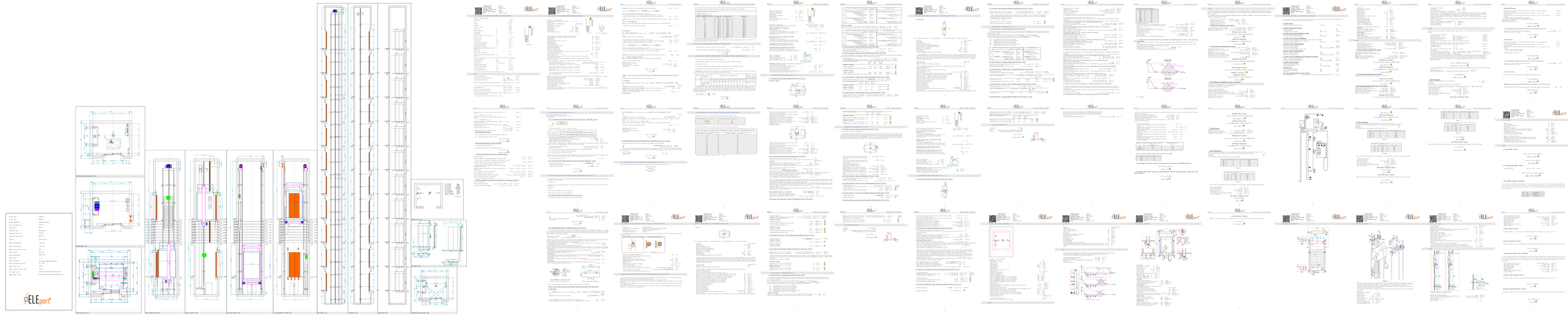

Structural Design
Project No. 2024-0
Sheet No. S-01
Date 15.03.2024
Scale 1:100 @ A1

Table of Contents

1. Design Basis Report — Page 1
2. Load Calculations — Page 2
3. Slab Design — Page 3
4. Beam Design — Page 4
5. Column Design — Page 5
6. Footing Design — Page 6
7. Staircase Design — Page 7
8. Retaining Wall Design — Page 8
9. Steel Connection Design — Page 9
10. Lift Pit Design — Page 10
11. Foundation Design — Page 11
12. Seismic Analysis — Page 12
13. Wind Load Analysis — Page 13
14. Deflection Check — Page 14
15. Crack Width Check — Page 15
16. Bar Bending Schedule — Page 16
17. Material Specifications — Page 17
18. Quality Control Plan — Page 18
19. Construction Sequence — Page 19
20. Drawing Index — Page 20

1. Design Basis Report

1.1 Introduction

This report presents the structural design of a proposed residential building comprising basement, ground floor, and mezzanine floor. The design is carried out in accordance with the relevant Indian Standard codes of practice.

1.2 Design Codes and Standards

- IS 456:2000 — Plain and Reinforced Concrete — Code of Practice
- IS 875 (Part 1):1987 — Dead Loads
- IS 875 (Part 2):1987 — Imposed Loads
- IS 875 (Part 3):2015 — Wind Loads
- IS 1893 (Part 1):2016 — Earthquake Resistant Design
- IS 13920:2016 — Ductile Detailing
- SP 16:1980 — Design Aids for Reinforced Concrete

1.3 Material Properties

Material	Grade	Property	Value
Concrete	M25	Characteristic compressive strength	25 N/mm²
		Modulus of elasticity	25000 N/mm²
		Density	25 kN/m³
Reinforcement	Fe 500	Characteristic yield strength	500 N/mm²
		Modulus of elasticity	200000 N/mm²
Masonry	230 mm thick	Density	20 kN/m³
	115 mm thick	Density	20 kN/m³

1.4 Load Combinations

1.5(DL + LL)
1.2(DL + LL + WL)
1.2(DL + LL − WL)
1.5(DL + WL)
1.5(DL − WL)
0.9DL + 1.5WL
0.9DL − 1.5WL
1.2(DL + LL + EL)
1.2(DL + LL − EL)
1.5(DL + EL)
1.5(DL − EL)
0.9DL + 1.5EL
0.9DL − 1.5EL

1.5 Exposure Condition

The exposure condition is assumed as Moderate for all structural members above ground level and Severe for members in contact with soil.

1.6 Assumptions

1. The soil bearing capacity is assumed as 200 kN/m² at a depth of 1.5 m below ground level.
2. The water table is assumed to be below the footing level.
3. All dimensions are in millimetres unless otherwise stated.
4. Grade slab is not considered in the structural analysis.
5. Unit weight of RCC is taken as 25 kN/m³.
6. Unit weight of brick masonry is taken as 20 kN/m³.

1.7 Design Philosophy

The structure is designed by the limit state method. The limit state of collapse is checked for all load combinations. The limit state of serviceability is checked for deflection and cracking.

2. Load Calculations

2.1 Dead Loads

Member	Thickness (mm)	Unit Weight (kN/m³)	Load (kN/m²)
Slab self weight	150	25	3.75
Floor finish	50	24	1.20
Plaster (ceiling)	12	20	0.24
Partition wall (equivalent)	—	—	1.00
Total dead load			6.19

2.2 Live Loads

Area	Load (kN/m²)
Residential rooms	2.0
Corridors and staircases	3.0
Balconies	3.0
Roof (accessible)	1.5
Roof (inaccessible)	0.75

2.3 Wind Loads

Basic wind speed, V_b = 39 m/s

Design wind speed, $V_z = V_b \times k_1 \times k_2 \times k_3$

Wind pressure, $p = 0.6 V_z^2$

2.4 Seismic Loads

Zone factor, Z = 0.16 (Zone II)

Importance factor, I = 1.0

Response reduction factor, R = 5.0

Seismic coefficient, $A_h = \frac{Z I S_a}{2 R g}$

3. Slab Design

3.1 Design Method

The slabs are designed by the coefficient method as per IS 456:2000, Annex D.

3.2 Slab Panel Data

Panel	l_x (m)	l_y (m)	l_y / l_x	Type
S1	3.00	4.50	1.50	Two way
S2	3.00	3.00	1.00	Two way
S3	3.00	6.00	2.00	One way
S4	3.00	4.50	1.50	Two way
S5	3.00	3.00	1.00	Two way
S6	3.00	6.00	2.00	One way

3.3 Moment Coefficients

Panel	α_{x-}	α_{x+}	α_{y-}	α_{y+}
S1	0.047	0.035	0.032	0.024
S2	0.032	0.024	0.032	0.024
S4	0.047	0.035	0.032	0.024
S5	0.032	0.024	0.032	0.024

3.4 Design Moments

$M_{x-} = \alpha_{x-} w l_x^2$

$M_{x+} = \alpha_{x+} w l_x^2$

$M_{y-} = \alpha_{y-} w l_x^2$

$M_{y+} = \alpha_{y+} w l_x^2$

3.5 Reinforcement Details

Panel	Direction	Moment (kNm/m)	Effective Depth (mm)	Area of Steel (mm²/m)	Bar Dia (mm)	Spacing (mm)
S1	l_x	12.4	125	312	10	200
	l_y	8.5	115	231	10	300
S2	l_x	8.5	125	212	10	300
	l_y	8.5	115	231	10	300
S4	l_x	12.4	125	312	10	200
	l_y	8.5	115	231	10	300
S5	l_x	8.5	125	212	10	300
	l_y	8.5	115	231	10	300

3.6 Check for Deflection

Span / effective depth ratio = 26 (modified)

Actual ratio = 24.5

Hence, deflection is within limits.

4. Beam Design

4.1 Beam Schedule

Beam	Size (mm)	Span (m)	Top Steel	Bottom Steel	Stirrups
B1	230 × 450	4.50	3 – 16 mm	3 – 16 mm	8 mm @ 150 c/c
B2	230 × 450	3.00	2 – 16 mm	3 – 16 mm	8 mm @ 150 c/c
B3	230 × 450	6.00	4 – 16 mm	4 – 16 mm	8 mm @ 150 c/c
B4	230 × 450	4.50	3 – 16 mm	3 – 16 mm	8 mm @ 150 c/c
B5	230 × 450	3.00	2 – 16 mm	3 – 16 mm	8 mm @ 150 c/c
B6	230 × 450	6.00	4 – 16 mm	4 – 16 mm	8 mm @ 150 c/c

4.2 Design Moments and Shear

$M_u = 1.5 (DL + LL) \frac{l^2}{12}$

$V_u = 1.5 (DL + LL) \frac{l}{2}$

4.3 Check for Shear

$\tau_v = \frac{V_u}{b d}$

τ_c from IS 456 Table 19

$\tau_v < \tau_c$ — hence safe.

5. Column Design

5.1 Column Schedule

Column	Size (mm)	Main Steel	Ties
C1	300 × 300	8 – 16 mm	8 mm @ 200 c/c
C2	300 × 300	8 – 16 mm	8 mm @ 200 c/c
C3	300 × 300	8 – 16 mm	8 mm @ 200 c/c
C4	300 × 300	8 – 16 mm	8 mm @ 200 c/c

5.2 Axial Load Capacity

$P_u = 0.4 f_{ck} A_c + 0.67 f_y A_{sc}$

6. Footing Design

6.1 Footing Schedule

Footing	Size (m)	Depth (mm)	Bottom Steel
F1	1.50 × 1.50	300	10 mm @ 150 c/c
F2	1.50 × 1.50	300	10 mm @ 150 c/c
F3	1.50 × 1.50	300	10 mm @ 150 c/c
F4	1.50 × 1.50	300	10 mm @ 150 c/c

6.2 Check for Bearing Pressure

$q = \frac{P}{A} \pm \frac{M}{Z}$

$q_{max} < 200$ kN/m² — hence safe.

7. Staircase Design

7.1 Staircase Data

Rise = 150 mm

Tread = 250 mm

Waist slab thickness = 150 mm

Width of staircase = 1.20 m

7.2 Design Loads

Dead load = 6.19 kN/m²

Live load = 3.0 kN/m²

$w = 1.5 (6.19 + 3.0) = 13.79$ kN/m²

7.3 Design Moment

$M_u = \frac{w l^2}{8}$

8. Retaining Wall Design

8.1 Data

Height of retaining wall = 3.0 m

Unit weight of soil = 18 kN/m³

Angle of internal friction = 30°

Coefficient of active pressure, $K_a = \frac{1 - \sin\phi}{1 + \sin\phi} = 0.333$

8.2 Lateral Pressure

$p = K_a \gamma h$

9. Steel Connection Design

9.1 Bolted Connection

Bolt diameter = 20 mm

Bolt grade = 4.6

Shear capacity of bolt = 49.4 kN

Bearing capacity of bolt = 84.0 kN

10. Lift Pit Design

10.1 Data

Size of lift pit = 2.0 m × 2.0 m × 1.5 m deep

Thickness of wall = 230 mm

Thickness of base slab = 300 mm

10.2 Design Pressure

$p = \gamma h$

11. Foundation Design

11.1 Isolated Footing

Size = 1.50 m × 1.50 m

Depth = 300 mm

Grade of concrete = M25

Grade of steel = Fe 500

11.2 Check for Bearing Pressure

$q = \frac{P}{A} \pm \frac{M}{Z}$

$q_{max} < 200$ kN/m² — hence safe.

12. Seismic Analysis

12.1 Seismic Data

Zone factor, Z = 0.16 (Zone II)

Importance factor, I = 1.0

Response reduction factor, R = 5.0

Soil type = Medium

12.2 Seismic Weight

Floor	Weight (kN)
Basement	1850
Ground floor	1920
Mezzanine floor	1210
Roof	1180
Total	6160

12.3 Base Shear

$V_b = A_h W$

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

13. Wind Load Analysis

13.1 Wind Data

Basic wind speed, V_b = 39 m/s

Terrain category = 2

Class = B

Risk coefficient, k_1 = 1.0

Topography factor, k_3 = 1.0

13.2 Wind Pressure

$V_z = V_b k_1 k_2 k_3$

$p = 0.6 V_z^2$

14. Deflection Check

14.1 Short Term Deflection

Span / effective depth ratio = 26 (modified)

Actual ratio = 24.5

Hence, deflection is within limits.

14.2 Long Term Deflection

Long term deflection = short term deflection × (1 + creep coefficient)

Creep coefficient = 1.6

15. Crack Width Check

15.1 Crack Width Calculation

$w_{cr} = \frac{3 a_{cr} \varepsilon_m}{1 + 2 (a_{cr} - c_{min}) / (h - x)}$

$w_{cr} < 0.3$ mm — hence safe.

16. Bar Bending Schedule

Member	Mark	Dia (mm)	No.	Length (m)	Total Length (m)	Weight (kg)
B1	B1-T	16	3	5.00	15.00	37.0
	B1-B	16	3	5.00	15.00	37.0
	B1-S	8	30	1.40	42.00	16.6
B2	B2-T	16	2	3.50	7.00	17.3
	B2-B	16	3	3.50	10.50	25.9
	B2-S	8	22	1.40	30.80	12.2
C1	C1-M	16	8	3.30	26.40	65.2
	C1-T	8	20	1.20	24.00	9.5
F1	F1-B	10	20	1.65	33.00	20.4

17. Material Specifications

17.1 Concrete

Concrete shall be of grade M25 conforming to IS 456:2000. Minimum cement content shall be 320 kg/m³. Maximum water-cement ratio shall be 0.45. Concrete shall be mixed in a batching plant and transported to site in transit mixers.

17.2 Reinforcement Steel

Reinforcement steel shall be of grade Fe 500 conforming to IS 1786:2008. Steel shall be free from rust, oil, grease, and loose mill scale. Bars shall be bent cold and shall not be straightened and rebent.

17.3 Cement

Cement shall be Ordinary Portland Cement 53 grade conforming to IS 12269:2013. Cement shall be stored in dry, weather-proof godowns on raised platforms.

17.4 Aggregates

Fine aggregate shall be natural river sand conforming to IS 383:2016. Coarse aggregate shall be crushed granite stone of 20 mm nominal size conforming to IS 383:2016.

17.5 Water

Water used for mixing and curing shall be clean and free from harmful impurities. Water shall conform to IS 456:2000, Clause 5.4.

17.6 Admixtures

Admixtures, if used, shall conform to IS 9103:1999. The use of admixtures shall be subject to approval of the Engineer-in-Charge.

18. Quality Control Plan

18.1 Concrete Cube Tests

Three cubes shall be cast for every 5 cubic metres of concrete or part thereof. The cubes shall be tested at 7 days and 28 days. The 28 day strength shall be not less than the characteristic strength.

18.2 Slump Test

Slump test shall be carried out for every batch of concrete. The slump shall be maintained between 75 mm and 100 mm for all structural members.

18.3 Reinforcement Inspection

All reinforcement shall be inspected before concreting. The cover, spacing, and bar diameter shall be checked against the approved drawings.

19. Construction Sequence

1. Excavation for foundation and basement.
2. Laying of PCC in foundation.
3. Construction of footings and basement walls.
4. Backfilling around basement walls.
5. Construction of ground floor slab and columns.
6. Construction of mezzanine floor slab and columns.
7. Construction of roof slab.
8. Brickwork and plastering.
9. Flooring, finishing, and painting.

20. Drawing Index

Drawing No.	Description
S-01	Basement Floor - 1:100
S-02	Ground Floor Plan - 1:100
S-03	Mezzanine Floor - 1:100
S-04	Terrace Floor Plan - 1:100
S-05	Roof Plan - 1:100
S-06	Staircase Section - 1:50
S-07	Staircase Section - 1:50
S-08	Lift Pit Section - 1:50
S-09	Lift Pit Section - 1:50
S-10	Column Schedule - 1:50
S-11	Column Schedule - 1:50
S-12	Beam Schedule - 1:50
S-13	Beam Schedule - 1:50
S-14	Slab Plan Showing Grades - 1:100