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-HA"

(for all soil types)

Rev. No.	Date	Description	Designed by	Checked by	Approved by
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Contractor logo and business name	Document Number
MITAS Energy & Metal Construction Inc. Eski Güvercinlik Yolu No: 113 Gazi 06560 Ankara / Turkey	7145A07-EG-FND-CLC-0515_01

Document Title	Scale	Sheet of Sheets
Foundation Design Calculations of Tower Type "12B-HA" (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	1 150
Type 5-Poor Soil-Submerge	Yes	Pad & Chimney	8	0	80

MİTAŞ ENERGY

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

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	90° C3,C NA+	776	2,688	-132,107
Maximum Axial Force, Uplift	90° C3, Min. WS,C NA+	-86	2,111	117,894

Maximum Loads on Foundation				
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	90° C3,C NA+	23,626	-25,538	-127,473
Maximum Axial Force, Uplift	90° C3, Min. WS,C NA+ Dear Berk,	20,338	-22,535	113,938

Design Standard: EN 1992:2004

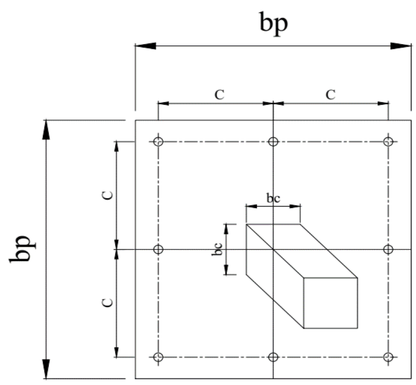
I applied a minor change in page number. Please replace the attached file.

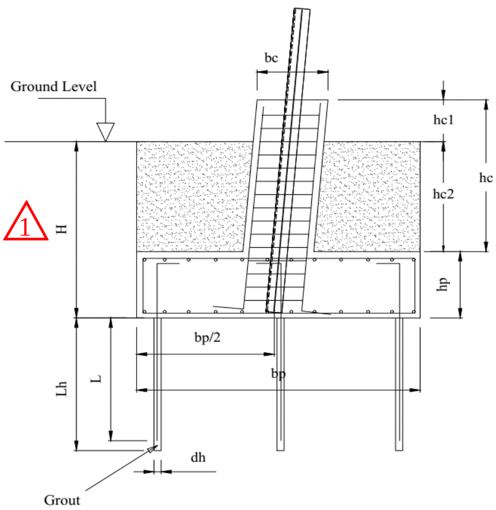
Inputs:

Regards,

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

Foundation Dimensions	Width of Pad	bp =	1.5	m	
	Height of Pad	hp =	0.7	m	
	Width of Chimney	bc =	0.7	m	
	Height of Chimney above ground level	hc1 =	0.3	m	
	Height of Chimney under ground level	hc2 =	0.7	m	
	Total Height of Chimney	hc =	1	m	
	Depth of Pad	H =	1.4	m	
	Inplane Slope	β =	10.16	Degree	
	Eccentricity (Bottom of Pad)	e =	0.30	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





* The foundation is in direct contact with undisturbed soil.

Ultimate Loads:

On Foundation	Compression	C =	140.22	ton
		Vcx =	25.99	ton
		Vcy =	-28.09	ton
	Tension	T =	125.33	ton
		Vtx =	22.37	ton
		Vty =	-24.79	ton

On Stub	Compression	Cs =	145.32	ton
		Vscx =	0.85	ton
		Vscy =	2.96	ton
	Tension	Ts =	129.68	ton
		Vstx =	-0.09	ton
		Vsty =	2.32	ton

Design of Anchors:

Volume of chimney above ground level	V1 =	0.15	m3
Volume of chimney under ground level	V2 =	0.34	m3
Volume of pad,	V3 =	1.58	m3
Total volume of foundation ,	Vf =	2.07	m3

Total weight of foundation, Wf = Vf * γc = 5.16 ton

Uplift Force, U = 125.33 ton

Design force for anchors, U net = U - Wf = 120.17 ton

Required anchor area for uplift, Asu = U net / (φs * Fy) = 28.29 cm2

Anchor arrangement:

No. of anchor rows, n = 3 Distance from hole center to pad edge = 0.2 m

Central Holes to be Ommited = Yes

Total No. of anchors holes, i = 8

Distance between anchor rows C = 55.0 cm

Distance of the last row to center, c = 55 cm

Σ di ^{2} = 12100

Anchor diameter, da = 1.6 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 = 4.02 cm

Total area of anchors, As =	32.17	cm2	>	28.29	OK

Uplift Force,	T =	125.71	ton
Bending Moment about x axis,	Mx =	3.95	ton.m
Bending Moment about y axis,	My =	-0.16	ton.m

Required Modulus of Section at x direction	Wx =	Mx / (φs * Fy) =	92.96	cm3
Required Modulus of Section at y direction	Wy =	My / (φs * Fy) =	-3.77	cm3

Required anchor area for bending moment about x axis, Asmx = n * m * Wx * c / (Σ di ^{2}) = 2.54 cm2

Required anchor area for bending moment about y axis, Asmy = n* m * Wy * c / (Σ di ^{2}) = 0.10 cm2

Total Required Area for Anchors, Astot = Asu + Asmx + Asmy =	30.93	cm2	<	32.17	OK

Bearing Capacity:

Compression Force,	C =	140.86	ton
Bending Moment about x axis,	Mx =	5.03	ton.m
Bending Moment about y axis,	My =	1.45	ton.m

Over Load of Concrete, Wf = 5.16 ton

Volume of the Soil directly above foundation Vsl = (H * bp^2) - V2 - V3 = 1.23 m3

Over Load of Soil directly above foundation Wsl= Vsl * γs = 3.14 ton

Overall Bearing Pressure = σp = ((C + Wf + Wsl)/A) =	6.63	kg/cm2	<	10.19	kg/cm2	OK

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) + (6*My)/(bp3) =$ 7.78 kg/cm2

Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) - (6*My)/(bp3) =$ 7.27 kg/cm2

Compression Stress at corner 3, $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) + (6*My)/(bp3) =$ 5.99 kg/cm2

Compression Stress at corner 4, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) - (6*My)/(bp3) =$ 5.48 kg/cm2

Max. Toe Pressure =	7.78	<	q_{all} =	12.74	OK
Min. Toe Pressure =	5.48	>	0		OK

Bond of Anchor and Grout Check :

Max. force of one anchor hole Pa = 16422 kg

Required embedded length of anchor in Rock, $L_{min} = Pa / (m * \tau_{gs} * \pi * da) =$ 81.7 cm

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

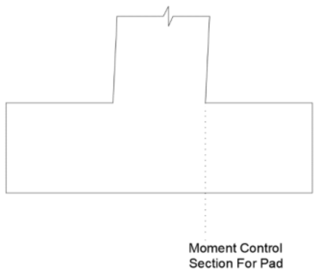
Bond of Grout and Rock Check :

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	>	16422	OK

Structural Design of Pad:

Longitudinal Rebar:



Compression Stress at section of Max. bending moment, σm = 7.05 kg/cm2

Mu = 862318 kg.cm = 86232 N.m

Effective Depth, dp = hp - cp = 0.625 m

$K = Mu / f'c * bp * dp^2 =$ 0.01104 < 0.167 OK

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

Z max = 618.85 > 593.75 ==>>> Zmax=0.95 dp = 593.75 mm

As = Mu / φs * fyr * z = 349

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 = 1365 mm2

As max = 42000 mm2

As = 1365

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

Rebar Quantity = 7

Rebar Spacing = 22.5

===> As= 1407 mm2

One Way Shear:

Compression Stress at critical section of shear , σv = 7.79 kg/cm2

Vu = -25241 kg = -252413 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 = 0.0015

$\sigma_{cp} = N_{ED}/A_C$ = 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 = 234728 N

Vr	>	Vu	OK

F.S= Not Defined!

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 6.63 kg/cm2

Vpunch = -428921 kg = -4289206 N

Resisting Shear of Concrete,

Vr = 1667194 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 = 2.36 ton.m = 23596 N.m

Rebar arrangement:

No. of Rebar rows, n = 3

Total No. of Rebars = 8

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

Σ Ai * di^2 = 4537.5

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

>>>>> A = M * c / (φs * fyr *Σ di^2)

As1= 2.7 cm2

B) Moment at the bottom of chimney about y axis

My max = -0.10 ton.m = -957 N.m

>>>>> A = M * c / (φs * fyr *Σdi2)

As2= 0.1 cm2

C) Axial required rebar area, As3 = Ts / (φs*Fys) = 15.3 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 = 18.1 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 = 18.1

Rebar Diameter = 20 mm =====> QTY = 6 =====> 8 =====> 8 Ø 20

===>> As final= 25.1 cm2

Rebar Quantity of One Row = 3

Rebar Spacing = 27.5

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

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

$e = l_0 /400 = 2*(hc)/400 =$ 5 mm

$N_{Ed} =$ 145.32 ton

$M_{0Ed,x} =$ 3.00 ton.m

$e_0 = h /30 > 20$ mm ==> $e_0 =$ 23 mm

$M_{Ed,x}$ = 3.73 ton.m

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

$M_{0Ed,y}$= 0.87 ton.m

$M_{Ed,y}$ = 3.39 ton.m

As * F yr / bc^2 * f'c = 0.128

N_{ED}/ f'c * bc^2 = 0.145

d2 = 144 mm

d2 / bc = 0.21

Interaction Chart Gives ===> MRd / f'c * bc3 = 0.08 ===> $M_{Rd,x} = M_{Rd,y}$ = 55.94 ton.m

N_{Rd} = Ac * f'c + As * Fyr = 772.74 ton

N_{Ed} / N_{Rd} = 0.19 ===> a = 1.07

$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a$ = 0.104 < 1 OK

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

Max Spacing of links = 400 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-HA

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	90° C3,C NA+	776	2,688	-132,107
Maximum Axial Force, Uplift	90° C3, Min. WS,C NA+	-86	2,111	117,894

Maximum Loads on Foundation				
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	90° C3,C NA+	23,626	-25,538	-127,473
Maximum Axial Force, Uplift	90° C3, Min. WS,C NA+	20,338	-22,535	113,938

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 =	1.8	m	
	Height of Pad	hp =	0.7	m	
	Width of Chimney	bc =	0.7	m	
	Height of Chimney above ground level	hc1 =	0.3	m	
	Height of Chimney under ground level	hc2 =	0.7	m	
	Total Height of Chimney	hc =	1	m	
	Depth of Pad	H =	1.4	m	
	Inplane Slope	β =	10.16	Degree	
	Eccentricity (Bottom of Pad)	e =	0.30	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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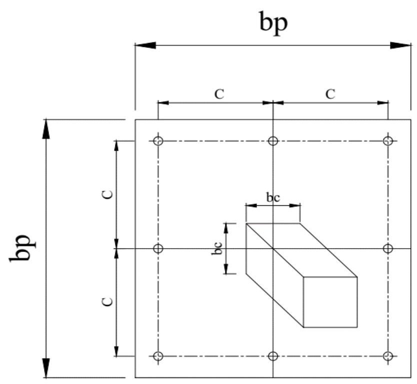
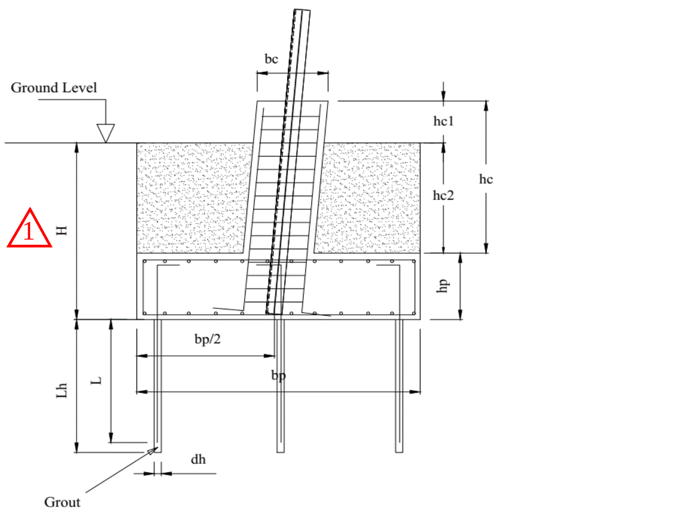




1 * The foundation is in direct contact with undisturbed soil.

Ultimate Loads:

On Foundation	Compression	C =	140.22	ton
		Vcx =	25.99	ton
		Vcy =	-28.09	ton
	Tension	T =	125.33	ton
		Vtx =	22.37	ton
		Vty =	-24.79	ton

On Stub	Compression	Cs =	145.32	ton
		Vscx =	0.85	ton
		Vscy =	2.96	ton
	Tension	Ts =	129.68	ton
		Vstx =	-0.09	ton
		Vsty =	2.32	ton

Design of Anchors:

Volume of chimney above ground level V1 = 0.15 m3
Volume of chimney under ground level V2 = 0.34 m3
Volume of pad, V3 = 2.27 m3
Total volume of foundation , Vf = 2.76 m3

Total weight of foundation, Wf = Vf * γc = 6.90 ton

Uplift Force, U = 125.33 ton

Design force for anchors, U net = U - Wf = 118.44 ton

Required anchor area for uplift, Asu = U net / (φs * Fy) = 27.88 cm2

Anchor arrangement:

No. of anchor rows, n = 3 — Distance from hole center to pad edge = 0.25 m

Central Holes to be Ommited = No

Total No. of anchors holes, i = 9

Distance between anchor rows C = 65.0 cm

Distance of the last row to center, c = 65 cm

$\Sigma\, di^2$ = 19600

Anchor diameter, da = 1.6 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 = 4.02 cm

Total area of anchors, As =	36.19	cm2	>	27.88	OK

Uplift Force, T = 125.71 ton
Bending Moment about x axis, Mx = 3.95 ton.m
Bending Moment about y axis, My = -0.16 ton.m

Required Modulus of Section at x direction Wx = Mx / (φs * Fy) = 92.96 cm3
Required Modulus of Section at y direction Wy = My / (φs * Fy) = -3.77 cm3

Required anchor area for bending moment about x axis, Asmx = n * m * Wx * c / (Σ di ^{2}) = 1.85 cm2

Required anchor area for bending moment about y axis, Asmy = n* m * Wy * c / (Σ di ^{2}) = 0.08 cm2

Total Required Area for Anchors, Astot = Asu + Asmx + Asmy =	29.81	cm2	<	36.19	OK

Bearing Capacity:

Compression Force, C = 140.86 ton
Bending Moment about x axis, Mx = 5.03 ton.m
Bending Moment about y axis, My = 1.45 ton.m

Over Load of Concrete, Wf = 6.90 ton

Volume of the Soil directly above foundation Vsl = (H * bp ^{2}) - V2 - V3 = 1.93 m3

Over Load of Soil directly above foundation Wsl= Vsl * γs = 3.92 ton

Overall Bearing Pressure = σp = ((C + Wf + Wsl)/A) =	4.68	kg/cm2	<	5.10	kg/cm2	OK

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) + (6*My)/(bp3) =$ 5.35 kg/cm2

Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) - (6*My)/(bp3) =$ 5.05 kg/cm2

Compression Stress at corner 3, $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) + (6*My)/(bp3) =$ 4.31 kg/cm2

Compression Stress at corner 4, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) - (6*My)/(bp3) =$ 4.02 kg/cm2

Max. Toe Pressure =	5.35	<	q_{all} =	6.37	OK
Min. Toe Pressure =	4.02	>	0		OK

Bond of Anchor and Grout Check :

Max. force of one anchor hole Pa = 14068 kg

Required embedded length of anchor in Rock, Lmin= Pa / (m * τ_{gs} * π * da) = 70.0 cm

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

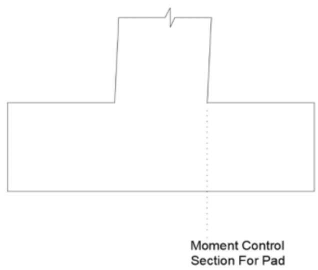
Bond of Grout and Rock Check :

Anchor Hole Diameter, Dh = 7.5 cm

Resisting bond force of the Grout and Rock, $F\tau_{gr} = \tau_{gr}$ * L* Dh * π =	35343	kg	>	14068	OK

Structural Design of Pad:

Longitudinal Rebar:



Compression Stress at section of Max. bending moment, σm = 4.88 kg/cm2

Mu = 1347821 kg.cm = 134782 N.m

Effective Depth, dp = hp - cp = 0.625 m

$K = Mu / f'c * bp * dp^2 =$ 0.01438 < 0.167 OK

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

Z max = 616.97 > 593.75 ==>>> Zmax=0.95 dp = 593.75 mm

As = Mu / φs * fyr * z = 545

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 = 1638 mm2

As max = 50400 mm2

As = 1638

Rebar Diameter = 16 mm =====> QTY = 9 =====> 9 =====> 9 Ø 16

Rebar Quantity = 9

Rebar Spacing = 20.6

===> As= 1810 mm2

One Way Shear:

Compression Stress at critical section of shear , σv = 5.24 kg/cm2

Vu = -6855 kg = -68547 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 = 281674 N

Vr	>	Vu	OK

F.S= Not Defined!

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 4.68 kg/cm2

Vpunch = -256841 kg = -2568410 N

Resisting Shear of Concrete,

Vr = 1667194 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 = 2.36 ton.m = 23596 N.m

Rebar arrangement:

No. of Rebar rows, n = 3

Total No. of Rebars = 8

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

Σ Ai * di^2 = 4537.5

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

>>>>> A = M * c / (φs * fyr *Σ di^2)

As1= 2.7 cm2

B) Moment at the bottom of chimney about y axis

My max = -0.10 ton.m = -957 N.m

>>>>> A = M * c / (φs * fyr *Σ di2)

As2= 0.1 cm2

C) Axial required rebar area, As3 = Ts / (φs*Fys) = 15.3 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 = 18.1 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 = 18.1

Rebar Diameter = 20 mm =====> QTY = 6 =====> 8 =====> 8 Ø 20

===>> As final= 25.1 cm2

Rebar Quantity of One Row = 3

Rebar Spacing = 27.5

Check for Compression :

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

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

$e = l_0 /400 = 2*(hc)/400 =$ 5 mm

$N_{Ed} =$ 145.32 ton

$M_{0Ed,x} =$ 3.00 ton.m

$e_0 = h /30 > 20$ mm ==> $e_0 =$ 23 mm

$M_{Ed,x}$ =	3.73	ton.m				
$M_{Ed,y} = M_{0Ed,y} + e * N_{Ed} > e_0 * N_{Ed}$						
$M_{0Ed,y}$=	0.87	ton.m				
$M_{Ed,y}$ =	3.39	ton.m				
$As * F yr / bc^2 * f'c$ =	0.128					
$N_{ED} / f'c * bc^2$ =	0.145					
d2 =	144	mm				
d2 / bc =	0.21					
Interaction Chart Gives ===> MRd / f'c * bc3 =		0.08	===> $M_{Rd,x} = M_{Rd,y}$ =	55.94	ton.m	
$N_{Rd} = Ac * f'c + As * Fyr$ =		772.74	ton			
N_{Ed} / N_{Rd} =	0.19	===>	a =	1.07		
$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a$ =		0.104	<	1	OK	

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

Max Spacing of links =	400	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-HA

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	90° C3,C NA+	776	2,688	-132,107
Maximum Axial Force, Uplift	90° C3, Min. WS,C NA+	-86	2,111	117,894

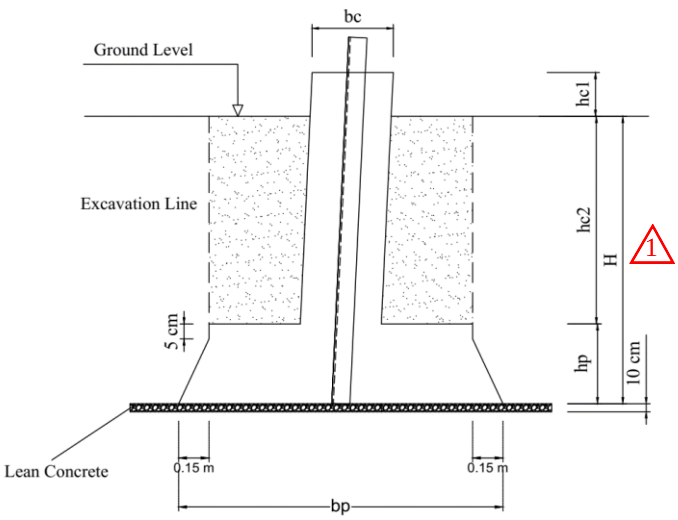
Maximum Loads on Foundation				
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	90° C3,C NA+	23,626	-25,538	-127,473
Maximum Axial Force, Uplift	90° C3, Min. WS,C NA+	20,338	-22,535	113,938

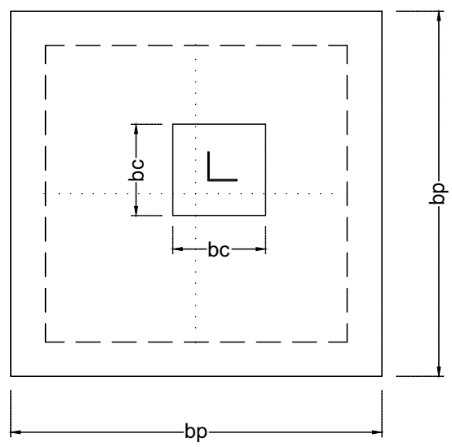
Design Standard: EN 1992:2004

Inputs:

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

	Width of Pad	bp =	2.1	m	
	Height of Pad	hp =	0.5	m	
	Width of Chimney	bc =	0.75	m	
	Height of Chimney above ground level	hc1 =	0.3	m	
	Height of Chimney unedr ground level	hc2 =	3.5	m	
	Depth of Pad	H =	4	m	
	Inplane Slope	β =	10.16	Degree	
	Diagonal Slope	γ =	14.22	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





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

Ultimate Loads:

On Foundation	Compression	C =	140.22	ton
		Vcx =	25.99	ton
		Vcy =	-28.09	ton
	Uplift	T =	125.33	ton
		Vtx =	22.37	ton
		Vty =	-24.79	ton

On Stub	Compression	Cs =	145.32	ton
		Vscx =	0.85	ton
		Vscy =	2.96	ton
	Uplift	Ts =	129.68	ton
		Vstx =	-0.09	ton
		Vsty =	2.32	ton

Soil Passive Pressure Coefficient Kp = tan 2 (45+φ/2) = 3.69
Passive Force on chimney, Fp1 = 34.56 ton
Passive Force on pad, Fp2 = 29.62 ton

Uplift:

Volume of chimney above ground level V1 = 0.17 m3
Volume of chimney under ground level V2 = 1.97 m3
Volume of pad, V3 = 1.90 m3
Total volume of foundation , Vf = 4.04 m3

Total weight of foundation, Wf = Vf * γc = 10.10 ton

Cone volume, $Vcone = (H/3)*(\pi*H^2*\tan^2\Theta + 3*bp^2 + 6*bp*H*\tan\theta) =$ 63.55 m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 = 59.68 m3
Soil weight above foundation, Ws = Vsoil * γb = 121.67 ton

Total resistance force against uplift, Ru= Ws + Wf = 131.77 ton
Uplift Force, U= 125.33 ton

131.77	>	125.33	OK

S.F.= 1.05

Bearing Capacity:

Compression Force, C = 140.86 ton
Bending Moment about x axis, Mx = -12.92 ton.m
Bending Moment about y axis, My = 3.73 ton.m

Over Load of Concrete Wf= 10.10 ton

Volume of the Soil directly above foundation $Vsl = (H * bp^2) - V2 - V3 =$ 13.77 m3

Over Load of Soil directly above foundation Wsl= Vsl * γb = 28.07 ton

Average Bearing Pressure = σp = ((C + Wf + Wsl)/A) =	4.06	kg/cm2	<	5.10	kg/cm2	OK

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 3.46 kg/cm2
Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 2.98 kg/cm2
Compression Stress at corner 3, $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 5.14 kg/cm2
Compression Stress at corner 4, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 4.66 kg/cm2

Max. Toe Pressure =	5.14	<	q_{all} =	6.37	OK
Min. Toe Pressure =	2.98	>		0	OK

S.F.= 1.24

Top Surface Pressure due to Uplift:

Uplift Force, T = 125.71 ton
Bending Moment about x axis, Mx = -8.97 ton.m
Bending Moment about y axis, My = -0.36 ton.m

Pressure due to Uplift at top surface at corner 1, $\sigma u1 = ((T-Wf)/A) + (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 2.02 kg/cm2
Pressure due to Uplift at top surface at corner 2, $\sigma u2 = ((T-Wf)/A) + (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 2.06 kg/cm2
Pressure due to Uplift at top surface at corner 3, $\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 3.18 kg/cm2
Pressure due to Uplift at top surface at corner 4, $\sigma u4 = ((T-Wf)/A) - (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 3.23 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 = 110.62 ton.m

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

Mr = 113.53 ton.m

Mr	>	Mo	OK

S.F.= 1.03

Sliding:

Sliding force, Fo = Vmax

Sliding force, Fo = 24.79 ton

Effective weight of foundation and soil at uplift case, Weff = 6.44 ton

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

Fr = 66.76

Fr	>	Fo	OK

S.F.= 2.69

Structural Design of Pad:

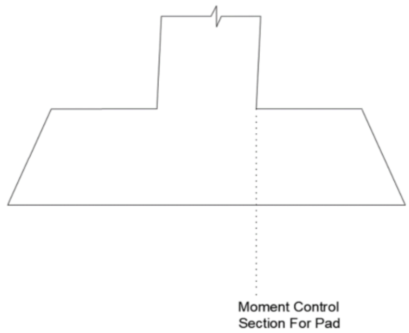
Longitudinal Rebar:

Compression :

Compression Stress at section of Max. bending moment at Pad , σmc = 4.36 kg/cm2

Uplift :

Compression Stress at section of Max. bending moment at Pad , σmu = 2.83 kg/cm2



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

Muc = 1915414 kg.cm = 187902 N.m

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

Muu = 1472528 kg.cm = 144455 N.m

Effective Depth of pad , dp = hp - cp = 0.425 m

Compression :

$K = Mu / f'c * bp * dp^2 =$ 0.037 < 0.167 OK

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

Z max = 410.6 > 403.75 ==>>> Zmax=0.95 dp = 403.75

As = Mu / φs * fyr * z = 1116.9 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 = 414.0 > 403.75 ==>>> Zmax=0.95 dp = 403.75

As = Mu / φs * fyr * z = 858.7 mm2

Top of Pad :

As2t= 858.7 mm2

Rebar Diameter= 12 mm =====> QTY = 8 ==>> 10 =====> 10 Ø 12 =====> 1131 mm2

Rebar Quantity = 10

Rebar Spacing = 183.3 mm

Bottom of Pad :

As2b= 1116.9 mm2

Rebar Diameter= 12 mm =====> QTY = 10 ==>> 11 =====> 11 Ø 12 =====> 1244 mm2

Rebar Quantity = 11

Rebar Spacing = 195.0 mm

Min. Rebar Check:

Ast =	2375.0	mm2				
ρst =	0.0027		>			
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 , $\sigma v =$ 4.70 kg/cm2

Vu =	21438	kg	=	214381	N	
k = 1 +(200/dp2)^0.5 < 2.0	>>>	k =	1.69		EN 1992-1-1:2004	6.2
$\rho_1 =$	0.0027					
$\sigma_{cp} = N_{ED}/A_C =$	0					
$C_{Rd,c} = 0.18/\gamma_c =$	0.12					
k1 =	0.15					
$v_{min} = 0.035 * k^{3/2} * f'c^{1/2} =$	0.343	Mpa			EN 1992-1-1:2004	6.3N
Vr =	315266	N				

Vr	>	Vu	OK

F.S= 1.47

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 4.06 kg/cm2

To check if punch shear section is defined in Pad ==> bp1 - (bc + 4dp2) = -0.35 < 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 = 8.97 ton.m = 89663 N.m

Rebar arrangement:

No. of rebars rows, n =	4	
Total No. of rebars =	12	
Distance of the last row to center, c =	30	cm
$\Sigma A_i * d_i^2 =$	7600	

$\varphi s * fyr = M * c / I$ >>>>> $\Sigma A_i * d_i^2 = M * c / \varphi s * fyr$

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

As1= 10.0 cm2

B) Moment at the bottom of chimney about y axis My max = 0.36 ton.m = 3636 N.m

$\varphi s * fyr = M * c / I$ As2= 0.4 cm2

C) Axial required rebar area, As3 = Ts / (φs*Fyr) = 15.3 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 =			25.7	cm2			
As min =	max (0.1*Cs/Fy , 0.002*Ac) =		11.3	cm2		9.12 N		
As max =	0.04 *Ac =		225.0	cm2		9.5.2.3		
As =	25.7							
Rebar Diameter =	20	mm =====>	QTY =	9	=====>	12	=====>	12 Ø 20
===>> As final=	37.7	cm2						
Rebar Quantity of One Row =	4							
Rebar Spacing =	20.0							

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

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

$e = l_0 /400 = 2*(hc)/400 =$	19	mm
$N_{Ed} =$	145.32	ton
$M_{0Ed, x} =$	11.42	ton.m
$e_0 = h /30 > 20$ mm ==> $e_0 =$	25	mm
$M_{Ed,x} =$	14.18	ton.m

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

$M_{0Ed, y} =$	3.29	ton.m
$M_{Ed,y} =$	6.06	ton.m
$As * F\ yr / bc^2 * f'c =$	0.168	
$N_{ED}/ f'c * bc^2 =$	0.127	
d2 =	142	mm
d2 / bc =	0.19	

Interaction Chart Gives ===>	$M_{Rd} / f'c * bc^3 =$	0.1	===> $M_{Rd,x} = M_{Rd,y} =$		57.34	ton.m
$N_{Rd} =$	Ac * f'c + As * Fyr =	924.65	ton			
$N_{Ed} / N_{Rd} =$	0.16	===>	a =	1.05		
$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a =$		0.326	<	1	OK	

Stirrup Rebar :

Max Spacing of links =	400	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-HA

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	90° C3,C NA+	776	2,688	-132,107
Maximum Axial Force, Uplift	90° C3, Min. WS,C NA+	-86	2,111	117,894

Maximum Loads on Foundation

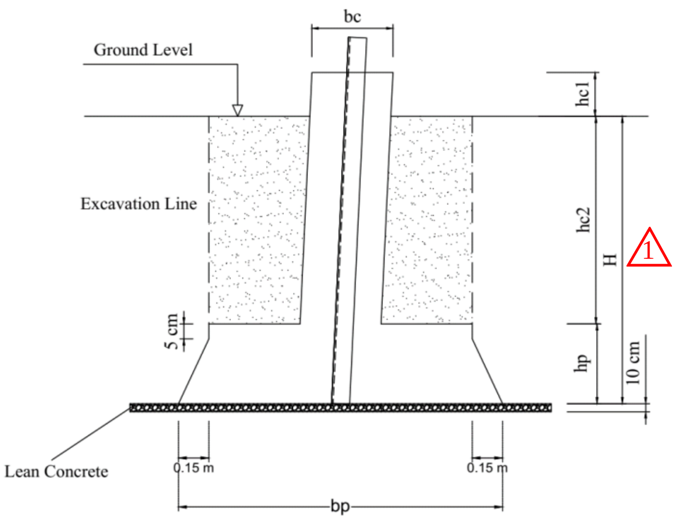
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	90° C3,C NA+	23,626	-25,538	-127,473
Maximum Axial Force, Uplift	90° C3, Min. WS,C NA+	20,338	-22,535	113,938

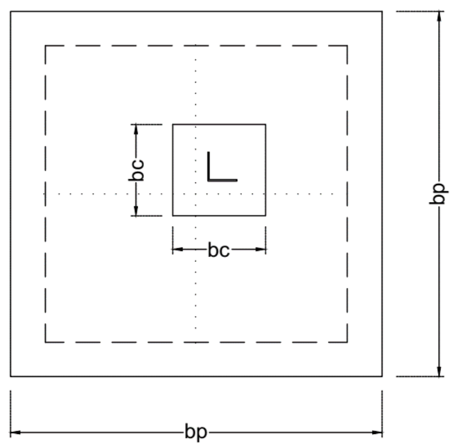
Design Standard: EN 1992:2004

Inputs:

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

	Width of Pad	bp =	2.6	m	
	Height of Pad	hp =	0.5	m	
	Width of Chimney	bc =	0.75	m	
	Height of Chimney above ground level	hc1 =	0.3	m	
	Height of Chimney unedr ground level	hc2 =	3.5	m	
	Depth of Pad	H =	4	m	
	Inplane Slope	β =	10.16	Degree	
	Diagonal Slope	γ =	14.22	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





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

Ultimate Loads:

On Foundation	Compression	C =	140.22	ton
		Vcx =	25.99	ton
		Vcy =	-28.09	ton
	Uplift	T =	125.33	ton
		Vtx =	22.37	ton
		Vty =	-24.79	ton

On Stub	Compression	Cs =	145.32	ton
		Vscx =	0.85	ton
		Vscy =	2.96	ton
	Uplift	Ts =	129.68	ton
		Vstx =	-0.09	ton
		Vsty =	2.32	ton

Soil Passive Pressure Coefficient Kp = tan 2 (45+φ/2) = 3.69
Passive Force on chimney, Fp1 = 29.38 ton
Passive Force on pad, Fp2 = 31.17 ton

Uplift:

Volume of chimney above ground level V1 = 0.17 m3
Volume of chimney under ground level V2 = 1.97 m3
Volume of pad, V3 = 3.00 m3
Total volume of foundation , Vf = 5.14 m3

Total weight of foundation, Wf = Vf * γc = 12.85 ton

Cone volume, Vcone = $(H/3)*(\pi*H^2*\tan^2\Theta + 3*bp^2 + 6*bp*H*\tan\theta)$ = 71.60 m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 = 66.63 m3
Soil weight above foundation, Ws = Vsoil * γb = 115.46 ton

Total resistance force against uplift, Ru= Ws + Wf = 128.30 ton
Uplift Force, U= 125.33 ton

128.30	>	125.33	OK

S.F.= 1.02

Bearing Capacity:

Compression Force, C = 140.86 ton
Bending Moment about x axis, Mx = -12.92 ton.m
Bending Moment about y axis, My = 3.73 ton.m

Over Load of Concrete Wf= 12.85 ton

Volume of the Soil directly above foundation Vsl = $(H * bp^2)$ - V2 - V3 = 22.07 m3

Over Load of Soil directly above foundation Wsl= Vsl * γb = 38.25 ton

Average Bearing Pressure = σp = ((C + Wf + Wsl)/A) =	2.84	kg/cm2	<	3.06	kg/cm2	OK

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) + (6*My)/(bp^3)$ = 2.53 kg/cm2
Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) - (6*My)/(bp^3)$ = 2.27 kg/cm2
Compression Stress at corner 3, $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) + (6*My)/(bp^3)$ = 3.41 kg/cm2
Compression Stress at corner 4, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) - (6*My)/(bp^3)$ = 3.15 kg/cm2

Max. Toe Pressure =	3.41	<	q_{all} =	3.82	OK
Min. Toe Pressure =	2.27	>		0	OK

S.F.= 1.12

Top Surface Pressure due to Uplift:

Uplift Force, T = 125.71 ton
Bending Moment about x axis, Mx = -8.97 ton.m
Bending Moment about y axis, My = -0.36 ton.m

Pressure due to Uplift at top surface at corner 1, $\sigma u1 = ((T-Wf)/A) + (6*Mx)/(bp^3) + (6*My)/(bp^3)$ = 1.35 kg/cm2
Pressure due to Uplift at top surface at corner 2, $\sigma u2 = ((T-Wf)/A) + (6*Mx)/(bp^3) - (6*My)/(bp^3)$ = 1.38 kg/cm2
Pressure due to Uplift at top surface at corner 3, $\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp^3) + (6*My)/(bp^3)$ = 1.96 kg/cm2
Pressure due to Uplift at top surface at corner 4, $\sigma u4 = ((T-Wf)/A) - (6*Mx)/(bp^3) - (6*My)/(bp^3)$ = 1.99 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 = 131.82 ton.m

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

Mr = 136.21 ton.m

Mr	>	Mo	OK

S.F.= 1.03

Sliding:

Sliding force, Fo = Vmax

Sliding force, Fo = 24.79 ton

Effective weight of foundation and soil at uplift case, Weff = 2.97 ton

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

Fr = 61.74

Fr	>	Fo	OK

S.F.= 2.49

Structural Design of Pad:

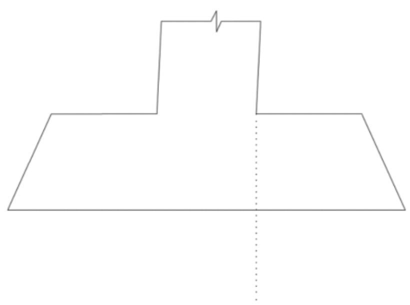
Longitudinal Rebar:

Compression :

Compression Stress at section of Max. bending moment at Pad , σmc = 2.97 kg/cm2

Uplift :

Compression Stress at section of Max. bending moment at Pad , σmu = 1.76 kg/cm2



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

Muc = 2858029 kg.cm = 280373 N.m

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

Muu = 2116761 kg.cm = 207654 N.m

Effective Depth of pad , dp = hp - cp = 0.425 m

Compression :

$K = Mu / f'c * bp * dp^2 =$ 0.045 < 0.167 OK

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

Z max = 407.5 > 403.75 ==>>> Zmax=0.95 dp = 403.75

As = Mu / φs * fyr * z = 1666.6 mm2

Uplift :

$K = Mu / f'c * bp * dp^2 =$ 0.033

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

Z max = 412.2 > 403.75 ==>>> Zmax=0.95 dp = 403.75

As = Mu / φs * fyr * z = 1234.4 mm2

Top of Pad :

As2t= 1234.4 mm2

Rebar Diameter= 12 mm =====> QTY = 11 ==>> 12 =====> 12 Ø 12 =====> 1357 mm2

Rebar Quantity = 12

Rebar Spacing = 195.5 mm

Bottom of Pad :

As2b= 1666.6 mm2

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

Rebar Quantity = 15

Rebar Spacing = 175.0 mm

Min. Rebar Check:

Ast =	3053.6	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 = 3.11 kg/cm2

Vu = 33660 kg = 336601 N

k = 1 +(200/dp2)^0.5 < 2.0 >>> k = 1.69 EN 1992-1-1:2004 6.2

ρ_1 = 0.0028

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

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

k1 = 0.15

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

Vr = 395270 N

Vr	>	Vu	OK

F.S= 1.17

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 2.84 kg/cm2

To check if punch shear section is defined in Pad ==> bp1 - (bc + 4dp2) = 0.15 > 0 ==> Punch Shear to be Checked in Pad 2

Vpunch = 30765 kg = 307647 N

Resisting Shear of Concrete,

Vr = 1268013 N

Vr	>	Vpunch	OK

F.S.= 4.12

Structural Design of Chimney:

Design of Longitudinal Reinforcement for Uplift :

A) Moment at the bottom of chimney about x axis Mx max = 8.97 ton.m = 89663 N.m

Rebar arrangement:

No. of rebars rows, n = 4

Total No. of rebars = 12

Distance of the last row to center, c = 30 cm

$\Sigma Ai*di^2$ = 7600

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

>>>>> A = M * c / (φs * fyr *Σdi^2)

As1= 10.0 cm2

B) Moment at the bottom of chimney about y axis My max = 0.36 ton.m = 3636 N.m

φs * fyr = M * c /I As2= 0.4 cm2

C) Axial required rebar area, As3 = Ts / (φs*Fyr) = 15.3 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 =			25.7	cm2			
As min =	max (0.1*Cs/Fy , 0.002*Ac) =		11.3	cm2		9.12 N		
As max =	0.04 *Ac =		225.0	cm2		9.5.2.3		
As =	25.7							
Rebar Diameter =	20	mm =====>	QTY =	9	=====>	12	=====>	12 Ø 20
===>> As final=	37.7	cm2						
Rebar Quantity of One Row =	4							
Rebar Spacing =	20.0							

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

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

$e = l_0 /400 = 2*(hc)/400 =$	19	mm
$N_{Ed} =$	145.32	ton
$M_{0Ed, x} =$	11.42	ton.m
$e_0 = h /30 > 20$ mm ==> $e_0 =$	25	mm
$M_{Ed,x} =$	14.18	ton.m

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

$M_{0Ed, y} =$	3.29	ton.m
$M_{Ed,y} =$	6.06	ton.m
$As * F yr / bc^2 * f'c =$	0.168	
$N_{ED}/ f'c * bc^2 =$	0.127	
d2 =	142	mm
d2 / bc =	0.19	

Interaction Chart Gives ===>	$M_{Rd} / f'c * bc^3 =$	0.1	===> $M_{Rd,x} = M_{Rd,y} =$		57.34	ton.m
$N_{Rd} =$	$Ac * f'c + As * Fyr =$	924.65	ton			
$N_{Ed} / N_{Rd} =$	0.16	===>	a =	1.05		
$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a =$		0.326	<	1	OK	

Stirrup Rebar :

Max Spacing of links =	400	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-HA

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	90° C3,C NA+	776	2,688	-132,107
Maximum Axial Force, Uplift	90° C3, Min. WS,C NA+	-86	2,111	117,894

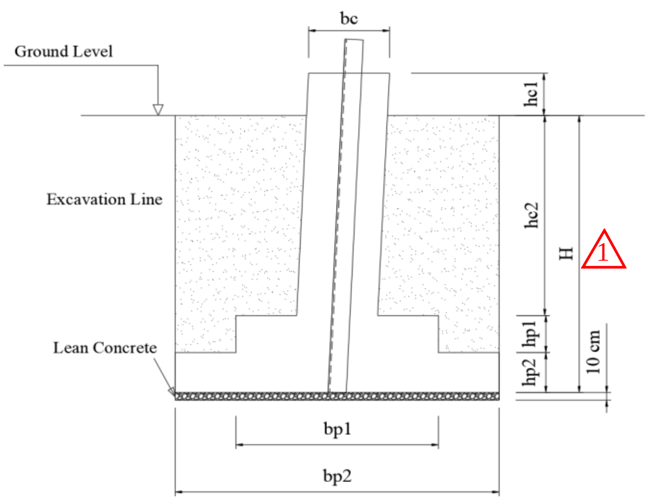
Maximum Loads on Foundation				
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	90° C3,C NA+	23,626	-25,538	-127,473
Maximum Axial Force, Uplift	90° C3, Min. WS,C NA+	20,338	-22,535	113,938

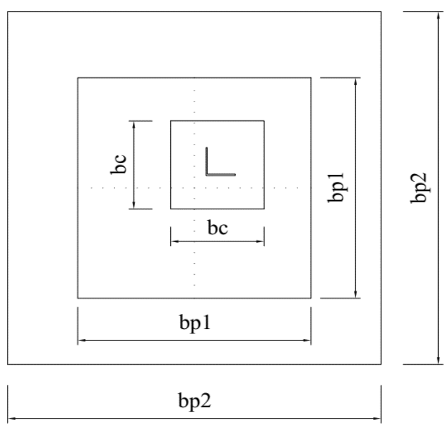
Design Standard: EN 1992:2004

Inputs:

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

Foundation Dimensions	Width of Pad 1	bp1 =	1.6	m	
	Width of Pad 2	bp2 =	3.1	m	
	Height of Pad 1	hp1 =	0.3	m	
	Height of Pad 2	hp2 =	0.3	m	
	Width of Chimney	bc =	0.75	m	
	Height of Chimney above ground level	hc1 =	0.3	m	
	Height of Chimney unedr ground level	hc2 =	3.4	m	
	Depth of Pad	H =	4	m	
	Inplane Slope	β =	10.16	Degree	
	Diagonal Slope	γ =	14.22	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 =	140.22	ton
		Vcx =	25.99	ton
		Vcy =	-28.09	ton
	Uplift	T =	125.33	ton
		Vtx =	22.37	ton
		Vty =	-24.79	ton

On Stub	Compression	Cs =	145.32	ton
		Vscx =	0.85	ton
		Vscy =	2.96	ton
	Uplift	Ts =	129.68	ton
		Vstx =	-0.09	ton
		Vsty =	2.32	ton

Soil Passive Pressure Coefficient	$K_p = \tan^2(45+\varphi/2)$ =	3.69	
Passive Force on chimney,	Fp1 =	27.72	ton
Passive Force on pad1,	Fp2 =	10.90	ton
Passive Force on pad2,	Fp3 =	22.90	ton

Uplift:

Volume of chimney above ground level	V1 =	0.17	m3
Volume of chimney under ground level	V2 =	1.91	m3
Volume of pad1,	V3 =	0.77	m3
Volume of pad2,	V4 =	2.88	m3
Total volume of foundation ,	Vf =	5.73	m3

Total weight of foundation, Wf = Vf * γc = 14.33 ton

Cone volume, $V_{cone} = (h/3)*(\pi*h^2*\tan^2\Theta + 3*bp2^2 + 6*bp2*h*\tan\theta)$ = 83.88 m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 = 81.20 m3

Soil weight above foundation, Ws = Vsoil * γb = 140.72 ton

Total resistance force against uplift, Ru= Ws + Wf = 155.05 ton

Uplift Force, U= 125.33 ton

155.05	>	125.33	OK

S.F.= 1.24

1

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

G: weight of foundation and soil vertical to the base = 71.30 ton

Z: uplift force on fondation = 113.94 ton

Z/G = 0.63 >>> Ratio = 0.93 OK

Bearing Capacity:

Compression Force,	C =	140.86	ton
Bending Moment about x axis,	Mx =	-12.92	ton.m
Bending Moment about y axis,	My =	3.73	ton.m

Over Load of Concrete Wf= 14.33 ton

Volume of the Soil directly above foundation Vsl = $(H * bp2^2)$ - V2 - V3 - V4 = 32.88 m3

Over Load of Soil directly above foundation Wsl= Vsl * γb = 56.97 ton

Average Bearing Pressure = σp = ((C + Wf + Wsl)/A) =	2.21	kg/cm2	<	3.06	kg/cm2	OK

Compression Stress at corner 1,	$\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3)$ =	2.02	kg/cm2
Compression Stress at corner 2,	$\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3)$ =	1.87	kg/cm2
Compression Stress at corner 3,	$\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3)$ =	2.54	kg/cm2
Compression Stress at corner 4,	$\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3)$ =	2.39	kg/cm2

Max. Toe Pressure =	2.54	<	q_{all} =	3.82	OK
Min. Toe Pressure =	1.87	>		0	OK

S.F.= 1.50

Top Surface Pressure due to Uplift:

Uplift Force,	T =	125.71	ton
Bending Moment about x axis,	Mx =	-8.73	ton.m
Bending Moment about y axis,	My =	-0.35	ton.m

Pressure due to Uplift at top surface at corner 1,	$\sigma u1 = ((T-Wf)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3)$ =	0.98	kg/cm2
Pressure due to Uplift at top surface at corner 2,	$\sigma u2 = ((T-Wf)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3)$ =	0.99	kg/cm2
Pressure due to Uplift at top surface at corner 3,	$\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3)$ =	1.33	kg/cm2
Pressure due to Uplift at top surface at corner 4,	$\sigma u4 = ((T-Wf)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3)$ =	1.34	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 = 155.31 ton.m

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

Mr = 196.57 ton.m

Mr	>	Mo	OK

S.F.= 1.27

Sliding:

Sliding force, Fo = Vmax

Sliding force, Fo = 24.79 ton

Effective weight of foundation and soil at uplift case, Weff = 29.72 ton

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

Fr = 73.40

Fr	>	Fo	OK

S.F.= 2.96

Structural Design of Pad:

Longitudinal Rebar:

Compression :

Compression Stress at section of Max. bending moment at Pad 1, σmc1 = 2.27 kg/cm2

Compression Stress at section of Max. bending moment at Pad 2, σmc2 = 2.34 kg/cm2

Uplift :

Compression Stress at section of Max. bending moment at Pad 1, σmu1 = 1.20 kg/cm2

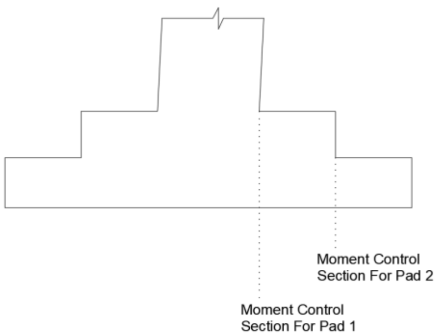
Compression Stress at section of Max. bending moment at Pad 2, σmu2 = 1.25 kg/cm2

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

Muc 1= 3879759 kg.cm = 380604 N.m

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

Muc 2= 1556113 kg.cm = 152655 N.m



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

Muu 1= 2761354 kg.cm = 270889 N.m

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

Muu 2= 1139054 kg.cm = 111741 N.m

Effective Depth of pad 1, dp1 = hp1+hp2 - cp = 0.525 m

Effective Depth of pad 2, dp2 = hp2 - cp = 0.225 m

Compression :

Pad 1:

$K = Mu / f'c * bp * dp^2 =$ 0.065 < 0.167 OK

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

Z max = 493 < 498.75 ==>>> OK

As = Mu / φs * fyr * z = 1853 mm2

Pad 2:

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

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

Z max = 209.4 < 213.75 ==>>> OK

As = Mu / φs * fyr * z = 1749.3 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 = 513.7 > 498.75 ==>>> Zmax=0.95 dp = 498.75

As = Mu / φs * fyr * z = 1303.5 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 = 213.8 > 213.75 ==>>> Zmax=0.95 dp = 213.75

As = Mu / φs * fyr * z = 1254.6 mm2

Top of Pad 1 :

As1t=	1303.5			mm2						
Rebar Diameter=	16	mm	=====>	QTY =	7 ==>>	7	=====>	7 Ø 16	=====>	1407 mm2
Rebar Quantity =	7									
Rebar Spacing =	241.7	mm								

Top of Pad 2 :

As2t=	1254.6	mm2								
Rebar Diameter=	12	mm	=====>	QTY =	12 ==>>	13	=====>	13 Ø 12	=====>	1470 mm2
Rebar Quantity =	13									
Rebar Spacing =	245.8	mm								

Bottom of Pad 2 :

As2b=	1852.5	mm2								
Rebar Diameter=	12	mm	=====>	QTY =	17 ==>>	17	=====>	17 Ø 12	=====>	1923 mm2
Rebar Quantity =	17									
Rebar Spacing =	184.4	mm								

Min. Rebar Check:

Ast = 4800.4 mm2

ρst = 0.0041 >

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 = 2.36 kg/cm2

Vu1 = 36757 kg = 367574 N

Compression Stress at critical section of shear at Pad2 , σv2 = 2.38 kg/cm2

Vu2 = 29013 kg = 290133 N

Pad 1

k = 1 +(200/dp1)^0.5 < 2.0 >>> k = 1.62 EN 1992-1-1:2004 6.2

$\rho_1 =$ 0.0041

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

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

k1 = 0.15

$v_{min} = 0.035 * k^{3/2} * f'c^{1/2} =$ 0.322 Mpa EN 1992-1-1:2004 6.3N

Vr1 = 459928 N

Vr1	>	Vu1	OK

F.S= 1.25

Pad 2

k = 1 +(200/dp2)^0.5 < 2.0 >>> k = 1.94 EN 1992-1-1:2004 6.2

ρ_1 = 0.0049

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

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

k1 = 0.15

$v_{min} = 0.035 * k^{3/2} * f'c^{1/2}$ = 0.424 Mpa EN 1992-1-1:2004 6.3N

Vr2 = 347143 N

Vr2	>	Vu2	OK

F.S= 1.20

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 2.21 kg/cm2

Pad 1

Vpunch1 = 39394 kg = 393942 N

Resisting Shear of Concrete,

Vr1 = 1968066 N

Vr1	>	Vpunch1	OK

F.S.= 5.00

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 = 55360 kg = 553602 N

Resisting Shear of Concrete,

Vr2 = 1033304 N

Vr2	>	Vpunch2	OK

F.S.= 1.87

Structural Design of Chimney:

Design of Longitudinal Reinforcement for Uplift :

A) Moment at the bottom of chimney about x axis Mx max = 8.73 ton.m = 87304 N.m

Rebar arrangement:

No. of rebars rows, n = 4

Total No. of rebars = 12

Distance of the last row to center, c = 30 cm

$\Sigma Ai*di^2$ = 7600

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

>>>>> A = M * c / (φs * fyr *Σdi^2)

As1= 9.7 cm2

B) Moment at the bottom of chimney about y axis My max = 0.35 ton.m = 3541 N.m

φs * fyr = M * c /I As2= 0.4 cm2

C) Axial required rebar area, As3 = Ts / (φs*Fyr) = 15.3 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 = 25.4 cm2

As min =	max (0.1*Cs/Fy , 0.002*Ac) =				11.3	cm2		9.12 N	
As max =	0.04 *Ac =				225.0	cm2		9.5.2.3	
As =	25.4								
Rebar Diameter =	20	mm	=====>	QTY =	9	=====>	12	=====>	12 Ø 20
===>> As final=	37.7	cm2							
Rebar Quantity of One Row =	4								
Rebar Spacing =	20.0								

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

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

$e = l_0 /400 = 2*(hc)/400 =$	18.5	mm
$N_{Ed} =$	145.32	ton
$M_{0Ed,x} =$	11.12	ton.m
$e_0 = h/30 > 20$ mm ==> $e_0 =$	25	mm
$M_{Ed,x} =$	13.80	ton.m

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

$M_{0Ed,y} =$	3.21	ton.m
$M_{Ed,y} =$	5.90	ton.m
$As * F yr / bc^2 * f'c =$	0.168	
$N_{ED}/ f'c * bc^2 =$	0.127	
d2 =	142	mm
d2 / bc =	0.19	

Interaction Chart Gives ===> $M_{Rd} / f'c * bc^3 =$ 0.1 ===> $M_{Rd,x} = M_{Rd,y} =$ 57.34 ton.m

$N_{Rd} =$ $Ac * f'c + As * Fyr =$ 924.65 ton

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

$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a =$ 0.317 < 1 OK

Stirrup Rebar :

Max Spacing of links =	400	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-HA

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	90° C3,C NA+	776	2,688	-132,107
Maximum Axial Force, Uplift	90° C3, Min. WS,C NA+	-86	2,111	117,894

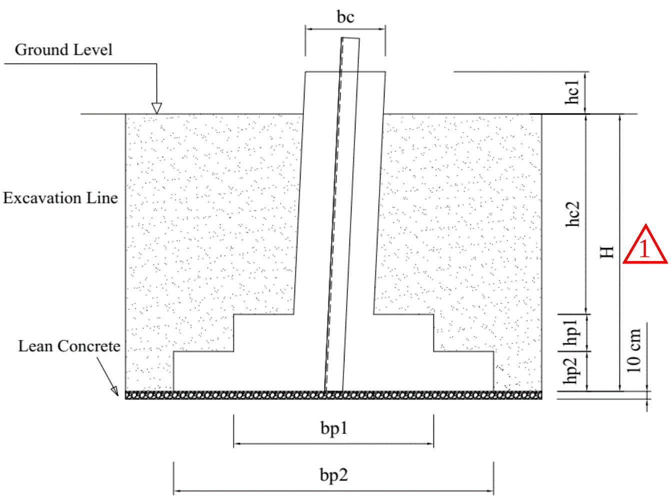
Maximum Loads on Foundation				
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	90° C3,C NA+	23,626	-25,538	-127,473
Maximum Axial Force, Uplift	90° C3, Min. WS,C NA+	20,338	-22,535	113,938

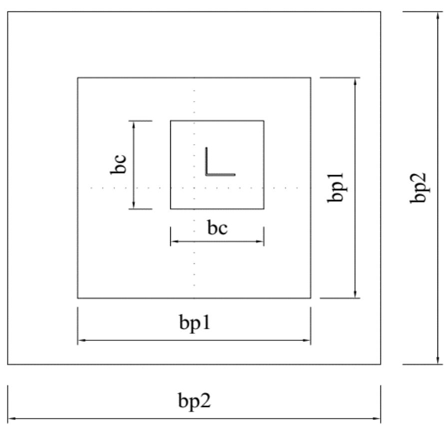
Design Standard: EN 1992:2004

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 =	3.4	m	
	Height of Pad 1	hp1 =	0.3	m	
	Height of Pad 2	hp2 =	0.3	m	
	Width of Chimney	bc =	0.75	m	
	Height of Chimney above ground level	hc1 =	0.3	m	
	Height of Chimney unedr ground level	hc2 =	3.4	m	
	Depth of Pad	H =	4	m	
	Inplane Slope	β =	10.16	Degree	
	Diagonal Slope	γ =	14.22	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 =	140.22	ton
		Vcx =	25.99	ton
		Vcy =	-28.09	ton
	Uplift	T =	125.33	ton
		Vtx =	22.37	ton
		Vty =	-24.79	ton

On Stub	Compression	Cs =	145.32	ton
		Vscx =	0.85	ton
		Vscy =	2.96	ton
	Uplift	Ts =	129.68	ton
		Vstx =	-0.09	ton
		Vsty =	2.32	ton

Soil Passive Pressure Coefficient	Kp = tan 2 (45+φ/2) =	2.46	
Passive Force on chimney,	Fp1 =	19.60	ton
Passive Force on pad1,	Fp2 =	8.19	ton
Passive Force on pad2,	Fp3 =	17.75	ton

Uplift:

Volume of chimney above ground level	V1 =	0.17	m3
Volume of chimney under ground level	V2 =	1.91	m3
Volume of pad1,	V3 =	0.87	m3
Volume of pad2,	V4 =	3.47	m3
Total volume of foundation ,	Vf =	6.42	m3

Total weight of foundation, Wf = Vf * γc = 16.04 ton

Cone volume, $Vcone = (h/3)*(\pi*h^2*\tan^2\Theta + 3*bp2^2 + 6*bp2*h*\tan\theta) =$ 75.80 m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 = 73.02 m3

Soil weight above foundation, Ws = Vsoil * γb = 133.99 ton

Total resistance force against uplift, Ru= Ws + Wf = 150.03 ton

Uplift Force, U= 125.33 ton

150.03	>	125.33	OK

S.F.= 1.20

1

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

G: weight of foundation and soil vertical to the base = 89.42 ton

Z: uplift force on fondation = 113.94 ton

Z/G = 0.78 >>> Ratio = 0.98 OK

Bearing Capacity:

Compression Force,	C =	140.86	ton
Bending Moment about x axis,	Mx =	-12.92	ton.m
Bending Moment about y axis,	My =	3.73	ton.m

Over Load of Concrete Wf= 16.04 ton

Volume of the Soil directly above foundation $Vsl = (H * bp2^2) - V2 - V3 - V4 =$ 39.99 m3

Over Load of Soil directly above foundation Wsl= Vsl * γb = 73.38 ton

Average Bearing Pressure = σp = ((C + Wf + Wsl)/A) =	1.99	kg/cm2	<	2.04	kg/cm2	OK

Compression Stress at corner 1,	$\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$	1.85	kg/cm2
Compression Stress at corner 2,	$\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$	1.74	kg/cm2
Compression Stress at corner 3,	$\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$	2.25	kg/cm2
Compression Stress at corner 4,	$\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$	2.13	kg/cm2

Max. Toe Pressure =	2.25	<	q_{all} =	2.55	OK
Min. Toe Pressure =	1.74	>		0	OK

S.F.= 1.13

Top Surface Pressure due to Uplift:

Uplift Force,	T =	125.71	ton
Bending Moment about x axis,	Mx =	-8.73	ton.m
Bending Moment about y axis,	My =	-0.35	ton.m

Pressure due to Uplift at top surface at corner 1,	$\sigma u1 = ((T-Wf)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$	0.81	kg/cm2
Pressure due to Uplift at top surface at corner 2,	$\sigma u2 = ((T-Wf)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$	0.82	kg/cm2
Pressure due to Uplift at top surface at corner 3,	$\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$	1.08	kg/cm2
Pressure due to Uplift at top surface at corner 4,	$\sigma u4 = ((T-Wf)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$	1.09	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 = 168.03 ton.m

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

Mr = 208.00 ton.m

Mr	>	Mo	OK

S.F.= 1.24

Sliding:

Sliding force, Fo = Vmax

Sliding force, Fo = 24.79 ton

Effective weight of foundation and soil at uplift case, Weff = 24.70 ton

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

Fr = 55.42

Fr	>	Fo	OK

S.F.= 2.24

Structural Design of Pad:

Longitudinal Rebar:

Compression :

Compression Stress at section of Max. bending moment at Pad 1, σmc1 = 2.04 kg/cm2

Compression Stress at section of Max. bending moment at Pad 2, σmc2 = 2.09 kg/cm2

Uplift :

Compression Stress at section of Max. bending moment at Pad 1, σmu1 = 0.98 kg/cm2

Compression Stress at section of Max. bending moment at Pad 2, σmu2 = 1.02 kg/cm2

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

Muc 1= 4519201 kg.cm = 443334 N.m

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

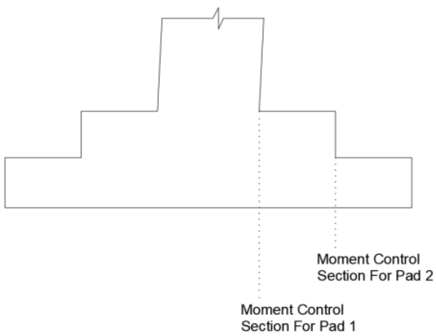
Muc 2= 1814756 kg.cm = 178028 N.m

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

Muu 1= 3125809 kg.cm = 306642 N.m

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

Muu 2= 1301624 kg.cm = 127689 N.m



Effective Depth of pad 1, dp1 = hp1+hp2 - cp = 0.525 m

Effective Depth of pad 2, dp2 = hp2 - cp = 0.225 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 = 490 < 498.75 ==>>> OK

As = Mu / φs * fyr * z = 2172 mm2

Pad 2:

$K = Mu / f'c * bp * dp^2 =$ 0.078 < 0.167 OK

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

Z max = 208.4 < 213.75 ==>>> OK

As = Mu / φs * fyr * z = 2050.5 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 =	513.4	>	498.75	==>>>	Zmax=0.95 dp =	498.75
As = Mu / φs * fyr * z =	1475.6	mm2				

Pad 2:

$K = Mu / f'c * bp * dp^2 =$	0.056

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

Z max =	213.4	<	213.75	==>>>	OK
As = Mu / φs * fyr * z =	1436.4	mm2			

Top of Pad 1 :

As1t=	1475.6	mm2									
Rebar Diameter=	16	mm	=====>	QTY =	8 ==>>	8	=====>	8 Ø 16	=====>	1608	mm2
Rebar Quantity =	8										
Rebar Spacing =	221.4	mm									

Top of Pad 2 :

As2t=	1436.4	mm2									
Rebar Diameter=	12	mm	=====>	QTY =	13 ==>>	14	=====>	14 Ø 12	=====>	1583	mm2
Rebar Quantity =	14										
Rebar Spacing =	250.0	mm									

Bottom of Pad 2 :

As2b=	2172.5	mm2									
Rebar Diameter=	12	mm	=====>	QTY =	20 ==>>	20	=====>	20 Ø 12	=====>	2262	mm2
Rebar Quantity =	20										
Rebar Spacing =	171.1	mm									

Min. Rebar Check:

Ast =	5453.8	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 =   2.10   kg/cm2

Vu1 =   41317   kg   =   413175   N

Compression Stress at critical section of shear at Pad2 ,   σv2 =   2.12   kg/cm2

Vu2 =   31325   kg   =   313253   N

Pad 1

k = 1 +(200/dp1)^0.5 < 2.0	>>>	k =	1.62		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					
$v_{min} = 0.035 * k^{3/2} * f'c^{1/2} =$	0.322	Mpa			EN 1992-1-1:2004	6.3N

Vr1 = 506056 N

Vr1	>	Vu1	OK	F.S=	1.22

Pad 2

k = 1 +(200/dp2)^0.5 < 2.0 >>> k = 1.94 EN 1992-1-1:2004 6.2

ρ_1 = 0.0050

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

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

k1 = 0.15

$v_{min} = 0.035 * k^{3/2} * f'c^{1/2}$ = 0.424 Mpa EN 1992-1-1:2004 6.3N

Vr2 = 384922 N

Vr2	>	Vu2	OK	F.S=	1.23

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 1.99 kg/cm2

Pad 1

Vpunch1 = 59981 kg = 599815 N

Resisting Shear of Concrete,

Vr1 = 1999856 N

Vr1	>	Vpunch1	OK	F.S.=	3.33

Pad 2

To check if punch shear section is defined in Pad 2 ==> bp1 - (bp2 + 4dp2) = 0.8 > 0 ==> Punch Shear to be Checked in Pad 2

Vpunch2 = 65315 kg = 653152 N

Resisting Shear of Concrete,

Vr2 = 1089944 N

Vr2	>	Vpunch2	OK	F.S.=	1.67

Structural Design of Chimney:

Design of Longitudinal Reinforcement for Uplift :

A) Moment at the bottom of chimney about x axis Mx max = 8.73 ton.m = 87304 N.m

Rebar arrangement:

No. of rebars rows, n = 4

Total No. of rebars = 12

Distance of the last row to center, c = 30 cm

$\Sigma Ai*di^2$ = 7600

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

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

As1= 9.7 cm2

B) Moment at the bottom of chimney about y axis My max = 0.35 ton.m = 3541 N.m

$\varphi s * fyr = M * c / I$ As2= 0.4 cm2

C) Axial required rebar area, $As3 = Ts / (\varphi s*Fyr)$ = 15.3 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 = 25.4 cm2

As min =	max (0.1*Cs/Fy , 0.002*Ac) =			11.3	cm2		9.12 N	
As max =	0.04 *Ac =			225.0	cm2		9.5.2.3	
As =	25.4							
Rebar Diameter =	20	mm	=====> QTY =	9	=====>	12	=====>	12 Ø 20
===>> As final=	37.7	cm2						
Rebar Quantity of One Row =	4							
Rebar Spacing =	20.0							

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

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

$e = l_0 /400 = 2*(hc)/400 =$	18.5	mm
$N_{Ed} =$	145.32	ton
$M_{0Ed,x} =$	11.12	ton.m
$e_0 = h /30 > 20$ mm ==> $e_0 =$	25	mm
$M_{Ed,x} =$	13.80	ton.m

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

$M_{0Ed,y} =$	3.21	ton.m
$M_{Ed,y} =$	5.90	ton.m
$As * F yr / bc^2 * f'c =$	0.168	
$N_{ED}/ f'c * bc^2 =$	0.127	
d2 =	142	mm
d2 / bc =	0.19	

Interaction Chart Gives ===>	$M_{Rd} / f'c * bc^3 =$	0.1	===> $M_{Rd,x} = M_{Rd,y} =$		57.34	ton.m
$N_{Rd} =$	$Ac * f'c + As * Fyr =$	924.65	ton			
$N_{Ed} / N_{Rd} =$	0.16	===>	a =	1.05		
$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a =$		0.317	<	1	OK	

Stirrup Rebar :

Max Spacing of links =	400	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-HA

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	90° C3,C NA+	776	2,688	-132,107
Maximum Axial Force, Uplift	90° C3, Min. WS,C NA+	-86	2,111	117,894

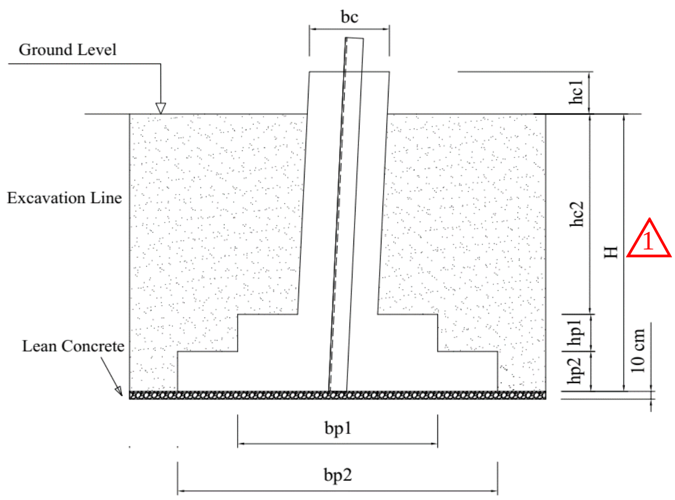
Maximum Loads on Foundation				
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	90° C3,C NA+	23,626	-25,538	-127,473
Maximum Axial Force, Uplift	90° C3, Min. WS,C NA+	20,338	-22,535	113,938

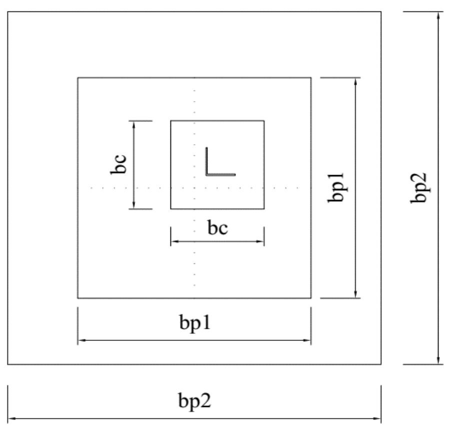
Design Standard: EN 1992:2004

Inputs:

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

Foundation Dimensions	Width of Pad 1	bp1 =	2.1	m	
	Width of Pad 2	bp2 =	4.4	m	
	Height of Pad 1	hp1 =	0.3	m	
	Height of Pad 2	hp2 =	0.3	m	
	Width of Chimney	bc =	0.75	m	
	Height of Chimney above ground level	hc1 =	0.3	m	
	Height of Chimney unedr ground level	hc2 =	3.4	m	
	Depth of Pad	H =	4	m	
	Inplane Slope	β =	10.16	Degree	
	Diagonal Slope	γ =	14.22	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 =	140.22	ton
		Vcx =	25.99	ton
		Vcy =	-28.09	ton
	Uplift	T =	125.33	ton
		Vtx =	22.37	ton
		Vty =	-24.79	ton

On Stub	Compression	Cs =	145.32	ton
		Vscx =	0.85	ton
		Vscy =	2.96	ton
	Uplift	Ts =	129.68	ton
		Vstx =	-0.09	ton
		Vsty =	2.32	ton

Soil Passive Pressure Coefficient $Kp = \tan 2\,(45+\varphi/2) =$ 2.46
Passive Force on chimney,   Fp1 =   10.89   ton
Passive Force on pad1,   Fp2 =   5.62   ton
Passive Force on pad2,   Fp3 =   12.76   ton

Uplift:

Volume of chimney above ground level   V1 =   0.17   m3
Volume of chimney under ground level   V2 =   1.91   m3
Volume of pad1,   V3 =   1.32   m3
Volume of pad2,   V4 =   5.81   m3
Total volume of foundation ,   Vf =   9.21   m3

Total weight of foundation, $Wf = Vf * \gamma c =$ 12.90   ton

Cone volume, $Vcone = (h/3)*(\pi*h^2*\tan^2\Theta + 3*bp2^2 + 6*bp2*h*\tan\theta) =$ 113.78   m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 =   110.54   m3
Soil weight above foundation, $Ws = Vsoil * \gamma b =$ 112.68   ton

Total resistance force against uplift,   Ru= Ws + Wf =   125.58   ton
Uplift Force,   U=   125.33   ton

125.58	>	125.33	OK

S.F.= 1.00

1

Additional condition: G/Z > 0.8   EN 50341 M.3.1.6
G: weight of foundation and soil vertical to the base =   82.62   ton
Z: uplift force on fondation =   113.94   ton

Z/G =   0.73   >>>   Ratio =   0.91   OK

Bearing Capacity:

Compression Force,   C =   140.86   ton
Bending Moment about x axis,   Mx =   -12.92   ton.m
Bending Moment about y axis,   My =   3.73   ton.m

Over Load of Concrete Wf=   12.90   ton

Volume of the Soil directly above foundation $Vsl = (H * bp2^2) - V2 - V3 - V4 =$ 68.40   m3

Over Load of Soil directly above foundation $Wsl = Vsl * \gamma b =$ 69.72   ton

Average Bearing Pressure = $\sigma p = ((C + Wf + Wsl)/A) =$	1.15	kg/cm2	<	2.04	kg/cm2	OK

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ 1.09   kg/cm2
Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ 1.04   kg/cm2
Compression Stress at corner 3, $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ 1.27   kg/cm2
Compression Stress at corner 4, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ 1.22   kg/cm2

Max. Toe Pressure =	1.27	<	q_{all} =	2.55	OK
Min. Toe Pressure =	1.04	>	0		OK

S.F.= 2.00

Top Surface Pressure due to Uplift:

Uplift Force,   T =   125.71   ton
Bending Moment about x axis,   Mx =   -8.73   ton.m
Bending Moment about y axis,   My =   -0.35   ton.m

Pressure due to Uplift at top surface at corner 1, $\sigma u1 = ((T-Wf)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ 0.52   kg/cm2
Pressure due to Uplift at top surface at corner 2, $\sigma u2 = ((T-Wf)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ 0.52   kg/cm2
Pressure due to Uplift at top surface at corner 3, $\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ 0.64   kg/cm2
Pressure due to Uplift at top surface at corner 4, $\sigma u4 = ((T-Wf)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ 0.65   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 = 210.45 ton.m

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

Mr = 225.50 ton.m

Mr	>	Mo	OK

S.F.= 1.07

Sliding:

Sliding force, Fo = Vmax

Sliding force, Fo = 24.79 ton

Effective weight of foundation and soil at uplift case, Weff = 0.25 ton

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

Fr = 29.37

Fr	>	Fo	OK

S.F.= 1.18

Structural Design of Pad:

Longitudinal Rebar:

Compression :

Compression Stress at section of Max. bending moment at Pad 1, σmc1 = 1.17 kg/cm2

Compression Stress at section of Max. bending moment at Pad 2, σmc2 = 1.20 kg/cm2

Uplift :

Compression Stress at section of Max. bending moment at Pad 1, σmu1 = 0.59 kg/cm2

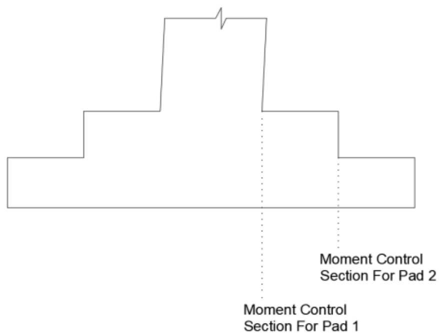
Compression Stress at section of Max. bending moment at Pad 2, σmu2 = 0.61 kg/cm2

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

Muc 1= 6401112 kg.cm = 627949 N.m

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

Muc 2= 2479806 kg.cm = 243269 N.m



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

Muu 1= 4595641 kg.cm = 450832 N.m

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

Muu 2= 1843101 kg.cm = 180808 N.m

Effective Depth of pad 1, dp1 = hp1+hp2 - cp = 0.525 m

Effective Depth of pad 2, dp2 = hp2 - cp = 0.225 m

Compression :

Pad 1:

$K = Mu / f'c * bp * dp^2 =$ 0.081 < 0.167 OK

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

Z max = 484 < 498.75 ==>>> OK

As = Mu / φs * fyr * z = 3113 mm2

Pad 2:

$K = Mu / f'c * bp * dp^2 =$ 0.082 < 0.167 OK

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

Z max = 207.4 < 213.75 ==>>> OK

As = Mu / φs * fyr * z = 2815.7 mm2

Uplift :

Pad 1:

$K = Mu / f'c * bp * dp^2 =$	0.028	<	0.167	OK			

$Z_{max} = dp * (1 + (1-3.529K)^{0.5})/2 \;<=\; 0.95 * dp$

Z max =	511.8	>	498.75	==>>>	Zmax=0.95 dp =	498.75
As = Mu / φs * fyr * z =	2169.4	mm2				

Pad 2:

$K = Mu / f'c * bp * dp^2 =$	0.061				

$Z_{max} = dp * (1 + (1-3.529K)^{0.5})/2 \;<=\; 0.95 * dp$

Z max =	212.2	<	213.75	==>>>	OK
As = Mu / φs * fyr * z =	2045.1	mm2			

Top of Pad 1 :										
As1t=	2169.4		mm2							
Rebar Diameter=	16	mm	=====>	QTY =	11 ==>>	11	=====>	11 Ø 16	=====>	2212 mm2
Rebar Quantity =	11									
Rebar Spacing =	195.0	mm								
Top of Pad 2 :										
As2t=	2045.1	mm2								
Rebar Diameter=	12	mm	=====>	QTY =	19 ==>>	19	=====>	19 Ø 12	=====>	2149 mm2
Rebar Quantity =	19									
Rebar Spacing =	236.1	mm								
Bottom of Pad 2 :										
As2b=	3113.0	mm2								
Rebar Diameter=	12	mm	=====>	QTY =	28 ==>>	28	=====>	28 Ø 12	=====>	3167 mm2
Rebar Quantity =	28									
Rebar Spacing =	157.4	mm								

Min. Rebar Check:

Ast =	7527.3	mm2			
ρst =	0.0046	>			
$\rho_{min} = 0.26*(0.3*(f'c^{(2/3)})/Fyr > 0.0013$	>>>	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 =	1.19	kg/cm2	
Vu1 =	49871	kg	=	498707	N
Compression Stress at critical section of shear at Pad2 ,		σv2 =	1.21	kg/cm2	
Vu2 =	34556	kg	=	345559	N

Pad 1

$k = 1 + (200/dp1)^{0.5} < 2.0$	>>>	k =	1.62	EN 1992-1-1:2004	6.2
$\rho_1 =$	0.0046				
$\sigma_{cp} = N_{ED}/A_C =$	0	No Axial Force!			
$C_{Rd,c} = 0.18/\gamma_c =$	0.12				
k1 =	0.15				
$v_{min} = 0.035 * k^{3/2} * f'c^{1/2} =$	0.322	Mpa		EN 1992-1-1:2004	6.3N

Vr1 = 660969 N

Vr1	>	Vu1	OK	F.S= 1.33

Pad 2

$k = 1 + (200/dp2)^{0.5} < 2.0$ >>> k = 1.94 EN 1992-1-1:2004 6.2

ρ_1 = 0.0054

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

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

k1 = 0.15

$v_{min} = 0.035 * k^{3/2} * f'c^{1/2}$ = 0.424 Mpa EN 1992-1-1:2004 6.3N

Vr2 = 509208 N

Vr2	>	Vu2	OK	F.S= 1.47

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 1.15 kg/cm2

Pad 1

Vpunch1 = 98416 kg = 984165 N

Resisting Shear of Concrete,

Vr1 = 2055778 N

Vr1	>	Vpunch1	OK	F.S.= 2.09

Pad 2

To check if punch shear section is defined in Pad 2 ==> bp1 - (bp2 + 4dp2) = 1.4 > 0 ==> Punch Shear to be Checked in Pad 2

Vpunch2 = 81867 kg = 818666 N

Resisting Shear of Concrete,

Vr2 = 1299340 N

Vr2	>	Vpunch2	OK	F.S.= 1.59

Structural Design of Chimney:

Design of Longitudinal Reinforcement for Uplift :

A) Moment at the bottom of chimney about x axis Mx max = 8.73 ton.m = 87304 N.m

Rebar arrangement:

No. of rebars rows, n = 4

Total No. of rebars = 12

Distance of the last row to center, c = 30 cm

$\Sigma Ai*di^2$ = 7600

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

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

As1= 9.7 cm2

B) Moment at the bottom of chimney about y axis My max = 0.35 ton.m = 3541 N.m

$\varphi s * fyr = M * c / I$ As2= 0.4 cm2

C) Axial required rebar area, $As3 = Ts / (\varphi s*Fyr)$ = 15.3 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 = 25.4 cm2

As min =	max (0.1*Cs/Fy , 0.002*Ac) =			11.3	cm2		9.12 N		
As max =	0.04 *Ac =			225.0	cm2		9.5.2.3		
As =	25.4								
Rebar Diameter =	20	mm	=====> QTY =	9	=====>	12	=====>	12 Ø 20	
===>> As final=	37.7	cm2							
Rebar Quantity of One Row =	4								
Rebar Spacing =	20.0								

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

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

$e = l_0 /400 = 2*(hc)/400 =$	18.5	mm
$N_{Ed} =$	145.32	ton
$M_{0Ed, x} =$	11.12	ton.m
$e_0 = h /30 > 20$ mm ==> $e_0 =$	25	mm
$M_{Ed,x} =$	13.80	ton.m

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

$M_{0Ed, y} =$	3.21	ton.m
$M_{Ed,y} =$	5.90	ton.m
$As * F yr / bc^2 * f'c =$	0.168	
$N_{ED}/ f'c * bc^2 =$	0.127	
d2 =	142	mm
d2 / bc =	0.19	

Interaction Chart Gives ===> $M_{Rd} / f'c * bc^3 =$ 0.1 ===> $M_{Rd,x} = M_{Rd,y} =$ 57.34 ton.m

$N_{Rd} =$ $Ac * f'c + As * Fyr =$ 924.65 ton

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

$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a =$ 0.317 < 1 OK

Stirrup Rebar :

Max Spacing of links =	400	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-HA

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	90° C3,C NA+	776	2,688	-132,107
Maximum Axial Force, Uplift	90° C3, Min. WS,C NA+	-86	2,111	117,894

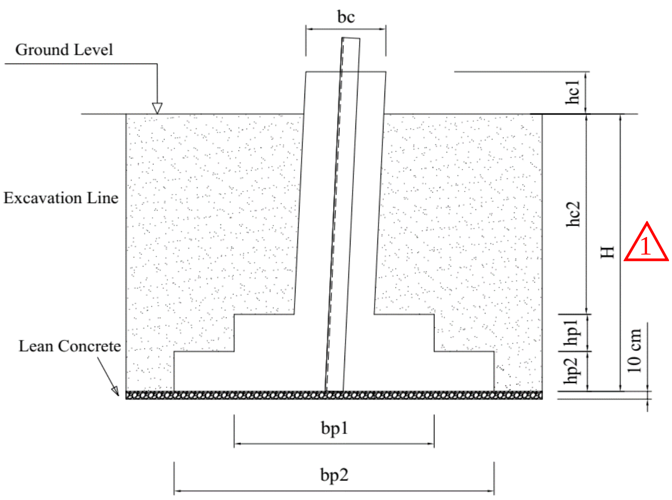
Maximum Loads on Foundation				
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	90° C3,C NA+	23,626	-25,538	-127,473
Maximum Axial Force, Uplift	90° C3, Min. WS,C NA+	20,338	-22,535	113,938

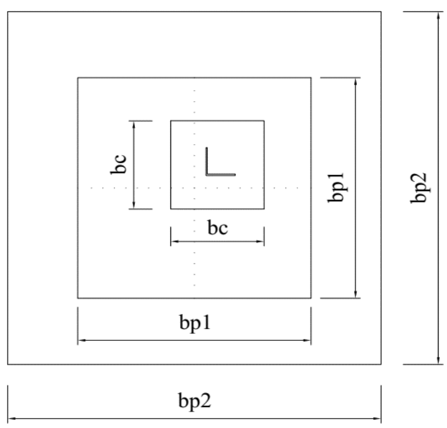
Design Standard: EN 1992:2004

Inputs:

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

Foundation Dimensions	Width of Pad 1	bp1 =	1.9	m	
	Width of Pad 2	bp2 =	4.2	m	
	Height of Pad 1	hp1 =	0.3	m	
	Height of Pad 2	hp2 =	0.3	m	
	Width of Chimney	bc =	0.75	m	
	Height of Chimney above ground level	hc1 =	0.3	m	
	Height of Chimney unedr ground level	hc2 =	3.4	m	
	Depth of Pad	H =	4	m	
	Inplane Slope	β =	10.16	Degree	
	Diagonal Slope	γ =	14.22	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 =	140.22	ton
		Vcx =	25.99	ton
		Vcy =	-28.09	ton
	Uplift	T =	125.33	ton
		Vtx =	22.37	ton
		Vty =	-24.79	ton

On Stub	Compression	Cs =	145.32	ton
		Vscx =	0.85	ton
		Vscy =	2.96	ton
	Uplift	Ts =	129.68	ton
		Vstx =	-0.09	ton
		Vsty =	2.32	ton

Soil Passive Pressure Coefficient Kp = tan 2 (45+φ/2) = 1.70
Passive Force on chimney, Fp1 = 12.01 ton
Passive Force on pad1, Fp2 = 5.61 ton
Passive Force on pad2, Fp3 = 13.44 ton

Uplift:

Volume of chimney above ground level V1 = 0.17 m3
Volume of chimney under ground level V2 = 1.91 m3
Volume of pad1, V3 = 1.08 m3
Volume of pad2, V4 = 5.29 m3
Total volume of foundation , Vf = 8.46 m3

Total weight of foundation, Wf = Vf * γc = 21.14 ton

Cone volume, $Vcone = (h/3)*(\pi*h^2*\tan^2\Theta + 3*bp2^2 + 6*bp2*h*\tan\theta) =$ 67.91 m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 = 64.92 m3
Soil weight above foundation, Ws = Vsoil * γb = 105.88 ton

Total resistance force against uplift, Ru= Ws + Wf = 127.02 ton
Uplift Force, U= 125.33 ton

127.02	>	125.33	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 = 122.71 ton
Z: uplift force on fondation = 113.94 ton

Z/G = 1.08 >>> Ratio = 1.35 OK

Bearing Capacity:

Compression Force, C = 140.86 ton
Bending Moment about x axis, Mx = -12.92 ton.m
Bending Moment about y axis, My = 3.73 ton.m

Over Load of Concrete Wf= 21.14 ton

Volume of the Soil directly above foundation $Vsl = (H * bp2^2) - V2 - V3 - V4 =$ 62.27 m3

Over Load of Soil directly above foundation Wsl= Vsl * γb = 101.57 ton

Average Bearing Pressure = σp = ((C + Wf + Wsl)/A) =	1.49	kg/cm2	<	1.53	kg/cm2	OK

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ 1.42 kg/cm2
Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ 1.36 kg/cm2
Compression Stress at corner 3, $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ 1.63 kg/cm2
Compression Stress at corner 4, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ 1.57 kg/cm2

Max. Toe Pressure =	1.63	<	q_{all} =	1.91	OK
Min. Toe Pressure =	1.36	>		0	OK

S.F.= 1.17

Top Surface Pressure due to Uplift:

Uplift Force, T = 125.71 ton
Bending Moment about x axis, Mx = -8.73 ton.m
Bending Moment about y axis, My = -0.35 ton.m

Pressure due to Uplift at top surface at corner 1, $\sigma u1 = ((T-Wf)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ 0.52 kg/cm2
Pressure due to Uplift at top surface at corner 2, $\sigma u2 = ((T-Wf)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ 0.52 kg/cm2
Pressure due to Uplift at top surface at corner 3, $\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ 0.66 kg/cm2
Pressure due to Uplift at top surface at corner 4, $\sigma u4 = ((T-Wf)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ 0.67 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 = 201.96 ton.m

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

Mr = 214.89 ton.m

Mr	>	Mo	OK

S.F.= 1.06

Sliding:

Sliding force, Fo = Vmax

Sliding force, Fo = 24.79 ton

Effective weight of foundation and soil at uplift case, Weff = 1.69 ton

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

Fr = 31.73

Fr	>	Fo	OK

S.F.= 1.28

Structural Design of Pad:

Longitudinal Rebar:

Compression :

Compression Stress at section of Max. bending moment at Pad 1, σmc1 = 1.51 kg/cm2

Compression Stress at section of Max. bending moment at Pad 2, σmc2 = 1.54 kg/cm2

Uplift :

Compression Stress at section of Max. bending moment at Pad 1, σmu1 = 0.61 kg/cm2

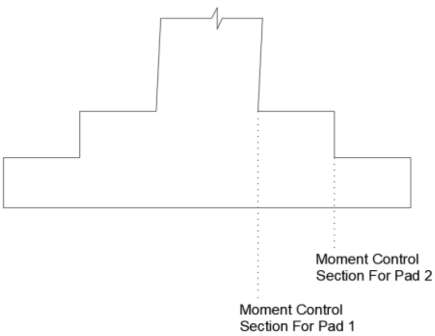
Compression Stress at section of Max. bending moment at Pad 2, σmu2 = 0.62 kg/cm2

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

Muc 1= 6346240 kg.cm = 622566 N.m

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

Muc 2= 2711179 kg.cm = 265967 N.m



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

Muu 1= 4025029 kg.cm = 394855 N.m

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

Muu 2= 1806823 kg.cm = 177249 N.m

Effective Depth of pad 1, dp1 = hp1+hp2 - cp = 0.525 m

Effective Depth of pad 2, dp2 = hp2 - cp = 0.225 m

Compression :

Pad 1:

K = Mu /f 'c * bp *dp^2 = 0.089 < 0.167 OK

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

Z max = 480 < 498.75 ==>>> OK

As = Mu / φs * fyr * z = 3114 mm2

Pad 2:

K = Mu /f 'c * bp *dp^2 = 0.094 < 0.167 OK

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

Z max = 204.5 < 213.75 ==>>> OK

As = Mu / φs * fyr * z = 3121.2 mm2

Uplift :

Pad 1:

$K = Mu / f'c * bp * dp^2$ =	0.026	<	0.167	OK			
Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp							
Z max =	512.9	>	498.75	==>>>	Zmax=0.95 dp =	498.75	
As = Mu / φs * fyr * z =	1900.1	mm2					

Pad 2:

$K = Mu / f'c * bp * dp^2$ =	0.063				
Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp					
Z max =	211.8	<	213.75	==>>>	OK
As = Mu / φs * fyr * z =	2008.3	mm2			

Top of Pad 1 :										
As1t=	1900.1	mm2								
Rebar Diameter=	16	mm	=====>	QTY =	10 ==>>	10	=====>	10 Ø 16	=====>	2011 mm2
Rebar Quantity =	10									
Rebar Spacing =	194.4	mm								
Top of Pad 2 :										
As2t=	2008.3	mm2								
Rebar Diameter=	12	mm	=====>	QTY =	18 ==>>	18	=====>	18 Ø 12	=====>	2036 mm2
Rebar Quantity =	18									
Rebar Spacing =	238.2	mm								
Bottom of Pad 2 :										
As2b=	3121.2	mm2								
Rebar Diameter=	12	mm	=====>	QTY =	28 ==>>	28	=====>	28 Ø 12	=====>	3167 mm2
Rebar Quantity =	28									
Rebar Spacing =	150.0	mm								

Min. Rebar Check:

Ast =	7213.1	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 =	1.54	kg/cm2	
Vu1 =	51123	kg	=	511230	N
Compression Stress at critical section of shear at Pad2 ,		σv2 =	1.55	kg/cm2	
Vu2 =	37773	kg	=	377725	N

Pad 1

k = 1 +(200/dp1)^0.5 < 2.0	>>>	k =	1.62	EN 1992-1-1:2004	6.2
ρ_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				
$v_{min} = 0.035 * k^{3/2} * f'c^{1/2}$ =	0.322	Mpa		EN 1992-1-1:2004	6.3N

$Vr1 =$ 623171 N

Vr1	>	Vu1	OK	F.S= 1.22

Pad 2

$k = 1 + (200/dp2)^{0.5} < 2.0$ >>> k = 1.94 EN 1992-1-1:2004 6.2

$\rho_1 =$ 0.0055

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

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

k1 = 0.15

$v_{min} = 0.035 * k^{3/2} * f'c^{1/2} =$ 0.424 Mpa EN 1992-1-1:2004 6.3N

$Vr2 =$ 490132 N

Vr2	>	Vu2	OK	F.S= 1.30

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 1.49 kg/cm2

Pad 1

Vpunch1 = 98321 kg = 983208 N

Resisting Shear of Concrete,

Vr1 = 2072552 N

Vr1	>	Vpunch1	OK	F.S.= 2.11

Pad 2

To check if punch shear section is defined in Pad 2 ==> bp1 - (bp2 + 4dp2) = 1.4 > 0 ==> Punch Shear to be Checked in Pad 2

Vpunch2 = 88836 kg = 888359 N

Resisting Shear of Concrete,

Vr2 = 1216860 N

Vr2	>	Vpunch2	OK	F.S.= 1.37

Structural Design of Chimney:

Design of Longitudinal Reinforcement for Uplift :

A) Moment at the bottom of chimney about x axis Mx max = 8.73 ton.m = 87304 N.m

Rebar arrangement:

No. of rebars rows, n = 4

Total No. of rebars = 12

Distance of the last row to center, c = 30 cm

$\Sigma Ai*di^2 =$ 7600

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

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

As1= 9.7 cm2

B) Moment at the bottom of chimney about y axis My max = 0.35 ton.m = 3541 N.m

$\varphi s * fyr = M * c / I$ As2= 0.4 cm2

C) Axial required rebar area, $As3 = Ts / (\varphi s*Fyr) =$ 15.3 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 = 25.4 cm2

As min =	max (0.1*Cs/Fy , 0.002*Ac) =			11.3	cm2	9.12 N		
As max =	0.04 *Ac =			225.0	cm2	9.5.2.3		
As =	25.4							
Rebar Diameter =	20	mm	=====> QTY =	9	=====>	12	=====>	12 Ø 20
===>> As final=	37.7	cm2						
Rebar Quantity of One Row =	4							
Rebar Spacing =	20.0							

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

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

$e = l_0 /400 = 2*(hc)/400 =$	18.5	mm
$N_{Ed} =$	145.32	ton
$M_{0Ed,x} =$	11.12	ton.m
$e_0 = h/30 > 20$ mm ==> $e_0 =$	25	mm
$M_{Ed,x} =$	13.80	ton.m

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

$M_{0Ed,y} =$	3.21	ton.m
$M_{Ed,y} =$	5.90	ton.m
$As * F yr / bc^2 * f'c =$	0.168	
$N_{ED}/ f'c * bc^2 =$	0.127	
d2 =	142	mm
d2 / bc =	0.19	

Interaction Chart Gives ===> $M_{Rd} / f'c * bc^3 =$ 0.1 ===> $M_{Rd,x} = M_{Rd,y} =$ 57.34 ton.m

$N_{Rd} =$ $Ac * f'c + As * Fyr =$ 924.65 ton

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

$(M_{Ed,x}/M_{Rd,x})^a + (M_{Ed,y}/M_{Rd,y})^a =$ 0.317 < 1 OK

Stirrup Rebar :

Max Spacing of links =	400	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-HA

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	90° C3,C NA+	776	2,688	-132,107
Maximum Axial Force, Uplift	90° C3, Min. WS,C NA+	-86	2,111	117,894

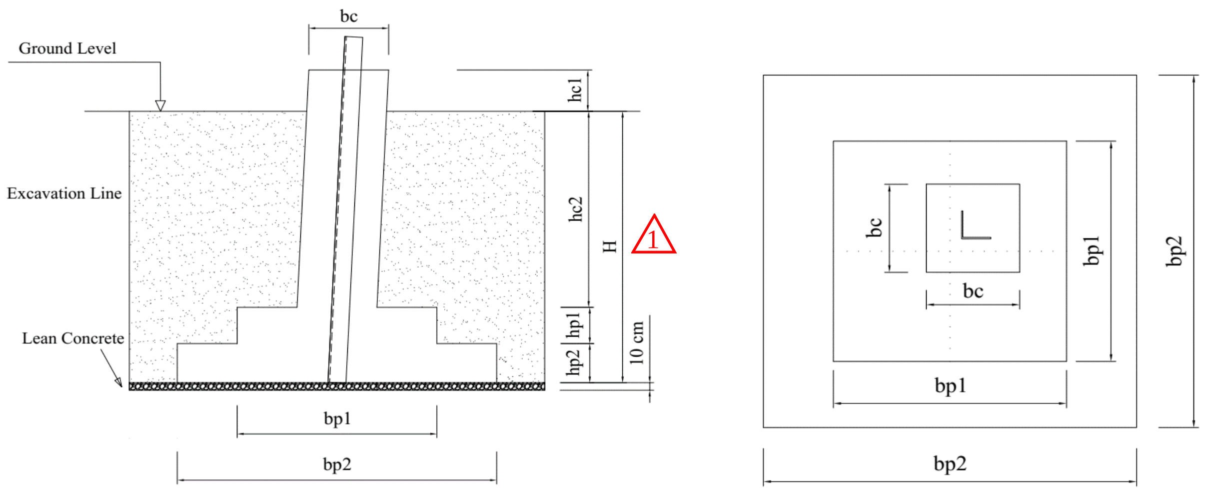
Maximum Loads on Foundation				
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	90° C3,C NA+	23,626	-25,538	-127,473
Maximum Axial Force, Uplift	90° C3, Min. WS,C NA+	20,338	-22,535	113,938

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 =	2.6	m	
	Width of Pad 2	bp2 =	6.2	m	
	Height of Pad 1	hp1 =	0.3	m	
	Height of Pad 2	hp2 =	0.3	m	
	Width of Chimney	bc =	0.75	m	
	Height of Chimney above ground level	hc1 =	0.3	m	
	Height of Chimney unedr ground level	hc2 =	3.4	m	
	Depth of Pad	H =	4	m	
	Inplane Slope	β =	10.16	Degree	
	Diagonal Slope	γ =	14.22	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 =	140.22	ton
		Vcx =	25.99	ton
		Vcy =	-28.09	ton
	Uplift	T =	125.33	ton
		Vtx =	22.37	ton
		Vty =	-24.79	ton

On Stub	Compression	Cs =	145.32	ton
		Vscx =	0.85	ton
		Vscy =	2.96	ton
	Uplift	Ts =	129.68	ton
		Vstx =	-0.09	ton
		Vsty =	2.32	ton

Soil Passive Pressure Coefficient Kp = tan 2 (45+φ/2) = 1.70
Passive Force on chimney, Fp1 = 6.00 ton
Passive Force on pad1, Fp2 = 3.84 ton
Passive Force on pad2, Fp3 = 9.92 ton

Uplift:

Volume of chimney above ground level V1 = 0.17 m3
Volume of chimney under ground level V2 = 1.91 m3
Volume of pad1, V3 = 2.03 m3
Volume of pad2, V4 = 11.53 m3
Total volume of foundation , Vf = 15.64 m3

Total weight of foundation, Wf = Vf * γc = 21.90 ton

Cone volume, $V_{cone} = (h/3)*(\pi*h^2*\tan^2\Theta + 3*bp2^2 + 6*bp2*h*\tan\theta) =$ 147.99 m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 = 144.05 m3
Soil weight above foundation, Ws = Vsoil * γb = 117.47 ton

Total resistance force against uplift, Ru= Ws + Wf = 139.37 ton
Uplift Force, U= 125.33 ton

139.37	>	125.33	OK

S.F.= 1.11

1

Additional condition: G/Z > 0.8 EN 50341 M.3.1.6
G: weight of foundation and soil vertical to the base = 134.67 ton
Z: uplift force on fondation = 113.94 ton

Z/G = 1.18 >>> Ratio = 1.48 OK

Bearing Capacity:

Compression Force, C = 140.86 ton
Bending Moment about x axis, Mx = -12.92 ton.m
Bending Moment about y axis, My = 3.73 ton.m

Over Load of Concrete Wf= 21.90 ton

Volume of the Soil directly above foundation $V_{sl} = (H * bp2^2) - V2 - V3 - V4 =$ 138.29 m3

Over Load of Soil directly above foundation Wsl= Vsl * γb = 112.77 ton

Average Bearing Pressure = σp = ((C + Wf + Wsl)/A) =	0.72	kg/cm2	<	0.82	kg/cm2	OK

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ 0.69 kg/cm2
Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ 0.67 kg/cm2
Compression Stress at corner 3, $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ 0.76 kg/cm2
Compression Stress at corner 4, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ 0.74 kg/cm2

Max. Toe Pressure =	0.76	<	q_{all} =	1.02	OK
Min. Toe Pressure =	0.67	>		0	OK

S.F.= 1.34

Top Surface Pressure due to Uplift:

Uplift Force, T = 125.71 ton
Bending Moment about x axis, Mx = -8.73 ton.m
Bending Moment about y axis, My = -0.35 ton.m

Pressure due to Uplift at top surface at corner 1, $\sigma u1 = ((T-Wf)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ 0.25 kg/cm2
Pressure due to Uplift at top surface at corner 2, $\sigma u2 = ((T-Wf)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ 0.25 kg/cm2
Pressure due to Uplift at top surface at corner 3, $\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ 0.29 kg/cm2
Pressure due to Uplift at top surface at corner 4, $\sigma u4 = ((T-Wf)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ 0.29 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 = 286.79 ton.m

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

Mr = 348.73 ton.m

Mr	>	Mo	OK

S.F.= 1.22

Sliding:

Sliding force, Fo = Vmax

Sliding force, Fo = 24.79 ton

Effective weight of foundation and soil at uplift case, Weff = 14.04 ton

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

Fr = 25.37

Fr	>	Fo	OK

S.F.= 1.02

Structural Design of Pad:

Longitudinal Rebar:

Compression :

Compression Stress at section of Max. bending moment at Pad 1, σmc1 = 0.72 kg/cm2

Compression Stress at section of Max. bending moment at Pad 2, σmc2 = 0.73 kg/cm2

Uplift :

Compression Stress at section of Max. bending moment at Pad 1, σmu1 = 0.27 kg/cm2

Compression Stress at section of Max. bending moment at Pad 2, σmu2 = 0.28 kg/cm2

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

Muc 1= 10646765 kg.cm = 1044448 N.m

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

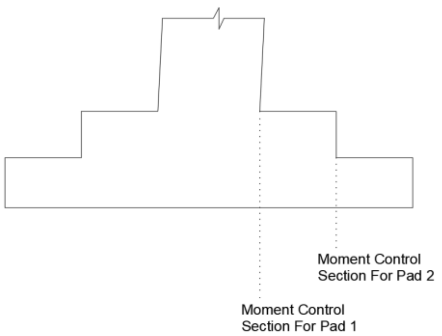
Muc 2= 4432235 kg.cm = 434802 N.m

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

Muu 1= 6574255 kg.cm = 644934 N.m

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

Muu 2= 2890482 kg.cm = 283556 N.m



Effective Depth of pad 1, dp1 = hp1+hp2 - cp = 0.525 m

Effective Depth of pad 2, dp2 = hp2 - cp = 0.225 m

Compression :

Pad 1:

$K = Mu / f'c * bp * dp^2 =$ 0.109 < 0.167 OK

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

Z max = 468 < 498.75 ==>>> OK

As = Mu / φs * fyr * z = 5353 mm2

Pad 2:

$K = Mu / f'c * bp * dp^2 =$ 0.104 < 0.167 OK

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

Z max = 202.0 < 213.75 ==>>> OK

As = Mu / φs * fyr * z = 5165.2 mm2

Uplift :

Pad 1:

$K = Mu / f'c * bp * dp^2 =$	0.028	<	0.167	OK			
Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp							
Z max =	511.5	>	498.75	==>>>	Zmax=0.95 dp =	498.75	
As = Mu / φs * fyr * z =	3103.4	mm2					

Pad 2:

$K = Mu / f'c * bp * dp^2 =$	0.068				
Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp					
Z max =	210.6	<	213.75	==>>>	OK
As = Mu / φs * fyr * z =	3230.9	mm2			

Top of Pad 1 :										
As1t=	3103.4		mm2							
Rebar Diameter=	16	mm	=====>	QTY =	16 ==>>	16	=====>	16 Ø 16	=====>	3217 mm2
Rebar Quantity =	16									
Rebar Spacing =	163.3	mm								
Top of Pad 2 :										
As2t=	3230.9	mm2								
Rebar Diameter=	12	mm	=====>	QTY =	29 ==>>	29	=====>	29 Ø 12	=====>	3280 mm2
Rebar Quantity =	29									
Rebar Spacing =	216.1	mm								
Bottom of Pad 2 :										
As2b=	5353.5	mm2								
Rebar Diameter=	16	mm	=====>	QTY =	27 ==>>	27	=====>	27 Ø 16	=====>	5429 mm2
Rebar Quantity =	27									
Rebar Spacing =	232.7	mm								

Min. Rebar Check:

Ast =	11925.5	mm2		
ρst =	0.0055	>		
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 =		0.73	kg/cm2
Vu1 =	62812	kg	=	628124	N
Compression Stress at critical section of shear at Pad2 ,		σv2 =		0.73	kg/cm2
Vu2 =	42899	kg	=	428991	N

Pad 1

k = 1 +(200/dp1)^0.5 < 2.0	>>>	k =	1.62	EN 1992-1-1:2004 6.2
$\rho_1 =$	0.0055			
$\sigma_{cp} = N_{ED}/A_C =$	0	No Axial Force!		
$C_{Rd,c} = 0.18/\gamma_c =$	0.12			
k1 =	0.15			
$v_{min} = 0.035 * k^{3/2} * f'c^{1/2} =$	0.322	Mpa		EN 1992-1-1:2004 6.3N

$Vr1 =$ 937757 N

Vr1	>	Vu1	OK

F.S= 1.49

Pad 2

$k = 1 + (200/dp2)^{0.5} < 2.0$ >>> k = 1.94 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

$v_{min} = 0.035 * k^{3/2} * f'c^{1/2} =$ 0.424 Mpa EN 1992-1-1:2004 6.3N

$Vr2 =$ 754487 N

Vr2	>	Vu2	OK

F.S= 1.76

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 0.72 kg/cm2

Pad 1

Vpunch1 = 137411 kg = 1374109 N

Resisting Shear of Concrete,

Vr1 = 2172407 N

Vr1	>	Vpunch1	OK

F.S.= 1.58

Pad 2

To check if punch shear section is defined in Pad 2 ==> bp1 - (bp2 + 4dp2) = 2.7 > 0 ==> Punch Shear to be Checked in Pad 2

Vpunch2 = 109424 kg = 1094243 N

Resisting Shear of Concrete,

Vr2 = 1609666 N

Vr2	>	Vpunch2	OK

F.S.= 1.47

Structural Design of Chimney:

Design of Longitudinal Reinforcement for Uplift :

A) Moment at the bottom of chimney about x axis Mx max = 8.73 ton.m = 87304 N.m

Rebar arrangement:

No. of rebars rows, n = 4

Total No. of rebars = 12

Distance of the last row to center, c = 30 cm

$\Sigma Ai*di^2 =$ 7600

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

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

As1= 9.7 cm2

B) Moment at the bottom of chimney about y axis My max = 0.35 ton.m = 3541 N.m

$\varphi s * fyr = M * c / I$ As2= 0.4 cm2

C) Axial required rebar area, $As3 = Ts / (\varphi s*Fyr) =$ 15.3 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 = 25.4 cm2

As min =	max (0.1*Cs/Fy , 0.002*Ac) =			11.3	cm2		9.12 N	
As max =	0.04 *Ac =			225.0	cm2		9.5.2.3	
As =	25.4							
Rebar Diameter =	20	mm	=====> QTY =	9	=====>	12	=====>	12 Ø 20
===>> As final=	37.7	cm2						
Rebar Quantity of One Row =	4							
Rebar Spacing =	20.0							

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

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

$e = l_0 /400 = 2*(hc)/400 =$	18.5	mm
$N_{Ed} =$	145.32	ton
$M_{0Ed, x} =$	11.12	ton.m
$e_0 = h /30 > 20$ mm ==> $e_0 =$	25	mm
$M_{Ed,x} =$	13.80	ton.m

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

$M_{0Ed, y} =$	3.21	ton.m
$M_{Ed,y} =$	5.90	ton.m
$As * F yr / bc^2 * f'c =$	0.168	
$N_{ED}/ f'c * bc^2 =$	0.127	
d2 =	142	mm
d2 / bc =	0.19	

Interaction Chart Gives ===>	$M_{Rd} / f'c * bc^3 =$	0.1	===> $M_{Rd,x} = M_{Rd,y} =$	57.34	ton.m	
$N_{Rd} =$	Ac * f'c + As * Fyr =	924.65	ton			
$N_{Ed} / N_{Rd} =$	0.16	===>	a =	1.05		
$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a =$		0.317	<	1	OK	

Stirrup Rebar :

Max Spacing of links =	400	mm	EN 1992-1-1:2004 9.5.3.3	
Rebar Space =	150	mm		==>> Ø8 @ 150 mm
Link Rebar Diameter =	8	mm		