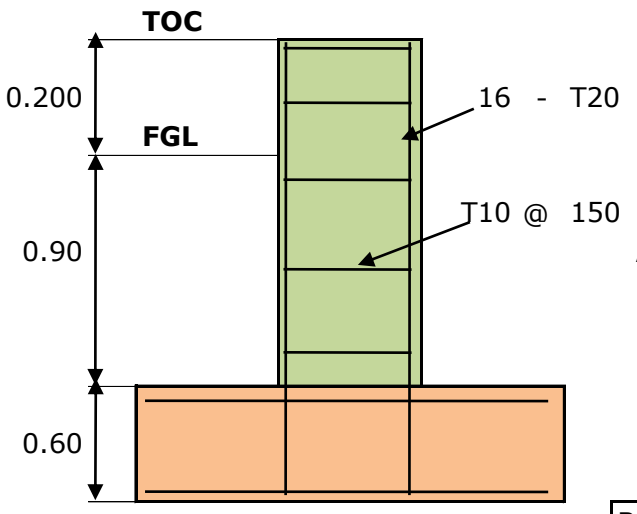
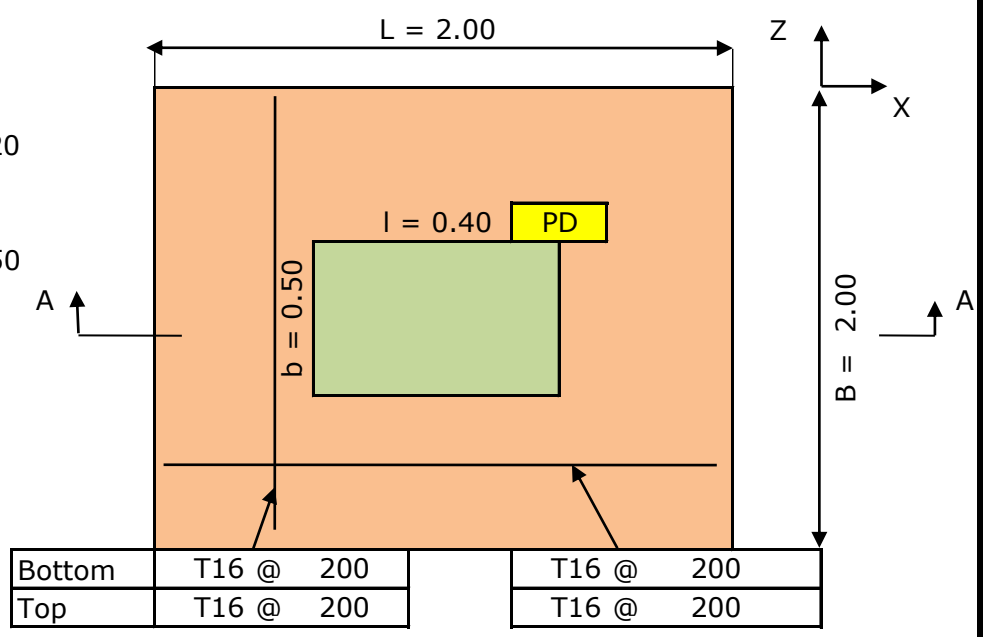
FOUNDATION DESIGN TYPE -1

ISOLATED FOUNDATION DESIGN ACI 318-14

Genaral sketch



SECTION -A A



PLAN

DESIGN DATA

Characteristic cube strength of concrete	=	f'_c	=	25	N/mm^2	Refer Clause 3.4.4 of Ref:
Characteristic cylindrical strength of concrete	=	f'_c	=	20	N/mm^2	(0.8 x 25)
Yield strength of steel	=	f_y	=	420	N/mm^2	Refer Clause 3.4.4 A and B of Process design basis Ref:
Unit weight of concrete	=	γ_c	=	25	kN/m^3	
Unit weight of soil	=	γ_s	=	17	kN/m^3	As per Geo-technical Investigation Report
Angle of friction of soil	=	ϕ	=	30	Deg	
Net allowable soil bearing capacity of soil (Considered as available at the depth of 2 m)	=	f_b	=	175	kN/m^2	
Gross bearing capacity of soil (Net SBC + γs*D1)			=	200.5	kN/m^2	175 + (17 x 1.5)
Friction coefficient considered for design	=	φ	=	0.4		Ref:
						Ref:
Allowable factor of safety against Overturning			=	1.75		Clause 3.4.4.E
Allowable factor of safety against Sliding			=	1.5		

FOUNDATION DATA

Length of footing	=	L	=	2.00	m
Breadth of footing	=	B	=	2.00	m
Depth of footing	=	D	=	0.60	m
Length of pedestal	=	l	=	0.40	m
Breadth of pedestal	=	b	=	0.50	m
Depth of footing below FGL	=	D_1	=	1.50	m
Depth of pedestal below FGL = D_1-D	=	d_1	=	0.90	m
Depth of pedestal above FGL	=	d_2	=	0.20	m
Clear cover considered	=	d'	=	75	mm
Effective depth = (D*1000-d'-Dia of bar/2)	=	d	=	517	mm

LOADS

Factored Load

(LOAD CASE:201 , NODE NO - 2)

Horiz.(Fx) (Fx in kN)	Vertical (Fy in kN)	Horizontal (Fz in kN)	Moment Mx(kNm)	Moment Mz(kNm)
20.00	126.00	20.00	30.0	30.00

DESIGN OF PEDESTAL

Self weight of pedestal = (d1+d2)*b*l*γc	=	Wp	=	5.5	kN
Total vertical load= 1.2*Wp + pipe load(Fy)			=	132.6	kN
Total moment in X direction= Mx+(Fz*(d_1+d_2))			=	52.00	kNm
Total moment in Z direction= Mz+(Fx*(d_1+d_2))			=	83.20	kNm

Factored Load

Total vertical load(Pu) (kN)	Mx (kNm)	Mz (kNm)
132.60	52	83.20

For a balanced section

Considering minimum reinforcement = (0.5%*l*b)	=		=	1000	mm^2	Ref. ACI-318-14 clause 16.3.4.1
Dia of bar considered				20	mm	
No of bars Provided				16	Nos	
Area of reinforcement provided (A_{st})				5024	mm^2	**Safe**

Check for Axial Compressive Strength

Maximum axial compressive strength

Ref. ACI-318-14 Clause 10.5.1.1

$\phi P_n \geq P_u$

$1/P_n = 1/P_{nx}+1/P_{nz}-1/P_o$

Where

P_{nx} = Nominal Axial Compressive Strength when eccentricity along x - axis

P_{nz} = Nominal Axial Compressive Strength when eccentricity along z - axis

P_o = Nominal Axial Strength at zero eccentricity

P_n = Nominal Axial Compressive Strength

Elastic modulus of steel	=	200000	N/mm2	Ref. ACI-318-14 clause 20.2.2.2
£y = fy/Es		0.0021		
cx = d(0.003/(0.003+£y)	=	185	mm	(d = l-d'-d_b/2)
cz = d(0.003/(0.003+£y)	=	244	mm	(d = b-d'-d_b/2)
β value (for 17 < fc' < 28)	=	0.85		Ref. ACI-318-14 Table 22.2.2.4.3
$a_x = \beta * c_x$	=	158	mm	
$a_z = \beta * c_z$	=	208	mm	
Strength Reduction factor (ϕ)	=	0.65	mm	Ref. ACI-318-14 Table 21.2.2

Nominal Axial Compressive Strength of section when eccentricity along -x-axis (P_{nx}) = $0.85*f'c*b*a_x$ = 1339 kN

Nominal Axial Compressive Strength of section when eccentricity along -z-axis (P_{nz}) = $0.85*f'c*l*a_z$ = 1411 kN

Nominal Axial Strength at Zero ecentricity (P_o)

$P_o = (0.85*f'c*(A_g-A_{st})+f_y*A_{st})$ Ref. ACI-318-14 clause 22.4.2.2

Where

A_g = Gross concrete area of pedestal

A_{st} = Total cross sectional area of longitudinal reinforcement

Gross concrete area of pedestal (A_g) = 200000 mm^2

Nominal Axial Strength at Zero ecentricity (P_o) = 5424.67 kN

Nominal Axial Compressive Strength (P_n) = 786.6 kN

Maximum Nominal Axial Compressive Strength of a member P_n max

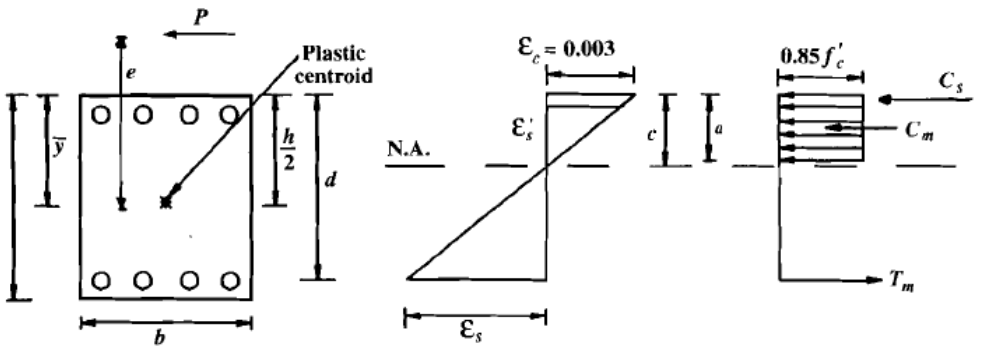
Where Ref. ACI-318-14 clause 22.4.2.1

P_n ,max = 0.80* P_o

P_n ,max > P_n = 4339.738 kN > 787 **Safe**

$\phi P_n \geq P_u$ = 511.27 kN ≥ 133 kN **Safe** Ref. ACI-318-14 Clause 10.5.1.1

Moment carrying capacity of pedestal (M_n)



When eccentricity along x - axis (M_{nx})

No of bars along z - axis / side	16	Nos
Area of bar along z- axis/side (A'_{sx} or A_{sx})	5024.0	mm^2

Maximum moment carrying capacity of section(M_{nx})

M_{nx} = $0.85*f'_c*b*a_x*(y-a_x/2)+A'_{sx}*f_y*(y-d'-d_b/2)+A_{sx}*f_y*((l-d'-d_b/2)-y)$ (y = l/2)

Maximum moment carrying capacity of section(M_{nx}) = 648 kNm

When eccentricity along z - axis (M_{nz})

No of bars along x - axis / side	16	Nos
Area of bar along x - axis/side (A'_{sz} or A_{sz})	5024.0	mm^2

Maximum moment carrying capacity of section(M_{nz})

M_{nz} = $0.85*f'_c*l*a_z*(y-a_z/2)+A'_{sz}*f_y*(y-d'-db/2)+A_{sz}*f_y*((b-d'-db/2)-y)$ (y = b/2)

Maximum moment carrying capacity of section(M_{nz}) = 954 kNm

$(Pu/\Phi) < P_n$	=	204.00	kN	<	787	Safe	Φ =	0.65	Ref. ACI-318-14 Table 21.2.2
$(Mux/\Phi) < M_{nx}$	=	80.00	kNm	<	648	Safe	Φ =	0.65	"
$(Muz/\Phi) < M_{nz}$	=	128.00	kNm	<	954	Safe	Φ =	0.65	"

Strength of section in combined axial & flexure

= $Pu/\Phi P_{ni} + M_{ux}/\Phi M_{nx} + M_{uz}/\Phi M_{nz} < 1$ 0.52 < 1 **Safe**

LATERAL TIES

Dia of lateral ties considered 10 mm

Spacing of lateral ties

a) Clear spacing at least (4/3) d_{agg}	27	mm	Ref. ACI-318-14 clause 25.7.2.1
b) 16 times of longitudinal reinforcement	320	mm	
c) 48 times of tie bar	480	mm	
smallest of b) & c)	320	mm	say 150 mm

Provide 10 mm dia lateral ties at 150 mm spacing

DESIGN OF FOOTING

Unfactored Load (LOAD CASE:101 , NODE NO - 2)

Horiz.(Fx) (Fx in kN)	Vertical (Fy in kN)	Horizontal (Fz in kN)	Moment Mx(kNm)	Moment Mz(kNm)
20.00	126.00	20.00	30.00	30.00

Weight of footing = (L*B*D*γc) = w_f = 60.00 kN

Weight of pedestal = (d1+d2)*b*l*γc = w_p = 5.50 kN

Weight of soil = (((L*B)-(l*b))*d1*γc) = w_s = 58.14 kN

Total self weight = $w_f+w_p+w_s$ = Wf = 123.64 kN

Total vertical load= Wf + pipe load(Fy) = 249.64 kN

Shear in X direction Fx = 20 kN

Shear in z direction Fz = 20 kN

Total moment in X direction= Mx+(Fz*depth of pedestal) = 64.000 kNm

Total moment in Z direction= Mz+(Fx*depth of pedestal) = 64.000 kNm

SBC CHECK

summary of foundation loading (unfactored)

Shear,Fx (kN)	Shear,Fz (kN)	Total vertical load,P(kN)	Mx (kNm)	Mz (kNm)
20.00	20.00	249.64	64.00	64.000

Check for soil pressure (Unfactored load considered)

Maximum soil pressure(q_{max}) = $P/LB+6Mx/LB^2+6Mz/L^2B$ < SBC (f_b)

Minimum soil pressure(q_{min}) = $P/LB-6Mx/LB^2-6Mz/L^2B$ > 0 (or) provide top reinf.

Max. soil pressure P/A+Mx/Zx+Mz/Zz	Min. soil pressure P/A-Mx/Zx-Mz/Zz	Max.Press. < SBC	Min.Press. > 0
158.4	-33.6	Safe	Uplift

EARTH PRESSURE IN EACH CORNER OF FOOTING

Factored Load

summary of foundation loading (factored)

Shear,Fx (kN)	Shear,Fz (kN)	Total vertical load,P (kN)	Mx (kNm)	Mz (kNm)
20.00	20	299.6	52.0	83.2

P/A+Mx/Zx+Mz/Zz = 176.29 kN/m^2

P/A-Mx/Zx+Mz/Zz = 98.29 kN/m^2

P/A+Mx/Zx-Mz/Zz = 51.49 kN/m^2

P/A-Mx/Zx-Mz/Zz = -26.51 kN/m^2

Max earth pressure = 176.29 kN/m^2

CHECK FOR SHEAR

Check for Two way shear (at d/2 from face of column)

To avoid diagonal tension failure, Vu/φ < Vc

Where

Vu = Shear due to loadings

Φ =	Strength reduction factor	=	0.75		Ref. ACI-318-14 Table 21.2.1
βc =	Ratio of long side to short side of column	=	1.25		
bo =	Perimeter of critical section taken at d/2 from column face	=	3868	mm	
αs =	(40 for interior columns,30 for edge columns, 20 for corner columns)	=	40		Ref. ACI-318-14 clause 22.6.5.3
d =	depth at which tension steel reinforce. placed	=	517	mm	

Vc = Allowable shear (smallest from the below equations)

Vc1 =	$0.17*(1+2/\beta)x\ \sqrt{f'c}\ xBo\ x\ d$	=	3952.89	kN
Vc2 =	$0.083(2+(\alpha_s xd/bo))x\sqrt{f'c}\ xBo\ x\ d$	=	5453.14	kN
Vc3 =	$0.33\sqrt{f'c}\ xBo\ x\ d$	=	2951.25	kN

Allowable two way shear (Vc)= Min(Vc1,Vc2,Vc3) = 2951.250 kN

Actual two way shear(Vu) = Factored soil pressure*(Area of footing-Area of critical section)

= 540.76 kN

Check for Two way shear		
Vu/Φ (KN)	Vc (kN)	Vu/Φ < Vc
721.01	2951.250	Safe

Check for One way shear (at d from face of column)

One way shear (Vu/φ < Vc)

where

Vc = Allowable shear = Min($0.17*\sqrt{f'c}$ x L.d, $0.17*\sqrt{f'c}$ x B.d) Ref. ACI-318-14 clause 22.5.5.1

Allowable one way shear = Vc = 786.11 kN

One way shear (Vu) = Factored soil pressure*Exposed area

Check for One way shear			
Vu/Φ(KN) (x-axis)	Vu/Φ(KN) (z-axis)	Vc (kN)	Vu/Φ < Vc
109.54	133.04	786	Safe

DESIGN OF REINFORCEMENT

Mu/Φ < Mn

Where

Mu = Maximum bending moment at face of column

Mn = Allowable moment

Φ = Strength reduction factor — 0.90 — Ref. ACI-318-14 Table 21.2.1

Maximum bending moment at face of column

= Factored soil pressure x (Cantilever^2)/2*Width of footing — Ref. ACI-318-14 Clause 13.2.7.1

Check for Moments			
Mu/Φ(KNm)(x-axis)	Mu/Φ(KNm)(z-axis)	Mn(kNm)	Mu/Φ < Mn
125.36	110.18	428	Safe

Reinforcement alog x - axis

Allowable moment (Mn) = As*fy*(d-a/2)

Where

a= As*fy/(0.85*f'_c*B)

Assuming (d-a/2) = 0.9d

Area of steel required (As) (Equating Mn=Mu/Φ) = $\frac{Mu/\Phi}{fy*0.9*d}$

Area of steel required (As_{reqd}) 712.76 mm^2

Minimum area of steel required (As_{min}) = 0.20%*B*d = 2068 mm^2 — Ref. ACI-318-14 Table 24.4.3.2

Dia of reinforcement considered 16 mm

Spacing of reinforcement required = $\frac{201}{2068}$ x 2000 = 194 mm

Say 200 mm

Provide 16 mm dia reinforcement at 200 mm c/c bothways top and bottom.

Area of steel provided (As_{prov}) 2009.6 mm^2

To check Mu/Φ < Mn

a= As*fy/(0.85*f'_c*B) 19.86 mm

Allowable moment(Mn) = As*fy*(d-a/2) = 428.0 kNm

Reinforcement alog z - axis

Allowable moment (Mn) = As*fy*(d-a/2)

Where

a= As*fy/(0.85*f'_c*L)

Assuming (d-a/2) = 0.9d

Area of steel required (As) (Equating Mn=Mu/Φ) = $\frac{Mu/\Phi}{fy*0.9*d}$

Area of steel required (As_{reqd}) 626.452 mm^2

Minimum area of steel required (As_{min}) = 0.20%*L*d = 2068 mm^2 Ref. ACI-318-14 Table 24.4.3.2

Dia of reinforcement considered = 16 mm

Spacing of reinforcement required = $\frac{201}{2068}$ x 2000 = 194 mm

Say 200 mm

Provide 16 mm dia reinforcement at 200 mm c/c bothways top and bottom.

Area of steel provided (As_{prov}) 2009.6 mm^2

To check Mu/Φ < Mn

a= As*fy/(0.85*f'_c*L) 19.86 mm

Allowable moment(Mn) = As*fy*(d-a/2) = 428.0 kNm

STABILITY CHECK

Against Overturning

Factor of safety against Overturning (Along X-axis)

$$= \frac{\text{Resisting moment}}{\text{Overturning moment}} = \frac{P \times L/2}{Mz} > 1.75$$

Overturning moment (kNm)	Resisting moment (kNm)	Actual FOS	Check FOS
64.000	249.6	3.90	Safe

Factor of safety against Overturning (Along Z-axis)

$$= \frac{\text{Resisting moment}}{\text{Overturning moment}} = \frac{P \times B/2}{Mx} > 1.75$$

Overturning moment (kNm)	Resisting moment (kNm)	Actual FOS	Check FOS
64.0	249.6	3.90	Safe

Against Sliding

Factor of safety against Sliding

$$= \frac{\text{Resisting force}}{\text{Sliding force}} = \frac{P \times \text{Friction coefficient}}{\text{Sqrt}(Fx^2+Fz^2)} > 1.5$$

Sliding force (kN)	Resisting force (kN)	Actual FOS	Check FOS
28.284	99.86	3.53	Safe