**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-MA"

# (for all soil types)

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|---|---|---|---|---|---|
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|---|---|---|
| Document Title | Scale | Sheet of Sheets |
| **Foundation Design Calculations of Tower Type "12A-MA"**<br>**(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-MA

| 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 | 60° C5,C NA+ | 1,490 | 3,764 | -160,380 |
| Maximum Axial Force, Uplift | 60° C5, Min. WS,C NA+ | 566 | 3,602 | 148,209 |

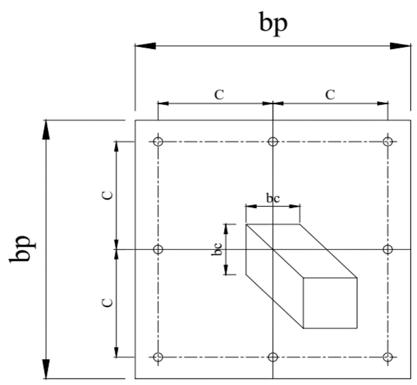
| Maximum Loads on Foundation | | | | |
|---|---|---|---|---|
| *Description* | *Load Combination* | *Foundation Components* | | |
| | | *Transversal* | *Longitudinal* | *Vertical* |
| | | kg | kg | kg |
| Maximum Axial Force, Compression | 60° C5,C NA+ | -27,630 | 29,903 | -155,176 |
| Maximum Axial Force, Uplift | 60° C5, Min. WS,C NA+ | -24,740 | 27,778 | 143,510 |

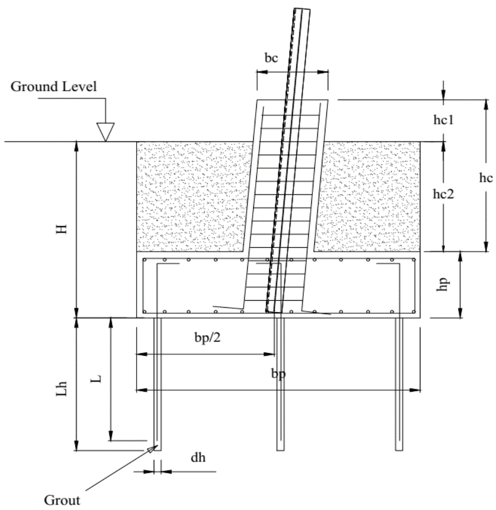
Design Standard: EN 1992:2004

**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 = | 0.7 | m | |
| | Total Height of Chimney | hc = | 1 | m | |
| | Depth of Pad | H = | 1.45 | m | |
| | Inplane Slope | β = | 9.56 | Degree | |
| | Eccentricity (Bottom of Pad) | e = | 0.29 | m | |
| Soil Specifications | Soil Type | Type 1-Sound Rock | | | |
| | Density | $\gamma_s$ = | 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 | $\gamma_c$ = | 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 | $\tau_{gs}$ = | 2 | Mpa | Ref. Pile Design in Construction Practice by Tomlinson Page 217 |
| | Grout and Rock Bond Stress | $\tau_{gr}$ = | 0.9 | Mpa | Ref. Pile Design in Construction Practice by Tomlinson Table 6.1 |
| | Concrete and Rebar Bond Stress | $\tau_{cr}$ = | 2.3 | Mpa | EN 50341 2012 Table K.2 |




* The foundation is in direct contact with undisturbed soil.

**Ultimate Loads:**

| | | | | |
|---|---|---|---|---|
| On Foundation | Compression | C = | 170.69 | ton |
| | | Vcx = | -30.39 | ton |
| | | Vcy = | 32.89 | ton |
| | Tension | T = | 157.86 | ton |
| | | Vtx = | -27.21 | ton |
| | | Vty = | 30.56 | ton |

| | | | | |
|---|---|---|---|---|
| On Stub | Compression | Cs = | 176.42 | ton |
| | | Vscx = | 1.64 | ton |
| | | Vscy = | 4.14 | ton |
| | Tension | Ts = | 163.03 | ton |
| | | Vstx = | 0.62 | ton |
| | | Vsty = | 3.96 | ton |

**Design of Anchors:**

Volume of chimney above ground level V1 = 0.15 m3
Volume of chimney under ground level V2 = 0.34 m3
Volume of pad, V3 = 1.69 m3
Total volume of foundation , Vf = 2.18 m3

Total weight of foundation, Wf = Vf * γc = 5.44 ton

Uplift Force, U = 157.86 ton

Design force for anchors, U net = U - Wf = 152.42 ton

Required anchor area for uplift, Asu = U net / ( φs * Fy) = 35.89 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

$\Sigma$ 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 | > | 35.89 | OK |

Uplift Force, T = 158.60 ton
Bending Moment about x axis, Mx = 6.93 ton.m
Bending Moment about y axis, My = 1.09 ton.m

Required Modulus of Section at x direction Wx = Mx / ( φs * Fy) = 163.27 cm3
Required Modulus of Section at y direction Wy = My / ( φs * Fy) = 25.64 cm3

Required anchor area for bending moment about x axis, Asmx = n * m * Wx * c / ($\Sigma$ di $^2$) = 4.45 cm2

Required anchor area for bending moment about y axis, Asmy = n* m * Wy * c / ($\Sigma$ di $^2$) = 0.70 cm2

| | | | | | |
|---|---|---|---|---|---|
| Total Required Area for Anchors, Astot = Asu + Asmx + Asmy = | 41.04 | cm2 | < | 50.27 | OK |

**Bearing Capacity:**

Compression Force, C = 171.63 ton
Bending Moment about x axis, Mx = 7.24 ton.m
Bending Moment about y axis, My = 2.87 ton.m

Over Load of Concrete, Wf = 5.44 ton

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

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

| | | | | | | |
|---|---|---|---|---|---|---|
| Overall Bearing Pressure = σp = ((C + Wf + Wsl )/A) = | 8.01 | kg/cm2 | < | 10.19 | kg/cm2 | OK |

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) + (6*My)/(bp3) =$ 9.81 kg/cm2

Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) - (6*My)/(bp3) =$ 8.79 kg/cm2

Compression Stress at corner 3, $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) + (6*My)/(bp3) =$ 7.23 kg/cm2

Compression Stress at corner 4, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) - (6*My)/(bp3) =$ 6.21 kg/cm2

| | | | | | |
|---|---|---|---|---|---|
| Max. Toe Pressure = | 9.81 | < | $q_{all}$ = | 12.74 | OK |
| Min. Toe Pressure = | 6.21 | > | 0 | | OK |

**Bond of Anchor and Grout Check :**

Max. force of one anchor hole Pa = 21787 kg

Required embedded length of anchor in Rock, $L_{min} = Pa / ( m * \tau_{gs} * \pi * da ) =$ 86.7 cm

Design embedded length of anchor in Rock, L= 230 cm

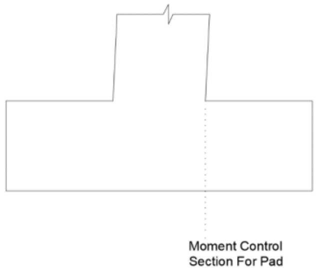
**Bond of Grout and Rock Check :**

Anchor Hole Diameter, Dh = 7.5 cm

| | | | | | |
|---|---|---|---|---|---|
| Resisting bond force of the Grout and Rock, $F\tau_{gr} = \tau_{gr} * L * Dh * \pi =$ | 48773 | kg | > | 21787 | OK |

**Structural Design of Pad:**

**Longitudinal Rebar:**




Compression Stress at section of Max. bending moment, $\sigma m =$ 8.61 kg/cm2

Mu = 1066793 kg.cm = 106679 N.m

Effective Depth, dp = hp - cp = 0.675 m

$K = Mu / f'c * bp * dp^2 =$ 0.01171 < 0.167 OK

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

Z max = 667.95 > 641.25 ==>>> Zmax=0.95 dp = 641.25 mm

As = Mu / φs * fyr * z = 399

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 , $\sigma v =$ 9.77 kg/cm2

Vu = -38590 kg = -385895 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

$\rho_1 =$ 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 = 8.01 kg/cm2

Vpunch = -606551 kg = -6065507 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 = 4.02 ton.m = 40185 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

$\Sigma$ 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= 4.6 cm2

B) Moment at the bottom of chimney about y axis

My max = 0.63 ton.m = 6311 N.m

>>>>> A = M * c / ( φs * fyr *Σdi2)

As2= 0.7 cm2

C) Axial required rebar area, As3 = Ts / ( φs*Fys) = 19.2 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 = 24.5 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 = 24.5

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

===>> As final= 25.1 cm2

Rebar Quantity of One Row = 3

Rebar Spacing = 27.5

**Check for Compression :**

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

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

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

$N_{Ed}$ = 176.42 ton

$M_{0Ed,x}$ = 4.20 ton.m

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

$M_{Ed,x}$ = 5.08 ton.m

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

$M_{0Ed,y}$= 1.66 ton.m

$M_{Ed,y}$ = 4.12 ton.m

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

$N_{ED} / f'c * bc^2$ = 0.177

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

$N_{Ed} / N_{Rd}$ = 0.23 ===> a = 1.11

$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a$ = 0.126 < 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-MA

| 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 | 60° C5,C NA+ | 1,490 | 3,764 | -160,380 |
| Maximum Axial Force, Uplift | 60° C5, Min. WS,C NA+ | 566 | 3,602 | 148,209 |

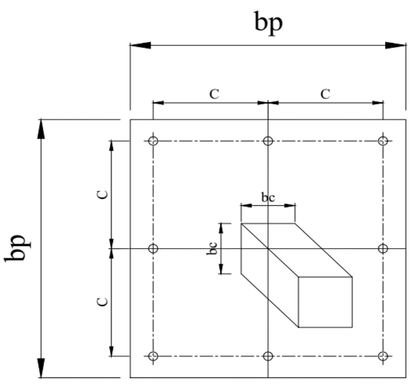
| Maximum Loads on Foundation | | | | |
|---|---|---|---|---|
| *Description* | *Load Combination* | *Foundation Components* | | |
| | | *Transversal* | *Longitudinal* | *Vertical* |
| | | kg | kg | kg |
| Maximum Axial Force, Compression | 60° C5,C NA+ | -27,630 | 29,903 | -155,176 |
| Maximum Axial Force, Uplift | 60° C5, Min. WS,C NA+ | -24,740 | 27,778 | 143,510 |

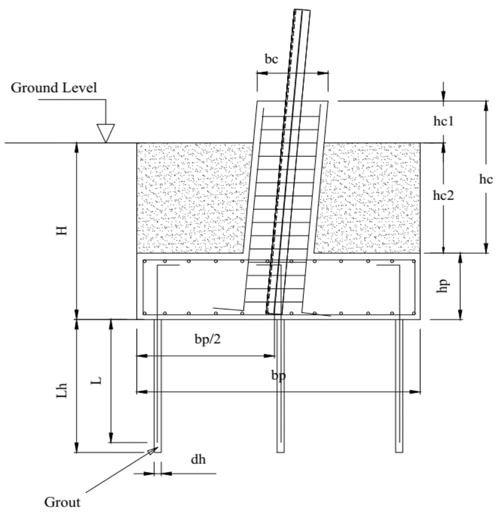
Design Standard: EN 1992:2004

**Inputs:**

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

| | | | | | |
|---|---|---|---|---|---|
| Foundation Dimensions | Width of Pad | bp = | 1.95 | 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 = | 0.7 | m | |
| | Total Height of Chimney | hc = | 1 | m | |
| | Depth of Pad | H = | 1.45 | m | |
| | Inplane Slope | $\beta$ = | 9.56 | Degree | |
| | Eccentricity (Bottom of Pad) | e = | 0.29 | m | |
| Soil Specifications | Soil Type | Type 2-Deleterious Rock | | | |
| | Density | $\gamma_s$ = | 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 | $\varphi$c = | 0.67 | | Tech. Spec. Section C1 3.2.2 |
| | Allowable Compressive Strength | f 'c = | 13.33 | Mpa | |
| | Density | $\gamma_c$ = | 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 | $\varphi$s = | 0.83 | | Tech. Spec. Section C1 3.2.2 |
| Bond Stress | Grout and Steel Bond Stress | $\tau_{gs}$ = | 2 | Mpa | Ref. Pile Design in Construction Practice by Tomlinson Page 217 |
| | Grout and Rock Bond Stress | $\tau_{gr}$ = | 0.6 | Mpa | Ref. Pile Design in Construction Practice by Tomlinson Table 6.1 |
| | Concrete and Rebar Bond Stress | $\tau_{cr}$ = | 2.3 | Mpa | EN 50341 2012 Table K.2 |




* The foundation is in direct contact with undisturbed soil.

MİTAŞ ENERGY

**Ultimate Loads:**

| | | | | |
|---|---|---|---|---|
| On Foundation | Compression | C = | 170.69 | ton |
| | | Vcx = | -30.39 | ton |
| | | Vcy = | 32.89 | ton |
| | Tension | T = | 157.86 | ton |
| | | Vtx = | -27.21 | ton |
| | | Vty = | 30.56 | ton |

| | | | | |
|---|---|---|---|---|
| On Stub | Compression | Cs = | 176.42 | ton |
| | | Vscx = | 1.64 | ton |
| | | Vscy = | 4.14 | ton |
| | Tension | Ts = | 163.03 | ton |
| | | Vstx = | 0.62 | ton |
| | | Vsty = | 3.96 | ton |

**Design of Anchors:**

| | | | |
|---|---|---|---|
| Volume of chimney above ground level | V1 = | 0.15 | m3 |
| Volume of chimney under ground level | V2 = | 0.34 | m3 |
| Volume of pad, | V3 = | 2.85 | m3 |
| Total volume of foundation , | Vf = | 3.34 | m3 |

Total weight of foundation, $W_f = V_f * \gamma c$ = 8.35 ton

Uplift Force, U = 157.86 ton

Design force for anchors, U net = U - Wf = 149.51 ton

Required anchor area for uplift, Asu = U net / ( φs * Fy) = 35.20 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 = 72.5 cm

Distance of the last row to center, c = 72.5 cm

$\Sigma\, di^2$ = 21025

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 | > | 35.20 | OK |
|---|---|---|---|---|---|

| | | | |
|---|---|---|---|
| Uplift Force, | T = | 158.60 | ton |
| Bending Moment about x axis, | Mx = | 6.93 | ton.m |
| Bending Moment about y axis, | My = | 1.09 | ton.m |

| | | | | |
|---|---|---|---|---|
| Required Modulus of Section at x direction | Wx = | Mx / ( φs * Fy) = | 163.27 | cm3 |
| Required Modulus of Section at y direction | Wy = | My / ( φs * Fy) = | 25.64 | cm3 |

Required anchor area for bending moment about x axis, $Asmx = n * m * Wx * c / (\Sigma\, di^2)$ = 3.38 cm2

Required anchor area for bending moment about y axis, $Asmy = n * m * Wy * c / (\Sigma\, di^2)$ = 0.53 cm2

| Total Required Area for Anchors, | Astot = Asu + Asmx + Asmy = | 39.11 | cm2 | < | 50.27 | OK |
|---|---|---|---|---|---|---|

**Bearing Capacity:**

| | | | |
|---|---|---|---|
| Compression Force, | C = | 171.63 | ton |
| Bending Moment about x axis, | Mx = | 7.24 | ton.m |
| Bending Moment about y axis, | My = | 2.87 | ton.m |

Over Load of Concrete, Wf = 8.35 ton

Volume of the Soil directly above foundation $Vsl = (H * bp^2) - V2 - V3$ = 2.32 m3

Over Load of Soil directly above foundation $Wsl = Vsl * \gamma s$ = 4.73 ton

| Overall Bearing Pressure = $\sigma p = ((C + Wf + Wsl)/A)$ = | 4.86 | kg/cm2 | < | 5.10 | kg/cm2 | OK |
|---|---|---|---|---|---|---|

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) + (6*My)/(bp3) =$ 5.68 kg/cm2
Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) - (6*My)/(bp3) =$ 5.21 kg/cm2
Compression Stress at corner 3, $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) + (6*My)/(bp3) =$ 4.50 kg/cm2
Compression Stress at corner 4, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) - (6*My)/(bp3) =$ 4.04 kg/cm2

| | | | | | |
|---|---|---|---|---|---|
| Max. Toe Pressure = | 5.68 | < | $q_{all}$ = | 6.37 | OK |
| Min. Toe Pressure = | 4.04 | > | 0 | | OK |

**Bond of Anchor and Grout Check :**

Max. force of one anchor hole Pa = 20763 kg

Required embedded length of anchor in Rock, $L_{min} = Pa / ( m * \tau_{gs} * \pi * da ) =$ 82.6 cm

Design embedded length of anchor in Rock, L= 300 cm

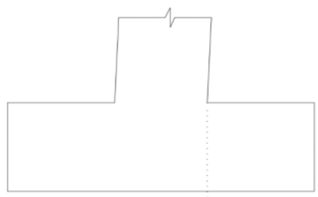
**Bond of Grout and Rock Check :**

Anchor Hole Diameter, Dh = 7.5 cm

Resisting bond force of the Grout and Rock, $F\tau_{gr} = \tau_{gr} * L * Dh * \pi =$ 42412 kg > 20763 OK

**Structural Design of Pad:**

**Longitudinal Rebar:**



Moment Control Section For Pad

Compression Stress at section of Max. bending moment, σm = 5.07 kg/cm2

Mu = 1971260 kg.cm = 197126 N.m

Effective Depth, dp = hp - cp = 0.675 m

$K = Mu / f'c * bp * dp^2 =$ 0.01664 < 0.167 OK

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

Z max = 664.94 > 641.25 ==>>> Zmax=0.95 dp = 641.25 mm

As = Mu / φs * fyr * z = 738

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 = 1901 mm2

As max = 58500 mm2

As = 1901

Rebar Diameter = 16 mm =====> QTY = 10 =====> 10 =====> 10 Ø 16

Rebar Quantity = 10

Rebar Spacing = 20.0

===> As= 2011 mm2

One Way Shear:

Compression Stress at critical section of shear , σv = 5.47 kg/cm2

Vu = -5183 kg = -51832 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

$\rho_1$ = 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 = 322839 N

| | | | |
|---|---|---|---|
| Vr | > | Vu | OK |

F.S= Not Defined!

Two Way Shear:

Average Compression Stress at the Middle of Pad , σ ave = 4.86 kg/cm2

Vpunch = -291993 kg = -2919932 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 = 4.02 ton.m = 40185 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

$\Sigma$ 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= 4.6 cm2

B) Moment at the bottom of chimney about y axis

My max = 0.63 ton.m = 6311 N.m

>>>>> A = M * c / ( φs * fyr *Σ di2)

As2= 0.7 cm2

C) Axial required rebar area, As3 = Ts / ( φs*Fys) = 19.2 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 = 24.5 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 = 24.5

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

===>> As final= 25.1 cm2

Rebar Quantity of One Row = 3

Rebar Spacing = 27.5

**Check for Compression :**

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

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

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

$N_{Ed} =$ 176.42 ton

$M_{0Ed,x} =$ 4.20 ton.m

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

| | | | | | | |
|---|---|---|---|---|---|---|
| $M_{Ed,x}$ = | 5.08 | ton.m | | | | |
| $M_{Ed,y} = M_{0Ed,y} + e * N_{Ed} > e_0 * N_{Ed}$ | | | | | | |
| $M_{0Ed,y}$= | 1.66 | ton.m | | | | |
| $M_{Ed,y}$ = | 4.12 | ton.m | | | | |
| $As * F yr / bc^2 * f'c$ = | 0.128 | | | | | |
| $N_{ED} / f'c * bc^2$ = | 0.177 | | | | | |
| 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 | | |
| $N_{Ed} / N_{Rd}$ = | 0.23 | | ===> | a = | 1.11 | |
| $(M_{Ed,x}/M_{Rd,x})^a + (M_{Ed,y}/M_{Rd,y})^a$ = | | | 0.126 | < | 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-MA

| 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 | 60° C5,C NA+ | 1,490 | 3,764 | -160,380 |
| Maximum Axial Force, Uplift | 60° C5, Min. WS,C NA+ | 566 | 3,602 | 148,209 |

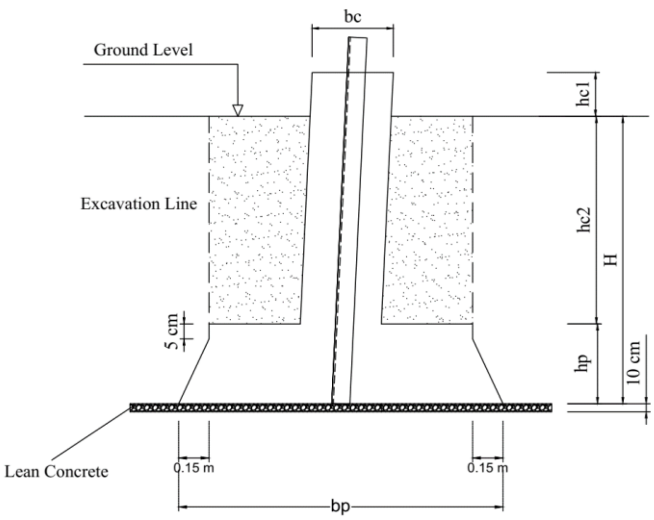
| Maximum Loads on Foundation | | | | |
|---|---|---|---|---|
| *Description* | *Load Combination* | *Foundation Components* | | |
| | | *Transversal* | *Longitudinal* | *Vertical* |
| | | kg | kg | kg |
| Maximum Axial Force, Compression | 60° C5,C NA+ | -27,630 | 29,903 | -155,176 |
| Maximum Axial Force, Uplift | 60° C5, Min. WS,C NA+ | -24,740 | 27,778 | 143,510 |

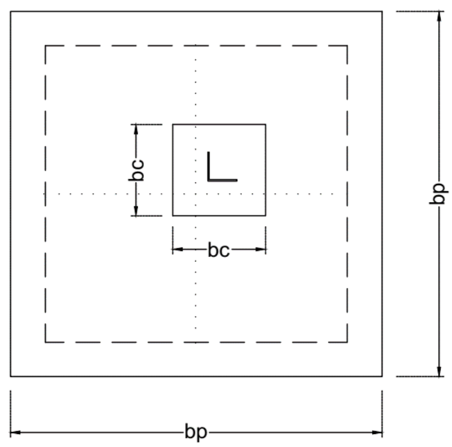
Design Standard: EN 1992:2004

**Inputs:**

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

| | | | | | |
|---|---|---|---|---|---|
| | Width of Pad | bp = | 2.6 | m | |
| | Height of Pad | hp = | 0.7 | 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 = | 3.3 | m | |
| | Depth of Pad | H = | 4 | m | |
| | Inplane Slope | $\beta$ = | 9.56 | Degree | |
| | Diagonal Slope | $\gamma$ = | 13.38 | Degree | |
| Soil Specifications | Soil Type | Type 2-Deleterious Rock | | | |
| | Natural Soil Density | $\gamma_s$ = | 2.04 | ton/m3 | |
| | Backfill Density | $\gamma_b$ = | 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 | $\Theta$ = | 25 | Degree | |
| | Internal Friction Angle | $\phi$ = | 35 | Degree | EN 50341 Table M.4 |
| | Friction Coefficient Between Soil and Concrete | $\mu$ = | 0.4 | | |
| Concrete | Compressive Strength(28 days of Cylindrical Sample) | f 'c = | 20 | Mpa | |
| | Strength Reduction Factor | $\varphi c$ = | 0.67 | | Tech. Spec. Section C1 3.2.2 |
| | Allowable Compressive Strength | f 'c = | 13.3 | Mpa | |
| | Density | $\gamma_c$ = | 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 | $\varphi s$ = | 0.83 | | Tech. Spec. Section C1 3.2.2 |




* The foundation is in direct contact with undisturbed soil.

**Ultimate Loads:**

| | | | | |
|---|---|---|---|---|
| On Foundation | Compression | C = | 170.69 | ton |
| | | Vcx = | -30.39 | ton |
| | | Vcy = | 32.89 | ton |
| | Uplift | T = | 157.86 | ton |
| | | Vtx = | -27.21 | ton |
| | | Vty = | 30.56 | ton |

| | | | | |
|---|---|---|---|---|
| On Stub | Compression | Cs = | 176.42 | ton |
| | | Vscx = | 1.64 | ton |
| | | Vscy = | 4.14 | ton |
| | Uplift | Ts = | 163.03 | ton |
| | | Vstx = | 0.62 | ton |
| | | Vsty = | 3.96 | ton |

Soil Passive Pressure Coefficient Kp = tan 2 (45+φ/2) = 3.69
Passive Force on chimney, Fp1 = 30.72 ton
Passive Force on pad, Fp2 = 49.98 ton

**Uplift:**

Volume of chimney above ground level V1 = 0.17 m3
Volume of chimney under ground level V2 = 1.86 m3
Volume of pad, V3 = 4.20 m3
Total volume of foundation , Vf = 6.23 m3

Total weight of foundation, Wf = Vf * γc = 15.57 ton

Cone volume, $Vcone = (H/3)*(\pi*H^2*\tan^2\Theta + 3*bp^2 + 6*bp*H*\tan\theta) =$ 80.41 m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 = 74.35 m3
Soil weight above foundation, Ws = Vsoil * γb = 151.58 ton

Total resistance force against uplift, Ru= Ws + Wf = 167.15 ton
Uplift Force, U= 157.86 ton

| | | | |
|---|---|---|---|
| 167.15 | > | 157.86 | OK |

S.F.= 1.06

**Bearing Capacity:**

Compression Force, C = 171.63 ton
Bending Moment about x axis, Mx = -18.05 ton.m
Bending Moment about y axis, My = 7.15 ton.m

Over Load of Concrete Wf= 15.57 ton

Volume of the Soil directly above foundation $Vsl = (H * bp^2) - V2 - V3 =$ 20.98 m3

Over Load of Soil directly above foundation Wsl= Vsl * γb = 42.78 ton

| | | | | | | |
|---|---|---|---|---|---|---|
| Average Bearing Pressure = σp = ((C + Wf + Wsl )/A) = | 3.40 | kg/cm2 | < | 5.10 | kg/cm2 | OK |

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 3.03 kg/cm2
Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 2.54 kg/cm2
Compression Stress at corner 3, $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 4.26 kg/cm2
Compression Stress at corner 4, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 3.77 kg/cm2

| | | | | | |
|---|---|---|---|---|---|
| Max. Toe Pressure = | 4.26 | < | $q_{all}$ = | 6.37 | OK |
| Min. Toe Pressure = | 2.54 | > | 0 | | OK |

S.F.= 1.49

**Top Surface Pressure due to Uplift:**

Uplift Force, T = 158.60 ton
Bending Moment about x axis, Mx = -14.47 ton.m
Bending Moment about y axis, My = 2.27 ton.m

Pressure due to Uplift at top surface at corner 1, $\sigma u1 = ((T-Wf)/A) + (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 1.70 kg/cm2
Pressure due to Uplift at top surface at corner 2, $\sigma u2 = ((T-Wf)/A) + (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 1.54 kg/cm2
Pressure due to Uplift at top surface at corner 3, $\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 2.69 kg/cm2
Pressure due to Uplift at top surface at corner 4, $\sigma u4 = ((T-Wf)/A) - (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 2.53 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 = 174.92 ton.m

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

Mr = 177.71 ton.m

| Mr | > | Mo | OK |
|---|---|---|---|

S.F.= 1.02

**Sliding:**

Sliding force, Fo = Vmax

Sliding force, Fo = 30.56 ton

Effective weight of foundation and soil at uplift case, Weff = 9.29 ton

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

Fr = 84.42

| Fr | > | Fo | OK |
|---|---|---|---|

S.F.= 2.76

**Structural Design of Pad:**

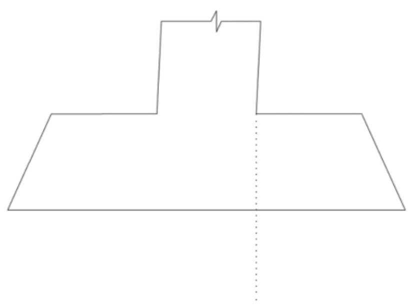
**Longitudinal Rebar:**

**Compression :**

Compression Stress at section of Max. bending moment at Pad , σmc = 3.58 kg/cm2

**Uplift :**

Compression Stress at section of Max. bending moment at Pad , σmu = 2.26 kg/cm2




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

Muc = 3558551 kg.cm = 349094 N.m

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

Muu = 2772579 kg.cm = 271990 N.m

Effective Depth of pad , dp = hp - cp = 0.625 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 = 610.4 > 593.75 ==>>> Zmax=0.95 dp = 593.75

As = Mu / φs * fyr * z = 1411.1 mm2

**Uplift :**

$K = Mu / f'c * bp * dp^2 =$ 0.020

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

Z max = 613.7 > 593.75 ==>>> Zmax=0.95 dp = 593.75

As = Mu / φs * fyr * z = 1099.4 mm2

**Top of Pad :**

As2t= 1099.4 mm2

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

Rebar Quantity = 10

Rebar Spacing = 238.9 mm

**Bottom of Pad :**

As2b= 1411.1 mm2

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

Rebar Quantity = 13

Rebar Spacing = 204.2 mm

Min. Rebar Check:

Ast = 2601.2 mm2

ρst = 0.0016 >

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 = 3.88 kg/cm2

Vu = 25539 kg = 255395 N

k = 1 +(200/dp2)^0.5 < 2.0 >>> k = 1.57 EN 1992-1-1:2004 6.2

$\rho_1$ = 0.0016

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

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

k1 = 0.15

$v_{min} = 0.035 * k^{3/2} * f'c^{1/2}$ = 0.307 Mpa EN 1992-1-1:2004 6.3N

Vr = 498303 N

| Vr | > | Vu | OK |
|---|---|---|---|

F.S= 1.95

**Two Way Shear:**

Average Compression Stress at the Middle of Pad , σ ave = 3.40 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 = 14.47 ton.m = 144666 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 *$\Sigma di^2$)

As1= 16.7 cm2

B) Moment at the bottom of chimney about y axis My max = 2.27 ton.m = 22719 N.m

φs * fyr = M * c /I As2= 2.6 cm2

C) Axial required rebar area, As3 = Ts / ( φs*Fyr) = 19.2 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 = | | 38.5 | 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 = | 38.5 | | | | | | | |
| Rebar Diameter = | 16 | mm | =====> | QTY = | 20 | =====> | 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 | mm |
| $N_{Ed} =$ | 176.42 | ton |
| $M_{0Ed, x} =$ | 15.11 | ton.m |
| $e_0 = h /30 > 20$ mm ==> $e_0 =$ | 25 | mm |
| $M_{Ed,x} =$ | 18.29 | ton.m |

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

| | | |
|---|---|---|
| $M_{0Ed, y} =$ | 5.98 | ton.m |
| $M_{Ed,y} =$ | 9.16 | ton.m |
| $As * F yr / bc^2 * f'c =$ | 0.179 | |
| $N_{ED}/ f'c * bc^2 =$ | 0.154 | |
| 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

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

$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a =$ 0.433 < 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-MA |

**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 | 60° C5,C NA+ | 1,490 | 3,764 | -160,380 |
| Maximum Axial Force, Uplift | 60° C5, Min. WS,C NA+ | 566 | 3,602 | 148,209 |

**Maximum Loads on Foundation**

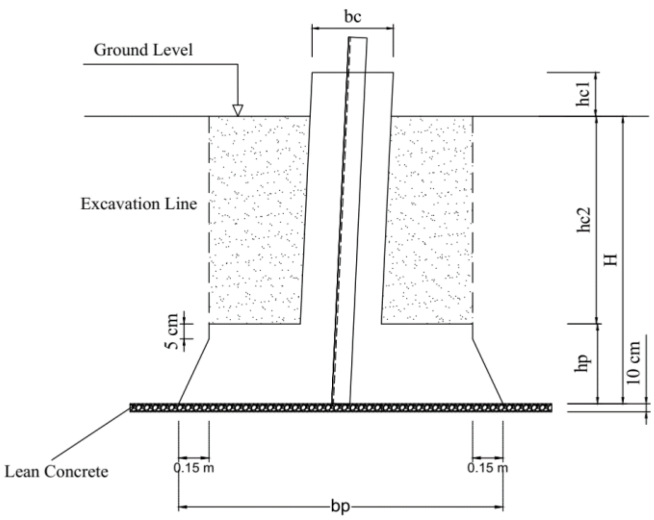
| *Description* | *Load Combination* | *Foundation Components* | | |
|---|---|---|---|---|
| | | *Transversal* | *Longitudinal* | *Vertical* |
| | | kg | kg | kg |
| Maximum Axial Force, Compression | 60° C5,C NA+ | -27,630 | 29,903 | -155,176 |
| Maximum Axial Force, Uplift | 60° C5, Min. WS,C NA+ | -24,740 | 27,778 | 143,510 |

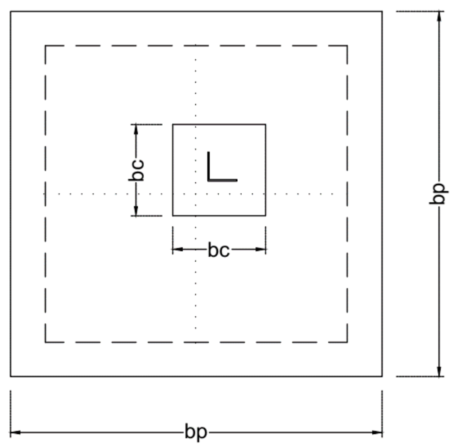
Design Standard: EN 1992:2004

**Inputs:**

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

| | | | | | |
|---|---|---|---|---|---|
| | Width of Pad | bp = | 3.1 | m | |
| | Height of Pad | hp = | 0.7 | 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 = | 3.3 | m | |
| | Depth of Pad | H = | 4 | m | |
| | Inplane Slope | β = | 9.56 | Degree | |
| | Diagonal Slope | γ = | 13.38 | Degree | |
| Soil Specifications | Soil Type | Type 3-Good Soil | | | |
| | Natural Soil Density | $\gamma_s$ = | 1.73 | ton/m3 | |
| | Backfill Density | $\gamma_b$ = | 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 | $\gamma_c$ = | 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 = | 170.69 | ton |
| | | Vcx = | -30.39 | ton |
| | | Vcy = | 32.89 | ton |
| | Uplift | T = | 157.86 | ton |
| | | Vtx = | -27.21 | ton |
| | | Vty = | 30.56 | ton |

| | | | | |
|---|---|---|---|---|
| On Stub | Compression | Cs = | 176.42 | ton |
| | | Vscx = | 1.64 | ton |
| | | Vscy = | 4.14 | ton |
| | Uplift | Ts = | 163.03 | ton |
| | | Vstx = | 0.62 | ton |
| | | Vsty = | 3.96 | ton |

Soil Passive Pressure Coefficient Kp = tan 2 (45+φ/2) = 3.69
Passive Force on chimney, Fp1 = 26.11 ton
Passive Force on pad, Fp2 = 50.65 ton

**Uplift:**

Volume of chimney above ground level V1 = 0.17 m3
Volume of chimney under ground level V2 = 1.86 m3
Volume of pad, V3 = 6.09 m3
Total volume of foundation , Vf = 8.12 m3

Total weight of foundation, Wf = Vf * γc = 20.29 ton

Cone volume, $Vcone = (H/3)*(\pi*H^2*\tan^2\Theta + 3*bp^2 + 6*bp*H*\tan\theta) =$ 89.46 m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 = 81.51 m3
Soil weight above foundation, Ws = Vsoil * γb = 141.25 ton

Total resistance force against uplift, Ru= Ws + Wf = 161.55 ton
Uplift Force, U= 157.86 ton

| | | | |
|---|---|---|---|
| 161.55 | > | 157.86 | OK |

S.F.= 1.02

**Bearing Capacity:**

Compression Force, C = 171.63 ton
Bending Moment about x axis, Mx = -18.05 ton.m
Bending Moment about y axis, My = 7.15 ton.m

Over Load of Concrete Wf= 20.29 ton

Volume of the Soil directly above foundation $Vsl = (H * bp^2) - V2 - V3 =$ 30.49 m3

Over Load of Soil directly above foundation Wsl= Vsl * γb = 52.84 ton

| | | | | | | |
|---|---|---|---|---|---|---|
| Average Bearing Pressure = σp = ((C + Wf + Wsl )/A) = | 2.55 | kg/cm2 | < | 3.06 | kg/cm2 | OK |

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 2.33 kg/cm2
Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 2.04 kg/cm2
Compression Stress at corner 3, $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 3.05 kg/cm2
Compression Stress at corner 4, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 2.77 kg/cm2

| | | | | | |
|---|---|---|---|---|---|
| Max. Toe Pressure = | 3.05 | < | $q_{all}$ = | 3.82 | OK |
| Min. Toe Pressure = | 2.04 | > | | 0 | OK |

S.F.= 1.25

**Top Surface Pressure due to Uplift:**

Uplift Force, T = 158.60 ton
Bending Moment about x axis, Mx = -14.47 ton.m
Bending Moment about y axis, My = 2.27 ton.m

Pressure due to Uplift at top surface at corner 1, $\sigma u1 = ((T-Wf)/A) + (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 1.19 kg/cm2
Pressure due to Uplift at top surface at corner 2, $\sigma u2 = ((T-Wf)/A) + (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 1.10 kg/cm2
Pressure due to Uplift at top surface at corner 3, $\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp^3) + (6*My)/(bp^3) =$ 1.78 kg/cm2
Pressure due to Uplift at top surface at corner 4, $\sigma u4 = ((T-Wf)/A) - (6*Mx)/(bp^3) - (6*My)/(bp^3) =$ 1.68 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 = 201.60 ton.m

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

Mr = 203.42 ton.m

| Mr | > | Mo | OK |
|---|---|---|---|

S.F.= 1.01

**Sliding:**

Sliding force, Fo = Vmax

Sliding force, Fo = 30.56 ton

Effective weight of foundation and soil at uplift case, Weff = 3.68 ton

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

Fr = 78.24

| Fr | > | Fo | OK |
|---|---|---|---|

S.F.= 2.56

**Structural Design of Pad:**

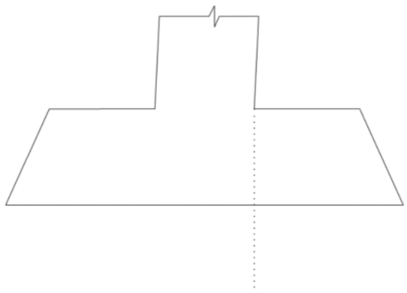
**Longitudinal Rebar:**

**Compression :**

Compression Stress at section of Max. bending moment at Pad , σmc = 2.63 kg/cm2

**Uplift :**

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



Moment Control
Section For Pad

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

Muc = 4807994 kg.cm = 471664 N.m

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

Muu = 3545864 kg.cm = 347849 N.m

Effective Depth of pad , dp = hp - cp = 0.625 m

**Compression :**

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

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

Z max = 608.5 > 593.75 ==>>> Zmax=0.95 dp = 593.75

As = Mu / φs * fyr * z = 1906.5 mm2

**Uplift :**

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

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

Z max = 612.9 > 593.75 ==>>> Zmax=0.95 dp = 593.75

As = Mu / φs * fyr * z = 1406.0 mm2

**Top of Pad :**

As2t= 1406.0 mm2

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

Rebar Quantity = 13

Rebar Spacing = 220.8 mm

**Bottom of Pad :**

As2b= 1906.5 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 = 3392.9 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 = 2.78 kg/cm2

Vu = 38774 kg = 387738 N

k = 1 +(200/dp2)^0.5 < 2.0 >>> k = 1.57 EN 1992-1-1:2004 6.2

$\rho_1$ = 0.0018

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

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

k1 = 0.15

$v_{min} = 0.035 * k^{3/2} * f'c^{1/2}$ = 0.307 Mpa EN 1992-1-1:2004 6.3N

Vr = 594130 N

| Vr | > | Vu | OK |
|---|---|---|---|

F.S= 1.53

**Two Way Shear:**

Average Compression Stress at the Middle of Pad , σ ave = 2.55 kg/cm2

To check if punch shear section is defined in Pad ==> bp1 - ( bc + 4dp2 ) = -0.15 < 0 ==> Not Defined

Vpunch = No Defined kg = Not Defined N

Resisting Shear of Concrete,

Vr = Not Defined N

| Vr | < | Vpunch | Not Defined |
|---|---|---|---|

F.S.= Not Defined

**Structural Design of Chimney:**

Design of Longitudinal Reinforcement for Uplift :

A) Moment at the bottom of chimney about x axis Mx max = 14.47 ton.m = 144666 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 *$\Sigma di^2$)

As1= 16.7 cm2

B) Moment at the bottom of chimney about y axis My max = 2.27 ton.m = 22719 N.m

φs * fyr = M * c /I As2= 2.6 cm2

C) Axial required rebar area, As3 = Ts / ( φs*Fyr) = 19.2 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 = | | | 38.5 | 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 = | 38.5 | | | | | | | |
| Rebar Diameter = | 16 | mm =====> | QTY = | 20 | =====> | 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 | mm |
| $N_{Ed} =$ | 176.42 | ton |
| $M_{0Ed, x} =$ | 15.11 | ton.m |
| $e_0 = h /30 > 20$ mm ==> $e_0 =$ | 25 | mm |
| $M_{Ed,x} =$ | 18.29 | ton.m |

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

| | | |
|---|---|---|
| $M_{0Ed, y} =$ | 5.98 | ton.m |
| $M_{Ed,y} =$ | 9.16 | ton.m |
| $As * F yr / bc^2 * f'c =$ | 0.179 | |
| $N_{ED}/ f'c * bc^2 =$ | 0.154 | |
| 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

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

$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a =$ 0.433 < 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-MA

| 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 | 60° C5,C NA+ | 1,490 | 3,764 | -160,380 |
| Maximum Axial Force, Uplift | 60° C5, Min. WS,C NA+ | 566 | 3,602 | 148,209 |

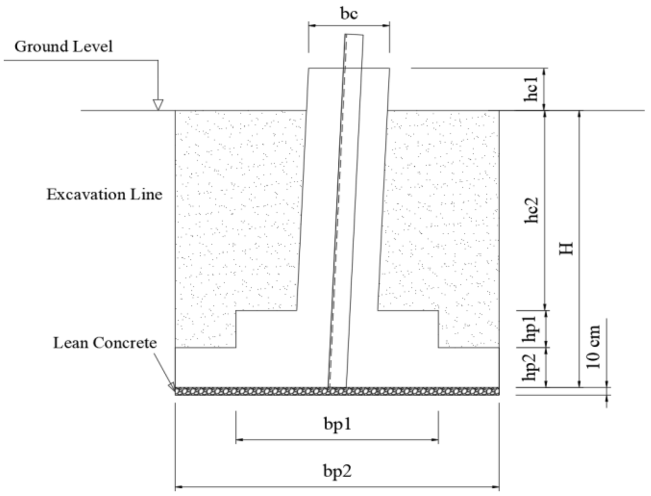
| Maximum Loads on Foundation | | | | |
|---|---|---|---|---|
| *Description* | *Load Combination* | *Foundation Components* | | |
| | | *Transversal* | *Longitudinal* | *Vertical* |
| | | kg | kg | kg |
| Maximum Axial Force, Compression | 60° C5,C NA+ | -27,630 | 29,903 | -155,176 |
| Maximum Axial Force, Uplift | 60° C5, Min. WS,C NA+ | -24,740 | 27,778 | 143,510 |

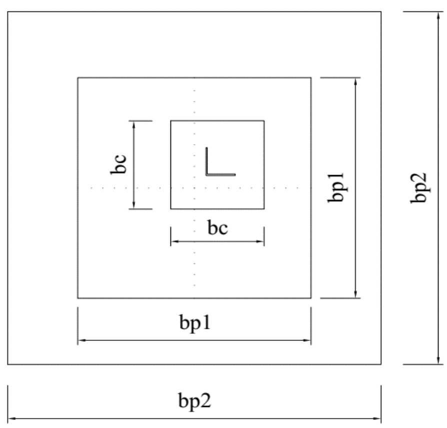
Design Standard: EN 1992:2004

**Inputs:**

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

| | | | | | |
|---|---|---|---|---|---|
| Foundation Dimensions | Width of Pad 1 | bp1 = | 1.7 | m | |
| | Width of Pad 2 | bp2 = | 3.45 | m | |
| | Height of Pad 1 | hp1 = | 0.35 | m | |
| | Height of Pad 2 | hp2 = | 0.35 | 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 = | 3.3 | m | |
| | Depth of Pad | H = | 4 | m | |
| | Inplane Slope | $\beta$ = | 9.56 | Degree | |
| | Diagonal Slope | $\gamma$ = | 13.38 | Degree | |
| Soil Specifications | Soil Type | Type 3-Good Soil | | | |
| | Natural Soil Density | $\gamma_s$ = | 1.73 | ton/m3 | |
| | Backfill Density | $\gamma_b$ = | 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 | $\Theta$ = | 22 | Degree | |
| | Internal Friction Angle | $\phi$ = | 35 | Degree | EN 50341 Table M.4 |
| | Friction Coefficient Between Soil and Concrete | $\mu$ = | 0.4 | | |
| Concrete | Compressive Strength(28 days of Cylindrical Sample) | f 'c = | 20 | Mpa | |
| | Strength Reduction Factor | $\varphi$c = | 0.67 | | Tech. Spec. Section C1 3.2.2 |
| | Allowable Compressive Strength | f 'c = | 13.3 | Mpa | |
| | Density | $\gamma_c$ = | 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 | $\varphi$s = | 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 = | 170.69 | ton |
| | | Vcx = | -30.39 | ton |
| | | Vcy = | 32.89 | ton |
| | Uplift | T = | 157.86 | ton |
| | | Vtx = | -27.21 | ton |
| | | Vty = | 30.56 | ton |

| | | | | |
|---|---|---|---|---|
| On Stub | Compression | Cs = | 176.42 | ton |
| | | Vscx = | 1.64 | ton |
| | | Vscy = | 4.14 | ton |
| | Uplift | Ts = | 163.03 | ton |
| | | Vstx = | 0.62 | ton |
| | | Vsty = | 3.96 | ton |

| | | | |
|---|---|---|---|
| Soil Passive Pressure Coefficient | Kp = tan 2 (45+φ/2) = | 3.69 | |
| Passive Force on chimney, | Fp1 = | 26.11 | ton |
| Passive Force on pad1, | Fp2 = | 13.22 | ton |
| Passive Force on pad2, | Fp3 = | 29.54 | ton |

**Uplift:**

| | | | |
|---|---|---|---|
| Volume of chimney above ground level | V1 = | 0.17 | m3 |
| Volume of chimney under ground level | V2 = | 1.86 | m3 |
| Volume of pad1, | V3 = | 1.01 | m3 |
| Volume of pad2, | V4 = | 4.17 | m3 |
| Total volume of foundation , | Vf = | 7.20 | m3 |

Total weight of foundation, Wf = Vf * γc = 18.01 ton

Cone volume, $V_{cone} = (h/3)*(\pi*h^2*\tan^2\Theta + 3*bp2^2 + 6*bp2*h*\tan\theta) =$ 95.88 m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 = 90.93 m3

Soil weight above foundation, Ws = Vsoil * γb = 157.57 ton

Total resistance force against uplift, Ru= Ws + Wf = 175.58 ton

Uplift Force, U= 157.86 ton

| | | | |
|---|---|---|---|
| 175.58 | > | 157.86 | OK |

S.F.= 1.11

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

G: weight of foundation and soil vertical to the base = 88.32 ton

Z: uplift force on fondation = 143.51 ton

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

**Bearing Capacity:**

| | | | |
|---|---|---|---|
| Compression Force, | C = | 171.63 | ton |
| Bending Moment about x axis, | Mx = | -18.05 | ton.m |
| Bending Moment about y axis, | My = | 7.15 | ton.m |

Over Load of Concrete Wf= 18.01 ton

Volume of the Soil directly above foundation $Vsl = (H * bp2^2) - V2 - V3 - V4 =$ 40.58 m3

Over Load of Soil directly above foundation Wsl= Vsl * γb = 70.32 ton

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

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ 2.02 kg/cm2

Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ 1.82 kg/cm2

Compression Stress at corner 3, $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ 2.55 kg/cm2

Compression Stress at corner 4, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ 2.34 kg/cm2

| | | | | | |
|---|---|---|---|---|---|
| Max. Toe Pressure = | 2.55 | < | $q_{all}$ = | 3.82 | OK |
| Min. Toe Pressure = | 1.82 | > | | 0 | OK |

S.F.= 1.50

**Top Surface Pressure due to Uplift:**

| | | | |
|---|---|---|---|
| Uplift Force, | T = | 158.60 | ton |
| Bending Moment about x axis, | Mx = | -14.47 | ton.m |
| Bending Moment about y axis, | My = | 2.27 | ton.m |

Pressure due to Uplift at top surface at corner 1, $\sigma u1 = ((T-Wf)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ 1.00 kg/cm2

Pressure due to Uplift at top surface at corner 2, $\sigma u2 = ((T-Wf)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ 0.94 kg/cm2

Pressure due to Uplift at top surface at corner 3, $\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ 1.43 kg/cm2

Pressure due to Uplift at top surface at corner 4, $\sigma u4 = ((T-Wf)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ 1.36 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 = 220.28 ton.m

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

Mr = 247.22 ton.m

| Mr | > | Mo | OK |
|---|---|---|---|

S.F.= 1.12

**Sliding:**

Sliding force, Fo = Vmax

Sliding force, Fo = 30.56 ton

Effective weight of foundation and soil at uplift case, Weff = 17.72 ton

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

Fr = 75.96

| Fr | > | Fo | OK |
|---|---|---|---|

S.F.= 2.49

**Structural Design of Pad:**

**Longitudinal Rebar:**

**Compression :**

Compression Stress at section of Max. bending moment at Pad 1, $\sigma mc1$ = 2.24 kg/cm2

Compression Stress at section of Max. bending moment at Pad 2, $\sigma mc2$ = 2.31 kg/cm2

**Uplift :**

Compression Stress at section of Max. bending moment at Pad 1, $\sigma mu1$ = 1.23 kg/cm2

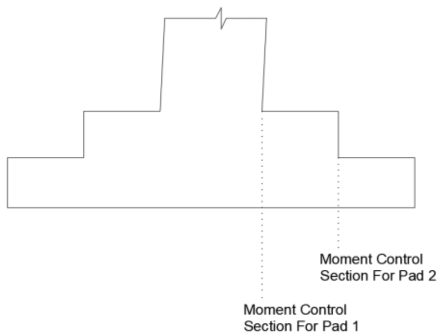
Compression Stress at section of Max. bending moment at Pad 2, $\sigma mu2$ = 1.29 kg/cm2

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

Muc 1= 5681109 kg.cm = 557317 N.m

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

Muc 2= 2338483 kg.cm = 229405 N.m




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

Muu 1= 4204749 kg.cm = 412486 N.m

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

Muu 2= 1792022 kg.cm = 175797 N.m

Effective Depth of pad 1, dp1 = hp1+hp2 - cp = 0.625 m

Effective Depth of pad 2, dp2 = hp2 - cp = 0.275 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 = 588 < 593.75 ==>>> OK

As = Mu / φs * fyr * z = 2274 mm2

**Pad 2:**

$K = Mu / f'c * bp * dp^2$ = 0.066 < 0.167 OK

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

Z max = 257.9 < 261.25 ==>>> OK

As = Mu / φs * fyr * z = 2134.5 mm2

**Uplift :**

**Pad 1:**

$K = Mu / f'c * bp * dp^2 =$ 0.023 < 0.167 OK

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

Z max = 612.1 > 593.75 ==>>> Zmax=0.95 dp = 593.75

As = Mu / φs * fyr * z = 1667.3 mm2

**Pad 2:**

$K = Mu / f'c * bp * dp^2 =$ 0.051

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

Z max = 262.1 > 261.25 ==>>> Zmax=0.95 dp = 261.25

As = Mu / φs * fyr * z = 1615.0 mm2

**Top of Pad 1 :**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| As1t= | 1667.3 | mm2 | | | | | | | | |
| Rebar Diameter= | 16 | mm | =====> | QTY = | 9 ==>> | 9 | =====> | 9 Ø 16 | =====> | 1810 mm2 |
| Rebar Quantity = | 9 | | | | | | | | | |
| Rebar Spacing = | 193.8 | mm | | | | | | | | |

**Top of Pad 2 :**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| As2t= | 1615.0 | mm2 | | | | | | | | |
| Rebar Diameter= | 12 | mm | =====> | QTY = | 15 ==>> | 15 | =====> | 15 Ø 12 | =====> | 1696 mm2 |
| Rebar Quantity = | 15 | | | | | | | | | |
| Rebar Spacing = | 235.7 | mm | | | | | | | | |

**Bottom of Pad 2 :**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| As2b= | 2274.3 | mm2 | | | | | | | | |
| Rebar Diameter= | 12 | mm | =====> | QTY = | 21 ==>> | 21 | =====> | 21 Ø 12 | =====> | 2375 mm2 |
| Rebar Quantity = | 21 | | | | | | | | | |
| Rebar Spacing = | 165.0 | mm | | | | | | | | |

Min. Rebar Check:

Ast = 5881.1 mm2

ρst = 0.0038 >

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 = 2.34 kg/cm2

Vu1 = 45534 kg = 455342 N

Compression Stress at critical section of shear at Pad2 , σv2 = 2.36 kg/cm2

Vu2 = 36626 kg = 366258 N

**Pad 1**

k = 1 +(200/dp1)^0.5 < 2.0 >>> k = 1.57 EN 1992-1-1:2004 6.2

$\rho_1 =$ 0.0038

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

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

k1 = 0.15

$v_{min} = 0.035 * k^{3/2} * f'c^{1/2} =$ 0.307 Mpa EN 1992-1-1:2004 6.3N

Vr1 = 570732 N

| Vr1 | > | Vu1 | OK |
|---|---|---|---|

F.S= 1.25

**Pad 2**

k = 1 +(200/dp2)^0.5 < 2.0 >>> k = 1.85 EN 1992-1-1:2004 6.2

$\rho_1$ = 0.0043

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

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

k1 = 0.15

$v_{min} = 0.035 * k^{3/2} * f'c^{1/2}$ = 0.395 Mpa EN 1992-1-1:2004 6.3N

Vr2 = 431890 N

| Vr2 | > | Vu2 | OK |
|---|---|---|---|

F.S= 1.18

**Two Way Shear:**

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

**Pad 1**

Vpunch1 = 43225 kg = 432251 N

Resisting Shear of Concrete,

Vr1 = 2507982 N

| Vr1 | > | Vpunch1 | OK |
|---|---|---|---|

F.S.= 5.80

**Pad 2**

To check if punch shear section is defined in Pad 2 ==> bp1 - ( bp2 + 4dp2 ) = 0.65 > 0 ==> Punch Shear to be Checked in Pad 2

Vpunch2 = 67057 kg = 670569 N

Resisting Shear of Concrete,

Vr2 = 1283872 N

| Vr2 | > | Vpunch2 | OK |
|---|---|---|---|

F.S.= 1.91

**Structural Design of Chimney:**

Design of Longitudinal Reinforcement for Uplift :

A) Moment at the bottom of chimney about x axis Mx max = 14.47 ton.m = 144666 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= 16.7 cm2

B) Moment at the bottom of chimney about y axis My max = 2.27 ton.m = 22719 N.m

$\varphi s * fyr = M * c / I$ As2= 2.6 cm2

C) Axial required rebar area, As3 = Ts / ( φs*Fyr) = 19.2 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 = 38.5 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 = | 38.5 | | | | | | | |
| Rebar Diameter = | 16 | mm | =====> QTY = | 20 | =====> | 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 | mm |
| $N_{Ed} =$ | 176.42 | ton |
| $M_{0Ed,x} =$ | 15.11 | ton.m |
| $e_0 = h /30 > 20$ mm ==> $e_0 =$ | 25 | mm |
| $M_{Ed,x} =$ | 18.29 | ton.m |

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

| | | |
|---|---|---|
| $M_{0Ed,y} =$ | 5.98 | ton.m |
| $M_{Ed,y} =$ | 9.16 | ton.m |
| $As * F yr / bc^2 * f'c =$ | 0.179 | |
| $N_{ED}/ f'c * bc^2 =$ | 0.154 | |
| 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 | | | |
| $N_{Ed} / N_{Rd} =$ | 0.19 | ===> | a = | 1.07 | | |
| $(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a =$ | | 0.433 | < | 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-MA |

**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 | 60° C5,C NA+ | 1,490 | 3,764 | -160,380 |
| Maximum Axial Force, Uplift | 60° C5, Min. WS,C NA+ | 566 | 3,602 | 148,209 |

**Maximum Loads on Foundation**

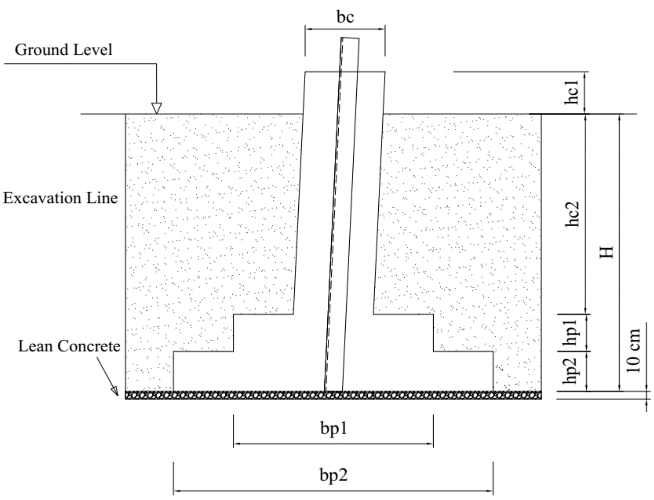
| Description | Load Combination | Foundation Components | | |
|---|---|---|---|---|
| | | *Transversal* | *Longitudinal* | *Vertical* |
| | | kg | kg | kg |
| Maximum Axial Force, Compression | 60° C5,C NA+ | -27,630 | 29,903 | -155,176 |
| Maximum Axial Force, Uplift | 60° C5, Min. WS,C NA+ | -24,740 | 27,778 | 143,510 |

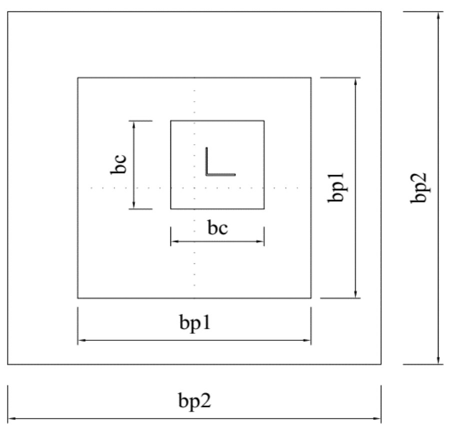
Design Standard: EN 1992:2004

**Inputs:**

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

| | | | | | |
|---|---|---|---|---|---|
| Foundation Dimensions | Width of Pad 1 | bp1 = | 1.8 | m | |
| | Width of Pad 2 | bp2 = | 3.7 | m | |
| | Height of Pad 1 | hp1 = | 0.35 | m | |
| | Height of Pad 2 | hp2 = | 0.35 | 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 = | 3.3 | m | |
| | Depth of Pad | H = | 4 | m | |
| | Inplane Slope | β = | 9.56 | Degree | |
| | Diagonal Slope | γ = | 13.38 | Degree | |
| Soil Specifications | Soil Type | Type 4-Normal Soil-Dry | | | |
| | Natural Soil Density | $\gamma_s$ = | 1.83 | ton/m3 | |
| | Backfill Density | $\gamma_b$ = | 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 | $\gamma_c$ = | 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 = | 170.69 | ton |
| | | Vcx = | -30.39 | ton |
| | | Vcy = | 32.89 | ton |
| | Uplift | T = | 157.86 | ton |
| | | Vtx = | -27.21 | ton |
| | | Vty = | 30.56 | ton |

| | | | | |
|---|---|---|---|---|
| On Stub | Compression | Cs = | 176.42 | ton |
| | | Vscx = | 1.64 | ton |
| | | Vscy = | 4.14 | ton |
| | Uplift | Ts = | 163.03 | ton |
| | | Vstx = | 0.62 | ton |
| | | Vsty = | 3.96 | ton |

Soil Passive Pressure Coefficient Kp = tan 2 (45+φ/2) = 2.46
Passive Force on chimney, Fp1 = 18.46 ton
Passive Force on pad1, Fp2 = 9.90 ton
Passive Force on pad2, Fp3 = 22.39 ton

**Uplift:**

Volume of chimney above ground level V1 = 0.17 m3
Volume of chimney under ground level V2 = 1.86 m3
Volume of pad1, V3 = 1.13 m3
Volume of pad2, V4 = 4.79 m3
Total volume of foundation , Vf = 7.95 m3

Total weight of foundation, Wf = Vf * γc = 19.88 ton

Cone volume, $Vcone = (h/3)*(\pi*h^2*\tan^2\Theta + 3*bp2^2 + 6*bp2*h*\tan\theta) =$ 85.58 m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 = 80.20 m3
Soil weight above foundation, Ws = Vsoil * γb = 147.15 ton

Total resistance force against uplift, Ru= Ws + Wf = 167.02 ton
Uplift Force, U= 157.86 ton

| 167.02 | > | 157.86 | OK |
|---|---|---|---|

S.F.= 1.06

**Additional condition:** G/Z > 0.8 EN 50341 M.3.1.6
G: weight of foundation and soil vertical to the base = 106.07 ton
Z: uplift force on fondation = 143.51 ton

Z/G = 0.74 >>> Ratio = 0.92 OK

**Bearing Capacity:**

Compression Force, C = 171.63 ton
Bending Moment about x axis, Mx = -18.05 ton.m
Bending Moment about y axis, My = 7.15 ton.m

Over Load of Concrete Wf= 19.88 ton

Volume of the Soil directly above foundation $Vsl = (H * bp2^2) - V2 - V3 - V4 =$ 46.98 m3

Over Load of Soil directly above foundation Wsl= Vsl * γb = 86.20 ton

| Average Bearing Pressure = σp = ((C + Wf + Wsl )/A) = | 2.03 | kg/cm2 | < | 2.04 | kg/cm2 | OK |
|---|---|---|---|---|---|---|

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ 1.90 kg/cm2
Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ 1.73 kg/cm2
Compression Stress at corner 3, $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ 2.33 kg/cm2
Compression Stress at corner 4, $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ 2.16 kg/cm2

| | | | | | |
|---|---|---|---|---|---|
| Max. Toe Pressure = | 2.33 | < | $q_{all}$ = | 2.55 | OK |
| Min. Toe Pressure = | 1.73 | > | 0 | | OK |

S.F.= 1.10

**Top Surface Pressure due to Uplift:**

Uplift Force, T = 158.60 ton
Bending Moment about x axis, Mx = -14.47 ton.m
Bending Moment about y axis, My = 2.27 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, $\sigma u2 = ((T-Wf)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ 0.82 kg/cm2
Pressure due to Uplift at top surface at corner 3, $\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ 1.21 kg/cm2
Pressure due to Uplift at top surface at corner 4, $\sigma u4 = ((T-Wf)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ 1.16 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 = 233.62 ton.m

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

Mr = 251.37 ton.m

| Mr | > | Mo | OK |
|---|---|---|---|

S.F.= 1.08

**Sliding:**

Sliding force, Fo = Vmax

Sliding force, Fo = 30.56 ton

Effective weight of foundation and soil at uplift case, Weff = 9.16 ton

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

Fr = 54.42

| Fr | > | Fo | OK |
|---|---|---|---|

S.F.= 1.78

**Structural Design of Pad:**

**Longitudinal Rebar:**

**Compression :**

Compression Stress at section of Max. bending moment at Pad 1, σmc1 = 2.07 kg/cm2

Compression Stress at section of Max. bending moment at Pad 2, σmc2 = 2.13 kg/cm2

**Uplift :**

Compression Stress at section of Max. bending moment at Pad 1, σmu1 = 1.05 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= 6359347 kg.cm = 623852 N.m

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

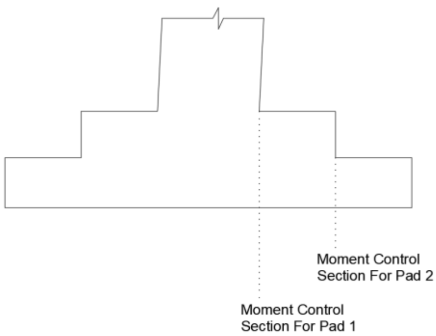
Muc 2= 2564554 kg.cm = 251583 N.m

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

Muu 1= 4584997 kg.cm = 449788 N.m

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

Muu 2= 1929028 kg.cm = 189238 N.m




Effective Depth of pad 1, dp1 = hp1+hp2 - cp = 0.625 m

Effective Depth of pad 2, dp2 = hp2 - cp = 0.275 m

**Compression :**

**Pad 1:**

$K = Mu / f'c * bp * dp^2 =$ 0.067 < 0.167 OK

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

Z max = 586 < 593.75 ==>>> OK

As = Mu / φs * fyr * z = 2556 mm2

**Pad 2:**

$K = Mu / f'c * bp * dp^2 =$ 0.067 < 0.167 OK

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

Z max = 257.5 < 261.25 ==>>> OK

As = Mu / φs * fyr * z = 2344.6 mm2

**Uplift :**

**Pad 1:**

$K = Mu / f'c * bp * dp^2 =$ 0.023 < 0.167 OK

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

Z max = 611.9 > 593.75 ==>>> Zmax=0.95 dp = 593.75

As = Mu / φs * fyr * z = 1818.1 mm2

**Pad 2:**

$K = Mu / f'c * bp * dp^2 =$ 0.051

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

Z max = 262.1 > 261.25 ==>>> Zmax=0.95 dp = 261.25

As = Mu / φs * fyr * z = 1738.5 mm2

**Top of Pad 1 :**

As1t= 1818.1 mm2

Rebar Diameter= 16 mm =====> QTY = 10 ==>> 10 =====> 10 Ø 16 =====> 2011 mm2

Rebar Quantity = 10

Rebar Spacing = 183.3 mm

**Top of Pad 2 :**

As2t= 1738.5 mm2

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

Rebar Quantity = 16

Rebar Spacing = 236.7 mm

**Bottom of Pad 2 :**

As2b= 2555.7 mm2

Rebar Diameter= 12 mm =====> QTY = 23 ==>> 23 =====> 23 Ø 12 =====> 2601 mm2

Rebar Quantity = 23

Rebar Spacing = 161.4 mm

Min. Rebar Check:

Ast = 6421.4 mm2

ρst = 0.0039 >

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 = 2.14 kg/cm2

Vu1 = 49933 kg = 499333 N

Compression Stress at critical section of shear at Pad2 , σv2 = 2.16 kg/cm2

Vu2 = 38302 kg = 383016 N

**Pad 1**

k = 1 +(200/dp1)^0.5 < 2.0 >>> k = 1.57 EN 1992-1-1:2004 6.2

$\rho_1 =$ 0.0039

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

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

k1 = 0.15

$v_{min} = 0.035 * k^{3/2} * f'c^{1/2} =$ 0.307 Mpa EN 1992-1-1:2004 6.3N

Vr1 = 613747 N

| Vr1 | > | Vu1 | OK |
|---|---|---|---|

F.S= 1.23

**Pad 2**

$k = 1 + (200/dp2)^{0.5} < 2.0$ >>> k = 1.85 EN 1992-1-1:2004 6.2

$\rho_1$ = 0.0043

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

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

k1 = 0.15

$v_{min} = 0.035 * k^{3/2} * f'c^{1/2}$ = 0.395 Mpa EN 1992-1-1:2004 6.3N

Vr2 = 464746 N

| Vr2 | > | Vu2 | OK |
|---|---|---|---|

F.S= 1.21

**Two Way Shear:**

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

**Pad 1**

Vpunch1 = 63590 kg = 635903 N

Resisting Shear of Concrete,

Vr1 = 2527163 N

| Vr1 | > | Vpunch1 | OK |
|---|---|---|---|

F.S.= 3.97

**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 = 75272 kg = 752717 N

Resisting Shear of Concrete,

Vr2 = 1338438 N

| Vr2 | > | Vpunch2 | OK |
|---|---|---|---|

F.S.= 1.78

**Structural Design of Chimney:**

Design of Longitudinal Reinforcement for Uplift :

A) Moment at the bottom of chimney about x axis Mx max = 14.47 ton.m = 144666 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= 16.7 cm2

B) Moment at the bottom of chimney about y axis My max = 2.27 ton.m = 22719 N.m

$\varphi s * fyr = M * c / I$ As2= 2.6 cm2

C) Axial required rebar area, As3 = Ts / ( φs*Fyr) = 19.2 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 = 38.5 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 = | 38.5 | | | | | | | |
| Rebar Diameter = | 16 | mm | =====> QTY = | 20 | =====> | 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 | mm |
| $N_{Ed} =$ | 176.42 | ton |
| $M_{0Ed, x} =$ | 15.11 | ton.m |
| $e_0 = h /30 > 20$ mm ==> $e_0 =$ | 25 | mm |
| $M_{Ed,x} =$ | 18.29 | ton.m |

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

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $M_{0Ed, y} =$ | 5.98 | ton.m | | | | | |
| $M_{Ed,y} =$ | 9.16 | ton.m | | | | | |
| $As * F yr / bc^2 * f'c =$ | 0.179 | | | | | | |
| $N_{ED}/ f'c * bc^2 =$ | 0.154 | | | | | | |
| 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 | | | |
| $N_{Ed} / N_{Rd} =$ | 0.19 | | ===> | a = | 1.07 | | |
| $(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a =$ | | | 0.433 | < | 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-MA

| 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 | 60° C5,C NA+ | 1,490 | 3,764 | -160,380 |
| Maximum Axial Force, Uplift | 60° C5, Min. WS,C NA+ | 566 | 3,602 | 148,209 |

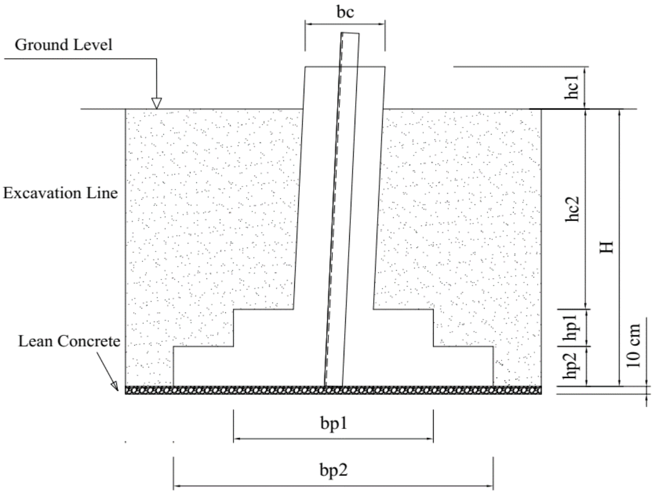
| Maximum Loads on Foundation | | | | |
|---|---|---|---|---|
| *Description* | *Load Combination* | *Foundation Components* | | |
| | | *Transversal* | *Longitudinal* | *Vertical* |
| | | kg | kg | kg |
| Maximum Axial Force, Compression | 60° C5,C NA+ | -27,630 | 29,903 | -155,176 |
| Maximum Axial Force, Uplift | 60° C5, Min. WS,C NA+ | -24,740 | 27,778 | 143,510 |

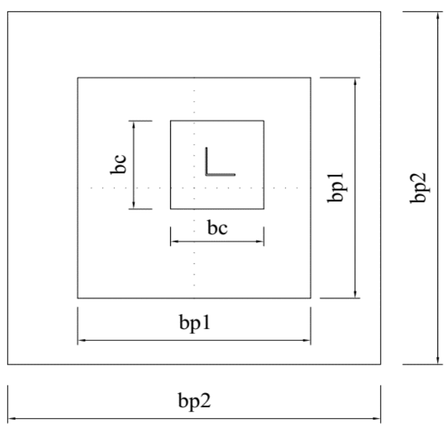
Design Standard: EN 1992:2004

**Inputs:**

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

| | | | | | |
|---|---|---|---|---|---|
| Foundation Dimensions | Width of Pad 1 | bp1 = | 2.2 | m | |
| | Width of Pad 2 | bp2 = | 5.15 | m | |
| | Height of Pad 1 | hp1 = | 0.35 | m | |
| | Height of Pad 2 | hp2 = | 0.35 | 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 = | 3.3 | m | |
| | Depth of Pad | H = | 4 | m | |
| | Inplane Slope | $\beta$ = | 9.56 | Degree | |
| | Diagonal Slope | $\gamma$ = | 13.38 | Degree | |
| Soil Specifications | Soil Type | Type 4-Normal Soil-Submerge | | | |
| | Natural Soil Density | $\gamma_s$ = | 1.02 | ton/m3 | |
| | Backfill Density | $\gamma_b$ = | 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 | $\Theta$ = | 15 | Degree | |
| | Internal Friction Angle | $\phi$ = | 25 | Degree | EN 50341 Table M.4 |
| | Friction Coefficient Between Soil and Concrete | $\mu$ = | 0.4 | | |
| Concrete | Compressive Strength(28 days of Cylindrical Sample) | f 'c = | 20 | Mpa | |
| | Strength Reduction Factor | $\varphi c$ = | 0.67 | | Tech. Spec. Section C1 3.2.2 |
| | Allowable Compressive Strength | f 'c = | 13.3 | Mpa | |
| | Density | $\gamma_c$ = | 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 | $\varphi s$ = | 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 = | 170.69 | ton |
| | | Vcx = | -30.39 | ton |
| | | Vcy = | 32.89 | ton |
| | Uplift | T = | 157.86 | ton |
| | | Vtx = | -27.21 | ton |
| | | Vty = | 30.56 | ton |

| | | | | |
|---|---|---|---|---|
| On Stub | Compression | Cs = | 176.42 | ton |
| | | Vscx = | 1.64 | ton |
| | | Vscy = | 4.14 | ton |
| | Uplift | Ts = | 163.03 | ton |
| | | Vstx = | 0.62 | ton |
| | | Vsty = | 3.96 | ton |

| | | | |
|---|---|---|---|
| Soil Passive Pressure Coefficient | Kp = tan 2 (45+φ/2) = | 2.46 | |
| Passive Force on chimney, | Fp1 = | 10.26 | ton |
| Passive Force on pad1, | Fp2 = | 6.72 | ton |
| Passive Force on pad2, | Fp3 = | 17.32 | ton |

**Uplift:**

| | | | |
|---|---|---|---|
| Volume of chimney above ground level | V1 = | 0.17 | m3 |
| Volume of chimney under ground level | V2 = | 1.86 | m3 |
| Volume of pad1, | V3 = | 1.69 | m3 |
| Volume of pad2, | V4 = | 9.28 | m3 |
| Total volume of foundation , | Vf = | 13.00 | m3 |

Total weight of foundation, Wf = Vf * γc = 19.50 ton

Cone volume, $V_{cone} = (h/3)*(\pi*h^2*\tan^2\Theta + 3*bp2^2 + 6*bp2*h*\tan\theta) =$ 146.03 m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 = 137.84 m3

Soil weight above foundation, Ws = Vsoil * γb = 140.51 ton

Total resistance force against uplift, Ru= Ws + Wf = 160.02 ton

Uplift Force, U= 157.86 ton

| | | | | |
|---|---|---|---|---|
| 160.02 | > | 157.86 | 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 = 114.57 ton

Z: uplift force on fondation = 143.51 ton

Z/G = 0.80 >>> Ratio = 1.00 OK

**Bearing Capacity:**

| | | | |
|---|---|---|---|
| Compression Force, | C = | 171.63 | ton |
| Bending Moment about x axis, | Mx = | -18.05 | ton.m |
| Bending Moment about y axis, | My = | 7.15 | ton.m |

Over Load of Concrete Wf= 19.50 ton

Volume of the Soil directly above foundation $V_{sl} = (H * bp2^2) - V2 - V3 - V4 =$ 93.26 m3

Over Load of Soil directly above foundation Wsl= Vsl * γb = 95.06 ton

| | | | | | | |
|---|---|---|---|---|---|---|
| Average Bearing Pressure = σp = ((C + Wf + Wsl )/A) = | 1.08 | kg/cm2 | < | 2.04 | kg/cm2 | OK |

| | | | |
|---|---|---|---|
| Compression Stress at corner 1, | $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ | 1.03 | kg/cm2 |
| Compression Stress at corner 2, | $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ | 0.97 | kg/cm2 |
| Compression Stress at corner 3, | $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ | 1.19 | kg/cm2 |
| Compression Stress at corner 4, | $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ | 1.13 | kg/cm2 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Max. Toe Pressure = | 1.19 | < | $q_{all}$ = | 2.55 | OK | S.F.= 2.14 |
| Min. Toe Pressure = | 0.97 | > | 0 | | OK | |

**Top Surface Pressure due to Uplift:**

| | | | |
|---|---|---|---|
| Uplift Force, | T = | 158.60 | ton |
| Bending Moment about x axis, | Mx = | -14.47 | ton.m |
| Bending Moment about y axis, | My = | 2.27 | ton.m |

| | | | |
|---|---|---|---|
| Pressure due to Uplift at top surface at corner 1, | $\sigma u1 = ((T-Wf)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ | 0.47 | 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, | $\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ | 0.60 | kg/cm2 |
| Pressure due to Uplift at top surface at corner 4, | $\sigma u4 = ((T-Wf)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ | 0.58 | 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 = 311.01 ton.m

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

Mr = 335.00 ton.m

| Mr | > | Mo | OK |
|---|---|---|---|

S.F.= 1.08

**Sliding:**

Sliding force, Fo = Vmax

Sliding force, Fo = 30.56 ton

Effective weight of foundation and soil at uplift case, Weff = 2.16 ton

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

Fr = 35.16

| Fr | > | Fo | OK |
|---|---|---|---|

S.F.= 1.15

**Structural Design of Pad:**

**Longitudinal Rebar:**

**Compression :**

Compression Stress at section of Max. bending moment at Pad 1, σmc1 = 1.09 kg/cm2

Compression Stress at section of Max. bending moment at Pad 2, σmc2 = 1.11 kg/cm2

**Uplift :**

Compression Stress at section of Max. bending moment at Pad 1, σmu1 = 0.53 kg/cm2

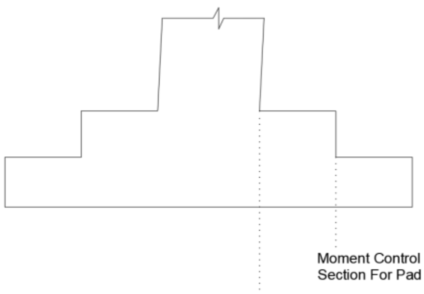
Compression Stress at section of Max. bending moment at Pad 2, σmu2 = 0.55 kg/cm2

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

Muc 1= 9962660 kg.cm = 977337 N.m

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

Muc 2= 4320125 kg.cm = 423804 N.m




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

Muu 1= 7102752 kg.cm = 696780 N.m

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

Muu 2= 3226165 kg.cm = 316487 N.m

Effective Depth of pad 1, dp1 = hp1+hp2 - cp = 0.625 m

Effective Depth of pad 2, dp2 = hp2 - cp = 0.275 m

**Compression :**

**Pad 1:**

$K = Mu / f'c * bp * dp^2 =$ 0.085 < 0.167 OK

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

Z max = 574 < 593.75 ==>>> OK

As = Mu / φs * fyr * z = 4088 mm2

**Pad 2:**

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

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

Z max = 253.5 < 261.25 ==>>> OK

As = Mu / φs * fyr * z = 4012.0 mm2

**Uplift :**

**Pad 1:**

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

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

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Z max = | 610.3 | > | 593.75 | ==>>> | Zmax=0.95 dp = | 593.75 | |
| As = Mu / φs * fyr * z = | 2816.5 | 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 = | 259.3 | < | 261.25 | ==>>> | OK |
| As = Mu / φs * fyr * z = | 2929.1 | mm2 | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Top of Pad 1 :** | | | | | | | | | | |
| As1t= | 2816.5 | mm2 | | | | | | | | |
| Rebar Diameter= | 16 | mm | =====> | QTY = | 15 ==>> | 15 | =====> | 15 Ø 16 | =====> | 3016 mm2 |
| Rebar Quantity = | 15 | | | | | | | | | |
| Rebar Spacing = | 146.4 | mm | | | | | | | | |
| **Top of Pad 2 :** | | | | | | | | | | |
| As2t= | 2929.1 | mm2 | | | | | | | | |
| Rebar Diameter= | 12 | mm | =====> | QTY = | 26 ==>> | 26 | =====> | 26 Ø 12 | =====> | 2941 mm2 |
| Rebar Quantity = | 26 | | | | | | | | | |
| Rebar Spacing = | 200.0 | mm | | | | | | | | |
| **Bottom of Pad 2 :** | | | | | | | | | | |
| As2b= | 4088.1 | mm2 | | | | | | | | |
| Rebar Diameter= | 12 | mm | =====> | QTY = | 37 ==>> | 37 | =====> | 37 Ø 12 | =====> | 4185 mm2 |
| Rebar Quantity = | 37 | | | | | | | | | |
| Rebar Spacing = | 138.9 | mm | | | | | | | | |

Min. Rebar Check:

| | | | | | |
|---|---|---|---|---|---|
| Ast = | 10141.1 | mm2 | | | |
| ρst = | 0.0046 | > | | | |
| 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 = | 1.11 | kg/cm2 | |
| Vu1 = 64704 | kg | = | 647043 | N |
| Compression Stress at critical section of shear at Pad2 , | σv2 = | 1.12 | kg/cm2 | |
| Vu2 = 47450 | kg | = | 474505 | N |

**Pad 1**

| | | | | | |
|---|---|---|---|---|---|
| k = 1 +(200/dp1)^0.5 < 2.0 | >>> | k = | 1.57 | EN 1992-1-1:2004 | 6.2 |
| $\rho_1 =$ | 0.0046 | | | | |
| $\sigma_{cp} = N_{ED}/A_C =$ | 0 | No Axial Force! | | | |
| $C_{Rd,c} = 0.18/\gamma_c =$ | 0.12 | | | | |
| k1 = | 0.15 | | | | |
| $v_{min} = 0.035 * k^{3/2} * f'c^{1/2} =$ | 0.307 | Mpa | | EN 1992-1-1:2004 | 6.3N |

Vr1 = 863091 N

| Vr1 | > | Vu1 | OK |
|---|---|---|---|

F.S= 1.33

**Pad 2**

k = 1 +(200/dp2)^0.5 < 2.0 >>> k = 1.85 EN 1992-1-1:2004 6.2

$\rho_1$ = 0.0050

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

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

k1 = 0.15

$v_{min} = 0.035 * k^{3/2} * f'c^{1/2}$ = 0.395 Mpa EN 1992-1-1:2004 6.3N

Vr2 = 679795 N

| Vr2 | > | Vu2 | OK |
|---|---|---|---|

F.S= 1.43

**Two Way Shear:**

Average Compression Stress at the Middle of Pad , σ ave = 1.08 kg/cm2

**Pad 1**

Vpunch1 = 128490 kg = 1284904 N

Resisting Shear of Concrete,

Vr1 = 2678095 N

| Vr1 | > | Vpunch1 | OK |
|---|---|---|---|

F.S.= 2.08

**Pad 2**

To check if punch shear section is defined in Pad 2 ==> bp1 - ( bp2 + 4dp2 ) = 1.85 > 0 ==> Punch Shear to be Checked in Pad 2

Vpunch2 = 112356 kg = 1123556 N

Resisting Shear of Concrete,

Vr2 = 1617748 N

| Vr2 | > | Vpunch2 | OK |
|---|---|---|---|

F.S.= 1.44

**Structural Design of Chimney:**

Design of Longitudinal Reinforcement for Uplift :

A) Moment at the bottom of chimney about x axis Mx max = 14.47 ton.m = 144666 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= 16.7 cm2

B) Moment at the bottom of chimney about y axis My max = 2.27 ton.m = 22719 N.m

$\varphi s * fyr = M * c / I$ As2= 2.6 cm2

C) Axial required rebar area, As3 = Ts / ( φs*Fyr) = 19.2 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 = 38.5 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 = | 38.5 | | | | | | | | | |
| Rebar Diameter = | 16 | mm | =====> | QTY = | 20 | =====> | 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 | mm |
| $N_{Ed} =$ | 176.42 | ton |
| $M_{0Ed, x} =$ | 15.11 | ton.m |
| $e_0 = h /30 > 20$ mm ==> $e_0 =$ | 25 | mm |
| $M_{Ed,x} =$ | 18.29 | ton.m |

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

| | | |
|---|---|---|
| $M_{0Ed, y} =$ | 5.98 | ton.m |
| $M_{Ed,y} =$ | 9.16 | ton.m |
| $As * F yr / bc^2 * f'c =$ | 0.179 | |
| $N_{ED}/ f'c * bc^2 =$ | 0.154 | |
| 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

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

$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a =$ 0.433 < 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-MA

| 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 | 60° C5,C NA+ | 1,490 | 3,764 | -160,380 |
| Maximum Axial Force, Uplift | 60° C5, Min. WS,C NA+ | 566 | 3,602 | 148,209 |

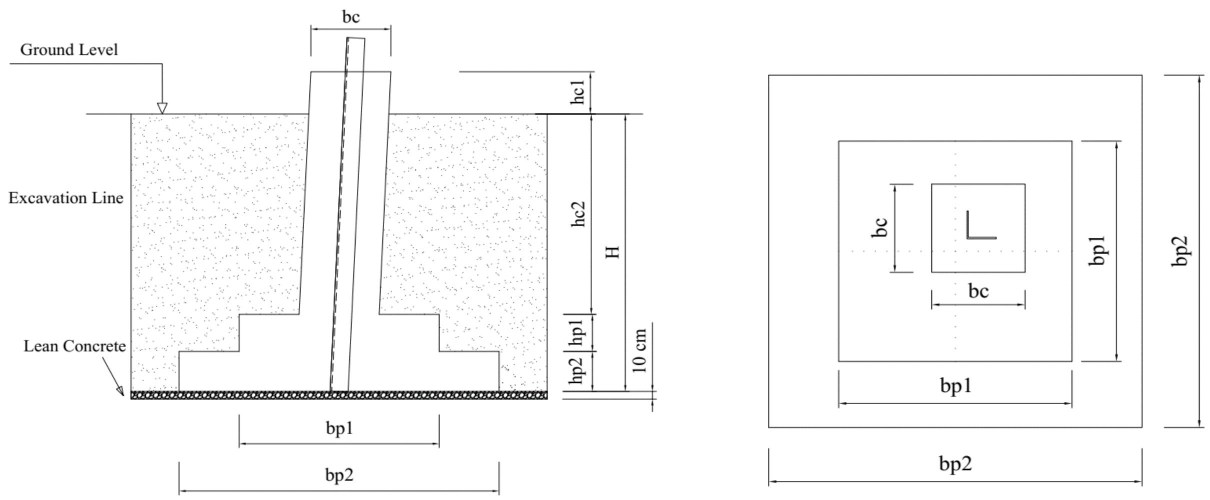
| Maximum Loads on Foundation | | | | |
|---|---|---|---|---|
| *Description* | *Load Combination* | *Foundation Components* | | |
| | | *Transversal* | *Longitudinal* | *Vertical* |
| | | kg | kg | kg |
| Maximum Axial Force, Compression | 60° C5,C NA+ | -27,630 | 29,903 | -155,176 |
| Maximum Axial Force, Uplift | 60° C5, Min. WS,C NA+ | -24,740 | 27,778 | 143,510 |

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 = | 4.8 | m | |
| | Height of Pad 1 | hp1 = | 0.35 | m | |
| | Height of Pad 2 | hp2 = | 0.35 | 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 = | 3.3 | m | |
| | Depth of Pad | H = | 4 | m | |
| | Inplane Slope | $\beta$ = | 9.56 | Degree | |
| | Diagonal Slope | $\gamma$ = | 13.38 | Degree | |
| Soil Specifications | Soil Type | Type 5-Poor Soil-Dry | | | |
| | Natural Soil Density | $\gamma_s$ = | 1.63 | ton/m3 | |
| | Backfill Density | $\gamma_b$ = | 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 | $\Theta$ = | 0 | Degree | |
| | Internal Friction Angle | $\phi$ = | 15 | Degree | EN 50341 Table M.4 |
| | Friction Coefficient Between Soil and Concrete | $\mu$ = | 0.4 | | |
| Concrete | Compressive Strength(28 days of Cylindrical Sample) | f 'c = | 20 | Mpa | |
| | Strength Reduction Factor | $\varphi c$ = | 0.67 | | Tech. Spec. Section C1 3.2.2 |
| | Allowable Compressive Strength | f 'c = | 13.3 | Mpa | |
| | Density | $\gamma_c$ = | 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 | $\varphi s$ = | 0.83 | | Tech. Spec. Section C1 3.2.2 |




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

* The foundation is cast inside formwork.

MİTAŞ ENERGY

**Ultimate Loads:**

| | | | | |
|---|---|---|---|---|
| On Foundation | Compression | C = | 170.69 | ton |
| | | Vcx = | -30.39 | ton |
| | | Vcy = | 32.89 | ton |
| | Uplift | T = | 157.86 | ton |
| | | Vtx = | -27.21 | ton |
| | | Vty = | 30.56 | ton |

| | | | | |
|---|---|---|---|---|
| On Stub | Compression | Cs = | 176.42 | ton |
| | | Vscx = | 1.64 | ton |
| | | Vscy = | 4.14 | ton |
| | Uplift | Ts = | 163.03 | ton |
| | | Vstx = | 0.62 | ton |
| | | Vsty = | 3.96 | ton |

| | | | |
|---|---|---|---|
| Soil Passive Pressure Coefficient | Kp = tan 2 (45+φ/2) = | 1.70 | |
| Passive Force on chimney, | Fp1 = | 11.31 | ton |
| Passive Force on pad1, | Fp2 = | 6.74 | ton |
| Passive Force on pad2, | Fp3 = | 17.80 | ton |

**Uplift:**

| | | | |
|---|---|---|---|
| Volume of chimney above ground level | V1 = | 0.17 | m3 |
| Volume of chimney under ground level | V2 = | 1.86 | m3 |
| Volume of pad1, | V3 = | 1.40 | m3 |
| Volume of pad2, | V4 = | 8.06 | m3 |
| Total volume of foundation , | Vf = | 11.49 | m3 |

Total weight of foundation, Wf = Vf * γc = 28.72 ton

Cone volume, $V_{cone} = (h/3)*(\pi*h^2*\tan^2\Theta + 3*bp2^2 + 6*bp2*h*\tan\theta) =$ 88.13 m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 = 80.84 m3

Soil weight above foundation, Ws = Vsoil * γb = 131.85 ton

Total resistance force against uplift, Ru= Ws + Wf = 160.57 ton

Uplift Force, U= 157.86 ton

| | | | |
|---|---|---|---|
| 160.57 | > | 157.86 | OK |

S.F.= 1.02

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

G: weight of foundation and soil vertical to the base = 160.57 ton

Z: uplift force on fondation = 143.51 ton

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

**Bearing Capacity:**

| | | | |
|---|---|---|---|
| Compression Force, | C = | 171.63 | ton |
| Bending Moment about x axis, | Mx = | -18.05 | ton.m |
| Bending Moment about y axis, | My = | 7.15 | ton.m |

Over Load of Concrete Wf= 28.72 ton

Volume of the Soil directly above foundation Vsl = $(H * bp2^2)$ - V2 - V3 - V4 = 80.84 m3

Over Load of Soil directly above foundation Wsl= Vsl * γb = 131.85 ton

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

| | | | |
|---|---|---|---|
| Compression Stress at corner 1, | $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ | 1.38 | kg/cm2 |
| Compression Stress at corner 2, | $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ | 1.31 | kg/cm2 |
| Compression Stress at corner 3, | $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ | 1.58 | kg/cm2 |
| Compression Stress at corner 4, | $\sigma p4 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ | 1.50 | kg/cm2 |

| | | | | | |
|---|---|---|---|---|---|
| Max. Toe Pressure = | 1.58 | < | $q_{all}$ = | 1.91 | OK |
| Min. Toe Pressure = | 1.31 | > | | 0 | OK |

S.F.= 1.21

**Top Surface Pressure due to Uplift:**

| | | | |
|---|---|---|---|
| Uplift Force, | T = | 158.60 | ton |
| Bending Moment about x axis, | Mx = | -14.47 | ton.m |
| Bending Moment about y axis, | My = | 2.27 | ton.m |

| | | | |
|---|---|---|---|
| Pressure due to Uplift at top surface at corner 1, | $\sigma u1 = ((T-Wf)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ | 0.50 | kg/cm2 |
| Pressure due to Uplift at top surface at corner 2, | $\sigma u2 = ((T-Wf)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3) =$ | 0.47 | kg/cm2 |
| Pressure due to Uplift at top surface at corner 3, | $\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3) =$ | 0.65 | 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 = 292.33 ton.m

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

Mr = 309.65 ton.m

| Mr | > | Mo | OK |
|---|---|---|---|

S.F.= 1.06

**Sliding:**

Sliding force, Fo = Vmax

Sliding force, Fo = 30.56 ton

Effective weight of foundation and soil at uplift case, Weff = 2.71 ton

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

Fr = 36.94

| Fr | > | Fo | OK |
|---|---|---|---|

S.F.= 1.21

**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 = 1.48 kg/cm2

**Uplift :**

Compression Stress at section of Max. bending moment at Pad 1, σmu1 = 0.58 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= 9585612 kg.cm = 940349 N.m

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

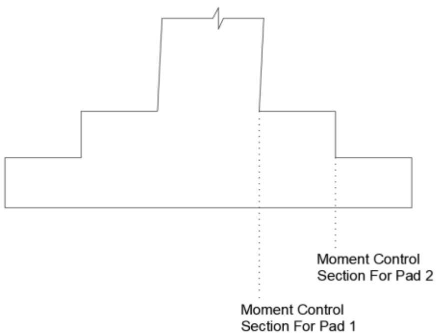
Muc 2= 4353157 kg.cm = 427045 N.m

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

Muu 1= 6102964 kg.cm = 598701 N.m

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

Muu 2= 2949119 kg.cm = 289309 N.m




Effective Depth of pad 1, dp1 = hp1+hp2 - cp = 0.625 m

Effective Depth of pad 2, dp2 = hp2 - cp = 0.275 m

**Compression :**

**Pad 1:**

$K = Mu / f'c * bp * dp^2 =$ 0.090 < 0.167 OK

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

Z max = 570 < 593.75 ==>>> OK

As = Mu / φs * fyr * z = 3956 mm2

**Pad 2:**

$K = Mu / f'c * bp * dp^2 =$ 0.088 < 0.167 OK

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

Z max = 251.6 < 261.25 ==>>> OK

As = Mu / φs * fyr * z = 4073.5 mm2

**Uplift :**

**Pad 1:**

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

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

Z max = 611.5 > 593.75 ==>>> Zmax=0.95 dp = 593.75

As = Mu / φs * fyr * z = 2420.0 mm2

**Pad 2:**

$K = Mu / f'c * bp * dp^2 =$ 0.060

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

Z max = 259.6 < 261.25 ==>>> OK

As = Mu / φs * fyr * z = 2674.2 mm2

**Top of Pad 1 :**

As1t= 2420.0 mm2

Rebar Diameter= 16 mm =====> QTY = 13 ==>> 13 =====> 13 Ø 16 =====> 2614 mm2

Rebar Quantity = 13

Rebar Spacing = 154.2 mm

**Top of Pad 2 :**

As2t= 2674.2 mm2

Rebar Diameter= 12 mm =====> QTY = 24 ==>> 24 =====> 24 Ø 12 =====> 2714 mm2

Rebar Quantity = 24

Rebar Spacing = 202.2 mm

**Bottom of Pad 2 :**

As2b= 4073.5 mm2

Rebar Diameter= 16 mm =====> QTY = 21 ==>> 21 =====> 21 Ø 16 =====> 4222 mm2

Rebar Quantity = 21

Rebar Spacing = 232.5 mm

Min. Rebar Check:

Ast = 9550.4 mm2

ρst = 0.0047 >

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 = 1.48 kg/cm2

Vu1 = 65384 kg = 653842 N

Compression Stress at critical section of shear at Pad2 , σv2 = 1.49 kg/cm2

Vu2 = 49761 kg = 497613 N

**Pad 1**

k = 1 +(200/dp1)^0.5 < 2.0 >>> k = 1.57 EN 1992-1-1:2004 6.2

$\rho_1 =$ 0.0047

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

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

k1 = 0.15

$v_{min} = 0.035 * k^{3/2} * f'c^{1/2} =$ 0.307 Mpa EN 1992-1-1:2004 6.3N

Vr1 = 802548 N

| Vr1 | > | Vu1 | OK |
|---|---|---|---|

F.S= 1.23

**Pad 2**

k = 1 +(200/dp2)^0.5 < 2.0 >>> k = 1.85 EN 1992-1-1:2004 6.2

$\rho_1$ = 0.0053

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

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

k1 = 0.15

$v_{min} = 0.035 * k^{3/2} * f'c^{1/2}$ = 0.395 Mpa EN 1992-1-1:2004 6.3N

Vr2 = 642864 N

| Vr2 | > | Vu2 | OK |
|---|---|---|---|

F.S= 1.29

**Two Way Shear:**

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

**Pad 1**

Vpunch1 = 124867 kg = 1248671 N

Resisting Shear of Concrete,

Vr1 = 2695187 N

| Vr1 | > | Vpunch1 | OK |
|---|---|---|---|

F.S.= 2.16

**Pad 2**

To check if punch shear section is defined in Pad 2 ==> bp1 - ( bp2 + 4dp2 ) = 1.7 > 0 ==> Punch Shear to be Checked in Pad 2

Vpunch2 = 115886 kg = 1158859 N

Resisting Shear of Concrete,

Vr2 = 1534270 N

| Vr2 | > | Vpunch2 | OK |
|---|---|---|---|

F.S.= 1.32

**Structural Design of Chimney:**

Design of Longitudinal Reinforcement for Uplift :

A) Moment at the bottom of chimney about x axis Mx max = 14.47 ton.m = 144666 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 *$\Sigma di^2$)

As1= 16.7 cm2

B) Moment at the bottom of chimney about y axis My max = 2.27 ton.m = 22719 N.m

φs * fyr = M * c /I As2= 2.6 cm2

C) Axial required rebar area, As3 = Ts / ( φs*Fyr) = 19.2 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 = 38.5 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 = | 38.5 | | | | | | | | |
| Rebar Diameter = | 16 | mm | =====> QTY = | 20 | =====> | 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 | mm |
| $N_{Ed} =$ | 176.42 | ton |
| $M_{0Ed,x} =$ | 15.11 | ton.m |
| $e_0 = h /30 > 20$ mm ==> $e_0 =$ | 25 | mm |
| $M_{Ed,x} =$ | 18.29 | ton.m |

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

| | | |
|---|---|---|
| $M_{0Ed,y} =$ | 5.98 | ton.m |
| $M_{Ed,y} =$ | 9.16 | ton.m |
| $As * F yr / bc^2 * f'c =$ | 0.179 | |
| $N_{ED}/ f'c * bc^2 =$ | 0.154 | |
| 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 | | | |
| $N_{Ed} / N_{Rd} =$ | 0.19 | ===> | a = | 1.07 | | |
| $(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a =$ | | 0.433 | < | 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-MA

| 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 | 60° C5,C NA+ | 1,490 | 3,764 | -160,380 |
| Maximum Axial Force, Uplift | 60° C5, Min. WS,C NA+ | 566 | 3,602 | 148,209 |

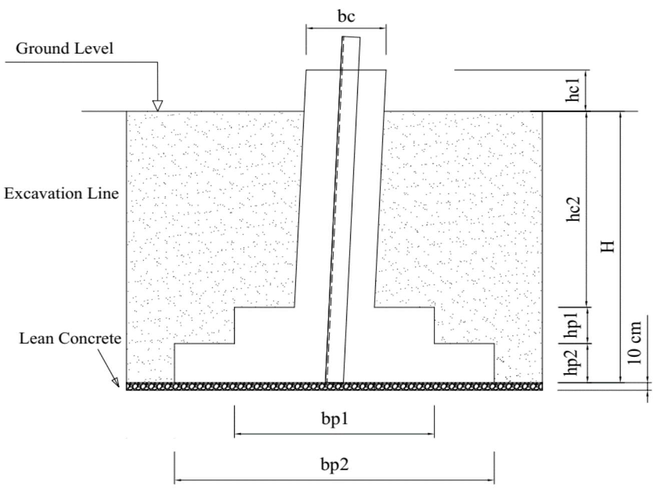
| Maximum Loads on Foundation | | | | |
|---|---|---|---|---|
| *Description* | *Load Combination* | *Foundation Components* | | |
| | | *Transversal* | *Longitudinal* | *Vertical* |
| | | kg | kg | kg |
| Maximum Axial Force, Compression | 60° C5,C NA+ | -27,630 | 29,903 | -155,176 |
| Maximum Axial Force, Uplift | 60° C5, Min. WS,C NA+ | -24,740 | 27,778 | 143,510 |

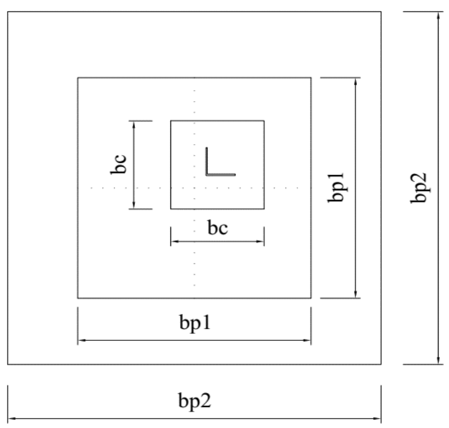
Design Standard: EN 1992:2004

**Inputs:**

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

| | | | | | |
|---|---|---|---|---|---|
| Foundation Dimensions | Width of Pad 1 | bp1 = | 2.8 | m | |
| | Width of Pad 2 | bp2 = | 7.1 | m | |
| | Height of Pad 1 | hp1 = | 0.35 | m | |
| | Height of Pad 2 | hp2 = | 0.35 | 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 = | 3.3 | m | |
| | Depth of Pad | H = | 4 | m | |
| | Inplane Slope | $\beta$ = | 9.56 | Degree | |
| | Diagonal Slope | $\gamma$ = | 13.38 | Degree | |
| Soil Specifications | Soil Type | Type 5-Poor Soil-Submerge | | | |
| | Natural Soil Density | $\gamma_s$ = | 0.82 | ton/m3 | |
| | Backfill Density | $\gamma_b$ = | 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 | $\Theta$ = | 0 | Degree | |
| | Internal Friction Angle | $\phi$ = | 15 | Degree | EN 50341 Table M.4 |
| | Friction Coefficient Between Soil and Concrete | $\mu$ = | 0.4 | | |
| Concrete | Compressive Strength(28 days of Cylindrical Sample) | f 'c = | 20 | Mpa | |
| | Strength Reduction Factor | $\varphi c$ = | 0.67 | | Tech. Spec. Section C1 3.2.2 |
| | Allowable Compressive Strength | f 'c = | 13.3 | Mpa | |
| | Density | $\gamma_c$ = | 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 | $\varphi s$ = | 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 = | 170.69 | ton |
| | | Vcx = | -30.39 | ton |
| | | Vcy = | 32.89 | ton |
| | Uplift | T = | 157.86 | ton |
| | | Vtx = | -27.21 | ton |
| | | Vty = | 30.56 | ton |

| | | | | |
|---|---|---|---|---|
| On Stub | Compression | Cs = | 176.42 | ton |
| | | Vscx = | 1.64 | ton |
| | | Vscy = | 4.14 | ton |
| | Uplift | Ts = | 163.03 | ton |
| | | Vstx = | 0.62 | ton |
| | | Vsty = | 3.96 | ton |

Soil Passive Pressure Coefficient Kp = tan 2 (45+φ/2) = 1.70
Passive Force on chimney, Fp1 = 5.66 ton
Passive Force on pad1, Fp2 = 4.72 ton
Passive Force on pad2, Fp3 = 13.16 ton

**Uplift:**

Volume of chimney above ground level V1 = 0.17 m3
Volume of chimney under ground level V2 = 1.86 m3
Volume of pad1, V3 = 2.74 m3
Volume of pad2, V4 = 17.64 m3
Total volume of foundation , Vf = 22.41 m3

Total weight of foundation, Wf = Vf * γc = 33.62 ton

Cone volume, Vcone = $(h/3)*(\pi*h^2*\tan^2\Theta + 3*bp2^2 + 6*bp2*h*\tan\theta)$ = 192.82 m3

Soil volume above foundation, Vsoil =Vcone -V2 -V3 = 179.40 m3
Soil weight above foundation, Ws = Vsoil * γb = 146.30 ton

Total resistance force against uplift, Ru= Ws + Wf = 179.92 ton
Uplift Force, U= 157.86 ton

| | | | |
|---|---|---|---|
| 179.92 | > | 157.86 | OK |

S.F.= 1.14

**Additional condition:** G/Z > 0.8 EN 50341 M.3.1.6
G: weight of foundation and soil vertical to the base = 179.92 ton
Z: uplift force on fondation = 143.51 ton

Z/G = 1.25 >>> Ratio = 1.57 OK

**Bearing Capacity:**

Compression Force, C = 171.63 ton
Bending Moment about x axis, Mx = -18.05 ton.m
Bending Moment about y axis, My = 7.15 ton.m

Over Load of Concrete Wf= 33.62 ton

Volume of the Soil directly above foundation Vsl = $(H * bp2^2)$ - V2 - V3 - V4 = 179.40 m3

Over Load of Soil directly above foundation Wsl= Vsl * γb = 146.30 ton

| | | | | | | |
|---|---|---|---|---|---|---|
| Average Bearing Pressure = σp = ((C + Wf + Wsl )/A) = | 0.70 | kg/cm2 | < | 0.82 | kg/cm2 | OK |

Compression Stress at corner 1, $\sigma p1 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3)$ = 0.68 kg/cm2
Compression Stress at corner 2, $\sigma p2 = ((C + Wf + Wsl)/A) + (6*Mx)/(bp2^3) - (6*My)/(bp2^3)$ = 0.66 kg/cm2
Compression Stress at corner 3, $\sigma p3 = ((C + Wf + Wsl)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3)$ = 0.74 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 = | 0.74 | < | $q_{all}$ = | 1.02 | OK |
| Min. Toe Pressure = | 0.66 | > | 0 | | OK |

S.F.= 1.38

**Top Surface Pressure due to Uplift:**

Uplift Force, T = 158.60 ton
Bending Moment about x axis, Mx = -14.47 ton.m
Bending Moment about y axis, My = 2.27 ton.m

Pressure due to Uplift at top surface at corner 1, $\sigma u1 = ((T-Wf)/A) + (6*Mx)/(bp2^3) + (6*My)/(bp2^3)$ = 0.23 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, $\sigma u3 = ((T-Wf)/A) - (6*Mx)/(bp2^3) + (6*My)/(bp2^3)$ = 0.28 kg/cm2
Pressure due to Uplift at top surface at corner 4, $\sigma u4 = ((T-Wf)/A) - (6*Mx)/(bp2^3) - (6*My)/(bp2^3)$ = 0.27 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 = 415.08 ton.m

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

Mr = 512.36 ton.m

| Mr | > | Mo | OK |
|---|---|---|---|

S.F.= 1.23

**Sliding:**

Sliding force, Fo = Vmax

Sliding force, Fo = 30.56 ton

Effective weight of foundation and soil at uplift case, Weff = 22.05 ton

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

Fr = 32.36

| 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 = 0.70 kg/cm2

Compression Stress at section of Max. bending moment at Pad 2, σmc2 = 0.71 kg/cm2

**Uplift :**

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

Compression Stress at section of Max. bending moment at Pad 2, σmu2 = 0.26 kg/cm2

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

Muc 1= 16085669 kg.cm = 1578004 N.m

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

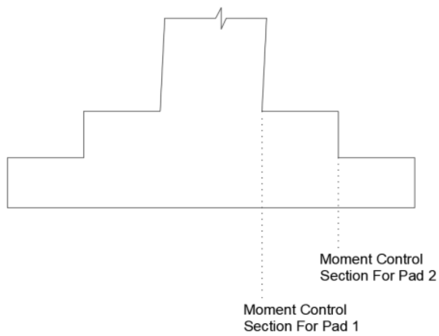
Muc 2= 6955550 kg.cm = 682339 N.m

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

Muu 1= 9481749 kg.cm = 930160 N.m

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

Muu 2= 4386186 kg.cm = 430285 N.m




Effective Depth of pad 1, dp1 = hp1+hp2 - cp = 0.625 m

Effective Depth of pad 2, dp2 = hp2 - cp = 0.275 m

**Compression :**

**Pad 1:**

K = Mu /f 'c * bp *dp$^2$ = 0.108 < 0.167 OK

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

Z max = 558 < 593.75 ==>>> OK

As = Mu / φs * fyr * z = 6785 mm2

**Pad 2:**

K = Mu /f 'c * bp *dp$^2$ = 0.095 < 0.167 OK

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

Z max = 249.5 < 261.25 ==>>> OK

As = Mu / φs * fyr * z = 6563.2 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 = 610.8 > 593.75 ==>>> Zmax=0.95 dp = 593.75

As = Mu / φs * fyr * z = 3759.8 mm2

**Pad 2:**

$K = Mu / f'c * bp * dp^2 =$ 0.060

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

Z max = 259.5 < 261.25 ==>>> OK

As = Mu / φs * fyr * z = 3978.7 mm2

**Top of Pad 1 :**

As1t= 3759.8 mm2

Rebar Diameter= 16 mm =====> QTY = 19 ==>> 19 =====> 19 Ø 16 =====> 3820 mm2

Rebar Quantity = 19

Rebar Spacing = 147.2 mm

**Top of Pad 2 :**

As2t= 3978.7 mm2

Rebar Diameter= 12 mm =====> QTY = 36 ==>> 36 =====> 36 Ø 12 =====> 4072 mm2

Rebar Quantity = 36

Rebar Spacing = 198.6 mm

**Bottom of Pad 2 :**

As2b= 6784.8 mm2

Rebar Diameter= 16 mm =====> QTY = 34 ==>> 34 =====> 34 Ø 16 =====> 6836 mm2

Rebar Quantity = 34

Rebar Spacing = 210.6 mm

Min. Rebar Check:

Ast = 14727.8 mm2

ρst = 0.0050 >

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 = 81046 kg = 810464 N

Compression Stress at critical section of shear at Pad2 , σv2 = 0.71 kg/cm2

Vu2 = 56176 kg = 561762 N

**Pad 1**

k = 1 +(200/dp1)^0.5 < 2.0 >>> k = 1.57 EN 1992-1-1:2004 6.2

$\rho_1 =$ 0.0050

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

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

k1 = 0.15

$v_{min} = 0.035 * k^{3/2} * f'c^{1/2} =$ 0.307 Mpa EN 1992-1-1:2004 6.3N

$Vr1 =$ 1188777 N

| | | | | |
|---|---|---|---|---|
| Vr1 | > | Vu1 | OK | F.S= 1.47 |

**Pad 2**

$k = 1 + (200/dp2)^{0.5} < 2.0$ >>> $k =$ 1.85 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

$v_{min} = 0.035 * k^{3/2} * f'c^{1/2} =$ 0.395 Mpa EN 1992-1-1:2004 6.3N

$Vr2 =$ 970490 N

| | | | | |
|---|---|---|---|---|
| Vr2 | > | Vu2 | OK | F.S= 1.73 |

**Two Way Shear:**

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

**Pad 1**

Vpunch1 = 176392 kg = 1763921 N

Resisting Shear of Concrete,

$Vr1 =$ 2749991 N

| | | | | |
|---|---|---|---|---|
| Vr1 | > | Vpunch1 | OK | F.S.= 1.56 |

**Pad 2**

To check if punch shear section is defined in Pad 2 ==> bp1 - ( bp2 + 4dp2 ) = 3.2 > 0 ==> Punch Shear to be Checked in Pad 2

Vpunch2 = 141736 kg = 1417360 N

Resisting Shear of Concrete,

$Vr2 =$ 2003276 N

| | | | | |
|---|---|---|---|---|
| Vr2 | > | Vpunch2 | OK | F.S.= 1.41 |

**Structural Design of Chimney:**

Design of Longitudinal Reinforcement for Uplift :

A) Moment at the bottom of chimney about x axis Mx max = 14.47 ton.m = 144666 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= 16.7 cm2

B) Moment at the bottom of chimney about y axis My max = 2.27 ton.m = 22719 N.m

$\varphi s * fyr = M * c / I$ As2= 2.6 cm2

C) Axial required rebar area, As3 = Ts / ( φs*Fyr) = 19.2 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 = 38.5 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 = | 38.5 | | | | | | | |
| Rebar Diameter = | 16 | mm =====> QTY = | 20 | =====> | 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 | mm |
| $N_{Ed} =$ | 176.42 | ton |
| $M_{0Ed, x} =$ | 15.11 | ton.m |
| $e_0 = h /30 > 20$ mm ==> $e_0 =$ | 25 | mm |
| $M_{Ed,x} =$ | 18.29 | ton.m |

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

| | | |
|---|---|---|
| $M_{0Ed, y} =$ | 5.98 | ton.m |
| $M_{Ed,y} =$ | 9.16 | ton.m |
| $As * F yr / bc^2 * f'c =$ | 0.179 | |
| $N_{ED}/ f'c * bc^2 =$ | 0.154 | |
| 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

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

$(M_{Ed,x}/M_{Rd,x})^a+(M_{Ed,y}/M_{Rd,y})^a =$ 0.433 < 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 | | |