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Date: 13-05-2025

STABILITY CERTIFICATE

(To be furnished while filing application for registration of building)

1. The detailed engineering and structure design of the proposed building comprising of Stilt + 3 floors + 4th floor (part) availing premium FSI at Plot No 107, developed plot estate for electrical , electronics and instruments industries, 6th and 13th main road, perungudi, Chennai 600096 Comprising S.No 7/2 has been done by me/us based on the report of geotechnical investigation (soil test) done by Ms. Geo Marine consultant Pvt ltd Report No. GT-2075 Dated 04th June, 2020 and considering the functional requirement of the building.

2. It is certified that among other factors, the proposed building has been designed to resist earthquake. I/We have checked various parameters and found that the proposed building would be safe.

3. I/We further certify that:

(i) The minimum grade of concrete is M35

(ii)The design and analysis has been done using the code of practice for plain and reinforced concrete as per IS 456, design loads as per IS Codes No IS 875 Part 1 to 2 and design of earthquake resistant structure as per IS Code No IS 1893-2016

4. The building will be safe and sound when used for the purpose for which it is designed.

Stamp and Signature

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STRUCTURAL DESIGN CALCULATION REPORT

PROPOSED CONSTRUCTION OF STILT + 3 FLOORS + 4TH FLOOR (PART) (18.25M HEIGHT COMMERCIAL IT/ITES OFFICE BUIDLING AVAILING PREMIUM FSI AT PLOT NO 107, DEVELOPED PLOT ESTATE FOR ELECTRICAL, ELECTRONICS AND INSTRUMENTATION INDUSTRIES, 6TH AND 13TH MAIN ROAD, PERUNGUDI, CHENNAI 600096 COMPRISED IN NEW S.NO 7/2 OF NEELANGARAI VILLAGE WITHIN THE LIMITS OF GREATER CHENNAI CORPORATION

FOR M/S. SPERO REALTY, CHENNAI

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CLIENT

FOR M/S. SPERO REALTY, CHENNAI

REV NO.	DATE	DESCRIPTION	STATUS	PREPARED BY	REVIEWED BY	APPRVD. BY
R0	13-05-25	STRUCTURAL DESIGN BASIS REPORT	OK	MAHESH	KALEEM	PERAM

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1.FOREWORD

The intent of this document is to identify and record all the pertinent input requirements, analysis & design criteria for the structural design of the building. It is aimed at formulating the basis of the structural analysis, design & detailing work that the Structural Engineer is planning in delivering the structural scheme of the building. The scheme will be compatible with the architectural theme, satisfy the functional needs, at the same time conforming to the Indian Standards and other applicable building norms to achieve safe, stable, strong and yet optimally economical structures.

The parameters adopted in this report are going to be the basis of the structural design calculations. 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 will aim to achieve

- Structural & functional integrity.
- Desirable Structural performance under characteristic service design loads.
- Desirable performance under the wind and earthquake forces as per the BIS provisions.
- Achieve Structural durability by selecting suitable materials and relevant requirements.

1.1 AGENCIES

Client :	M/s. Spero Realty
Architect :	M/s. Kharche & Associates
Structural Design Consultant :	M/s. A P Engineers, Chennai.

2.PROJECT DESCRIPTION

2.1 GENERAL

The proposed construction of (Stilt + 3 floors + 4th floor part) 18.25m Height Commercial IT / ITES Office Building at Plot no :107, Developed plot estate for Electrical, Electronics and Instruments Industries, 6th & 13th main road Perungudi, Chennai-600096, comprised in new s.no 7/2 of neelankarai village, Tamilnadu. It consist of Commercial buildings (Stilt+3 floors + 4th floor part). In which, Stilt floors are designed to accommodate car parks/two wheeler parkings whereas the 1st floor to 3rd floor & 4th floor part is designed as office space.

2.2 THE BUILDING

The proposed construction of a Commercial building consisting of Ground + 3 floors + 4th floor part . The Architectural & Structural configuration of the building is well defined and captured with lifestyle that fulfill the perfect living. The configuration of the building is given as below,

Table 2.1 : Architectural & Structural Configuration and Floor heights :

Residential Building	Stilt+4 Storey+Roof
Stilt Floor height (Car Park)	4.50m
1st Floor to 3th Floors height (Office space)	3.40m
4th floor part (Office space)	3.40m
LMR & Roof	4.35m
Head Room	3.00m

2.2.1 Architectural Configuration

Architecturally, it is configured fairly a linear **Rectangular** shaped buildings with the plan size of Commercial Building 31.3m width (Horizontal dimension) and 25.95m(Vertical dimension) above ground level. The Lift & Staircases are placed corner of the building. The building is designed with adequate no of Lift & General staircases to cater the vertical transportation smoothly & to ensure the safe escape from both the buildings safely under eventuality of fire.

2.2.2 Structural Configuration

Structurally, the building is essentially a R.C.C. framed structure with columns and the building framing system is conceptualized with a conventional system of RCC Column connected by Floor Beams with slabs. The columns are connected to each other with a network of R.C.C beams and RC slabs with the slabs acting as in-plane rigid diaphragms for each of the floors. The Beams are assigned as frame elements in the 3D model. The structural system is designed with RC Columns which are connected by Beam-Slab.
Based on the sub-soil condition and the load intensity of the vertical members, Pile Foundation is designed as Foundation system.

3.LIST OF CODES

All design of structures shall comply with the requirements specified in the following.

- Relevant Indian Standard Codes of Practice
- National Building Code.
- Local Building regulations.
- Other relevant International codes where required.

All applicable latest editions of codes and standards will be referred and adopted in the analysis of structures and the design and detailing of structural members. All structural elements design shall be carried out primarily based on Indian Standards and Codes with latest revision, with amendments if any, as on date. In addition, other international codes and standards shall also be referred when required and relevant.

In the analysis, design and detailing of the building, the following Indian Standard codes of latest amendment will be used.

3.1 DESIGN LOADS (OTHER THAN EARTHQUAKE LOADS)

IS CODE	DESCRIPTION
IS 875 (Part 1):1987(Rev2018)	Code of practice for Design Loads (Other than Earthquake) for Buildings & Structures -Dead Loads (Unit Weight of Building Material and Stored Material)
IS 875 (Part 2):1987(Rev2018)	Code of practice for Design Loads (Other than Earthquake) for Buildings & Structures - Imposed Loads
IS 875 (Part 3):2015(Rev2020)	Code of practice for Design Loads (Other than Earthquake) for Buildings & Structures - Wind Loads
IS 875 (Part 4):1987(Rev2018)	Code of practice for Design Loads (Other than Earthquake) for Buildings & Structures - Snow Loads
IS 875 (Part 5):1987(Rev2018)	Code of practice for Design Loads (Other than Earthquake) for Buildings & Structures – Special Loads and Load Combinations

3.2 DESIGN FOR EARTHQUAKE RESISTANCE

IS CODE	DESCRIPTION
IS 1893 : 2016 Part-1	Criteria for Earthquake Resistance design of structures.
IS 4326:2013 (Rev-2018)	Earthquake Resistant Design and Construction of Buildings – Code of Practice
IS 13920:2016 (Rev-2021)	Ductile Detailing of Reinforced Concrete Structures subject to Seismic Forces - Code of Practice.
IS 16700 : 2017	Criteria for Structural Safety of Tall Concrete Buildings

3.3 DESIGN OF STEEL STRUCTURAL ELEMENTS

IS CODE	DESCRIPTION
IS 800: 2007 (Rev-2021)	Code of Practice for General Construction in Steel
IS 2062: 2011 (Rev-2017)	Steel for General structural purposes
IS 3757 :1985 (Rev-2019)	Specification for High Strength Structural Bolts
IS 7215 : 1974 (Rev-2019)	Tolerances for Fabrication of Steel Structures
IS 7205 : 1974 (Rev-2021)	Safety Code for erection of Structural Steel work
IS 12843:1989 (Rev-2021)	Tolerances for Erection of Steel Structures

3.4 DESIGN OF CONCRETE ELEMENTS

IS CODE	DESCRIPTION
IS 456: 2000 (Rev-2016)	Plain and Reinforced Concrete - Code of practice
IS 2950-1981 (Reaff-2018)	Indian Standard Code of Practice for Design and Construction of Raft Foundation (Part – 1)
IS : 2911-Part-1(Sec-2)	Indian Standard Code of Practice for Design and Construction of Pile Foundation-Bored Cast In situ Piles
IS 2911-Part-4-2013	Design and Construction of Pile Foundation - Code of practice -Load Tests on Pile
IS 1904 : 2021	Indian Standard Code of practice for design & construction foundations in Soil : General Requirements
IS 2974 : 1982 (Rev-2018)	Code of practice for design & construction of machine foundation
SP 34	Handbook on Concrete Reinforcement & Detailing
SP 7(Part IV)-2016	National Building code of India
IS 1786-2008 (Rev-2018)	Specification for high strength deformed bars and wires for concrete Reinforcement.
IS 3370 (part I) (Rev-2019)	Code of practice for concrete structure for the storage of liquids-Part-1 : General Requirements

IS 3370(part II) (Rev-2019)	Code of practice for concrete structure for the storage of liquids-Part-2 : Reinforced Concrete structures

Table 3.5 Design of Concrete Elements - International codes

IS Code	Description
BS 8110 : 1997	Structural use of concrete. Code of Practice for design and construction
ACI 318	Building Code requirements for Structural Concrete

4.DESIGN PARAMETERS

4.1 LOADS – SELF WEIGHT OF MATERIALS

Table-4.1.1 : Unit Weight of Materials

Material	Density
Reinforced Cement Concrete	25.00 kN/m3
Plain Cement/Screed Concrete	24.00 kN/m3
Cement Mortar	20.00 kN/m3
Conventional brick	20.00 kN/m3
Structural Steel	78.50 kN/m3
Cinder Concrete (Filling material)	08.00 kN/m3
Dry soil	18.00 kN/m3
Wet Soil	22.00 kN/m3
Landscape soil	16.00 kN/m3
Glass	28.00 kN/m3
Water	10.00 kN/m3

Table 4.1.2 – Infill wall loadings with AAC block

150mm thick wall with 20mm plaster on each side per meter height of wall	1.52 kN/m
200mm thick wall with 20mm plaster on each side per meter height of wall	1.92 kN/m

4.2 LOADS - IMPOSED LOADS ON SLAB

The following are the imposed loads in the structural slabs, in addition to the self-weight and the floor finishes. (Self-weight of slab will be as per the thickness mentioned in the respective drawings and the Floor finishes of 75mm thickness have been considered on all floors for commercial space).

Structural steel work shall conform to IS 226 and IS 2062 for Indian steel sections.

Table 4.2.1 Office

Load Component	Thickness (mm)	Load	Units
Floor Finishes+service		2.4	kN/m2
Partition Loads		1.0	kN/m2
Live Load		4.0	kN/m2

Table 4.2.2 Electrical room

Load Component	Thickness (mm)	Load	Units
Floor Finishes		1.2	kN/m2
Partition Loads		-	kN/m2
Live Load		5.0	kN/m2

Table 4.2.3 Toilets

Load Component	Thickness (mm)	Load	Units
Finishes		1.20	kN/m2
Sunk & Filled	100 mm	2.5	kN/m2
Live Load		2.0	kN/m2

Table 4.2.5 Roof Terraces

Load Component	Thickness (mm)	Load	Units
Weathering course with water - proofing		3.0	kN/m2
Live Load		4.0	kN/m2

Table 4.2.6 Corridors, Passage

Load Component	Thickness (mm)	Load	Units
Finishes		2.4	kN/m2
Live Load		3.0	kN/m2

Table 4.2.7 Staircases

Load Component	Thickness (mm)	Load	Units
Steps	150 (Riser)- 75mm Avg thickness	1.8	kN/m2
Finishes	-	1.2	kN/m2
Live Load	-	4.0	kN/m2

Table 4.2.8 Lift Machine Rooms

Load Component	Thickness (mm)	Load	Units
Finishes		1.8	kN/m2
Live Load		10.0	kN/m2

5.MATERIALS

5.1 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

Table 5.1.1 Grade of Concrete for Individual Structural elements

Sl.No.	Structural Elements	Min. Grade of Concrete
1.	Pile	M35
2.	Pile cap	M35
3.	RC Columns	M35
4.	RC Beams	M35
5.	RC Slabs	M35
6.	UG Tank	M35
7.	Other Structural	M25

Table 5.1.2 Concrete Properties

Young's Modulus of Elasticity of Concrete	5000√fck
Poisson Ratio's Ratio v =	0.2
Coefficient of Thermal expansion	5.5x10-6

5.2 REINFORCEMENT

The characteristic tensile properties of steel used in design shall be as follows.

Reinforcement Characteristic yield strength fyk (N/mm2) for rest	500 N/mm2
Young's Modulus E (kN/mm2)	200 kN/mm2
Poisson's ratio	0.3
Coefficient of Thermal expansion, α (oC-1)	12x10-6

5.3 STRUCTURAL STEEL

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

Structural steel	Grade E=250	Grade E-350
Tensile strength	410 N/mm2	490 N/mm2
Yield stress t<20mm	250 N/mm2	350 N/mm2
Yield stress t = 20mm to 40mm	240 N/mm2	330 N/mm2
Yield stress t> 40mm	230 N/mm2	320 N/mm2
Young's Modulus (E)	200,000 N/mm2	200,000 N/mm2
Density	78.5 kN/m3	78.5 kN/m3

5.4 PRESTRESSING STEEL (Wherever applicable)

The post-tension system is considered for prestressing works. Prestressing strands of diameter of 12.7mm / 15.2mm which are in compliance to IS 14268-1995, shall be used.

Strand diameter	12.7mm	15.2mm
Nominal area	98.7mm2	141mm2
Tensile strength	1860 N/mm2	1860 N/mm2
Modulus of elasticity	195 N/mm2	195 N/mm2
Minimum breaking load of strand	184 kN	

General assumptions for PT Slab & Beam Design

1. Strength design of prestressed member for flexure and axial loads shall be based on assumptions given in IS1343/ Clause 18.3 (Chapter 18) ACI-318

2. Design moment strength of flexural members shall be computed by the strength design method of the code IS1343/ACI-318

3. Prestressed flexural members shall be classified as class U, Class T or Class C based on extreme fiber stress (Ft) in tension in pre compressed tensile zone calculated at service loads.

4. Serviceability Design Requirements are as per clause 18.3 ACI-318/ IS1343

5. Deflection of pre-stressed flexural members shall be calculated in accordance with Clause 18.3.5- ACI-318/IS1343

6. Permissible tensile stresses in flexural member are as per Class-C (Table 18.3.3- ACI-318) / IS1343

7. Permissible stresses in prestressing steel shall not exceed the following

8. Due to prestressing steel jacking force 0.94 Fpy (specified yield strength of prestressing steel in psi) but not greater than the lesser of 0.80 (Fpu specified tensile strength of Pre-stressing steel)and the maximum value recommended by the manufacturer of prestressing steel or anchorage devices.

9. Immediate after prestress transfer 0.82 Fpy but not greater than 0.74 Fpu (specified tensile strength of prestressing steel)

10. Minimum Bonded reinforcement shall be provided in all prestressed flexural members is as per Clause 18.9-ACI-318 / IS1343.

11. Minimum average effective prestress of 125 psi on the slab section tributary to the tendon or tendon group.

12. Required elongation shall be determined from average load-elongation curves for the prestressing steel used. Generally 7% tolerance in prestressing steel force determined by gauge pressure and elongation measurements for post tension construction.

6.SUB-SOIL CONDITION

Soil investigation report no. GT-2075 dated June, 2020 referred for sub-soil condition & designing suitable foundation. As per report, the Soil Investigation carried out & the report prepared by C.V. Prasad. There are Three (3) Bore holes are investigated to ascertain the sub-soil condition at the proposed site through both field & lab tests. All boreholes are terminated at hard Clay-Shale layer encountered at a depth around 12m, where SPT (N) value encountered more than 100. As per the Bore hole data, the top layer is Filled up with predominantly brown sand exists with « N » value of 6. From 1m to 2m, it is a brown moist medium stiff silty clay of high plasticity with « N » value is in the range of 2. From 2m to 5, it is Pale to Medium Grey, Moist, Poorly Graded, Fine to Medium Grains, Very Loose, Silty sand exists with « N » value 5. From 5 to 7m, it is a Pale to Medium Grey, Moist, Poorly Graded, Fine to Medium Grains, Loose, Silty SAND exists with a « N » value in the range of 25. From 7m to 9m, it is a Pale to Medium Grey, Moist, Poorly Graded, Fine to Medium Grains, Medium Dense to Very Dense, Silty sand exists with the « N » value ranging from 54. From 10m to 16m, it is a Brownish Grey, Very Dense, Completely Weathered Rock (Descent from Hypersthene Granite/ Charnockite) exists with a « N » value more than 100 where the bore hole is terminated. During the time of soil investigation (June- 2020) the Ground Water Table (GWT) reported is 1m from existing ground level

Based on the sub-soil condition explored through the field and lab tests, consultant recommended to design Pile as Foundation system as the top soil is good in nature.

7.DESIGN CRITERIA

7.1 DESIGN LIFE

The design life of the building is assumed as 50 years. This requirement is applicable only for concrete works and not applicable to replaceable finishing materials, water proofing and thermal insulations, facades etc. Hence periodic maintenance/refurbishment is required for all replaceable materials.

7.2 TEMPERATURE EFFECTS

Temperature changes can cause additional stresses to the structure and has potential to increase in loads will be considered in the design of structural elements. Temperature effects will be considered for an ambient temperature variation from temperature during construction.

The maximum and minimum temperature for city of Chennai as recorded by Indian Metrological Department are as follows.

Maximum mean Temperature	45°C
Minimum mean Temperature	15°C
Average ambient Temperature during construction	30°C

The structural system will be designed for the effect of temperature variation. A temperature variation of ±15° C will be considered in the structural analysis for consideration of thermal effect on structural elements.

7.2.1 EXPANSION JOINTS

Above ground has been provided at suitable locations considering the size (length and width) of the building and the effect of temperature variation, with two (2) Expansion Joints (EJ) in order to split all the three structure independent.

7.3 WIND LOAD

Design wind load for the buildings shall be estimated as per IS 875 (Part 3): 2015. Design wind speed (Vz) is based on such as location, basic wind speed, terrain, cyclone condition and topography.

Location of the building	Chennai
Basic Wind speed - Vb m/sec	50 m/sec
Risk Coefficient (Probability factor) -k1	1.0
Terrain factor (Terrain-3) – k2 for the height of 21m	1.011
Topography factor – k3	1.0
Importance factor (Cyclonic region) – k4	1.0

Design wind speed (Vz) = Vb*k1*k2*k3*k4 =50x1x1.0x1.0x1.0 = 50.0 m/sec

Wind pressure (Pz) = 0.6 Vz^2 = 0.6x 50.0^2 =1500.0 N/m2

For design of building wind pressure 1.50 kN/m2 is considered.

Design wind pressure (Pd) = Kd*Ka*Kc*Pz

Where Kd - Wind Directionality factor = 1.0

Ka – Area averaging factor = 0.8

Kc – Combination factor = 0.9

Design Wind pressure = 1.50x1x0.8x0.9 = 1.08 kN/m2

7.4 DYNAMIC WIND ANALYSIS

As per IS 875 (Part 3) - 2015, clause 9.1 Dynamic wind analysis has to be carried out if the buildings meet the following criteria.

a). Buildings and closed structures with a height to minimum lateral dimension ratio (H/Wmin) is more than 5(or)

b). Building and structures whose natural frequency in the first mode is less than 1.0 Hz.

(a). (18.25m/31.3m) is 0.583 < 5.

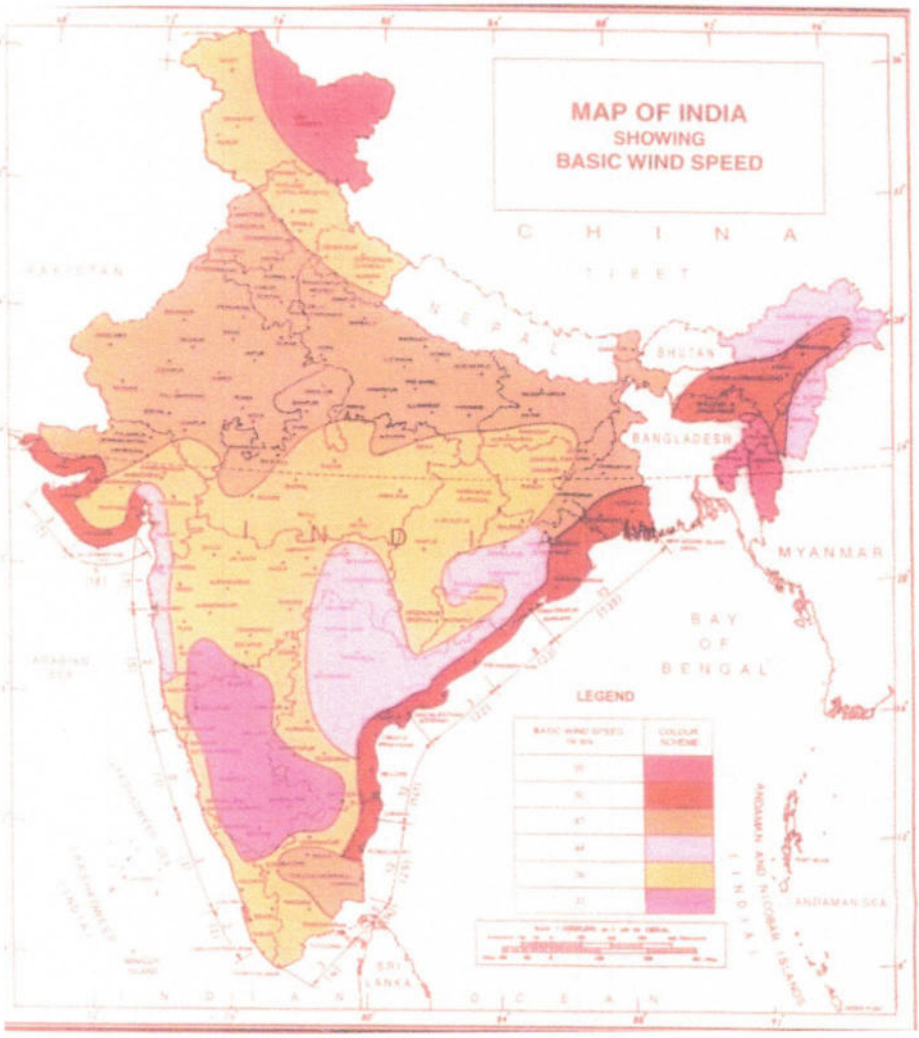
Hence Wind dynamic analysis not required.

(b) Fundamental period of the building = Ta = 0.09H/(D)^0.5 = (0.09 x 18.25) / (31.3) ^0.5=0.450

Natural frequency 1/Ta = 1/0.450 =2.22>1.0

Hence Wind dynamic analysis not required.

7.5 SEISMIC LATERAL FORCE



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

Base shear Vb = Ah 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).

The seismic weight is a summation of total dead load and 25% of live load for Reisdential Buildings with the live load is less than 3 kN/sq.m for Residential Building.

The Fundamental natural period of vibration (Ta) in seconds of a RC building is estimated by using the following formula, Ta = 0.075h^0.75 /$\sqrt{Aw}$

Where h is the height of the building in meters. d is the base dimension of the building at the plinth level, in m along the considered direction of the lateral force and Aw is wall area as below,

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

where

h = height of building as defined in 7.6.2(a), in m;

A_{wi} = effective cross-sectional area of wall i in first storey of building, in m^2;

L_{wi} = length of structural wall i in first storey in the considered direction of lateral forces, in m;

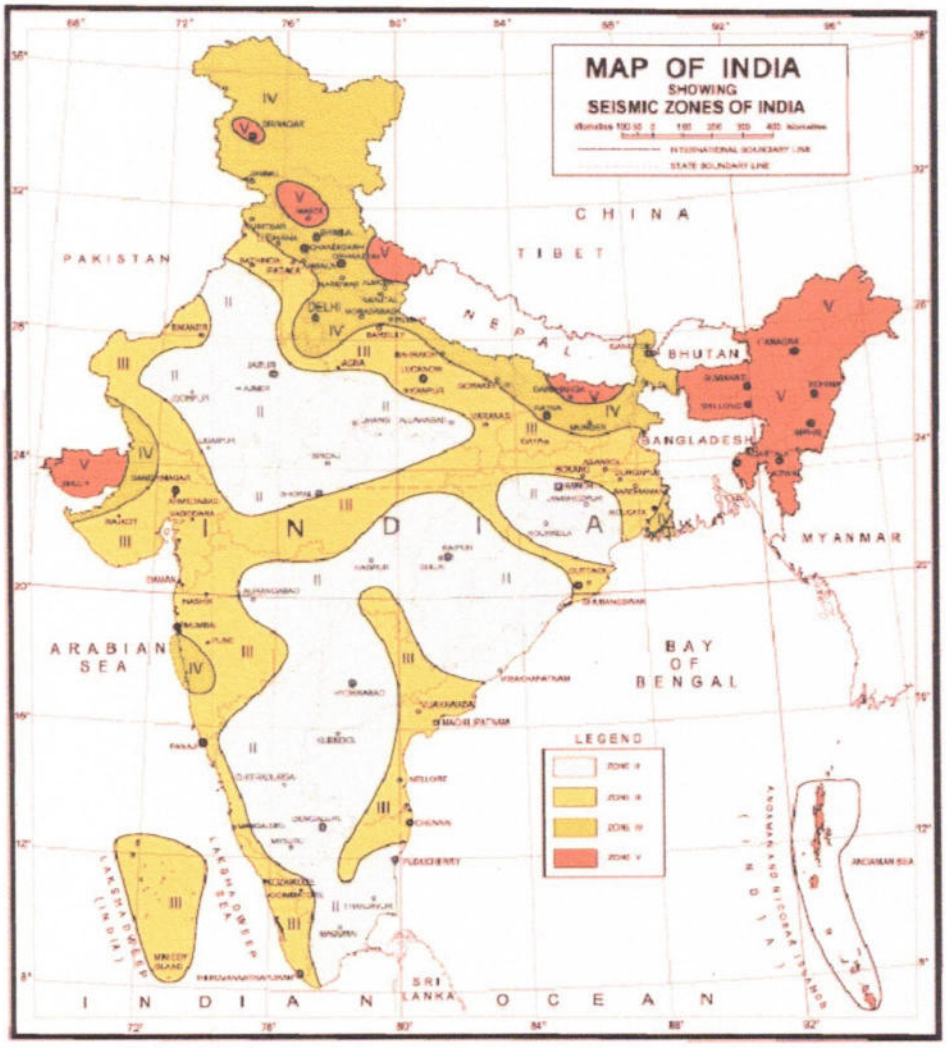
d = base dimension of the building at the plinth level along the considered direction of earthquake shaking, in m; and

N_w = number of walls in the considered direction of earthquake shaking.

The value of L_{wi}/h to be used in this equation shall not exceed 0.9.

7.5.1 Design Parameters for estimation of seismic loading

Sl.No.	Description	Parameters as per IS-1893-2016
1.	Location - Chennai	Seismic zone III
2.	Seismic Zone Factor	0.16
3.	Response Reduction Factor : RC buildings with special moment resisting frame (SMRF)	5.0
4	Importance factor (Residential building)	1.2
5	Type of Soil (hard)	Type 1 Rock
6	Damping coefficient	5%



7.5.2 BASE SHEAR

Height of the building (h) = 18.5m (measured from Ground floor)

d (along the length of the building) = 31.3m

b (along the breadth of the building) = 25.95m

a) Ta (along x) = 0.09h/d^0.5

= 0.297 Sec

b) Ta (along y) = 0.09h/d^0.5

= 0.326 Sec

From IS 1893: 2002, Clause 6.4.2, Design horizontal seismic coefficient

$$Ah = \frac{Z}{2} \times \frac{I}{} \times Sa$$

Where,

Z for Zone III = 0.16

I for Commercial Building = 1.2 (Refer to IS 1893-2016, Table.8)

Response Reduction Factor for RC buildings with

Flat slab = 3.0 as per (Table 9)

Sa/g (For Rocky) x direction & y direction = 0.25 (Refer to IS 1893-2016, page 13, Fig 1)

Design horizontal seismic coefficient and base shear

X- direction Ahx = 0.008 Vbx = 0.008W

Y- direction Ahy = 0.008 Vby = 0.008W

7.5.3 DYNAMIC ANALYSIS

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

Time period	: Calculated with the assumption of Flat Slab with Structural wall System.
Number of modes Considered	: 12 Numbers (Min)
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 as per IS: 1893-2016

Design Eccentricity

While performing structural analysis by the Seismic Coefficient Method or the Response Spectrum Method, the design eccentricity e_{di} to be used at floor i shall be taken as:

$$e_{di} = \begin{cases} 1.5e_{si} + 0.05b_i \\ e_{si} - 0.05b_i \end{cases}$$

8.Structural Analysis and Design

8.1 ASSUMPTIONS CONSIDERED IN THE DESIGN

The assumptions for structural analysis and design are as below,

- Elastic analysis (plane remains plane).
- Structure shall be analysed for the most adverse load conditions and envelope of forces shall be designed for
- Cracked section properties of structural RC structural elements are used in the analysis as per IS 16700-2017, clause 7.2, Table 6.

8.2 CONCRETE COVER

Concrete cover to the reinforcement in structural elements is based on durability and fire rating. The fire rating of 2hrs is considered for structural elements for the commercial development.

Sl. No.	Structural Elements	Cover in mm
1.	Pile	75
2.	Pile cap	75
3.	RC walls	30
4.	Columns	40
5.	Beams	35
6.	Slabs	25
7.	UG Tank Base Slab/Wall	40

8.3 METHOD FOR ANALYSIS

Computer-aided analysis using finite element method (FEM) shall be carried out for the design of structural elements. For 3D or 2D structural frame analysis latest version of software ETABS, SAFE shall be used, Prokon, RCDC and verified in-house spread sheets will be used for the design of reinforced concrete (RC) and steel elements in consideration of flexure, shear and axial forces. RAPT will be used for the design of pre-stressed concrete elements.

8.3.1 ASSUMPTIONS FOR 3D MODEL ANALYSIS USING ETABS

Columns : Frame Element

Beam Element : Frame Element

Slab : Membrane

The following are general parameters adopted in the analysis and design,
Modulus of Elasticity of Concrete -5000√fck
Wall element considered as Shell element

The following parameters and methods are adopted in creating ETABS 3D model for the buildings and design of structural elements.

- The 3D ETABS model generated based on the preliminary floor plans (shuttering drawings) prepared using preliminary sizes.
- Sectional properties are assigned to all the structural elements as per the preliminary floor plans (shuttering drawings).
- External & Internal in fill wall loads are assigned as uniformly distributed line load on beams and as area load if the wall is intend to distribute on slab directly. These loads are assigned under SIDL type load case.
- Slabs are modeled as shell element if floor system is Flat slab and the slab has been modeled as membrane in Beam-slab as floor system and slabs are assigned with horizontal diaphragms.
- Live Load reduction is considered in the design of Foundation and Column as per the Code : IS 875-1987 (Part-II), clause.3.2.1.
- Area design load i.e. Live load/SIDL or any other load is applied at floor relevant to its usage.
- All lateral loads & parameters are assigned as per Codes IS 1893-2016 & IS 875-2015.
- Temperature loads are applied on to the terraces and to areas directly exposed to sun.
- Beams under Torsion is required to maintain Equilibrium will be designed for Torsion in accordance with IS 456-2000, clause 41.1 to 41.4 and for all other beams torsional stiffness is neglected in the analysis by applying stiffness modifier as 0.01 to torsional constant "J". Hence no specific design for Torsion is required for these beams.
- Chennai is zone-III. Hence ductile design and detailing is followed as per the IS-13920-2016 code recommendation.
- Concrete cover to reinforcement complied accordance with IS 456-2000, Table.16 & 16A.
- UG Sump and STP is designed for the crack width of 0.2mm whereas the Building structural elements are designed for the crack width of 0.3mm.
- Secondary beams are not designed for ductile detailing.
- Long term deflections are checked by manual calculation using excel spread sheet wherever necessary. Also crack width calculation will be done using spread sheet wherever necessary.

Area Load & Application : Applied as uniformly distributed area load with intensity proportionate to its usage as mentioned in the Loading items in the DBR.

Line (Wall) Load & Application : non load bearing or infill wall loads are calculated appropriately and Applied as uniformly distributed line load.

Lateral Load Resisting Systems : The proposed structure conceptualized to be " Buildings with Ductile RC Structural walls and Special Moment Resisting Frame (OMRF) ". In this case the lateral load will be transferred primarily by RC walls and Columns for proportion of its stiffness in the direction considered. Response factor used "4" as per IS-1893-2016.

9.LOAD COMBINATIONS

The various loads shall be combined in accordance with the stipulations in IS 875 (Part 5) 1987 and IS 456: 2000. The structure will be checked for serviceability Limit State and Ultimate Limit State (Limit State of Collapse) conditions. The load factors to be used for the load combinations are shown in the Table below. The structural elements shall be designed and checked for the critical forces from the combinations.

Load Combination	DL	IL	TL	Spec X	Spec Y	WX	WY
Serviceability Limit State- combinations							
LC1 (D.L +T.L.)	1.0	-	1.0	-	-	-	-
LC2 (D.L + I.L +T.L.)	1.0	1.0	1.0	-	-	-	-
LC3 (D.L + T.L + Spec X)	1.0	-	1.0	1.0	-	-	-
LC4 (D.L + T.L + Spec Y)	1.0	-	1.0	-	1.0	-	-
LC6 (D.L + T.L + W X)	1.0	-	1.0	-	-	1.0	-
LC7 (D.L + T.L – W X)	1.0	-	1.0	-	-	-1.0	-
LC8 (D.L + T.L + W Y)	1.0	-	1.0	-	-	-	1.0
LC9 (D.L + T.L – W Y)	1.0	-	1.0	-	-	-	-1.0
LC10 (D.L + I.L + T.L + Spec X)	1.0	0.8	1.0	0.8	-	-	-
LC11 (D.L + I.L + T.L + Spec Y)	1.0	0.8	1.0	-	0.8	-	-
LC12 (D.L + I.L + T.L + W X)	1.0	0.8	1.0	-	-	0.8	-
LC13 (D.L + I.L + T.L - W X)	1.0	0.8	1.0	-	-	-0.8	-
LC14 (D.L + I.L + T.L + W Y)	1.0	0.8	1.0	-	-	-	0.8
LC15 (D.L + I.L + T.L - WY)	1.0	0.8	1.0	-	-	-	-0.8
Ultimate Limit State – Combinations							
Comb1 (D.L + T.L)	1.5	-	1.0	-	-	-	-
Comb2 (D.L + I.L + T.L)	1.5	1.5	1.0	-	-	-	-
Comb3 (D.L + I.L + T.L + Spec X/Spec XC / Spec XW)	1.2	1.2	1.0	1.2	-	-	-
Comb4 (D.L + I.L + T.L + Spec Y/Spec YC / Spec YW)	1.2	1.2	1.0	-	1.2	-	-
Comb5 (D.L + I.L + T.L + W X)	1.2	1.2	1.0	-	-	1.2	-
Comb6 (D.L + I.L + T.L – W X)	1.2	1.2	1.0	-	-	-1.2	-
Comb7 (D.L + I.L + T.L + W Y)	1.2	1.2	1.0	-	-	-	1.2
Comb9 (D.L + I.L + T.L - W Y)	1.2	1.2	1.0	-	-	-	-1.2

Comb10 (D.L + T.L + Spec X/Spec XC / Spec XW)	1.5	-	1.0	1.5	-	-	-
Comb12 (D.L + T.L + Spec Y/Spec YC / Spec YW)	1.5	-	1.0	-	1.5	-	-
Comb13 (D.L + T.L + Spec X/Spec XC / Spec XW)	0.9	-	1.0	1.5			
Comb14 (D.L + T.L + Spec Y/Spec YC / Spec YW)	0.9	-	1.0		1.5		
Comb15 (D.L + T.L – Spec Y)	1.5	-	1.0	-	-1.5	-	-
Comb16 (D.L + T.L + W X)	1.5	-	1.0	-	-	1.5	-
Comb17 (D.L + T.L – W X)	1.5	-	1.0	-	-	-1.5	-
Comb18 (D.L + T.L + W Y)	1.5	-	1.0	-	-	-	1.5
Comb19 (D.L + T.L – W Y)	1.5	-	1.0	-	-	-	-1.5
Comb20 (D.L + T.L + W X)	0.9	-	1.0	-	-	1.5	-
Comb21 (D.L + T.L – W X)	0.9	-	1.0	-	-	-1.5	-
Comb22 (D.L + T.L + W Y)	0.9	-	1.0	-	-	-	1.5
Comb23 (D.L + T.L – W Y)	0.9	-	1.0	-	-	-	-1.5

DL: Dead Load IL : Imposed Load TL – Temperature Load
Spec X: Earthquake Load in X-dir. WX: Wind Load in X-dir.
Spec Y: Earthquake Load in Y-dir. WY: Wind Load in Y-dir.

10.ACCEPTANCE CRITERIA

Under Serviceability Limit State the limiting structural deflection shall be as follows.
Total deflection under all imposed loads including temperature, creep and shrinkage shall not exceed **L/250.**
In the above limiting value, the deflection contribution due to temperature, creep and shrinkage shall not be more than **L/350**.
Lateral deflection (sway) due to wind shall not exceed **H/500 (0.002 H)** where H is the height of the building above ground.

10.1 CRACK WIDTH LIMITS

The Limiting values of crack width as per clause 35.3 of IS : 456-2000 is followed in the design

- In general, For all Buildings structural elements includes slabs, beams etc, the crack width is limited to 0.3mm.
- For water retaining structures and Basement-3 slab/wall elements the crack width is limited to 0.2mm.

11.Design of Structural Elements and Foundation

11.1 FOUNDATION DESIGN

The proposed Residential Building comprises Stilt+3 storey +4th floor part structure. The vertical elements like Columns are moderately loaded. The structure is provided with columns are adequately spreaded across in order to satisfy the structural requirements for both gravity and lateral loads.

As per the soil test report recommendation, designed Pile as Foundation system.

Sl.No.	Pile Diamater (D) in mm	Working Compression capacity in MT	Tension capacity in MT	Socketing length in Shale	Pile Length** including socketing length (Appx.) in m	Remarks
1	600	200	-	2.5XD	13	-
2	500	140	-	2.5XD	13	-

11.2 SHEAR WALL/COLUMN

RC Structural Walls & Columns which are supporting both vertical loads and lateral forces are designed for the most adverse load conditions and envelope of the forces which will be the maximum for that structural element from the load combinations considered in the 3D analysis. ETABS/RCDC a design software will be used to design the element for the maximum forces obtained from the load combinations. As the building is located in Zone III, ductile details shall be followed.

11.3 BEAMS

Each Beam will be designed for maximum forces from the 3D analysis and RCDC or RAPT Pre-stress concrete design software shall be used to design of RC members. As the building is located in Zone III, ductile details shall be followed.

11.4 SLABS

Slab will be designed using SAFE software. Other regular floor slabs will be designed using in-house spread sheet and unique/special shaped slabs will be designed using SAFE.

12.EXTERNAL WORKS – ROADS, DRAINS & COMPOUND WALL

12.1 Road works

Road pavement can be flexible pavement or rigid pavement. Road pavement consists of subgrade, sub-base, base course, asphalt base course and asphalt wearing course. Subgrade is the soil layer at road formation level, sub-base and base course compacted approved graded aggregate or other suitable material and over which asphalt will be laid. Asphalt layer consists of asphalt base course and asphalt wearing course. For rigid pavement approved concrete mix laid base course in place of asphalt. Specification for works will be provided separately.

12.2 Drains

Depending on the layout of rain water drainage system, reinforcement details for drains and culverts as required will be provided.

12.3 Compound wall

As per the architectural intend the compound wall will be designed. If it is required it will be designed to retain soil for certain height. It will also be designed for the lateral pressure. Foundation could be designed with Short Pile taking the soil/site condition in to account.

13.POST-TENSIONING DESIGN

13.1 PRE-STRESS LOAD

The total jacking force of 75% of breaking force of the strand in the tendon is applied along the perimeter of Pour as specified in PT shop drawing.

13.2 LOAD COMBINATIONS

SW – Self weight

SDL - Superimposed Dead Load

LL - Live Load (For Long term deflection, only portion of the live load(25%) that is sustained needs to be considered)

P – Pre-stressing force available at transfer after immediate losses

P' – Pre-stressing force available at service after allowing all losses (including long- term losses)

13.2.1 Load Combinations for Limit State of Collapse

1.5*(SW + SDL + LL) + 1.0*P'

13.2.2 Load Combinations for Limit State of Serviceability at Service

1.0*(SW + SDL + LL) + 1.1*P'

1.0*(SW + SDL + LL) + 0.9*P'

13.2.3 Load Combinations for Limit State of Serviceability at Transfer

1.0*SW + 1.0*P

3.3 MATERIAL GRADE AND PROPERTIES

13.3.1 Concrete

Minimum Concrete cube compressive strength at 28 days shall be 35*(Will be updated based on General notes drawing) N/mm2.

Minimum Concrete cube compressive strength at transfer shall be 25 N/mm2.

For Stilt Floor Roof (Non Tower), Minimum Concrete cube compressive strength at 28 days shall be 40*(Will be updated based on General notes drawing) N/mm2.

13.3.2 Un-Tensioned Steel

Conventional/Un-tensioned reinforcement bars, having the following minimum Yield Strength shall be used

Flexure - 550 N/mm2 (Fe550) Shear - 550 N/mm2 (Fe550)

13.3.3 Pre-Stressing Strand

Type of StrandClass 2, Low relaxation seven ply Strand Conforming to IS 14268 :1995 (Reaffirmed 1997)

Nominal Tensile Strength, fy	:	1860 N/mm^2
Diameter & Nominal Area	:	0.5" (12.7 mm) & 98.71 mm^2 Specific Breaking Load : 183.7 kN
Friction Parameters	:	μ = 0.2/rad & k = 0.0017/m
Serviceability Classification	:	0.2mm crack width. Type 3 – IS1343 :2012
System	:	Bonded.

13.4 DESIGN/DETAILING CONSIDERATION

13.4.1 Detailing of Tendons and Un-tensioned Reinforcement

The spacing of distributed tendons shall not exceed 8 times the thickness of slab.

Minimum Un-tensioned reinforcement of 0.12% of total cross sectional area will be provided in Post-tensioned Slabs. For Post-Tensioned Beams 0.2% of total cross sectional area will be provided as minimum Un-tensioned reinforcement. In addition to the IS code provisions.

13.4.2 Fire Rating and cover to Reinforcement and HT strand

Fire rating considered - 2 Hours
Exposure condition - Moderate

13.4.3 Minimum Clear cover to Un-tensioned reinforcement bars shall be as follows

For Beams

Continuous - 30 mm
Simply Supported - 40 mm

For Slabs

Continuous - 25 mm
Simply Supported - 35 mm

Minimum Clear cover to HT strands shall be as follows Beams and Slabs

From beam Soffits - 40 mm
Rest of the Places in Beams - 30 mm
Slabs - 30 mm

13.5 DEFLECTION

The maximum deflection in the Post tensioned Member under service loads (including creep and shrinkage) shall be restricted to as per Cl 23.2 of IS 456:2000 & Cl 24.1.2 of IS 1343:2012.

The final deflection due to all loads including the effects 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**.

13.6 STRESS LIMIT

Design will be carried out to meet the serviceability requirements of Type 3 as per Cl 24.2.1(c) of IS 1343:2012.

The concrete stresses at service in PT Slabs shall be limited to the recommendations of Clause 24.2.1 (c) & Table 10 of IS1343. Where ever the tensile stress limits are exceeded additional reinforcement will be detailed as per the code requirements.

Minimum average Pre-compression for internal structure **-0.9MPa**
Minimum average Pre-compression for Exposed structure **-1.2Mpa**

13.7 PUNCHING SHEAR

Checks for Punching Shear will be carried out to satisfy ultimate limit state requirements (with M35/40* grade of concrete) according to IS456 :2000. Shear reinforcement required if any, shall be provided in the detailed drawing. At Transfer stage with M25 grade of concrete, Punching shear check will be carried out for transfer load combination

13.8 ANALYSIS AND DESIGN SOFTWARE

The analysis and design will be carried out using the "RAPT". This 2-dimensional software is capable of carrying out the analysis and design of Post-tensioned floor plate using Equivalent Frame method (as per Cl. 31.5 of IS456:2000). If required by the engineer, additional hand calculations for capacity & Stresses checks shall be provided by sub-contractor to verify software results.

13.9 STRESSING

The total jacking force of 75% of characteristic tensile strength of strand is applied at concrete strength of 25 Mpa.

13.10 POUR/CLOSURE STRIP

Pour/closure strips are located appropriately so as to facilitate the planned pour sequence. The Pour strip is designed as RCC strip stitching pours on either side. Adequate un-tensioned (disconnected) reinforcement is provided in pour strip to satisfy the Ultimate moment condition. Form work/shuttering have to be retained in the panel (where pour strip is located) until the concrete in the pour strip achieves the required design strength.

13.11 STRUCTURAL ANALYSIS BRIEF

The analysis and design will be carried out using the "RAPT". This 2-dimensional software is capable of carrying out the analysis and design of Post-tensioned floor plate using Substitute Frame method (as per Cl. 31.5 of IS456:2000) in accordance to the latest prevailing codes. The walls, columns, drops, slab, beams and cut-outs are modeled appropriately as per the structural configuration in the General Arrangement drawing. Floor Loadings are applied as per the loading diagram. Tendons are modeled with appropriate profiles. Losses in tendons are computed internally. Pour strips, tower crane cut-outs or any other temporary discontinuity/opening in slabs are not analyzed as cantilever slabs.

13.12 DESIGN VALUES/CODE CHECK :

13.12.1 Serviceability Check :

13.12.1.1 Initial Stage/Transfer Stage :

The stress and Deflection at Transfer stage is checked

The stress shall not exceed the values specified below. These values are as per IS1343 :2012, Cl.24.2.1 and Cl. 24.3.2.1. & BS8110 :1997, Cl.4.3.5.2 The limit values under "Initial Load Stresses" in analysis input shall be as follows,

i. Tensile Stress Limit	– 0.36*√fci =0.36*√25	= **01.80 N/mm2**
ii. Compressive Stress Limit	– 0.4 * fci = 0.4 * 25	= **10.00 N/mm2.**

13.12.1.2 Service Stage :

The stress and Deflection at Service stage is checked

The stress shall not exceed the values specified below. These values are as per IS1343 :2012, Cl.24.3.1 and Table 10. "Stresses" in analysis input shall be as follows,

I. Tensile Stress Limit = **04.40 N/mm2**

II. Compressive Stress Limit – 0.40 * fck =0.40 * 35= **14.00 N/mm2.**

Wherever tensile stress exceeds 04.40 N/mm2 (where ever tendon continuity cannot be maintained/tendons cannot be provided due to unavailability of adequate length, additional reinforcements can be added in the tension zone as per Table 10 of IS1343 :2012. However, total hypothetical tensile stress shall not exceed 0.25 times fck = 0.25*35 = **08.75 N/mm2.**

Minimum Pre-compression (P/A) for service condition is checked and shall not be less than 0.9 N/mm2.

13.13 PHILOSOPHY FOR PRE-STRESS LOSSES

For post tensioned members, Loss due to Elastic Shortening, Relaxation of stresses in steel, Shrinkage of concrete, Creep of concrete, Friction and Anchorage Slip are encountered and are accounted for. Long term losses (Relaxation of stresses in steel, Shrinkage of concrete, Creep of concrete).

Applied prestressing force at site-0.75x183.75 = **137.8 kN**

13.14 FORM WORK AND BACK PROPPING

Formwork shall remain in position until tendons have been fully stressed and the strand elongations results are satisfactory. The design and erection of shuttering for PT slabs and the back-propping required for the lower floors, shall be carried out by the Principal contractors confirming to relevant IS codes.

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