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 "12A-LA"

(for all soil types)

Rev. No.	Date	Description	Designed by	Checked by	Approved by
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Document Title	Scale	Sheet of Sheets
Foundation Design Calculations of Tower Type "12A-LA" (for all soil types)	**n.a.**	Page **1** of 52

Soils and Foundations Specifications

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

Soil Type:	Type 1-Sound Rock
Foundation Type:	Rock Anchor
Tower Type:	12A-LA

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	30° C5,C NA+	1,776	3,018	-129,012
Maximum Axial Force, Uplift	30° C5, Min. WS,C NA+	1,105	3,023	119,055

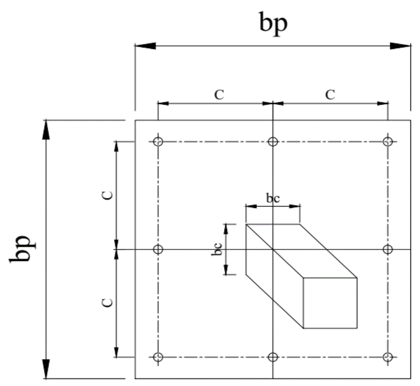
Maximum Loads on Foundation				
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	30° C5,C NA+	22,110	23,353	-124,987
Maximum Axial Force, Uplift	30° C5, Min. WS,C NA+	19,878	-21,796	115,385

Design Standard: EN 1992:2004

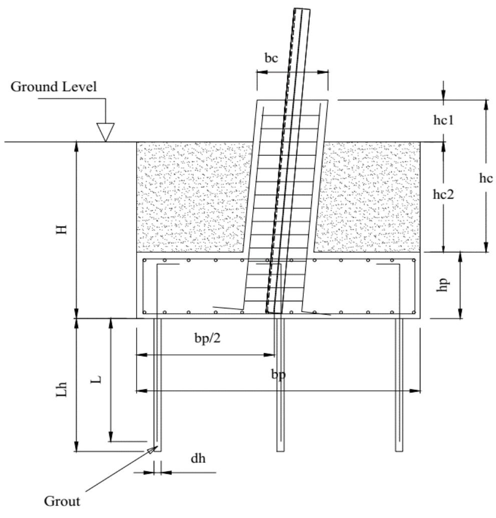
Inputs:

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

Foundation Dimensions	Width of Pad	bp =	1.5	m	
	Height of Pad	hp =	0.75	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 =	0.65	m	
	Total Height of Chimney	hc =	0.95	m	
	Depth of Pad	H =	1.4	m	
	Inplane Slope	β =	9.24	Degree	
	Eccentricity (Bottom of Pad)	e =	0.28	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 =	137.49	ton
		Vcx =	24.32	ton
		Vcy =	25.69	ton
	Tension	T =	126.92	ton
		Vtx =	21.87	ton
		Vty =	-23.98	ton

On Stub	Compression	Cs =	141.91	ton
		Vscx =	1.95	ton
		Vscy =	3.32	ton
	Tension	Ts =	130.96	ton
		Vstx =	1.22	ton
		Vsty =	3.33	ton

Design of Anchors:

Volume of chimney above ground level V1 = 0.15 m3
Volume of chimney under ground level V2 = 0.32 m3
Volume of pad, V3 = 1.69 m3
Total volume of foundation , Vf = 2.15 m3

Total weight of foundation, Wf = Vf * γc = 5.38 ton

Uplift Force, U = 126.92 ton

Design force for anchors, U net = U - Wf = 121.54 ton

Required anchor area for uplift, Asu = U net / (φs * Fy) = 28.62 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 = 2.0 cm

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

Total anchor area in one hole = 6.28 cm

Total area of anchors, As =	50.27	cm2	>	28.62	OK

Uplift Force, T = 127.64 ton
Bending Moment about x axis, Mx = 5.65 ton.m
Bending Moment about y axis, My = 2.07 ton.m

Required Modulus of Section at x direction Wx = Mx / (φs * Fy) = 133.11 cm3
Required Modulus of Section at y direction Wy = My / (φs * Fy) = 48.66 cm3

Required anchor area for bending moment about x axis, Asmx = n * m * Wx * c / (Σ di ^{2}) = 3.63 cm2

Required anchor area for bending moment about y axis, Asmy = n* m * Wy * c / (Σ di ^{2}) = 1.33 cm2

Total Required Area for Anchors, Astot = Asu + Asmx + Asmy =	33.57	cm2	<	50.27	OK

Bearing Capacity:

Compression Force, C = 138.31 ton
Bending Moment about x axis, Mx = 5.64 ton.m
Bending Moment about y axis, My = 3.32 ton.m

Over Load of Concrete, Wf = 5.38 ton

Volume of the Soil directly above foundation Vsl = (H * bp ^{2}) - V2 - V3 = 1.14 m3

Over Load of Soil directly above foundation Wsl= Vsl * γs = 2.92 ton

Overall Bearing Pressure = σp = ((C + Wf + Wsl)/A) =	6.52	kg/cm2	<	10.19	kg/cm2	OK

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) + (6*My)/(bp3) =$ 8.11 kg/cm2

Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) - (6*My)/(bp3) =$ 6.93 kg/cm2

Compression Stress at corner 3, $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) + (6*My)/(bp3) =$ 6.10 kg/cm2

Compression Stress at corner 4, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) - (6*My)/(bp3) =$ 4.92 kg/cm2

Max. Toe Pressure =	8.11	<	q_{all} =	12.74	OK
Min. Toe Pressure =	4.92	>	0		OK

Bond of Anchor and Grout Check :

Max. force of one anchor hole Pa = 17825 kg

Required embedded length of anchor in Rock, Lmin= Pa / (m * τ_{gs} * π * da) = 70.9 cm

Design embedded length of anchor in Rock, L= 200 cm

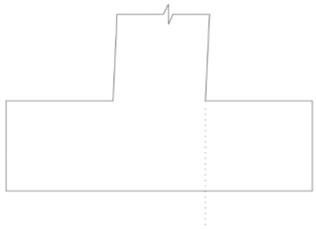
Bond of Grout and Rock Check :

Anchor Hole Diameter, Dh = 7.5 cm

Resisting bond force of the Grout and Rock, $F\tau_{gr} = \tau_{gr}$ * L* Dh * π =	42412	kg	>	17825	OK

Structural Design of Pad:

Longitudinal Rebar:



Moment Control Section For Pad

Compression Stress at section of Max. bending moment, σm = 6.98 kg/cm2

Mu = 861039 kg.cm = 86104 N.m

Effective Depth, dp = hp - cp = 0.675 m

$K = Mu / f'c * bp * dp^2 =$ 0.00945 < 0.167 OK

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

Z max = 669.33 > 641.25 ==>>> Zmax=0.95 dp = 641.25 mm

As = Mu / φs * fyr * z = 322

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 = 1463 mm2

As max = 45000 mm2

As = 1463

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

Rebar Quantity = 8

Rebar Spacing = 19.3

===> As= 1608 mm2

One Way Shear:

Compression Stress at critical section of shear , σv = 7.89 kg/cm2

Vu = -31093 kg = -310928 N Not defined since Theorical shear check distance is more than pad width!

k = 1 +(200/dp)^0.5 < 2.0 >>> k = 1.54 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

$v_{min} = 0.035 * k^{3/2} * f'c^{1/2}$ = 0.245 Mpa EN 1992-1-1:2004 6.3N

Vr = 248338 N

Vr	>	Vu	OK

F.S= Not Defined!

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 6.52 kg/cm2

Vpunch = -491868 kg = -4918685 N

Resisting Shear of Concrete,

Vr = 1867882 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 = 3.20 ton.m = 32008 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= 3.7 cm2

B) Moment at the bottom of chimney about y axis

My max = 1.17 ton.m = 11701 N.m

>>>>> A = M * c / (φs * fyr *Σ di2)

As2= 1.3 cm2

C) Axial required rebar area, As3 = Ts / (φs*Fys) = 15.4 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 = 20.4 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 = 20.4

Rebar Diameter = 20 mm =====> QTY = 7 =====> 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

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

$e = l_0 /400 = 2*(hc)/400 =$ 4.75 mm

$N_{Ed} =$ 141.91 ton

$M_{0Ed,x} =$ 3.20 ton.m

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

$M_{Ed,x}$ = 3.87 ton.m

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

$M_{0Ed,y}$= 1.88 ton.m

$M_{Ed,y}$ = 3.31 ton.m

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

N_{ED}/ f'c * bc^2 = 0.142

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} = 0.18 ===> a = 1.07

$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a$ = 0.106 < 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: 12A-LA

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	30° C5,C NA+	1,776	3,018	-129,012
Maximum Axial Force, Uplift	30° C5, Min. WS,C NA+	1,105	3,023	119,055

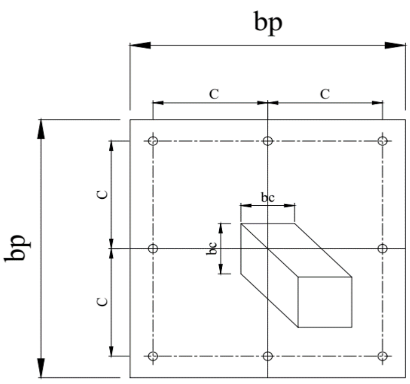
Maximum Loads on Foundation				
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	30° C5,C NA+	22,110	23,353	-124,987
Maximum Axial Force, Uplift	30° C5, Min. WS,C NA+	19,878	-21,796	115,385

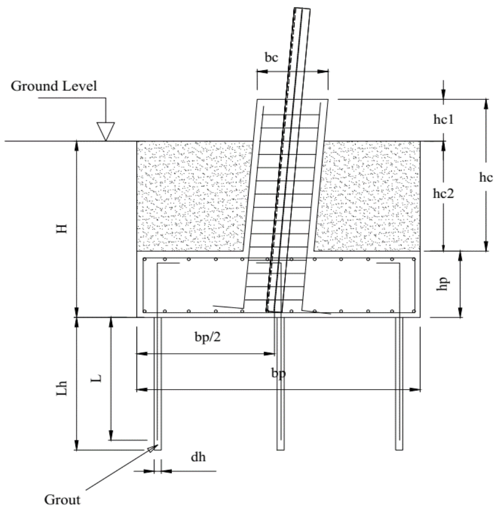
Design Standard: EN 1992:2004

Inputs:

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

Foundation Dimensions	Width of Pad	bp =	1.75	m	
	Height of Pad	hp =	0.75	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 =	0.65	m	
	Total Height of Chimney	hc =	0.95	m	
	Depth of Pad	H =	1.4	m	
	Inplane Slope	β =	9.24	Degree	
	Eccentricity (Bottom of Pad)	e =	0.28	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





* The foundation is in direct contact with undisturbed soil.

Ultimate Loads:

On Foundation	Compression	C =	137.49	ton
		Vcx =	24.32	ton
		Vcy =	25.69	ton
	Tension	T =	126.92	ton
		Vtx =	21.87	ton
		Vty =	-23.98	ton

On Stub	Compression	Cs =	141.91	ton
		Vscx =	1.95	ton
		Vscy =	3.32	ton
	Tension	Ts =	130.96	ton
		Vstx =	1.22	ton
		Vsty =	3.33	ton

Design of Anchors:

Volume of chimney above ground level V1 = 0.15 m3
Volume of chimney under ground level V2 = 0.32 m3
Volume of pad, V3 = 2.30 m3
Total volume of foundation , Vf = 2.76 m3

Total weight of foundation, Wf = Vf * γc = 6.91 ton

Uplift Force, U = 126.92 ton

Design force for anchors, U net = U - Wf = 120.02 ton

Required anchor area for uplift, Asu = U net / (φs * Fy) = 28.26 cm2

Anchor arrangement:

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

Central Holes to be Ommited = Yes

Total No. of anchors holes, i = 8

Distance between anchor rows C = 62.5 cm

Distance of the last row to center, c = 62.5 cm

Σ di ^{2} = 15625

Anchor diameter, da = 2.0 cm

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

Total anchor area in one hole = 6.28 cm

Total area of anchors, As =	50.27	cm2	>	28.26	OK

Uplift Force, T = 127.64 ton
Bending Moment about x axis, Mx = 5.65 ton.m
Bending Moment about y axis, My = 2.07 ton.m

Required Modulus of Section at x direction Wx = Mx / (φs * Fy) = 133.11 cm3
Required Modulus of Section at y direction Wy = My / (φs * Fy) = 48.66 cm3

Required anchor area for bending moment about x axis, Asmx = n * m * Wx * c / (Σ di ^{2}) = 3.19 cm2

Required anchor area for bending moment about y axis, Asmy = n* m * Wy * c / (Σ di ^{2}) = 1.17 cm2

Total Required Area for Anchors, Astot = Asu + Asmx + Asmy =	32.62	cm2	<	50.27	OK

Bearing Capacity:

Compression Force, C = 138.31 ton
Bending Moment about x axis, Mx = 5.64 ton.m
Bending Moment about y axis, My = 3.32 ton.m

Over Load of Concrete, Wf = 6.91 ton

Volume of the Soil directly above foundation Vsl = (H * bp^2) - V2 - V3 = 1.67 m3

Over Load of Soil directly above foundation Wsl= Vsl * γs = 3.41 ton

Overall Bearing Pressure = σp = ((C + Wf + Wsl)/A) =	4.85	kg/cm2	<	5.10	kg/cm2	OK

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) + (6*My)/(bp3) =$ 5.86 kg/cm2

Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) - (6*My)/(bp3) =$ 5.11 kg/cm2

Compression Stress at corner 3, $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) + (6*My)/(bp3) =$ 4.59 kg/cm2

Compression Stress at corner 4, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) - (6*My)/(bp3) =$ 3.85 kg/cm2

Max. Toe Pressure =	5.86	<	q_{all} =	6.37	OK
Min. Toe Pressure =	3.85	>	0		OK

Bond of Anchor and Grout Check :

Max. force of one anchor hole Pa = 17318 kg

Required embedded length of anchor in Rock, Lmin= $Pa / (m * \tau_{gs} * \pi * da)$ = 68.9 cm

Design embedded length of anchor in Rock, L= 280 cm

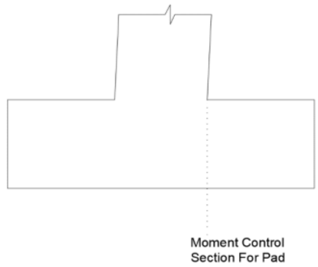
Bond of Grout and Rock Check :

Anchor Hole Diameter, Dh = 7.5 cm

Resisting bond force of the Grout and Rock, $F\tau_{gr} = \tau_{gr} * L * Dh * \pi$ =	39584	kg	>	17318	OK

Structural Design of Pad:

Longitudinal Rebar:



Compression Stress at section of Max. bending moment, σm = 5.11 kg/cm2

Mu = 1260384 kg.cm = 126038 N.m

Effective Depth, dp = hp - cp = 0.675 m

$K = Mu / f'c * bp * dp^2$ = 0.01186 < 0.167 OK

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

Z max = 667.86 > 641.25 ==>>> Zmax=0.95 dp = 641.25 mm

As = Mu / φs * fyr * z = 472

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 = 1706 mm2

As max = 52500 mm2

As = 1706

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

Rebar Quantity = 9

Rebar Spacing = 20.0

===> As= 1810 mm2

One Way Shear:

Compression Stress at critical section of shear , σv = 5.59 kg/cm2

Vu = -14192 kg = -141924 N Not defined since Theorical shear check distance is more than pad width!

k = 1 +(200/dp)^0.5 < 2.0 >>> k = 1.54 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

$v_{min} = 0.035 * k^{3/2} * f'c^{1/2}$ = 0.245 Mpa EN 1992-1-1:2004 6.3N

Vr = 289728 N

Vr	>	Vu	OK

F.S= Not Defined!

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 4.85 kg/cm2

Vpunch = -327281 kg = -3272815 N

Resisting Shear of Concrete,

Vr = 1867882 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 = 3.20 ton.m = 32008 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= 3.7 cm2

B) Moment at the bottom of chimney about y axis

My max = 1.17 ton.m = 11701 N.m

>>>>> A = M * c / (φs * fyr *Σ di2)

As2= 1.3 cm2

C) Axial required rebar area, As3 = Ts / (φs*Fys) = 15.4 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 = 20.4 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 = 20.4

Rebar Diameter = 20 mm =====> QTY = 7 =====> 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

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

$e = l_0 /400 = 2*(hc)/400 =$ 4.75 mm

$N_{Ed} =$ 141.91 ton

$M_{0Ed,x} =$ 3.20 ton.m

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

$M_{Ed,x}$ = 3.87 ton.m

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

$M_{0Ed,y}$= 1.88 ton.m

$M_{Ed,y}$ = 3.31 ton.m

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

N_{ED}/ f'c * bc^2 = 0.142

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} = 0.18 ===> a = 1.07

$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a$ = 0.106 < 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: 12A-LA

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	30° C5,C NA+	1,776	3,018	-129,012
Maximum Axial Force, Uplift	30° C5, Min. WS,C NA+	1,105	3,023	119,055

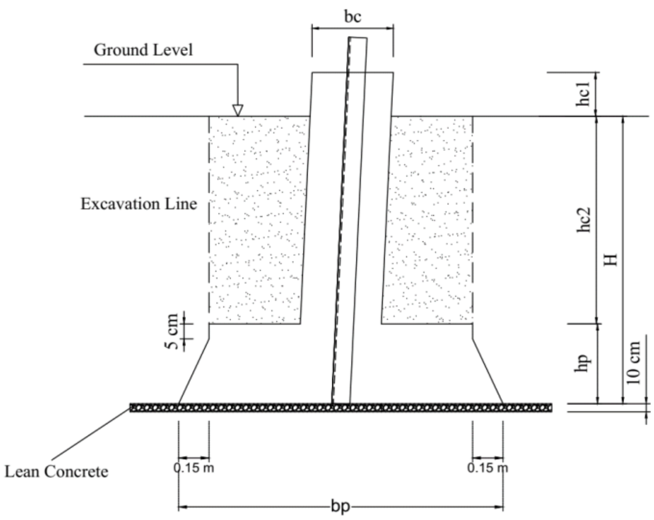
Maximum Loads on Foundation				
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	30° C5,C NA+	22,110	23,353	-124,987
Maximum Axial Force, Uplift	30° C5, Min. WS,C NA+	19,878	-21,796	115,385

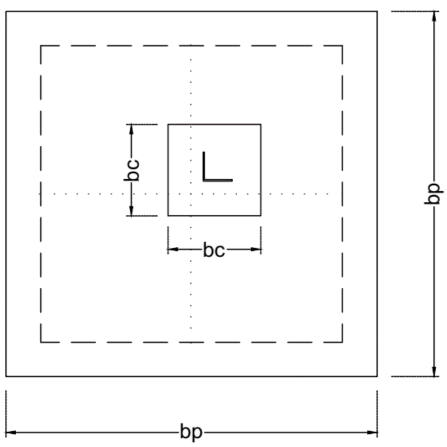
Design Standard: EN 1992:2004

Inputs:

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

	Width of Pad	bp =	2.2	m	
	Height of Pad	hp =	0.6	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 =	9.24	Degree	
	Diagonal Slope	γ =	12.94	Degree	
Soil Specifications	Soil Type	Type 2-Deleterious Rock			
	Natural Soil Density	γ_s =	2.04	ton/m3	
	Backfill Density	γ_b =	2.04	ton/m3	Tech. Spec. Section C1 4.1
	Bearing Capacity	q_{all} =	5.10	kg/cm2	Tech. Spec. Section C1 4.1
	Frustum Angle	Θ =	25	Degree	
	Internal Friction Angle	ϕ =	35	Degree	EN 50341 Table M.4
	Friction Coefficient Between Soil and Concrete	μ =	0.4		
Concrete	Compressive Strength(28 days of Cylindrical Sample)	f 'c =	20	Mpa	
	Strength Reduction Factor	φc =	0.67		Tech. Spec. Section C1 3.2.2
	Allowable Compressive Strength	f 'c =	13.3	Mpa	
	Density	γ_c =	2.5	ton/m3	
	Pad Cover Thickness	cp=	0.075	m	
	Chimney Cover Thickness	cc=	0.075	m	
Steel	Yield Strength of Rebars	Fyr =	500	Mpa	
	Strength Reduction Factor	φs =	0.83		Tech. Spec. Section C1 3.2.2





* The foundation is in direct contact with undisturbed soil.

Ultimate Loads:

On Foundation	Compression	C =	137.49	ton
		Vcx =	24.32	ton
		Vcy =	25.69	ton
	Uplift	T =	126.92	ton
		Vtx =	21.87	ton
		Vty =	-23.98	ton

On Stub	Compression	Cs =	141.91	ton
		Vscx =	1.95	ton
		Vscy =	3.32	ton
	Uplift	Ts =	130.96	ton
		Vstx =	1.22	ton
		Vsty =	3.33	ton

Soil Passive Pressure Coefficient Kp = tan 2 (45+φ/2) = 3.69
Passive Force on chimney, Fp1 = 32.61 ton
Passive Force on pad, Fp2 = 36.74 ton

Uplift:

Volume of chimney above ground level V1 = 0.17 m3
Volume of chimney under ground level V2 = 1.91 m3
Volume of pad, V3 = 2.52 m3
Total volume of foundation , Vf = 4.60 m3

Total weight of foundation, Wf = Vf * γc = 11.51 ton

Cone volume, $Vcone = (H/3)*(\pi*H^2*\tan^2 \Theta + 3*bp^2 + 6*bp*H*\tan\theta) =$ 66.76 m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 = 62.33 m3
Soil weight above foundation, Ws = Vsoil * γb = 127.07 ton

Total resistance force against uplift, Ru= Ws + Wf = 138.58 ton
Uplift Force, U= 126.92 ton

138.58	>	126.92	OK

S.F.= 1.09

Bearing Capacity:

Compression Force, C = 138.31 ton
Bending Moment about x axis, Mx = -14.46 ton.m
Bending Moment about y axis, My = 8.51 ton.m

Over Load of Concrete Wf= 11.51 ton

Volume of the Soil directly above foundation $Vsl = (H * bp^2) - V2 - V3 =$ 14.93 m3

Over Load of Soil directly above foundation Wsl= Vsl * γb = 30.43 ton

Average Bearing Pressure = σp = ((C + Wf + Wsl)/A) =	3.72	kg/cm2	<	5.10	kg/cm2	OK

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 3.39 kg/cm2
Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 2.43 kg/cm2
Compression Stress at corner 3, $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 5.02 kg/cm2
Compression Stress at corner 4, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 4.06 kg/cm2

Max. Toe Pressure =	5.02	<	q_{all} =	6.37	OK
Min. Toe Pressure =	2.43	>	0		OK

S.F.= 1.27

Top Surface Pressure due to Uplift:

Uplift Force, T = 127.64 ton
Bending Moment about x axis, Mx = -12.47 ton.m
Bending Moment about y axis, My = 4.56 ton.m

Pressure due to Uplift at top surface at corner 1, $\sigma u1 = ((T-Wf)/A) + (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 1.95 kg/cm2
Pressure due to Uplift at top surface at corner 2, $\sigma u2 = ((T-Wf)/A) + (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 1.44 kg/cm2
Pressure due to Uplift at top surface at corner 3, $\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 3.36 kg/cm2
Pressure due to Uplift at top surface at corner 4, $\sigma u4 = ((T-Wf)/A) - (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 2.85 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 = 121.45 ton.m

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

Mr = 124.92 ton.m

Mr	>	Mo	OK

S.F.= 1.03

Sliding:

Sliding force, Fo = Vmax

Sliding force, Fo = 23.98 ton

Effective weight of foundation and soil at uplift case, Weff = 11.65 ton

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

Fr = 74.02

Fr	>	Fo	OK

S.F.= 3.09

Structural Design of Pad:

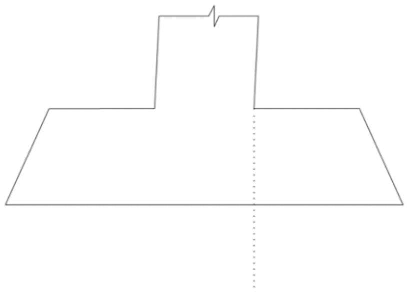
Longitudinal Rebar:

Compression :

Compression Stress at section of Max. bending moment at Pad , σmc = 4.00 kg/cm2

Uplift :

Compression Stress at section of Max. bending moment at Pad , σmu = 2.64 kg/cm2



Moment Control Section For Pad

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

Muc = 2120169 kg.cm = 207989 N.m

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

Muu = 1704215 kg.cm = 167184 N.m

Effective Depth of pad , dp = hp - cp = 0.525 m

Compression :

$K = Mu / f'c * bp * dp^2 =$ 0.026 < 0.167 OK

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

Z max = 512.8 > 498.75 ==>>> Zmax=0.95 dp = 498.75

As = Mu / φs * fyr * z = 1000.8 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 = 515.2 > 498.75 ==>>> Zmax=0.95 dp = 498.75

As = Mu / φs * fyr * z = 804.5 mm2

Top of Pad :

As2t= 804.5 mm2

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

Rebar Quantity = 8

Rebar Spacing = 250.0 mm

Bottom of Pad :

As2b= 1000.8 mm2

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

Rebar Quantity = 10

Rebar Spacing = 227.8 mm

Min. Rebar Check:

Ast = 2035.8 mm2

ρst = 0.0018 >

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 = 4.39 kg/cm2

Vu = 16596 kg = 165963 N

k = 1 +(200/dp2)^0.5 < 2.0 >>> k = 1.62 EN 1992-1-1:2004 6.2

ρ_1 = 0.0018

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

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

k1 = 0.15

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

Vr = 371806 N

Vr	>	Vu	OK

F.S= 2.24

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 3.72 kg/cm2

To check if punch shear section is defined in Pad ==> bp1 - (bc + 4dp2) = -0.65 < 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 = 12.47 ton.m = 124664 N.m

Rebar arrangement:

No. of rebars rows, n = 6

Total No. of rebars = 20

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

$\Sigma Ai*di^2$ = 12240

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

>>>>> A = M * c / (φs * fyr *Σdi^2)

As1= 14.4 cm2

B) Moment at the bottom of chimney about y axis My max = 4.56 ton.m = 45573 N.m

φs * fyr = M * c /I As2= 5.3 cm2

C) Axial required rebar area, As3 = Ts / (φs*Fyr) = 15.4 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 =			35.1	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 =	35.1							
Rebar Diameter =	16	mm =====>	QTY =	18	=====>	20	=====>	20 Ø 16
===>> As final=	40.2	cm2						
Rebar Quantity of One Row =	6							
Rebar Spacing =	12.0							

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
$N_{Ed} =$	141.91	ton
$M_{0Ed,\,x} =$	12.45	ton.m
$e_0 = h /30 > 20$ mm ==> $e_0 =$	25	mm
$M_{Ed,x} =$	15.07	ton.m

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

$M_{0Ed,\,y} =$	7.32	ton.m
$M_{Ed,y} =$	9.95	ton.m
$As * F\ yr / bc^2 * f'c =$	0.179	
$N_{ED}/ f'c * bc^2 =$	0.124	
d2 =	147	mm
d2 / bc =	0.20	

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 =	935.32	ton			
$N_{Ed} / N_{Rd} =$	0.15	===>	a =	1.04		
$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a =$		0.409	<	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: 12A-LA

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	30° C5,C NA+	1,776	3,018	-129,012
Maximum Axial Force, Uplift	30° C5, Min. WS,C NA+	1,105	3,023	119,055

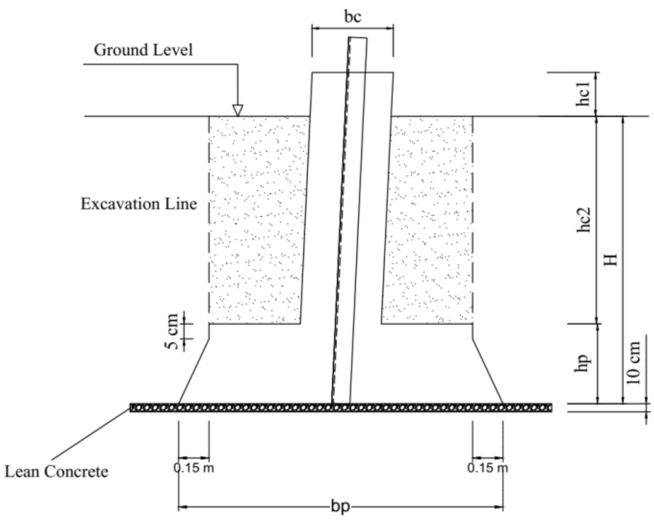
Maximum Loads on Foundation				
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	30° C5,C NA+	22,110	23,353	-124,987
Maximum Axial Force, Uplift	30° C5, Min. WS,C NA+	19,878	-21,796	115,385

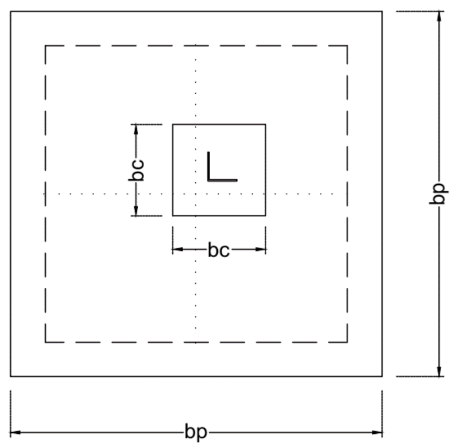
Design Standard: EN 1992:2004

Inputs:

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

	Width of Pad	bp =	2.65	m	
	Height of Pad	hp =	0.6	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 =	9.24	Degree	
	Diagonal Slope	γ =	12.94	Degree	
Soil Specifications	Soil Type	Type 3-Good Soil			
	Natural Soil Density	γ_s =	1.73	ton/m3	
	Backfill Density	γ_b =	1.73	ton/m3	Tech. Spec. Section C1 4.1
	Bearing Capacity	q_{all} =	3.06	kg/cm2	Tech. Spec. Section C1 4.1
	Frustum Angle	Θ =	22	Degree	
	Internal Friction Angle	ϕ =	35	Degree	EN 50341 Table M.4
	Friction Coefficient Between Soil and Concrete	μ =	0.4		
Concrete	Compressive Strength(28 days of Cylindrical Sample)	f 'c =	20	Mpa	
	Strength Reduction Factor	φc =	0.67		Tech. Spec. Section C1 3.2.2
	Allowable Compressive Strength	f 'c =	13.3	Mpa	
	Density	γ_c =	2.5	ton/m3	
	Pad Cover Thickness	cp=	0.075	m	
	Chimney Cover Thickness	cc=	0.075	m	
Steel	Yield Strength of Rebars	Fyr =	500	Mpa	
	Strength Reduction Factor	φs =	0.83		Tech. Spec. Section C1 3.2.2





* The foundation is in direct contact with undisturbed soil.

Ultimate Loads:

On Foundation	Compression	C =	137.49	ton
		Vcx =	24.32	ton
		Vcy =	25.69	ton
	Uplift	T =	126.92	ton
		Vtx =	21.87	ton
		Vty =	-23.98	ton

On Stub	Compression	Cs =	141.91	ton
		Vscx =	1.95	ton
		Vscy =	3.32	ton
	Uplift	Ts =	130.96	ton
		Vstx =	1.22	ton
		Vsty =	3.33	ton

Soil Passive Pressure Coefficient Kp = tan 2 (45+φ/2) = 3.69
Passive Force on chimney, Fp1 = 27.72 ton
Passive Force on pad, Fp2 = 37.62 ton

Uplift:

Volume of chimney above ground level V1 = 0.17 m3
Volume of chimney under ground level V2 = 1.91 m3
Volume of pad, V3 = 3.75 m3
Total volume of foundation , Vf = 5.83 m3

Total weight of foundation, $Wf = Vf * \gamma c =$ 14.58 ton

Cone volume, $Vcone = (H/3)*(\pi*H^2*\tan^2\Theta + 3*bp^2 + 6*bp*H*\tan\theta) =$ 73.29 m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 = 67.63 m3
Soil weight above foundation, $Ws = Vsoil * \gamma b =$ 117.20 ton

Total resistance force against uplift, Ru= Ws + Wf = 131.77 ton
Uplift Force, U= 126.92 ton

131.77	>	126.92	OK

S.F.= 1.04

Bearing Capacity:

Compression Force, C = 138.31 ton
Bending Moment about x axis, Mx = -14.46 ton.m
Bending Moment about y axis, My = 8.51 ton.m

Over Load of Concrete Wf= 14.58 ton

Volume of the Soil directly above foundation $Vsl = (H * bp^2) - V2 - V3 =$ 22.43 m3

Over Load of Soil directly above foundation $Wsl = Vsl * \gamma b =$ 38.87 ton

Average Bearing Pressure = $\sigma p = ((C + Wf + Wsl)/A) =$	2.73	kg/cm2	<	3.06	kg/cm2	OK

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 2.54 kg/cm2
Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 1.99 kg/cm2
Compression Stress at corner 3, $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 3.47 kg/cm2
Compression Stress at corner 4, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 2.92 kg/cm2

Max. Toe Pressure =	3.47	<	q_{all} =	3.82	OK
Min. Toe Pressure =	1.99	>		0	OK

S.F.= 1.10

Top Surface Pressure due to Uplift:

Uplift Force, T = 127.64 ton
Bending Moment about x axis, Mx = -12.47 ton.m
Bending Moment about y axis, My = 4.56 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, $\sigma u2 = ((T-Wf)/A) + (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 1.06 kg/cm2
Pressure due to Uplift at top surface at corner 3, $\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 2.16 kg/cm2
Pressure due to Uplift at top surface at corner 4, $\sigma u4 = ((T-Wf)/A) - (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 1.86 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 = 140.76 ton.m

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

Mr = 142.28 ton.m

Mr	>	Mo	OK

S.F.= 1.01

Sliding:

Sliding force, Fo = Vmax

Sliding force, Fo = 23.98 ton

Effective weight of foundation and soil at uplift case, Weff = 4.85 ton

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

Fr = 67.28

Fr	>	Fo	OK

S.F.= 2.81

Structural Design of Pad:

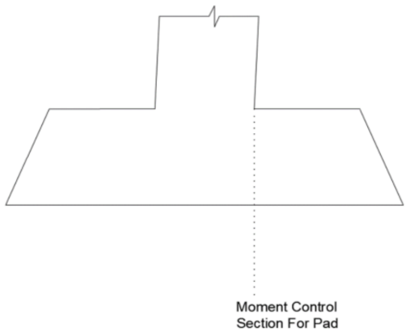
Longitudinal Rebar:

Compression :

Compression Stress at section of Max. bending moment at Pad , σmc = 2.86 kg/cm2

Uplift :

Compression Stress at section of Max. bending moment at Pad , σmu = 1.72 kg/cm2



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

Muc = 2985059 kg.cm = 292834 N.m

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

Muu = 2290965 kg.cm = 224744 N.m

Effective Depth of pad , dp = hp - cp = 0.525 m

Compression :

$K = Mu / f'c * bp * dp^2 =$ 0.030 < 0.167 OK

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

Z max = 510.7 > 498.75 ==>>> Zmax=0.95 dp = 498.75

As = Mu / φs * fyr * z = 1409.1 mm2

Uplift :

$K = Mu / f'c * bp * dp^2 =$ 0.023

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

Z max = 514.1 > 498.75 ==>>> Zmax=0.95 dp = 498.75

As = Mu / φs * fyr * z = 1081.5 mm2

Top of Pad :

As2t= 1081.5 mm2

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

Rebar Quantity = 10

Rebar Spacing = 244.4 mm

Bottom of Pad :

As2b= 1409.1 mm2

Rebar Diameter= 12 mm =====> QTY = 13 ==>> 13 =====> 13 Ø 12 =====> 1470 mm2

Rebar Quantity = 13

Rebar Spacing = 208.3 mm

Min. Rebar Check:

Ast =	2601.2	mm2			
ρst =	0.0019		>		
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 = 3.05 kg/cm2

Vu = 28527 kg = 285270 N

k = 1 +(200/dp2)^0.5 < 2.0 >>> k = 1.62 EN 1992-1-1:2004 6.2

ρ_1 = 0.0019

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

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

k1 = 0.15

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

Vr = 447857 N

Vr	>	Vu	OK

F.S= 1.57

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 2.73 kg/cm2

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

Vpunch = No Defined kg = Not Defined N

Resisting Shear of Concrete,

Vr = Not Defined N

Vr	<	Vpunch	Not Defined

F.S.= Not Defined

Structural Design of Chimney:

Design of Longitudinal Reinforcement for Uplift :

A) Moment at the bottom of chimney about x axis Mx max = 12.47 ton.m = 124664 N.m

Rebar arrangement:

No. of rebars rows, n = 6

Total No. of rebars = 20

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

$\Sigma Ai*di^2$ = 12240

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

>>>>> A = M * c / (φs * fyr *Σdi^2)

As1= 14.4 cm2

B) Moment at the bottom of chimney about y axis My max = 4.56 ton.m = 45573 N.m

φs * fyr = M * c /I As2= 5.3 cm2

C) Axial required rebar area, As3 = Ts / (φs*Fyr) = 15.4 cm2

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

MİTAŞ ENERGY

Total Required Longitudinal rebar area	Ast =As1+As2+As3 =			35.1	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 =	35.1							
Rebar Diameter =	16	mm =====>	QTY =	18	=====>	20	=====>	20 Ø 16
===>> As final=	40.2	cm2						
Rebar Quantity of One Row =	6							
Rebar Spacing =	12.0							

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
$N_{Ed} =$	141.91	ton
$M_{0Ed,\,x} =$	12.45	ton.m
$e_0 = h /30 > 20$ mm ==> $e_0 =$	25	mm
$M_{Ed,x} =$	15.07	ton.m

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

$M_{0Ed,\,y} =$	7.32	ton.m
$M_{Ed,y} =$	9.95	ton.m
As * F yr / bc^2 * f'c =	0.179	
N_{ED}/ f'c * bc^2 =	0.124	
d2 =	147	mm
d2 / bc =	0.20	

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 =	935.32	ton			
N_{Ed} / N_{Rd} =	0.15	===>	a =	1.04		
$(M_{Ed,x}/M_{Rd,x})^a + (M_{Ed,y}/M_{Rd,y})^a$ =		0.409	<	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: 12A-LA

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	30° C5,C NA+	1,776	3,018	-129,012
Maximum Axial Force, Uplift	30° C5, Min. WS,C NA+	1,105	3,023	119,055

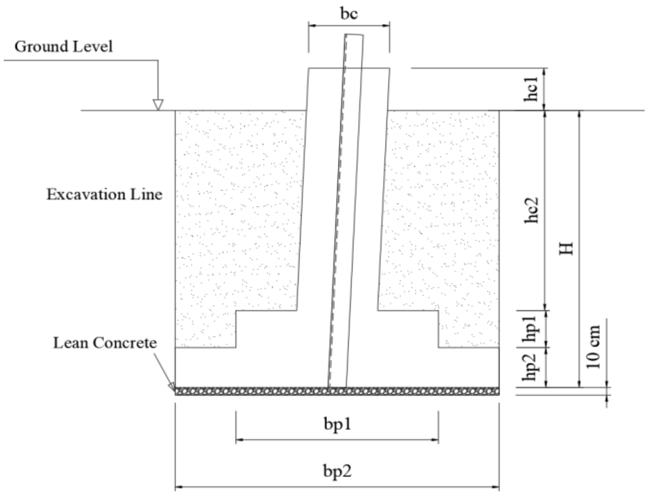
Maximum Loads on Foundation				
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	30° C5,C NA+	22,110	23,353	-124,987
Maximum Axial Force, Uplift	30° C5, Min. WS,C NA+	19,878	-21,796	115,385

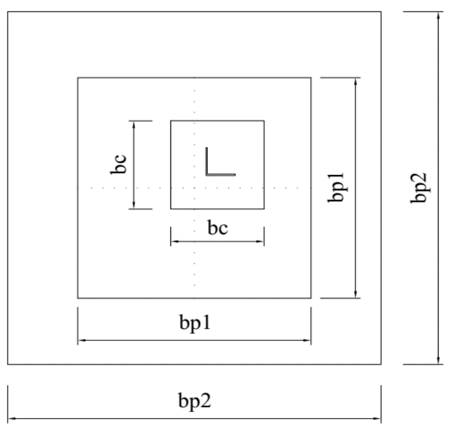
Design Standard: EN 1992:2004

Inputs:

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

Foundation Dimensions	Width of Pad 1	bp1 =	1.65	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 =	9.24	Degree	
	Diagonal Slope	γ =	12.94	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

* The foundation is in direct contact with undisturbed soil.

Ultimate Loads:

On Foundation	Compression	C =	137.49	ton
		Vcx =	24.32	ton
		Vcy =	25.69	ton
	Uplift	T =	126.92	ton
		Vtx =	21.87	ton
		Vty =	-23.98	ton

On Stub	Compression	Cs =	141.91	ton
		Vscx =	1.95	ton
		Vscy =	3.32	ton
	Uplift	Ts =	130.96	ton
		Vstx =	1.22	ton
		Vsty =	3.33	ton

Soil Passive Pressure Coefficient	Kp = tan 2 (45+φ/2) =	3.69	
Passive Force on chimney,	Fp1 =	27.72	ton
Passive Force on pad1,	Fp2 =	11.24	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 =	0.82	m3
Volume of pad2,	V4 =	2.88	m3
Total volume of foundation ,	Vf =	5.78	m3

Total weight of foundation, Wf = Vf * γc = 14.45 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 = 79.71 m3

Soil weight above foundation, Ws = Vsoil * γb = 138.14 ton

Total resistance force against uplift, Ru= Ws + Wf = 152.59 ton

Uplift Force, U= 126.92 ton

152.59	>	126.92	OK

S.F.= 1.20

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

G: weight of foundation and soil vertical to the base = 71.34 ton

Z: uplift force on fondation = 115.39 ton

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

Bearing Capacity:

Compression Force,	C =	138.31	ton
Bending Moment about x axis,	Mx =	-14.46	ton.m
Bending Moment about y axis,	My =	8.51	ton.m

Over Load of Concrete Wf= 14.45 ton

Volume of the Soil directly above foundation $V_{sl} = (H * bp2^2) - V2 - V3 - V4 =$ 32.83 m3

Over Load of Soil directly above foundation Wsl= Vsl * γb = 56.89 ton

Average Bearing Pressure = σp = ((C + Wf + Wsl)/A) =	2.18	kg/cm2	<	3.06	kg/cm2	OK

Compression Stress at corner 1,	$\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$	2.06	kg/cm2
Compression Stress at corner 2,	$\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$	1.72	kg/cm2
Compression Stress at corner 3,	$\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$	2.64	kg/cm2
Compression Stress at corner 4,	$\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$	2.30	kg/cm2

Max. Toe Pressure =	2.64	<	q_{all} =	3.82	OK
Min. Toe Pressure =	1.72	>		0	OK

S.F.= 1.45

Top Surface Pressure due to Uplift:

Uplift Force,	T =	127.64	ton
Bending Moment about x axis,	Mx =	-12.47	ton.m
Bending Moment about y axis,	My =	4.56	ton.m

Pressure due to Uplift at top surface at corner 1,	$\sigma u1 = ((T-Wf)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$	1.02	kg/cm2
Pressure due to Uplift at top surface at corner 2,	$\sigma u2 = ((T-Wf)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$	0.83	kg/cm2
Pressure due to Uplift at top surface at corner 3,	$\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$	1.52	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 = 160.07 ton.m

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

Mr = 193.36 ton.m

Mr	>	Mo	OK

S.F.= 1.21

Sliding:

Sliding force, Fo = Vmax

Sliding force, Fo = 23.98 ton

Effective weight of foundation and soil at uplift case, Weff = 25.66 ton

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

Fr = 72.12

Fr	>	Fo	OK

S.F.= 3.01

Structural Design of Pad:

Longitudinal Rebar:

Compression :

Compression Stress at section of Max. bending moment at Pad 1, σmc1 = 2.25 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 = 1.24 kg/cm2

Compression Stress at section of Max. bending moment at Pad 2, σmu2 = 1.31 kg/cm2

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

Muc 1= 3873561 kg.cm = 379996 N.m

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

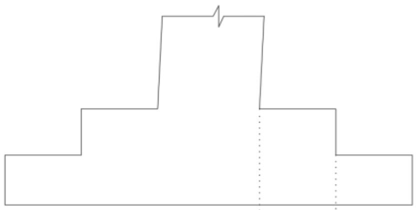
Muc 2= 1455335 kg.cm = 142768 N.m

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

Muu 1= 2921933 kg.cm = 286642 N.m

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

Muu 2= 1132220 kg.cm = 111071 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:

$K = Mu / f'c * bp * dp^2 =$ 0.063 < 0.167 OK

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

Z max = 494 < 498.75 ==>>> OK

As = Mu / φs * fyr * z = 1846 mm2

Pad 2:

$K = Mu / f'c * bp * dp^2 =$ 0.068 < 0.167 OK

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

Z max = 210.5 < 213.75 ==>>> OK

As = Mu / φs * fyr * z = 1627.6 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 =	513.1	>	498.75	==>>>	Zmax=0.95 dp =	498.75	
As = Mu / φs * fyr * z =	1379.3	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 =	213.9	>	213.75	==>>>	Zmax=0.95 dp =	213.75	
As = Mu / φs * fyr * z =	1247.1	mm2					

Top of Pad 1 :										
As1t=	1379.3		mm2							
Rebar Diameter=	16	mm	=====>	QTY =	7 ==>>	7	=====>	7 Ø 16	=====>	1407 mm2
Rebar Quantity =	7									
Rebar Spacing =	250.0	mm								
Top of Pad 2 :										
As2t=	1247.1	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=	1845.5	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 =	0.0040	>		

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 = 2.35 kg/cm2

Vu1 = 36726 kg = 367260 N

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

Vu2 = 27663 kg = 276634 N

Pad 1

k = 1 +(200/dp1)^0.5 < 2.0	>>>	k =	1.62	EN 1992-1-1:2004	6.2
$\rho_1 =$	0.0040				
$\sigma_{cp} = N_{ED}/A_C =$	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 = 463826 N

Vr1	>	Vu1	OK

F.S= 1.26

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= 1.25

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 2.18 kg/cm2

Pad 1

Vpunch1 = 38758 kg = 387576 N

Resisting Shear of Concrete,

Vr1 = 1959780 N

Vr1	>	Vpunch1	OK

F.S.= 5.06

Pad 2

To check if punch shear section is defined in Pad 2 ==> bp1 - (bp2 + 4dp2) = 0.55 > 0 ==> Punch Shear to be Checked in Pad 2

Vpunch2 = 50546 kg = 505463 N

Resisting Shear of Concrete,

Vr2 = 1055700 N

Vr2	>	Vpunch2	OK

F.S.= 2.09

Structural Design of Chimney:

Design of Longitudinal Reinforcement for Uplift :

A) Moment at the bottom of chimney about x axis Mx max = 12.47 ton.m = 124664 N.m

Rebar arrangement:

No. of rebars rows, n = 6

Total No. of rebars = 20

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

$\Sigma Ai*di^2$ = 12240

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

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

As1= 14.4 cm2

B) Moment at the bottom of chimney about y axis My max = 4.56 ton.m = 45573 N.m

$\varphi s * fyr = M * c / I$ As2= 5.3 cm2

C) Axial required rebar area, As3 = Ts / (φs*Fyr) = 15.4 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 = 35.1 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 =	35.1							
Rebar Diameter =	16	mm	=====> QTY =	18	=====>	20	=====>	20 Ø 16
===>> As final=	40.2	cm2						
Rebar Quantity of One Row =	6							
Rebar Spacing =	12.0							

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
$N_{Ed} =$	141.91	ton
$M_{0Ed, x} =$	12.45	ton.m
$e_0 = h /30 > 20$ mm ==> $e_0 =$	25	mm
$M_{Ed,x} =$	15.07	ton.m

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

$M_{0Ed, y} =$	7.32	ton.m
$M_{Ed,y} =$	9.95	ton.m
$As * F yr / bc^2 * f'c =$	0.179	
$N_{ED}/ f'c * bc^2 =$	0.124	
d2 =	147	mm
d2 / bc =	0.20	

Interaction Chart Gives ===>	$M_{Rd} / f'c * bc^3 =$	0.1	===> $M_{Rd,x} = M_{Rd,y} =$		57.34	ton.m
$N_{Rd} =$	$Ac * f'c + As * Fyr =$	935.32	ton			
$N_{Ed} / N_{Rd} =$	0.15	===>	a =	1.04		
$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a =$		0.409	<	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: 12A-LA

Maximum Loads on Stub				
		Stub Force Components		
Description	*Load Combination*	*Shear Force Transversal component*	*Shear Force Longitudinal component*	*Axial force*
		kg	kg	kg
Maximum Axial Force, Compression	30° C5,C NA+	1,776	3,018	-129,012
Maximum Axial Force, Uplift	30° C5, Min. WS,C NA+	1,105	3,023	119,055

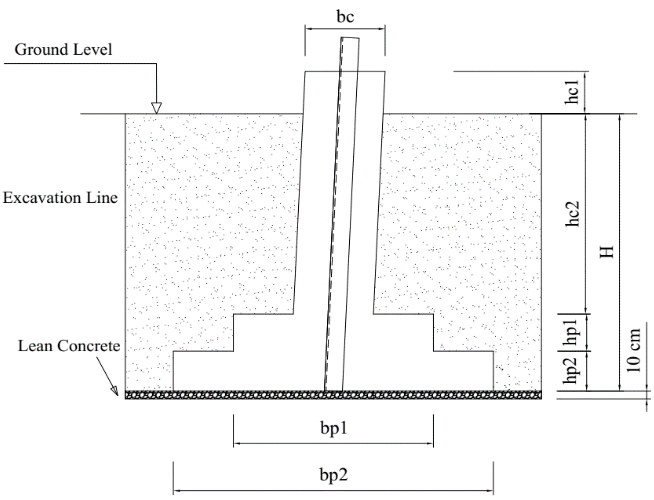
Maximum Loads on Foundation				
		Foundation Components		
Description	*Load Combination*	*Transversal*	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	30° C5,C NA+	22,110	23,353	-124,987
Maximum Axial Force, Uplift	30° C5, Min. WS,C NA+	19,878	-21,796	115,385

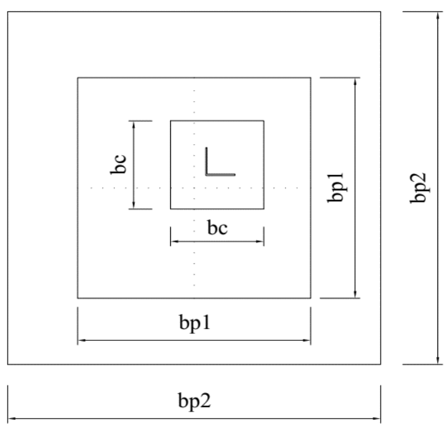
Design Standard: EN 1992:2004

Inputs:

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

Foundation Dimensions	Width of Pad 1	bp1 =	1.65	m	
	Width of Pad 2	bp2 =	3.35	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 =	9.24	Degree	
	Diagonal Slope	γ =	12.94	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

* The foundation is cast inside formwork.

Ultimate Loads:

On Foundation	Compression	C =	137.49	ton
		Vcx =	24.32	ton
		Vcy =	25.69	ton
	Uplift	T =	126.92	ton
		Vtx =	21.87	ton
		Vty =	-23.98	ton

On Stub	Compression	Cs =	141.91	ton
		Vscx =	1.95	ton
		Vscy =	3.32	ton
	Uplift	Ts =	130.96	ton
		Vstx =	1.22	ton
		Vsty =	3.33	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 =	7.94	ton
Passive Force on pad2,	Fp3 =	17.49	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 =	0.82	m3
Volume of pad2,	V4 =	3.37	m3
Total volume of foundation ,	Vf =	6.26	m3

Total weight of foundation, Wf = Vf * γc = 15.66 ton

Cone volume, $Vcone = (h/3)*(\pi*h^2*\tan^2\Theta + 3*bp2^2 + 6*bp2*h*\tan\theta) =$ 74.11 m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 = 69.69 m3

Soil weight above foundation, Ws = Vsoil * γb = 127.88 ton

Total resistance force against uplift, Ru= Ws + Wf = 143.54 ton

Uplift Force, U= 126.92 ton

143.54	>	126.92	OK

S.F.= 1.13

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

G: weight of foundation and soil vertical to the base = 86.84 ton

Z: uplift force on fondation = 115.39 ton

Z/G = 0.75 >>> Ratio = 0.94 OK

Bearing Capacity:

Compression Force,	C =	138.31	ton
Bending Moment about x axis,	Mx =	-14.46	ton.m
Bending Moment about y axis,	My =	8.51	ton.m

Over Load of Concrete Wf= 15.66 ton

Volume of the Soil directly above foundation $Vsl = (H * bp2^2) - V2 - V3 - V4 =$ 38.79 m3

Over Load of Soil directly above foundation Wsl= Vsl * γb = 71.18 ton

Average Bearing Pressure = σp = ((C + Wf + Wsl)/A) =	2.01	kg/cm2	<	2.04	kg/cm2	OK

Compression Stress at corner 1,	$\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$	1.91	kg/cm2
Compression Stress at corner 2,	$\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$	1.64	kg/cm2
Compression Stress at corner 3,	$\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$	2.37	kg/cm2
Compression Stress at corner 4,	$\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$	2.10	kg/cm2

Max. Toe Pressure =	2.37	<	q_{all} =	2.55	OK
Min. Toe Pressure =	1.64	>	0		OK

S.F.= 1.07

Top Surface Pressure due to Uplift:

Uplift Force,	T =	127.64	ton
Bending Moment about x axis,	Mx =	-12.47	ton.m
Bending Moment about y axis,	My =	4.56	ton.m

Pressure due to Uplift at top surface at corner 1,	$\sigma u1 = ((T-Wf)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$	0.87	kg/cm2
Pressure due to Uplift at top surface at corner 2,	$\sigma u2 = ((T-Wf)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$	0.73	kg/cm2
Pressure due to Uplift at top surface at corner 3,	$\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$	1.27	kg/cm2
Pressure due to Uplift at top surface at corner 4,	$\sigma u4 = ((T-Wf)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$	1.12	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 = 170.80 ton.m

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

Mr = 195.99 ton.m

Mr	>	Mo	OK

S.F.= 1.15

Sliding:

Sliding force, Fo = Vmax

Sliding force, Fo = 23.98 ton

Effective weight of foundation and soil at uplift case, Weff = 16.62 ton

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

Fr = 51.68

Fr	>	Fo	OK

S.F.= 2.16

Structural Design of Pad:

Longitudinal Rebar:

Compression :

Compression Stress at section of Max. bending moment at Pad 1, σmc1 = 2.06 kg/cm2

Compression Stress at section of Max. bending moment at Pad 2, σmc2 = 2.12 kg/cm2

Uplift :

Compression Stress at section of Max. bending moment at Pad 1, σmu1 = 1.04 kg/cm2

Compression Stress at section of Max. bending moment at Pad 2, σmu2 = 1.10 kg/cm2

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

Muc 1= 4397691 kg.cm = 431413 N.m

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

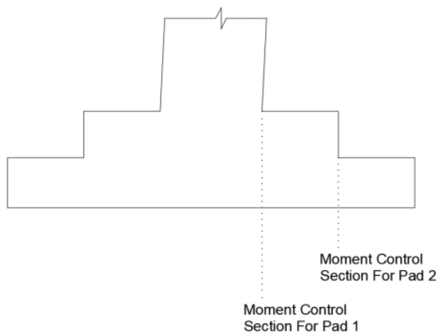
Muc 2= 1838478 kg.cm = 180355 N.m

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

Muu 1= 3241936 kg.cm = 318034 N.m

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

Muu 2= 1407537 kg.cm = 138079 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 = 2114 mm2

Pad 2:

$K = Mu / f'c * bp * dp^2 =$ 0.080 < 0.167 OK

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

Z max = 207.9 < 213.75 ==>>> OK

As = Mu / φs * fyr * z = 2082.4 mm2

MİTAŞ ENERGY

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 =	512.7	>	498.75	==>>>	Zmax=0.95 dp =	498.75	
As = Mu / φs * fyr * z =	1530.4	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 =	212.1	<	213.75	==>>>	OK
As = Mu / φs * fyr * z =	1562.1	mm2			

Top of Pad 1 :										
As1t=	1530.4		mm2							
Rebar Diameter=	16	mm	=====>	QTY =	8 ==>>	8	=====>	8 Ø 16	=====>	1608 mm2
Rebar Quantity =	8									
Rebar Spacing =	214.3	mm								
Top of Pad 2 :										
As2t=	1562.1	mm2								
Rebar Diameter=	12	mm	=====>	QTY =	14 ==>>	14	=====>	14 Ø 12	=====>	1583 mm2
Rebar Quantity =	14									
Rebar Spacing =	246.2	mm								
Bottom of Pad 2 :										
As2b=	2114.5	mm2								
Rebar Diameter=	12	mm	=====>	QTY =	19 ==>>	19	=====>	19 Ø 12	=====>	2149 mm2
Rebar Quantity =	19									
Rebar Spacing =	177.8	mm								

Min. Rebar Check:

Ast =	5340.7	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 =	2.13	kg/cm2	
Vu1 = 40498	kg	=	404978	N
Compression Stress at critical section of shear at Pad2 ,	σv2 =	2.15	kg/cm2	
Vu2 = 31723	kg	=	317234	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 = 495612 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 = 377365 N

Vr2	>	Vu2	OK

F.S= 1.19

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 2.01 kg/cm2

Pad 1

Vpunch1 = 55939 kg = 559386 N

Resisting Shear of Concrete,

Vr1 = 1999755 N

Vr1	>	Vpunch1	OK

F.S.= 3.57

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 = 64960 kg = 649599 N

Resisting Shear of Concrete,

Vr2 = 1061965 N

Vr2	>	Vpunch2	OK

F.S.= 1.63

Structural Design of Chimney:

Design of Longitudinal Reinforcement for Uplift :

A) Moment at the bottom of chimney about x axis Mx max = 12.47 ton.m = 124664 N.m

Rebar arrangement:

No. of rebars rows, n = 6

Total No. of rebars = 20

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

$\Sigma Ai*di^2$ = 12240

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

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

As1= 14.4 cm2

B) Moment at the bottom of chimney about y axis My max = 4.56 ton.m = 45573 N.m

$\varphi s * fyr = M * c / I$ As2= 5.3 cm2

C) Axial required rebar area, As3 = Ts / (φs*Fyr) = 15.4 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 = 35.1 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 =	35.1							
Rebar Diameter =	16	mm	=====> QTY =	18	=====>	20	=====>	20 Ø 16
===>> As final=	40.2	cm2						
Rebar Quantity of One Row =	6							
Rebar Spacing =	12.0							

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
$N_{Ed} =$	141.91	ton
$M_{0Ed, x} =$	12.45	ton.m
$e_0 = h /30 > 20$ mm ==> $e_0 =$	25	mm
$M_{Ed,x} =$	15.07	ton.m

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

$M_{0Ed, y} =$	7.32	ton.m
$M_{Ed,y} =$	9.95	ton.m
$As * F yr / bc^2 * f'c =$	0.179	
$N_{ED}/ f'c * bc^2 =$	0.124	
d2 =	147	mm
d2 / bc =	0.20	

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

$N_{Rd} =$ $Ac * f'c + As * Fyr =$ 935.32 ton

$N_{Ed} / N_{Rd} =$ 0.15 ===> a = 1.04

$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a =$ 0.409 < 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: 12A-LA

Maximum Loads on Stub

Description	*Load Combination*	*Stub Force Components* Shear Force Transversal component (kg)	Shear Force Longitudinal component (kg)	Axial force (kg)
Maximum Axial Force, Compression	30° C5,C NA+	1,776	3,018	-129,012
Maximum Axial Force, Uplift	30° C5, Min. WS,C NA+	1,105	3,023	119,055

Maximum Loads on Foundation

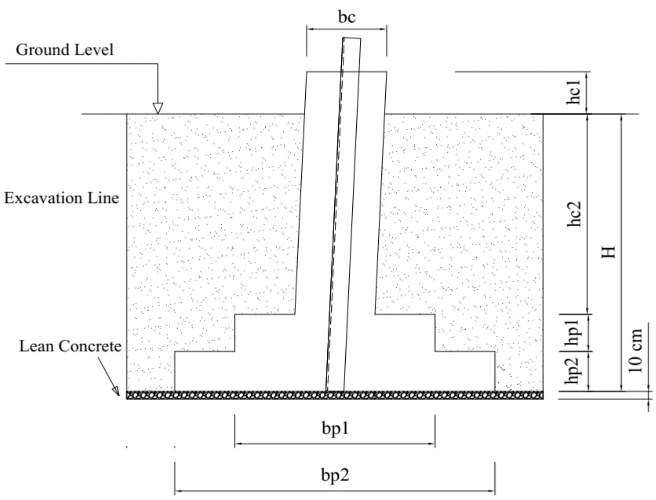
Description	*Load Combination*	*Foundation Components* Transversal (kg)	Longitudinal (kg)	Vertical (kg)
Maximum Axial Force, Compression	30° C5,C NA+	22,110	23,353	-124,987
Maximum Axial Force, Uplift	30° C5, Min. WS,C NA+	19,878	-21,796	115,385

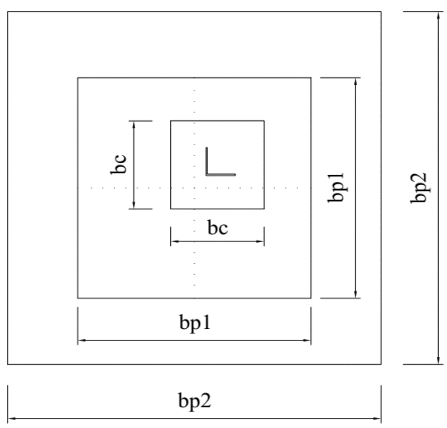
Design Standard: EN 1992:2004

Inputs:

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

Foundation Dimensions	Width of Pad 1	bp1 =	2	m	
	Width of Pad 2	bp2 =	4.5	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 =	9.24	Degree	
	Diagonal Slope	γ =	12.94	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





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

* The foundation is cast inside formwork.

Ultimate Loads:

On Foundation	Compression	C =	137.49	ton
		Vcx =	24.32	ton
		Vcy =	25.69	ton
	Uplift	T =	126.92	ton
		Vtx =	21.87	ton
		Vty =	-23.98	ton

On Stub	Compression	Cs =	141.91	ton
		Vscx =	1.95	ton
		Vscy =	3.32	ton
	Uplift	Ts =	130.96	ton
		Vstx =	1.22	ton
		Vsty =	3.33	ton

Soil Passive Pressure Coefficient Kp = tan 2 (45+φ/2) = 2.46
Passive Force on chimney, Fp1 = 10.89 ton
Passive Force on pad1, Fp2 = 5.35 ton
Passive Force on pad2, Fp3 = 13.05 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 = 1.20 m3
Volume of pad2, V4 = 6.08 m3
Total volume of foundation , Vf = 9.36 m3

Total weight of foundation, Wf = Vf * γc = 14.03 ton

Cone volume, Vcone = $(h/3)*(\pi*h^2*\tan^2\Theta + 3*bp2^2 + 6*bp2*h*\tan\theta)$ = 118.00 m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 = 111.85 m3
Soil weight above foundation, Ws = Vsoil * γb = 114.01 ton

Total resistance force against uplift, Ru= Ws + Wf = 128.05 ton
Uplift Force, U= 126.92 ton

128.05	>	126.92	OK

S.F.= 1.01

Additional condition: G/Z > 0.8 EN 50341 M.3.1.6
G: weight of foundation and soil vertical to the base = 87.24 ton
Z: uplift force on fondation = 115.39 ton

Z/G = 0.76 >>> Ratio = 0.95 OK

Bearing Capacity:

Compression Force, C = 138.31 ton
Bending Moment about x axis, Mx = -14.46 ton.m
Bending Moment about y axis, My = 8.51 ton.m

Over Load of Concrete Wf= 14.03 ton

Volume of the Soil directly above foundation Vsl = $(H * bp2^2)$ - V2 - V3 - V4 = 71.81 m3

Over Load of Soil directly above foundation Wsl= Vsl * γb = 73.20 ton

Average Bearing Pressure = σp = ((C + Wf + Wsl)/A) =	1.11	kg/cm2	<	2.04 kg/cm2	OK

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3)$ = 1.07 kg/cm2
Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3)$ = 0.96 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, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3)$ = 1.15 kg/cm2

Max. Toe Pressure =	1.27	<	q_{all} =	2.55	OK
Min. Toe Pressure =	0.96	>	0		OK

S.F.= 2.01

Top Surface Pressure due to Uplift:

Uplift Force, T = 127.64 ton
Bending Moment about x axis, Mx = -12.47 ton.m
Bending Moment about y axis, My = 4.56 ton.m

Pressure due to Uplift at top surface at corner 1, $\sigma u1 = ((T-Wf)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3)$ = 0.51 kg/cm2
Pressure due to Uplift at top surface at corner 2, $\sigma u2 = ((T-Wf)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3)$ = 0.45 kg/cm2
Pressure due to Uplift at top surface at corner 3, $\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3)$ = 0.67 kg/cm2
Pressure due to Uplift at top surface at corner 4, $\sigma u4 = ((T-Wf)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3)$ = 0.61 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 = 220.14 ton.m

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

Mr = 234.83 ton.m

Mr	>	Mo	OK

S.F.= 1.07

Sliding:

Sliding force, Fo = Vmax

Sliding force, Fo = 23.98 ton

Effective weight of foundation and soil at uplift case, Weff = 1.12 ton

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

Fr = 29.74

Fr	>	Fo	OK

S.F.= 1.24

Structural Design of Pad:

Longitudinal Rebar:

Compression :

Compression Stress at section of Max. bending moment at Pad 1, σmc1 = 1.13 kg/cm2

Compression Stress at section of Max. bending moment at Pad 2, σmc2 = 1.16 kg/cm2

Uplift :

Compression Stress at section of Max. bending moment at Pad 1, σmu1 = 0.57 kg/cm2

Compression Stress at section of Max. bending moment at Pad 2, σmu2 = 0.60 kg/cm2

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

Muc 1= 6613037 kg.cm = 648739 N.m

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

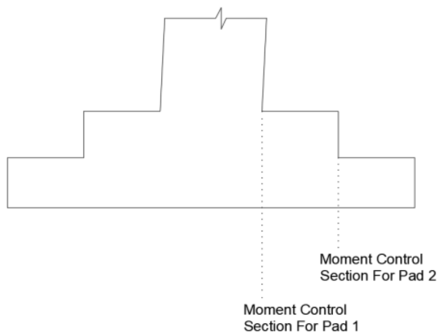
Muc 2= 2862616 kg.cm = 280823 N.m

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

Muu 1= 4906528 kg.cm = 481330 N.m

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

Muu 2= 2207399 kg.cm = 216546 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 = 0.088 < 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 = 3242 mm2

Pad 2:

K = Mu /f 'c * bp *dp^2 = 0.092 < 0.167 OK

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

Z max = 204.8 < 213.75 ==>>> OK

As = Mu / φs * fyr * z = 3290.2 mm2

MİTAŞ ENERGY

Uplift :

Pad 1:

$K = Mu / f'c * bp * dp^2$ =	0.029	<	0.167	OK			
Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp							
Z max =	511.2	>	498.75	==>>>	Zmax=0.95 dp =	498.75	
As = Mu / φs * fyr * z =	2316.2	mm2					

Pad 2:

$K = Mu / f'c * bp * dp^2$ =	0.071				
Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp					
Z max =	209.8	<	213.75	==>>>	OK
As = Mu / φs * fyr * z =	2476.9	mm2			

Top of Pad 1 :										
As1t=	2316.2	mm2								
Rebar Diameter=	16	mm	=====>	QTY =	12 ==>>	12	=====>	12 Ø 16	=====>	2413 mm2
Rebar Quantity =	12									
Rebar Spacing =	168.2	mm								
Top of Pad 2 :										
As2t=	2476.9	mm2								
Rebar Diameter=	12	mm	=====>	QTY =	22 ==>>	22	=====>	22 Ø 12	=====>	2488 mm2
Rebar Quantity =	22									
Rebar Spacing =	207.1	mm								
Bottom of Pad 2 :										
As2b=	3290.2	mm2								
Rebar Diameter=	12	mm	=====>	QTY =	30 ==>>	30	=====>	30 Ø 12	=====>	3393 mm2
Rebar Quantity =	30									
Rebar Spacing =	150.0	mm								

Min. Rebar Check:

Ast =	8293.8	mm2			
ρst =	0.0051	>			
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 =	1.15	kg/cm2	
Vu1 =	50660	kg	=	506596	N
Compression Stress at critical section of shear at Pad2 ,		σv2 =	1.17	kg/cm2	
Vu2 =	37370	kg	=	373704	N

Pad 1

k = 1 +(200/dp1)^0.5 < 2.0	>>>	k =	1.62	EN 1992-1-1:2004	6.2
ρ_1 =	0.0051				
$\sigma_{cp} = N_{ED}/A_C$ =	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

$Vr1 =$ 680576 N

Vr1	>	Vu1	OK

F.S= 1.34

Pad 2

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

$\rho_1 =$ 0.0058

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

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

k1 = 0.15

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

Vr2 = 534609 N

Vr2	>	Vu2	OK

F.S= 1.43

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 1.11 kg/cm2

Pad 1

Vpunch1 = 100308 kg = 1003080 N

Resisting Shear of Concrete,

Vr1 = 2126606 N

Vr1	>	Vpunch1	OK

F.S.= 2.12

Pad 2

To check if punch shear section is defined in Pad 2 ==> bp1 - (bp2 + 4dp2) = 1.6 > 0 ==> Punch Shear to be Checked in Pad 2

Vpunch2 = 88501 kg = 885008 N

Resisting Shear of Concrete,

Vr2 = 1286322 N

Vr2	>	Vpunch2	OK

F.S.= 1.45

Structural Design of Chimney:

Design of Longitudinal Reinforcement for Uplift :

A) Moment at the bottom of chimney about x axis Mx max = 12.47 ton.m = 124664 N.m

Rebar arrangement:

No. of rebars rows, n = 6

Total No. of rebars = 20

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

$\Sigma Ai*di^2 =$ 12240

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

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

As1= 14.4 cm2

B) Moment at the bottom of chimney about y axis My max = 4.56 ton.m = 45573 N.m

$\varphi s * fyr = M * c / I$ As2= 5.3 cm2

C) Axial required rebar area, $As3 = Ts / (\varphi s*Fyr) =$ 15.4 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 = 35.1 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 =	35.1							
Rebar Diameter =	16	mm =====>	QTY =	18	=====>	20	=====>	20 Ø 16
===>> As final=	40.2	cm2						
Rebar Quantity of One Row =	6							
Rebar Spacing =	12.0							

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
$N_{Ed} =$	141.91	ton
$M_{0Ed,x} =$	12.45	ton.m
$e_0 = h /30 > 20$ mm ==> $e_0 =$	25	mm
$M_{Ed,x} =$	15.07	ton.m

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

$M_{0Ed,y} =$	7.32	ton.m
$M_{Ed,y} =$	9.95	ton.m
$As * F yr / bc^2 * f'c =$	0.179	
$N_{ED}/ f'c * bc^2 =$	0.124	
d2 =	147	mm
d2 / bc =	0.20	

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

$N_{Rd} =$ $Ac * f'c + As * Fyr =$ 935.32 ton

$N_{Ed} / N_{Rd} =$ 0.15 ===> a = 1.04

$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a =$ 0.409 < 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: 12A-LA

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	30° C5,C NA+	1,776	3,018	-129,012
Maximum Axial Force, Uplift	30° C5, Min. WS,C NA+	1,105	3,023	119,055

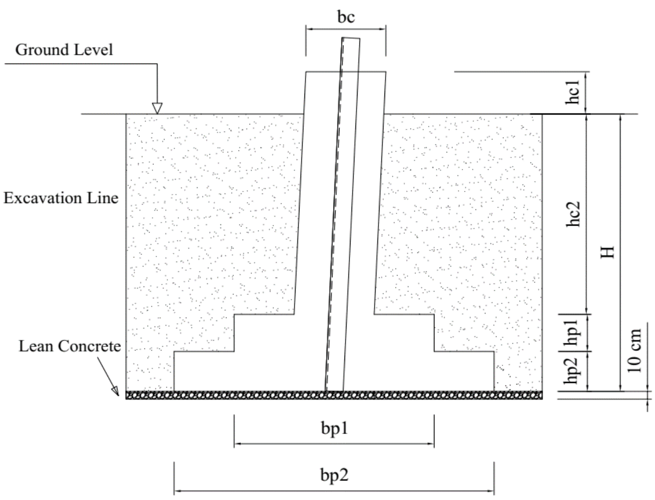
Maximum Loads on Foundation				
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	30° C5,C NA+	22,110	23,353	-124,987
Maximum Axial Force, Uplift	30° C5, Min. WS,C NA+	19,878	-21,796	115,385

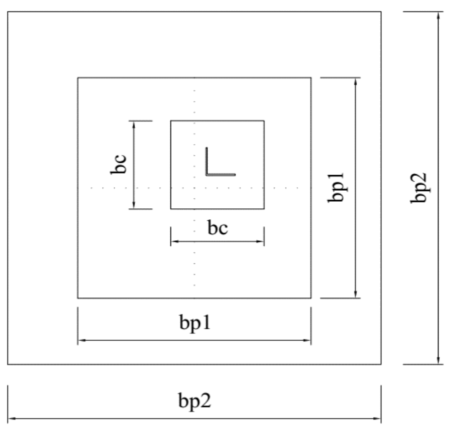
Design Standard: EN 1992:2004

Inputs:

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

Foundation Dimensions	Width of Pad 1	bp1 =	2	m	
	Width of Pad 2	bp2 =	4.3	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 =	9.24	Degree	
	Diagonal Slope	γ =	12.94	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

* The foundation is cast inside formwork.

Ultimate Loads:

On Foundation	Compression	C =	137.49	ton
		Vcx =	24.32	ton
		Vcy =	25.69	ton
	Uplift	T =	126.92	ton
		Vtx =	21.87	ton
		Vty =	-23.98	ton

On Stub	Compression	Cs =	141.91	ton
		Vscx =	1.95	ton
		Vscy =	3.32	ton
	Uplift	Ts =	130.96	ton
		Vstx =	1.22	ton
		Vsty =	3.33	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 =	5.90	ton
Passive Force on pad2,	Fp3 =	13.76	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 =	1.20	m3
Volume of pad2,	V4 =	5.55	m3
Total volume of foundation ,	Vf =	8.83	m3

Total weight of foundation, Wf = Vf * γc = 22.07 ton

Cone volume, Vcone = $(h/3)*(\pi*h^2*\tan^2\Theta + 3*bp2^2 + 6*bp2*h*\tan\theta)$ = 71.19 m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 = 65.30 m3

Soil weight above foundation, Ws = Vsoil * γb = 106.50 ton

Total resistance force against uplift, Ru= Ws + Wf = 128.58 ton

Uplift Force, U= 126.92 ton

128.58	>	126.92	OK

S.F.= 1.01

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

G: weight of foundation and soil vertical to the base = 128.58 ton

Z: uplift force on fondation = 115.39 ton

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

Bearing Capacity:

Compression Force,	C =	138.31	ton
Bending Moment about x axis,	Mx =	-14.46	ton.m
Bending Moment about y axis,	My =	8.51	ton.m

Over Load of Concrete Wf= 22.07 ton

Volume of the Soil directly above foundation Vsl = $(H * bp2^2)$ - V2 - V3 - V4 = 65.30 m3

Over Load of Soil directly above foundation Wsl= Vsl * γb = 106.50 ton

Average Bearing Pressure = σp = ((C + Wf + Wsl)/A) =	1.44	kg/cm2	<	1.53	kg/cm2	OK

Compression Stress at corner 1,	$\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3)$ =	1.40	kg/cm2
Compression Stress at corner 2,	$\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3)$ =	1.27	kg/cm2
Compression Stress at corner 3,	$\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3)$ =	1.62	kg/cm2
Compression Stress at corner 4,	$\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3)$ =	1.49	kg/cm2

Max. Toe Pressure =	1.62	<	q_{all} =	1.91	OK
Min. Toe Pressure =	1.27	>		0	OK

S.F.= 1.18

Top Surface Pressure due to Uplift:

Uplift Force,	T =	127.64	ton
Bending Moment about x axis,	Mx =	-12.47	ton.m
Bending Moment about y axis,	My =	4.56	ton.m

Pressure due to Uplift at top surface at corner 1,	$\sigma u1 = ((T-Wf)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3)$ =	0.51	kg/cm2
Pressure due to Uplift at top surface at corner 2,	$\sigma u2 = ((T-Wf)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3)$ =	0.44	kg/cm2
Pressure due to Uplift at top surface at corner 3,	$\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3)$ =	0.70	kg/cm2
Pressure due to Uplift at top surface at corner 4,	$\sigma u4 = ((T-Wf)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3)$ =	0.63	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 = 211.56 ton.m

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

Mr = 222.45 ton.m

Mr	>	Mo	OK

S.F.= 1.05

Sliding:

Sliding force, Fo = Vmax

Sliding force, Fo = 23.98 ton

Effective weight of foundation and soil at uplift case, Weff = 1.65 ton

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

Fr = 32.33

Fr	>	Fo	OK

S.F.= 1.35

Structural Design of Pad:

Longitudinal Rebar:

Compression :

Compression Stress at section of Max. bending moment at Pad 1, σmc1 = 1.46 kg/cm2

Compression Stress at section of Max. bending moment at Pad 2, σmc2 = 1.49 kg/cm2

Uplift :

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

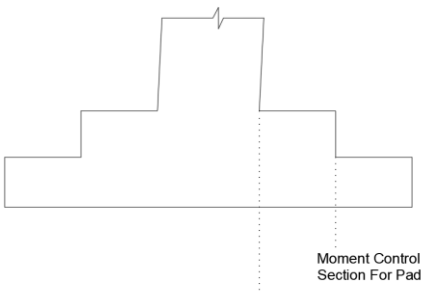
Compression Stress at section of Max. bending moment at Pad 2, σmu2 = 0.61 kg/cm2

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

Muc 1= 6556990 kg.cm = 643241 N.m

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

Muc 2= 2643296 kg.cm = 259307 N.m



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

Muu 1= 4329332 kg.cm = 424707 N.m

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

Muu 2= 1843192 kg.cm = 180817 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 = 0.088 < 0.167 OK

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

Z max = 481 < 498.75 ==>>> OK

As = Mu / φs * fyr * z = 3211 mm2

Pad 2:

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 = 205.6 < 213.75 ==>>> OK

As = Mu / φs * fyr * z = 3027.1 mm2

Uplift :

Pad 1:

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

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

Z max =	512.2	>	498.75	==>>>	Zmax=0.95 dp =	498.75
As = Mu / φs * fyr * z =	2043.7	mm2				

Pad 2:

$K = Mu / f'c * bp * dp^2 =$	0.062				

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

Z max =	211.9	<	213.75	==>>>	OK
As = Mu / φs * fyr * z =	2048.3	mm2			

Top of Pad 1 :										
As1t=	2043.7	mm2								
Rebar Diameter=	16	mm	=====>	QTY =	11 ==>>	11	=====>	11 Ø 16	=====>	2212 mm2
Rebar Quantity =	11									
Rebar Spacing =	185.0	mm								
Top of Pad 2 :										
As2t=	2048.3	mm2								
Rebar Diameter=	12	mm	=====>	QTY =	19 ==>>	19	=====>	19 Ø 12	=====>	2149 mm2
Rebar Quantity =	19									
Rebar Spacing =	230.6	mm								
Bottom of Pad 2 :										
As2b=	3211.3	mm2								
Rebar Diameter=	12	mm	=====>	QTY =	29 ==>>	29	=====>	29 Ø 12	=====>	3280 mm2
Rebar Quantity =	29									
Rebar Spacing =	148.2	mm								

Min. Rebar Check:

Ast =	7640.4	mm2			
ρst =	0.0049	>			
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 =	1.49	kg/cm2	
Vu1 =	51938	kg	=	519383	N
Compression Stress at critical section of shear at Pad2 ,		σv2 =	1.51	kg/cm2	
Vu2 =	36816	kg	=	368163	N

Pad 1

k = 1 +(200/dp1)^0.5 < 2.0	>>>	k =	1.62	EN 1992-1-1:2004	6.2
$\rho_1 =$	0.0049				
$\sigma_{cp} = N_{ED}/A_C =$	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

$Vr1 =$ 649832 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

$\rho_1 =$ 0.0056

$\sigma_{cp} = N_{ED}/A_C =$ 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 = 504994 N

Vr2	>	Vu2	OK

F.S= 1.37

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 1.44 kg/cm2

Pad 1

Vpunch1 = 100566 kg = 1005664 N

Resisting Shear of Concrete,

Vr1 = 2088836 N

Vr1	>	Vpunch1	OK

F.S.= 2.08

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 = 86127 kg = 861265 N

Resisting Shear of Concrete,

Vr2 = 1271580 N

Vr2	>	Vpunch2	OK

F.S.= 1.48

Structural Design of Chimney:

Design of Longitudinal Reinforcement for Uplift :

A) Moment at the bottom of chimney about x axis Mx max = 12.47 ton.m = 124664 N.m

Rebar arrangement:

No. of rebars rows, n = 6

Total No. of rebars = 20

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

$\Sigma Ai*di^2 =$ 12240

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

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

As1= 14.4 cm2

B) Moment at the bottom of chimney about y axis My max = 4.56 ton.m = 45573 N.m

$\varphi s * fyr = M * c / I$ As2= 5.3 cm2

C) Axial required rebar area, $As3 = Ts / (\varphi s*Fyr) =$ 15.4 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 = 35.1 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 =	35.1							
Rebar Diameter =	16	mm	=====> QTY =	18	=====>	20	=====>	20 Ø 16
===>> As final=	40.2	cm2						
Rebar Quantity of One Row =	6							
Rebar Spacing =	12.0							

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

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

$e = l_0 /400 = 2*(hc)/400 =$	18.5	mm
$N_{Ed} =$	141.91	ton
$M_{0Ed,x} =$	12.45	ton.m
$e_0 = h /30 > 20$ mm ==> $e_0 =$	25	mm
$M_{Ed,x} =$	15.07	ton.m

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

$M_{0Ed,y} =$	7.32	ton.m
$M_{Ed,y} =$	9.95	ton.m
$As * F yr / bc^2 * f'c =$	0.179	
$N_{ED} / f'c * bc^2 =$	0.124	
d2 =	147	mm
d2 / bc =	0.20	

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 = 935.32 ton

$N_{Ed} / N_{Rd} =$ 0.15 ===> a = 1.04

$(M_{Ed,x}/M_{Rd,x})^a + (M_{Ed,y}/M_{Rd,y})^a =$ 0.409 < 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:	12A-LA

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	30° C5,C NA+	1,776	3,018	-129,012
Maximum Axial Force, Uplift	30° C5, Min. WS,C NA+	1,105	3,023	119,055

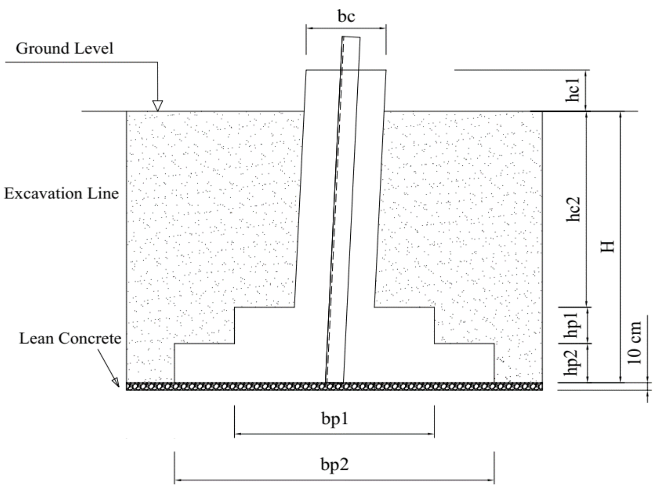
Maximum Loads on Foundation				
Description	*Load Combination*	*Foundation Components*		
		Transversal	*Longitudinal*	*Vertical*
		kg	kg	kg
Maximum Axial Force, Compression	30° C5,C NA+	22,110	23,353	-124,987
Maximum Axial Force, Uplift	30° C5, Min. WS,C NA+	19,878	-21,796	115,385

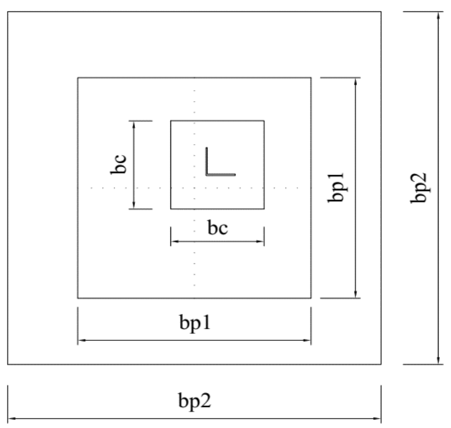
Design Standard: EN 1992:2004

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 =	6.3	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 =	9.24	Degree	
	Diagonal Slope	γ =	12.94	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





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

* The foundation is cast inside formwork.

Ultimate Loads:

On Foundation	Compression	C =	137.49	ton
		Vcx =	24.32	ton
		Vcy =	25.69	ton
	Uplift	T =	126.92	ton
		Vtx =	21.87	ton
		Vty =	-23.98	ton

On Stub	Compression	Cs =	141.91	ton
		Vscx =	1.95	ton
		Vscy =	3.32	ton
	Uplift	Ts =	130.96	ton
		Vstx =	1.22	ton
		Vsty =	3.33	ton

Soil Passive Pressure Coefficient $Kp = \tan 2\,(45+\varphi/2) =$ 1.70
Passive Force on chimney, Fp1 = 6.00 ton
Passive Force on pad1, Fp2 = 3.84 ton
Passive Force on pad2, Fp3 = 10.08 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 = 11.91 m3
Total volume of foundation , Vf = 16.02 m3

Total weight of foundation, $Wf = Vf * \gamma c =$ 24.02 ton

Cone volume, $Vcone = (h/3)*(\pi*h^2*\tan^2\Theta + 3*bp2^2 + 6*bp2*h*\tan\theta) =$ 152.81 m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 = 142.91 m3
Soil weight above foundation, $Ws = Vsoil * \gamma b =$ 116.54 ton

Total resistance force against uplift, Ru= Ws + Wf = 140.57 ton
Uplift Force, U= 126.92 ton

140.57	>	126.92	OK

S.F.= 1.11

Additional condition: G/Z > 0.8 EN 50341 M.3.1.6
G: weight of foundation and soil vertical to the base = 140.57 ton
Z: uplift force on fondation = 115.39 ton

Z/G = 1.22 >>> Ratio = 1.52 OK

Bearing Capacity:

Compression Force, C = 138.31 ton
Bending Moment about x axis, Mx = -14.46 ton.m
Bending Moment about y axis, My = 8.51 ton.m

Over Load of Concrete Wf= 24.02 ton

Volume of the Soil directly above foundation $Vsl = (H * bp2^2) - V2 - V3 - V4 =$ 142.91 m3

Over Load of Soil directly above foundation $Wsl = Vsl * \gamma b =$ 116.54 ton

Average Bearing Pressure = $\sigma p = ((C + Wf + Wsl)/A) =$	0.70	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, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ 0.65 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, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ 0.72 kg/cm2

Max. Toe Pressure =	0.76	<	q_{all} =	1.02	OK
Min. Toe Pressure =	0.65	>	0		OK

S.F.= 1.35

Top Surface Pressure due to Uplift:

Uplift Force, T = 127.64 ton
Bending Moment about x axis, Mx = -12.47 ton.m
Bending Moment about y axis, My = 4.56 ton.m

Pressure due to Uplift at top surface at corner 1, $\sigma u1 = ((T-Wf)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ 0.24 kg/cm2
Pressure due to Uplift at top surface at corner 2, $\sigma u2 = ((T-Wf)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ 0.22 kg/cm2
Pressure due to Uplift at top surface at corner 3, $\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ 0.30 kg/cm2
Pressure due to Uplift at top surface at corner 4, $\sigma u4 = ((T-Wf)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ 0.28 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 = 297.38 ton.m

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

Mr = 356.38 ton.m

Mr	>	Mo	OK

S.F.= 1.20

Sliding:

Sliding force, Fo = Vmax

Sliding force, Fo = 23.98 ton

Effective weight of foundation and soil at uplift case, Weff = 13.64 ton

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

Fr = 25.38

Fr	>	Fo	OK

S.F.= 1.06

Structural Design of Pad:

Longitudinal Rebar:

Compression :

Compression Stress at section of Max. bending moment at Pad 1, σmc1 = 0.71 kg/cm2

Compression Stress at section of Max. bending moment at Pad 2, σmc2 = 0.72 kg/cm2

Uplift :

Compression Stress at section of Max. bending moment at Pad 1, σmu1 = 0.26 kg/cm2

Compression Stress at section of Max. bending moment at Pad 2, σmu2 = 0.27 kg/cm2

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

Muc 1= 10913038 kg.cm = 1070569 N.m

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

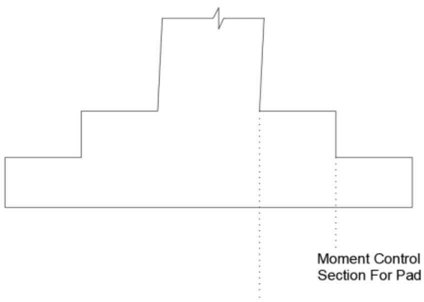
Muc 2= 4623111 kg.cm = 453527 N.m

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

Muu 1= 6844925 kg.cm = 671487 N.m

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

Muu 2= 3073756 kg.cm = 301535 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:

$K = Mu / f'c * bp * dp^2 =$ 0.112 < 0.167 OK

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

Z max = 467 < 498.75 ==>>> OK

As = Mu / φs * fyr * z = 5506 mm2

Pad 2:

$K = Mu / f'c * bp * dp^2 =$ 0.107 < 0.167 OK

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

Z max = 201.3 < 213.75 ==>>> OK

As = Mu / φs * fyr * z = 5406.1 mm2

Uplift :

Pad 1:

$K = Mu / f'c * bp * dp^2$ =	0.029	<	0.167	OK			
Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp							
Z max =	511.2	>	498.75	==>>>	Zmax=0.95 dp =	498.75	
As = Mu / φs * fyr * z =	3231.2	mm2					

Pad 2:

$K = Mu / f'c * bp * dp^2$ =	0.071				
Z max = dp * (1 + (1-3.529K)^0.5)/2 <= 0.95 *dp					
Z max =	209.9	<	213.75	==>>>	OK
As = Mu / φs * fyr * z =	3447.6	mm2			

Top of Pad 1 :										
As1t=	3231.2		mm2							
Rebar Diameter=	16	mm	=====>	QTY =	17 ==>>	17	=====>	17 Ø 16	=====>	3418 mm2
Rebar Quantity =	17									
Rebar Spacing =	153.1	mm								
Top of Pad 2 :										
As2t=	3447.6	mm2								
Rebar Diameter=	12	mm	=====>	QTY =	31 ==>>	31	=====>	31 Ø 12	=====>	3506 mm2
Rebar Quantity =	31									
Rebar Spacing =	205.0	mm								
Bottom of Pad 2 :										
As2b=	5506.5	mm2								
Rebar Diameter=	16	mm	=====>	QTY =	28 ==>>	28	=====>	28 Ø 16	=====>	5630 mm2
Rebar Quantity =	28									
Rebar Spacing =	227.8	mm								

Min. Rebar Check:

Ast =	12553.8	mm2			
ρst =	0.0057	>			
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 =	0.71	kg/cm2	
Vu1 =	63460	kg	=	634600	N
Compression Stress at critical section of shear at Pad2 ,		σv2 =	0.72	kg/cm2	
Vu2 =	43680	kg	=	436801	N

Pad 1

k = 1 +(200/dp1)^0.5 < 2.0	>>>	k =	1.62	EN 1992-1-1:2004	6.2
ρ_1 =	0.0057				
$\sigma_{cp} = N_{ED}/A_C$ =	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 = 960512 N

Vr1	>	Vu1	OK

F.S= 1.51

Pad 2

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

ρ_1 = 0.0064

$\sigma_{cp} = N_{ED}/A_C$ = 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 = 774851 N

Vr2	>	Vu2	OK

F.S= 1.77

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 0.70 kg/cm2

Pad 1

Vpunch1 = 138307 kg = 1383071 N

Resisting Shear of Concrete,

Vr1 = 2202340 N

Vr1	>	Vpunch1	OK

F.S.= 1.59

Pad 2

To check if punch shear section is defined in Pad 2 ==> bp1 - (bp2 + 4dp2) = 2.8 > 0 ==> Punch Shear to be Checked in Pad 2

Vpunch2 = 110708 kg = 1107076 N

Resisting Shear of Concrete,

Vr2 = 1626871 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 = 12.47 ton.m = 124664 N.m

Rebar arrangement:

No. of rebars rows, n = 6

Total No. of rebars = 20

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

$\Sigma Ai*di^2$ = 12240

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

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

As1= 14.4 cm2

B) Moment at the bottom of chimney about y axis My max = 4.56 ton.m = 45573 N.m

$\varphi s * fyr = M * c / I$ As2= 5.3 cm2

C) Axial required rebar area, $As3 = Ts / (\varphi s*Fyr)$ = 15.4 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 = 35.1 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 =	35.1							
Rebar Diameter =	16	mm =====> QTY =	18	=====>	20	=====>	20 Ø 16	
===>> As final=	40.2	cm2						
Rebar Quantity of One Row =	6							
Rebar Spacing =	12.0							

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
$N_{Ed} =$	141.91	ton
$M_{0Ed, x} =$	12.45	ton.m
$e_0 = h /30 > 20$ mm ==> $e_0 =$	25	mm
$M_{Ed,x} =$	15.07	ton.m

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

$M_{0Ed, y} =$	7.32	ton.m
$M_{Ed,y} =$	9.95	ton.m
$As * F yr / bc^2 * f'c =$	0.179	
$N_{ED}/ f'c * bc^2 =$	0.124	
d2 =	147	mm
d2 / bc =	0.20	

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 =	935.32	ton			
$N_{Ed} / N_{Rd} =$	0.15	===>	a =	1.04		
$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a =$		0.409	<	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		