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-NS"

(for all soil types)

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Foundation Design Calculations of Tower Type "12B-NS" (for all soil types)	**n.a.**	Page **1** of 47

Soils and Foundations Specifications

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

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

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	C2,C BI+	-2,099	-2,130	-44,839
Maximum Axial Force, Uplift	C2-,C BI-	-2,159	-2,184	34,504

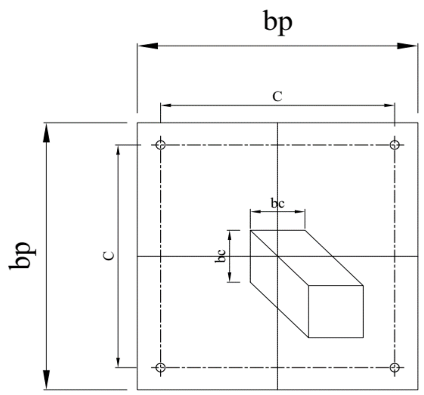
Maximum Loads on Foundation				
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	C2,C BI+	-8,674	8,704	-43,221
Maximum Axial Force, Uplift	C2-,C BI-	-7,194	7,219	33,101

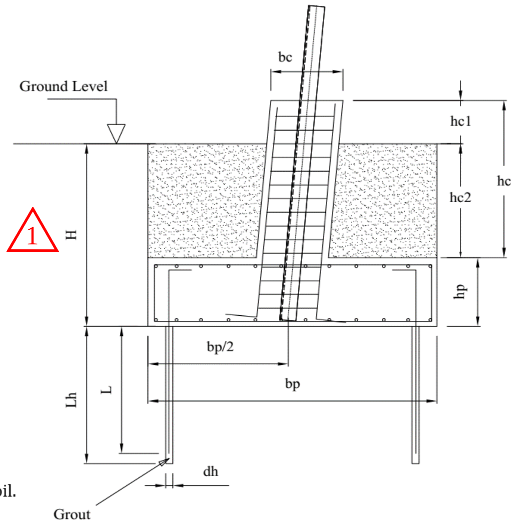
Design Standard: EN 1992:2004

Inputs:

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

Foundation Dimensions	Width of Pad	bp =	1.2	m	
	Height of Pad	hp =	0.65	m	
	Width of Chimney	bc =	0.6	m	
	Height of Chimney above ground level	hc1 =	0.3	m	
	Height of Chimney under ground level	hc2 =	0.6	m	
	Total Height of Chimney	hc =	0.9	m	
	Depth of Pad	H =	1.25	m	
	Inplane Slope	β =	8.64	Degree	
	Eccentricity (Bottom of Pad)	e =	0.24	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





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

Ultimate Loads:

On Foundation	Compression	C =	47.54	ton
		Vcx =	-9.54	ton
		Vcy =	9.57	ton
	Tension	T =	36.41	ton
		Vtx =	-7.91	ton
		Vty =	7.94	ton

On Stub	Compression	Cs =	49.32	ton
		Vscx =	-2.31	ton
		Vscy =	-2.34	ton
	Tension	Ts =	37.95	ton
		Vstx =	-2.38	ton
		Vsty =	-2.40	ton

Design of Anchors:

Volume of chimney above ground level V1 = 0.11 m3
Volume of chimney under ground level V2 = 0.22 m3
Volume of pad, V3 = 0.94 m3
Total volume of foundation , Vf = 1.26 m3

Total weight of foundation, Wf = Vf * γc = 3.15 ton

Uplift Force, U = 36.41 ton

Design force for anchors, U net = U - Wf = 33.26 ton

Required anchor area for uplift, Asu = U net / (φs * Fy) = 7.83 cm2

Anchor arrangement:

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

Central Holes to be Ommited = No

Total No. of anchors holes, i = 4

Distance between anchor rows C = 80.0 cm

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

Σ di ^{2} = 6400

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 =	16.08	cm2	>	7.83	OK

Uplift Force, T = 37.11 ton
Bending Moment about x axis, Mx = -3.72 ton.m
Bending Moment about y axis, My = -3.68 ton.m

Required Modulus of Section at x direction Wx = Mx / (φs * Fy) = -87.68 cm3
Required Modulus of Section at y direction Wy = My / (φs * Fy) = -86.67 cm3

Required anchor area for bending moment about x axis, Asmx = n * m * Wx * c / (Σ di ^{2}) = 2.19 cm2

Required anchor area for bending moment about y axis, Asmy = n* m * Wy * c / (Σ di ^{2}) = 2.17 cm2

Total Required Area for Anchors, Astot = Asu + Asmx + Asmy =	12.19	cm2	<	16.08	OK

Bearing Capacity:

Compression Force, C = 48.23 ton
Bending Moment about x axis, Mx = -3.63 ton.m
Bending Moment about y axis, My = -3.58 ton.m

Over Load of Concrete, Wf = 3.15 ton

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

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

Overall Bearing Pressure = σp = ((C + Wf + Wsl)/A) =	3.68	kg/cm2	<	10.19	kg/cm2	OK

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) + (6*My)/(bp3) =$ 1.18 kg/cm2

Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) - (6*My)/(bp3) =$ 3.66 kg/cm2

Compression Stress at corner 3, $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) + (6*My)/(bp3) =$ 3.70 kg/cm2

Compression Stress at corner 4, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) - (6*My)/(bp3) =$ 6.19 kg/cm2

Max. Toe Pressure =	6.19	<	q_{all} =	12.74	OK
Min. Toe Pressure =	1.18	>	0		OK

Bond of Anchor and Grout Check :

Max. force of one anchor hole Pa = 12944 kg

Required embedded length of anchor in Rock, $L_{min} = Pa / (m * \tau_{gs} * \pi * da) =$ 64.4 cm

Design embedded length of anchor in Rock, L= 130 cm

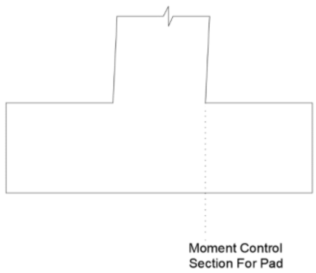
Bond of Grout and Rock Check :

Anchor Hole Diameter, Dh = 7.5 cm

Resisting bond force of the Grout and Rock, $F\tau_{gr} = \tau_{gr} * L * Dh * \pi =$ 27567 kg > 12944 OK

Structural Design of Pad:

Longitudinal Rebar:



Compression Stress at section of Max. bending moment, σm = 4.31 kg/cm2

Mu = 247345 kg.cm = 24734 N.m

Effective Depth, dp = hp - cp = 0.575 m

$K = Mu / f'c * bp * dp^2 =$ 0.00468 < 0.167 OK

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

Z max = 572.62 > 546.25 ==>>> Zmax=0.95 dp = 546.25 mm

As = Mu / φs * fyr * z = 109

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 = 1014 mm2

As max = 31200 mm2

As = 1014

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

Rebar Quantity = 6

Rebar Spacing = 21.0

===> As= 1206 mm2

One Way Shear:

Compression Stress at critical section of shear , σv = 5.52 kg/cm2

Vu = -16763 kg = -167626 N Not defined since Theorical shear check distance is more than pad width!

k = 1 +(200/dp)^0.5 < 2.0 >>> k = 1.59 EN 1992-1-1:2004 6.2

ρ_1 = 0.0017

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

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

k1 = 0.15

$v_{min} = 0.035 * k^{3/2} * f'c^{1/2} =$ 0.256 Mpa EN 1992-1-1:2004 6.3N

Vr = 176761 N

Vr	>	Vu	OK

F.S= Not Defined!

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 3.68 kg/cm2

Vpunch = -205949 kg = -2059492 N

Resisting Shear of Concrete,

Vr = 1417870 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 = -2.19 ton.m = -21872 N.m

Rebar arrangement:

No. of Rebar rows, n = 3

Total No. of Rebars = 8

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

Σ Ai * di^2 = 3037.5

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

>>>>> A = M * c / (φs * fyr *Σ di^2)

As1= 3.1 cm2

B) Moment at the bottom of chimney about y axis

My max = -2.16 ton.m = -21621 N.m

>>>>> A = M * c / (φs * fyr *Σdi2)

As2= 3.0 cm2

C) Axial required rebar area, As3 = Ts / (φs*Fys) = 4.5 cm2

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

Total Longitudinal rebar area Ast =As1+As2+As3 = 10.5 cm2

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

As max = 0.04 *Ac = 144.0 cm2 9.5.2.3

As = 10.5

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

===>> As final= 16.1 cm2

Rebar Quantity of One Row = 3

Rebar Spacing = 22.5

Check for Compression :

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

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

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

$N_{Ed} =$ 49.32 ton

$M_{0Ed,x} =$ 2.13 ton.m

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

$M_{Ed,x}$ = 2.35 ton.m

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

$M_{0Ed,y}$= 2.10 ton.m

$M_{Ed,y}$ = 2.32 ton.m

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

N_{ED}/ f'c * bc^2 = 0.067

d2 = 131 mm

d2 / bc = 0.22

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

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

N_{Ed} / N_{Rd} = 0.09 ===> a = 0.99

$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a$ = 0.145 < 1 OK

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

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

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

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	C2,C BI+	-2,099	-2,130	-44,839
Maximum Axial Force, Uplift	C2-,C BI-	-2,159	-2,184	34,504

Maximum Loads on Foundation				
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	C2,C BI+	-8,674	8,704	-43,221
Maximum Axial Force, Uplift	C2-,C BI-	-7,194	7,219	33,101

Design Standard: EN 1992:2004

Inputs:

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

Foundation Dimensions	Width of Pad	bp =	1.4	m	
	Height of Pad	hp =	0.65	m	
	Width of Chimney	bc =	0.6	m	
	Height of Chimney above ground level	hc1 =	0.3	m	
	Height of Chimney under ground level	hc2 =	0.6	m	
	Total Height of Chimney	hc =	0.9	m	
	Depth of Pad	H =	1.25	m	
	Inplane Slope	β =	8.64	Degree	
	Eccentricity (Bottom of Pad)	e =	0.24	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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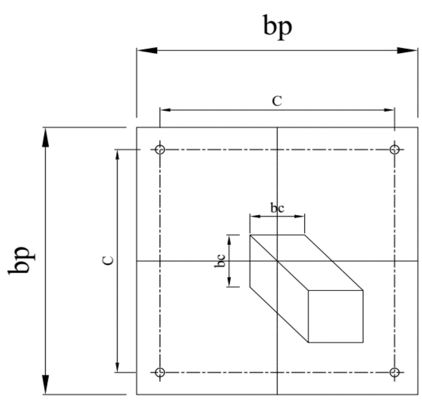

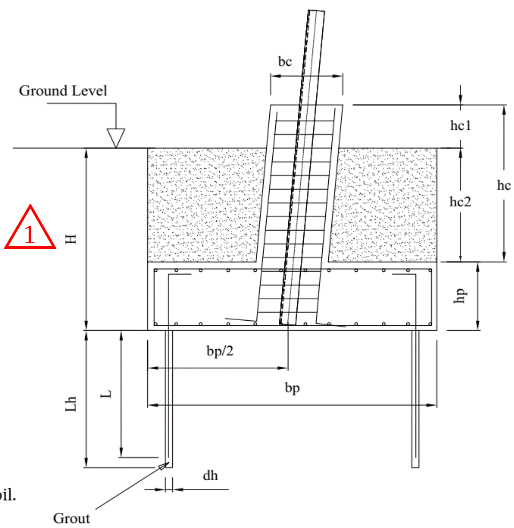

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1 * The foundation is in direct contact with undisturbed soil.

Ultimate Loads:

On Foundation	Compression	C =	47.54	ton
		Vcx =	-9.54	ton
		Vcy =	9.57	ton
	Tension	T =	36.41	ton
		Vtx =	-7.91	ton
		Vty =	7.94	ton

On Stub	Compression	Cs =	49.32	ton
		Vscx =	-2.31	ton
		Vscy =	-2.34	ton
	Tension	Ts =	37.95	ton
		Vstx =	-2.38	ton
		Vsty =	-2.40	ton

Design of Anchors:

Volume of chimney above ground level V1 = 0.11 m3
Volume of chimney under ground level V2 = 0.22 m3
Volume of pad, V3 = 1.27 m3
Total volume of foundation , Vf = 1.60 m3

Total weight of foundation, Wf = Vf * γc = 4.00 ton

Uplift Force, U = 36.41 ton

Design force for anchors, U net = U - Wf = 32.42 ton

Required anchor area for uplift, Asu = U net / (φs * Fy) = 7.63 cm2

Anchor arrangement:

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

Central Holes to be Ommited = No

Total No. of anchors holes, i = 4

Distance between anchor rows C = 90.0 cm

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

Σdi^2 = 8100

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 =	16.08	cm2	>	7.63	OK

Uplift Force, T = 37.11 ton
Bending Moment about x axis, Mx = -3.72 ton.m
Bending Moment about y axis, My = -3.68 ton.m

Required Modulus of Section at x direction Wx = Mx / (φs * Fy) = -87.68 cm3
Required Modulus of Section at y direction Wy = My / (φs * Fy) = -86.67 cm3

Required anchor area for bending moment about x axis, Asmx = n * m * Wx * c / (Σdi^2) = 1.95 cm2

Required anchor area for bending moment about y axis, Asmy = n* m * Wy * c / (Σdi^2) = 1.93 cm2

Total Required Area for Anchors, Astot = Asu + Asmx + Asmy =	11.51	cm2	<	16.08	OK

Bearing Capacity:

Compression Force, C = 48.23 ton
Bending Moment about x axis, Mx = -3.63 ton.m
Bending Moment about y axis, My = -3.58 ton.m

Over Load of Concrete, Wf = 4.00 ton

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

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

Overall Bearing Pressure = σp = ((C + Wf + Wsl)/A) =	2.76	kg/cm2	<	5.10	kg/cm2	OK

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) + (6*My)/(bp3) =$ 1.19 kg/cm2

Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) - (6*My)/(bp3) =$ 2.75 kg/cm2

Compression Stress at corner 3, $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) + (6*My)/(bp3) =$ 2.78 kg/cm2

Compression Stress at corner 4, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) - (6*My)/(bp3) =$ 4.34 kg/cm2

Max. Toe Pressure =	4.34	<	q_{all} =	6.37	OK
Min. Toe Pressure =	1.19	>	0		OK

Bond of Anchor and Grout Check :

Max. force of one anchor hole Pa = 12218 kg

Required embedded length of anchor in Rock, $L_{min} = Pa / (m * \tau_{gs} * \pi * da) =$ 60.8 cm

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

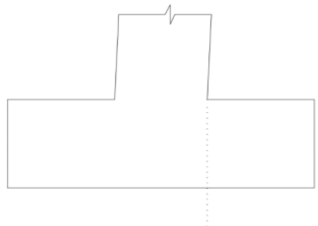
Bond of Grout and Rock Check :

Anchor Hole Diameter, Dh = 7.5 cm

Resisting bond force of the Grout and Rock, $F\tau_{gr} = \tau_{gr} * L * Dh * \pi =$	25447	kg	>	12218	OK

Structural Design of Pad:

Longitudinal Rebar:


Moment Control Section For Pad

Compression Stress at section of Max. bending moment, $\sigma m =$ 3.10 kg/cm2

Mu = 367895 kg.cm = 36789 N.m

Effective Depth, dp = hp - cp = 0.575 m

$K = Mu / f'c * bp * dp^2 =$ 0.00596 < 0.167 OK

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

Z max = 571.96 > 546.25 ==>>> Zmax=0.95 dp = 546.25 mm

As = Mu / φs * fyr * z = 162

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 = 1183 mm2

As max = 36400 mm2

As = 1183

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

Rebar Quantity = 6

Rebar Spacing = 25.0

===> As= 1206 mm2

One Way Shear:

Compression Stress at critical section of shear , $\sigma v =$ 3.76 kg/cm2

Vu = -8661 kg = -86614 N Not defined since Theorical shear check distance is more than pad width!

k = 1 +(200/dp)^0.5 < 2.0 >>> k = 1.59 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

$v_{min} = 0.035 * k^{3/2} * f'c^{1/2} =$ 0.256 Mpa EN 1992-1-1:2004 6.3N

Vr = 206221 N

Vr	>	Vu	OK

F.S= Not Defined!

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 2.76 kg/cm2

Vpunch = -140415 kg = -1404146 N

Resisting Shear of Concrete,

Vr = 1417870 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 = -2.19 ton.m = -21872 N.m

Rebar arrangement:

No. of Rebar rows, n = 3

Total No. of Rebars = 8

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

Σ Ai * di^2 = 3037.5

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

>>>>> A = M * c / (φs * fyr *Σ di^2)

As1= 3.1 cm2

B) Moment at the bottom of chimney about y axis

My max = -2.16 ton.m = -21621 N.m

>>>>> A = M * c / (φs * fyr *Σdi2)

As2= 3.0 cm2

C) Axial required rebar area, As3 = Ts / (φs*Fys) = 4.5 cm2

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

Total Longitudinal rebar area Ast =As1+As2+As3 = 10.5 cm2

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

As max = 0.04 *Ac = 144.0 cm2 9.5.2.3

As = 10.5

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

===>> As final= 16.1 cm2

Rebar Quantity of One Row = 3

Rebar Spacing = 22.5

Check for Compression :

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

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

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

$N_{Ed} =$ 49.32 ton

$M_{0Ed,x} =$ 2.13 ton.m

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

$M_{Ed,x}$ =	2.35	ton.m

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

$M_{0Ed,y}$=	2.10	ton.m
$M_{Ed,y}$ =	2.32	ton.m
As * F yr / bc^2 * f'c =	0.112	
N_{ED}/ f'c * bc^2 =	0.067	
d2 =	131	mm
d2 / bc =	0.22	

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

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

N_{Ed} / N_{Rd} = 0.09 ===> a = 0.99

$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a$ = 0.145 < 1 OK

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

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

MİTAŞ ENERGY

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

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	C2,C BI+	-2,099	-2,130	-44,839
Maximum Axial Force, Uplift	C2-,C BI-	-2,159	-2,184	34,504

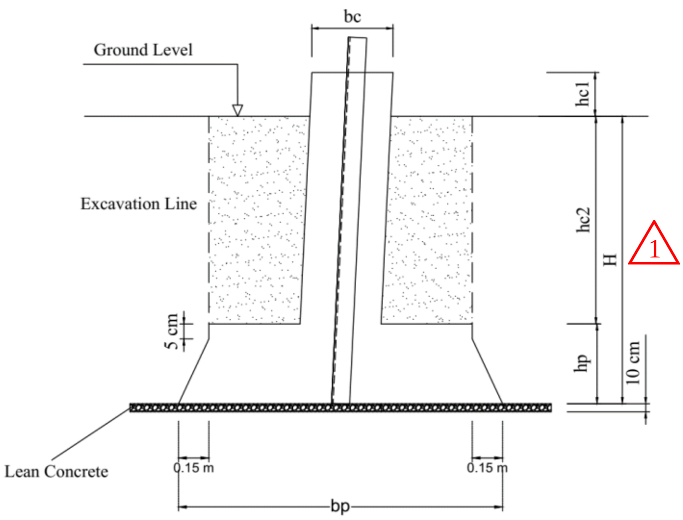
Maximum Loads on Foundation				
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	C2,C BI+	-8,674	8,704	-43,221
Maximum Axial Force, Uplift	C2-,C BI-	-7,194	7,219	33,101

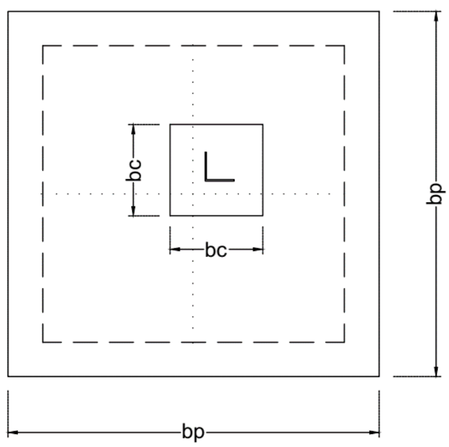
Design Standard: EN 1992:2004

Inputs:

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

	Width of Pad	bp =	1.8	m	
	Height of Pad	hp =	0.4	m	
	Width of Chimney	bc =	0.65	m	
	Height of Chimney above ground level	hc1 =	0.3	m	
	Height of Chimney unedr ground level	hc2 =	2.4	m	
	Depth of Pad	H =	2.8	m	
	Inplane Slope	β =	8.64	Degree	
	Diagonal Slope	γ =	12.10	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 =	47.54	ton
		Vcx =	-9.54	ton
		Vcy =	9.57	ton
	Uplift	T =	36.41	ton
		Vtx =	-7.91	ton
		Vty =	7.94	ton

On Stub	Compression	Cs =	49.32	ton
		Vscx =	-2.31	ton
		Vscy =	-2.34	ton
	Uplift	Ts =	37.95	ton
		Vstx =	-2.38	ton
		Vsty =	-2.40	ton

Soil Passive Pressure Coefficient   Kp = tan 2 (45+φ/2) =   3.69
Passive Force on chimney,   Fp1 =   14.08   ton
Passive Force on pad,   Fp2 =   14.08   ton

Uplift:

Volume of chimney above ground level   V1 =   0.13   m3
Volume of chimney under ground level   V2 =   1.01   m3
Volume of pad,   V3 =   1.09   m3
Total volume of foundation ,   Vf =   2.23   m3

Total weight of foundation,   Wf = Vf * γc =   5.57   ton

Cone volume, $Vcone = (H/3)*(\pi*H^2*\tan^2\Theta + 3*bp^2 + 6*bp*H*\tan\theta) =$ 27.23   m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 =   25.13   m3
Soil weight above foundation,   Ws = Vsoil * γb =   51.23   ton

Total resistance force against uplift,   Ru= Ws + Wf =   56.81   ton
Uplift Force,   U=   36.41   ton

56.81	>	36.41	OK	S.F.= 1.56

Bearing Capacity:

Compression Force,   C =   48.23   ton
Bending Moment about x axis,   Mx =   7.35   ton.m
Bending Moment about y axis,   My =   -7.24   ton.m

Over Load of Concrete Wf=   5.57   ton

Volume of the Soil directly above foundation $Vsl = (H * bp^2) - V2 - V3 =$ 6.97   m3

Over Load of Soil directly above foundation   Wsl= Vsl * γb =   14.21   ton

Average Bearing Pressure = σp = ((C + Wf + Wsl)/A) =	2.10	kg/cm2	<	5.10	kg/cm2	OK

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 2.11   kg/cm2
Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 3.60   kg/cm2
Compression Stress at corner 3, $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 0.60   kg/cm2
Compression Stress at corner 4, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 2.09   kg/cm2

Max. Toe Pressure =	3.60	<	q_{all} =	6.37	OK	S.F.= 1.77
Min. Toe Pressure =	0.60	>		0	OK	

Top Surface Pressure due to Uplift:

Uplift Force,   T =   37.11   ton
Bending Moment about x axis,   Mx =   6.56   ton.m
Bending Moment about y axis,   My =   -6.49   ton.m

Pressure due to Uplift at top surface at corner 1, $\sigma u1 = ((T-Wf)/A) + (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 0.98   kg/cm2
Pressure due to Uplift at top surface at corner 2, $\sigma u2 = ((T-Wf)/A) + (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 2.32   kg/cm2
Pressure due to Uplift at top surface at corner 3, $\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ -0.37   kg/cm2
Pressure due to Uplift at top surface at corner 4, $\sigma u4 = ((T-Wf)/A) - (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 0.97   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 = 17.58 ton.m

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

Mr = 41.77 ton.m

Mr	>	Mo	OK

S.F.= 2.38

Sliding:

Sliding force, Fo = Vmax

Sliding force, Fo = 7.94 ton

Effective weight of foundation and soil at uplift case, Weff = 20.39 ton

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

Fr = 36.32

Fr	>	Fo	OK

S.F.= 4.57

Structural Design of Pad:

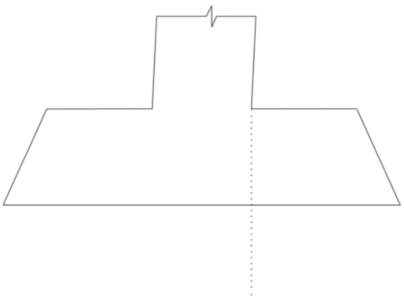
Longitudinal Rebar:

Compression :

Compression Stress at section of Max. bending moment at Pad , σmc = 2.37 kg/cm2

Uplift :

Compression Stress at section of Max. bending moment at Pad , σmu = 1.22 kg/cm2



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

Muc = 656012 kg.cm = 64355 N.m

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

Muu = 447730 kg.cm = 43922 N.m

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

Compression :

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

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

Z max = 317.6 > 308.75 ==>>> Zmax=0.95 dp = 308.75

As = Mu / φs * fyr * z = 500.2 mm2

Uplift :

$K = Mu / f'c * bp * dp^2 =$ 0.017

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

Z max = 320.0 > 308.75 ==>>> Zmax=0.95 dp = 308.75

As = Mu / φs * fyr * z = 341.4 mm2

Top of Pad :

As2t= 341.4 mm2

Rebar Diameter= 12 mm =====> QTY = 4 ==>> 7 =====> 7 Ø 12 =====> 792 mm2

Rebar Quantity = 7

Rebar Spacing = 225.0 mm

Bottom of Pad :

As2b= 500.2 mm2

Rebar Diameter= 12 mm =====> QTY = 5 ==>> 8 =====> 8 Ø 12 =====> 905 mm2

Rebar Quantity = 8

Rebar Spacing = 235.7 mm

Min. Rebar Check:

Ast = 1696.5 mm2

ρst = 0.0029 >

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

ρmax = 0.040 EN 1992-1-1:2004 9.2.1.1

ρst > ρmin OK

ρst < ρmax OK

One Way Shear:

Compression Stress at critical section of shear at Pad , σv = 2.64 kg/cm2

Vu = 10173 kg = 101727 N

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

ρ_1 = 0.0029

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

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

k1 = 0.15

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

Vr = 225070 N

Vr	>	Vu	OK

F.S= 2.21

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 2.10 kg/cm2

To check if punch shear section is defined in Pad ==> bp1 - (bc + 4dp2) = -0.15 < 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 = 6.56 ton.m = 65615 N.m

Rebar arrangement:

No. of rebars rows, n = 4

Total No. of rebars = 12

Distance of the last row to center, c = 25 cm

$\Sigma A_i * d_i^2$ = 5277.8

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

>>>>> A = M * c / (φs * fyr *Σd_i^2)

As1= 8.8 cm2

B) Moment at the bottom of chimney about y axis My max = 6.49 ton.m = 64862 N.m

φs * fyr = M * c /I As2= 8.7 cm2

C) Axial required rebar area, As3 = Ts / (φs*Fyr) = 4.5 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 =		21.9	cm2			
As min =	max (0.1*Cs/Fy , 0.002*Ac) =	8.5	cm2		9.12 N		
As max =	0.04 *Ac =	169.0	cm2		9.5.2.3		
As =	21.9						
Rebar Diameter =	16	mm =====> QTY =	11	=====>	12	=====>	12 Ø 16
===>> As final=	24.1	cm2					
Rebar Quantity of One Row =	4						
Rebar Spacing =	16.7						

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

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

$e = l_0 /400 = 2*(hc)/400 =$	13.5	mm
$N_{Ed} =$	49.32	ton
$M_{0Ed, x} =$	6.40	ton.m
$e_0 = h /30 > 20$ mm ==> $e_0 =$	22	mm
$M_{Ed,x} =$	7.06	ton.m

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

$M_{0Ed, y} =$	6.31	ton.m
$M_{Ed,y} =$	6.97	ton.m
$As * F yr / bc^2 * f'c =$	0.143	
$N_{ED}/ f'c * bc^2 =$	0.057	
d2 =	131	mm
d2 / bc =	0.20	

Interaction Chart Gives ===>	$M_{Rd} / f'c * bc^3 =$	0.1	===> $M_{Rd,x} = M_{Rd,y} =$		37.33	ton.m	
$N_{Rd} =$	Ac * f'c + As * Fyr =	676.72	ton				
$N_{Ed} / N_{Rd} =$	0.07	===>	a =	0.98			
$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a =$		0.391	<	1	OK		

Stirrup Rebar :

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

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

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	C2,C BI+	-2,099	-2,130	-44,839
Maximum Axial Force, Uplift	C2-,C BI-	-2,159	-2,184	34,504

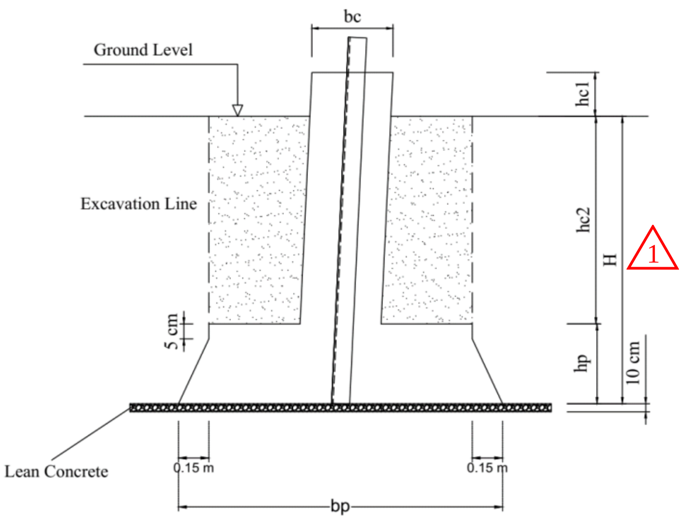
Maximum Loads on Foundation				
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	C2,C BI+	-8,674	8,704	-43,221
Maximum Axial Force, Uplift	C2-,C BI-	-7,194	7,219	33,101

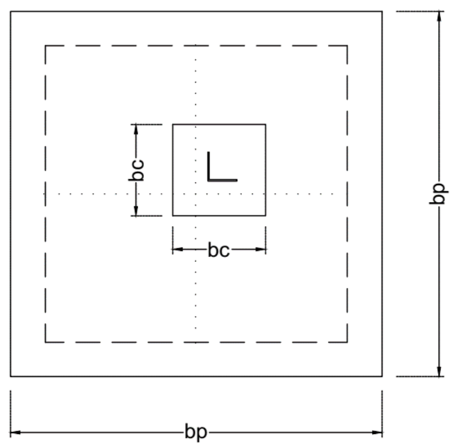
Design Standard: EN 1992:2004

Inputs:

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

	Width of Pad	bp =	1.8	m	
	Height of Pad	hp =	0.4	m	
	Width of Chimney	bc =	0.65	m	
	Height of Chimney above ground level	hc1 =	0.3	m	
	Height of Chimney unedr ground level	hc2 =	2.4	m	
	Depth of Pad	H =	2.8	m	
	Inplane Slope	β =	8.64	Degree	
	Diagonal Slope	γ =	12.10	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 =	47.54	ton
		Vcx =	-9.54	ton
		Vcy =	9.57	ton
	Uplift	T =	36.41	ton
		Vtx =	-7.91	ton
		Vty =	7.94	ton

On Stub	Compression	Cs =	49.32	ton
		Vscx =	-2.31	ton
		Vscy =	-2.34	ton
	Uplift	Ts =	37.95	ton
		Vstx =	-2.38	ton
		Vsty =	-2.40	ton

Soil Passive Pressure Coefficient   Kp = tan 2 (45+φ/2) =   3.69
Passive Force on chimney,   Fp1 =   11.97   ton
Passive Force on pad,   Fp2 =   11.97   ton

Uplift:

Volume of chimney above ground level   V1 =   0.13   m3
Volume of chimney under ground level   V2 =   1.01   m3
Volume of pad,   V3 =   1.09   m3
Total volume of foundation ,   Vf =   2.23   m3

Total weight of foundation,   Wf = Vf * γc =   5.57   ton

Cone volume,   Vcone = $(H/3)*(\pi*H^2*\tan^2\Theta + 3*bp^2 + 6*bp*H*\tan\theta)$ =   24.23   m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 =   22.12   m3
Soil weight above foundation,   Ws = Vsoil * γb =   38.34   ton

Total resistance force against uplift,   Ru= Ws + Wf =   43.91   ton
Uplift Force,   U=   36.41   ton

43.91	>	36.41	OK	S.F.= 1.21

Bearing Capacity:

Compression Force,   C =   48.23   ton
Bending Moment about x axis,   Mx =   7.35   ton.m
Bending Moment about y axis,   My =   -7.24   ton.m

Over Load of Concrete Wf=   5.57   ton

Volume of the Soil directly above foundation   Vsl = $(H * bp^2)$ - V2 - V3 =   6.97   m3

Over Load of Soil directly above foundation   Wsl= Vsl * γb =   12.08   ton

Average Bearing Pressure = σp = ((C + Wf + Wsl)/A) =	2.03	kg/cm2	<	3.06	kg/cm2	OK

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) + (6*My)/(bp^3)$ =   2.04   kg/cm2
Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) - (6*My)/(bp^3)$ =   3.53   kg/cm2
Compression Stress at corner 3, $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) + (6*My)/(bp^3)$ =   0.53   kg/cm2
Compression Stress at corner 4, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) - (6*My)/(bp^3)$ =   2.02   kg/cm2

Max. Toe Pressure =	3.53	<	q_{all} =	3.82	OK	S.F.= 1.08
Min. Toe Pressure =	0.53	>		0	OK	

Top Surface Pressure due to Uplift:

Uplift Force,   T =   37.11   ton
Bending Moment about x axis,   Mx =   6.56   ton.m
Bending Moment about y axis,   My =   -6.49   ton.m

Pressure due to Uplift at top surface at corner 1, $\sigma u1 = ((T-Wf)/A) + (6*Mx)/(bp^3) + (6*My)/(bp^3)$ =   0.98   kg/cm2
Pressure due to Uplift at top surface at corner 2, $\sigma u2 = ((T-Wf)/A) + (6*Mx)/(bp^3) - (6*My)/(bp^3)$ =   2.32   kg/cm2
Pressure due to Uplift at top surface at corner 3, $\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp^3) + (6*My)/(bp^3)$ =   -0.37   kg/cm2
Pressure due to Uplift at top surface at corner 4, $\sigma u4 = ((T-Wf)/A) - (6*Mx)/(bp^3) - (6*My)/(bp^3)$ =   0.97   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 = 17.58 ton.m

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

Mr = 32.10 ton.m

Mr	>	Mo	OK

S.F.= 1.83

Sliding:

Sliding force, Fo = Vmax

Sliding force, Fo = 7.94 ton

Effective weight of foundation and soil at uplift case, Weff = 7.50 ton

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

Fr = 26.94

Fr	>	Fo	OK

S.F.= 3.39

Structural Design of Pad:

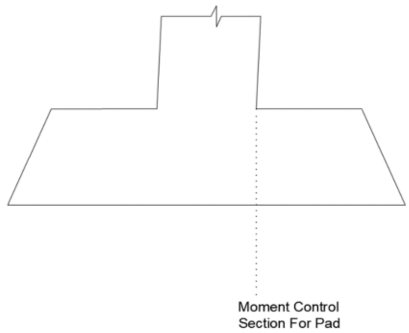
Longitudinal Rebar:

Compression :

Compression Stress at section of Max. bending moment at Pad , σmc = 2.31 kg/cm2

Uplift :

Compression Stress at section of Max. bending moment at Pad , σmu = 1.22 kg/cm2



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

Muc = 658279 kg.cm = 64577 N.m

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

Muu = 447730 kg.cm = 43922 N.m

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

Compression :

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

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

Z max = 317.5 > 308.75 ==>>> Zmax=0.95 dp = 308.75

As = Mu / φs * fyr * z = 502.0 mm2

Uplift :

$K = Mu / f'c * bp * dp^2 =$ 0.017

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

Z max = 320.0 > 308.75 ==>>> Zmax=0.95 dp = 308.75

As = Mu / φs * fyr * z = 341.4 mm2

Top of Pad :

As2t= 341.4 mm2

Rebar Diameter= 12 mm =====> QTY = 4 ==>> 7 =====> 7 Ø 12 =====> 792 mm2

Rebar Quantity = 7

Rebar Spacing = 225.0 mm

Bottom of Pad :

As2b= 502.0 mm2

Rebar Diameter= 12 mm =====> QTY = 5 ==>> 8 =====> 8 Ø 12 =====> 905 mm2

Rebar Quantity = 8

Rebar Spacing = 235.7 mm

Min. Rebar Check:

Ast = 1696.5 mm2

ρst = 0.0029 >

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

ρmax = 0.040 EN 1992-1-1:2004 9.2.1.1

ρst > ρmin OK

ρst < ρmax OK

One Way Shear:

Compression Stress at critical section of shear at Pad , σv = 2.58 kg/cm2

Vu = 10207 kg = 102070 N

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

ρ_1 = 0.0029

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

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

k1 = 0.15

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

Vr = 225070 N

Vr	>	Vu	OK

F.S= 2.21

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 2.03 kg/cm2

To check if punch shear section is defined in Pad ==> bp1 - (bc + 4dp2) = -0.15 < 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 = 6.56 ton.m = 65615 N.m

Rebar arrangement:

No. of rebars rows, n = 4

Total No. of rebars = 12

Distance of the last row to center, c = 25 cm

$\Sigma Ai*di^2$ = 5277.8

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

>>>>> A = M * c / (φs * fyr *Σdi^2)

As1= 8.8 cm2

B) Moment at the bottom of chimney about y axis My max = 6.49 ton.m = 64862 N.m

φs * fyr = M * c /I As2= 8.7 cm2

C) Axial required rebar area, As3 = Ts / (φs*Fyr) = 4.5 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 =			21.9	cm2			
As min =	max (0.1*Cs/Fy , 0.002*Ac) =			8.5	cm2		9.12 N		
As max =	0.04 *Ac =			169.0	cm2		9.5.2.3		
As =	21.9								
Rebar Diameter =	16	mm	=====>	QTY =	11	=====>	12	=====>	12 Ø 16
===>> As final=	24.1	cm2							
Rebar Quantity of One Row =	4								
Rebar Spacing =	16.7								

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

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

$e = l_0 /400 = 2*(hc)/400 =$	13.5	mm
$N_{Ed} =$	49.32	ton
$M_{0Ed, x} =$	6.40	ton.m
$e_0 = h /30 > 20$ mm ==> $e_0 =$	22	mm
$M_{Ed,x} =$	7.06	ton.m

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

$M_{0Ed, y} =$	6.31	ton.m
$M_{Ed,y} =$	6.97	ton.m
$As * F yr / bc^2 * f'c =$	0.143	
$N_{ED}/ f'c * bc^2 =$	0.057	
d2 =	131	mm
d2 / bc =	0.20	

Interaction Chart Gives ===>	$M_{Rd} / f'c * bc^3 =$	0.1	===> $M_{Rd,x} = M_{Rd,y} =$	37.33	ton.m	
$N_{Rd} =$	$Ac * f'c + As * Fyr =$	676.72	ton			
$N_{Ed} / N_{Rd} =$	0.07	===>	a =	0.98		
$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a =$		0.391	<	1	OK	

Stirrup Rebar :

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

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

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	C2,C BI+	-2,099	-2,130	-44,839
Maximum Axial Force, Uplift	C2-,C BI-	-2,159	-2,184	34,504

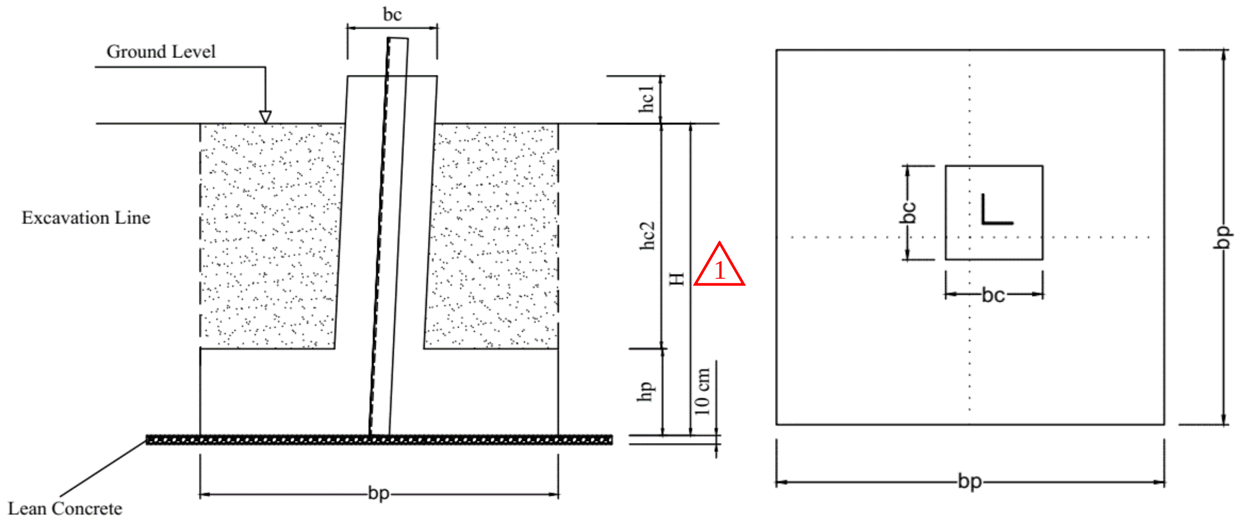
Maximum Loads on Foundation				
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	C2,C BI+	-8,674	8,704	-43,221
Maximum Axial Force, Uplift	C2-,C BI-	-7,194	7,219	33,101

Design Standard: EN 1992:2004

Inputs:

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

	Width of Pad	bp =	1.95	m	
	Height of Pad	hp =	0.4	m	
	Width of Chimney	bc =	0.65	m	
	Height of Chimney above ground level	hc1 =	0.3	m	
	Height of Chimney unedr ground level	hc2 =	2.4	m	
	Depth of Pad	H =	2.8	m	
	Inplane Slope	β =	8.64	Degree	
	Diagonal Slope	γ =	12.10	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 =	47.54	ton
		Vcx =	-9.54	ton
		Vcy =	9.57	ton
	Uplift	T =	36.41	ton
		Vtx =	-7.91	ton
		Vty =	7.94	ton

On Stub	Compression	Cs =	49.32	ton
		Vscx =	-2.31	ton
		Vscy =	-2.34	ton
	Uplift	Ts =	37.95	ton
		Vstx =	-2.38	ton
		Vsty =	-2.40	ton

Soil Passive Pressure Coefficient $\quad K_p = \tan 2\,(45+\varphi/2) =$ 3.69
Passive Force on chimney, $\quad F_{p1} =$ 11.97 ton
Passive Force on pad, $\quad F_{p2} =$ 12.97 ton

Uplift:

Volume of chimney above ground level $\quad V1 =$ 0.13 m3
Volume of chimney under ground level $\quad V2 =$ 1.01 m3
Volume of pad, $\quad V3 =$ 1.52 m3
Total volume of foundation , $\quad Vf =$ 2.66 m3

Total weight of foundation, $\quad Wf = Vf * \gamma c =$ 6.65 ton

Cone volume, $\quad Vcone = (H/3)*(\pi*H^2*\tan^2\Theta + 3*bp^2 + 6*bp*H*\tan\theta) =$ 23.54 m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 = 21.77 m3
Soil weight above foundation, $\quad Ws = Vsoil * \gamma b =$ 37.72 ton

Total resistance force against uplift, $\quad Ru= Ws + Wf =$ 44.38 ton
Uplift Force, $\quad U=$ 36.41 ton

44.38	>	36.41	OK	S.F.= 1.22

1 **Additional condition:** G/Z > 0.67 $\quad$ EN 50341 M.3.1.6
G: weight of foundation and soil vertical to the base = 20.71 ton
Z: uplift force on fondation = 33.10 ton

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

Bearing Capacity:

Compression Force, $\quad C =$ 48.23 ton
Bending Moment about x axis, $\quad Mx =$ 7.35 ton.m
Bending Moment about y axis, $\quad My =$ -7.24 ton.m

Over Load of Concrete Wf= 6.65 ton

Volume of the Soil directly above foundation $\quad Vsl = (H * bp^2) - V2 - V3 =$ 8.11 m3

Over Load of Soil directly above foundation $\quad Wsl= Vsl * \gamma b =$ 14.06 ton

Average Bearing Pressure = $\sigma p = ((C + Wf + Wsl)/A) =$	1.81	kg/cm2	<	3.06	kg/cm2	OK

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 1.82 kg/cm2
Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 2.99 kg/cm2
Compression Stress at corner 3, $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 0.63 kg/cm2
Compression Stress at corner 4, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 1.80 kg/cm2

Max. Toe Pressure =	2.99	<	q_{all} =	3.82	OK	S.F.= 1.28
Min. Toe Pressure =	0.63	>		0	OK	

Top Surface Pressure due to Uplift:

Uplift Force, $\quad T =$ 37.11 ton
Bending Moment about x axis, $\quad Mx =$ 6.56 ton.m
Bending Moment about y axis, $\quad My =$ -6.49 ton.m

Pressure due to Uplift at top surface at corner 1, $\sigma u1 = ((T-Wf)/A) + (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 0.81 kg/cm2
Pressure due to Uplift at top surface at corner 2, $\sigma u2 = ((T-Wf)/A) + (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 1.86 kg/cm2
Pressure due to Uplift at top surface at corner 3, $\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ -0.25 kg/cm2
Pressure due to Uplift at top surface at corner 4, $\sigma u4 = ((T-Wf)/A) - (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 0.79 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 = 19.48 ton.m

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

Mr = 34.98 ton.m

Mr	>	Mo	OK

S.F.= 1.80

Sliding:

Sliding force, Fo = Vmax

Sliding force, Fo = 7.94 ton

Effective weight of foundation and soil at uplift case, Weff = 7.97 ton

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

Fr = 28.13

Fr	>	Fo	OK

S.F.= 3.54

Structural Design of Pad:

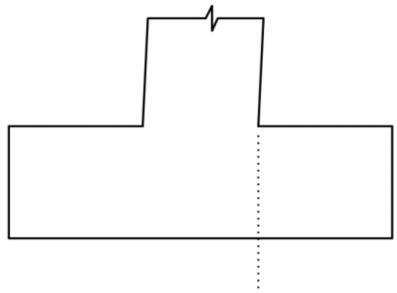
Longitudinal Rebar:

Compression :

Compression Stress at section of Max. bending moment at Pad , σmc = 2.01 kg/cm2

Uplift :

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



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

Muc = 765981 kg.cm = 75143 N.m

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

Muu = 500065 kg.cm = 49056 N.m

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

Compression :

$K = Mu / f'c * bp * dp^2 =$ 0.027 < 0.167 OK

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

Z max = 317.0 > 308.75 ==>>> Zmax=0.95 dp = 308.75

As = Mu / φs * fyr * z = 584.1 mm2

Uplift :

$K = Mu / f'c * bp * dp^2 =$ 0.018

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

Z max = 319.8 > 308.75 ==>>> Zmax=0.95 dp = 308.75

As = Mu / φs * fyr * z = 381.3 mm2

Top of Pad :

As2t= 381.3 mm2

Rebar Diameter= 12 mm =====> QTY = 4 ==>> 9 =====> 9 Ø 12 =====> 1018 mm2

Rebar Quantity = 9

Rebar Spacing = 225.0 mm

Bottom of Pad :

As2b= 584.1 mm2

Rebar Diameter= 12 mm =====> QTY = 6 ==>> 9 =====> 9 Ø 12 =====> 1018 mm2

Rebar Quantity = 9

Rebar Spacing = 225.0 mm

Min. Rebar Check:

Ast =	2035.8	mm2			
ρst =	0.0032	>			
$\rho min = 0.26*(0.3*(f'c\hat{}(2/3))/Fyr > 0.0013$ >>>		0.0013		EN 1992-1-1:2004 9.1N	
ρmax =		0.040		EN 1992-1-1:2004 9.2.1.1	
	ρst	>	ρmin	OK	
	ρst	<	ρmax	OK	

One Way Shear:

Compression Stress at critical section of shear at Pad , σv = 2.21 kg/cm2

Vu =	11994	kg =	119936	N
k = 1 +(200/dp2)^0.5 < 2.0 >>>	k =	1.78		EN 1992-1-1:2004 6.2
ρ_1 =	0.0032			
$\sigma_{cp} = N_{ED}/A_C$ =	0			
$C_{Rd,c} = 0.18/\gamma_c$ =	0.12			
k1 =	0.15			
$v_{min} = 0.035 * k^{3/2} * f'c^{1/2}$ =	0.373	Mpa		EN 1992-1-1:2004 6.3N
Vr =	252282	N		

Vr	>	Vu	OK	F.S=	2.10

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 1.81 kg/cm2

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

Vpunch = 5067 kg = Not Defined N

Resisting Shear of Concrete,

Vr = 864754 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 = 6.56 ton.m = 65615 N.m

Rebar arrangement:

No. of rebars rows, n =	4	
Total No. of rebars =	12	
Distance of the last row to center, c =	25	cm
$\Sigma Ai*di^2$ =	5277.8	

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

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

As1= 8.8 cm2

B) Moment at the bottom of chimney about y axis My max = 6.49 ton.m = 64862 N.m

$\varphi s * fyr = M * c / I$ As2= 8.7 cm2

C) Axial required rebar area, As3 = Ts / (φs*Fyr) = 4.5 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 =   21.9   cm2

As min =   max (0.1*Cs/Fy , 0.002*Ac) =   8.5   cm2   9.12 N

As max =   0.04 *Ac =   169.0   cm2   9.5.2.3

As =   21.9

Rebar Diameter =   16   mm   =====>   QTY =   11   =====>   12   =====>   12 Ø 16

===>> As final=   24.1   cm2

Rebar Quantity of One Row =   4

Rebar Spacing =   16.7

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

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

$e = l_0 /400 = 2*(hc)/400 =$ 13.5   mm

$N_{Ed} =$ 49.32   ton

$M_{0Ed,\,x} =$ 6.40   ton.m

$e_0 = h /30 > 20$ mm ==> $e_0 =$ 22   mm

$M_{Ed,x} =$ 7.06   ton.m

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

$M_{0Ed,\,y} =$ 6.31   ton.m

$M_{Ed,y} =$ 6.97   ton.m

$As * F\,yr / bc^2 * f'c =$ 0.143

$N_{ED}/ f'c * bc^2 =$ 0.057

d2 =   131   mm

d2 / bc =   0.20

Interaction Chart Gives ===> $M_{Rd} / f'c * bc^3 =$ 0.1   ===> $M_{Rd,x} = M_{Rd,y} =$ 37.33   ton.m

$N_{Rd} =$ Ac * f'c + As * Fyr =   676.72   ton

$N_{Ed} / N_{Rd} =$ 0.07   ===>   a =   0.98

$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a =$ 0.391   <   1   OK

Stirrup Rebar :

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

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

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	C2,C BI+	-2,099	-2,130	-44,839
Maximum Axial Force, Uplift	C2-,C BI-	-2,159	-2,184	34,504

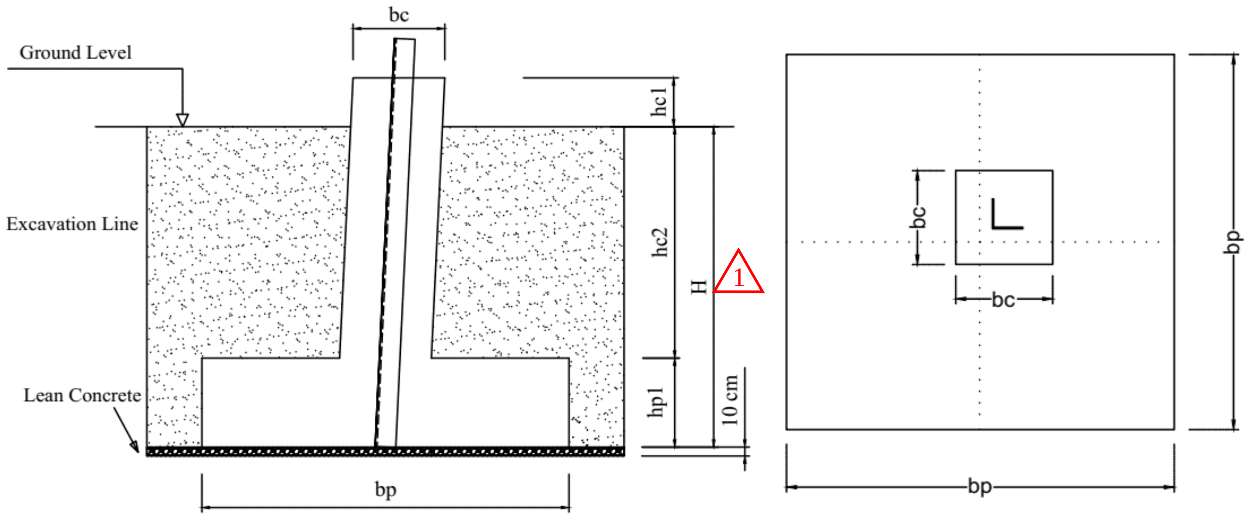
Maximum Loads on Foundation				
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	C2,C BI+	-8,674	8,704	-43,221
Maximum Axial Force, Uplift	C2-,C BI-	-7,194	7,219	33,101

Design Standard: EN 1992:2004

Inputs:

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

	Width of Pad	bp =	2.15	m	
	Height of Pad	hp =	0.4	m	
	Width of Chimney	bc =	0.65	m	
	Height of Chimney above ground level	hc1 =	0.3	m	
	Height of Chimney unedr ground level	hc2 =	2.4	m	
	Depth of Pad	H =	2.8	m	
	Inplane Slope	β =	8.64	Degree	
	Diagonal Slope	γ =	12.10	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



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

Ultimate Loads:

On Foundation	Compression	C =	47.54	ton
		Vcx =	-9.54	ton
		Vcy =	9.57	ton
	Uplift	T =	36.41	ton
		Vtx =	-7.91	ton
		Vty =	7.94	ton

On Stub	Compression	Cs =	49.32	ton
		Vscx =	-2.31	ton
		Vscy =	-2.34	ton
	Uplift	Ts =	37.95	ton
		Vstx =	-2.38	ton
		Vsty =	-2.40	ton

Soil Passive Pressure Coefficient Kp = tan 2 (45+φ/2) = 2.46
Passive Force on chimney, Fp1 = 8.46 ton
Passive Force on pad, Fp2 = 10.11 ton

Uplift:

Volume of chimney above ground level V1 = 0.13 m3
Volume of chimney under ground level V2 = 1.01 m3
Volume of pad, V3 = 1.85 m3
Total volume of foundation , Vf = 2.99 m3

Total weight of foundation, Wf = Vf * γc = 7.47 ton

Cone volume, $V_{cone} = (H/3)*(\pi*H^2*\tan^2\Theta + 3*bp^2 + 6*bp*H*\tan\theta) =$ 21.13 m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 = 19.19 m3
Soil weight above foundation, Ws = Vsoil * γb = 35.21 ton

Total resistance force against uplift, Ru= Ws + Wf = 42.69 ton
Uplift Force, U= 36.41 ton

42.69	>	36.41	OK

S.F.= 1.17

1

Additional condition: G/Z > 0.80 EN 50341 M.3.1.6
G: weight of foundation and soil vertical to the base = 25.97 ton
Z: uplift force on fondation = 33.10 ton

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

Bearing Capacity:

Compression Force, C = 48.23 ton
Bending Moment about x axis, Mx = 7.35 ton.m
Bending Moment about y axis, My = -7.24 ton.m

Over Load of Concrete Wf= 7.47 ton

Volume of the Soil directly above foundation Vsl = $(H * bp^2)$ - V2 - V3 = 10.08 m3

Over Load of Soil directly above foundation Wsl= Vsl * γb = 18.50 ton

Average Bearing Pressure = σp = ((C + Wf + Wsl)/A) =	1.61	kg/cm2	<	2.04	kg/cm2	OK

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 1.61 kg/cm2
Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 2.49 kg/cm2
Compression Stress at corner 3, $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 0.72 kg/cm2
Compression Stress at corner 4, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 1.60 kg/cm2

Max. Toe Pressure =	2.49	<	q_{all} =	2.55	OK
Min. Toe Pressure =	0.72	>		0	OK

S.F.= 1.03

Top Surface Pressure due to Uplift:

Uplift Force, T = 37.11 ton
Bending Moment about x axis, Mx = 6.56 ton.m
Bending Moment about y axis, My = -6.49 ton.m

Pressure due to Uplift at top surface at corner 1, $\sigma u1 = ((T-Wf)/A) + (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 0.65 kg/cm2
Pressure due to Uplift at top surface at corner 2, $\sigma u2 = ((T-Wf)/A) + (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 1.43 kg/cm2
Pressure due to Uplift at top surface at corner 3, $\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ -0.15 kg/cm2
Pressure due to Uplift at top surface at corner 4, $\sigma u4 = ((T-Wf)/A) - (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 0.64 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 = 22.00 ton.m

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

Mr = 36.90 ton.m

Mr	>	Mo	OK

S.F.= 1.68

Sliding:

Sliding force, Fo = Vmax

Sliding force, Fo = 7.94 ton

Effective weight of foundation and soil at uplift case, Weff = 6.27 ton

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

Fr = 21.08

Fr	>	Fo	OK

S.F.= 2.65

Structural Design of Pad:

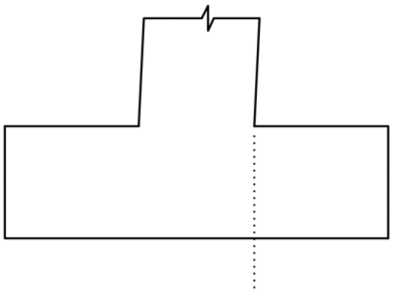
Longitudinal Rebar:

Compression :

Compression Stress at section of Max. bending moment at Pad , σmc = 1.74 kg/cm2

Uplift :

Compression Stress at section of Max. bending moment at Pad , σmu = 0.76 kg/cm2



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

Muc = 910142 kg.cm = 89285 N.m

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

Muu = 571524 kg.cm = 56066 N.m

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

Compression :

K = Mu /f 'c * bp *dp^2 = 0.029 < 0.167 OK

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

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

As = Mu / φs * fyr * z = 694.0 mm2

Uplift :

K = Mu /f 'c * bp *dp^2 = 0.019

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

Z max = 319.6 > 308.75 ==>>> Zmax=0.95 dp = 308.75

As = Mu / φs * fyr * z = 435.8 mm2

Top of Pad :

As2t= 435.8 mm2

Rebar Diameter= 12 mm =====> QTY = 4 ==>> 9 =====> 9 Ø 12 =====> 1018 mm2

Rebar Quantity = 9

Rebar Spacing = 250.0 mm

Bottom of Pad :

As2b= 694.0 mm2

Rebar Diameter= 12 mm =====> QTY = 7 ==>> 9 =====> 9 Ø 12 =====> 1018 mm2

Rebar Quantity = 9

Rebar Spacing = 250.0 mm

Min. Rebar Check:

Ast = 2035.8 mm2

ρst = 0.0029 >

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

ρmax = 0.040 EN 1992-1-1:2004 9.2.1.1

ρst > ρmin OK

ρst < ρmax OK

One Way Shear:

Compression Stress at critical section of shear at Pad , σv = 1.87 kg/cm2

Vu = 13895 kg = 138946 N

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

ρ_1 = 0.0029

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

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

k1 = 0.15

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

Vr = 269250 N

Vr	>	Vu	OK

F.S= 1.94

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 1.61 kg/cm2

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

Vpunch = 13776 kg = 137756 N

Resisting Shear of Concrete,

Vr = 837063 N

Vr	>	Vpunch	OK

F.S.= 6.08

Structural Design of Chimney:

Design of Longitudinal Reinforcement for Uplift :

A) Moment at the bottom of chimney about x axis Mx max = 6.56 ton.m = 65615 N.m

Rebar arrangement:

No. of rebars rows, n = 4

Total No. of rebars = 12

Distance of the last row to center, c = 25 cm

$\Sigma Ai*di^2$ = 5277.8

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

>>>>> A = M * c / (φs * fyr *Σdi^2)

As1= 8.8 cm2

B) Moment at the bottom of chimney about y axis My max = 6.49 ton.m = 64862 N.m

φs * fyr = M * c /I As2= 8.7 cm2

C) Axial required rebar area, As3 = Ts / (φs*Fyr) = 4.5 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 =			21.9	cm2			
As min =	max (0.1*Cs/Fy , 0.002*Ac) =		8.5	cm2		9.12 N		
As max =	0.04 *Ac =		169.0	cm2		9.5.2.3		
As =	21.9							
Rebar Diameter =	16	mm =====>	QTY =	11	=====>	12	=====>	12 Ø 16
===>> As final=	24.1	cm2						
Rebar Quantity of One Row =	4							
Rebar Spacing =	16.7							

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

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

$e = l_0 /400 = 2*(hc)/400 =$	13.5	mm
$N_{Ed} =$	49.32	ton
$M_{0Ed, x} =$	6.40	ton.m
$e_0 = h /30 > 20$ mm ==> $e_0 =$	22	mm
$M_{Ed,x} =$	7.06	ton.m

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

$M_{0Ed, y} =$	6.31	ton.m
$M_{Ed,y} =$	6.97	ton.m
$As * F yr / bc^2 * f'c =$	0.143	
$N_{ED}/ f'c * bc^2 =$	0.057	
d2 =	131	mm
d2 / bc =	0.20	

Interaction Chart Gives ===>	$M_{Rd} / f'c * bc^3 =$	0.1	===> $M_{Rd,x} = M_{Rd,y} =$		37.33	ton.m
$N_{Rd} =$	$Ac * f'c + As * Fyr =$	676.72	ton			
$N_{Ed} / N_{Rd} =$	0.07	===>	a =	0.98		
$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a =$		0.391	<	1	OK	

Stirrup Rebar :

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

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

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	C2,C BI+	-2,099	-2,130	-44,839
Maximum Axial Force, Uplift	C2-,C BI-	-2,159	-2,184	34,504

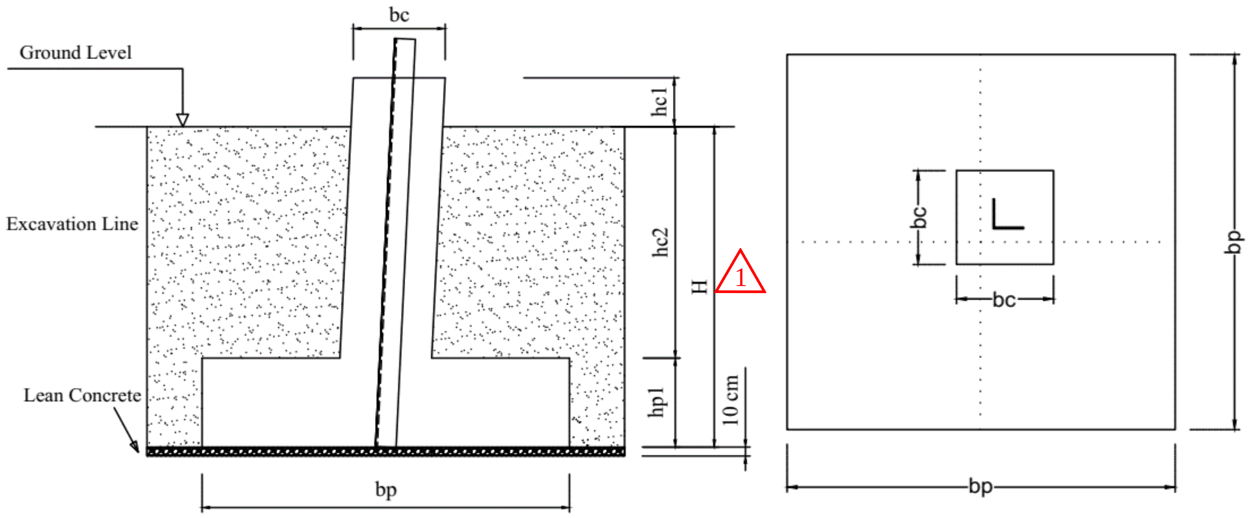
Maximum Loads on Foundation				
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	C2,C BI+	-8,674	8,704	-43,221
Maximum Axial Force, Uplift	C2-,C BI-	-7,194	7,219	33,101

Design Standard: EN 1992:2004

Inputs:

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

	Width of Pad	bp =	2.85	m	
	Height of Pad	hp =	0.4	m	
	Width of Chimney	bc =	0.65	m	
	Height of Chimney above ground level	hc1 =	0.3	m	
	Height of Chimney unedr ground level	hc2 =	2.4	m	
	Depth of Pad	H =	2.8	m	
	Inplane Slope	β =	8.64	Degree	
	Diagonal Slope	γ =	12.10	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 =	1.5	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 =	47.54	ton
		Vcx =	-9.54	ton
		Vcy =	9.57	ton
	Uplift	T =	36.41	ton
		Vtx =	-7.91	ton
		Vty =	7.94	ton

On Stub	Compression	Cs =	49.32	ton
		Vscx =	-2.31	ton
		Vscy =	-2.34	ton
	Uplift	Ts =	37.95	ton
		Vstx =	-2.38	ton
		Vsty =	-2.40	ton

Soil Passive Pressure Coefficient Kp = tan 2 (45+φ/2) = 2.46
Passive Force on chimney, Fp1 = 4.70 ton
Passive Force on pad, Fp2 = 7.44 ton

Uplift:

Volume of chimney above ground level V1 = 0.13 m3
Volume of chimney under ground level V2 = 1.01 m3
Volume of pad, V3 = 3.25 m3
Total volume of foundation , Vf = 4.39 m3

Total weight of foundation, Wf = Vf * γc = 6.58 ton

Cone volume, $V_{cone} = (H/3)*(\pi*H^2*\tan^2\Theta + 3*bp^2 + 6*bp*H*\tan\theta) =$ 32.76 m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 = 30.13 m3
Soil weight above foundation, Ws = Vsoil * γb = 30.71 ton

Total resistance force against uplift, Ru= Ws + Wf = 37.29 ton
Uplift Force, U= 36.41 ton

37.29	>	36.41	OK

S.F.= 1.02

1

Additional condition: G/Z > 0.80 EN 50341 M.3.1.6
G: weight of foundation and soil vertical to the base = 25.42 ton
Z: uplift force on fondation = 33.10 ton

Z/G = 0.77 >>> Ratio = 0.96 OK

Bearing Capacity:

Compression Force, C = 48.23 ton
Bending Moment about x axis, Mx = 7.35 ton.m
Bending Moment about y axis, My = -7.24 ton.m

Over Load of Concrete Wf= 6.58 ton

Volume of the Soil directly above foundation $Vsl = (H * bp^2) - V2 - V3 =$ 18.48 m3

Over Load of Soil directly above foundation Wsl= Vsl * γb = 18.84 ton

Average Bearing Pressure = σp = ((C + Wf + Wsl)/A) =	0.91	kg/cm2	<	2.04	kg/cm2	OK

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 0.91 kg/cm2
Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 1.28 kg/cm2
Compression Stress at corner 3, $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 0.53 kg/cm2
Compression Stress at corner 4, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 0.90 kg/cm2

Max. Toe Pressure =	1.28	<	q_{all} =	2.55	OK
Min. Toe Pressure =	0.53	>		0	OK

S.F.= 1.98

Top Surface Pressure due to Uplift:

Uplift Force, T = 37.11 ton
Bending Moment about x axis, Mx = 6.56 ton.m
Bending Moment about y axis, My = -6.49 ton.m

Pressure due to Uplift at top surface at corner 1, $\sigma u1 = ((T-Wf)/A) + (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 0.38 kg/cm2
Pressure due to Uplift at top surface at corner 2, $\sigma u2 = ((T-Wf)/A) + (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 0.71 kg/cm2
Pressure due to Uplift at top surface at corner 3, $\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 0.04 kg/cm2
Pressure due to Uplift at top surface at corner 4, $\sigma u4 = ((T-Wf)/A) - (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 0.37 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 = 30.84 ton.m

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

Mr = 42.72 ton.m

Mr	>	Mo	OK

S.F.= 1.39

Sliding:

Sliding force, Fo = Vmax

Sliding force, Fo = 7.94 ton

Effective weight of foundation and soil at uplift case, Weff = 0.88 ton

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

Fr = 12.50

Fr	>	Fo	OK

S.F.= 1.57

Structural Design of Pad:

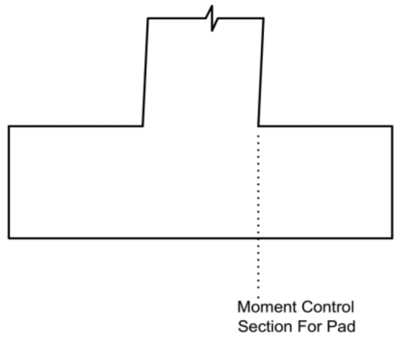
Longitudinal Rebar:

Compression :

Compression Stress at section of Max. bending moment at Pad , σmc = 0.95 kg/cm2

Uplift :

Compression Stress at section of Max. bending moment at Pad , σmu = 0.41 kg/cm2



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

Muc = 1385457 kg.cm = 135913 N.m

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

Muu = 865810 kg.cm = 84936 N.m

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

Compression :

$K = Mu / f'c * bp * dp^2 =$ 0.034 < 0.167 OK

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

Z max = 315.0 > 308.75 ==>>> Zmax=0.95 dp = 308.75

As = Mu / φs * fyr * z = 1056.5 mm2

Uplift :

$K = Mu / f'c * bp * dp^2 =$ 0.021

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

Z max = 318.8 > 308.75 ==>>> Zmax=0.95 dp = 308.75

As = Mu / φs * fyr * z = 660.2 mm2

Top of Pad :

As2t= 660.2 mm2

Rebar Diameter= 12 mm =====> QTY = 6 ==>> 12 =====> 12 Ø 12 =====> 1357 mm2

Rebar Quantity = 12

Rebar Spacing = 245.5 mm

Bottom of Pad :

As2b= 1056.5 mm2

Rebar Diameter= 12 mm =====> QTY = 10 ==>> 12 =====> 12 Ø 12 =====> 1357 mm2

Rebar Quantity = 12

Rebar Spacing = 245.5 mm

Min. Rebar Check:

Ast =	2714.3	mm2				
ρst =	0.0029		>			
ρmin = 0.26*(0.3*(f'c^(2/3))/Fyr > 0.0013	>>>		0.0013		EN 1992-1-1:2004	9.1N
ρmax =			0.040		EN 1992-1-1:2004	9.2.1.1
		ρst	>	ρmin	OK	
		ρst	<	ρmax	OK	

One Way Shear:

Compression Stress at critical section of shear at Pad , σv = 0.99 kg/cm2

Vu =	17686	kg	=	176861	N		
k = 1 +(200/dp2)^0.5 < 2.0	>>>	k =	1.78			EN 1992-1-1:2004	6.2
ρ_1 =	0.0029						
$\sigma_{cp} = N_{ED}/A_C$ =	0						
$C_{Rd,c} = 0.18/\gamma_c$ =	0.12						
k1 =	0.15						
$v_{min} = 0.035 * k^{3/2} * f'c^{1/2}$ =	0.373	Mpa				EN 1992-1-1:2004	6.3N
Vr =	357607	N					

Vr	>	Vu	OK

F.S= 2.02

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 0.91 kg/cm2

To check if punch shear section is defined in Pad ==> bp1 - (bc + 4dp2) = 0.9 > 0 ==> Punch Shear to be Checked in Pad 2

Vpunch = 31004 kg = 310040 N

Resisting Shear of Concrete,

Vr = 838691 N

Vr	>	Vpunch	OK

F.S.= 2.71

Structural Design of Chimney:

Design of Longitudinal Reinforcement for Uplift :

A) Moment at the bottom of chimney about x axis Mx max = 6.56 ton.m = 65615 N.m

Rebar arrangement:

No. of rebars rows, n =	4	
Total No. of rebars =	12	
Distance of the last row to center, c =	25	cm
$\Sigma Ai*di^2$ =	5277.8	

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

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

As1= 8.8 cm2

B) Moment at the bottom of chimney about y axis My max = 6.49 ton.m = 64862 N.m

$\varphi s * fyr = M * c / I$ As2= 8.7 cm2

C) Axial required rebar area, As3 = Ts / (φs*Fyr) = 4.5 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 =		21.9	cm2				
As min =	max (0.1*Cs/Fy , 0.002*Ac) =	8.5	cm2		9.12 N			
As max =	0.04 *Ac =	169.0	cm2		9.5.2.3			
As =	21.9							
Rebar Diameter =	16	mm	=====>	QTY =	11	=====>	12	=====> 12 Ø 16
===>> As final=	24.1	cm2						
Rebar Quantity of One Row =	4							
Rebar Spacing =	16.7							

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

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

$e = l_0 /400 = 2*(hc)/400 =$	13.5	mm
$N_{Ed} =$	49.32	ton
$M_{0Ed,x} =$	6.40	ton.m
$e_0 = h /30 > 20$ mm ==> $e_0 =$	22	mm
$M_{Ed,x} =$	7.06	ton.m

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

$M_{0Ed,y} =$	6.31	ton.m
$M_{Ed,y} =$	6.97	ton.m
$As * F yr / bc^2 * f'c =$	0.143	
$N_{ED}/ f'c * bc^2 =$	0.057	
d2 =	131	mm
d2 / bc =	0.20	

Interaction Chart Gives ===>	$M_{Rd} / f'c * bc^3 =$	0.1	===> $M_{Rd,x} = M_{Rd,y} =$		37.33	ton.m
$N_{Rd} =$	$Ac * f'c + As * Fyr =$	676.72	ton			
$N_{Ed} / N_{Rd} =$	0.07	===>	a =	0.98		
$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a =$		0.391	<	1	OK	

Stirrup Rebar :

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

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

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	C2,C BI+	-2,099	-2,130	-44,839
Maximum Axial Force, Uplift	C2-,C BI-	-2,159	-2,184	34,504

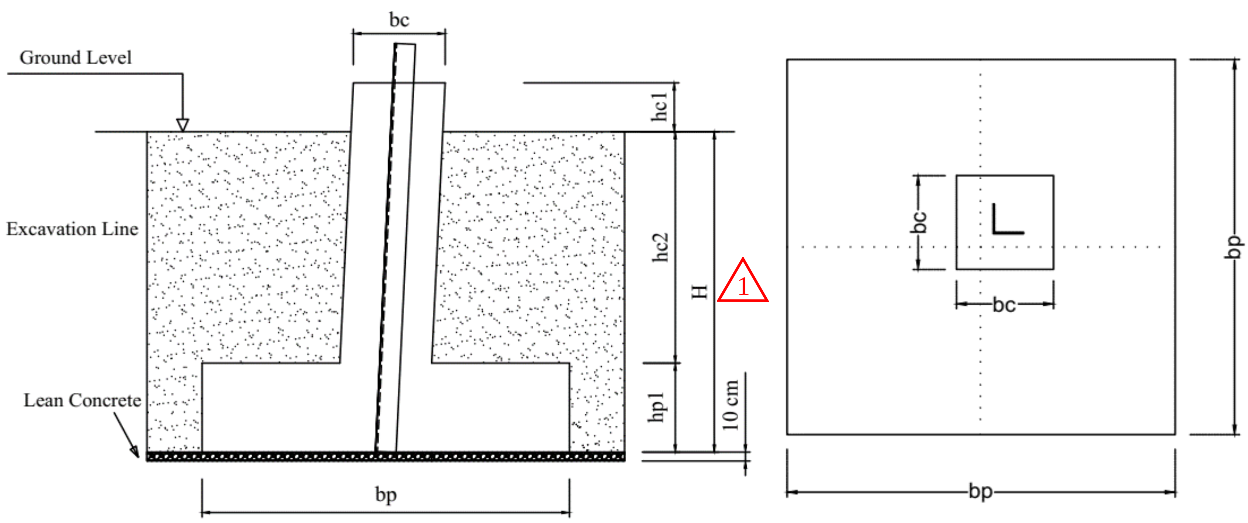
Maximum Loads on Foundation				
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	C2,C BI+	-8,674	8,704	-43,221
Maximum Axial Force, Uplift	C2-,C BI-	-7,194	7,219	33,101

Design Standard: EN 1992:2004

Inputs:

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

	Width of Pad	bp =	2.7	m	
	Height of Pad	hp =	0.4	m	
	Width of Chimney	bc =	0.65	m	
	Height of Chimney above ground level	hc1 =	0.3	m	
	Height of Chimney unedr ground level	hc2 =	2.4	m	
	Depth of Pad	H =	2.8	m	
	Inplane Slope	β =	8.64	Degree	
	Diagonal Slope	γ =	12.10	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



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

Ultimate Loads:

On Foundation	Compression	C =	47.54	ton
		Vcx =	-9.54	ton
		Vcy =	9.57	ton
	Uplift	T =	36.41	ton
		Vtx =	-7.91	ton
		Vty =	7.94	ton

On Stub	Compression	Cs =	49.32	ton
		Vscx =	-2.31	ton
		Vscy =	-2.34	ton
	Uplift	Ts =	37.95	ton
		Vstx =	-2.38	ton
		Vsty =	-2.40	ton

Soil Passive Pressure Coefficient $Kp = \tan^2 (45+\varphi/2)$ = 1.70
Passive Force on chimney, Fp1 = 5.19 ton
Passive Force on pad, Fp2 = 7.78 ton

Uplift:

Volume of chimney above ground level V1 = 0.13 m3
Volume of chimney under ground level V2 = 1.01 m3
Volume of pad, V3 = 2.92 m3
Total volume of foundation , Vf = 4.06 m3

Total weight of foundation, $Wf = Vf * \gamma c$ = 10.14 ton

Cone volume, $Vcone = (H/3)*(\pi*H^2*\tan^2\Theta + 3*bp^2 + 6*bp*H*\tan\theta)$ = 18.95 m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 = 16.48 m3
Soil weight above foundation, $Ws = Vsoil * \gamma b$ = 26.88 ton

Total resistance force against uplift, Ru= Ws + Wf = 37.02 ton
Uplift Force, U= 36.41 ton

37.02	>	36.41	OK

S.F.= 1.02

1

Additional condition: G/Z > 0.80 EN 50341 M.3.1.6
G: weight of foundation and soil vertical to the base = 37.02 ton
Z: uplift force on fondation = 33.10 ton

Z/G = 1.12 >>> Ratio = 1.40 OK

Bearing Capacity:

Compression Force, C = 48.23 ton
Bending Moment about x axis, Mx = 7.35 ton.m
Bending Moment about y axis, My = -7.24 ton.m

Over Load of Concrete Wf= 10.14 ton

Volume of the Soil directly above foundation $Vsl = (H * bp^2) - V2 - V3$ = 16.48 m3

Over Load of Soil directly above foundation $Wsl= Vsl * \gamma b$ = 26.88 ton

Average Bearing Pressure = $\sigma p = ((C + Wf + Wsl)/A)$ =	1.17	kg/cm2	<	1.53	kg/cm2	OK

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) + (6*My)/(bp^3)$ = 1.17 kg/cm2
Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) - (6*My)/(bp^3)$ = 1.61 kg/cm2
Compression Stress at corner 3, $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) + (6*My)/(bp^3)$ = 0.72 kg/cm2
Compression Stress at corner 4, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) - (6*My)/(bp^3)$ = 1.17 kg/cm2

Max. Toe Pressure =	1.61	<	q_{all} =	1.91	OK
Min. Toe Pressure =	0.72	>		0	OK

S.F.= 1.18

Top Surface Pressure due to Uplift:

Uplift Force, T = 37.11 ton
Bending Moment about x axis, Mx = 6.56 ton.m
Bending Moment about y axis, My = -6.49 ton.m

Pressure due to Uplift at top surface at corner 1, $\sigma u1 = ((T-Wf)/A) + (6*Mx)/(bp^3) + (6*My)/(bp^3)$ = 0.37 kg/cm2
Pressure due to Uplift at top surface at corner 2, $\sigma u2 = ((T-Wf)/A) + (6*Mx)/(bp^3) - (6*My)/(bp^3)$ = 0.77 kg/cm2
Pressure due to Uplift at top surface at corner 3, $\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp^3) + (6*My)/(bp^3)$ = -0.03 kg/cm2
Pressure due to Uplift at top surface at corner 4, $\sigma u4 = ((T-Wf)/A) - (6*Mx)/(bp^3) - (6*My)/(bp^3)$ = 0.37 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 = 28.95 ton.m

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

Mr = 39.37 ton.m

Mr	>	Mo	OK

S.F.= 1.36

Sliding:

Sliding force, Fo = Vmax

Sliding force, Fo = 7.94 ton

Effective weight of foundation and soil at uplift case, Weff = 0.61 ton

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

Fr = 13.21

Fr	>	Fo	OK

S.F.= 1.66

Structural Design of Pad:

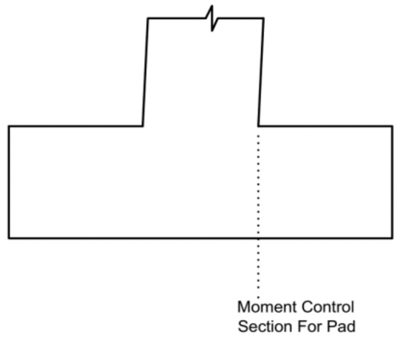
Longitudinal Rebar:

Compression :

Compression Stress at section of Max. bending moment at Pad , σmc = 1.22 kg/cm2

Uplift :

Compression Stress at section of Max. bending moment at Pad , σmu = 0.42 kg/cm2



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

Muc = 1340704 kg.cm = 131523 N.m

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

Muu = 736612 kg.cm = 72262 N.m

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

Compression :

$K = Mu / f'c * bp * dp^2 =$ 0.035 < 0.167 OK

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

Z max = 314.8 > 308.75 ==>>> Zmax=0.95 dp = 308.75

As = Mu / φs * fyr * z = 1022.4 mm2

Uplift :

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

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

Z max = 319.5 > 308.75 ==>>> Zmax=0.95 dp = 308.75

As = Mu / φs * fyr * z = 561.7 mm2

Top of Pad :

As2t= 561.7 mm2

Rebar Diameter= 12 mm =====> QTY = 5 ==>> 12 =====> 12 Ø 12 =====> 1357 mm2

Rebar Quantity = 12

Rebar Spacing = 231.8 mm

Bottom of Pad :

As2b= 1022.4 mm2

Rebar Diameter= 12 mm =====> QTY = 10 ==>> 12 =====> 12 Ø 12 =====> 1357 mm2

Rebar Quantity = 12

Rebar Spacing = 231.8 mm

Min. Rebar Check:

Ast =	2714.3	mm2			
ρst =	0.0031		>		
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 =	1.28	kg/cm2	
Vu =	17839		kg =	178393	N	
k = 1 +(200/dp2)^0.5 < 2.0	>>>	k =	1.78			EN 1992-1-1:2004 6.2
ρ_1 =	0.0031					
$\sigma_{cp} = N_{ED}/A_C$ =	0					
$C_{Rd,c} = 0.18/\gamma_c$ =	0.12					
k1 =	0.15					
$v_{min} = 0.035 * k^{3/2} * f'c^{1/2}$ =	0.373	Mpa				EN 1992-1-1:2004 6.3N
Vr =	344947	N				
	Vr		>	Vu	OK	F.S= 1.93

Two Way Shear:

Average Compression Stress at the Middle of Pad ,			σ ave =	1.17	kg/cm2	
To check if punch shear section is defined in Pad ==>		bp1 - (bc + 4dp2) =		0.75	>	0 ==> Punch Shear to be Checked in Pad 2
Vpunch =	29954	kg	=	299543	N	

Resisting Shear of Concrete,

Vr =	853943	N				
	Vr		>	Vpunch	OK	F.S.= 2.85

Structural Design of Chimney:

Design of Longitudinal Reinforcement for Uplift :

A) Moment at the bottom of chimney about x axis Mx max = 6.56 ton.m = 65615 N.m

Rebar arrangement:

No. of rebars rows, n =	4	
Total No. of rebars =	12	
Distance of the last row to center, c =	25	cm
$\Sigma Ai*di^2$ =	5277.8	

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

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

As1= 8.8 cm2

B) Moment at the bottom of chimney about y axis My max = 6.49 ton.m = 64862 N.m

$\varphi s * fyr = M * c / I$ As2= 8.7 cm2

C) Axial required rebar area, As3 = Ts / (φs*Fyr) = 4.5 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 =		21.9	cm2				
As min =	max (0.1*Cs/Fy , 0.002*Ac) =	8.5	cm2		9.12 N			
As max =	0.04 *Ac =	169.0	cm2		9.5.2.3			
As =	21.9							
Rebar Diameter =	16	mm =====>	QTY =	11	=====>	12	=====>	12 Ø 16
===>> As final=	24.1	cm2						
Rebar Quantity of One Row =	4							
Rebar Spacing =	16.7							

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

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

$e = l_0 /400 = 2*(hc)/400 =$	13.5	mm
$N_{Ed} =$	49.32	ton
$M_{0Ed, x} =$	6.40	ton.m
$e_0 = h /30 > 20$ mm ==> $e_0 =$	22	mm
$M_{Ed,x} =$	7.06	ton.m

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

$M_{0Ed, y} =$	6.31	ton.m
$M_{Ed,y} =$	6.97	ton.m
$As * F yr / bc^2 * f'c =$	0.143	
$N_{ED}/ f'c * bc^2 =$	0.057	
d2 =	131	mm
d2 / bc =	0.20	

Interaction Chart Gives ===>	$M_{Rd} / f'c * bc^3 =$	0.1	===> $M_{Rd,x} = M_{Rd,y} =$		37.33	ton.m
$N_{Rd} =$	$Ac * f'c + As * Fyr =$	676.72	ton			
$N_{Ed} / N_{Rd} =$	0.07	===>	a =	0.98		
$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a =$		0.391	<	1	OK	

Stirrup Rebar :

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

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

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	C2,C BI+	-2,099	-2,130	-44,839
Maximum Axial Force, Uplift	C2-,C BI-	-2,159	-2,184	34,504

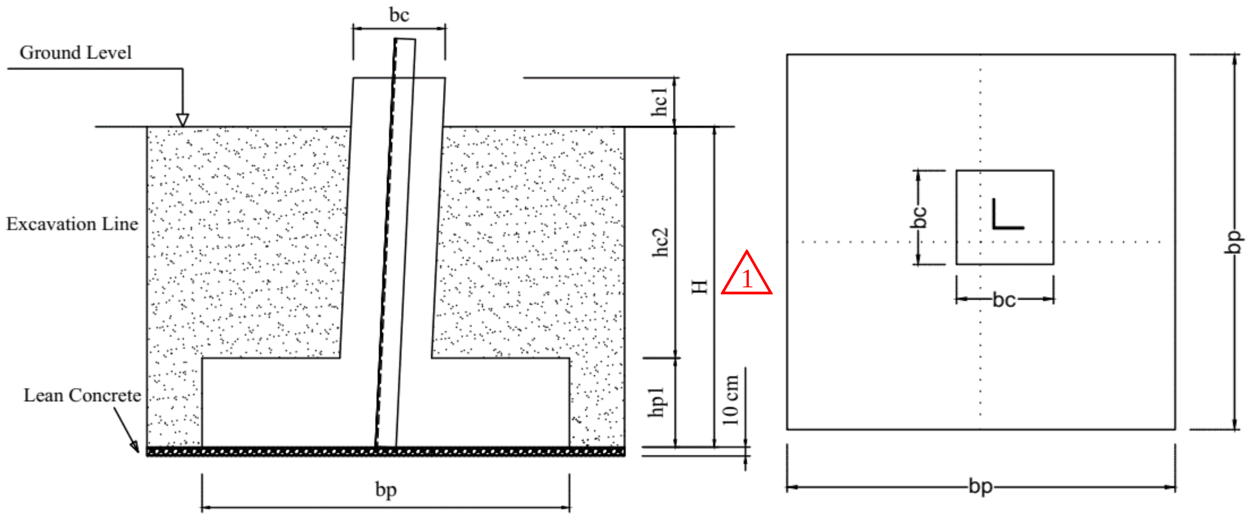
Maximum Loads on Foundation				
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	C2,C BI+	-8,674	8,704	-43,221
Maximum Axial Force, Uplift	C2-,C BI-	-7,194	7,219	33,101

Design Standard: EN 1992:2004

Inputs:

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

	Width of Pad	bp =	3.75	m	
	Height of Pad	hp =	0.4	m	
	Width of Chimney	bc =	0.65	m	
	Height of Chimney above ground level	hc1 =	0.3	m	
	Height of Chimney unedr ground level	hc2 =	2.4	m	
	Depth of Pad	H =	2.8	m	
	Inplane Slope	β =	8.64	Degree	
	Diagonal Slope	γ =	12.10	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 =	1.5	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 =	47.54	ton
		Vcx =	-9.54	ton
		Vcy =	9.57	ton
	Uplift	T =	36.41	ton
		Vtx =	-7.91	ton
		Vty =	7.94	ton

On Stub	Compression	Cs =	49.32	ton
		Vscx =	-2.31	ton
		Vscy =	-2.34	ton
	Uplift	Ts =	37.95	ton
		Vstx =	-2.38	ton
		Vsty =	-2.40	ton

Soil Passive Pressure Coefficient $K_p = \tan 2\,(45+\varphi/2) =$ 1.70
Passive Force on chimney, Fp1 = 2.59 ton
Passive Force on pad, Fp2 = 5.40 ton

Uplift:

Volume of chimney above ground level V1 = 0.13 m3
Volume of chimney under ground level V2 = 1.01 m3
Volume of pad, V3 = 5.63 m3
Total volume of foundation , Vf = 6.77 m3

Total weight of foundation, $W_f = V_f * \gamma_c =$ 10.15 ton

Cone volume, $V_{cone} = (H/3)*(\pi*H^2*\tan^2\Theta + 3*bp^2 + 6*bp*H*\tan\theta) =$ 36.56 m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 = 32.74 m3
Soil weight above foundation, $W_s = V_{soil} * \gamma_b =$ 26.70 ton

Total resistance force against uplift, Ru= Ws + Wf = 36.84 ton
Uplift Force, U= 36.41 ton

36.84	>	36.41	OK

S.F.= 1.01

1

Additional condition: G/Z > 0.80 EN 50341 M.3.1.6
G: weight of foundation and soil vertical to the base = 36.84 ton
Z: uplift force on fondation = 33.10 ton

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

Bearing Capacity:

Compression Force, C = 48.23 ton
Bending Moment about x axis, Mx = 7.35 ton.m
Bending Moment about y axis, My = -7.24 ton.m

Over Load of Concrete Wf= 10.15 ton

Volume of the Soil directly above foundation $V_{sl} = (H * bp^2) - V2 - V3 =$ 32.74 m3

Over Load of Soil directly above foundation $W_{sl} = V_{sl} * \gamma_b =$ 26.70 ton

Average Bearing Pressure = $\sigma_p = ((C + W_f + W_{sl})/A) =$	0.60	kg/cm2	<	0.82	kg/cm2	OK

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 0.61 kg/cm2
Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 0.77 kg/cm2
Compression Stress at corner 3, $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 0.44 kg/cm2
Compression Stress at corner 4, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 0.60 kg/cm2

Max. Toe Pressure =	0.77	<	q_{all} =	1.02	OK
Min. Toe Pressure =	0.44	>		0	OK

S.F.= 1.32

Top Surface Pressure due to Uplift:

Uplift Force, T = 37.11 ton
Bending Moment about x axis, Mx = 6.56 ton.m
Bending Moment about y axis, My = -6.49 ton.m

Pressure due to Uplift at top surface at corner 1, $\sigma u1 = ((T-Wf)/A) + (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 0.19 kg/cm2
Pressure due to Uplift at top surface at corner 2, $\sigma u2 = ((T-Wf)/A) + (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 0.34 kg/cm2
Pressure due to Uplift at top surface at corner 3, $\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 0.04 kg/cm2
Pressure due to Uplift at top surface at corner 4, $\sigma u4 = ((T-Wf)/A) - (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 0.19 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 = 42.21 ton.m

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

Mr = 54.40 ton.m

Mr	>	Mo	OK

S.F.= 1.29

Sliding:

Sliding force, Fo = Vmax

Sliding force, Fo = 7.94 ton

Effective weight of foundation and soil at uplift case, Weff = 0.43 ton

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

Fr = 8.17

Fr	>	Fo	OK

S.F.= 1.03

Structural Design of Pad:

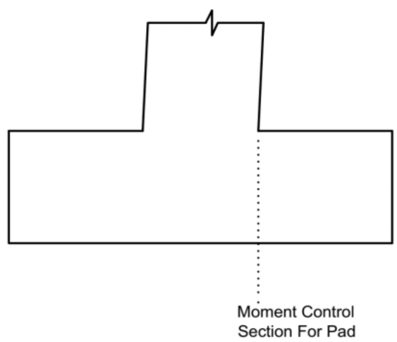
Longitudinal Rebar:

Compression :

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

Uplift :

Compression Stress at section of Max. bending moment at Pad , σmu = 0.20 kg/cm2



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

Muc = 2116278 kg.cm = 207607 N.m

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

Muu = 1107338 kg.cm = 108630 N.m

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

Compression :

$K = Mu / f'c * bp * dp^2 =$ 0.039 < 0.167 OK

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

Z max = 313.3 > 308.75 ==>>> Zmax=0.95 dp = 308.75

As = Mu / φs * fyr * z = 1613.8 mm2

Uplift :

$K = Mu / f'c * bp * dp^2 =$ 0.021

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

Z max = 319.0 > 308.75 ==>>> Zmax=0.95 dp = 308.75

As = Mu / φs * fyr * z = 844.4 mm2

Top of Pad :

As2t= 844.4 mm2

Rebar Diameter= 12 mm =====> QTY = 8 ==>> 16 =====> 16 Ø 12 =====> 1810 mm2

Rebar Quantity = 16

Rebar Spacing = 240.0 mm

Bottom of Pad :

As2b= 1613.8 mm2

Rebar Diameter= 12 mm =====> QTY = 15 ==>> 16 =====> 16 Ø 12 =====> 1810 mm2

Rebar Quantity = 16

Rebar Spacing = 240.0 mm

Min. Rebar Check:

Ast =	3619.1	mm2			
ρst =	0.0030	>			
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 =	0.63	kg/cm2	
Vu =	21385	kg =	213849	N	
k = 1 +(200/dp2)^0.5 < 2.0 >>>	k =	1.78			EN 1992-1-1:2004 6.2
ρ_1 =	0.0030				
$\sigma_{cp} = N_{ED}/A_C$ =	0				
$C_{Rd,c} = 0.18/\gamma_c$ =	0.12				
k1 =	0.15				
$v_{min} = 0.035 * k^{3/2} * f'c^{1/2}$ =	0.373	Mpa			EN 1992-1-1:2004 6.3N
Vr =	472617	N			
	Vr	>	Vu	OK	F.S= 2.21

Two Way Shear:

Average Compression Stress at the Middle of Pad ,		σ ave =	0.60	kg/cm2	
To check if punch shear section is defined in Pad ==>	bp1 - (bc + 4dp2) =	1.8	>	0 ==>	Punch Shear to be Checked in Pad 2
Vpunch =	43473	kg =	434726	N	

Resisting Shear of Concrete,

Vr =	842402	N			
	Vr	>	Vpunch	OK	F.S.= 1.94

Structural Design of Chimney:

Design of Longitudinal Reinforcement for Uplift :

A) Moment at the bottom of chimney about x axis — Mx max = 6.56 ton.m = 65615 N.m

Rebar arrangement:

No. of rebars rows, n =	4	
Total No. of rebars =	12	
Distance of the last row to center, c =	25	cm
$\Sigma Ai*di^2$ =	5277.8	

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

>>>>> A = M * c / (φs * fyr *Σdi^2)

As1= 8.8 cm2

B) Moment at the bottom of chimney about y axis — My max = 6.49 ton.m = 64862 N.m

φs * fyr = M * c /I — As2= 8.7 cm2

C) Axial required rebar area, As3 = Ts / (φs*Fyr) = 4.5 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 =			21.9	cm2				
As min =	max (0.1*Cs/Fy , 0.002*Ac) =		8.5	cm2		9.12 N			
As max =	0.04 *Ac =		169.0	cm2		9.5.2.3			
As =	21.9								
Rebar Diameter =	16	mm	=====>	QTY =	11	=====>	12	=====>	12 Ø 16
===>> As final=	24.1	cm2							
Rebar Quantity of One Row =	4								
Rebar Spacing =	16.7								

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

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

$e = l_0 /400 = 2*(hc)/400 =$	13.5	mm
$N_{Ed} =$	49.32	ton
$M_{0Ed, x} =$	6.40	ton.m
$e_0 = h /30 > 20$ mm ==> $e_0 =$	22	mm
$M_{Ed,x} =$	7.06	ton.m

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

$M_{0Ed, y} =$	6.31	ton.m
$M_{Ed,y} =$	6.97	ton.m
$As * F yr / bc^2 * f'c =$	0.143	
$N_{ED}/ f'c * bc^2 =$	0.057	
d2 =	131	mm
d2 / bc =	0.20	

Interaction Chart Gives ===>	$M_{Rd} / f'c * bc^3 =$	0.1	===> $M_{Rd,x} = M_{Rd,y} =$		37.33	ton.m
$N_{Rd} =$	$Ac * f'c + As * Fyr =$	676.72	ton			
$N_{Ed} / N_{Rd} =$	0.07	===>	a =	0.98		
$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a =$		0.391	<	1	OK	

Stirrup Rebar :

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