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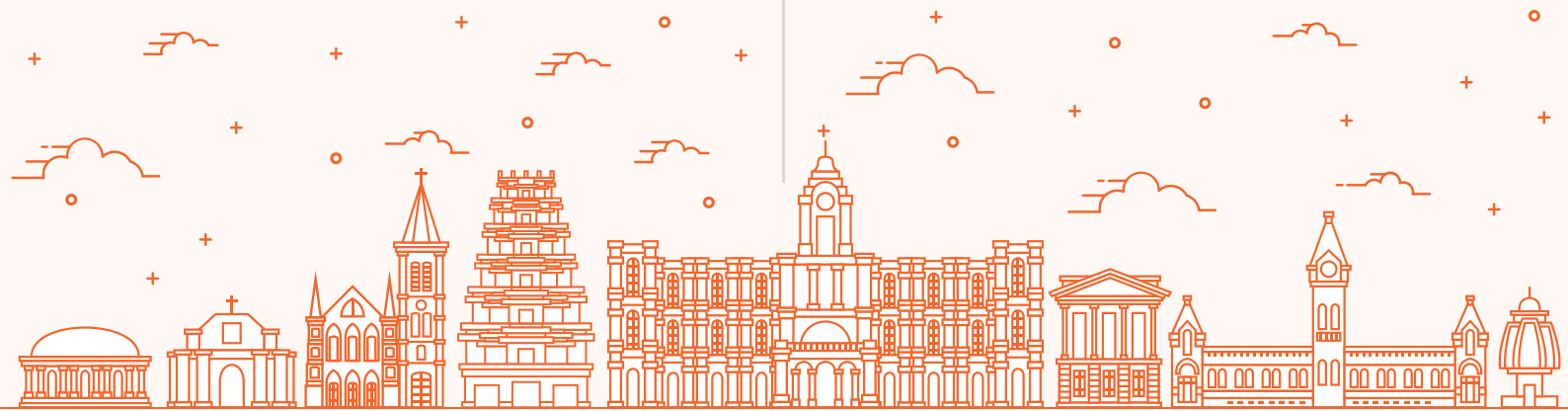

STRUCTURAL DESIGN BASIS REPORT

of

BRIGADE MORGAN HEIGHTS
CHENNAI

For

BRIGADE ENTERPRISES

Rd	16-12-2024		Comments	ARUN	PRASHANTH	NNNK
Rc	27-11-2024		Comments	VISHWAS	ARUN/PRASHANTH	NNNK
Rb	06-06-2024		Comments	SANTOSH N	ARUN/PRASHANTH	NNNK
Ra	08-05-2024		PRELIMINARY	SANTOSH N	ARUN/PRASHANTH	NNNK
REV NO.	**DATE**	**DESCRIPTION**	**STATUS**	**PREPARED BY**	**REVIEWED BY**	**APPRVD. BY**

N.N. NAGENDRA KUMAR
Registered Structural Engineer Grade-I (SE)
SE/GR-I/2019/03/064 Dated 29-03-2024
1307 Brigade Towers, 135 Brigade Road,
Bangalore - 560025. M : 9845038100
Email : nagendra@sterlingblr.com

STRUCTURAL ENGINEERS

STERLING ENGINEERING CONSULTANCY SERVICES PVT. LTD.

1307, BRIGADE TOWERS, 135, BRIGADE ROAD, BANGALORE – 560 025
PHONES: +91-080-22244810, +91-080-22244811 FAX: +91-080-22210753

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N.N. NAGENDRA KUMAR
Registered Structural Engineer Grade-I (SE)
SE/GR-I/2019/03/064 Dated 29-03-2024
1307 Brigade Towers, 135 Brigade Road,
Bangalore - 560025. M : 9845038100
Email : nagendra@sterlingblr.com

1. Foreword

This report contains the Design parameters in Structural Analysis and Design for the proposed Residential Building for Brigade Morgan Heights, Perumbakkam, Chennai for Brigade Tetrarch pvt ltd.

The proposed structure is categorized for Residential use.

The intent of this document is to identify and record all the pertinent input requirements, analysis & design criteria for 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. Hence it is expected that the planning and design team members - architects, services consultants and project management team - give their feedback and approval to the parameters, suggestions, recommendations and queries mentioned in the report.

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.
- Resistance to loads due to natural phenomena i.e. wind and earthquakes.
- Structural durability & maintainability.

N. N. Nagendra

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Registered Structural Engineer Grade-I (SE)
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Email : nagendra@sterlingblr.com

2. Project Description

Project: Brigade Morgan Heights.
Location: Perumbakkam, Chennai.

2.1 Agencies

Owner	**: BRIGADE TETRACH PVT. LIMITED.**
Architects	**: Zachariah consultants (India) Pvt. Ltd, Bangalore.**
Structural Consultants	**: Sterling Engineering Consultancy Services (P) Ltd., Bengaluru**
Services Consultants	**: LEAD consultancy and engineering services (India) Pvt.Ltd**
HVAC Consultants	**: LEAD consultancy and engineering services (India) Pvt.Ltd**
Electrical consultants	**: LEAD consultancy and engineering services (India) Pvt.Ltd**
Landscape Consultants	**: Terra-firma landscape architecture.**

2.2 The Project Description:

The proposed project consists of three residential clusters namely front residential tower 1 with 4 parking levels and 21 residential units with a height of 78.725m. Rear residential Tower 2 with 4 parking and 15 floors buildings of height of 60.875m, Rear residential Tower 3 with 3 parking and 11 upper floors with a height of 45.675m and clubhouse which consists of ground+7 floors and terrace. All of the residential clusters are supported by wall-beam-slab system or MIVAN construction. Clubhouse is supported by beam and slab system with 4 floors and terrace.

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1) Front Residential Tower 01 :

Ground Floor (+4.05m)

Most of the ground floor area in consists of parking space with 174 car parks, 26 disabled car parks. It consists of 8 fire staircases which give access to residential units and 2 staircases which go down to the pump room from basement level. It also consists of 12 passenger service lifts and 4 service lifts. An 8 meter wide fire driveway runs through the perimeter of the building and 4.5m driveway connecting the parking spaces. It also houses 4 electrical rooms fire command center, network provider room, DG panel room at various locations at this level.

First floor (+7.95m) :
Similar to Ground floor first floor completely consists of parking spaces with lifts and staircases and does not house any electrical rooms etc. It just houses 4.5m driveway fire driveway for vehicular movement.

Second floor (+11.25m) and third floor (+14.55m):
The second and third floor consists of lifts and staircases and entire space is reserved for parking.

Fourth floor (+19.05m):
From 4th floor level entire floor is reserved for residential units. The transfer girder level is provided at this level wherein the upper floors are supported.

Fifth (+22.025m) to terrace (+81.475m):
From 5th floor to terrace level entire area is reserved for residential units.

Nineteenth floor lvl (Refuge floor) (+63.675m):
Most of the nineteenth floor is reserved for residential units and part of it is reserved for refuge area.

2) Rear Residential Tower 02:

Rear residential tower 2 consists of 19F (4P+15R) with a building height of 60.875m.

Ground floor (+4.05m): The space at ground floor of tower 02 is reserved mainly for parking area and consists 8m wide fire driveway all round. The entire building consists of 2 fire staircases, 1 service lift and 4 passenger lifts to access the upper floors of this building. This floor consists of electrical room, Fire communication room, landscape area, rain water sump along with lobby area.

First floor (+7.95m) : Similar to Ground floor first floor completely consists of parking spaces with lifts and staircases and does not house any electrical rooms etc. It just houses 4.5m driveway for vehicular movement.

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Second floor (+11.25m) and third floor (+14.55m): The second and third floor consists of lifts and staircases and entire space is reserved for parking.

Fourth floor (+19.05m): From 4th floor level entire floor is reserved for residential units. The transfer girder level is provided at this level wherein the upper floors are supported.

Fifth (+22.025m) to terrace (+63.625): From 5th floor to terrace level entire area is reserved for residential units.

3) Rear Residential Tower 03 :

Rear residential tower 3 consists of 14F (3P+11R) with a building height of 45.675m.

Ground floor (+4.05m): The space at ground floor of tower 02 is reserved mainly for parking area and consists 8m wide fire driveway all round. The entire building consists of 2 fire staircases, 1 service lift and 4 passenger lifts to access the upper floors of this building. This floor consists of electrical room, Network provider room, landscape area along with lobby area.

First floor (+7.95m) : Similar to Ground floor first floor completely consists of parking spaces with lifts and staircases and does not house any electrical rooms etc. It just houses 4.5m driveway for vehicular movement.

Second floor (+11.25m) : The second floor consists of lifts and staircases and entire space is reserved for parking.

Third floor (+15.75m): From 3rd floor level entire floor is reserved for residential units. The transfer girder level is provided at this level wherein the upper floors are supported.

Fourth (+18.725m) to terrace (+48.425m): From 5th floor to terrace level entire area is reserved for residential units.

4) Clubhouse:

Clubhouse consists of ground+ 7 upper floors and terrace.

Ground floor (+0.5m): Ground floor consists of 2 lifts and two staircases. Ground floor space is allocated for waiting area, mph, reception, pre function area, pantry, store, convenience store and pharmacy, crèche, laundry, clinic, electric room, communication room, fire command center and toilets.

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First floor (+4.00m): Majority of the first floor area is allocated for badminton court. The entrance to badminton court from lift lobby to badminton court is through a 2m wide corridor. It also houses pantry, association office, meeting room toilets and open terrace next to fire staircase.

Second floor (+7.50m): At this level badminton court area is a double height area. Also it houses squash area which is also a double height area. It also consists of AV room and board games and children's play area and toilet area.

Third floor (+11.00 m): At this level, we have pool table, teens play area, foose ball, air hockey area, table tennis court and toilet area.

Fourth floor (+14.500 m): At this level, majority of this area is allocated to gym area, yoga terrace, swimming pool area services, co-working space and toilets. Also at this level there is a connecting bridge connecting the clubhouse to podium level. The gym area, yoga terrace and co-working space is a double height area as we have swimming pool in the entire area of sixth floor along with lifts and staicases.

Sixth floor (+21.55 m): The sixth floor level is entirely allocated to swimming pool area of depth 1.5m along with staircases and lifts.

Seventh floor (+24.950 m): The seventh floor level is entirely an open area with lift and staircase closure area.

3. List of Codes

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

3.1 DESIGN LOADS (OTHER THAN EARTHQUAKE LOADS)

IS Code	Description
IS 875(Part 1): 1987	Dead Loads – Unit Weight of Building Material and Stored Material
IS 875(Part 2): 1987	Imposed Loads
IS 875(Part 3): 2015	Wind Loads

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3.2 DESIGN FOR EARTHQUAKE RESISTANCE

IS Code	Description
IS 1893:(part 1)2016	Criteria for earthquake resistance design of structures.
IS 4326: 1993	Earthquake Resistant Design and Construction of Buildings – Code of Practice
IS 13920: 2016	Code of practice for ductile detailing of reinforced structure subjected to seismic forces.
IS 16700:2023	Criteria for Structural Safety of Tall Concrete Buildings

3.3 DESIGN OF STEEL STRUCTURAL ELEMENTS

IS Code	Description
IS 800: 2007	Code of Practice for General Construction in Steel
IS 2062	Steel for general structural purposes

3.4 DESIGN OF CONCRETE ELEMENTS

IS Code	Description
IS 456: 2000	Plain and Reinforced Concrete - Code of practice
IS 1904	Indian Standard Code of practice for design & construction foundations in Soil: General Requirements
IS 2950	Indian Standard Code of Practice for Design and Construction of Raft Foundation (Part – 1)
IS 2974	Code of practice for design & construction of machine foundation
SP 16	Structural use of concrete. Design charts for singly reinforced beams, doubly reinforced beams and columns.
SP 34	Handbook on Concrete Reinforcement & Detailing
SP 7(Part IV)	National Building code of India
IS 1786	Specification for high strength deformed bars and wires for concrete reinforcement.
IS 3370 (part I)	Code of practice for concrete structure for the storage of liquids

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4. Design Parameters

4.1 Materials of Construction

The structure is predominantly RCC Mivan structure with ordinary RC structural walls for residential towers and RCC framed structure beam and slab for clubhouse area. These walls will also be responsible for lateral load resistance. Rigid/Semi rigid diaphragms are assigned at every floor based on the continuity of the floor plate available.

Concrete:

Concrete Grade ranging from M60 to M30 shall be used in RCC structural members. Concrete Mix M15 shall be used in filling, plum concrete, leveling courses and other non-structural items.

Density of reinforced concrete is assumed as 25.00 KN/cu.m
Minimum cement content, water cement ratio etc. shall conform to IS 456:2000 code provisions for durability and strength criteria.

Cement:

Ordinary Portland cement of grade 53 or higher confirming to IS 8112 and IS 12269 are specified for concrete grades ranging from M30 to M60.

Aggregates:

The sizes of coarse aggregates confirm to IS 383. Nominal maximum size of coarse aggregate is 20 mm, suitably graded as per the requirement of mix design.
The fine aggregates confirm to the specifications of IS 383.

Water:

Water used for construction shall comply with IS 456:2000.

Reinforcement:

High yield strength deformed bars conforming to IS 1786 with f_y = 550 N/ sq.mm

Structural Steel:

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

Soil Parameters:

Geo-technical investigation was carried out in 35 borehole locations. The stratigraphy of the 35 exploratory boreholes in general consists of soft to very soft clay with high plasticity. Hence pile foundation was recommended. The load carrying capacity and depth along with diameter of piles as recommended is indicated in the table below:

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Bangalore - 560025. M : 9845038100
Email : nagendra@sterlingblr.com

TABLE:- 5.2 RECOMMENDED SAFE LOAD CARRYING CAPACITIES OF BORED CAST-IN SITU PILES								
Sl.No	Reference Bore hole No.	Length of Pile below E.G.L	Assumed Length of Cut-Off Below	Length of Pile below Cut-off	Dia.of Pile in (mm)	SAFE LOAD CARRYING CAPACITY (kN)		
						Vertical Load Carrying Capacity	Pull Out Capacity	Lateral Load Carrying Capacity
1.0	BH-35	10.0	1.0	9.00	600	2200	300	50
2.0					750	3000	370	65
3.0					900	4000	440	75
4.0					1000	5000	490	85
COMPOUND WALL								
1.0	BH-35	7.0	0.0	7.00	450	700	130	38

Concrete Grades of Structural Elements,

i)	Piles, footings & Pedestals	-	M40
ii)	Raft & Retaining wall	-	M30
iii)	Columns and RC Walls		M30 to M60
iv)	Underground Tanks & OHT	-	M30
v)	Slab & Drop Panels	-	M30
vi)	Beams & Ramps	-	M30
vii)	Staircase	-	M30

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Email : nagendra@sterlingblr.com

4.2 Loading Standards

4.2.1 Imposed Loads on slabs

The following are the imposed loads on 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
Floor finishes of 50 mm (100kg/m^2) thickness have been considered on all floors.

(i) Living, Dining, Bedrooms and Kitchens (Residential occupancy)

Load Component	Thickness (mm)	UDL (kN/m^2)
Live Load		2.00
Finishes	50mm	1.25

(ii) Corridors, Passages, Lobbies, waiting area.

Load Component	Thickness (mm)	UDL (kN/m^2)
Finishes		1.25
Live Load		3.00

(iii) Terraces

Load Component	Thickness (mm)	UDL (kN/m^2)
Integrated Water-Proofing/screed to slope	150 (avg thickness)	3.60
Live Load		1.50

AHU, Cooling towers, Chiller platforms & treated fresh air unit loadings are applied on terrace floor as specified in the vendor drawing. It can be over raised floor.

(iv) Toilets and balconies

Load Component	Thickness (mm)	UDL (kN/m^2)
Finishes		1.25
Sunk & Filled	125mm, 200mm	3.125,5.0
Live Load toilet		2.00
Live load balcony		3.00

(v) Staircases

Load Component	Thickness (mm)	UDL (kN/m^2)
Steps	150 (Riser) Assuming 75mm Avg thickness	1.875
Finishes		1.25
Live load		3.00

(vi) Lift Machine Rooms, Elec. Rooms and DG Area

Load Component	Thickness (mm)	UDL (kN/m^2)
Finishes	75mm	1.50
Live load		10.00
services		0.85

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(vii) Self - Weight of Different Walls

Wall Type	Thickness (mm)	UDL (kN/m^2)
External Wall		
Concrete Block-work	200	4.8
Internal Partition Wall		
Block work	100	2.40

Density of Wall (Including plastering) = 24.0 KN/ m^3

(viii) Parking Space and Drive-way Ramps

Load Component	Thickness (mm)	UDL (kN/m^2)
Finishes	75mm	1.50
Live Load (LMV)		3.0 (with impact loading)
Services		0.85

(ix) Landscape on podium level

Load Component	Thickness (mm)	UDL (kN/m^2)
450mm filling 1150mm filling	0.450 x 21 kN/m^3 1.150x 21 kN/m^3	9.45 24.15
Live Load (Fire Tender Movement) on slab if any		16.00
Live Load (LMV)		3.00

Note: As per NBC, Fire Tender load shall be considered with partial load factor of 1.05 with gravity loads. The fire tender load will not be considered in Mass source (for seismic weight consideration) and for lateral load analysis.

(x) Engineering Area, Security Rooms, Electrical, AHU rooms, Server room, Chiller Platform and other storage etc.

Load Component	Thickness (mm)	UDL (kN/m^2)
Finishes	75	1.50
Live Load (non-reducible)		7.50
services		0.85

(xi) Refuge Areas

Load Component	Thickness (mm)	UDL (kN/m^2)
Live Load		5.00
Finishes		1.50
Sunk if any	150	3.75 (PCC)
	300	3.0 (Cinder Fill)

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(xii) Badminton court, Squash court, table tennis, pool table.

Load Component	Thickness (mm)	UDL (kN/m^2)
Live Load		5.00
Finishes	50mm	1.25
services		0.85

(xiii) Association office, meeting room

Load Component	Thickness (mm)	UDL (kN/m^2)
Live Load		3.00
Finishes	50mm	1.25
services		0.85

(xiv) Audio video room

Load Component	Thickness (mm)	UDL (kN/m^2)
Live Load	Including seating	5.00
Finishes	50mm	1.25
services		0.85

(xv) Board games and children's play area, teens play area

Load Component	Thickness (mm)	UDL (kN/m^2)
Live Load		4.00
Finishes	50mm	1.25
services		0.85

(xvi) Gym

Load Component	Thickness (mm)	UDL (kN/m^2)
Live Load		5.00
Finishes	50mm	1.25
services		0.85

(xvii) Yoga terrace

Load Component	Thickness (mm)	UDL (kN/m^2)
Live Load		4.00
Finishes	50mm	1.25
services		0.85

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(xviii) Swimming pool, , pool deck area

Load Component	Thickness (mm)	UDL (kN/m^2)
Water load	1500 (density 10kN/m3)	15.00
Finishes	100mm water proofing +tiles	4.00
Live load		3.00
Pool deck	150mm finishes	3.75

(xix) Pool services

Load Component	Thickness (mm)	UDL (kN/m^2)
Live load		5.00
finishes	150mm finishes	3.75

Fire tender where applicable Wheel /Axial load – IRC Class-A, 60.00 Tonnes of Design load above pavements will be considered.

Fire tender movement along the periphery of the building on the podium slab with fire engine loading will be considered and the Uniformly Distributed load works out to be q = 16.0 KN/m^2.

4.2.2 Wind loads

Wind loads will be calculated in accordance with IS 875: Part 3.
Design wind speed,

$$V_Z = V_b \times k_1 \times k_2 \times k_3 \times k_4$$

V_b	⟶	Basic wind velocity for Bengaluru	=	50 m/s
k_1	⟶	Risk coefficient for all general buildings (For a design life of 50 years)	=	1.0
k_2	⟶	Terrain category 2, (H=73.25m)	=	1.20
k_3	⟶	Topography factor	=	1.0
k_4	⟶	Improtance factor	=	1.0

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Based on the above values we need to calculate V_Z followed by P_Z,
Design wind pressure,

$$P_Z = 0.6 \times V_Z^2$$

Further to Design Wind Pressure (P_Z) appropriate pressure coefficient will be used as applicable.

4.2.3 Seismic Loads

The seismic load calculations will be carried out in accordance with IS: 1893 - 2016.
(IS 13920-2016 code of practice for ductile detailing of reinforced structure subjected to seismic forces specifies that all structures in the zone III and above i.e., zone III, IV and V requires special design or ductile detailing other than following general principles of limit state design and detailing given in IS 456 are also generally required for adequate safety against these medium intensity earthquakes.)

As per this code, Chennai lies in Zone III with zone factor Z = 0.16

The design horizontal seismic co-efficient for a structure shall be determined by the following expressions.

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

Z - Zone factor for Zone II
- Medium Seismic Intensity = 0.16

I - Importance factor = 1.2

R - Response reduction factor for buildings with ductile RC walls
= 4.0

$\frac{Sa}{g}$ - Average response acceleration co-efficient which depends on soil types, natural period and damping values.

T - Natural period.

Since all the three towers have height equal to 50m or above the time period shall be adopted as per 6.3.4 pg no 7 of IS 16700-2023. For clubhouse time period shall be as per IS-1893- 2016.

$T_a = 0.0644\ H^{0.9}$ for concrete moment resisting frame systems; and
$T_a = 0.0672\ H^{0.75}$ for all other concrete structural systems

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Ta=0.075 H^(0.75)

H- Height of the building from base.

A damping of 5% is considered.

Live load used in calculations of seismic weights is 25% of actual applied load as per IS 1893 (Part 1): 2016.

4.2.4 Shrinkage Effects

Expansion joint in the building are considered from typical floors. To avoid shrinkage cracks it is necessary to predetermine the construction sequences leaving shrinkage strips concreted subsequently. Also thermal analysis is been carried out for the structure combining all towers at ground level, the load cases for this kind is mentioned in the load cases considered for design.

4.2.5 Soil Loads

Fire tender movement along the periphery with fire engine loading shall be considered as surcharge on the drive ways next to retaining walls. The Equivalent Uniformly Distributed load of the fire tender works out to be q = 16.0 KN/ m^2 is considered.

4.2.6 Thermal Effects

Temperature variation produces stresses in the structure, as it tends to expand and contract. In the structures, with large geometrical dimensions, the effect of temperature is important in the behavior and final design. Due to deformation of expansion & contraction - between day & night, and between the seasons - the effect on the durability of structure and on the supported finishes is significant to produce considerable results.

The structure will be analyzed for the following conditions of temperature variation, if required.

Case 1	
Overall temperature variation between day and nights and between summer and winter conditions.	10 ^{0}C
Case 2	
Differential inside and outside temperature considering that the building is air-conditioned and thermally insulated.	10 ^{0}C

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5. Load Combinations

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

Load Combination	LOAD FACTORS							
	D L	L L	Wind	Earthquake	Temperature	Spec x	Spec y	Spec z
LC-1	1.5	-	-	-	-	-	-	-
LC-2	1.5	1.5	-	-	-	-	-	-
LC-3	1.2	1.2	1.2 (x)	-	-	-	-	-
LC-4	1.2	1.2	-1.2 (x)	-	-	-	-	-
LC-5	1.2	1.2	1.2 (y)	-	-	-	-	-
LC-6	1.2	1.2	-1.2 (y)	-	-	-	-	-
LC-7	1.2	1.2	-	1.2 (x)	-	-	-	-
LC-8	1.2	1.2	-	-1.2 (x)	-	-	-	-
LC-9	1.2	1.2	-	1.2 (y)	-	-	-	-
LC-10	1.2	1.2	-	-1.2 (y)	-	-	-	-
LC-11	1.5	-	1.5 (x)	-	-	-	-	-
LC-12	1.5	-	-1.5 (x)	-	-	-	-	-
LC-13	1.5	-	1.5 (y)	-	-	-	-	-
LC-14	1.5	-	-1.5 (y)	-	-	-	-	-
LC-15	1.5	-	-	1.5 (x)	-	-	-	-
LC-16	1.5	-	-	-1.5 (x)	-	-	-	-
LC-17	1.5	-	-	1.5 (y)	-	-	-	-
LC-18	1.5	-	-	-1.5 (y)	-	-	-	-
LC-19	0.9	-	1.5 (x)	-	-	-	-	-
LC-20	0.9	-	-1.5 (x)	-	-	-	-	-
LC-21	0.9	-	1.5 (y)	-	-	-	-	-
LC-22	0.9	-	-1.5 (y)	-	-	-	-	-
LC-23	0.9	-	-	1.5 (x)	-	-	-	-
LC-24	0.9	-	-	-1.5 (x)	-	-	-	-
LC-25	0.9	-	-	1.5 (y)	-	-	-	-
LC-26	0.9	-	-	-1.5 (y)	-	-	-	-
LC-27	1.2	1.2	-	-	1.2	-	-	-
LC-28	1.2	1.2	-	-	-	1.2		
LC-29	1.2	1.2	-	-	-		1.2	-
LC-30	1.5	-	-	-	-	1.5	-	-
LC-31	1.5	-	-	-	-	-	1.5	-
LC-32	0.9	-	-	-	-	1.5	-	-
LC-33	0.9	-	-	-	-	-	1.5	-
LC-34	1.5	-	-	-	-	1.5	0.45	0.45
LC-35	1.5	-	-	-	-	0.45	1.5	0.45
LC-36	1.5	-	-	-	-	-1.5	-0.45	-0.45

N. N Nagendra

N.N. NAGENDRA KUMAR
Registered Structural Engineer Grade-I (SE)
SE/GR-I/2019/03/064 Dated 29-03-2024
1307 Brigade Towers, 135 Brigade Road,
Bangalore - 560025. M : 9845038100
Email : nagendra@sterlingblr.com

LC-37	1.5	-	-	-	-	-0.45	-1.5	-0.45
LC-38	1.5	-	-	-	1.5	-	-	-
LC-39	1.5	-	-	-	-1.5	-	-	-
LC-40	1.2	1.2	-	-	-	1.2	0.36	0.36
LC-41	1.2	1.2	-	-	-	0.36	1.2	0.36
LC-42	1.2	1.2	-	-	-	-1.2	-0.36	-0.36
LC-43	1.2	1.2	-	-	-	-0.36	-1.2	-0.36
LC-44	1.2	1.2	-	-	-1.2	-	-	-
LC-45	0.9	-	-	-	-	1.5	0.45	0.45
LC-46	0.9	-	-	-	-	0.45	1.5	0.45
LC-47	0.9	-	-	-	-	-1.5	-0.45	-0.45
LC-48	0.9	-	-	-	-	-0.45	-1.5	-0.45
LC-49	0.9	-	-	-	1.5	-	-	-
LC-50	0.9	-	-	-	- 1.5	-	-	-
LC-51	1.2	1.2	-	-	1.2	1.2	0.36	0.36
LC-52	1.2	1.2	-	-	-1.2	-1.2	-0.36	-0.36
LC-53	1.2	1.2	-	-	1.2	0.36	1.2	0.36
LC-54	1.2	1.2	-	-	-1.2	-0.36	-1.2	-0.36
LC-55	1.5	-	-	-	1.5	1.5	0.45	0.45
LC-56	1.5	-	-	-	-1.5	-1.5	-0.45	-0.45
LC-57	1.5	-	-	-	1.5	0.45	1.5	0.45
LC-58	1.5	-	-	-	-1.5	-0.45	-1.5	-0.45
LC-59	0.9	-	-	-	1.5	1.5	0.45	0.45
LC-60	0.9	-	-	-	-1.5	-1.5	-0.45	-0.45
LC-61	0.9	-	-	-	1.5	0.45	1.5	0.45
LC-62	0.9	-	-	-	-1.5	-0.45	-1.5	-0.45
LC-63	1.2	1.2	1.2 (x)	-	1.2	-	-	-
LC-64	1.2	1.2	-1.2 (x)	-	-1.2	-	-	-
LC-65	1.2	1.2	1.2 (y)	-	1.2	-	-	-
LC-66	1.2	1.2	-1.2 (y)	-	-1.2	-	-	-
LC-67	1.5	-	1.5 (x)	-	1.5	-	-	-
LC-68	1.5	-	-1.5 (x)	-	-1.5	-	-	-
LC-69	1.5	-	1.5 (y)	-	1.5	-	-	-
LC-70	1.5	-	-1.5 (y)	-	-1.5	-	-	-
LC-71	0.9	-	1.5 (x)	-	1.5	-	-	-
LC-72	0.9	-	-1.5 (x)	-	-1.5	-	-	-
LC-73	0.9	-	1.5 (y)	-	1.5	-	-	-
LC-74	0.9	-	-1.5 (y)	-	-1.5	-	-	-

Suffixes x, y in above table indicates the lateral direction and z indicates the vertical direction in which the forces are applied.

All members will be designed for the largest value of the design forces obtained due to positive as well as negative values of reversible forces (Wind and Earthquake).

The Static load cases are used to study the behavior of the building under seismic loading and for design only dynamic load cases will be considered.

N. N. Nagendra

N.N. NAGENDRA KUMAR
Registered Structural Engineer Grade-I (SE)
SE/GR-I/2019/03/064 Dated 29-03-2024
1307 Brigade Towers, 135 Brigade Road,
Bangalore - 560025. M : 9845038100
Email : nagendra@sterlingblr.com

6. Proposed Approach of Structural Analysis

After preliminary sizing of various structural members, a computer model of the structural frame of the building will be generated for carrying out computer analysis for the effects of vertical and lateral load that are likely to be imposed on the structure.

The building structure will be analyzed using the ETABS 17.0.1 software for the following computer models of the building.

i) Floor analysis of all floors - for vertical loads and thermal effects with the entire building space frame.

ii) Space frame analysis (Static) of the entire structure - for wind loads.

iii) Space frame analysis (Dynamic) of the entire structure - for seismic loads.

ETABS 17.0.1 has been thoroughly tested, validated and recognized internationally by several organizations and is well suited for the analysis of building systems.

Geometrical dimensions, member properties and member-node connectivity, including eccentricities will be modeled in the analysis problem. Variation in material grades, if present, will be considered.
Wind load derivations will be carried out using coefficients / factors in accordance with the relevant Indian codes.

The seismic loads will be derived from the results of dynamic analysis of the structure in accordance with the relevant code of practice.

The permissible values of the load factors and stresses will be utilized within the purview of the Indian Standards.

The computer analysis will produce accurate individual member forces, reactions at foundation level and deflection pattern of the entire structure as well as individual members. This data will then be used to confirm / review the member sizes and arrive at the most appropriate design of the structural members. Some re-runs of the analysis program might be required for arriving at the optimum structural space frame characteristics that satisfy the strength and stability criteria in all respects.

Design of different structural elements will be carried out using In-house developed spreadsheets and packages, software's like STAAD-pro-2005, ETABS 17.0.1,CSI Safe 2016, RCDC etc,.

N. N Nagendra

N.N. NAGENDRA KUMAR
Registered Structural Engineer Grade-I (SE)
SE/GR-I/2019/03/064 Dated 29-03-2024
1307 Brigade Towers, 135 Brigade Road,
Bangalore - 560025. M : 9845038100
Email : nagendra@sterlingblr.com

7. Design of Structural Elements

For the design of R.C.C. elements, the Limit State Method will be used as per IS 456-2000. Materials of construction will be predominantly concrete with consideration for strength and durability. For other elements, in view of the level of stresses to be borne by the members both in compression as well as flexure.

High Yield Strength Deformed bars conforming to IS: 1786 with Fy = 550 MPa shall be used as reinforcement.

Structural steel with Fy = 250/355 MPa Grade shall be used.

Covers to reinforcement shall be in accordance with IS: 456:2000 corresponding to moderate exposure conditions for the super-structure or severe exposure conditions for the sub-structure and to satisfy a fire rating of 1 hour as per National building code of India- SP7 (part IV).

Cover to Reinforcement:

Covers to reinforcement shall be in accordance with IS 456:2000 corresponding to moderate exposure and to satisfy fire rating of 2 hours (The building falls under type II construction) as per National Building Code of India – SP-7(part IV)

Covers to reinforcement shall be in accordance with NBC-2016 to satisfy fire rating of 2 hours and is considered as indicated below,

i) For continuous beams	- 30mm
ii) For simply supported beams	- 40mm
iii) For columns fully exposed	- 40mm
iv) For continuous slabs	- 25mm
v) Footing and Footing Beams and Plinth Beams	- 50 mm
a. Raft slab	
b. Bottom	- 75 mm
c. Top	- 50 mm
vi) Water tanks / Sump tank	
d. On earth face	- 50 mm
e. On water face	- 40 mm
f. On other face	- 25mm

vii) Pile, pile caps and pile cap bottom: 50mm, 60mm and 75mm bottom.

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SE/GR-I/2019/03/064 Dated 29-03-2024
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Bangalore - 560025. M : 9845038100
Email : nagendra@sterlingblr.com

8. Foundation system

8.1 Foundations for the Building:

Geo-technical investigation was carried out in 35 borehole locations. The stratigraphy of the 35 exploratory boreholes in general consists of soft to very soft clay with high plasticity. Hence pile foundation was recommended.

Alternate to open foundation adopt piles with minimum 1.5 D socket into the hard rock. The following data are guidelines for termination of piles:

- In vicinity of boreholes BH-12, BH-14, BH-15, BH-18, BH-19, BH-27 & BH-28, the depth of hard fresh rock is encountered at about 7.5m below the existing ground level.
- In vicinity of boreholes BH-21 & BH-26, the depth to hard fresh rock is observed at 5.0m below the existing ground level.
- Except the above borehole location, the piles can be taken up to a depth of 10.0m below the existing ground level.

The piles can be installed by drilling with direct mud circulation technique *(Bored Cast Insitu Piles)* and the provisional safe load carrying capacity of bored cast insitu piles taken to a depth of 10.0m below the top of filling in compression, tension and lateral for different diameters is worked out as per IS 2911-Part-I-Section-2 and are presented in Table-5.2.

TABLE:- 5.2 RECOMMENDED SAFE LOAD CARRYING CAPACITIES OF BORED CAST-IN SITU PILES

Sl.No	Reference Bore hole No.	Length of Pile below E.G.L	Assumed Length of Cut-Off Below	Length of Pile below Cut-off	Dia.of Pile in (mm)	SAFE LOAD CARRYING CAPACITY (kN)		
						Vertical Load Carrying Capacity	Pull Out Capacity	Lateral Load Carrying Capacity
1.0	BH-35	10.0	1.0	9.00	600	2200	300	50
2.0					750	3000	370	65
3.0					900	4000	440	75
4.0					1000	5000	490	85
COMPOUND WALL								
1.0	BH-35	7.0	0.0	7.00	450	700	130	38

9. Stability of Structures

9.1 For the purpose of stability of the structure against overturning, the restoring moment shall not be less than 1.2 times the maximum overturning moments due to dead load plus 1.4 times the maximum overturning moments due to imposed loads. In case where dead load provides the restoring moments only 0.9 times in dead load shall be considered. The restoring moments due to imposed loads shall be ignored.

9.2 The factor of safety against sliding shall not be less than 1.40.

9.3 Factor of safety against buoyancy shall be not less than 1.20 ignoring the superimposed loading.

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Registered Structural Engineer Grade-I (SE)
SE/GR-I/2019/03/064 Dated 29-03-2024
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10. Other Data

Specific requirements of floor and wall cutouts for services, sinking (extent & depth) of floors in services, kitchen, utility and toilet areas, external architectural features, and entrance canopies are provided as required by Architects and Service Consultants. The relevant information is obtained from them in the form of drawings.
Escalators, Lift loads and lift machine room equipment and cutout layouts will be obtained from the lift manufacturers. An impact factor of 100% will be considered in the lift supporting structures.

11. Value Engineering Exercises

In order to optimize the material consumption, sample analysis and design exercises have been undertaken with different combinations of member sizes and the required reinforcement and formwork will be estimated. Results of these exercises have been considered in arriving at the structural scheme of the building.

12. Design Development

i) A layout of columns / shear walls and beams has already been developed.

ii) The structural General Arrangement plans have been submitted for perusal of the design team members and got the principal approval, which will be expected to note the salient features of the structural system and examine the compatibility with various requirements of architecture and other engineering disciplines. The co-ordination among various design team members will be part of the design development process and we - as structural engineers - will be a part of the process.

iii) The sizes of the various structural elements like columns, walls, beams and slabs have been arrived based on the following analysis,

a. DL+LL analysis.
b. Earthquake –Static Analysis.

iv) cracked section properties of walls, beams, columns and slabs shall be considered for factored and un-factored loads.

a. Walls – 0.7(Factored) and 0.9(Un-factored)
b. Columns – 0.7(Factored) and 0.9(Un-factored)
c. Beams – 0.35(Factored) and 0.7(Un-factored)
d. slabs – 0.25(Factored) and 0.35(Un-factored)

N. N Nagendra

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Registered Structural Engineer Grade-I (SE)
SE/GR-I/2019/03/064 Dated 29-03-2024
1307 Brigade Towers, 135 Brigade Road,
Bangalore - 560025. M : 9845038100
Email : nagendra@sterlingblr.com

13. Analysis for the lateral loads

Seismic analysis:

For the purpose of the lateral analysis, the entire structure is modeled as a 3D space frame with concrete walls, columns and beams at different floor levels. The floor slab is also modeled along with frame members to have diaphragm effect in plane of slab.

For the purpose of the lateral analysis, the entire structure is modeled as a 3D space frame with columns, beams and slabs at different floor levels. After assigning required geometrical properties and gravity loads on structure it is then subjected to appropriate seismic forces. It is to be noted that the lateral deflection limit of H/250 for earthquake and H/500 for wind of the building at the terrace level is within the limit.

Wind load analysis:

As per IS 875 (Part 3): 2015 Cl. 9.1, Page no-45

In general, the following guidelines may be used for examining the problems of wind-induced oscillations.

a) **Buildings and closed structures with a height to minimum lateral dimension ratio of more than about 5.0, or**

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

As per above mentioned clause in tower-01 and tower-02, the natural frequency in the first mode is less than 1.0Hz. Hence dynamic wind analysis is considered and Wind loads are evaluated manually and are applied as “Exposure from extents of rigid diaphragms” at various levels

The modeling of the structure would be same as the one used for the seismic analysis as explained above.

The structures are analyzed for the various load combinations as per IS: 456-2000. The condensed output containing only the result for the critical load combination is obtained by using computer software’s developed in-house for the purpose, which use the STAAD Pro 2004 / ETABS 17.0.1 analysis output as their input.

For designing the structural steel members, the guidelines of IS: 800-2007 is adopted. For the design of the R.C.C structures the recommendations of IS: 456-2000 is followed. Limit State design would be adopted with appropriate load factors for the various load combinations.

P-Delta Analysis:

If the deformations in a structure are large enough, they may in-turn affect the forces on the building which will again affect the deformation. This effect has been considered in the analysis of this tall structure. The building has a double height entrance lobby which may induce such an effect.

N. N Nagendra

N.N. NAGENDRA KUMAR
Registered Structural Engineer Grade-I (SE)
SE/GR-I/2019/03/064 Dated 29-03-2024
1307 Brigade Towers, 135 Brigade Road,
Bangalore - 560025. M : 9845038100
Email : nagendra@sterlingblr.com

Torsional Irregularity and Soft Story:

The structure is ensured to have neither static nor dynamic irregularity. The structure is also checked for soft story, especially the transfer levels.

Temperature Analysis:

Slab elements are designed for the forces obtained from the coefficients given in Annex-D in IS: 456 -2000 and using the limit state design method. Wall load on slab is taken as uniformly distributed over entire area. Flat slab is modeled as shell element and is meshed to transfer loads to the columns. Slab is exported to SAFE software where further analysis and design is carried out.

Design of suspended floor / roof slabs:

Slab elements are designed for the forces obtained from the coefficients given in Annex-D in IS: 456 -2000 and using the limit state design method.

Design of beams:

Beams are designed by using E-TABS software and RCDC for critical load combinations.

Design of columns:

R.C Columns are designed for bi-axial bending for the forces of critical load combination. The designs are made using in-house spread sheets & E-TABS software/RCDC. For reinforcement bars of diameter greater than 16mm, mechanical couplers shall be used as per IS16172:2014 code provisions.

Design of footings:

The pile foundation with grade beam (at top of pile cap level) are designed for the forces of critical load combination.

Limit state method of design is adopted for pile foundation.The designs are done using SAFE software, as per the guide lines of IS: 456-2000. For this purpose, the condensed output of the ETABS 17.0.1 is used as input for these programs (RCDC and SAFE).

N. N Nagendra

N.N. NAGENDRA KUMAR
Registered Structural Engineer Grade-I (SE)
SE/GR-I/2019/03/064 Dated 29-03-2024
1307 Brigade Towers, 135 Brigade Road,
Bangalore - 560025. M : 9845038100
Email : nagendra@sterlingblr.com

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We're honored to be part of your real estate journey

3/350/2 Mettukuppam,
OMR Thoraipakkam,
Chennai, India

hello@verified.realestate
+91 9996 12 9996
www.verified.realestate