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" VATSA AMAZE " PROPOSED CONSTRUCTION OF GROUP HOUSING DEVELOPMENT CONSISTING OF 2 BLOCKS; BLOCK A-STILT FLOOR + 5 FLOORS (HEIGHT- 18.30M) RESIDENTIAL BUILDING 20 DWELLING UNITS; BLOCK B- STILT FLOOR +4 FLOORS + 5TH FLOOR (PART - LADIES GYM , GENTS GYM & ASSOCIATION ROOM) (HEIGHT- 18.30M) RESIDENTIAL BUILDING WITH 87 DWELLING UNITS TOTALLY 107 DWELLING UNITS (AFFORDABLE HOUSING) AT VASANTHAPURAM MAIN ROAD, MANGADU, CHENNAI COMPRISED IN S.NO.475/1PART (AS PER DOCUMENT) AND 475/1B (AS PER PATTA) OF MANGADU-B VILLAGE WITHIN THE LIMITS OF MANGADU MUNICIPALITY.

STRUCTURAL DESIGN CALCULATION

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1. INTRODUCTION

The proposed Residential building consists of two blocks. Block A consists of Stilt floor + 5 upper floors & Block B consists of Stilt Floor +4 Floors + 5th Floor (Part – Ladies Gym, Gents Gym & Association Room). The structure is designed as a Reinforced concrete framed structure supported on pile foundation. The structure is built for Residential use. The columns, beams and slabs are considered and designed as reinforced concrete members.

BLOCK-A

Building size

Length (X-direction)	–	12.60m
Width (Y-direction)	–	34.80m

Height

Stilt floor	–	3.20m
Typical floor	–	3.20m

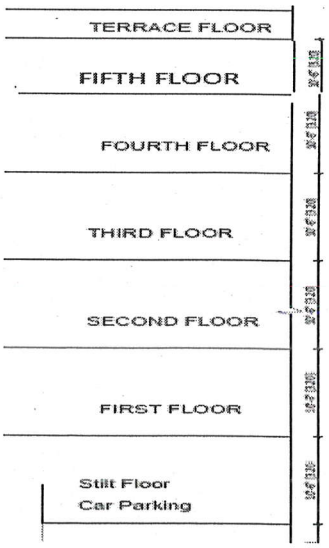
BLOCK-B

Building size

Length (X-direction)	–	20.10m
Width (Y-direction)	–	88.50m

Height

Stilt floor	–	3.20m
Typical floor	–	3.20m



BLOCK A&B

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2. GRADE OF MATERIALS

i) Concrete

Characteristic concrete strength (concrete grade) for the project shall be based on exposure condition and forces to be supported by specified structural elements. The minimum cement content and maximum water–cement ratio shall be as per IS code 456:2000. The minimum 28-day compressive strength of concrete for specified structural elements shall be as follows

Grade of Concrete for Pile, pilecap, columns and shear wall is M30.

Grade of Concrete for all other Structural elements is M25.

Concrete Properties

Young's Modulus of Elasticity of Concrete	$5000\sqrt{fck}$
Poisson Ratio's Ratio v =	0.2

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ii) Reinforcement

Grade of Steel reinforcement for all Structural elements is Fe500.

The characteristictensile properties of steel in design shall be as follows.

Reinforcement Characteristic yield strength f_y (N/mm^2)	Fe500
Young's Modulus E (kN/mm^2)	200kN/mm^2
Poisson's ratio	0.3
Coefficient of Thermal expansion, α ($^oC^{-1}$)	$12x10^{-6}$
Density	78.5 kN/m^3
Diameters [in mm]: 8, 10, 12, 16, 20, 25 & 32	

iii) Structural steel

All structural steel, if used, shall conform to Indian standard IS: 2062-2011.

Structural steel	Grade E=250	Grade E-350
Tensile strength	410 N/mm^2	490 N/mm^2
Yield stress t<20mm	250 N/mm^2	350 N/mm^2
Yield stress t = 20mm to 40mm	240 N/mm^2	330 N/mm^2
Yield stress t> 40mm	230 N/mm^2	320 N/mm^2
Young's Modulus (E)	200,000 N/mm^2	200,000 N/mm^2
Density	78.5 kN/m^3	78.5 kN/m^3

Self-weights are calculated on the basis of unit weights of materials given in IS 875 (Part 1) the data provided by consultant and other service consultants will be used for the specific materials.

Materials	Unit weight kN/m^3
Steel	78.50
Plain Cement Concrete	24.00
Reinforced Cement Concrete	25.00
Soil Fill	16.00
Water	10.00
Cement Concrete screed	24.00
AAC block	10.00
Solid block wall (Concrete)	22.00

Normal weight aggregates shall be considered for arriving at self-weight of all Concrete works.

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3. DESIGN STANDARDS

The relevant Indian Standard Codes, as given below, shall be followed for structural design:

Sl.No.	Code	Description
1.	IS-875 (Part 1) – 1987	Code of Practice for Design Loads (other than earthquake) for buildings and structures – Unit weights of buildings materials and stored material.
2.	IS-875 (Part 2) – 1987	Code of Practice for Design Loads (other than earthquake) for buildings and structures – Imposed loads.
3.	IS-875 (Part 3) – 2015	Code of Practice for Design Loads (other than earthquake) for buildings and structures – Wind loads.
4.	IS-875 (Part 4) – 1987	Code of Practice for Design Loads (other than earthquake) for buildings and structures – Snow loads.
5.	IS-875 (Part 5) – 1987	Code of Practice for Design Loads (other than earthquake) for buildings and structures – Special loads and load combinations.
6.	IS: 456 – 2000	Code of Practice for Plain and Reinforced Concrete.

7.	IS: 1786 – 2008	High Strength Deformed Steel Bars and Wires for Concrete Reinforcement - Specification.
8.	IS: 13920 – 2016	Ductile detailing of reinforced concrete structures subjected to seismic forces - Code of practice
9	IS: 800 – 1984/2007	Code of Practice for General Construction in Steel.
10.	IS: 1893 (Part 1) – 2016	Criteria for Earthquake resistant design of structures.

4. DESIGN DATA

1. No. of floors
   BLOCK-A = stilt +5upper floors
   BLOCK-B = stilt +4floors+5th Floor (Part – Ladies Gym, Gents Gym & Association Room).
2. Total height of building = 18.30m above GL
3. Capacity of 500mm Dia 20m Deep Pile = 75 T (as per soil report)
4. Density of Concrete = 25 kN/m^3
5. D.L. due to partitions (Light Partition as per IS 875) = 1.50 kN/m^2
6. D.L. due to flooring = 0.040x22=0.88 ≈1.00 kN/m^2
7. Wall Load (200mm thick wall): Typical Floor = 3.2m-0.45m=2.75m x 0.20m x20 = 11.0 kN/m
8. Live Load in Stairs, corridor &lobby = 3.00 kN/m^2
9. Live Load in Rooms & Kitchen = 2.00 kN/m^2
10. Live Load in Terrace = 1.50 kN/m2
11. Live Load in toilets = 2.00 kN/m^2
12. L.L in Lift Machine Room = 10.00 kN/m^2
13. Basic wind speed = 50 m/sec
14. Design wind pressure (Max.) = 1.34 kN/m^2
15. Seismic Zone = Zone III
16. Design mix = M30 for columns & shear wall, M25 for all other RC members

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5. ANALYSIS OF STRUCTURE

Computer-aided analysis using finite element method (FEM) shall be carried out for the Analysis of structure.

Assumptions:

- The structure is idealized as 3D space frame and analyzed using Etabs software package for both vertical and lateral loads.
- The structure is analyzed for specific loads like dead load, live load, wind and seismic loads and for the load combinations as given in the relevant codes.
- Temperature load is applied on the terrace floor of the buildings.

Column	:	Frame Element
RC Wall	:	Wall (Shell) Element
Beam element:		Frame Element
Slab element	:	Membrane Element

For 3D or 2D structural frame analysis ETABS or SAFE software shall be used, verified in-house spreadsheets will be used for the design of reinforced concrete (RC) and steel elements in consideration of flexure, shear and axial forces.

The following are general parameters adopted in the analysis and design, Consideration of Diaphragm – Semi Rigid Diaphragm.

6. DESIGN CONCEPT

Limit State concept of design will be used as per IS: 456-2000 & SP - 16. The detailing of reinforcement shall be done satisfying the requirements of IS: 456, SP-16, IS: 13920, IS: 4326 and SP-34.

The Slabs and beams are checked for deflection as per IS 456. Cover for Reinforcement is considered as per Table 16A of NBC, for a Fire resistance of **2 hrs.**

7. LOAD CASE

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7.1 Primary Load

- Dead Load (DL)
- Live Load (LL)
- Earthquake Load (EL)
- Wind Load (WL)

7.2 Load Combinations

The following combinations of Loads as per IS 1893 is considered in the E Tabs Analysis.

1. 1.5(DL +LL)
2. 1.2(DL + LL ± WL)
3. 1.2(DL +LL ± EL)

4. 1.5(DL ± EL)
5. 1.5(DL ± WL)
6. 0.9DL ± 1.5EL
7. 0.9DL ± 1.5WL

Load Combination	Limit State of Collapse			Limit State of Serviceability		
	DL	LL	WL/EL	DL	LL	WL/EL
DL + LL	1.5	1.5	--	1.0	1.0	--
DL +/- WL	1.5 or 0.9[$]	--	1.5	1.0	--	1.0
DL + LL +/- WL	1.2	1.2	1.2	1.0	0.8	0.8
DL +/- EL	1.5 or 0.9[$]	--	1.5	1.0	--	1.0
DL + LL +/- EL	1.2	1.2	1.2	1.0	0.8	0.8

[$]This value is to be considered when stability against overturning or stress reversal is critical

DL - Dead load
LL - Live load
WL - Wind load
EL - Earthquake load

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Wind load and earthquake load shall be considered for both X & Y directions.
The above load combinations will be considered and effect of worst combinations will be taken for design of various building elements.
Whenever imposed load is combined with earthquake load the appropriate part of imposed load as specified in IS: 1893 – 2016 will be used both for evaluating earthquake effect and for combined load effects used in such combination.

General Load Combinations considered in the analysis are as follows:

Combinations considered for the design of the various building elements:					
COMB 1	1.5 DL	+	1.5 LL		
COMB 2	1.2 DL	+	1.2 LL	+	1.2 SPECX
COMB03	1.2 DL	+	1.2 LL	+	1.2 SPECY

COMB04	1.5 DL			+	1.5 SPECX
COMB05	1.5 DL			+	1.5 SPECY
COMB06	0.9 DL			+	1.5 SPECX
COMB07	0.9 DL			+	1.5 SPECY
COMB08	1.2 DL	+	1.2 LL	+	1.2 WLX
COMB09	1.2 DL	+	1.2 LL	-	1.2 WLX
COMB10	1.2 DL	+	1.2 LL	+	1.2 WLY
COMB11	1.2 DL	+	1.2 LL	-	1.2 WLY
COMB12	1.5 DL			+	1.5 WLX
COMB13	1.5 DL			-	1.5 WLX
COMB14	1.5 DL			+	1.5 WLY
COMB15	1.5 DL			-	1.5 WLY
COMB16	0.9 DL			+	1.5 WLX
COMB17	0.9 DL			-	1.5 WLX
COMB18	0.9 DL			+	1.5 WLY
COMB19	0.9 DL			-	1.5 WLY
COMB21	0.9 DL			+	1.5 TL
COMB22	1.5 DL			+	1.5 TL
COMB23	1.5 DL	+	1.5 LL	+	1.5 TL
COMB24	1.2 DL			+	1.2 TL

Un-factored Loads to be taken for foundation design:

FOUN01	1.0 DL	+	1.0 LL		0.8 SPECX
FOUN02	1.0 DL	+	0.8 LL	+	0.8 SPECX
FOUN03	1.0 DL	+	0.8 LL	+	0.8 SPECY
FOUN04	1.0 DL			+	1.0 SPECX
FOUN05	1.0 DL			+	1.0 SPECY
FOUN06	1.0 DL	+	0.8 LL	+	0.8 WLX
FOUN07	1.0 DL	+	0.8 LL	-	0.8 WLX
FOUN08	1.0 DL	+	0.8 LL	+	0.8 WLY
FOUN09	1.0 DL	+	0.8 LL	-	0.8 WLY

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FOUN10	1.0 DL			+	1.0 WLX
FOUN11	1.0 DL			-	1.0 WLX
FOUN12	1.0 DL			+	1.0 WLY
FOUN13	1.0 DL			-	1.0 WLY
FOUN14	1.0 DL			+	1.0 TL
FOUN15	1.0 DL	+	1.0 LL	+	1.0 TL
DL - Dead Load					
LL - Live Load					
EL - Earthquake Load					
WL - Wind Load					
* Note - Seismic Load Cases have both "MAX" and "MIN" Load Cases for +ve & -ve Directions respectively.					

8. WIND LOAD

Wind loads and pressures are calculated based on the static design wind pressure. This pressure has been considered for the load analysis and applied to the model. The wind pressure shall be calculated based on the data furnished below and other provisions laid in IS: 875 (Part 3) – 2015.

The design wind velocity at any given height and at a given site is given by,

$Vz = V_b\, k_1 k_2\, k_3\, k_4$

where,

V_b- basic wind speed in m/s at 18m height

k_1 - probability or risk factor

k_2 - terrain, height and structure size factor

k_3 - local topography factor

Basic wind speed = 50 m/sec

Risk coefficient, k_1 = 1.0

Terrain category = 2

Height factor- k_2 = Varies with height

Terrain, size height & structure factor, k_2 up to 16 m height = 1.05
(as per Cl. 6.3.2 of IS 875 Part 3 - 2015)

Topography factor k_3 = 1.0

as per Cl. 6.3.3 of IS 875 Part 3 - 2015)

k_4 – Importance factor = 1.0 (Other buildings)

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(As per cl.6.3.4 of IS875 part 3 - 2015)

Design wind speed at any height z, V_z $= 50 \times 1 \times 1.05 \times 1 \times 1$

$= 52.50$ m/sec

The design wind pressure, Pz in MPa at any height above mean ground level is given by,

$p_z = 0.6\ V_z^2$

$= 0.6 \times 51.5^2$

$= 1653\ N/m^2$

$p_z = 1.653\ kN/m^2$

$p_d = K_d \times K_a \times K_c \times p_z$ where, as per IS875 PART 3 - 2015

K_d - wind directionality factor $= 1.0$

K_a - area averaging factor $= 0.9$

K_c - combination factor $= 0.9$

Therefore, $p_d = 1.0 \times 0.9 \times 0.9 \times 1.653$ $= 1.34\ kN/m^2 > 0.7\ p_z$

The wind pressure of $1.34\ kN/m^2$ is applied along the height of the column.

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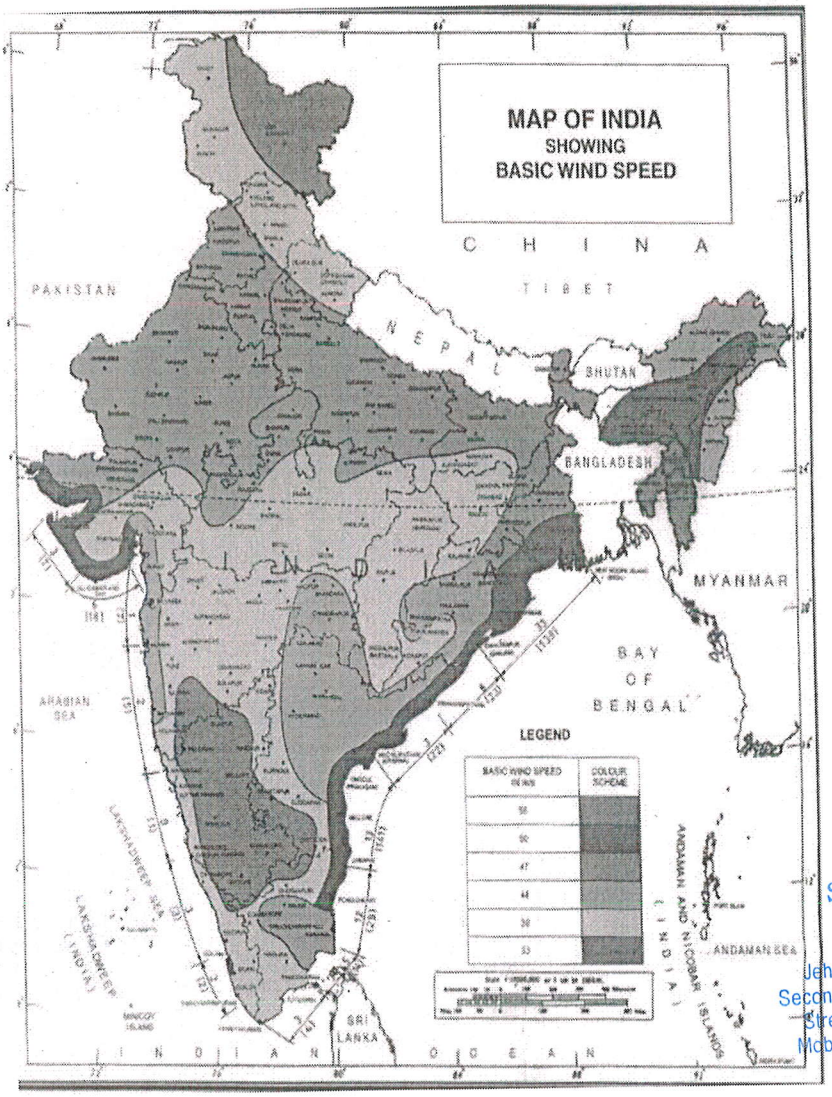

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9. SEISMIC LOAD

The Proposed Residential building at Chennai falls under Zone III as per the IS Code. Response spectrum method shall be used, for seismic analysis of R.C. Frames as recommended by IS: 1893-2016

Seismic Zone	=Zone III
Zone Factor 'Z'	=0.16
Response Reduction Factor 'R' (for SMRF)	=5.00
Importance Factor 'I'	=1.20
Type of Structure	=1.00

SEISMIC ANALYSIS:

9.1. STATIC ANALYSIS:

Design of lateral force under seismic condition shall be as per IS1893 – 2016. Total lateral force (base shear) of the building shall be estimated as per clause 7.2.1 of IS1893 – 2016 which provides by

$$V_b = A_h W$$

Ah is horizontal seismic coefficient and W is seismic weight of the building, Horizontal seismic coefficient depends on location of the building (Zone factor Z), usage of the building (Importance factor, I), building lateral resisting system (Response reduction factor, R) and design acceleration coefficient (Sa /g) which is based on subsoil condition and fundamental natural period (Ta).

For the proposed building is for residential use. Considering it, the seismic weight is summation of total dead load and 50% of live load where live load is greater than 3 KN/sq.m, 25% for live load equal or lesser than 3 KN/sq.m.

From IS 1893:2016 clause 6.4.2, Design horizontal seismic coefficient

$$Ah = \frac{Z\ I\ Sa}{2\ R\ g}$$

Where, Z for Zone III = 0.10
Importance factor = 1.2
R for SMRF = 5.0

i. T = 0.09 h / √d (Refer IS 1893 - 2016 clause 7.6.2c),
ii. T = (0.075 h0.75) / (√Aw) (Refer IS 1893 - 2016 clause 7.6.2b),
iii. T = (0.075 h0.75) (Refer IS 1893 - 2016 clause 7.6.2a);

The time period has been calculated for all above specified cases and it ensured that the case (ii) time period is not greater than case (iii) and not lesser than case-(i).

Where,

T is Fundamental natural period

For the building height with reference to IS: 1893-2016 the building is well connected with basement wall in all four sides, so for the time period calculation the heights are considered as follows,

h = Height of the structure from Stilt Floor to Roof.
d = Width of the building along the direction of lateral force.
Aw = Total effective wall area in square meter

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9.2. DYNAMIC ANALYSIS:

Response spectrum method of Dynamic Analysis carried out with following parameters pertaining to dynamic analysis.

Number of modes Considered : 12 Numbers (Minimum)

Modal Combination Method Used : Complete Quadratic combination (CQC).
Directional Combination Method used : Square root of the sum of Square (SRSS).
Modal case type : Eigen vector Method

10. COVER FOR REINFORCEMENT:

Cover for Reinforcement is considered as per Table 16A of NBC, for a Fire resistance of **2 hrs.**

Pile	= 50 mm
Pile cap bottom	= 75mm
Columns	= 40 mm
Beams	= 30 mm
Slabs	= 25 mm
Retaining wall	= 40 mm for earth side and 25mm for inner side
Shear wall	= 25 mm

11. FOUNDATION SYSTEM:

As per GEO TECHNICAL SOLUTIONS

Bored Cast In-situ Pile Capacities as per IS-2911 Part-1 Sec-2 :2010					
Pile Termination Level Below EGL (m)	Pile Dia (mm)	Safe Vertical Capacity (Tones)	Safe Uplift Capacity (Tones)	Safe Lateral Capacity wrt 5mm Ddeflection	
				Free Head (Tones)	Fixed Head* (Tones)
20.0	450	64	45	1.3	3.3
	500	75	50	1.5	3.9
	600	95	60	2.0	5.2
*Note: Apply 0.75 for Group efficiency for lateral capacities					

We have taken 500mm dia pile with capacity of 75 T (750 kN) with depth 20.0m below E.G.L.

The support condition for columns in ETABS model is considered as fixed support.

12. CONSTRUCTION JOINT:

Construction joints and shrinkage strips will be planned with the contractor and only be used in locations pre-approved by consultants.

1) No construction joint is allowed in the sunken portion.

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2) Preferred at l/3 from support.
3) Construction joint shall be placed at accessible location for maintenance purpose.
4) Joints are common source of weakness, therefore it is desirable to avoid or at least minimize the same.

13. EXPANSION JOINT

Length of the building(Block B) is 88.55m x 20.1m. Hence expansions joints have been provided at one location in X direction. Hence, the building has divided into two blocks.

14 FLOOR LOADING

a) FLOOR SLABS LOAD

The floor slab and beams are designed as conventional slab members for floor loads as mentioned below.

RC Conventional Slab:

Self-Weight of 150 thk. slab	= 3.75 kN/m^2
Load due to Floor Finish	= 1.00 kN/m^2
Load due to Partition load	= 1.50 kN/m^2
Live load	= 2.00 kN/m^2
	8.25 kN/m^2

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15. SERVICEABILITY CHECK

a. For Deflections:

The final deflection due to all loads including the effect of temperature, creep and shrinkage and measured from the as-cast level of the supports of floors, roofs and all other horizontal members should not normally exceed span / 250.

The deflection including the effect of temperature, creep and shrinkage occurring after the erection of partitions and the application of finishes should not normally exceed Span / 350 or 20 mm whichever is less.

b. Lateral drift:

Under transient wind load the lateral sway at the top should not exceed H/500, where H is the total height of the building.

The storey drift in any storey due to the minimum specified design lateral force, with partial load factor of 1, shall not exceed 0.004 times the storey height.

c. For Cracking

Surface crack width shall not exceed 0.3 mm in general and for water retaining structure it is limited to 0.2 mm.

16. TYPICAL DESIGN CALCULATION

16.1 Typical Design of Pile cap

Pile cap is analyzed using the Truss Analogy theory.

DESIGN OF PILE CAP PC2 WITH 2 PILES:

Grade of Concrete	= M30
Grade of Steel F_y	= Fe 500
Pile cap depth,	= 900 mm
Cover	= 75 mm
Carrying capacity of Pile	= 750 kN(as per soil report)
Max. unfactored load on column	= 1470 kN
Diameter of pile	= 500 mm
Number of piles	= 2

Centre to centre of piles, L = 1500 mm

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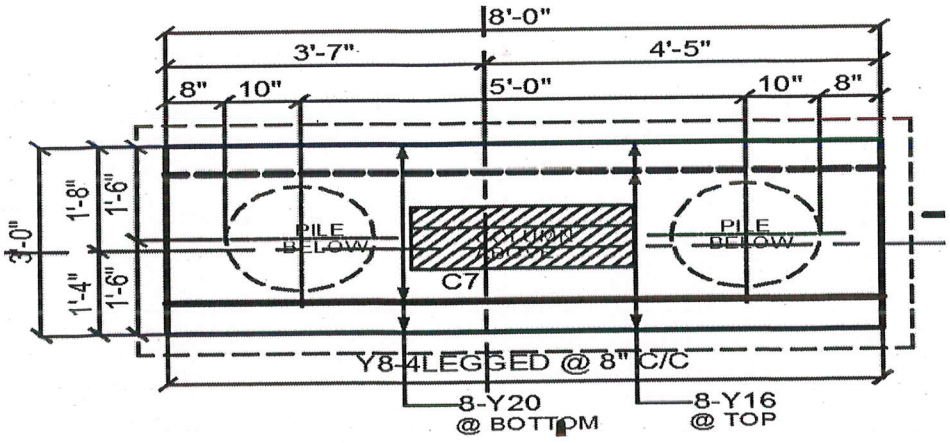

Column size

Length along X axis, **a = 600 mm**

Length along Y axis, **b = 300 mm**

Tensile force to be resisted by reinforcement

Tension along X-X $= \frac{P\,(3L^2-a^2)}{12LD}$

Tension along Y-Y = $1470(3x1.5^2-0.6^2)/\,(12x1.5x0.825)$ = **632.5 kN**

Area of steel $= \frac{\text{Tensile Force}}{0.87\,F_y} = 632.5 \times 10^3 \times 1.5 / 0.87 \times 500 = 2181\ mm^2$

Tension along Y-Y $= \frac{P\,(3L^2-b^2)}{12LD}$

Tension along Y-Y = $1470(3x1.5^2-0.3^2)/\,(12x1.5x0.825)$ = **659 kN**

Area of steel $= \frac{\text{Tensile Force}}{0.87\,F_y} = 659 \times 10^3 \times 1.5 / 0.87 \times 500 = 2272\ mm^2$

Minimum percentage of steel $0.12 \times 900 \times 900 = 972\ mm^2$

Provide 8nos-Y20mm at Bottom

Provide 8nos-Y16 at Top.

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16.2 DESIGN OF COLUMNS:

Typical Design of Column:

C1 - COLUMN (up to Stilt floor roof - 300 X 600)

Total load on column = 1615KN

1.1.1 Max. Moment in Z-Direction = 41 KN-m
1.1.2 Max. Moment in Y-Direction = 195 KN-m
Concrete grade for column = M30

A_{st} = $5184\ mm^2$

p = 2.88%
p/f_{ck} = 0.10
$P_u / f_{ck} bd$ = 0.30
$M_u / f_{ck} b^2 d$ = 0.130
$M_u / f_{ck} bd^2$ = 0.165
Muy_1 = 211KN-m
Muz_1 = 535KN-m
Puz/Ag = 22N/mm^2
Muy/Muy_1 = 0.926
Muz/Muz_1 = 0.076
∝n = 1.34

$(Muy/Muy_1)^{\propto n} + (Muz/Muz_1)^{\propto n}$ = 0.934 (For Max. My with corresponding axial load & Mz)

Hence safe.

Provide 300 x 600 columns with 8Nos Y25 + 4 Nos Y20 with Y8 rings @ 6" (as per drawing)

16.3 DESIGN OF TYPICAL FLOOR BEAM:

Mu (+) = 42 kN.m
Mu (-) = 86 kN.m
Shear = 111 kN
Beam size = 200 X 450mm
b_f = 500 mm
Effective depth = 410mm
Grade of Concrete = M25
Grade of Steel = Fe500

Tension Reinforcement Details:

Mu (+) / (bf * d^2) = (42 x 10 ^ 6) / (500 * 410 * 410)
= 0.50 N/mm^2
For 0.50 N/mm^2; p_t = 0.12%
Then Ast = 0.12 * 500 * 410/100
= 246mm^2
No of bars = 246 / ((π * 16^2) / 4)
= 1.22Nos.

Provide 2-Y16 (throughout) @ bottom

Mu (-) / (B * d^2) = (86* 10 ^ 6) / (200 * 410 * 410)
= 2.56 N/mm^2

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For 2.56 N/mm^2, p_t = 0.68%;

Then Ast = 0.66 * 200 * 410/100

= 560 mm^2

= 560 / ((π * 16^2) / 4)

No of bars = 2.78 Nos.

Provide 2-Y16 throughout + 2-Y12 @ support in top.

Shear Reinforcement Details:

τv = Vu / (B*d)

τv = 111*10^3 / (200 * 410)

= 1.35

τc = 0.54

Hence $\tau v > \tau c$

Provide 8mm dia stirrup

Vus = ($\tau v - \tau c$) * B *d

Sv = (0.87 *fy* d * Asv) / (Vus)

Sv = 180mm

Reinforcement Details:

Provide 8mm dia rod with 4" C/C at supports and 8mm with 6" at mid span

Provide 2-Y16 (throughout) @ bottom

Provide 2-Y16 throughout + 2-Y12 @ support in top.

16.4 DESIGN OF TYPICAL FLOOR SLAB:

Design of floor slab (S1): (R.C.C. Slab)

Size of the Slab = 5.44m X 2.95m

Thickness of Slab = 130mm

l_y / l_x = 1.84

- ve B.M 0.065 x 2.95^2 x 11.75 kN/m^2 = 6.64 kN.m

+ ve B.M 0.050x 2.95^2 x 11.75 kN/m^2 = 5.11 kN.m

Provide 130 mm thick slab.

M_u / bd^2 = 0.65, p_t = 0.15, A_{st} = 152 sq.mm^2

M_u / bd^2 = 0.50, p_t = 0.12, A_{st} = 122 sq.mm^2

PROVIDE:

Y8 @ 150mm c/c (shorter span)

Y8 @ 180mm c/c (longer span)

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