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PROPOSED RESIDENTIAL DEVELOPMENT

AT MANGANDU, CHENNAI

STRUCTURAL DESIGN BASIS REPORT



Rev. No	Date of Issue	Prepared	Checked	Reviewed	Approved
R0	05-08-2017	Ramani	HPY	TSG	TSG

PROJECT TEAM

CLIENT

CYBERCITY Builders &
Developers Pvt Ltd.



PROJECT

Gardencity Realty Pvt Ltd

CONSULTANTS



STRUCTURAL

Innotech Engineering Consult
Pvt. Ltd.



CONSULTANT

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1. General Information

1.1 Preamble

M/s Cybercity Builders & Developers Pvt Ltd is proposing to construct Residential Development at Chennai, Architecture conceptualized by **M/s Gardencity Realty Pvt Ltd .**, Bangalore with Structural Engineering Consultancy services provided by **M/s. Innotech Engineering Consult Pvt. Ltd.**, Bangalore.

1.2 Objective of This Report

This detailed design basis report is being presented to indicate the standardized design methodology followed for structural analysis, designs and detailing during the process and highlight the critical assumptions made for designs during the initial stages. Any major revisions in assumptions / criteria shall have repercussions on designs and revised reports shall be submitted in such cases. Also various output from software.

1.3 Salient Features of the Project:

1.3.1 Site Location

The project is planned in 12.916 acres plot, located at Mangadu Chennai.

1.3.2 Building Description:

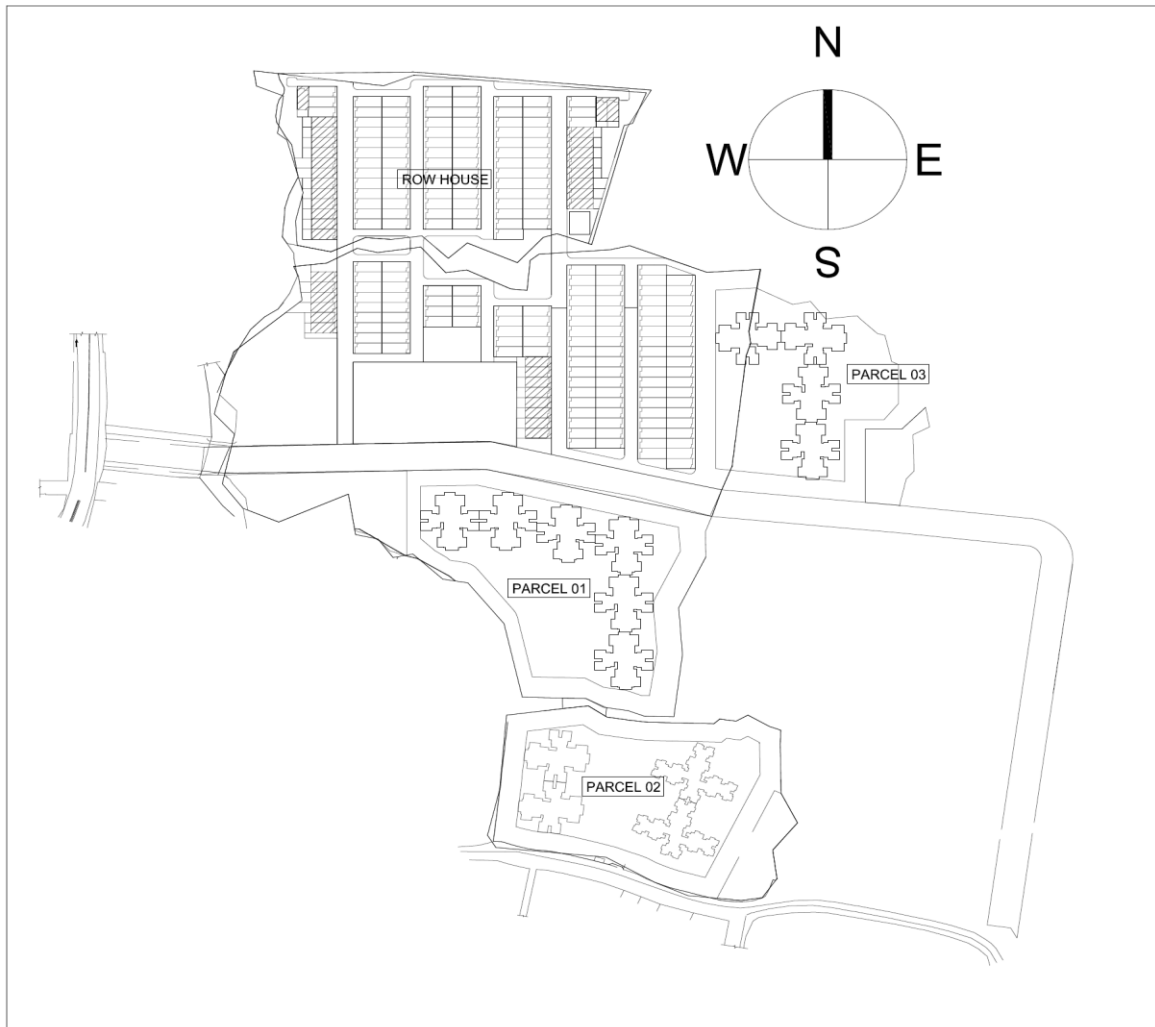
The entire project consists of 3 Parcel. The features and details of the Parcel are presented in the below sections

Parcel 01 – 6 Towers with Club House

Parcel 02 – 4 Towers with Club House

Parcel 03 – 4 Towers with Club House

Parcel 02 will be develop in Phase 01.



Key plan

1.3.2.1 Description of Substructure

NO. OF BASEMENTS	Two/Three Basements
Column, Core Wall, Slab System	RCC
Foundation System	Pile foundations.
Retaining wall	Propped Cantilever
Intended Use of basements	Parking
Expansion/Separation joints provided around the building	Yes.

1.3.2.2 Description of Superstructure

No. of Floors	Parcel01 3Basements+Ground+19 floors Terrace Floor. Parcel02: 2Basements+Ground+19 floors Terrace Floor. Parcel03: 3Basements+Ground+19 floors Terrace Floor.
Type of floor slab	Basement : Flat Slab System Ground Floor : Panel Slab System Transfer Floor: Girder Beam and Slab System. Typical Floor : Aluminium Form Work/Wall System

1.3.3 Building Use and Function

Basement: This area is predominantly used as a parking space and other services like storm water sump.

Ground Floor: The maximum floor area used for transfer the above level. The main entry or exit is controlled at this floor.

First Floor to 19th floor: The maximum floor area used as residential space with appropriate services like toilet, Balcony and maintenance room.

Terrace floor: Terrace floor areas will be utilized for services and partly gathering place.

1.4 Statutory Requirements

The design of the civil, Structure will comply with the requirements of the following:

- National Building Code.
- Local Building Regulations.
- Bureau of Indian standard codes.
- International codes as applicable.
- Any other regulation as advised by the client.

1.5 Design Philosophy

1.5.1 Concrete Structures

The proposed Structure is to develop residential campus; in cast in-situ concrete construction with slab options like Flat Slab/Panel Slab system the core wall around lifts and staircase are of cast in situ concrete to resist lateral forces.

The Structural design of the proposed project is based on Indian Standard Codes and is analysed for Dead, Live, Wind and Seismic Load conditions taking into relevant load combinations recommended by the codes & structural elements are designed in limit state design as per IS Code.

The Vertical Loads including the dead and super imposed loads and the Lateral loads due to wind and seismic forces are transferred to the soil through proposed Reinforced

Concrete Core Walls/Shear Walls, columns and footings. Footings/Foundations are sized with consideration to the safe bearing capacity of soil at the level of transfer of load recommended by specialist soil investigation consultants as the case may be.

1.5.2. Design Life

The design life of the building is assumed as 50 years subject to maintain of building as per IS code recommendation satisfying for the criteria of environmental conditions. This requirement is applicable only for concrete works and not applicable to replaceable finishing materials, water proofing membrane and thermal insulations (if any). Hence periodic maintenance / refurbishment are required for all replaceable material for longer life.

1.5.3 Liquid retaining structures

Following are the design considerations for the liquid retaining structures as per IS 3370 Part-2 (2009)

- Crack width- The maximum calculated surface width of cracks for direct tension and flexure or restrained temperature and moisture effects shall not exceed 0.2mm with specified cover.
- Strength
- Deflection and is designed based on the above criteria by limit state method.

1.5.4 Design Interface

This structure has physical interface with almost all the disciplines like Architecture, Geotechnical, MEP Services and Landscape etc. The Structure proposed is of cast in-situ concrete construction with Columns, RC shear walls and Suitable slab system concreted at intervals.

1.5.5 Vendors Design Work

Any Vendors Design work, the loading inputs shall be furnished by Innotech and the final detailed designs are verified and approved by Innotech.

2 Codes and Standards:

Specific applicable codes and standards shall be identified in the Design Philosophy as appropriate. The latest editions of the Codes and Standards shall be used. All design work shall be based on Indian Standards and Codes latest revision, with amendments if any, as on date.

Appropriate following Indian CODES and STANDARDS are followed while designing the structure:

2.1 Loadings

IS: 875 -1987 Code of Practice for Design Loads (Other than Earthquake) for Building and Structures-Unit Weights of Buildings Materials and Stored Material.

PART 1 - Dead Loads

PART 2 - Live loads or Imposed Loads

PART 3 – Wind Loads (IS: 875 -1987)

PART 5 - Special Loads and Load Combinations

2.2 Design for Earthquake Resistance

IS: 1893 (Part-1)-2016 Indian Standard Criteria for Earthquake Resistant Design of Structures

IS 4326: 1993 Earthquake resistant design and construction of buildings – code of practice.

2.3 Design of Reinforced Concrete Elements

IS: 456 - 2000 Code of Practice for Plain and Reinforced Concrete

IS: 1786-2008 Specification for High Strength Deformed Steel Bars and Wires for Concrete Reinforcement

IS13920-1993&2016 Ductile detailing of reinforced concrete structures subjected to seismic forces - code of practice

IS16172-2014 Reinforcement Couplers for Mechanical Splicing of bars in concrete.

SP: 16 Design aid for reinforced concrete to IS: 456.

SP: 23 Hand book on concrete mixes

SP: 24 Explanatory hand book on code of practice for PCC

SP: 34 Hand book on Concrete reinforcement and Detailing

2.4 Structural Steel Elements

IS: 800-2007 Code of practice for general construction in steel.

SP: 6-(1)-1964 Hand book on structural steel sections.

IS: 432 (Part-1)-1982 Specification of Mild Steel and Medium Tensile Steel bars and Hard drawn Steel Wire for concrete reinforcement –Mild Steel and Medium Tensile Steel Bars

IS: 2062 -2011 Indian standard Code of Practice for Hot rolled and high tensile structural steel – specifications.

2.5 Earthwork

IS 3764 Code of safety for Excavation work

2.6 Soil and Foundation

IS 8009: 1976 Code of practice for calculation of settlements of foundations.

IS: 1904-1986 Indian Standard Code of practice for Design & Construction foundations in Soil: General Requirements.

IS 2950 (Part1)-1981 Indian Standard Code of Practice for Design & Construction of raft foundation – (Part –1)

IS: 3370 (Part-2)-2009 Concrete Structures for Storage of Liquids –code of Practice.

2.7 Fire Safety of Building

IS: 1642-1989 Indian Standard Code of practice for Fire Safety of Buildings (General): Details of Construction.

Wherever appropriate, if any Indian regulation does not exist or not available for any particular criteria, appropriate British standards and ACI-318-2011, ACI-209R-92 will be followed.

2.8 Mechanical Couplers

IS: 16172-2014 Reinforcement concrete for Mechanical splices of bars in concrete-Specifications.

3 Materials

Materials specified will confirm to the latest edition of the relevant Indian Standards or other accepted standard. Specifications for materials will include for sampling and testing as stipulated in the design standards. Detailed material specifications will be included in the Technical Specification.

3.1 Concrete

Compressive Strength of concrete:

Keeping the durability and structural requirement, the proposed strength of various elements of structure will be as follows:

Structural concrete shall have Compressive Strength as mentioned below:

Foundation to Ground Floor Columns, Core Walls, RC walls & Transfer/Girder level beam shall have cube crushing strength of **50N/sq. mm at 28 days.**

Above Ground Floor to Level-3 floor level shall have cube crushing strength of **40N/sq. mm at 28 days.**

Level-3 to Terrace floor level shall have cube crushing strength of **30N/sq. mm at 28 days.**

Structural concrete for RCC Slab and Beam shall have Compressive Strength of **30N/sq. mm at 28 days.**

Grade of concrete:

Plain cement concrete shall have Compressive Strength of **20 N/sq.mm (M20) at 28 days.**

Footing-30 N/sq. mm at 28 days.

Retaining wall & Grade slab-30N/sq. mm at 28 days.

UG Sump & STP-30N/sq. mm at 28 days.

Minimum grade of concrete should be M30, as per IS 456-2000, Table-5

3.2 Reinforcement Steel:

All reinforcement shall confirm to IS: 1786 – 2008 having minimum yield strength of **500 N/sq mm (Fe 500D).**

HYSD-TMT bars of grade 500 conforming to IS: 1786.	
Young's Modulus	: $E_s = 200,000 \text{ N/Sq mm}$
Yield Stress	: $f_y = 500 \text{ N/Sq mm}$
Diameters [in mm]	: 6,8, 10, 12, 16, 20, 25 & 32
Density	: 78.5 kN/cum

Note: Third Party test to be conducted before fabrication as per codal requirement.

3.3 Structural Steel:

All structural steel shall confirm to IS -2062-2011.

Grade: E-250

Tensile strength	: 410 N/ mm^2
Yield stress	: 250 N/ mm^2 ($t < 20\text{mm}$)
	: 240 N/ mm^2 ($t = 20\text{-}40 \text{ mm}$)
	: 230 N/ mm^2 ($t > 40 \text{ mm}$)

Grade: E-350

Tensile strength	: 490 N/ mm^2
Yield stress	: 350 N/ mm^2 ($t < 20\text{mm}$)
	: 330 N/ mm^2 ($t = 20\text{-}40 \text{ mm}$)
	: 320 N/ mm^2 ($t > 40 \text{ mm}$)

Young's Modulus (E) : $200,000 \text{ N/ mm}^2$

Density : 78.5 kN/m^3 ,

Poisson's Ratio : 0.30

Thermal Expansion Coefficient : $\epsilon = 1.2 \times 10^{-5} / ^\circ\text{C}$

3.4 Structural Weld Mesh

All reinforcement shall confirm to IS: 1786 – 2008 having minimum yield strength of 500 N/sq.mm.

HYSD-TMT bars of grade 500 conforming to IS: 1786.

Young's Modulus	: $E = 200,000 \text{ N/Sq mm}$
Yield Stress	: $f_y = 500 \text{ N/Sq mm}$
Diameters [in mm]	: 5 mm, 6 mm, 7 mm
Density	: 78.5 kN/cum

3.5 Masonry Wall

The detailing of the masonry walls to the RCC elements both vertical and horizontal along with RCC bands will be provided by architects.

Grade for the masonry wall are specified in architectural drawings.

3.6 Coupler

Type – II couplers shall be used for columns, core walls and beams to minimize the congestion in the reinforcement.

As per ACI-318R-14, Clause 25.5.7.1 Couplers strength should be greater than or equal to 1.25 times of yield strength of rebar.

Total percentage of reinforcement should not exceed 6 % at any junction of lapping area.

4 Design Data

4.1 Dead Loads

Dead load shall include weight of all structural and Architectural components. Self-weight of the materials shall be calculated on the basis of unit weights given in IS: 875(part 1)-1987.

Unit weight of Reinforced cement concrete	2500Kg/cum – 25 kN/cum
Unit weight of reinforcement steel	7850Kg/cum – 78.5 kN/cum
Water	1000Kg/cum – 10 kN/cum
Glass	2720Kg/cum – 27.20 kN/cum
Stainless steel	7850Kg/cum – 78.5 kN/cum
Solid Block Masonry (SBM) Including plastering.	2200Kg/cum – 22 kN/cum
Light weight filling material	1000Kg/cum – 10 kN/cum
Soil –Dry	1800Kg/cum – 18 kN/cum
Soil – perfectly Wet	2195Kg/cum – 21.95kN/cum
Unit weight of screed	2400Kg/cum – 24 kN/cum
Reinforced cement concrete precast member	2500Kg/cum – 25 kN/cum
Aluminium composite panels (6mm thick)	3.5 Kg/sq meter – 0.03 kN/sq meter
Thermo coal	25Kg/cum – 0.25 kN/cum

Following loads are considered while designing the structural elements apart from dead load (self-weight) as per code.

4.2 Live Loads and Super Imposed Dead Loads

SL No.	Loading requirements	As per IS code / NBC / Consultant	As per client requirement/MEP	Designed Loads
Super imposed dead load as per IS:875 (Part 1)-1987				
1	Floor finishes 50mm thk.(staircase)	120 kg/m ²		120 kg/m ²
2	Floor finishes 50mm thk.(Residential)	120 kg/m ²		120 kg/m ²
3	Floor finishes 100mm thk.(parking & Ground floor)	240 kg/m ²		240 kg/m ²
4	150mm thk Filling (Balcony & Utility)	360 kg/m ²		360 kg/m ²
5	200mm S.B.M wall load per meter ht.	440 kg/m		440 kg/m
6	150mm S.B.M wall load per meter ht.	330 kg/m		330 kg/m
7	100mm S.B.M wall load per meter ht.	220 kg/m		220 kg/m
8	RCC Parapet of 1.2m height @ terrace - 200mm thick	600 kg/m		600 kg/m
9	Electrical panel room @ Ground floor level (Excluding finish)		750 kg/m ²	750 kg/m ²
10	AHU room (Excluding finish)		500 kg/m ²	500 kg/m ²
11	Pump room (Excluding finish)		750 kg/m ²	750 kg/m ²
12	450mm soil filling including water proofing(Podium)		945 kg/m ²	945 kg/m ²
13	150mm screed filling on terrace slab	360 kg/m ²		360 kg/m ²
14	Landscaping on terrace of towers		Not considered	Not considered
15	Lift machine room (Excluding finish)	1000 kg/m ²		1000 kg/m ²
16	OHT (water depth)		As per actual	As per actual
17	Floor Finishes 75mm thk (Club House)	180 kg/m ²		180 kg/m ²
18	Club House – Swimming Pool	Water load as per drg		

Live load as per IS:875 (Part 2)-1987				
SL No.	Loading requirements	As per IS code / NBC / Consultant	As per client requirement/MEP	Designed Loads
1	Car parking @ B3,B2 & B1 Level	300 kg/m ²		300 kg/m ²
2	Car driveway @ B3,B2 & B1 Level	300 kg/m ²		300 kg/m ²
3	Car parking @ Stilt Floor Level(Single stack)	300 kg/m ²		300 kg/m ²
4	Car driveway @ Stilt Floor Level	500 kg/m ²		500 kg/m ²
5	Loading and Unloading bay	1000 kg/m ²		1000 kg/m ²
6	Fire truck loading	45 MTON		45 MTON
7	Design of columns & footings at podium Area -Fire tender load	1000 kg/m ²		1000 kg/m ²
8	Checking of Punching Shear at fire tender Movement slab & beam (Refer calculation)	1521 kg/m ²		1521 kg/m ²
9	Design of slab & beam at fire tender Movement (Refer calculation)	1521 kg/m ²		1521 kg/m ²
10	Living, kitchen, bed room, toilet	200 kg/m ²		200 kg/m ²
11	Podium area other than fire driveway	400 kg/m ²		400 kg/m ²
12	Lobby, Balconies and corridor	300 kg/m ²		300 kg/m ²
13	Ramp without fire truck movement	500 kg/m ²		500 kg/m ²
14	Ramp with fire truck movement	1000 kg/m ²		1000 kg/m ²
15	Staircase @ B2,B1 & Stilt Floor	400 kg/m ²		400 kg/m ²
16	Staircase From Podium to Terrace	300 kg/m ²		300 kg/m ²
17	Toilet room	200 kg/m ²		200 kg/m ²
18	OHT Top slab not accessible /No eqt.	75 kg/m ²		75 kg/m ²
19	Staircase roof not accessible/No eqt.	75 kg/m ²		75 kg/m ²
20	Club House	500 kg/m ²		500 kg/m ²

NOTE:

* Live Load is not considered at UPS, TRANSFORMER & ELECTRICAL PANEL ROOM, since same is accounted in super imposed dead load.

4.3 Seismic load as per IS-1893 2016

1	Town	Chennai
2	Zone – Annex - E	III
3	Zone co-efficient(Z) Table -02	0.16
4	Importance factor(I) Table - 06	1.2
5	Response reduction factor(R) a. Tower Area b. Tower basement c. Podium Area	4 5 4 (RC buildings with OMRF)
6	Fundamental Natural period in sec – Clause 7.6.2	$T_a = 0.09h/\sqrt{d}$
7	Ductile detailing As per IS-13920	Required
8	N Values from Bore Logs Report	$N < 10$
9	Soil Type- Table -01 of IS-1893:2002	Type 3 Soft Soil
10	Damping ratio	5%

Percentage of imposed load to be considered in seismic weight calculation as per IS-1893-2002 (cl. 7.3.1)

Impose uniformity distributed floor loads(kN/m ²)(Live Load)	Percentage of imposed loads
Up to and including 3.0	25
Above 3.0	50

Typical Calculation: Block -01(Parcel 02)

Base dimension of the building along the considered direction of lateral force

$L = 64.54\text{M}$,

$B=48.45\text{ M}$, $H=59.95\text{M}$.

$T_a = \frac{0.09h}{\sqrt{d}}$ from CL - 7.6.2 - IS 1893 (Part-I) 2002

$T_{ax} = 0.09 \times 52.536 / \sqrt{78.4} = 0.533\text{ sec for X}$

$T_{ay} = 0.09 \times 0.677 / \sqrt{47.2} = 0.6877\text{ sec for Y}$

$V_b = A_h * W$

W = Seismic weight of the structure from Etabs

A_h = Horizontal seismic coefficient as per code

$S_a/g = 1/T = 1.87\text{ for X}$

$S_a/g = 1/T = 1.45\text{ for Y from IS 1893 (Part-I):2016}$

HORIZONTAL SEISMIC CO-EFFICIENT

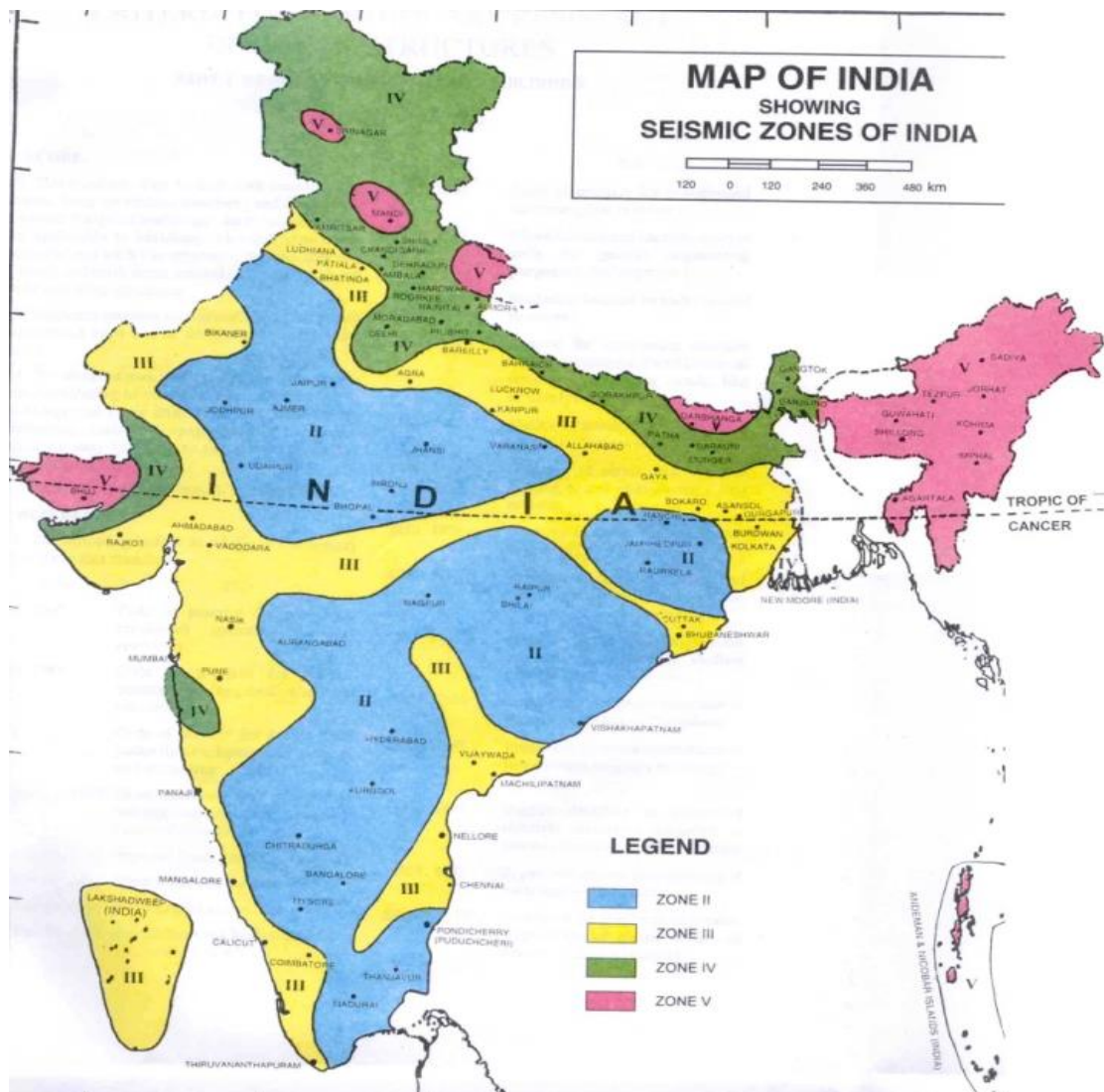
$$A_{h_x} = \frac{Z \times I S_a}{2 \times R_g} = \frac{0.16 \times 1.0 \times 1.87}{2 \times 5} = 0.02992 \text{ For X}$$

$$A_{h_y} = \frac{Z \times I S_a}{2 \times R_g} = \frac{0.16 \times 1.0 \times 1.45}{2 \times 5} = 0.0232 \text{ For Y}$$

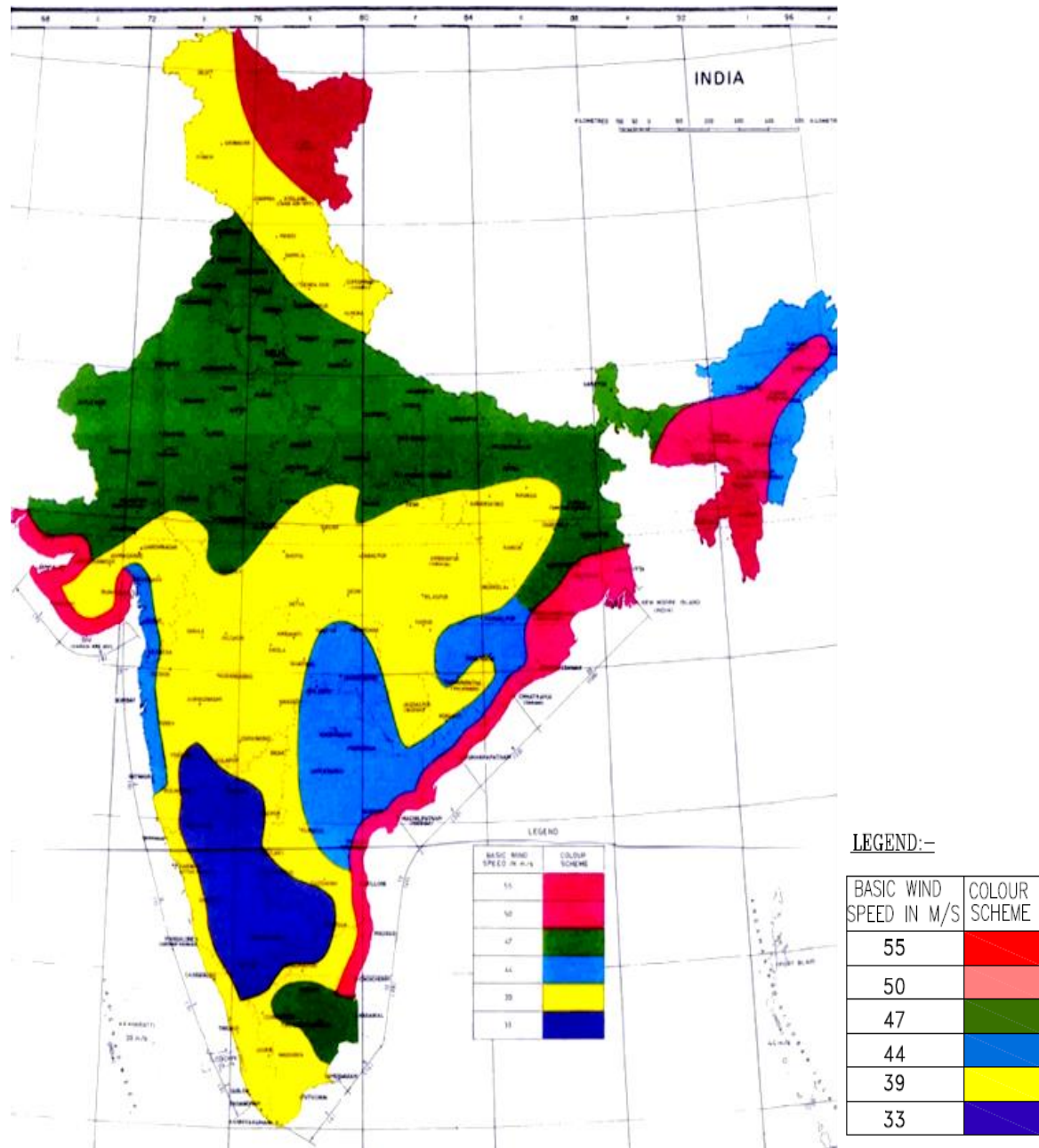
Design seismic base shear

$$V_{bx} = A_h W$$

$$V_{by} = A_h W$$



4.4 Wind Load



Wind Map of India

Wind load as per IS:875 (Part 3)-2015		
1	Zone	Chennai
2	Basic wind speed (V _b) m/sec- Appendix-A	50 m/sec
3	Risk co-efficient (k ₁)-Table-01	1.0 (for general buildings)
4	Terrain, height and size factore (k ₂ ')	As per table 02
5	Topography factor (k ₃)	1.0
6	Important factor (k ₄)	1.2
7	Design wind speed (V _z)	$V_z = V_b * k_1 * k_2' * k_3 * k_4$
8	Design wing pressure (P _z)	$P_z = 0.6 * V_z^2$
9	Internal and External co-efficient as per IS:875 (part 3)	Not Required As per Closed Structure

It is generally recognized that absolute sway is not a perceivable parameter; however limiting sway is used to provide a reasonable level of stiffness and in order to limit damage to non-structural elements as well as limit size of curtain wall joints, etc.

Generally tall building lateral load resisting systems are sized on the basis of limiting Overall lateral sways to limits of approximately Overall Height/500 under the 50 year return Period wind loads.

Height of Building = 59.95 m from Ground Level

Permissible Deflection = 59.95/500

= 119mm.

Calculation of Design Wind Pressure (P_z) and wind speed (V_z):

The wind pressure has been calculated based on the data furnished below and other provisions laid in IS 875 (Part-3) – 1987

BLOCK -1(Parcel 02)

Design wind speed $V_z = V_b * K_1 * K_2' * K_3 * K_4$

Design wind pressure $P_z = 0.6 * V_z^2$

Where,

V_b=50 m/sec (Chennai)

K₁=Risk Coefficient

=1.0 as per table 1 of IS-875(3)

K₂'=Terrain, height and structure size factor.

Therefore, category-02, class-C for Height-30 m

= 1.04 as per table-33 of IS-875(3)

K₃=Topography factor

=1.0 as per clause 5.3.3 IS-875(3)

Then,

V_z=50 x 1 x 1.04 x 1.0 x 1.0 =52 m/sec

$P_z = 0.6 \times 52^2 = 1622 \text{ N/m}^2$ at 60 m height.

Similar Pressure calculations are done between 10 to 60 m height.

Dynamic wind analysis check as per IS 875 part III clause 7.1: **BLOCK 01(Parcel 02)**

Check for wind dynamic effects for

As per IS 875 – part (III)

Clause-7.1

H = 59.95 m, L = 64.545m and B = 48.45m

a) $H/B = 59.95/48.45 = 1.23 < 5.0$

Dynamic wind analysis not required.

b) $T = 0.09 \times H / \sqrt{48.45} = 0.775 \text{ Sec.}$

$Fr = 0.775 \text{ Hz} == 1/0.775 = 1.29 > 1.0 \text{ Hz}$

Dynamic wind analysis is not required.

4.5 Temperature Loads:

The effect of temperature will be considered wherever applicable in accordance with relevant Indian codes. The coefficient for thermal expansion and contraction will be in accordance with IS: 456 and IS: 800 for concrete and steel respectively.

The maximum and minimum temperatures for city of Chennai are published by the metrological department are

According to IS 875 (part 5) the following climatic data is assumed:

Maximum mean temperature 45°C

Minimum mean temperature 18°C

Assumed temperature during construction 27°C

Therefore a constant temperature variation is applied of: +7.5° / -12.5° C

4.6 Special Loads

Load due to the following catastrophe scenarios are not considered in the design.

- Exceptional loads due to terrorist attacks. (Explosions)
- Accidental loads. (Falling of aircraft on the building).
- Accidental hitting of vehicle on the façade.
- Snow load.
- Gas Explosion.

4.7 Soil Pressure on Retaining Wall

Water pressure considered in the design of retaining wall

Assumed Soil Properties:

Angle of shearing resistance	ϕ	= 30°
Load on Wall		
Density of Soil (Saturated)	γ_{sat}	= 21 kN/cu.m
General Surcharge on the soil retained	$\gamma_{surcharge}$	= 10 kN/cu.m
Water pressure		=10 kN/m ³ (For full height as per Geotechnical recommendations)

4.8 Water Pressure on Grade/stitch slab

Sub soil drainage system is proposed all around external face of Retaining wall and below Grade slab.

Considering the effect of sub soil drainage system in place, the water pressure on grade slab reduces. 50% of the upward water pressure is considered on grade slab for the design and checking of stability of grade slab.

5.0 Geotechnical Investigation:

Geo Technical investigation has been carried out using heavy duty rotary drilling technique to ascertain the nature of the strata and know the repercussion due to the same on structural system as well as on construction activity. As per the soil report furnished by **M/S GEO FOUNDATION & STRUCTURES PVT LTD**, Chennai, the below ground soil strata details are as follows.

Number of bores drilled	: 24 Bores (BH-1 to BH-24)
Bore depths	: 30.0m from EGL.
Depth of basement	: 11.05m from FGL for Parcel 01 & Parcel 03
Depth of basement	: 7.75m from FGL for Parcel 02

Soil profile:

Refer Soil Report.

Water table: Ground water table is at Ground level as per Geotechnical Report

Settlement : within 25mm

FOUNDATIONS:

Footings (Pile foundation) are designed based on Geo Technical investigation report and will dissipate all the vertical and horizontal loads safely to the strata below taken to rest in hard strata. The following tables are given pile capacity for various diameters.

Approximate Length of Pile from Existing Ground Lvl(m)	Diameter of Pile(mm)	Recommended Safe Vertical Capacity (Ton)
24 to 25	500	75
	600	100
	750	140
	900	200

6. Structural Analysis :

6.1 General

The structural analysis is carried out by finite element method using the commercially available latest software **E-tabs/ STAAD Pro V8i / SAFE** for the load combinations as per standards. The designs of the RCC elements are made using the Limit State method with appropriate load factors as per IS: 456-2000 using RCDC, DRAFTWIN and spread sheet/E-Tab, etc. Designs of structural steel members are made using elastic method as per IS: 800 with relevant allowable stresses. Design of PT slabs are analysed and designed using ADOPT and RAPT software.

6.2 Method of Analysis

As per clause 7.1 & 7.8 (IS 1893(Part 1):2002), structure is irregular with respect to mass and stiffness of structure also total height of the structure is more than 40m in seismic zone III, accordingly dynamic analysis shall be carried out.

Generation of ETABS model

- Preliminary sized cad formatted shuttering drawing of each floor shall be created and exported to E-tab and 3D model shall be generated.
- Initial preliminary analysis for each structural member shall be carried out and accordingly the shuttering layout shall be prepared.
- The floor slabs shall be modelled as shell elements and assigned/defined as semi rigid diaphragm
- Staircase flight / ramp slabs are modelled as horizontal element at respective floor levels to arrive the gravity loading on column for design of foundations.
- Mesh size assigned for shell area is 1m x 1m as mesh size or finer mesh sizes

- The reinforced concrete columns are rigidly connected with the floor slabs.
- All vertical walls elements are assigned with auto meshing to achieve accurate designs
- Soil and water pressure are not accounted for the structural 3D analysis, however the same shall be considered for individual element analysis and design.
- Slab on grade is not considered for 3D analysis.
- Sectional properties are assigned to all the structural elements as per preliminary drawings.
- Section Modifiers are considered as per ACI 318- 14(if required)
 - Slabs: $0.25I_g$
 - Beams $0.35I_g$
 - Walls: $0.7I_g$
 - Columns: $0.7I_g$
- As per IS 456 clause 41.1 beams where torsion is required to maintain equilibrium will be designed for torsion in accordance with 41.2, 41.3 and 41.40. However for all other beams torsional stiffness is neglected in the analysis by applying stiffness modifier as 0.25 to torsional constant "J". Hence no specific design for torsion is required for these beams.
- As per IS - 13920, the minimum shear wall / Beams / Column thickness is considered as 200mm.
- Covers to reinforcement shall be in accordance with IS: 456-2000 corresponding to moderate exposure conditions.
- Design loading shall be applied at relevant floor as per specified design loads
- Wall loads are assigned as line loads wherever the walls are well defined and External and partition walls are assigned under SIDL load case.
- Mechanical equipment loads are converted into UDL and applied for respective bays.
- Architectural features are not modelled, however the respective SIDL are accounted into analysis.

- Live load reduction is considered for designing of columns and shear walls.
- All lateral loads applied as per IS codes.
- Actual OHT, staircase, chiller locations and loadings are considered in the 3D analysis.
- Temperature loads are applied to terrace and some part of podium area. Which are directly exposed to sun.
- 3D model shall be analysed by dynamic analysis.
- Wherever the beams failing for shear in ETABS model, manual sway shear calculation is done as per IS 13920-2016 clause 6.3.2.
- UG sump and STP are analysed and designed separately for crack width of 0.2mm.
- Secondary beams are not designed for earthquake detailing.
- Long term deflection are checked using excel spread sheet.
- Crack width calculation is checked using excel spread sheet.
- Since Chennai in zone III, Ductile detailing norms are adopted to make the building earthquake resistant in accordance with IS: 13920:2016.
- With the expansion joint around the building, the mass participation ratio of 65 % at the third mode is satisfied as per IS1893:2016.
- Lateral sway for torsional displacement is less than 1.5 times the minimum displacement which satisfies IS1893:2016.
- Vertical earthquake effects to be considered in the design and clause no.6.3.4.1 and 6.3.3 shall be followed.
- Vertical acceleration to be done with the seismic mass as per the X & Y direction.
- Importance factor is 1.2 and it satisfies as per the IS1893:2016
- Ductile detailing shall be done on the walls which is resting on the column and negate the remaining walls when considering lateral loads.
- Dynamic analysis shall be done which takes care of vertical, plan, weak storey, soft storey and irregularity.
- Stiffness modifier to be done for columns (70%) and beams (35%).

Serviceability Limit State (SLS)

As per IS 1893: 2016 (part-1) the story drift due to minimum specified lateral force with partial load factor of 1.0 shall not exceed **0.004 h_s** , where h_s is the story height under consideration

The vertical deflection under imposed load should be limited as follows:

L/250 taking into accounts all imposed loading, including temperature and creep/shrinkage.

L/350 taking into accounts all imposed loading, including temperature and creep/shrinkage after erecting the finishes. Or 20mm whichever is less.

6.3 Load Combination

The results obtained from the computer analysis in the form of member forces and reactions will be used for design the structural members. The following load combinations of the member forces will be considered for arriving at the design forces.

Live Load reductions are considered as per IS 875 Part –II for Column, Shear wall and Footing Design. All lateral load carrying elements are oriented in orthogonal direction. Hence load combinations as per IS – 1893 clause 6.3.4, is not required.

Static Load Combinations

NO	Load Combinations	LOAD FACTORS					
		DL	LL	WLx	WLy	EQx	EQy
DCon1	DL	1.5	-	-	-	-	-
DCon 2	DL+LL	1.5	1.5	-	-	-	-
DCon 3	DL+LL+WLx	1.2	1.2	1.2	-	-	-
DCon 4	DL+LL-WLx	1.2	1.2	-1.2	-	-	-
DCon 5	DL+LL+WLy	1.2	1.2	-	1.2	-	-
DCon 6	DL+LL-WLy	1.2	1.2	-	-1.2	-	-
DCon 7	DL+WLx	1.5	-	1.5	-	-	-
DCon 8	DL-WLx	1.5	-	-1.5	-	-	-
DCon 9	DL+WLy	1.5	-	-	1.5	-	-
DCon 10	DL-WLy	1.5	-	-	-1.5	-	-
DCon 11	DL+WLx	0.9	-	1.5	-	-	-

DCon 12	DL-WLx	0.9	-	-1.5	-	-	-
DCon 13	DL+WLy	0.9	-	-	1.5	-	-
DCon 14	DL-WLy	0.9	-	-	-1.5	-	-
DCon 15	DL+LL+EQx	1.2	1.2	-	-	1.2	-
DCon 16	DL+LL-EQx	1.2	1.2	-	-	-1.2	-
DCon 17	DL+LL+EQy	1.2	1.2	-	-	-	1.2
DCon 18	DL+LL-EQy	1.2	1.2	-	-	-	-1.2
DCon 19	DL+EQx	1.5	-	-	-	1.5	-
DCon 20	DL-EQx	1.5	-	-	-	-1.5	-
DCon 21	DL+EQy	1.5	-	-	-	-	1.5
DCon 22	DL-EQy	1.5	-	-	-	-	-1.5
DCon 23	DL+EQx	0.9	-	-	-	1.5	-
DCon 24	DL-EQx	0.9	-	-	-	-1.5	-
DCon 25	DL+EQy	0.9	-	-	-	-	1.5
DCon 26	DL-EQy	0.9	-	-	-	-	-1.5

Dynamic Load Combinations

NO	Load Combinations	LOAD FACTORS					
		DL	LL	SPECX	SPECY		
DCon 27	DL+LL+Spec-x	1.2	1.2	1.2	-		
DCon 28	DL+LL+Spec-y	1.2	1.2	-	1.2		
DCon 29	DL+LL+Spec-x	1.5	1.5	1.5	-		
DCon 30	DL+LL+Spec-x	1.5	1.5	-	1.5		
DCon 31	DL+LL+Spec-x	0.9	0.9	1.5	-		
DCon 32	DL+LL+Spec-y	0.9	0.9	-	1.5		

TABLE3:Temperature load Combinations
Load Combination

Load Factor

	D.L	L.L	WL _x	WL _y	EL _x	EL _y	EL _z	TL
DL+TL	1.5	-	-	-	-	-	-	1.0
DL+LL+TL	1.5	1.5	-	-	-	-	-	1.0
DL+LL+WX+TL	1.2	1.2	1.2					1.0
DL+LL-WX+TL	1.2	1.2	-1.2					1.0
DL+LL+WY+TL	1.2	1.2		1.2				1.0
DL+LL-WY+TL	1.2	1.2		-1.2				1.0
DL+WX+TL	1.5		1.5					1.0
DL-WX+TL	1.5		-1.5					1.0
DL+WY+TL	1.5			1.5				1.0
DL-WY+TL	1.5			-1.5				1.0
DL+WX+TL	0.9		1.5					1.0
DL-WX+TL	0.9		-1.5					1.0
DL+WY+TL	0.9			1.5				1.0
DL-WY+TL	0.9			-1.5				1.0
SERVICE LOAD COMBINATIONS								
DL + LL+WLX	1	1	1					
DL+LL - WLX	1	1	-1					
DL +LL+ WLY	1	1		1				
DL+LL-WLY	1	1		-1				

DL + WLX	1		1					
DL - WLX	1		-1					
DL + WLY	1			1				
DL - WLY	1			-1				
DL + LL + SPECX	1	1			1			
DL + LL - SPECX	1	1			-1			
DL + LL + SPECY	1	1				1		

DL + LL - SPECY	1	1				-1		
DL + LL + SPECZ	1	1					1	
DL + LL - SPECZ	1	1					-1	
DL+SPECX	1				1			
DL-SPECX	1				-1			
DL+SPECY	1					1		
DL-SPECY	1					-1		
DL+SPECZ	1						1	
DL-SPECZ	1						-1	

TEMPERATURE LOAD COMBINATIONS (Limit States of Serviceability)

DL+WX+TEMP	1	-	1	-	-	-	-	1
DL-WX+TEMP	1	-	-1	-	-	-	-	1
DL+WY+TEMP	1	-	-	1	-	-	-	1
DL-WY+TEMP	1	-	-	-1	-	-	-	1
DL+SPECX+TEMP	1	-	-	-	1	-	-	1
DL-SPECX+TEMP	1	-	-	-	-1	-	-	1
DL+SPECY+TEMP	1	-	-	-	-	1	-	1
DL-SPECY+TEMP	1	-	-	-	-	-1	-	1
DL+SPECZ+TEMP	1	-	-	-	-	-	1	1
DL-SPECZ+TEMP	1	-	-	-	-	-	-1	1
DL+LL+WX+TEMP	1	0.8	0.8	-	-	-	-	1
DL+LL-WX+TEMP	1	0.8	-0.8	-	-	-	-	1
DL+LL+WY+TEMP	1	0.8	-	0.8	-	-	-	1
DL+LL-WY+TEMP	1	0.8	-	-0.8	-	-	-	1
DL+LL+SPECX+TEMP	1	0.8	-	-	0.8	-	-	1
DL+LL-SPECX+TEMP	1	0.8	-	-	-0.8	-	-	1
DL+LL+SPECY+TEMP	1	0.8	-	-	-	0.8	-	1

DL+LL-SPECY+TEMP	1	0.8	-	-	-	-0.8	-	1
DL+LL-SPECZ+TEMP	1	0.8	-	-	-	-	0.8	1
DL+LL-SPECZ+TEMP	1	0.8	-	-	-	-	-0.8	1
DL-Dead load, LL-Live load, WL-Wind load, EL-Seismic load, TL-Temperatura load								

7 Structural Designs:

The structure shall be designed according to the Limit State Method as specified in IS: 456-2000. Appropriate loads and its combinations, as per relevant clauses in Code IS 456:2000 Code IS 875 (Part-5) 1987, for the most unfavourable effects are chosen for design.

7.1 Foundation:

The Pile and Pile Cap analysis and design is carried out by finite element method using the commercially available latest software **SAFE-12.1.3** and in house spread sheets.

The pile and Pile Cap are designed based on the results and forces obtained from **Etabs** for the critical condition using modulus of sub grade reactions for combined and raft foundations.

The depth of pile are derived as per IS code requirement, it is include of flexure, one way and Two Way shear Check.

Slab on grade is a stitched slab between the footings and is non-structural element. However the geotechnical investigation report indicates mention of water table in the bore holes executed by them. Hence, uplift pressure is considered in the grade slab design.

7.2 RCC Columns

The column design is carried out by finite element method using the commercially available latest software Etab and in house spread sheets detailed in AutoCAD and drafting

- Columns are designed for biaxial bending and critical load combinations
- Columns are designed for reduced live load as per IS- 875(II)
- Columns are detailed as per IS - 13920

The design of the reinforcement shall be consider the limits for maximum reinforcement ratio as per standards as well as construction requirement.

Where the permissible bearing stress on the concrete in the supporting or supported member would be exceeded, reinforcement shall be provided for developing the excess force, either by extending the longitudinal bars into the supporting member, or by dowels.

7.3 RCC Core wall / Shear Wall

The RC core wall / Shear wall design is carried out by finite element method using the commercially available latest software Etabs.

The walls are mainly designed for vertical as well as horizontal load from structure and also ensure the overall structural stability

- Core walls are designed for worst of two cases,
 - Case 1 – Check individual legs with respect to gravity loads (DL + SIDL+LL)
 - Case 2 – Check combined wall for lateral load combination

Vertical Projections

Tower, Tanks, parapet and other vertical cantilever projections attached to buildings and projecting above the roof, shall be designed and checked for stability for the **five times** the design horizontal seismic coefficient.

7.4 RCC Beams

The RC beam design is carried out by finite element method using the commercially available latest software Etabs and also using by spread sheet wherever complexity in Etabs design.

7.5 RCC Slab

The RCC slab analysis and design is carried out by finite element method using the commercially available latest software SAFE-12.1.3 and in house spread sheets

The Slab is designed based on the results and forces obtained from Etabs for the critical condition.

Horizontal Projections

All horizontal projections like cornices and balconies shall be designed and checked for stability for the **five times** the design horizontal seismic coefficient.

7.6 Staircase Slab

The RCC Staircase slab analysis and design is carried out by 3D finite element method using the commercially available latest software STAAD PRO V8i and in house spread sheets.

7.7 Retaining Wall

The Retaining wall analysis and design is carried out by single line element using the commercially available latest software STAAD PRO V8i and in house spread sheets. Subsoil drainage system is adopted all around the retaining wall.

The retaining wall is designed for lateral earth pressure and water table up to full height and checked for both shear and bending.

All Propped cantilever walls are designed for active earth pressure.

All cantilever walls are designed for earth retaining walls as earth at rest.

7.8 Environmental Conditions, Corrosion and Fire Protection for Concrete

As per clause 8.2.2 IS 456:2000, the general environment to which the concrete will be exposed during its working life is classified into five levels of severity, that is, mild, moderate, severe, very severe and extreme as described in below table.

Cover for steel to protect from fire and corrosion, moderate environment condition is considered.

- As per table 16, IS 456-2000, nominal cover to meet durability requirement is for Moderate condition is 30mm (type of exposure-Concrete surfaces sheltered from saturated salt air in coastal area) is considered for all internal structural element.
- Nominal cover to meet durability requirement is for severe condition is 45mm (type of exposure- Concrete exposed to coastal environment) is considered for all external structural element.

- For exposure condition "severe" and "very severe", where concrete grade is M30 and above.
- Fire Resistance for slab is considered 1-1/2 hours and Beam, Column and Wall is considered 2 hours.

Structural elements		Environment		Fire resistance		Cover to reinforcement adopted	Remarks
		Mod	Severe	1 1/2 ho	2 hou		Refer clause 26.4.2,21.4 and 26.4.3 and Table16& 16A
Footing		-	50	-	-	50	
Interior columns		40	-	-	40	40	Concrete surfaces sheltered from saturated salt air in coastal area
Exterior columns		-	45	-	40	45	
Shear wall/core wall(interior)		30	-	-	25	30	
SW/ CW	Inner face	30			25	30	
	exterior face	-	45	-	25	45	
Beams interior (simply supported)		30	-	20	-	30	
Beams exterior (simply supported)			45	20		45	
Beams interior (continuous)		30	-	20	-	30	
Beams exterior (continuous)			45	20	-	45	
Slabs (simply supported)		30	-	25	-	30	
Slabs (continuous)		30	-	20	-	30	
Ribs(simply supported)		30	-	35	-	30	
Ribs (continuous)		30	-	20	-	30	
staircase		30	-	25	-	30	
Retaining wall Earth side			45	-	-	45	
Water retaining	Inner		45			45	
	exterior						
Basement side			45			45	

7.10 Expansion & Construction Joints:

Expansion joints are normally provided when structure exceeds 45m length. The width of the joints is being calculated as per IS-1893-2002, clause 7.11.3.

However as the length of building in this project is more than 45m and the expansion joint are not provided, thermal analysis shall be carried out to ascertain their effect and accordingly the design shall be carried out

Construction joints and shrinkage strips will be planned with the coordination of construction agencies.

7.11 Excavation Methodology:

- Slush formed by any water accumulation should be removed and refilled by lean concrete.
- If water accumulates in the foundation trenches, dewatering should be done by pumping out water from a level lower than the foundation level to maintain downward flow of water.
- Earth retention if required depending on the Geological Report shall be provided.
- Rock blasting is not advised, suitable system as per site conditions shall be adopted in consultation with geo tech consultant.

8. Types of Structural System:

Proposed structure shall be designed with above mentioned data with the slab system as below.

Floors	Proposed structural slab system options	Concluded slab system
Basement level	Flat Plate Slab System	Flat Plate Slab System
Typical floor	1. Mivan Structural Slab System. 2. Beams and Slab System.	Mivan Structural Slab System
Podium Floor	1. Voided Slab System 2. Girder Beam and Slab System	Girder Beam and Slab System.

Annexure

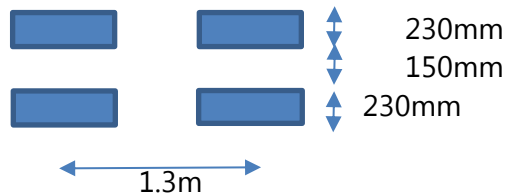
Calculation of Fire Tender load on slab for checking of punching shear.

Fire tender load = 45Tonnes

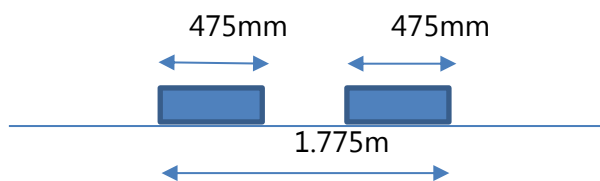
Slab Thickness = 300mm

Filling Depth = 450mm

Back wheel:

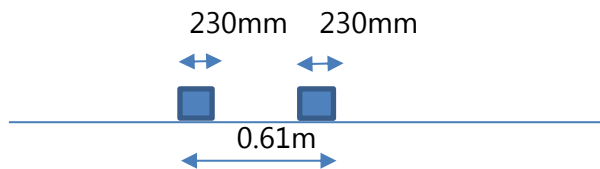


Dispersion length:



$$\begin{aligned}\text{Effective length of load} &= 2(\text{slab thickness} + \text{filling depth}) + 1.775 \\ &= 2(0.30 + 0.450) + 1.775 \\ &= 3.275 \text{ m}\end{aligned}$$

Dispersion width:



$$\begin{aligned}\text{Effective width of load} &= 2(\text{slab thickness} + \text{filling depth}) + 0.61 \\ &= 2(0.30 + 0.45) + 0.61 \\ &= 2.11 \text{ m}\end{aligned}$$

Load from back wheel = 18T

$$W_1 = 180 / (3.275 \times 2.11) = 26.05 \text{ kN/M}^2$$

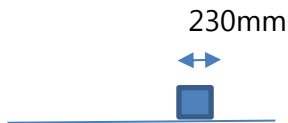
Front wheel:

Dispersion length:



$$\begin{aligned}
 \text{Effective length of load} &= 2(\text{slab thickness} + \text{filling depth}) + 0.475 \\
 &= 2 (0.30+0.450) + 0.475 \\
 &= 1.975 \text{ m}
 \end{aligned}$$

Dispersion width:



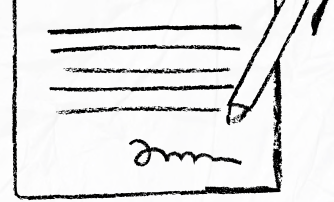
$$\begin{aligned}
 \text{Effective width of load} &= 2(\text{slab thickness} + \text{filling depth}) + 0.61 \\
 &= 2 (0.30+0.450) + 0.23 \\
 &= 1.73\text{m}
 \end{aligned}$$

Load from back wheel = 2.25T

$$W_2 = 22.50 / (2.975 \times 1.73) = 4.37 \text{ kN/M}^2$$

Design load of Slab and Beam at fire tender Movement

$$\begin{aligned}
 W_3 &= (W_1 + W_2) / 2 \\
 &= (26.05 + 4.37) / 2 \\
 &= 15.21 \text{ kN/M}^2
 \end{aligned}$$



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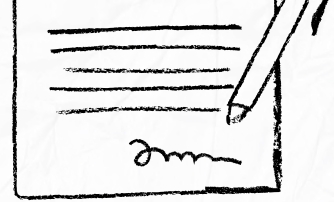
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