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V. RUKMANGATHAN M.TECH (STRUC. ENGG)

Structural Engineer

Structural Design, Project Management and Cost consultant

Date: 14/06/2021

STRUCTURAL STABILTIY CERTIFICATE

This is to certify that the structural design for project **"Market Of India" (Block 06)** comprising located at plot bearing survey No: 218/5, 218/2, 219/1 to 6, 220/2 of block 11,221/2, 222/1 & 2 of block 12, Perambur Town, Division 73, Zone VI, Chennai – 600 012. The building is designed for 3 basement + Ground Floor + 1st Floor to 4th Floor (Shops, Food Court & Multiplex) + 5th Floor (Parking, Food court & Multiplex) + 6th Floor to 9th Floor (partly shops & partly parking) + 10th Floor (Shops) + 11th Floor part to 15th Floor part (Office use); and its designed to carry all kind of load combinations. The structural design of building is carried out as per guide lines provided in

1. IS - 456 - Code of practice for Plain and Reinforced Cement concrete
2. IS - 875 - (Part - 1 to 5) - Code of practice for loads
3. IS - 1893 - 2002 - Code of practice for Earthquake Resistant design and construction of building
4. IS - 4326 - 1993 - Code of practice for Earthquake Resistant design and construction of building
5. IS - 2911 (Part 1 to 4) - Code of practice for design and construction of deep foundation
6. IS - 3370 (Part 1 to 4) - Code of practice for the storage of liquid for concrete structure
7. IS - 13920 - 1993 - Code of practice for ductile detailing of reinforced concrete structures
8. SP - 16 - Design Aids for Reinforced Cement Concrete
9. SP - 23 - Hand book on concrete mixes
10. SP - 34 - Hand book on concrete reinforcement and detailing

The structural design for the said building is safe, sound and stable.

V. RUKMANGATHAN, M.Tech (Struc.Engg.)
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V. RUKMANGATHAN
STRUCTURAL ENGINEER

PROJECT:

MARKET OF INDIA

PROPOSED MARKET
AT CHENNAI

DESIGN BASIS REPORT

ARCHITECTS:-

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SURAT-395007

STRUCTURAL CONSULTANT:-

CBM ENGINEERS INDIA
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REVISION RECORD SHEET

DATE	REV.NO	REVISION DETAILS
2018-06-30	R0	FOR APPROVAL
2018-07-18	R1	FOR APPROVAL
2020-01-21	R2	APPROVED
2024-15-05	R3	APPROVED

CONTENTS

1. FOREWORD

1.1 Description of the Project

2. CODES, STANDARDS AND REFERENCES

2.1 Loads

2.2 Foundations

2.3 Reinforced cement concrete

2.4 Structural steel

2.5 Handbook & special publications

3. DESCRIPTION OF STRUCTURE:

3.1 Location

3.2 Structural System

3.2.1 Gravity Load resisting system

3.2.2 Lateral Load resisting system

3.2.3 Substructure

4. DESIGN APPROACH:

4.1 Design data provided by client

4.1.1 Geotechnical investigation report

4.2 Design life

4.3 Material properties

4.3.1 Material grades

4.3.2 Sub Grade

4.3.3 Safe bearing capacity

4.4 Material Unit Weight

4.4.1 Dead load (DL)

4.4.2 Design loads (LL- As per IS-875-Part-2)

4.4.3 Temperature load (TL-As per IS-875-Part-5)

4.4.4 Wind load (WL-As per IS-875-Part-3)

4.4.5 Seismic load (EL-As per IS-1893)

4.4.6 Fire Tender load

4.4.7 Hydrostatic load

4.4.8 Soil load (SL) – Overburden or surcharge

4.5 Durability consideration

4.5.1 Meteorological Conditions

4.5.2 Nominal Cover

4.6 Fire Rating

5. ANALYSIS METHODOLOGY

5.1 Numerical Model

5.2 Design Philosophy

5.3 Stiffness Modifiers

5.4 Features of the FEM Model

5.4.1 Cast in situ RCC Shearwalls (160MM Thick)

5.4.2 Cast in situ RCC Flat Slab

5.4.3 Stairs

5.4.4 Structural Connections

5.4.5 Reference from International Codes

5.4.6 Transverse Reinforcement

5.4.7 Maximum Concrete Design Shear Stress

6. LOAD COMBINATIONS

7. SERVICEABILITY CONSIDERATIONS

8. DESIGN PROCEDURE

9. DETAILING CONSIDERATIONS

10. CONCLUSION

ANNEXURE

1. FOREWORD:

The proposed project " Market of India" is a market located at Chennai, Tamil Nadu, India.

The project consists of 11 story of typical market area including Parking Floor and 1 floor Future provision and additional 4 story for office. The basement plan dimension is around 246 x 235 m. The plan dimension for other floors in the market area is around 210 x 235 m. The market building is 41.10 m above lower ground floor. Above the small shop floor level, part of the building for office use continues to another 18 m. The building is designed as per Indian standards (IS codes). The design is sound and safe.

1.1 DESCRIPTION OF THE PROJECT

a. **Project Name:** MARKET OF INDIA

b. **Location:** Chennai

c. **Client:** M/s. SPR Constructions Pvt. Ltd

d. **Architect:** M/s. THE BLACK INK

e. **Structural Engineer:** M/s. CBM Engineers INDIA

- **BASEMENT:** 2 Basements are primarily dedicated to parking, lumber space and can also accommodate electrical rooms, pump rooms, water tanks etc. Height of Basement 2 is 5.4 m and height of Basement 1 is 4.2 m.

  All floors will have a shop level and a mezzanine level. At mezzanine levels, slabs will be provided in shops; passages/ corridors will be double height. A central large atrium and few smaller atriums are provided in the floors. The floor to floor height for the various levels are as below:

  - Basement 2 – 5.4 m
  - Basement 1 – 4.2 m
  - Lower Ground Floor Cellar – 3.45 m
  - Lower Ground Floor – 4.2 m
  - Ground Floor – 3.6 m
  - Ground Floor Mezzanine – 3.6 m
  - Upper Ground Floor – 3.6 m
  - Upper Ground Floor Mezzanine – 3.6 m
  - Parking Floor – 3.6 m
  - Concourse Floor – 3.6 m
  - Concourse Mezzanine Floor – 3.6 m
  - Top Floor – 3.6 m
  - Top Floor Mezzanine – 3.6 m
  - Small Shop Floor – 4.5 m
  - WSM Future Floor-1 - 3.6 m
  - Office Floor partial terrace – 3.6 m
  - Office Floor - 2 – 3.6 m
  - Office Floor - 3 – 3.6 m
  - Office Floor - 4 – 3.6 m
  - Office Floor - 5 – 3.6 m

  Terrace will be provided over part of top level and the rest of the area will have office building of 4 floors with a floor height of 3.6m.

  The building will have combination of shear walls, columns with beams, RCC slabs to support the floors. The structure will be constructed in reinforced concrete and will be supported on foundation as per soil properties provided by geotechnical engineer. As the size of the floor plate is very large, 1 expansion joint in each direction is provided dividing the floor plate in 4 quadrants. Expansion joints are provided only at the upper floors. Outside road level is matched with lower ground shop level. Hence, the retaining walls are provided up to lower ground shop level and there are no expansion joints till lower ground shop level.

  The structure was designed earlier with single basement and construction was started at site. As per geotechnical report, soil at 1st basement level is very poor and piles were provided. Part of the piling work was completed at site. However, this was stopped as piling was turning out to be costly. In the present design, three basements are provided. Soil at the 3rd basement level is relatively better and raft foundation can be adopted. As the water table is high (almost at NGL), raft will be required anyways. In areas where piling was not done, raft foundation will be provided. In areas where piling was completed, piles will be dismantled up to foundation level. It may not be possible to use the existing plies as this may lead to differential settlement as the part of the raft will rest on the piles and the remaining part will directly rest on soil. If possible, the existing piles will be used to support the new raft.

1.2 OBJECTIVE OF THE REPORT

This report forms the basis of the structural analysis and design process for a proposed mid-rise structure. This report aims at formulating the design parameters that the structural consultant has adopted in developing the structural analysis, design and detailing work of the building which will be compatible with the architectural theme, satisfies the functional needs, adhering to other applicable building norms & Indian Standards provisions to achieve safe, stable, strong yet optimally economical structures.

This report covers the minimum design requirement to establish the unified design basis that will form the overall design philosophy to be adopted in the structural design of the proposed building. The design assumptions are presented under different heads below.

The design will aim to achieve,

- Structural and functional integrity
- Desirable structural performance under characteristic service design loads
- Resistance to loads due to natural phenomena i.e. wind and earthquakes
- Structural durability and maintainability
- Structural safety, performance during fire and fire safety measures

2. CODES, STANDARDS AND REFERENCES:

DESIGN CODES:

The following Indian Codes and Standards shall generally be used for design of structural work. All applicable Indian Standard (IS) Codes shall be used. In all cases, the latest revisions with amendments, if any, shall be followed (as on date of LOI):

LOADS

IS: 875 (Part 1 to 5)	Code of Practice for design loads (other than earthquake) for buildings and structures
IS: 1893-2016 (Part - 1)	Criteria for earthquake resistant design of structures

FOUNDATIONS

IS: 1080	Code of Practice for design and construction of shallow foundations in soils (other than raft, ring and shell)
IS: 1904	Code of Practice for design and construction of foundations of soils: General requirement loads (other than earthquake) for buildings and structures
IS: 2911 (Part 1 to 4)	Code of Practice for design and construction of pile foundations
IS: 2950	Code of Practice for design and construction of raft foundations - Part 1: Design.

REINFORCED CEMENT CONCRETE

IS: 456 2000	Code of Practice for Plain and Reinforced Concrete
IS: 13920 (2016)	Code of Practice for ductile detailing for RCC structures subjected to seismic forces
IS: 3370: (2009)	Code of Practice for concrete structure for the storage of liquids
ACI: 318M	Building Code requirements for Structural concrete
BS 8110-1: 1997	Structural Use of concrete Part-1

STRUCTURAL STEEL

IS: 800 - 2007	Code of Practice for General Construction in Steel
IS: 1642	Code of Practice for Fire Safety of Buildings (General): Details of Construction

HANDBOOK AND SPECIAL PUBLICATIONS

SP: 6	Handbook for Structural Engineering
	Part 1 Structural steel sections
	Part 2 Steel beams and plate girders
	Part 3 Steel columns & struts
	Part 4 Use of high strength friction grip bolts
	Part 5 Cold formed light gauge steel structures
	Part 6 Application of plastic theory in steel structures
	Part 7 Simple welded girders
SP: 16	Design aids for reinforced concrete conforming IS:456–1978.
SP: 34	Handbook of concrete reinforcement and detailing

REINFORCEMENT

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

3. DESCRIPTION OF STRUCTURE:

3.1 LOCATION

The proposed project is a market building located at Chennai, Tamil Nadu, India.

3.2 STRUCTURAL SYSTEM

3.2.1 GRAVITY LOAD RESISTING SYSTEM

- Beam-slab system is provided in super structure and flat slab with drop panel in sub structure to carry the gravity load of system.
- Floor structure of the building will be conventional reinforced concrete floor structure supported by shear walls and columns.
- Gravity load is carried by the floor slab which transfers the loads to beams, columns and walls. The vertical elements - columns and shear walls will distribute the gravity load of building to foundation.

3.2.2 LATERAL LOAD RESISTING SYSTEM

- The lateral load resisting system is Ductile Shear walls with Moment resisting frame.
- The lateral loads due to wind and seismic forces are dissipated to soil through the proposed reinforced concrete core walls/ columns.

3.2.3 SUBSTRUCTURE

- The substructure is used for parking and lumber (storage) purposes. The floor framing system will comprise of reinforced concrete flat slab with drop panel. Beam-slab system will be provided at locations where lower headroom is acceptable. Retaining walls will be provided up to lower ground shop level. The retaining walls shall be designed for earth pressure and gravity load. The lower ground shop level will have beam-slab system.

4. DESIGN APPROACH:

4.1 DESIGN DATA PROVIDED BY CLIENT

4.1.1 GEOTECHNICAL INVESTIGATION REPORT

Furnished by client.

4.2 DESIGN LIFE

The design life of the building shall be 50 years.

4.3 MATERIAL PROPERTIES

4.3.1 MATERIAL GRADES

The minimum grade of concrete to be used depends on the exposure conditions to which the structural elements are subjected to. Deformed reinforcing bars: Grade 550 (fy = 550 N/mm2), for shear reinforcement Fe 415 is considered in design of members - Confirming to requirements of IS 1786.

ELEMENT	CONCRETE GRADE
Foundation	M35
Retaining Wall	M30
Grade Slab	M25
Columns & Shear Walls	M50
Slabs	M35
Beams	M35
PCC	M10

For columns, M60 grade of concrete is preferred to reduce column sizes. However, as per requirements of the construction team, the grade is restricted to M50.

4.3.2 GEOTECHNICAL DATA

The geotechnical investigation has been carried out by PRASAD ARMSTRONG YEN GEC (P) LTD. and the report dated 10th May 2018 have been submitted to us.

Bearing Capacity: 40T/sqm at 9-10 m below EGL

Ground Water Table: Almost till NGL

Sub grade modulus: 7500 T/m^3

Based on the geotechnical report, recommendations are as follows:-

TYPE OF FOUNDATIONS

Combined raft foundations at 9-10 m below EGL.

If existing piles are used for supporting raft, then part of the raft will be on piles remaining part will be resting directly on soil. This may lead to differential settlement. Geotechnical consultant to confirm the use of existing piles.

4.4 MATERIAL UNIT WEIGHT

DESIGN LOADS: AS PER IS 875-PART-I &II

4.4.1 DEAD LOAD (DL)

UNIT WEIGHT

Plain Cement Concrete	=	24.0 kN/m^3
Reinforced Cement Concrete	=	25.0 kN/m^3
Brick masonry with plaster	=	20.00 kN/m^3
Soil filling	=	18.0 kN/m^3
Floor finish	=	24.0 kN/m^3
➢ 75mm thickness	=	1.8 kN/m^2
➢ Services and ceiling	=	0.5 kN/m^2
Landscape load	=	as per landscape details

All Level partition wall (Light weight Block) = 3.45 kN/m

4.4.2 DESIGN LOADS (LL- AS PER IS-875-PART-2)

Shops (Partly retail- partly wholesale)	= 5.0 kN/m2
Parking area	= 5.0 kN/m2
Landscape area	= 5.0 kN/m2
Storage/ lumber area (basements)	= 5.0 kN/m2
Mezzanine floor	= 7.5 kN/m2
Stairs / Corridors/ Passages	= 5.0 kN/m2
(subject to loads from crowds and wheeled vehicles)	
Toilets	= 2.0 kN/m2
Terraces	= 2 kN/m2
	landscape loads as per actual
Lift machine room	= 10.0 kN/m2 or as per actual

Actual loading due to lift loads shall be ascertained and design live loads shall be suitably modified (if required) and considered.

4.4.3 TEMPERATURE LOAD (TL-AS PER IS-875-PART-5)

Temperature variation produces stresses in the structure, as it expands and contracts with the gain and loss of thermal energy. In the structures, with large geometrical dimensions, the effect of temperature may be important in the behavior and final design. Due to cyclic deformation – between day time and nights, and between winter and summer – the effect on the durability of structure and the supported finishes may be significant to produce fatigue.

Highest Maximum Temperature = 40°C

Lowest Minimum Temperature = 20°C

For analysis, two cases to be considered:

a) ±5ºC -all floors from ground to top floor mezzanine level ; ±10ºC at roof

b) ±5ºC -individual one floor at a time. (from ground to top floor mezzanine level); ±10ºC at roof

4.4.4 WIND LOAD (WL-AS PER IS-875)

WIND ANALYSIS AS PER IS 875 - PART 3 - 2015

WIND DATA

Basic Wind Speed	Vb	=	50.00	m/sec
Terrain Category	TC	=	3	

DESIGN FACTORS

Risk Coefficient	k1	=	1.00
Terrain & Height Factor	k2	=	as per Table 2
Topography Factor	k3	=	1.00
Importance Factor for cyclonic region	k4	=	1.00

The forces due to earthquake loads are considerable higher than wind loads. Hence, no further checks have been made for wind loads.

4.4.5 SEISMIC LOAD (EL-As per IS-1893)

SEISMIC LOAD AS PER IS 1893- 2016

The proposed tower is located at Chennai, Tamil Nadu. As per IS: 1893-2016, Chennai falls under Zone III.

SEISMIC ZONE		=	III
SEISMIC ZONE FACTOR	Z	=	0.16
IMPORTANCE FACTOR	I	=	1.2
TYPE OF LATERAL SYSTEM		=	Ductile Shear walls with Moment Resisting Frame
RESPOSE REDUCTION FACTOR	R	=	5
DAMPING		=	5% FOR RCC

The floor plate is provided with one expansion joint in each direction dividing the floor plate in 4 quadrants considering the present development. And the future development is also proposed separately by introducing additional expansion joint. The time period is calculated for each part.
For example, right side part Time period calculation given below:
Time period is calculated with RC shear wall (as per Amendment – 1). (Detail calculation provided in Annexure -B)

HEIGHT OF BUILDING				
For X direction	H	=	60.0	m
For Y direction (with effective height Formula)	H	=	55.0	m

$$A_w = \sum_{i=1}^{N_w} \left[A_{wi} \left\{ 0.2 + \left(\frac{L_{wi}}{h} \right) \right\}^2 \right]$$

Ta – X direction = 1.03 s

Ta – Y direction = 1.02 s

SOIL	TYPE-II-Medium stiff soil site		
SOIL COEFFICIENT	Sa/g, x-dir.	=	1.32
	Sa/g, y-dir.	=	1.333

DESIGN BASE SHEAR	Vb	=	Ah x W

WHERE, W = SEISMIC DEAD LOAD, AND IT INCLUDES,

* CONSTRUCTION DEAD LOAD

* SUPERIMPOSED DEAD LOAD, INCLUDING PARTITION LOAD

*50% OF LIVE LOAD

* TOTAL OPERATING WEIGHT OF PERMANENT EQUIPMENT

As per Cl. 6.4.2.1- IS 1893:2016, "the N value to be used shall be the weighted average of N of soil layers from the existing ground level to 30 m below existing ground level". As per the geotechnical report, the N values up to 30 m from EGL are vary along with depth. The weighted average for N up to 30 m will not exceed 30. Hence, soil type II can be considered. (calculation attached in ANNEXURE-C)

4.4.6 FIRE TENDER LOAD

Fire tender load will be considered as per fire tender path. Fire tender load is considered as accidental load and load factors are considered accordingly in load combinations involving fire tender loads. Loads due to following two types of fire tenders are considered.

45ton standard fire tender; 75ton fire tender with jacks

Details of wheel loads, jack loads and various loading conditions to be considered for design of structural members are provided in Annexure-A.

4.4.7 HYDROSTATIC LOAD (HL)

The area where the proposed building is located gets flooded during rains. The raft is 9-10 m below EGL. As per the geo-technical report, the raft is to be designed for minimum uplift pressure of 12 T/m^2.

4.4.8 SOIL LOAD (SL) – OVERBURDEN OR SURCHARGE

Factor of safety against overturning and sliding considered in design is 1.55.

4.5 DURABILITY CONSIDERATION:

4.5.1 METEOROLOGICAL CONDITIONS

EXPOSURE CONDITION	ELEMENT
Moderate	Slabs, Beams & Columns/Walls above ground
Moderate	Foundation & structures below ground

Moderate exposure condition shall be explained as one where concrete surfaces are sheltered from severe rain or freezing whilst wet; concrete exposed to condensation and rain; concrete continuously under water; concrete in contact under non-aggressive soil; concrete surfaces sheltered from saturated salt in coastal areas.

4.5.2 NOMINAL COVER

Minimum values of nominal cover of normal weight aggregate concrete which should be provided to all reinforcement depends on the exposure condition and fire rating considered. Cover to the reinforcement shall be in accordance with IS 456:2000 corresponding to moderate exposure conditions for superstructure, substructure and to satisfy the specified fire rating.

ELEMENT	NOMINAL COVER
Foundation	50mm (bottom) and 75mm (sides)
Beam (Simply supported / continuous)	40 / 30 mm
Slab (Simply supported / continuous)	35 / 25 mm
Columns & Shear Walls	40mm
Staircase waist slab	30mm
Retaining wall (Earth side/ inside face)	40 / 25 mm
Plinth beams	40mm
Water tank walls	40mm
Parapet, pardi and kerb walls	30mm

In case of slabs, if main reinforcement diameter exceeds 12mm then cover for moderate exposure condition shall be increased by 5mm.

4.6 FIRE RATING

A structural element required to have fire resistance should be designed to possess an appropriate degree of resistance to flame penetration; heat transmission and failure. As per the planning, the proposed building is to be used for various purposes. As per the classification based on occupancy, major part of the building is used for retail shops- hence, it can be termed as mercantile building; the office spaces above fall under business building; part of the basements fall under storage building category. The respective FAR limits for mercantile, business and storage buildings are 1.8, 2.9 and 1.5. This will have to be confirmed by the architects. If the actual FAR exceeds these limits, part of that building will have Type I construction. Else, Type II construction will be followed.

The fire rating for various structural elements considering Type II construction are as follows:

FIRE RATING	ELEMENT
2.0 HRS	Main Frame (main beams & columns/walls), staircases and lift walls
1.5 HRS	Slabs and secondary beams

The fire rating will increase in case of Type I construction.

5. ANALYSIS METHODOLOGY:

5.1 NUMERICAL MODEL

A comprehensive 3-dimensional analysis of the superstructure shall be carried out with ETABS 2017. Geometrical dimensions, member properties and member-node connectivity are modeled in the FEM computer program and the following structural analysis was performed:

- Linear static analysis

Following Static loads cases are considered in the analysis:

- DL - Dead Load: Includes self-weight of the structure.
- SDL – Super Imposed Dead Load: Includes Finishes, wall Loads, Soil filling loads etc...
- LL - Live Load: Includes Live loads based on functionality as per IS: 875 (Part-2)

- Linear dynamic analysis with response spectrum method.

Following are the details pertaining to dynamic analysis.

- Time period: User defined time period as per cl: 7.6.2 of IS:1893.
- Base Shear Enhancement : Initial Scale factor of Ig/2R is used to enhance the base shear.
- Number of modes Considered : Ensure 90% participation
- Modal Combination Method Used : complete Quadratic combination (CQC).
- Spatial Combination Method used : Square root of the sum of Square (SRSS) .
- Modal case type : Ritz vector Method
- Orthogonal directional seismic effect : Not applicable
- Accidental torsion considered : 5% of the building plan dimension
- Missing mass correction : Missing mass correction is taken care with Ritz vector method.

- Foundation- Depending upon geotechnical criteria. Raft foundation is proposed. SAFE software is used for design of foundations, podium slabs and floor slabs.
- Buildings shall be assessed for a combination of gravity and lateral loads, and detailed appropriately.
- For the design of various structural elements like foundations, columns, beams, slab etc. in-house developed spreadsheets will be used wherever applicable.

5.2 DESIGN PHILOSOPHY

3-Dimensional structural analysis will be carried out using structural analysis and design software ETABS. The whole structure will be idealized as a space frame. Slabs, Beams, Walls and Columns (if any) in the structure will be modelled as line/shell/membrane elements as applicable. Stiffness of members is modelled considering the effect of cracked sections.

As per IS 456 Code of Practice for Plain and Reinforced Concrete member stiffness can be based on cracked section properties and for the calculation of deflection reduced moment of inertia of section shall be used based on cracked section.

Main Reinforcement provided in design of member will be of grade Fe550 (with minimum yield strength = 550 N/sq mm). Shear reinforcement provided in the design of member will be of grade Fe 415.

For Flat slab, IS 456 (limit state method) would be used for the long term deflection check and design.

5.3 STIFFNESS MODIFIERS

The properties modifiers considered in the analysis are given below.

Element	Moment of Inertia (Factored Load)	Moment of Inertia (Unfactored Load)
Beams	0.35Ig	0.70Ig
Columns	0.70Ig	0.90Ig
Slabs	0.25Ig	0.35Ig
Walls(Uncraked)	0.70Ig	0.90Ig
Walls (Craked)	0.35Ig	0.50Ig

Where, Ig = Gross moment of Inertia

5.4 FEATURES OF THE FEM MODEL

5.4.1 CAST-IN-SITU RCC SHEARWALLS

a. The RCC shear walls have been modeled as shell elements and at each level the walls below and above the floor are fully connected (monolithic) to each other.
b. Fine meshing of the walls has been achieved by using the auto meshing option of ETABS. Auto line constraint and edge restraints options have been used.
c. All the shear walls are, wherever possible, connected to the floor diaphragm.
d. RCC shear walls are designed as per analysis and manually where ever required.

5.4.2 CAST-IN-SITU RCC SLAB

a. The floor slabs have been modeled as shell elements to achieve continuity in the slab.

b. Fine meshing of the floor slabs has been achieved by using the auto meshing option of ETABS. The maximum size of the mesh used in the FEM model is 1000 mm. Auto line constraint and edge restraints options have been used

c. At each floor level a horizontal semi-rigid diaphragm has been assigned to all the slabs.

5.4.3 STAIRS

a. The staircase slab will not be modeled and load will be applied as line loads on supporting members.

5.4.4 STRUCTURAL CONNECTIONS

a. All the structural connections between cast in-situ concrete members are modeled as Monolithic.

5.4.5 REFERENCE FROM INTERNATIONAL CODES:

We will also use the ACI-318 2011 code for the design & detailing of the structure. In addition to IS codes we will use this code for the provisions which have not been adequately covered in IS 456 code.

5.4.6 TRANSVERSE REINFORCEMENT:

- Transverse reinforcement detailing for the compression members shall be based as per ACI 318 the latest code. Ties shall be arranged such that every corner and alternate longitudinal bar shall have lateral support and no bar shall be farther than 150mm clear on each side along the tie from such a laterally supported bar.
- The cross ties shall have 135 degrees bend at one end and the same shall engage vertical and horizontal both bars at one end while the other end shall have 90 degrees bend which shall be made at site. The 90 degrees hooks of two successive cross ties engaging the same longitudinal bars shall be alternated end for end.
- All the column and shear wall reinforcement detailing drawings shall show prominently the seismic 135 degrees. Hook engaging longitudinal and transverse bars, the successive hooks on same bar shall have 90 degrees hook on alternate end for end. The provisions of cross tie shall be clearly sketched in all column and shear wall reinforcement drawings.

5.4.7 MAXIMUM CONCRETE DESIGN SHEAR STRESS:

- As per IS: 456, maximum permissible shear stress is 4 N/mm2 for concrete grade of M40 and higher. SP 24, the explanatory handbook to IS: 456, gives following formula for calculating maximum permissible shear stress corresponding to grade of concrete.

$\tau_{c\,max} = 0.83\sqrt{f_c}$
Where fc is cylinder strength of concrete in N/mm2.

- Applying this formula for concrete grades higher than M40 will give maximum permissible shear stress higher than 4 N/mm2. Other international standards such as ACI-318 also specify higher maximum permissible shear stress for concrete grades above M40. Even Indian Standard for pre-stressed concrete specifies higher maximum permissible shear stress for concrete grades above M40.

6. LOAD COMBINATIONS

PRIMARY LOAD CASES

DL	Dead Load
SDL	Super Dead
LL	Live Load
SPECx	Earthquake Load in X Direction
SPECy	Earthquake Load in Y Direction
WLx	Wind Load in X Direction
WLy	Wind Load in Y Direction
TL	Temperature Load

ULTIMATE LOAD COMBINATIONS

- 1.5 DL + 1.5 SDL
- 1.5 DL + 1.5 SDL + 1.5 LL
- 1.2 DL + 1.2 SDL + 1.2 LL ± 1.2 SPECX
- 1.2 DL + 1.2 SDL + 1.2 LL ± 1.2 SPECY
- 1.2 DL + 1.2 SDL + 1.2 LL ± 1.2 WLx or GUSTX
- 1.2 DL + 1.2 SDL + 1.2 LL ± 1.2 WLy or GUSTY
- 1.5 DL + 1.5 SDL ± 1.5 SPECX
- 1.5 DL + 1.5 SDL ± 1.5 SPECY
- 1.5 DL + 1.5 SDL ± 1.5 WLx or GUSTX
- 1.5 DL + 1.5 SDL ± 1.5 WLy or GUSTY
- 0.9 DL + 0.9 SDL ± 1.5 SPECX
- 0.9 DL + 0.9 SDL ± 1.5 SPECY
- 0.9 DL + 0.9 SDL ± 1.5 WLx or GUSTX
- 0.9 DL + 0.9 SDL ± 1.5 WLy or GUSTY

ULTIMATE LOAD COMBINATIONS WITH TEMPERATURE

- 1.4 DL + 1.4 SDL ± 1.4 TL
- 0.75 (1.4DL + 1.4 SDL + 1.7 LL ± 1.4 TL)
- 0.75 (1.4DL + 1.4 SDL + 1.7 LL ± 1.2SPECX ± 1.4 TL)
- 0.75 (1.4DL + 1.4 SDL + 1.7 LL ± 1.2WL ± 1.4 TL)

SERVICE LOAD COMBINATIONS

- 1.0 DL + 1.0 SDL + 1.0 LL
- 1.0 DL + 1.0 SDL + 0.8 LL ± 0.8 SPECX
- 1.0 DL + 1.0 SDL + 0.8 LL ± 0.8 SPECY
- 1.0 DL + 1.0 SDL + 0.8 LL ± 0.8 WLx or GUSTX
- 1.0 DL + 1.0 SDL + 0.8 LL ± 0.8 WLy or GUSTY
- 1.0 DL + 1.0 SDL ± 1.0 SPECX
- 1.0 DL + 1.0 SDL ± 1.0 SPECY
- 1.0 DL + 1.0 SDL ± 1.0 WLx or GUSTX
- 1.0 DL + 1.0 SDL ± 1.0 WLy or GUSTY

- Wind load and Seismic load shall not be considered to act simultaneously. The effect of both the forces shall be considered separately.

- Load combination is necessary to ensure the requirement safety and economy in the design of structure. It considers the probability of individual loads acting together, their disposition in relation to other loads and severity of stresses or deformations caused by combinations of various loads. Whichever combination produces worst effect in building, foundation and structural member shall be adopted in analysis and design.

- Live loads for column & foundation design will be reduced as allowed by IS 875 Part 2.

Reduction in Imposed loads for the design of Columns, Shear walls and foundations: (IS 875 Part II)

Number of Floors	% Reduction in Total Imposed load on all floors to be carried by the member under construction
1	0
2	10
3	20
4	30
5 to 10	40
Over 10	50

7. SERVICEABILITY CONSIDERATIONS:

DEFLECTION

Max permissible vertical deflection – RCC Structure

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

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

Max permissible lateral deflection –

i.For wind -- H/500

ii.For earthquake -- storey drift <= H/250

STABILITY OF STRUCTURE

The minimum Factor of Safety against overturning, sliding and hydrostatic uplift shall be as per relevant IS codes.

The stability of a structure as a whole against overturning shall be ensured so that the restoring moment shall be not less than the sum of 1.2 times the maximum overturning moment due to the characteristic dead load and 1.4 times the maximum overturning moment due to the characteristic imposed loads. In cases where dead load provides the restoring moment, only 0.9 times the characteristic dead load shall be considered. Restoring moment due to imposed loads shall be ignored.

The structure shall have a factor against sliding of not less than 1.4 under the most adverse combination of the applied characteristic forces. In this case only 0.9 times the characteristic dead load shall be taken into account.

Crack Width

Limiting values of crack width as per Clause 35.3 of IS 456-2000 is followed in the design. In general, for slabs and beams, the crack width is limited to 0.3 mm.

For basement retaining wall and water retaining structures, crack width is limited to 0.2 mm.

8. DESIGN PROCEDURE

Structural members will be designed based on results of ETABS analysis. ETABS concrete design modulus will be used for columns, shear walls and beams. Slabs supported on beams will be designed by hand calculations. Design of these slabs will be verified by SAFE. SAFE analysis models will be prepared by exporting individual floors from ETABS analysis model. Raft will be analysed and designed using SAFE. Support reactions exported from ETABS analysis will be used as loads for raft analysis in SAFE.

For design of superstructure elements, ETABS Models will be prepared for each Part. But left and right side tower part is mirror with all respect.

The central atrium has Lift core as per architectural intent. And due to architectural planning limitation, Lift wall cannot be start from Foundation. And so, these walls are being floated from above level.

The Floating Lift wall will not be a part of lateral load resisting system and hence the Earthquake force taken by Lift wall will be transferred to the other walls and columns which will be a part of lateral load resisting system. The Load combinations with EQ cases are enhance with the factor to increase the lateral load with respect to the floating walls. (Detail calculation attached in ANNEXURE – D).

Hence, the framing columns, beams and shear walls which are the part of MRF Models shall be designed based on the governing load combinations after comparing the design forces

8.1 Design and Detailing of Columns/Walls

Design of columns and walls will be carried out based on results of ETABS shear wall design module and ETABS concrete frame design module. All vertical elements whose B/D ratio (ratio of larger plan dimension to smaller plan dimension) is less than 4 will be modelled as line elements (columns), if B/D ratio is greater than 4, it will be modelled as area element.

All columns shall be treated as ductile column fulfilling requirements given in IS13920: 2016.

Design of shear walls shall be carried out for the governing load combinations after enhancing the forces due to floating walls from ETABS model.

For design, walls are classified in two categories. Walls having a single leg are called shear walls and walls having number of legs connected together are called core walls. Core walls will be considered to act as a single unit and will be designed accordingly. This will be achieved in ETABS analysis model by assigning same pier label to all legs of a single core wall.

For design of shear reinforcement of walls, separate pier label will be assign to all legs by creating separate model. And Shear checks are carried out from that separate model.

Design of shear wall as per ETABS shear wall design module will be cross-checked by calculations based on relevant Indian Standards, as in some cases ETABS shear wall design module considers additional slenderness moments for design even when these are not required to be added as per code provisions. As walls are provided along both principal orthogonal axes (X and Y) each individual wall will be considered as braced in minor direction.

For walls with concrete grade higher than M40, maximum permissible shear stress will be considered more than 4 N/mm^2 as specified below:

As per IS: 456, maximum permissible shear stress is 4 N/mm2 for concrete grade of M40 and higher. SP 24, the explanatory handbook to IS: 456, gives following formula for calculating maximum permissible shear stress corresponding to grade of concrete.

$$\tau_{c\,max} = 0.83\sqrt{f_c}$$

Where fc is cylinder strength of concrete in N/mm2.

Applying this formula for concrete grades higher than M40 will give maximum permissible shear stress higher than 4 N/mm2. Other international standards such as ACI-318 also specify higher maximum permissible shear stress for concrete grades above M40. Even Indian Standard for pre-stressed concrete specifies higher maximum permissible shear stress for concrete grades above M40. Maximum permissible shear stress for concrete grade above M40 will be considered as given below.

M45 - 4.3 N/mm2

M50 - 4.6 N/mm2

9. DETAILING CONSIDERATIONS:

Ductile detailing for the structural elements shall be done in accordance with IS: 13920-2016.
Detailing for all structural members shall be in accordance with IS: 456 & SP: 34.

10. CONCLUSION

The design basis outlined in this document has been based on currently available data issued by the client and the architect. It will need to be updated if design objectives or assumptions are revised, or if more complete information becomes available in the future. As

such, this document should be thoroughly reviewed and verified by the architect and client for accuracy and completeness. Any perceived non-conformance with project standards or expectations should be brought to our attention as early as possible.

ANNEXURE A

FIRE TENDER LOAD

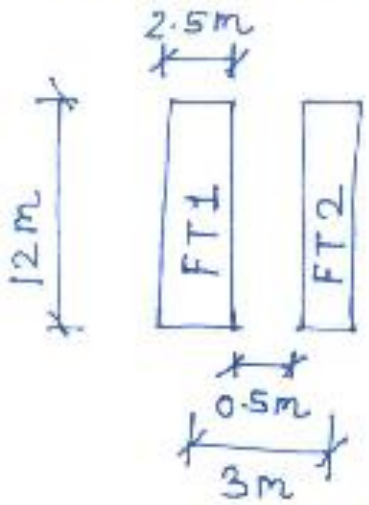
Note on Fire Tender Load

Following fire tender loads are considered at ground level in specified path for fire tender.

1. Standard Fire Tender (45T)

Length = 12m
Width = 2.5m
Total weight = 460 kN
Rear axle load = 300 kN
on area 1.35m x 2.25m

Centre to centre spacing of adjacent fire tenders = 3m



Loads critical for design will be 2 loads of 300 kN each separated by 3m.

Point loads for checking punching in slab can be considered as shown in figure on next page.

2

DATA FOR FIRE ENGINE

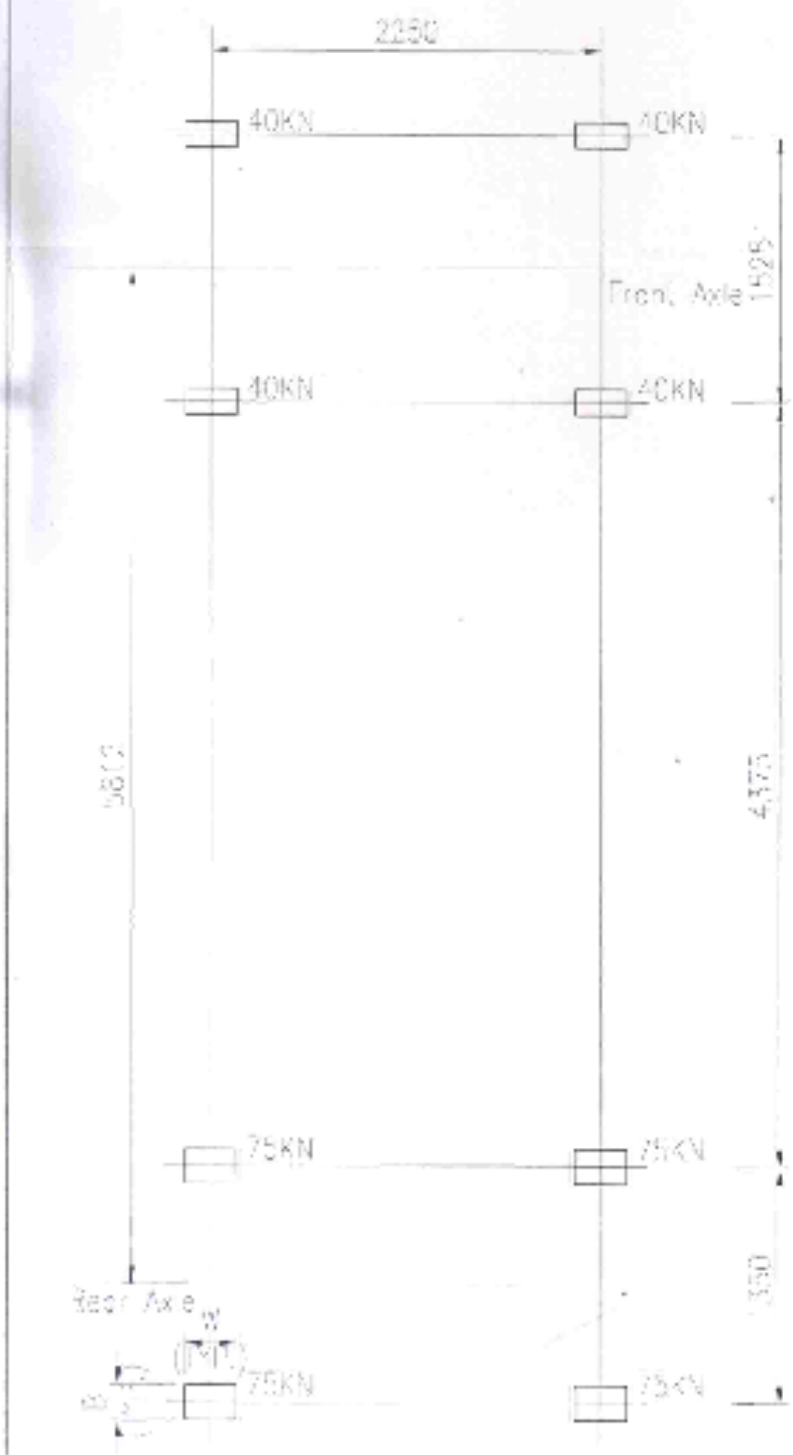
STANDARD

DIMENSIONS

Max.Overall length	= 12000 mm
Wheelbase Mean	= 5900 mm
Wheelbase 1st–2nd axle	= 1525 mm
Wheelbase 2nd–3rd axle	= 4375 mm
Wheelbase 3rd–4th axle	= 1350 mm
Max Overall Width	= 2500 mm
Traveling Height	= 3950 mm (approx.)

WEIGHT

Rated Weight	
1st axle	= 80 KN
2nd axle	= 80 KN
3rd axle	= 150 KN
4th axle	= 150 KN
Gross Vehicle Weight	= 460 KN
Actual Weight	
Front axle	= 130 KN
Rear axle	= 273 KN
Total	= 403 KN



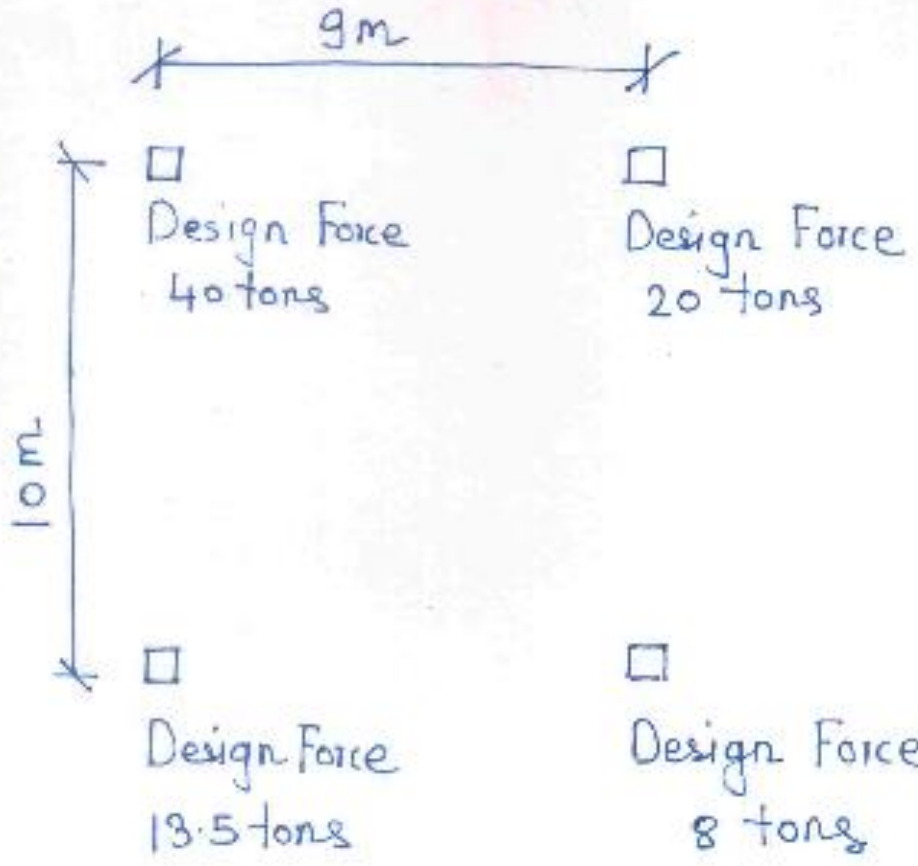
WHEEL APPROXIMATE CONTACT AREA

SNO	LOAD	B	W
1.	40KN	150	300
2.	75KN	200	400

TYP.LOAD DIAGRAM FOR
STANDARD FIRE ENGINE

2. 75 ton Fire Tender

Spacing of jacks & ~~pc~~ jack loads during operation ~~are~~ are shown in figure below.



Load critical for design will be point load of 400 KN (40 tons)

Load on Structural Members

1. Axial loads on columns & Foundations

   a] Two standard fire tenders, rear axles on either side of columns

   $P = 300 + 300 = 600\ kN$.

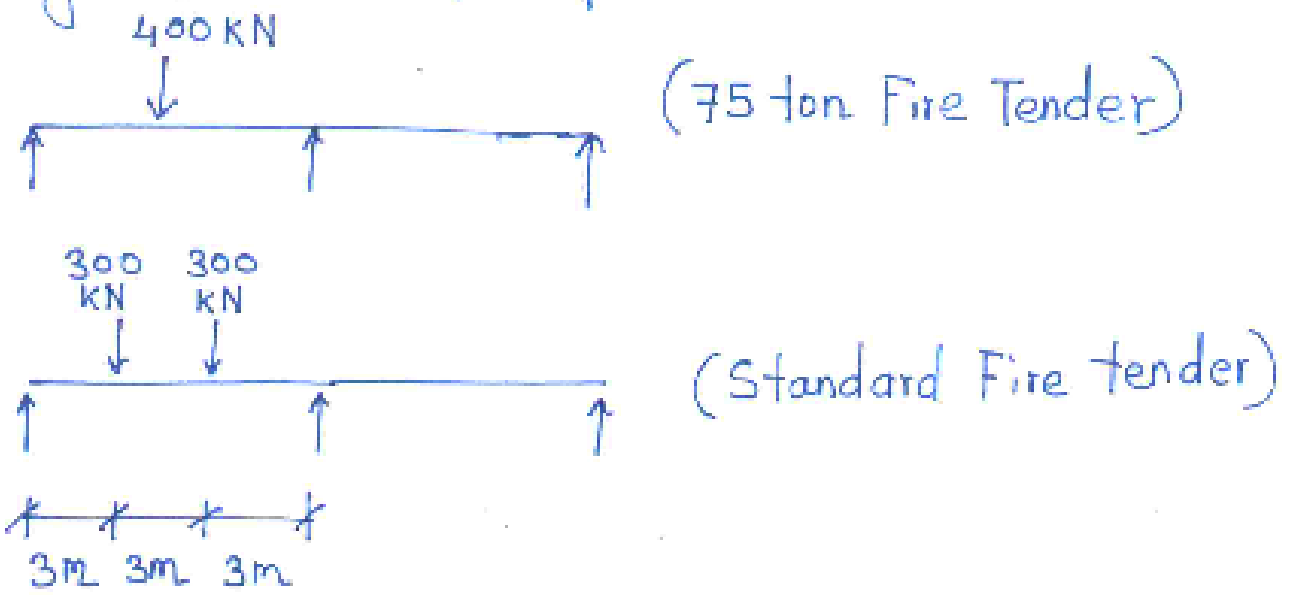
   b] One 75T fire tender

   $P = 480\ kN$.

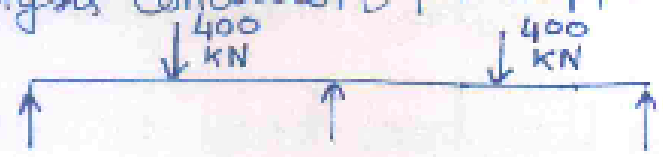
2. Analysis conditions for moments in beams/column strips and columns and shear in beams.

   Typical spans are considered as 9m

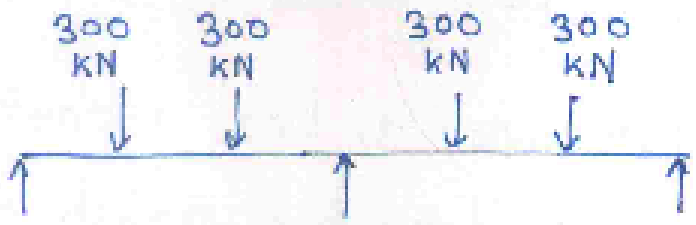
   a] Analysis condition for span moments



b] Analysis condition for support moments

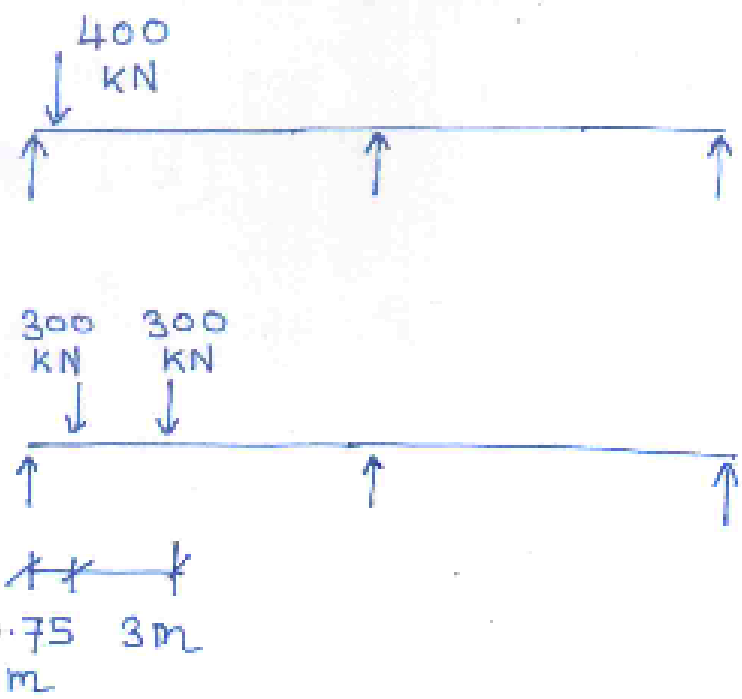


(75 ton Fire Tender)



(Standard Fire Tender)

c] Analysis condition for shear in beams



Design Load Combination

- Seismic or wind load will not act simultaneously with fire ~~to~~ tender load.
- Fire tender load is considered as accidental load

Hence design load combination will be

$$1.1 \times [DL + SIDL + 25\%.LL + \text{Fire Tender Load}]$$

(While checking punching, fire tender load is primary load and load factor will be considered as 1.5)

ANNEXURE B

TIME PERIOD CALCULATION

For all the part, the time periods are calculated as per clause 7.6.2 of IS 1893-2016 as per Amendment-1.

As in X direction, width of the building is same for the entire height of the structure, for X Direction Full height (from ground to Terrace) is considered to calculate time period, while in Y direction area reduces for office floors, so height is calculated with effective height formula.

As for example, detail calculation of Time period for right side part is given below:

MOI_RIGHT PART - OFFICE AREA PORTION_EFFECTIVE HT CALCULATION FOR Y- DIRECTION)				
Floor	height (mm)	h_i (mm)	A_i (m^2)	A_ih_i (m^2.mm)
TERRACE FLOOR	3450	59550	2375.87	141483058.5
OFFICE-3	3300	56100	2375.87	133286307
OFFICE-2	3300	52800	2375.87	125445936
OFFICE-1	5100	49500	2375.87	117605565
TERRACE OFFICE GF	4200	44400	7872.09	349520796
WSM FUTURE-2	3600	40200	7872.09	316458018
WSM FUTURE-1	3600	36600	7872.09	288118494
1ST FLOOR - MEZZ	3600	33000	5793.13	191173290
1ST FLOOR	3600	29400	7872.09	231439446
CONCPURSE - MEZZ	3600	25800	5793.13	149462754
CONCOURSE	3600	22200	7872.09	174760398
PARKING SKIP	3600	18600	7872.09	146420874
UPPER GROUND - MEZZ	3600	15000	5793.13	86896950
UPPER GROUND	3600	11400	7872.09	89741826
GROUND FLOOR - MEZZ	3600	7800	5793.13	45186414
GROUND FLOOR	4200	4200	7872.09	33062778
			95652.72	2631871040
		h =	55	m

Time Period Calculation:

	MOI(RIGHT SIDE)- AS PER AMENDMENT FORMULA										
	H (m)	60				H (m)	55				
	X Direction					Y Direction					
SW MARK	Length	Thickness	Number of walls	Area of wall	Aw	SW Mark	Length	Thickness	Number of walls	Area of wall	Aw
SW7	4.75	0.3	1	1.425	0.111	SW8	3.3	0.3	1	0.99	0.067
SW10-H	3.2	0.3	3	0.96	0.185	SW9	5.45	0.3	1	1.64	0.146
SW-11	3.3	0.3	1	0.99	0.064	SW10-V	10.8	0.35	1	3.78	0.594
SW12-H	5.475	0.35	1	1.91625	0.163	SW12-V	4.775	0.35	1	1.67	0.137
SW52	2	0.6	1	1.2	0.065	SW5-V	4.75	0.3	1	1.43	0.117
SW5-H	8.05	0.3	1	2.415	0.350	SW6A	2.6	0.3	1	0.78	0.048
SW6	3.6	0.3	1	1.08	0.085	SW48,50	3.4	0.4	2	1.36	0.186
SW47,49	1.2	0.4	2	0.48	0.049	SW17-V	3.5	0.3	1	1.05	0.073
SW17-H	7.95	0.35	1	2.7825	0.308	SW17-V	3.35	0.3	1	1.01	0.068
SW16A-H	5.4	0.3	1	1.62	0.167	SW18	3.5	0.3	1	1.05	0.073
SW16-H	8.75	0.35	1	3.0625	0.482	SW16A-V	3.5	0.3	2	1.05	0.146
SW3	3.6	0.3	1	1.08	0.085	SW16-V	8.12	0.35	1	2.84	0.343
SW4-H	8.05	0.3	1	2.415	0.350	SW18A	2	0.3	1	0.60	0.034
						SW4-V	4.75	0.3	1	1.43	0.117
						SW4A	2.6	0.3	1	0.78	0.048
	Sum of Aw				2.465		Sum of Aw				2.197
	Tx walls (Time Period)				1.030		Tx walls (Time Period)				1.022

ANNEXURE C

WEIGHTED AVERAGE ‘N’ VALUE

Weighted Average 'N' value calculation:

Based on the data provided in soil report for Field 'N' values, corrected N values are calculated as below:

Sr. No.	Depth (m)	Di (m)	Overburden (kN/m^2)	Correction Factor as per IS 1893	N_i Fileld value	N_i Corrected value as per IS 1893		Field Value		Corrected value as per IS 1893	
	0							DiNi	Di/Ni	DiNi	Di/Ni
	1	1	18	2.357	11	25.9		11.0	0.091	25.9	0.039
	1.75	0.75	31.5	1.782	6	10.7		4.5	0.125	8.0	0.070
	2.5	0.75	45	1.491	32	47.7		24.0	0.023	35.8	0.016
	3.25	0.75	58.5	1.307	9	11.8		6.8	0.083	8.8	0.064
	4	0.75	72	1.179	2	2.4		1.5	0.375	1.8	0.318
	4.75	0.75	85.5	1.081	0	0.0		0.0	0.000	0.0	0.000
	5.5	0.75	99	1.005	0	0.0		0.0	0.000	0.0	0.000
	6.25	0.75	112.5	0.943	0	0.0		0.0	0.000	0.0	0.000
	7	0.75	126	0.891	9	8.0		6.8	0.083	6.0	0.094
	8	1	144	0.833	17	14.2		17.0	0.059	14.2	0.071
	9	1	162	0.786	32	25.1		32.0	0.031	25.1	0.040
	10	1	180	0.745	33	24.6		33.0	0.030	24.6	0.041
	11.5	1.5	207	0.695	36	25.0		54.0	0.042	37.5	0.060
	13	1.5	234	0.654	59	38.6		88.5	0.025	57.9	0.039
	14.5	1.5	261	0.619	37	22.9		55.5	0.041	34.4	0.065
	16	1.5	288	0.589	46	27.1		69.0	0.033	40.7	0.055
	17.5	1.5	315	0.563	100	56.3		150.0	0.015	84.5	0.027
	19	1.5	342	0.541	100	54.1		150.0	0.015	81.1	0.028
	20.5	1.5	369	0.521	100	52.1		150.0	0.015	78.1	0.029
	22.5	2	405	0.497	98	48.7		196.0	0.020	97.4	0.041
	24.5	2	441	0.476	80	38.1		160.0	0.025	76.2	0.053
	26.5	2	477	0.458	100	45.8		200.0	0.020	91.6	0.044
	28.5	2	513	0.442	100	44.2		200.0	0.020	88.3	0.045
	30	1.5	540	0.430	100	43.0		150.0	0.015	64.5	0.035
		30						1759.5	1.187	982	1.271
								DN/D	58.7	DN/D	32.7
								D/(D/N)	25.3	D/(D/N)	23.6

Atmospheric pressu	100	kN/m^2
Soil unit weight	18	kN/m^3

ANNEXURE D

EARTHQUAKE FORCE FOR FLOATING WALL

As briefly discussed above, Lift walls are started from above level like floating wall. And so the floating walls are not considered as a part of Lateral load resisting force.

To ignore the floating wall from lateral load resisting system, the rest of the walls are enhanced with the ratio derived from the calculation to take 100% of EQ forces to rest of the walls and columns.

The EQ forces of floating wall are calculated at ground bottom level (from where EQ forces are applied), and calculate the percentage of EQ forces taken by floating wall.

Floating wall Reaction at Ground Floor bottom:

SPEC X = 4307 kN

SPEC Y = 5074 kN

Total Earthquake force at Ground Floor bottom level:

SPEC X = 41801 kN

SPEC Y = 39868 kN

Percentage of Earthquake taken by Floating Wall :

SPEC X = 4307 / 41801 x 100 = 10.30 %

SPEC Y = 5074 / 39868 x 100 = 12.72 %

Actual Earthquake of building:

SPEC X = 41801 – 4307 KN = 37494 kN

SPEC Y = 39868 – 5074 kN = 34794 kN

The multiplying factor to enhance the all shear wall and columns are as below:

SPEC X = 41801 / 37494 kN = 1.12

SPEC Y = 39868 / 34794 kN = 1.15

Thus above derive factor will multiply with all SPEC combination in ETABS Load Combinations Definition.

For example: For 1.5 DL + 1.5 SPEC X case will be 1.5 DL + 1.68 SPEC X



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