$ 0.373 Mpa EN 1992-1-1:2004 6.3N

Vr = 273408 N

Vr	>	Vu	OK

F.S= 1.40

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 2.44 kg/cm2

To check if punch shear section is defined in Pad ==> bp1 - (bc + 4dp2) = 0.2 > 0 ==> Punch Shear to be Checked in Pad 2

Vpunch = 23124 kg = 231242 N

Resisting Shear of Concrete,

Vr = 855528 N

Vr	>	Vpunch	OK

F.S.= 3.70

Structural Design of Chimney:

Design of Longitudinal Reinforcement for Uplift :

A) Moment at the bottom of chimney about x axis Mx max = 2.09 ton.m = 20869 N.m

Rebar arrangement:

No. of rebars rows, n = 4

Total No. of rebars = 12

Distance of the last row to center, c = 27.5 cm

$\Sigma Ai*di^2 =$ 6386.1

φs * fyr = M * c /I >>>>> $\Sigma Ai*di^2 = M * c / \varphi s * fyr$

>>>>> $A = M * c / (\varphi s * fyr * \Sigma di^2)$

As1= 2.5 cm2

B) Moment at the bottom of chimney about y axis My max = 1.67 ton.m = 16710 N.m

φs * fyr = M * c /I As2= 2.0 cm2

C) Axial required rebar area, As3 = Ts / (φs*Fyr) = 9.3 cm2

How Much of Uplift Force to be considered = 50 % of Uplift force is considered because Long Stub transfers 50 % of the force itself!

Total Required Longitudinal rebar area	Ast =As1+As2+As3 =		13.8	cm2				
As min =	max (0.1*Cs/Fy , 0.002*Ac) =	9.8	cm2		9.12 N			
As max =	0.04 *Ac =	196.0	cm2		9.5.2.3			
As =	13.8							
Rebar Diameter =	16	mm	=====>	QTY =	7	=====>	12	=====> 12 Ø 16
===>> As final=	24.1	cm2						
Rebar Quantity of One Row =	4							
Rebar Spacing =	18.3							

Check for Compression :

$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a <= 1$ EN 1992-1-1:2004 5.39

$M_{Ed,x} = M_{0Ed,x} + e * N_{Ed} > e_0 * N_{Ed}$

$e = l_0 /400 = 2*(hc)/400 =$	16.5	mm
$N_{Ed} =$	89.08	ton
$M_{0Ed,x} =$	3.33	ton.m
$e_0 = h /30 > 20$ mm ==> $e_0 =$	23	mm
$M_{Ed,x} =$	4.80	ton.m

$M_{Ed,y} = M_{0Ed,y} + e * N_{Ed} > e_0 * N_{Ed}$

$M_{0Ed,y} =$	0.16	ton.m
$M_{Ed,y} =$	2.08	ton.m
$As * F yr / bc^2 * f'c =$	0.123	
$N_{ED}/ f'c * bc^2 =$	0.089	
d2 =	136	mm
d2 / bc =	0.19	

Interaction Chart Gives ===>	$M_{Rd} / f'c * bc^3 =$	0.1	===> $M_{Rd,x} = M_{Rd,y} =$	46.62	ton.m	
$N_{Rd} =$	$Ac * f'c + As * Fyr =$	768.47	ton			
$N_{Ed} / N_{Rd} =$	0.12	===>	a =	1.01		
$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a =$		0.143	<	1	OK	

Stirrup Rebar :

Max Spacing of links =	320	mm	EN 1992-1-1:2004 9.5.3.3	
Rebar Space =	150	mm		==>> Ø8 @ 150 mm
Link Rebar Diameter =	8	mm		

Soil Type: Type 3-Good Soil
Foundation Type: Pad & Chimney
Tower Type: 12B-LC

Maximum Loads on Stub				
Description	*Load Combination*	*Stub Force Components*		
		Shear Force Transversal component	*Shear Force Longitudinal component*	*Axial force*
		kg	kg	kg
Maximum Axial Force, Compression	0° C5,C NA+	44	905	-80,978
Maximum Axial Force, Uplift	0° C5, Min. WS,C NA+	455	568	71,478

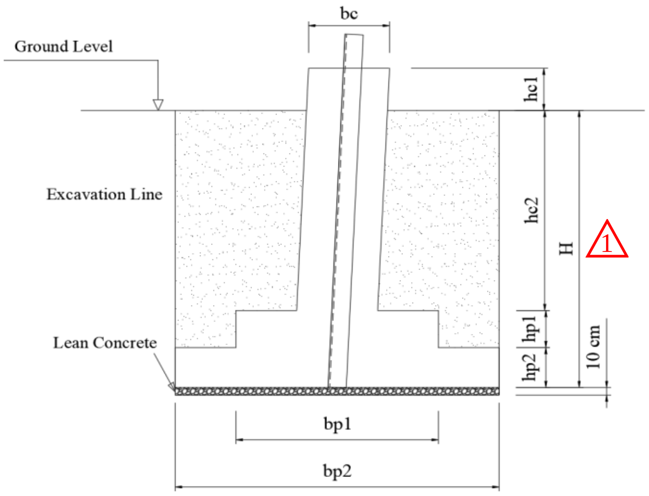
Maximum Loads on Foundation				
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	0° C5,C NA+	-12,480	13,429	-78,881
Maximum Axial Force, Uplift	0° C5, Min. WS,C NA+	-10,616	11,638	69,725

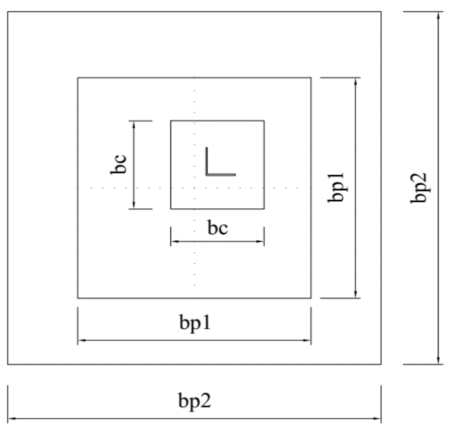
Design Standard: EN 1992:2004

Inputs:

Factor of Safety for Loads F.S.= 1.1 (As per Technical Specifications)

Foundation Dimensions	Width of Pad 1	bp1 =	1.3	m	
	Width of Pad 2	bp2 =	2.6	m	
	Height of Pad 1	hp1 =	0.25	m	
	Height of Pad 2	hp2 =	0.25	m	
	Width of Chimney	bc =	0.7	m	
	Height of Chimney above ground level	hc1 =	0.3	m	
	Height of Chimney unedr ground level	hc2 =	2.9	m	
	Depth of Pad	H =	3.4	m	
	Inplane Slope	β =	9.02	Degree	
	Diagonal Slope	γ =	12.63	Degree	
Soil Specifications	Soil Type	Type 3-Good Soil			
	Natural Soil Density	γ_s =	1.73	ton/m3	
	Backfill Density	γ_b =	1.73	ton/m3	Tech. Spec. Section C1 4.1
	Bearing Capacity	q_{all} =	3.06	kg/cm2	Tech. Spec. Section C1 4.1
	Frustum Angle	Θ =	22	Degree	
	Internal Friction Angle	ϕ =	35	Degree	EN 50341 Table M.4
	Friction Coefficient Between Soil and Concrete	μ =	0.4		
Concrete	Compressive Strength(28 days of Cylindrical Sample)	f 'c =	20	Mpa	
	Strength Reduction Factor	φc =	0.67		Tech. Spec. Section C1 3.2.2
	Allowable Compressive Strength	f 'c =	13.3	Mpa	
	Density	γ_c =	2.5	ton/m3	
	Pad Cover Thickness	cp=	0.075	m	
	Chimney Cover Thickness	cc=	0.075	m	
Steel	Yield Strength of Rebars	Fyr =	500	Mpa	
	Strength Reduction Factor	φs =	0.83		Tech. Spec. Section C1 3.2.2





Pad 1 ==> Top Pad
Pad 2 ==> Bottom Pad

1 * The foundation is in direct contact with undisturbed soil.

Ultimate Loads:

On Foundation	Compression	C =	86.77	ton
		Vcx =	-13.73	ton
		Vcy =	14.77	ton
	Uplift	T =	76.70	ton
		Vtx =	-11.68	ton
		Vty =	12.80	ton

On Stub	Compression	Cs =	89.08	ton
		Vscx =	0.05	ton
		Vscy =	1.00	ton
	Uplift	Ts =	78.63	ton
		Vstx =	0.50	ton
		Vsty =	0.62	ton

Soil Passive Pressure Coefficient	$K_p = \tan^2(45+\varphi/2) =$	3.69	
Passive Force on chimney,	Fp1 =	18.82	ton
Passive Force on pad1,	Fp2 =	6.29	ton
Passive Force on pad2,	Fp3 =	13.61	ton

Uplift:

Volume of chimney above ground level	V1 =	0.15	m3
Volume of chimney under ground level	V2 =	1.42	m3
Volume of pad1,	V3 =	0.42	m3
Volume of pad2,	V4 =	1.69	m3
Total volume of foundation ,	Vf =	3.68	m3

Total weight of foundation, $W_f = V_f * \gamma_c =$ 9.20 ton

Cone volume, $V_{cone} = (h/3)*(\pi*h^2*\tan^2\Theta + 3*bp2^2 + 6*bp2*h*\tan\theta) =$ 50.68 m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 = 48.83 m3

Soil weight above foundation, $W_s = V_{soil} * \gamma_b =$ 84.63 ton

Total resistance force against uplift, Ru= Ws + Wf = 93.83 ton

Uplift Force, U= 76.70 ton

93.83	>	76.70	OK

S.F.= 1.22

Additional condition: G/Z > 0.67 — EN 50341 M.3.1.6

G: weight of foundation and soil vertical to the base = 42.91 ton

Z: uplift force on fondation = 69.72 ton

Z/G = 0.62 >>> Ratio = 0.92 OK

Bearing Capacity:

Compression Force,	C =	86.92	ton
Bending Moment about x axis,	Mx =	-3.73	ton.m
Bending Moment about y axis,	My =	0.18	ton.m

Over Load of Concrete Wf= 9.20 ton

Volume of the Soil directly above foundation $V_{sl} = (H * bp2^2) - V2 - V3 - V4 =$ 19.45 m3

Over Load of Soil directly above foundation $W_{sl} = V_{sl} * \gamma_b =$ 33.71 ton

Average Bearing Pressure = $\sigma_p = ((C + W_f + W_{sl})/A) =$	1.92	kg/cm2	<	3.06	kg/cm2	OK

Compression Stress at corner 1,	$\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$	1.80	kg/cm2
Compression Stress at corner 2,	$\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$	1.79	kg/cm2
Compression Stress at corner 3,	$\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$	2.05	kg/cm2
Compression Stress at corner 4,	$\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$	2.04	kg/cm2

Max. Toe Pressure =	2.05	<	$q_{all} =$	3.82	OK
Min. Toe Pressure =	1.79	>		0	OK

S.F.= 1.86

Top Surface Pressure due to Uplift:

Uplift Force,	T =	76.72	ton
Bending Moment about x axis,	Mx =	-2.02	ton.m
Bending Moment about y axis,	My =	1.62	ton.m

Pressure due to Uplift at top surface at corner 1,	$\sigma u1 = ((T-Wf)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$	0.99	kg/cm2
Pressure due to Uplift at top surface at corner 2,	$\sigma u2 = ((T-Wf)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$	0.87	kg/cm2
Pressure due to Uplift at top surface at corner 3,	$\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$	1.12	kg/cm2
Pressure due to Uplift at top surface at corner 4,	$\sigma u4 = ((T-Wf)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$	1.01	kg/cm2

Overturning:

Overturning Moment, Mo= Ts * ((((bp2/3)+((hp1+hp2) * tan β)*cos β) + (Vstmax * (((hc1+hc2+hp1+hp2)/cos β)- (((bp2/3)+(hp1+hp2) * tan β)* sin β))

Mo = 75.71 ton.m

Resisting Moment, Mr = (Ws/2)*(5*bp2/6)+Wf*(bp2/3)

Mr = 99.65 ton.m

Mr	>	Mo	OK

S.F.= 1.32

Sliding:

Sliding force, Fo = Vmax

Sliding force, Fo = 12.80 ton

Effective weight of foundation and soil at uplift case, Weff = 17.13 ton

Resisting force, Fr = Weff * μ + Fp1 + Fp2 + Fp3 =

Fr = 45.57

Fr	>	Fo	OK

S.F.= 3.56

Structural Design of Pad:

Longitudinal Rebar:

Compression :

Compression Stress at section of Max. bending moment at Pad 1, σmc1 = 1.95 kg/cm2

Compression Stress at section of Max. bending moment at Pad 2, σmc2 = 1.98 kg/cm2

Uplift :

Compression Stress at section of Max. bending moment at Pad 1, σmu1 = 1.02 kg/cm2

Compression Stress at section of Max. bending moment at Pad 2, σmu2 = 1.03 kg/cm2

Max. bending moment at Pad1, **(Compression)**

Muc 1= 1776663 kg.cm = 174291 N.m

Max. bending moment at Pad2, **(Compression)**

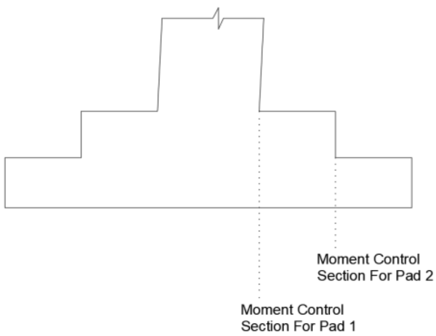
Muc 2= 813319 kg.cm = 79787 N.m

Max. bending moment at Pad1, **(Uplift)**

Muu 1= 1233215 kg.cm = 120978 N.m

Max. bending moment at Pad2, **(Uplift)**

Muu 2= 580241 kg.cm = 56922 N.m



Effective Depth of pad 1, dp1 = hp1+hp2 - cp = 0.425 m

Effective Depth of pad 2, dp2 = hp2 - cp = 0.175 m

Compression :

Pad 1:

K = Mu /f 'c * bp *dp^2 = 0.056 < 0.167 OK

Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp

Z max = 403 < 403.75 ==>>> OK

As = Mu / φs * fyr * z = 1038 mm2

Pad 2:

K = Mu /f 'c * bp *dp^2 = 0.075 < 0.167 OK

Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp

Z max = 162.5 < 166.25 ==>>> OK

As = Mu / φs * fyr * z = 1178.4 mm2

Uplift :

Pad 1:

$K = Mu / f'c * bp * dp^2 =$	0.019	<	0.167	OK			

Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp

Z max =	417.6	>	403.75	==>>>	Zmax=0.95 dp =	403.75	
As = Mu / φs * fyr * z =	719.1	mm2					

Pad 2:

$K = Mu / f'c * bp * dp^2 =$	0.054						

Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp

Z max =	166.3	>	166.25	==>>>	Zmax=0.95 dp =	166.25	
As = Mu / φs * fyr * z =	821.7	mm2					

Top of Pad 1 :										
As1t=	719.1			mm2						
Rebar Diameter=	12	mm	=====>	QTY =	7 ==>>	7	=====>	7 Ø 12	=====>	792 mm2
Rebar Quantity =	7									
Rebar Spacing =	191.7	mm								
Top of Pad 2 :										
As2t=	821.7	mm2								
Rebar Diameter=	12	mm	=====>	QTY =	8 ==>>	11	=====>	11 Ø 12	=====>	1244 mm2
Rebar Quantity =	11									
Rebar Spacing =	245.0	mm								
Bottom of Pad 2 :										
As2b=	1178.4	mm2								
Rebar Diameter=	12	mm	=====>	QTY =	11 ==>>	11	=====>	11 Ø 12	=====>	1244 mm2
Rebar Quantity =	11									
Rebar Spacing =	245.0	mm								

Min. Rebar Check:

Ast =	3279.8	mm2			
ρst =	0.0042	>			
ρmin = 0.26*(0.3*(f'c^(2/3))/Fyr > 0.0013 >>>		0.0013		EN 1992-1-1:2004 9.1N	
ρmax =		0.040		EN 1992-1-1:2004 9.2.1.1	
	ρst	>	ρmin	OK	
	ρst	<	ρmax	OK	

One Way Shear:

Compression Stress at critical section of shear at Pad1 ,		σv1 =	2.00	kg/cm2	
Vu1 =	20743	kg	=	207427	N
Compression Stress at critical section of shear at Pad2 ,		σv2 =	2.00	kg/cm2	
Vu2 =	18262	kg	=	182624	N

Pad 1

k = 1 +(200/dp1)^0.5 < 2.0	>>>	k =	1.69	EN 1992-1-1:2004	6.2
$\rho_1 =$	0.0042				
$\sigma_{cp} = N_{ED}/A_C =$	0	No Axial Force!			
$C_{Rd,c} = 0.18/\gamma_c =$	0.12				
k1 =	0.15				
$v_{min} = 0.035 * k^{3/2} * f'c^{1/2} =$	0.343	Mpa		EN 1992-1-1:2004	6.3N

Vr1 = 320918 N

Vr1	>	Vu1	OK

F.S= 1.55

Pad 2

k = 1 +(200/dp2)^0.5 < 2.0 >>> k = 2.00 EN 1992-1-1:2004 6.2

ρ_1 = 0.0055

$\sigma_{cp} = N_{ED}/A_C$ = 0

$C_{Rd,c} = 0.18/\gamma_c$ = 0.12

k1 = 0.15

$v_{min} = 0.035 * k^{3/2} * f'c^{1/2}$ = 0.443 Mpa EN 1992-1-1:2004 6.3N

Vr2 = 242393 N

Vr2	>	Vu2	OK

F.S= 1.33

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 1.92 kg/cm2

Pad 1

Vpunch1 = 22974 kg = 229742 N

Resisting Shear of Concrete,

Vr1 = 1423477 N

Vr1	>	Vpunch1	OK

F.S.= 6.20

Pad 2

To check if punch shear section is defined in Pad 2 ==> bp1 - (bp2 + 4dp2) = 0.6 > 0 ==> Punch Shear to be Checked in Pad 2

Vpunch2 = 39386 kg = 393862 N

Resisting Shear of Concrete,

Vr2 = 689806 N

Vr2	>	Vpunch2	OK

F.S.= 1.75

Structural Design of Chimney:

Design of Longitudinal Reinforcement for Uplift :

A) Moment at the bottom of chimney about x axis Mx max = 2.02 ton.m = 20236 N.m

Rebar arrangement:

No. of rebars rows, n = 4

Total No. of rebars = 12

Distance of the last row to center, c = 27.5 cm

$\Sigma Ai*di^2$ = 6386.1

$\varphi s * fyr = M * c / I$ >>>>> $\Sigma Ai*di^2 = M * c / \varphi s * fyr$

>>>>> $A = M * c / (\varphi s * fyr * \Sigma di^2)$

As1= 2.5 cm2

B) Moment at the bottom of chimney about y axis My max = 1.62 ton.m = 16204 N.m

$\varphi s * fyr = M * c / I$ As2= 2.0 cm2

C) Axial required rebar area, As3 = Ts / (φs*Fyr) = 9.3 cm2

How Much of Uplift Force to be considered = 50 % of Uplift force is considered because Long Stub transfers 50 % of the force itself!

Total Required Longitudinal rebar area Ast =As1+As2+As3 = 13.7 cm2

As min =	max (0.1*Cs/Fy , 0.002*Ac) =				9.8	cm2		9.12 N		
As max =	0.04 *Ac =				196.0	cm2		9.5.2.3		
As =	13.7									
Rebar Diameter =	16	mm	=====>	QTY =	7	=====>	12	=====>	12 Ø 16	
===>> As final=	24.1	cm2								
Rebar Quantity of One Row =	4									
Rebar Spacing =	18.3									

Check for Compression :

$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a <= 1$ EN 1992-1-1:2004 5.39

$M_{Ed,x} = M_{0Ed,x} + e * N_{Ed} > e_0 * N_{Ed}$

$e = l_0 /400 = 2*(hc)/400 =$	16	mm
$N_{Ed} =$	89.08	ton
$M_{0Ed, x} =$	3.23	ton.m
$e_0 = h /30 > 20$ mm ==> $e_0 =$	23	mm
$M_{Ed,x} =$	4.65	ton.m

$M_{Ed,y} = M_{0Ed,y} + e * N_{Ed} > e_0 * N_{Ed}$

$M_{0Ed, y} =$	0.16	ton.m
$M_{Ed,y} =$	2.08	ton.m
$As * F yr / bc^2 * f'c =$	0.123	
$N_{ED}/ f'c * bc^2 =$	0.089	
d2 =	136	mm
d2 / bc =	0.19	

Interaction Chart Gives ===> $M_{Rd} / f'c * bc^3 =$ 0.1 ===> $M_{Rd,x} = M_{Rd,y} =$ 46.62 ton.m

$N_{Rd} =$ $Ac * f'c + As * Fyr =$ 768.47 ton

$N_{Ed} / N_{Rd} =$ 0.12 ===> a = 1.01

$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a =$ 0.140 < 1 OK

Stirrup Rebar :

Max Spacing of links =	320	mm	EN 1992-1-1:2004 9.5.3.3	
Rebar Space =	150	mm		==>> Ø8 @ 150 mm
Link Rebar Diameter =	8	mm		

Soil Type:	Type 4-Normal Soil-Dry
Foundation Type:	Pad & Chimney
Tower Type:	12B-LC

Maximum Loads on Stub

Description	*Load Combination*	*Stub Force Components*		
		Shear Force Transversal component	*Shear Force Longitudinal component*	*Axial force*
		kg	kg	kg
Maximum Axial Force, Compression	0° C5,C NA+	44	905	-80,978
Maximum Axial Force, Uplift	0° C5, Min. WS,C NA+	455	568	71,478

Maximum Loads on Foundation

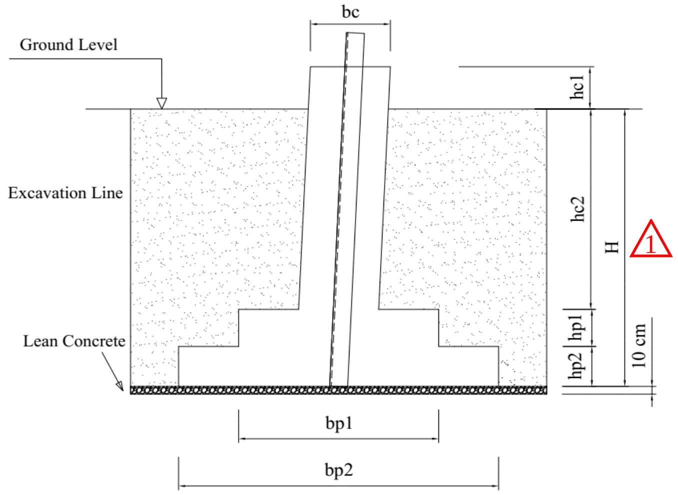
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	0° C5,C NA+	-12,480	13,429	-78,881
Maximum Axial Force, Uplift	0° C5, Min. WS,C NA+	-10,616	11,638	69,725

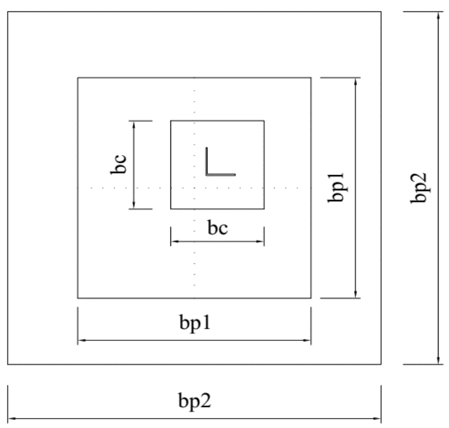
Design Standard: EN 1992:2004

Inputs:

Factor of Safety for Loads F.S.= 1.1 (As per Technical Specifications)

Foundation Dimensions	Width of Pad 1	bp1 =	1.4	m	
	Width of Pad 2	bp2 =	2.8	m	
	Height of Pad 1	hp1 =	0.25	m	
	Height of Pad 2	hp2 =	0.25	m	
	Width of Chimney	bc =	0.7	m	
	Height of Chimney above ground level	hc1 =	0.3	m	
	Height of Chimney unedr ground level	hc2 =	2.9	m	
	Depth of Pad	H =	3.4	m	
	Inplane Slope	β =	9.02	Degree	
	Diagonal Slope	γ =	12.63	Degree	
Soil Specifications	Soil Type	Type 4-Normal Soil-Dry			
	Natural Soil Density	γ_s =	1.83	ton/m3	
	Backfill Density	γ_b =	1.83	ton/m3	Tech. Spec. Section C1 4.1
	Bearing Capacity	q_{all} =	2.04	kg/cm2	Tech. Spec. Section C1 4.1
	Frustum Angle	Θ =	15	Degree	
	Internal Friction Angle	ϕ =	25	Degree	EN 50341 Table M.4
	Friction Coefficient Between Soil and Concrete	μ =	0.4		
Concrete	Compressive Strength(28 days of Cylindrical Sample)	f 'c =	20	Mpa	
	Strength Reduction Factor	φc =	0.67		Tech. Spec. Section C1 3.2.2
	Allowable Compressive Strength	f 'c =	13.3	Mpa	
	Density	γ_c =	2.5	ton/m3	
	Pad Cover Thickness	cp=	0.075	m	
	Chimney Cover Thickness	cc=	0.075	m	
Steel	Yield Strength of Rebars	Fyr =	500	Mpa	
	Strength Reduction Factor	φs =	0.83		Tech. Spec. Section C1 3.2.2





Pad 1 ==> Top Pad
Pad 2 ==> Bottom Pad

1 * The foundation is cast inside formwork.

Ultimate Loads:

On Foundation	Compression	C =	86.77	ton
		Vcx =	-13.73	ton
		Vcy =	14.77	ton
	Uplift	T =	76.70	ton
		Vtx =	-11.68	ton
		Vty =	12.80	ton

On Stub	Compression	Cs =	89.08	ton
		Vscx =	0.05	ton
		Vscy =	1.00	ton
	Uplift	Ts =	78.63	ton
		Vstx =	0.50	ton
		Vsty =	0.62	ton

Soil Passive Pressure Coefficient   Kp = tan 2 (45+φ/2) =   2.46
Passive Force on chimney,   Fp1 =   13.31   ton
Passive Force on pad1,   Fp2 =   4.79   ton
Passive Force on pad2,   Fp3 =   10.36   ton

Uplift:

Volume of chimney above ground level	V1 =	0.15	m3
Volume of chimney under ground level	V2 =	1.42	m3
Volume of pad1,	V3 =	0.49	m3
Volume of pad2,	V4 =	1.96	m3
Total volume of foundation ,	Vf =	4.02	m3

Total weight of foundation,   Wf = Vf * γc =   10.05   ton

Cone volume, $Vcone = (h/3)*(\pi*h^2*\tan^2\Theta + 3*bp2^2 + 6*bp2*h*\tan\theta) =$ 44.41   m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 =   42.50   m3
Soil weight above foundation,   Ws = Vsoil * γb =   77.98   ton

Total resistance force against uplift,   Ru= Ws + Wf =   88.03   ton
Uplift Force,   U=   76.70   ton

88.03	>	76.70	OK

S.F.= 1.15

1

Additional condition: G/Z > 0.8   EN 50341 M.3.1.6
G: weight of foundation and soil vertical to the base =   51.85   ton
Z: uplift force on fondation =   69.72   ton

Z/G =   0.74   >>>   Ratio =   0.93   OK

Bearing Capacity:

Compression Force,	C =	86.92	ton
Bending Moment about x axis,	Mx =	-3.73	ton.m
Bending Moment about y axis,	My =	0.18	ton.m

Over Load of Concrete Wf=   10.05   ton

Volume of the Soil directly above foundation $Vsl = (H * bp2^2) - V2 - V3 - V4 =$ 22.79   m3

Over Load of Soil directly above foundation   Wsl= Vsl * γb =   41.81   ton

Average Bearing Pressure = σp = ((C + Wf + Wsl)/A) =	1.77	kg/cm2	<	2.04	kg/cm2	OK

Compression Stress at corner 1,	$\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$	1.67	kg/cm2
Compression Stress at corner 2,	$\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$	1.66	kg/cm2
Compression Stress at corner 3,	$\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$	1.88	kg/cm2
Compression Stress at corner 4,	$\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$	1.87	kg/cm2

Max. Toe Pressure =	1.88	<	q_{all} =	2.55	OK
Min. Toe Pressure =	1.66	>		0	OK

S.F.= 1.36

Top Surface Pressure due to Uplift:

Uplift Force,	T =	76.72	ton
Bending Moment about x axis,	Mx =	-2.02	ton.m
Bending Moment about y axis,	My =	1.62	ton.m

Pressure due to Uplift at top surface at corner 1,	$\sigma u1 = ((T-Wf)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$	0.84	kg/cm2
Pressure due to Uplift at top surface at corner 2,	$\sigma u2 = ((T-Wf)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$	0.75	kg/cm2
Pressure due to Uplift at top surface at corner 3,	$\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$	0.95	kg/cm2
Pressure due to Uplift at top surface at corner 4,	$\sigma u4 = ((T-Wf)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$	0.86	kg/cm2

Overturning:

Overturning Moment, Mo= Ts * ((((bp2/3)+((hp1+hp2) * tan β)*cos β) + (Vstmax * (((hc1+hc2+hp1+hp2)/cos β)- (((bp2/3)+(hp1+hp2) * tan β)* sin β))

Mo = 80.88 ton.m

Resisting Moment, Mr = (Ws/2)*(5*bp2/6)+Wf*(bp2/3)

Mr = 100.35 ton.m

Mr	>	Mo	OK

S.F.= 1.24

Sliding:

Sliding force, Fo = Vmax

Sliding force, Fo = 12.80 ton

Effective weight of foundation and soil at uplift case, Weff = 11.33 ton

Resisting force, Fr = Weff * μ + Fp1 + Fp2 + Fp3 =

Fr = 32.99

Fr	>	Fo	OK

S.F.= 2.58

Structural Design of Pad:

Longitudinal Rebar:

Compression :

Compression Stress at section of Max. bending moment at Pad 1, σmc1 = 1.80 kg/cm2

Compression Stress at section of Max. bending moment at Pad 2, σmc2 = 1.82 kg/cm2

Uplift :

Compression Stress at section of Max. bending moment at Pad 1, σmu1 = 0.86 kg/cm2

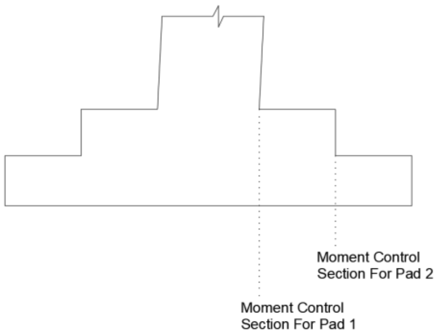
Compression Stress at section of Max. bending moment at Pad 2, σmu2 = 0.88 kg/cm2

Max. bending moment at Pad1, **(Compression)**

Muc 1= 2028809 kg.cm = 199026 N.m

Max. bending moment at Pad2, **(Compression)**

Muc 2= 876054 kg.cm = 85941 N.m



Max. bending moment at Pad1, **(Uplift)**

Muu 1= 1376771 kg.cm = 135061 N.m

Max. bending moment at Pad2, **(Uplift)**

Muu 2= 615060 kg.cm = 60337 N.m

Effective Depth of pad 1, dp1 = hp1+hp2 - cp = 0.425 m

Effective Depth of pad 2, dp2 = hp2 - cp = 0.175 m

Compression :

Pad 1:

K = Mu /f 'c * bp *dp^2 = 0.059 < 0.167 OK

Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp

Z max = 402 < 403.75 ==>>> OK

As = Mu / φs * fyr * z = 1189 mm2

Pad 2:

K = Mu /f 'c * bp *dp^2 = 0.075 < 0.167 OK

Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp

Z max = 162.5 < 166.25 ==>>> OK

As = Mu / φs * fyr * z = 1269.3 mm2

Uplift :

Pad 1:

$K = Mu / f'c * bp * dp^2 =$	0.020	<	0.167	OK			
Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp							
Z max =	417.4	>	403.75	==>>>	Zmax=0.95 dp =	403.75	
As = Mu / φs * fyr * z =	802.8	mm2					

Pad 2:

$K = Mu / f'c * bp * dp^2 =$	0.053						
Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp							
Z max =	166.4	>	166.25	==>>>	Zmax=0.95 dp =	166.25	
As = Mu / φs * fyr * z =	871.0	mm2					

Top of Pad 1 :											
As1t=	802.8	mm2									
Rebar Diameter=	12	mm	=====>	QTY =	8 ==>>	8	=====>	8 Ø 12	=====>	905	mm2
Rebar Quantity =	8										
Rebar Spacing =	178.6	mm									
Top of Pad 2 :											
As2t=	871.0	mm2									
Rebar Diameter=	12	mm	=====>	QTY =	8 ==>>	12	=====>	12 Ø 12	=====>	1357	mm2
Rebar Quantity =	12										
Rebar Spacing =	240.9	mm									
Bottom of Pad 2 :											
As2b=	1269.3	mm2									
Rebar Diameter=	12	mm	=====>	QTY =	12 ==>>	12	=====>	12 Ø 12	=====>	1357	mm2
Rebar Quantity =	12										
Rebar Spacing =	240.9	mm									

Min. Rebar Check:

Ast =	3619.1	mm2			
ρst =	0.0043		>		
ρmin = 0.26*(0.3*(f'c^(2/3))/Fyr > 0.0013	>>>		0.0013		EN 1992-1-1:2004 9.1N
ρmax =			0.040		EN 1992-1-1:2004 9.2.1.1
		ρst	>	ρmin	OK
		ρst	<	ρmax	OK

One Way Shear:

Compression Stress at critical section of shear at Pad1 ,		σv1 =	1.83	kg/cm2	
Vu1 =	23050	kg	=	230502	N
Compression Stress at critical section of shear at Pad2 ,		σv2 =	1.83	kg/cm2	
Vu2 =	18741	kg	=	187414	N

Pad 1

k = 1 +(200/dp1)^0.5 < 2.0	>>>	k =	1.69	EN 1992-1-1:2004 6.2
$\rho_1 =$	0.0043			
$\sigma_{cp} = N_{ED}/A_C =$	0	No Axial Force!		
$C_{Rd,c} = 0.18/\gamma_c =$	0.12			
k1 =	0.15			
$v_{min} = 0.035 * k^{3/2} * f'c^{1/2} =$	0.343	Mpa		EN 1992-1-1:2004 6.3N

Vr1 = 348418 N

Vr1	>	Vu1	OK

F.S= 1.51

Pad 2

k = 1 +(200/dp2)^0.5 < 2.0 >>> k = 2.00 EN 1992-1-1:2004 6.2

ρ_1 = 0.0055

$\sigma_{cp} = N_{ED}/A_C$ = 0

$C_{Rd,c} = 0.18/\gamma_c$ = 0.12

k1 = 0.15

$v_{min} = 0.035 * k^{3/2} * f'c^{1/2}$ = 0.443 Mpa EN 1992-1-1:2004 6.3N

Vr2 = 262164 N

Vr2	>	Vu2	OK

F.S= 1.40

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 1.77 kg/cm2

Pad 1

Vpunch1 = 33427 kg = 334272 N

Resisting Shear of Concrete,

Vr1 = 1435069 N

Vr1	>	Vpunch1	OK

F.S.= 4.29

Pad 2

To check if punch shear section is defined in Pad 2 ==> bp1 - (bp2 + 4dp2) = 0.7 > 0 ==> Punch Shear to be Checked in Pad 2

Vpunch2 = 42142 kg = 421419 N

Resisting Shear of Concrete,

Vr2 = 730231 N

Vr2	>	Vpunch2	OK

F.S.= 1.73

Structural Design of Chimney:

Design of Longitudinal Reinforcement for Uplift :

A) Moment at the bottom of chimney about x axis Mx max = 2.02 ton.m = 20236 N.m

Rebar arrangement:

No. of rebars rows, n = 4

Total No. of rebars = 12

Distance of the last row to center, c = 27.5 cm

$\Sigma Ai*di^2$ = 6386.1

φs * fyr = M * c /I >>>>> $\Sigma Ai*di^2$ = M * c / φs * fyr

>>>>> A = M * c / (φs * fyr *Σdi^2)

As1= 2.5 cm2

B) Moment at the bottom of chimney about y axis My max = 1.62 ton.m = 16204 N.m

φs * fyr = M * c /I As2= 2.0 cm2

C) Axial required rebar area, As3 = Ts / (φs*Fyr) = 9.3 cm2

How Much of Uplift Force to be considered = 50 % of Uplift force is considered because Long Stub transfers 50 % of the force itself!

Total Required Longitudinal rebar area Ast =As1+As2+As3 = 13.7 cm2

As min =	max (0.1*Cs/Fy , 0.002*Ac) =			9.8	cm2	9.12 N		
As max =	0.04 *Ac =			196.0	cm2	9.5.2.3		
As =	13.7							
Rebar Diameter =	16	mm	=====> QTY =	7	=====>	12	=====>	12 Ø 16
===>> As final=	24.1	cm2						
Rebar Quantity of One Row =	4							
Rebar Spacing =	18.3							

Check for Compression :

$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a <= 1$ EN 1992-1-1:2004 5.39

$M_{Ed,x} = M_{0Ed,x} + e * N_{Ed} > e_0 * N_{Ed}$

$e = l_0 /400 = 2*(hc)/400 =$	16	mm
$N_{Ed} =$	89.08	ton
$M_{0Ed, x} =$	3.23	ton.m
$e_0 = h /30 > 20$ mm ==> $e_0 =$	23	mm
$M_{Ed,x} =$	4.65	ton.m

$M_{Ed,y} = M_{0Ed,y} + e * N_{Ed} > e_0 * N_{Ed}$

$M_{0Ed, y} =$	0.16	ton.m
$M_{Ed,y} =$	2.08	ton.m
$As * F yr / bc^2 * f'c =$	0.123	
$N_{ED}/ f'c * bc^2 =$	0.089	
d2 =	136	mm
d2 / bc =	0.19	

Interaction Chart Gives ===> $M_{Rd} / f'c * bc^3 =$ 0.1 ===> $M_{Rd,x} =M_{Rd,y} =$ 46.62 ton.m

$N_{Rd} =$ $Ac * f'c + As * Fyr =$ 768.47 ton

$N_{Ed} / N_{Rd} =$ 0.12 ===> a = 1.01

$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a =$ 0.140 < 1 OK

Stirrup Rebar :

Max Spacing of links =	320	mm	EN 1992-1-1:2004 9.5.3.3
Rebar Space =	150	mm	==>> Ø8 @ 150 mm
Link Rebar Diameter =	8	mm	

Soil Type: Type 4-Normal Soil-Submerge
Foundation Type: Pad & Chimney
Tower Type: 12B-LC

Maximum Loads on Stub				
Description	*Load Combination*	*Stub Force Components*		
		Shear Force Transversal component	*Shear Force Longitudinal component*	*Axial force*
		kg	kg	kg
Maximum Axial Force, Compression	0° C5,C NA+	44	905	-80,978
Maximum Axial Force, Uplift	0° C5, Min. WS,C NA+	455	568	71,478

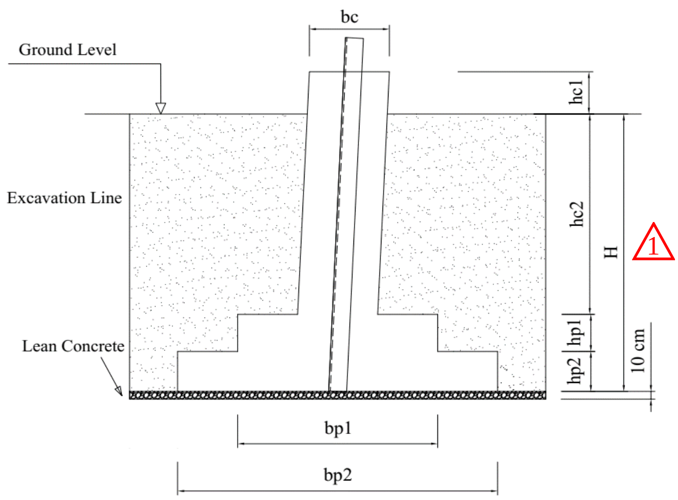
Maximum Loads on Foundation				
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	0° C5,C NA+	-12,480	13,429	-78,881
Maximum Axial Force, Uplift	0° C5, Min. WS,C NA+	-10,616	11,638	69,725

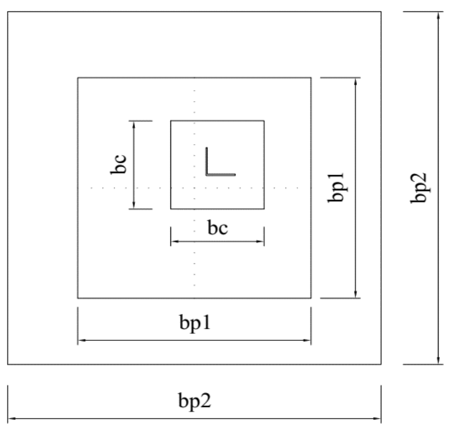
Design Standard: EN 1992:2004

Inputs:

Factor of Safety for Loads F.S.= 1.1 (As per Technical Specifications)

Foundation Dimensions	Width of Pad 1	bp1 =	1.8	m	
	Width of Pad 2	bp2 =	3.75	m	
	Height of Pad 1	hp1 =	0.25	m	
	Height of Pad 2	hp2 =	0.25	m	
	Width of Chimney	bc =	0.7	m	
	Height of Chimney above ground level	hc1 =	0.3	m	
	Height of Chimney unedr ground level	hc2 =	2.9	m	
	Depth of Pad	H =	3.4	m	
	Inplane Slope	β =	9.02	Degree	
	Diagonal Slope	γ =	12.63	Degree	
Soil Specifications	Soil Type	Type 4-Normal Soil-Submerge			
	Natural Soil Density	γ_s =	1.02	ton/m3	
	Backfill Density	γ_b =	1.02	ton/m3	Tech. Spec. Section C1 4.1
	Bearing Capacity	q_{all} =	2.04	kg/cm2	Tech. Spec. Section C1 4.1
	Frustum Angle	Θ =	15	Degree	
	Internal Friction Angle	ϕ =	25	Degree	EN 50341 Table M.4
	Friction Coefficient Between Soil and Concrete	μ =	0.4		
Concrete	Compressive Strength(28 days of Cylindrical Sample)	f 'c =	20	Mpa	
	Strength Reduction Factor	φc =	0.67		Tech. Spec. Section C1 3.2.2
	Allowable Compressive Strength	f 'c =	13.3	Mpa	
	Density	γ_c =	1.4	ton/m3	
	Pad Cover Thickness	cp=	0.075	m	
	Chimney Cover Thickness	cc=	0.075	m	
Steel	Yield Strength of Rebars	Fyr =	500	Mpa	
	Strength Reduction Factor	φs =	0.83		Tech. Spec. Section C1 3.2.2





Pad 1 ==> Top Pad
Pad 2 ==> Bottom Pad

1 * The foundation is cast inside formwork.

Ultimate Loads:

On Foundation	Compression	C =	86.77	ton
		Vcx =	-13.73	ton
		Vcy =	14.77	ton
	Uplift	T =	76.70	ton
		Vtx =	-11.68	ton
		Vty =	12.80	ton

On Stub	Compression	Cs =	89.08	ton
		Vscx =	0.05	ton
		Vscy =	1.00	ton
	Uplift	Ts =	78.63	ton
		Vstx =	0.50	ton
		Vsty =	0.62	ton

Soil Passive Pressure Coefficient	Kp = tan 2 (45+φ/2) =	2.46	
Passive Force on chimney,	Fp1 =	7.39	ton
Passive Force on pad1,	Fp2 =	3.42	ton
Passive Force on pad2,	Fp3 =	7.71	ton

Uplift:

Volume of chimney above ground level	V1 =	0.15	m3
Volume of chimney under ground level	V2 =	1.42	m3
Volume of pad1,	V3 =	0.81	m3
Volume of pad2,	V4 =	3.52	m3
Total volume of foundation ,	Vf =	5.89	m3

Total weight of foundation, Wf = Vf * γc = 8.25 ton

Cone volume, $V_{cone} = (h/3)*(\pi*h^2*\tan^2\Theta + 3*bp2^2 + 6*bp2*h*\tan\theta) =$ 70.25 m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 = 68.02 m3

Soil weight above foundation, Ws = Vsoil * γb = 69.34 ton

Total resistance force against uplift, Ru= Ws + Wf = 77.59 ton

Uplift Force, U= 76.70 ton

77.59	>	76.70	OK	S.F.= 1.01

1 **Additional condition:** G/Z > 0.8 EN 50341 M.3.1.6

G: weight of foundation and soil vertical to the base = 51.13 ton

Z: uplift force on fondation = 69.72 ton

Z/G = 0.73 >>> Ratio = 0.92 OK

Bearing Capacity:

Compression Force,	C =	86.92	ton
Bending Moment about x axis,	Mx =	-3.73	ton.m
Bending Moment about y axis,	My =	0.18	ton.m

Over Load of Concrete Wf= 8.25 ton

Volume of the Soil directly above foundation $Vsl = (H * bp2^2) - V2 - V3 - V4 =$ 42.07 m3

Over Load of Soil directly above foundation Wsl= Vsl * γb = 42.88 ton

Average Bearing Pressure = σp = ((C + Wf + Wsl)/A) =	0.98	kg/cm2	<	2.04	kg/cm2	OK

Compression Stress at corner 1,	$\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$	0.94	kg/cm2
Compression Stress at corner 2,	$\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$	0.94	kg/cm2
Compression Stress at corner 3,	$\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$	1.03	kg/cm2
Compression Stress at corner 4,	$\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$	1.02	kg/cm2

Max. Toe Pressure =	1.03	<	q_{all} =	2.55	OK	S.F.= 2.48
Min. Toe Pressure =	0.94	>		0	OK	

Top Surface Pressure due to Uplift:

Uplift Force,	T =	76.72	ton
Bending Moment about x axis,	Mx =	-2.02	ton.m
Bending Moment about y axis,	My =	1.62	ton.m

Pressure due to Uplift at top surface at corner 1,	$\sigma u1 = ((T-Wf)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$	0.48	kg/cm2
Pressure due to Uplift at top surface at corner 2,	$\sigma u2 = ((T-Wf)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$	0.45	kg/cm2
Pressure due to Uplift at top surface at corner 3,	$\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$	0.53	kg/cm2
Pressure due to Uplift at top surface at corner 4,	$\sigma u4 = ((T-Wf)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$	0.49	kg/cm2

Overturning:

Overturning Moment, Mo= Ts * ((((bp2/3)+((hp1+hp2) * tan β)*cos β) + (Vstmax * (((hc1+hc2+hp1+hp2)/cos β)- (((bp2/3)+(hp1+hp2) * tan β)* sin β))

Mo = 105.44 ton.m

Resisting Moment, Mr = (Ws/2)*(5*bp2/6)+Wf*(bp2/3)

Mr = 118.65 ton.m

Mr	>	Mo	OK

S.F.= 1.13

Sliding:

Sliding force, Fo = Vmax

Sliding force, Fo = 12.80 ton

Effective weight of foundation and soil at uplift case, Weff = 0.89 ton

Resisting force, Fr = Weff * μ + Fp1 + Fp2 + Fp3 =

Fr = 18.88

Fr	>	Fo	OK

S.F.= 1.47

Structural Design of Pad:

Longitudinal Rebar:

Compression :

Compression Stress at section of Max. bending moment at Pad 1, σmc1 = 0.99 kg/cm2

Compression Stress at section of Max. bending moment at Pad 2, σmc2 = 1.00 kg/cm2

Uplift :

Compression Stress at section of Max. bending moment at Pad 1, σmu1 = 0.49 kg/cm2

Compression Stress at section of Max. bending moment at Pad 2, σmu2 = 0.50 kg/cm2

Max. bending moment at Pad1, **(Compression)**

Muc 1= 3126618 kg.cm = 306721 N.m

Max. bending moment at Pad2, **(Compression)**

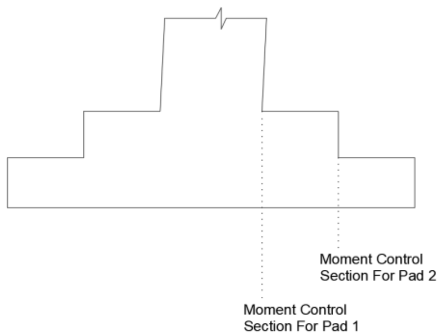
Muc 2= 1240013 kg.cm = 121645 N.m

Max. bending moment at Pad1, **(Uplift)**

Muu 1= 2196409 kg.cm = 215468 N.m

Max. bending moment at Pad2, **(Uplift)**

Muu 2= 901819 kg.cm = 88468 N.m



Effective Depth of pad 1, dp1 = hp1+hp2 - cp = 0.425 m

Effective Depth of pad 2, dp2 = hp2 - cp = 0.175 m

Compression :

Pad 1:

$K = Mu / f'c * bp * dp^2 =$ 0.071 < 0.167 OK

Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp

Z max = 397 < 403.75 ==>>> OK

As = Mu / φs * fyr * z = 1856 mm2

Pad 2:

$K = Mu / f'c * bp * dp^2 =$ 0.079 < 0.167 OK

Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp

Z max = 161.7 < 166.25 ==>>> OK

As = Mu / φs * fyr * z = 1805.2 mm2

Uplift :

Pad 1:

$K = Mu / f'c * bp * dp^2 =$	0.024	<	0.167	OK			

Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp

Z max =	415.9	>	403.75	==>>>	Zmax=0.95 dp =	403.75
As = Mu / φs * fyr * z =	1280.8	mm2				

Pad 2:

$K = Mu / f'c * bp * dp^2 =$ 0.058

Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp

Z max =	165.6	<	166.25	==>>>	OK
As = Mu / φs * fyr * z =	1282.4	mm2			

Top of Pad 1 :

As1t=	1280.8		mm2								
Rebar Diameter=	16	mm	=====>	QTY =	7 ==>>	8	=====>	8 Ø 16	=====>	1608	mm2
Rebar Quantity =	8										
Rebar Spacing =	235.7	mm									

Top of Pad 2 :

As2t=	1282.4	mm2									
Rebar Diameter=	12	mm	=====>	QTY =	12 ==>>	16	=====>	16 Ø 12	=====>	1810	mm2
Rebar Quantity =	16										
Rebar Spacing =	240.0	mm									

Bottom of Pad 2 :

As2b=	1856.3	mm2									
Rebar Diameter=	12	mm	=====>	QTY =	17 ==>>	17	=====>	17 Ø 12	=====>	1923	mm2
Rebar Quantity =	17										
Rebar Spacing =	225.0	mm									

Min. Rebar Check:

Ast =	5340.7	mm2			
ρst =	0.0048	>			
ρmin = 0.26*(0.3*(f'c^(2/3))/Fyr > 0.0013	>>>	0.0013		EN 1992-1-1:2004	9.1N
ρmax =		0.040		EN 1992-1-1:2004	9.2.1.1
	ρst	>	ρmin	OK	
	ρst	<	ρmax	OK	

One Way Shear:

Compression Stress at critical section of shear at Pad1 ,		σv1 =	1.00	kg/cm2	
Vu1 =	29538	kg	=	295383	N
Compression Stress at critical section of shear at Pad2 ,		σv2 =	1.01	kg/cm2	
Vu2 =	20820	kg	=	208198	N

Pad 1

k = 1 +(200/dp1)^0.5 < 2.0	>>>	k =	1.69	EN 1992-1-1:2004	6.2
$\rho_1 =$	0.0048				
$\sigma_{cp} = N_{ED}/A_C =$	0	No Axial Force!			
$C_{Rd,c} = 0.18/\gamma_c =$	0.12				
k1 =	0.15				
$v_{min} = 0.035 * k^{3/2} * f'c^{1/2} =$	0.343	Mpa		EN 1992-1-1:2004	6.3N

Vr1 = 476595 N

Vr1	>	Vu1	OK

F.S= 1.61

Pad 2

k = 1 +(200/dp2)^0.5 < 2.0 >>> k = 2.00 EN 1992-1-1:2004 6.2

ρ_1 = 0.0057

$\sigma_{cp} = N_{ED}/A_C$ = 0

$C_{Rd,c} = 0.18/\gamma_c$ = 0.12

k1 = 0.15

$v_{min} = 0.035 * k^{3/2} * f'c^{1/2}$ = 0.443 Mpa EN 1992-1-1:2004 6.3N

Vr2 = 354206 N

Vr2	>	Vu2	OK

F.S= 1.70

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 0.98 kg/cm2

Pad 1

Vpunch1 = 61218 kg = 612176 N

Resisting Shear of Concrete,

Vr1 = 1490551 N

Vr1	>	Vpunch1	OK

F.S.= 2.43

Pad 2

To check if punch shear section is defined in Pad 2 ==> bp1 - (bp2 + 4dp2) = 1.25 > 0 ==> Punch Shear to be Checked in Pad 2

Vpunch2 = 52304 kg = 523044 N

Resisting Shear of Concrete,

Vr2 = 887793 N

Vr2	>	Vpunch2	OK

F.S.= 1.70

Structural Design of Chimney:

Design of Longitudinal Reinforcement for Uplift :

A) Moment at the bottom of chimney about x axis Mx max = 2.02 ton.m = 20236 N.m

Rebar arrangement:

No. of rebars rows, n = 4

Total No. of rebars = 12

Distance of the last row to center, c = 27.5 cm

$\Sigma Ai*di^2$ = 6386.1

$\varphi s * fyr = M * c / I$ >>>>> $\Sigma Ai*di^2 = M * c / \varphi s * fyr$

>>>>> $A = M * c / (\varphi s * fyr * \Sigma di^2)$

As1= 2.5 cm2

B) Moment at the bottom of chimney about y axis My max = 1.62 ton.m = 16204 N.m

$\varphi s * fyr = M * c / I$ As2= 2.0 cm2

C) Axial required rebar area, As3 = Ts / (φs*Fyr) = 9.3 cm2

How Much of Uplift Force to be considered = 50 % of Uplift force is considered because Long Stub transfers 50 % of the force itself!

Total Required Longitudinal rebar area Ast =As1+As2+As3 = 13.7 cm2

As min =	max (0.1*Cs/Fy , 0.002*Ac) =			9.8	cm2		9.12 N	
As max =	0.04 *Ac =			196.0	cm2		9.5.2.3	
As =	13.7							
Rebar Diameter =	16	mm	=====> QTY =	7	=====>	12	=====>	12 Ø 16
===>> As final=	24.1	cm2						
Rebar Quantity of One Row =	4							
Rebar Spacing =	18.3							

Check for Compression :

$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a$ <= 1 EN 1992-1-1:2004 5.39

$M_{Ed,x} = M_{0Ed,x} + e * N_{Ed} > e_0 * N_{Ed}$

$e = l_0 /400 = 2*(hc)/400 =$	16	mm
$N_{Ed} =$	89.08	ton
$M_{0Ed, x} =$	3.23	ton.m
$e_0 = h /30 > 20$ mm ==> $e_0 =$	23	mm
$M_{Ed,x} =$	4.65	ton.m

$M_{Ed,y} = M_{0Ed,y} + e * N_{Ed} > e_0 * N_{Ed}$

$M_{0Ed, y} =$	0.16	ton.m
$M_{Ed,y} =$	2.08	ton.m
$As * F yr / bc^2 * f'c =$	0.123	
$N_{ED}/ f'c * bc^2 =$	0.089	
d2 =	136	mm
d2 / bc =	0.19	

Interaction Chart Gives ===>	$M_{Rd} / f'c * bc^3 =$	0.1	===> $M_{Rd,x} = M_{Rd,y} =$		46.62	ton.m
$N_{Rd} =$	$Ac * f'c + As * Fyr =$	768.47	ton			
$N_{Ed} / N_{Rd} =$	0.12	===>	a =	1.01		
$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a =$		0.140	<	1	OK	

Stirrup Rebar :

Max Spacing of links =	320	mm	EN 1992-1-1:2004 9.5.3.3	
Rebar Space =	150	mm		==>> Ø8 @ 150 mm
Link Rebar Diameter =	8	mm		

Soil Type: Type 5-Poor Soil-Dry
Foundation Type: Pad & Chimney
Tower Type: 12B-LC

Maximum Loads on Stub				
Description	*Load Combination*	*Stub Force Components*		
		Shear Force Transversal component	*Shear Force Longitudinal component*	*Axial force*
		kg	kg	kg
Maximum Axial Force, Compression	0° C5,C NA+	44	905	-80,978
Maximum Axial Force, Uplift	0° C5, Min. WS,C NA+	455	568	71,478

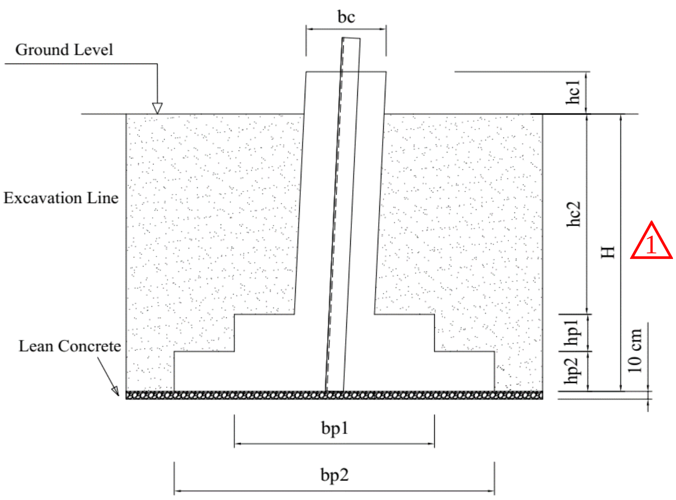
Maximum Loads on Foundation				
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	0° C5,C NA+	-12,480	13,429	-78,881
Maximum Axial Force, Uplift	0° C5, Min. WS,C NA+	-10,616	11,638	69,725

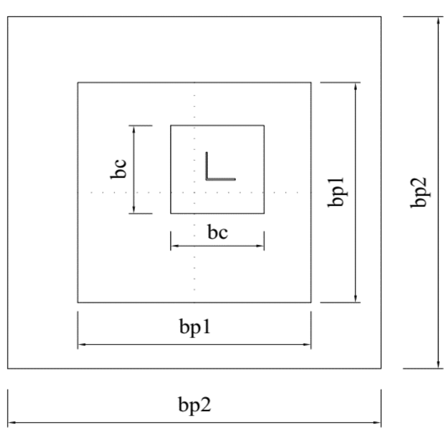
Design Standard: EN 1992:2004

Inputs:

Factor of Safety for Loads F.S.= 1.1 (As per Technical Specifications)

Foundation Dimensions	Width of Pad 1	bp1 =	1.7	m	
	Width of Pad 2	bp2 =	3.55	m	
	Height of Pad 1	hp1 =	0.25	m	
	Height of Pad 2	hp2 =	0.25	m	
	Width of Chimney	bc =	0.7	m	
	Height of Chimney above ground level	hc1 =	0.3	m	
	Height of Chimney unedr ground level	hc2 =	2.9	m	
	Depth of Pad	H =	3.4	m	
	Inplane Slope	β =	9.02	Degree	
	Diagonal Slope	γ =	12.63	Degree	
Soil Specifications	Soil Type	Type 5-Poor Soil-Dry			
	Natural Soil Density	γ_s =	1.63	ton/m3	
	Backfill Density	γ_b =	1.63	ton/m3	Tech. Spec. Section C1 4.1
	Bearing Capacity	q_{all} =	1.53	kg/cm2	Tech. Spec. Section C1 4.1
	Frustum Angle	Θ =	0	Degree	
	Internal Friction Angle	ϕ =	15	Degree	EN 50341 Table M.4
	Friction Coefficient Between Soil and Concrete	μ =	0.4		
Concrete	Compressive Strength(28 days of Cylindrical Sample)	f 'c =	20	Mpa	
	Strength Reduction Factor	φc =	0.67		Tech. Spec. Section C1 3.2.2
	Allowable Compressive Strength	f 'c =	13.3	Mpa	
	Density	γ_c =	2.5	ton/m3	
	Pad Cover Thickness	cp=	0.075	m	
	Chimney Cover Thickness	cc=	0.075	m	
Steel	Yield Strength of Rebars	Fyr =	500	Mpa	
	Strength Reduction Factor	φs =	0.83		Tech. Spec. Section C1 3.2.2





Pad 1 ==> Top Pad
Pad 2 ==> Bottom Pad

1 * The foundation is cast inside formwork.

Ultimate Loads:

On Foundation	Compression	C =	86.77	ton
		Vcx =	-13.73	ton
		Vcy =	14.77	ton
	Uplift	T =	76.70	ton
		Vtx =	-11.68	ton
		Vty =	12.80	ton

On Stub	Compression	Cs =	89.08	ton
		Vscx =	0.05	ton
		Vscy =	1.00	ton
	Uplift	Ts =	78.63	ton
		Vstx =	0.50	ton
		Vsty =	0.62	ton

Soil Passive Pressure Coefficient	Kp = tan 2 (45+φ/2) =	1.70	
Passive Force on chimney,	Fp1 =	8.15	ton
Passive Force on pad1,	Fp2 =	3.56	ton
Passive Force on pad2,	Fp3 =	8.05	ton

Uplift:

Volume of chimney above ground level	V1 =	0.15	m3
Volume of chimney under ground level	V2 =	1.42	m3
Volume of pad1,	V3 =	0.72	m3
Volume of pad2,	V4 =	3.15	m3
Total volume of foundation ,	Vf =	5.44	m3

Total weight of foundation, Wf = Vf * γc = 13.60 ton

Cone volume, Vcone = (h/3)*(π*h^2*tan ^{2} Θ + 3*bp2 ^{2} + 6* bp2 * h * tan θ) = 41.27 m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 = 39.13 m3

Soil weight above foundation, Ws = Vsoil * γb = 63.82 ton

Total resistance force against uplift, Ru= Ws + Wf = 77.42 ton

Uplift Force, U= 76.70 ton

77.42	>	76.70	OK

S.F.= 1.01

1

Additional condition: G/Z > 0.8 EN 50341 M.3.1.6

G: weight of foundation and soil vertical to the base = 74.85 ton

Z: uplift force on fondation = 69.72 ton

Z/G = 1.07 >>> Ratio = 1.34 OK

Bearing Capacity:

Compression Force,	C =	86.92	ton
Bending Moment about x axis,	Mx =	-3.73	ton.m
Bending Moment about y axis,	My =	0.18	ton.m

Over Load of Concrete Wf= 13.60 ton

Volume of the Soil directly above foundation Vsl = (H * bp2^2) - V2 - V3 - V4 = 37.55 m3

Over Load of Soil directly above foundation Wsl= Vsl * γb = 61.25 ton

Average Bearing Pressure = σp = ((C + Wf + Wsl)/A) =	1.28	kg/cm2	<	1.53	kg/cm2	OK

Compression Stress at corner 1,	σp1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =	1.24	kg/cm2
Compression Stress at corner 2,	σp2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =	1.23	kg/cm2
Compression Stress at corner 3,	σp3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =	1.34	kg/cm2
Compression Stress at corner 4,	σp4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =	1.33	kg/cm2

Max. Toe Pressure =	1.34	<	q $_{all}$ =	1.91	OK
Min. Toe Pressure =	1.23	>		0	OK

S.F.= 1.43

Top Surface Pressure due to Uplift:

Uplift Force,	T =	76.72	ton
Bending Moment about x axis,	Mx =	-2.02	ton.m
Bending Moment about y axis,	My =	1.62	ton.m

Pressure due to Uplift at top surface at corner 1,	σu1 = ((T-Wf)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =	0.50	kg/cm2
Pressure due to Uplift at top surface at corner 2,	σu2 = ((T-Wf)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =	0.45	kg/cm2
Pressure due to Uplift at top surface at corner 3,	σu3 = ((T-Wf)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =	0.55	kg/cm2
Pressure due to Uplift at top surface at corner 4,	σu4 = ((T-Wf)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =	0.51	kg/cm2

Overturning:

Overturning Moment, Mo= Ts * ((((bp2/3)+((hp1+hp2) * tan β)*cos β) + (Vstmax * (((hc1+hc2+hp1+hp2)/cos β)- (((bp2/3)+(hp1+hp2) * tan β)* sin β))

Mo = 100.27 ton.m

Resisting Moment, Mr = (Ws/2)*(5*bp2/6)+Wf*(bp2/3)

Mr = 110.50 ton.m

Mr	>	Mo	OK

S.F.= 1.10

Sliding:

Sliding force, Fo = Vmax

Sliding force, Fo = 12.80 ton

Effective weight of foundation and soil at uplift case, Weff = 0.73 ton

Resisting force, Fr = Weff * μ + Fp1 + Fp2 + Fp3 =

Fr = 20.06

Fr	>	Fo	OK

S.F.= 1.57

Structural Design of Pad:

Longitudinal Rebar:

Compression :

Compression Stress at section of Max. bending moment at Pad 1, σmc1 = 1.29 kg/cm2

Compression Stress at section of Max. bending moment at Pad 2, σmc2 = 1.31 kg/cm2

Uplift :

Compression Stress at section of Max. bending moment at Pad 1, σmu1 = 0.51 kg/cm2

Compression Stress at section of Max. bending moment at Pad 2, σmu2 = 0.51 kg/cm2

Max. bending moment at Pad1, **(Compression)**

Muc 1= 3054047 kg.cm = 299602 N.m

Max. bending moment at Pad2, **(Compression)**

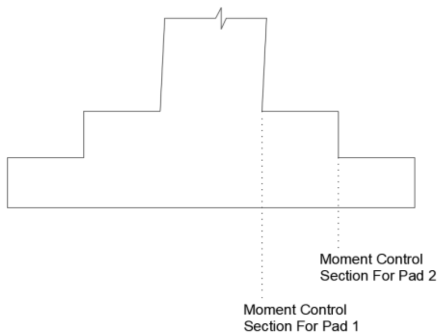
Muc 2= 1232063 kg.cm = 120865 N.m

Max. bending moment at Pad1, **(Uplift)**

Muu 1= 1876929 kg.cm = 184127 N.m

Max. bending moment at Pad2, **(Uplift)**

Muu 2= 794734 kg.cm = 77963 N.m



Effective Depth of pad 1, dp1 = hp1+hp2 - cp = 0.425 m

Effective Depth of pad 2, dp2 = hp2 - cp = 0.175 m

Compression :

Pad 1:

K = Mu /f 'c * bp *dp^2 = 0.073 < 0.167 OK

Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp

Z max = 396 < 403.75 ==>>> OK

As = Mu / φs * fyr * z = 1818 mm2

Pad 2:

K = Mu /f 'c * bp *dp^2 = 0.083 < 0.167 OK

Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp

Z max = 161.0 < 166.25 ==>>> OK

As = Mu / φs * fyr * z = 1801.6 mm2

Uplift :

Pad 1:

$K = Mu / f'c * bp * dp^2 =$ 0.022 < 0.167 OK

Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp

Z max = 416.8 > 403.75 ==>>> Zmax=0.95 dp = 403.75

As = Mu / φs * fyr * z = 1094.5 mm2

Pad 2:

$K = Mu / f'c * bp * dp^2 =$ 0.054

Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp

Z max = 166.3 > 166.25 ==>>> Zmax=0.95 dp = 166.25

As = Mu / φs * fyr * z = 1125.5 mm2

Top of Pad 1 :

As1t= 1094.5 mm2

Rebar Diameter= 12 mm =====> QTY = 10 ==>> 10 =====> 10 Ø 12 =====> 1131 mm2

Rebar Quantity = 10

Rebar Spacing = 172.2 mm

Top of Pad 2 :

As2t= 1125.5 mm2

Rebar Diameter= 12 mm =====> QTY = 10 ==>> 15 =====> 15 Ø 12 =====> 1696 mm2

Rebar Quantity = 15

Rebar Spacing = 242.9 mm

Bottom of Pad 2 :

As2b= 1818.0 mm2

Rebar Diameter= 12 mm =====> QTY = 17 ==>> 17 =====> 17 Ø 12 =====> 1923 mm2

Rebar Quantity = 17

Rebar Spacing = 212.5 mm

Min. Rebar Check:

Ast = 4750.1 mm2

ρst = 0.0045 >

ρmin = 0.26*(0.3*(f'c^(2/3))/Fyr > 0.0013 >>> 0.0013 EN 1992-1-1:2004 9.1N

ρmax = 0.040 EN 1992-1-1:2004 9.2.1.1

ρst > ρmin OK

ρst < ρmax OK

One Way Shear:

Compression Stress at critical section of shear at Pad1 , σv1 = 1.31 kg/cm2

Vu1 = 30055 kg = 300549 N

Compression Stress at critical section of shear at Pad2 , σv2 = 1.31 kg/cm2

Vu2 = 21549 kg = 215493 N

Pad 1

k = 1 +(200/dp1)^0.5 < 2.0 >>> k = 1.69 EN 1992-1-1:2004 6.2

$\rho_1 =$ 0.0045

$\sigma_{cp} = N_{ED}/A_C =$ 0 No Axial Force!

$C_{Rd,c} = 0.18/\gamma_c =$ 0.12

k1 = 0.15

$v_{min} = 0.035 * k^{3/2} * f'c^{1/2} =$ 0.343 Mpa EN 1992-1-1:2004 6.3N

Vr1 = 441609 N

Vr1	>	Vu1	OK

F.S= 1.47

Pad 2

k = 1 +(200/dp2)^0.5 < 2.0 >>> k = 2.00 EN 1992-1-1:2004 6.2

ρ_1 = 0.0058

$\sigma_{cp} = N_{ED}/A_C$ = 0

$C_{Rd,c} = 0.18/\gamma_c$ = 0.12

k1 = 0.15

$v_{min} = 0.035 * k^{3/2} * f'c^{1/2}$ = 0.443 Mpa EN 1992-1-1:2004 6.3N

Vr2 = 338013 N

Vr2	>	Vu2	OK

F.S= 1.57

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 1.28 kg/cm2

Pad 1

Vpunch1 = 60499 kg = 604987 N

Resisting Shear of Concrete,

Vr1 = 1460340 N

Vr1	>	Vpunch1	OK

F.S.= 2.41

Pad 2

To check if punch shear section is defined in Pad 2 ==> bp1 - (bp2 + 4dp2) = 1.15 > 0 ==> Punch Shear to be Checked in Pad 2

Vpunch2 = 53490 kg = 534904 N

Resisting Shear of Concrete,

Vr2 = 856849 N

Vr2	>	Vpunch2	OK

F.S.= 1.60

Structural Design of Chimney:

Design of Longitudinal Reinforcement for Uplift :

A) Moment at the bottom of chimney about x axis Mx max = 2.02 ton.m = 20236 N.m

Rebar arrangement:

No. of rebars rows, n = 4

Total No. of rebars = 12

Distance of the last row to center, c = 27.5 cm

$\Sigma Ai*di^2$ = 6386.1

φs * fyr = M * c /I >>>>> $\Sigma Ai*di^2$ = M * c / φs * fyr

>>>>> A = M * c / (φs * fyr *Σdi^2)

As1= 2.5 cm2

B) Moment at the bottom of chimney about y axis My max = 1.62 ton.m = 16204 N.m

φs * fyr = M * c /I As2= 2.0 cm2

C) Axial required rebar area, As3 = Ts / (φs*Fyr) = 9.3 cm2

How Much of Uplift Force to be considered = 50 % of Uplift force is considered because Long Stub transfers 50 % of the force itself!

Total Required Longitudinal rebar area Ast =As1+As2+As3 = 13.7 cm2

As min =	max (0.1*Cs/Fy , 0.002*Ac) =			9.8	cm2		9.12 N		
As max =	0.04 *Ac =			196.0	cm2		9.5.2.3		
As =	13.7								
Rebar Diameter =	16	mm	=====> QTY =	7	=====>	12	=====>	12 Ø 16	
===>> As final=	24.1	cm2							
Rebar Quantity of One Row =	4								
Rebar Spacing =	18.3								

Check for Compression :

$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a$ <= 1 EN 1992-1-1:2004 5.39

$M_{Ed,x} = M_{0Ed,x} + e * N_{Ed} > e_0 * N_{Ed}$

$e = l_0$ /400 = 2*(hc)/400 =	16	mm
N_{Ed} =	89.08	ton
$M_{0Ed,\,x}$ =	3.23	ton.m
e_0 = h /30 > 20 mm ==> e_0 =	23	mm
$M_{Ed,x}$ =	4.65	ton.m

$M_{Ed,y} = M_{0Ed,y} + e * N_{Ed} > e_0 * N_{Ed}$

$M_{0Ed,\,y}$ =	0.16	ton.m
$M_{Ed,y}$ =	2.08	ton.m
As * F yr / bc^2 * f'c =	0.123	
N_{ED}/ f'c * bc^2 =	0.089	
d2 =	136	mm
d2 / bc =	0.19	

Interaction Chart Gives ===>	M_{Rd} / f'c * bc^3 =	0.1	===> $M_{Rd,x} = M_{Rd,y}$ =		46.62	ton.m	
N_{Rd} =	Ac * f'c + As * Fyr =	768.47	ton				
N_{Ed} / N_{Rd} =	0.12	===>	a =	1.01			
$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a$ =		0.140	<	1	OK		

Stirrup Rebar :

Max Spacing of links =	320	mm	EN 1992-1-1:2004 9.5.3.3	
Rebar Space =	150	mm		==>> Ø8 @ 150 mm
Link Rebar Diameter =	8	mm		

Soil Type: Type 5-Poor Soil-Submerge
Foundation Type: Pad & Chimney
Tower Type: 12B-LC

Maximum Loads on Stub				
Description	*Load Combination*	*Stub Force Components*		
		Shear Force Transversal component	*Shear Force Longitudinal component*	*Axial force*
		kg	kg	kg
Maximum Axial Force, Compression	0° C5,C NA+	44	905	-80,978
Maximum Axial Force, Uplift	0° C5, Min. WS,C NA+	455	568	71,478

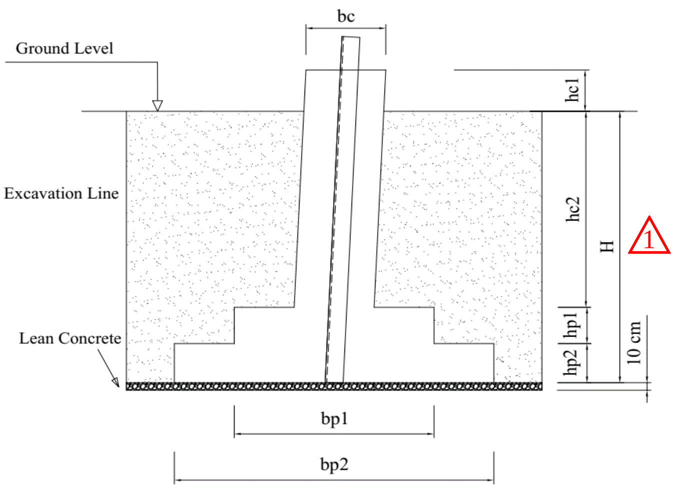
Maximum Loads on Foundation				
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	0° C5,C NA+	-12,480	13,429	-78,881
Maximum Axial Force, Uplift	0° C5, Min. WS,C NA+	-10,616	11,638	69,725

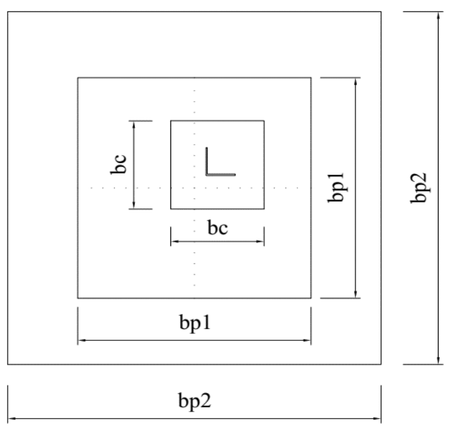
Design Standard: EN 1992:2004

Inputs:

Factor of Safety for Loads F.S.= 1.1 (As per Technical Specifications)

Foundation Dimensions	Width of Pad 1	bp1 =	2.2	m	
	Width of Pad 2	bp2 =	5.1	m	
	Height of Pad 1	hp1 =	0.25	m	
	Height of Pad 2	hp2 =	0.25	m	
	Width of Chimney	bc =	0.7	m	
	Height of Chimney above ground level	hc1 =	0.3	m	
	Height of Chimney unedr ground level	hc2 =	2.9	m	
	Depth of Pad	H =	3.4	m	
	Inplane Slope	β =	9.02	Degree	
	Diagonal Slope	γ =	12.63	Degree	
Soil Specifications	Soil Type	Type 5-Poor Soil-Submerge			
	Natural Soil Density	γ_s =	0.82	ton/m3	
	Backfill Density	γ_b =	0.82	ton/m3	Tech. Spec. Section C1 4.1
	Bearing Capacity	q_{all} =	0.82	kg/cm2	Tech. Spec. Section C1 4.1
	Frustum Angle	Θ =	0	Degree	
	Internal Friction Angle	ϕ =	15	Degree	EN 50341 Table M.4
	Friction Coefficient Between Soil and Concrete	μ =	0.4		
Concrete	Compressive Strength(28 days of Cylindrical Sample)	f 'c =	20	Mpa	
	Strength Reduction Factor	φc =	0.67		Tech. Spec. Section C1 3.2.2
	Allowable Compressive Strength	f 'c =	13.3	Mpa	
	Density	γ_c =	1.4	ton/m3	
	Pad Cover Thickness	cp=	0.075	m	
	Chimney Cover Thickness	cc=	0.075	m	
Steel	Yield Strength of Rebars	Fyr =	500	Mpa	
	Strength Reduction Factor	φs =	0.83		Tech. Spec. Section C1 3.2.2





Pad 1 ==> Top Pad
Pad 2 ==> Bottom Pad

1 * The foundation is cast inside formwork.

Ultimate Loads:

On Foundation	Compression	C =	86.77	ton
		Vcx =	-13.73	ton
		Vcy =	14.77	ton
	Uplift	T =	76.70	ton
		Vtx =	-11.68	ton
		Vty =	12.80	ton

On Stub	Compression	Cs =	89.08	ton
		Vscx =	0.05	ton
		Vscy =	1.00	ton
	Uplift	Ts =	78.63	ton
		Vstx =	0.50	ton
		Vsty =	0.62	ton

Soil Passive Pressure Coefficient Kp = tan 2 (45+φ/2) = 1.70
Passive Force on chimney, Fp1 = 4.08 ton
Passive Force on pad1, Fp2 = 2.30 ton
Passive Force on pad2, Fp3 = 5.78 ton

Uplift:

Volume of chimney above ground level V1 = 0.15 m3
Volume of chimney under ground level V2 = 1.42 m3
Volume of pad1, V3 = 1.21 m3
Volume of pad2, V4 = 6.50 m3
Total volume of foundation , Vf = 9.28 m3

Total weight of foundation, Wf = Vf * γc = 12.99 ton

Cone volume, $Vcone = (h/3)*(\pi*h^2*\tan^2\Theta + 3*bp2^2 + 6*bp2*h*\tan\theta) =$ 85.18 m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 = 82.55 m3
Soil weight above foundation, Ws = Vsoil * γb = 67.32 ton

Total resistance force against uplift, Ru= Ws + Wf = 80.31 ton
Uplift Force, U= 76.70 ton

80.31	>	76.70	OK

S.F.= 1.05

1 **Additional condition:** G/Z > 0.8 EN 50341 M.3.1.6
G: weight of foundation and soil vertical to the base = 77.66 ton
Z: uplift force on fondation = 69.72 ton

Z/G = 1.11 >>> Ratio = 1.39 OK

Bearing Capacity:

Compression Force, C = 86.92 ton
Bending Moment about x axis, Mx = -3.73 ton.m
Bending Moment about y axis, My = 0.18 ton.m

Over Load of Concrete Wf= 12.99 ton

Volume of the Soil directly above foundation $Vsl = (H * bp2^2) - V2 - V3 - V4 =$ 79.30 m3

Over Load of Soil directly above foundation Wsl= Vsl * γb = 64.67 ton

Average Bearing Pressure = σp = ((C + Wf + Wsl)/A) =	0.63	kg/cm2	<	0.82	kg/cm2	OK

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ 0.62 kg/cm2
Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ 0.62 kg/cm2
Compression Stress at corner 3, $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ 0.65 kg/cm2
Compression Stress at corner 4, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ 0.65 kg/cm2

Max. Toe Pressure =	0.65	<	q_{all} =	1.02	OK
Min. Toe Pressure =	0.62	>		0	OK

S.F.= 1.57

Top Surface Pressure due to Uplift:

Uplift Force, T = 76.72 ton
Bending Moment about x axis, Mx = -2.02 ton.m
Bending Moment about y axis, My = 1.62 ton.m

Pressure due to Uplift at top surface at corner 1, $\sigma u1 = ((T-Wf)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ 0.24 kg/cm2
Pressure due to Uplift at top surface at corner 2, $\sigma u2 = ((T-Wf)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ 0.23 kg/cm2
Pressure due to Uplift at top surface at corner 3, $\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ 0.26 kg/cm2
Pressure due to Uplift at top surface at corner 4, $\sigma u4 = ((T-Wf)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ 0.25 kg/cm2

Overturning:

Overturning Moment, Mo= Ts * ((((bp2/3)+((hp1+hp2) * tan β)*cos β) + (Vstmax * (((hc1+hc2+hp1+hp2)/cos β)- (((bp2/3)+(hp1+hp2) * tan β)* sin β))

Mo = 140.34 ton.m

Resisting Moment, Mr = (Ws/2)*(5*bp2/6)+Wf*(bp2/3)

Mr = 165.14 ton.m

Mr	>	Mo	OK

S.F.= 1.18

Sliding:

Sliding force, Fo = Vmax

Sliding force, Fo = 12.80 ton

Effective weight of foundation and soil at uplift case, Weff = 3.62 ton

Resisting force, Fr = Weff * μ + Fp1 + Fp2 + Fp3 =

Fr = 13.61

Fr	>	Fo	OK

S.F.= 1.06

Structural Design of Pad:

Longitudinal Rebar:

Compression :

Compression Stress at section of Max. bending moment at Pad 1, σmc1 = 0.64 kg/cm2

Compression Stress at section of Max. bending moment at Pad 2, σmc2 = 0.64 kg/cm2

Uplift :

Compression Stress at section of Max. bending moment at Pad 1, σmu1 = 0.25 kg/cm2

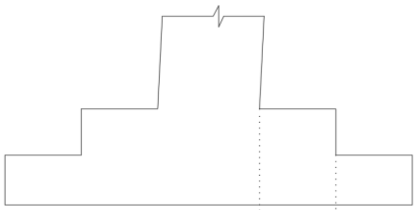
Compression Stress at section of Max. bending moment at Pad 2, σmu2 = 0.25 kg/cm2

Max. bending moment at Pad1, **(Compression)**

Muc 1= 5039151 kg.cm = 494341 N.m

Max. bending moment at Pad2, **(Compression)**

Muc 2= 2088576 kg.cm = 204889 N.m



Max. bending moment at Pad1, **(Uplift)**

Muu 1= 3104591 kg.cm = 304560 N.m

Max. bending moment at Pad2, **(Uplift)**

Muu 2= 1353448 kg.cm = 132773 N.m

Effective Depth of pad 1, dp1 = hp1+hp2 - cp = 0.425 m

Effective Depth of pad 2, dp2 = hp2 - cp = 0.175 m

Compression :

Pad 1:

$K = Mu / f'c * bp * dp^2 =$ 0.093 < 0.167 OK

Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp

Z max = 387 < 403.75 ==>>> OK

As = Mu / φs * fyr * z = 3069 mm2

Pad 2:

$K = Mu / f'c * bp * dp^2 =$ 0.098 < 0.167 OK

Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp

Z max = 158.2 < 166.25 ==>>> OK

As = Mu / φs * fyr * z = 3108.4 mm2

Uplift :

Pad 1:

$K = Mu / f'c * bp * dp^2 =$	0.025	<	0.167	OK			

Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp

Z max =	415.5	>	403.75	==>>>	Zmax=0.95 dp =	403.75
As = Mu / φs * fyr * z =	1810.4	mm2				

Pad 2:

$K = Mu / f'c * bp * dp^2 =$	0.064

Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp

Z max =	164.5	<	166.25	==>>>	OK
As = Mu / φs * fyr * z =	1936.8	mm2			

Top of Pad 1 :

As1t=	1810.4	mm2								
Rebar Diameter=	16	mm	=====>	QTY =	10 ==>>	10	=====>	10 Ø 16	=====>	2011 mm2
Rebar Quantity =	10									
Rebar Spacing =	227.8	mm								

Top of Pad 2 :

As2t=	1936.8	mm2								
Rebar Diameter=	12	mm	=====>	QTY =	18 ==>>	21	=====>	21 Ø 12	=====>	2375 mm2
Rebar Quantity =	21									
Rebar Spacing =	247.5	mm								

Bottom of Pad 2 :

As2b=	3108.4	mm2								
Rebar Diameter=	12	mm	=====>	QTY =	28 ==>>	28	=====>	28 Ø 12	=====>	3167 mm2
Rebar Quantity =	28									
Rebar Spacing =	183.3	mm								

Min. Rebar Check:

Ast =	7552.4	mm2		
ρst =	0.0052	>		
ρmin = 0.26*(0.3*(f'c^(2/3))/Fyr > 0.0013	>>>	0.0013		EN 1992-1-1:2004 9.1N
ρmax =		0.040		EN 1992-1-1:2004 9.2.1.1
	ρst	>	ρmin	OK
	ρst	<	ρmax	OK

One Way Shear:

Compression Stress at critical section of shear at Pad1 ,		σv1 =	0.64	kg/cm2	
Vu1 =	36868	kg	=	368684	N
Compression Stress at critical section of shear at Pad2 ,		σv2 =	0.64	kg/cm2	
Vu2 =	25265	kg	=	252648	N

Pad 1

k = 1 +(200/dp1)^0.5 < 2.0	>>>	k =	1.69	EN 1992-1-1:2004 6.2
$\rho_1 =$	0.0052			
$\sigma_{cp} = N_{ED}/A_C =$	0	No Axial Force!		
$C_{Rd,c} = 0.18/\gamma_c =$	0.12			
k1 =	0.15			
$v_{min} = 0.035 * k^{3/2} * f'c^{1/2} =$	0.343	Mpa		EN 1992-1-1:2004 6.3N

$Vr1 =$ 638488 N

Vr1	>	Vu1	OK

F.S= 1.73

Pad 2

k = 1 +(200/dp2)^0.5 < 2.0 >>> k = 2.00 EN 1992-1-1:2004 6.2

$\rho_1 =$ 0.0062

$\sigma_{cp} = N_{ED}/A_C =$ 0

$C_{Rd,c} = 0.18/\gamma_c =$ 0.12

k1 = 0.15

$v_{min} = 0.035 * k^{3/2} * f'c^{1/2} =$ 0.443 Mpa EN 1992-1-1:2004 6.3N

Vr2 = 496032 N

Vr2	>	Vu2	OK

F.S= 1.96

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 0.63 kg/cm2

Pad 1

Vpunch1 = 82703 kg = 827029 N

Resisting Shear of Concrete,

Vr1 = 1531398 N

Vr1	>	Vpunch1	OK

F.S.= 1.85

Pad 2

To check if punch shear section is defined in Pad 2 ==> bp1 - (bp2 + 4dp2) = 2.2 > 0 ==> Punch Shear to be Checked in Pad 2

Vpunch2 = 66551 kg = 665511 N

Resisting Shear of Concrete,

Vr2 = 1069786 N

Vr2	>	Vpunch2	OK

F.S.= 1.61

Structural Design of Chimney:

Design of Longitudinal Reinforcement for Uplift :

A) Moment at the bottom of chimney about x axis Mx max = 2.02 ton.m = 20236 N.m

Rebar arrangement:

No. of rebars rows, n = 4

Total No. of rebars = 12

Distance of the last row to center, c = 27.5 cm

$\Sigma Ai*di^2 =$ 6386.1

φs * fyr = M * c /I >>>>> $\Sigma Ai*di^2 =$ M * c / φs * fyr

>>>>> A = M * c / (φs * fyr *Σdi^2)

As1= 2.5 cm2

B) Moment at the bottom of chimney about y axis My max = 1.62 ton.m = 16204 N.m

φs * fyr = M * c /I As2= 2.0 cm2

C) Axial required rebar area, As3 = Ts / (φs*Fyr) = 9.3 cm2

How Much of Uplift Force to be considered = 50 % of Uplift force is considered because Long Stub transfers 50 % of the force itself!

Total Required Longitudinal rebar area Ast =As1+As2+As3 = 13.7 cm2

MİTAŞ ENERGY

As min =	max (0.1*Cs/Fy , 0.002*Ac) =				9.8	cm2		9.12 N		
As max =	0.04 *Ac =				196.0	cm2		9.5.2.3		
As =	13.7									
Rebar Diameter =	16	mm	=====>	QTY =	7	=====>	12	=====>	12 Ø 16	
===>> As final=	24.1	cm2								
Rebar Quantity of One Row =	4									
Rebar Spacing =	18.3									

Check for Compression :

$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a <= 1$ EN 1992-1-1:2004 5.39

$M_{Ed,x} = M_{0Ed,x} + e * N_{Ed} > e_0 * N_{Ed}$

$e = l_0 /400 = 2*(hc)/400 =$	16	mm
N_{Ed} =	89.08	ton
$M_{0Ed,x}$ =	3.23	ton.m
$e_0 = h /30 > 20$ mm ==> e_0 =	23	mm
$M_{Ed,x}$ =	4.65	ton.m

$M_{Ed,y} = M_{0Ed,y} + e * N_{Ed} > e_0 * N_{Ed}$

$M_{0Ed,y}$ =	0.16	ton.m
$M_{Ed,y}$ =	2.08	ton.m
$As * F yr / bc^2 * f'c$ =	0.123	
$N_{ED}/ f'c * bc^2$ =	0.089	
d2 =	136	mm
d2 / bc =	0.19	

Interaction Chart Gives ===> $M_{Rd} / f'c * bc^3$ = 0.1 ===> $M_{Rd,x} = M_{Rd,y}$ = 46.62 ton.m

N_{Rd} = Ac * f'c + As * Fyr = 768.47 ton

N_{Ed} / N_{Rd} = 0.12 ===> a = 1.01

$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a$ = 0.140 < 1 OK

Stirrup Rebar :

Max Spacing of links =	320	mm	EN 1992-1-1:2004 9.5.3.3	
Rebar Space =	150	mm		==>> Ø8 @ 150 mm
Link Rebar Diameter =	8	mm		