Design Documents

Output 1_Design review
(Structure design)

Training of Trainers
May 2024
DCQR

Contents

Design Report

PROJECT NAME

B+G+9 Storied Residential Building

Structural Design Basis Report

Submission date- December-2023

CONSULTANT:

SB CONSULTANT LTD.

A.K.M Saiful Bari, PEng.
Principal Structural Engineer
FIEB:- 8374,DMINB-CE-0011

B+G+9 STORIED RESIDENTIAL BUILDING

DECLARATION

We, hereby declare based on 1.9.2 of BNBC 2020 that this report is a design basis report for structural analysis and design made for (B+G+9) storied building considering BNBC 2020, ASCE-7-05 code at Basundhara, Dhaka, Bangladesh.

Objective of the report

This design report is prepared for other structural design engineers to verify independently the design parameters and the member sizes using basic information in this report. Design review shall be performed through independent calculations, based on the information provided in the design documents prepared and signed by the original structural design engineers, to verify the design parameters including applied loads, methods of analysis and design, and final design dimensions and other details of the structural elements. The reviewing engineer shall also check the sufficiency and appropriateness of the supplied structural drawings for construction.

Rights of all the documents

A.K.M Saiful Bari, PEng.
Principal Structural Engineer
FIEB: - 8374, DMINB-CE-0011

Md. Faishal Hasan
Structural Engineer
MIEB-41002

2

TABLE OF CONTENTS

3

4

1.0 EXECUTIVE SUMMARY

SB Consultant Ltd. has engaged to perform structural design of (B+G+9) storied building at Bashundhara, Dhaka, Bangladesh. The main purpose of this analysis and design is to determine, whether the building will sufficient capacity to support the anticipated vertical and lateral loads as per BNBC-2020. The major descriptions about this building are listed below.

- The anticipated vertical and lateral loads are considered as per BNBC-2020. The basic structural system of this building is considered **DUAL SYSTEM (MOMENT RESISTING FRAME-IMRF)**
- According to soil test report, we are considered pile foundation. All columns are supported by pile foundation. Provided pile cap size, length and pile depth, reinforcements are adequate to resist vertical and lateral loads.
- All columns have sufficient size and reinforcements to carry the vertical and lateral loads.
- All grade and floor beams are adequate in size and reinforcements to carry the flexure and shear forces.
- Provided slab thickness and reinforcements are adequate to resist vertical floor loads.

5

2.0 INTRODUCTION

This report sets out the basic design criteria, which **SB Consultant Ltd.** adopts in the civil and structural design of this project. It contains loading criteria, material strengths and geotechnical information used in the design of the various elements making up the project. This report will also form part of our calculations for submission to the approving authority for the construction permit application.

6

3.0 GENERAL DESCRIPTION OF THE STRUCTURE

The building, namely, comprises (B+G+9) storied residential building. The following Table-1 shows the basic information of the structure.

Table-1: Basic information of the Structure

Item	Description
Basic Structural System	Dual System (intermediate moment frame-IMF) Table 6.2.19 E.2. Special reinforced concrete shear walls
Typical Floor Area	Approximately 397.8 m^2 per floor
Number of Stories	11 (B+G+9)
Floor Usage	Residential Building
Foundation Type	Pile Foundation
Slab Type	Beam supported cast in situ slab
Design Drawing	A credible structural design drawing has been prepared
Floor height (Ground floor to Top)	34.5 m

The structural solutions adopted for the project are described in detail in this report, but the principal aspects are as follows:

- In foundation design pile foundation has been considered according to soil condition as per soil test report.
- The super structure is proposed to be beam supported slab which has variable slab thickness considering panel size of floor.
- Lateral stability of the structure is provided principally by the Shear wall, Column and Beam.

The systems proposed provide the most economic structure suited for this type of development which can achieve the aesthetic ambitions and functional requirement of the authority.

Seismic Force–Resisting System	Response Reduction Factor, R	System Overstrength Factor, Ω_o	Deflection Amplification Factor, C_d	Seismic Design Category B	Seismic Design Category C	Seismic Design Category D
				Height limit (m)		
E. DUAL SYSTEMS: INTERMEDIATE MOMENT FRAMES CAPABLE OF RESISTING AT LEAST 25% OF PRESCRIBED SEISMIC FORCES (with bracing or shear wall)						
1. Special steel concentrically braced frames	6	2.5	5	NL	NL	11
2. Special reinforced concrete shear walls	6.5	2.5	5	NL	NL	50
3. Ordinary reinforced masonry shear walls	3	3	3	NL	50	NP
4. Ordinary reinforced concrete shear walls	5.5	2.5	4.5	NL	NL	NP

7

4.0 BUILDING REGULATIONS & DESIGN CODES

The civil and structural design will be conducted in accordance with Bangladesh national building codes or alternative international standards commonly adopted in Bangladesh.

4.1 DEAD AND LIVE LOADS

Bangladesh National Building Code (BNBC- 2020).

Note that this regulation is applied for general floor loads. Higher loads will be considered for special loading areas and M&E spaces.

4.2 SEISMIC DESIGN

Applied Seismic load in FEM model as per ASCE-7-05, which support the Bangladesh National Building Code (BNBC- 2020).

4.3 WIND DESIGN

Applied Wind load in FEM model as per ASCE-7-05, which support the Bangladesh National Building Code (BNBC- 2020).

4.4 REINFORCED CONCRETE DESIGN

Bangladesh National Building Code (BNBC- 2020).

Building Code Requirements for Structural Concrete (ACI-318-08), American Concrete Institute.

8

5.0 MATERIAL SPECIFICATIONS

5.1 GENERAL STANDARDS

Material standards specified for this project will be a combination of Bangladesh National Building Code (BNBC-2020) and, chosen to be compatible with the materials readily available in Bangladesh. Standards used will include:

5.2 CONCRETE AND REINFORCEMENT STRENGTHS

5.2.1 Concrete Grades

Therefore, following compressive strength has been considered for the design of the building

Part	28 days cylinder strength (MPa)
Pile	21
Columns	31
Walls	31
Beams/ Slabs	24.13
Beam-Column joint	24.13

5.2.2 Reinforcement Grades

Main reinforcement (TMT deformed bars), f_y = 414 MPa for all Members

5.3 MINIMUM CONCRETE COVER

The minimum concrete cover is generally in accordance with BNBC-2020 standard.

- Beam & Columns-40mm
- Slab- 20mm
- Structural walls- 20mm (Inside wall)

9

6.0 LOADINGS

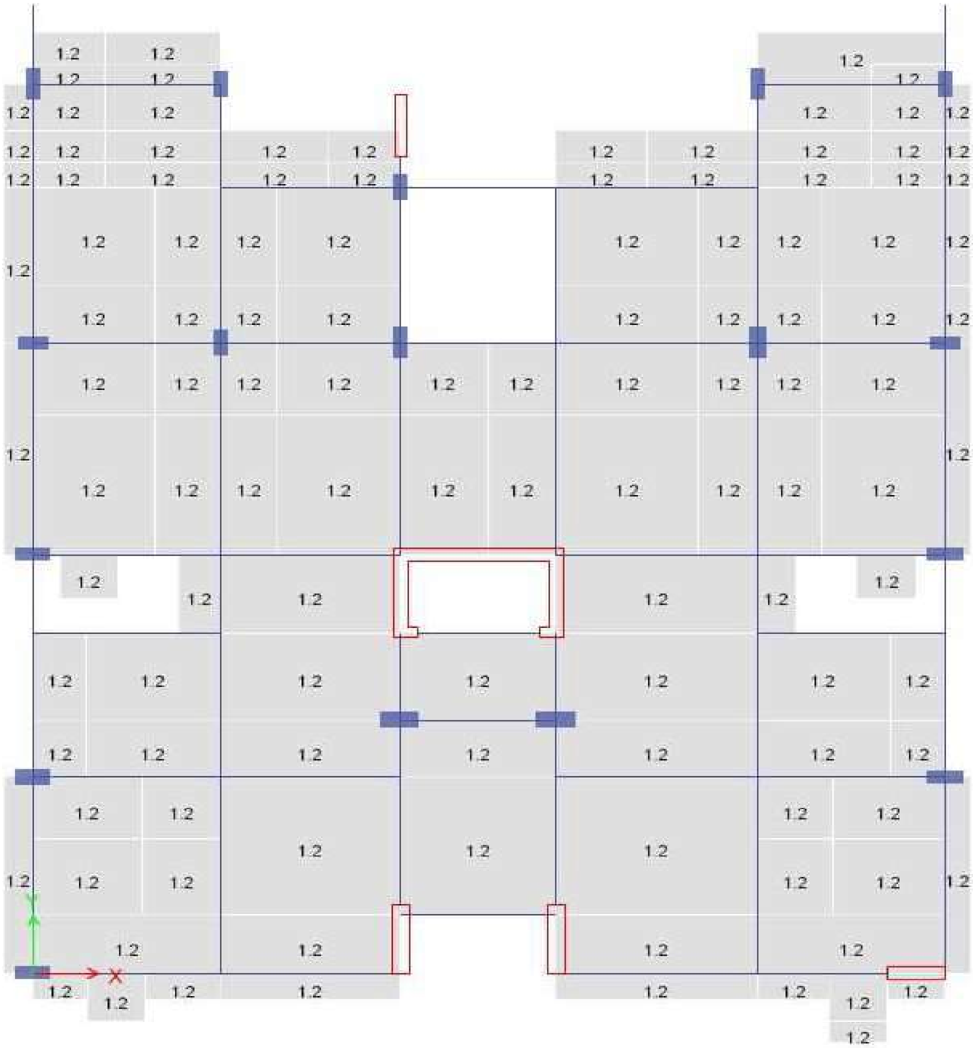
6.1 GRAVITY LOADS ON FLOORS

Typical values are given here, and these will be updated where necessary as the design progresses. These values are based on Bangladesh National Building Code (BNBC: 2020)

6.1.1 Dead Loads:

Weight of slab (using Reinforced concrete unit weight of 24 kN/m^3)

Floor finishes screed including floor finishes (typically 5-cm. total thickness allowed.) = 1.2 kPa



Floor finish in model

10

6.1.2 Superimposed Dead Loads:

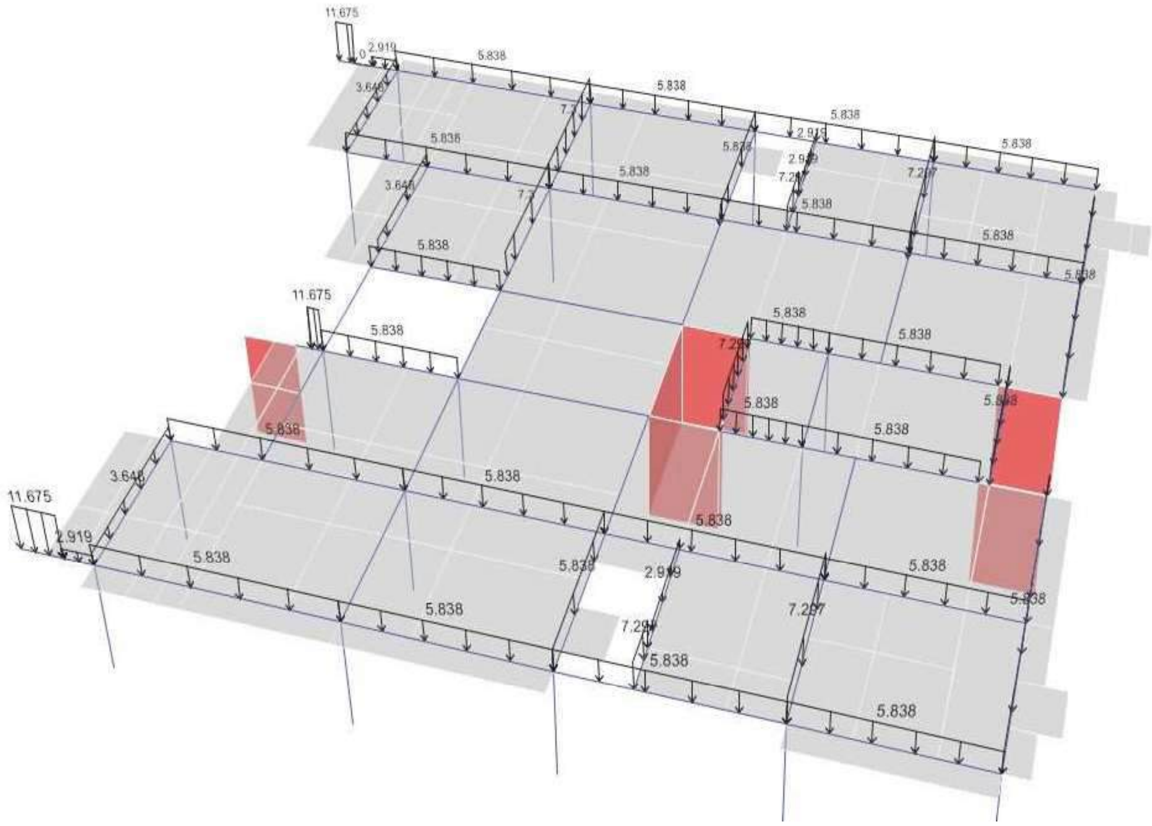
Weight of Brick wall (using Brick unit weight of 19.46 kN/m^3

Calculation of partition wall:

Considering 125mm thickness wall of height of 3000mm, slab thickness 125mm, floor beam depth of 600mm and unit weight of brick 19.46 kN/m^3

Uniformly distributed load = 0.125 *19.46*(3000-600)/1000 = 5.838 kN/m

** Same principle shall be applied for wall load calculation.



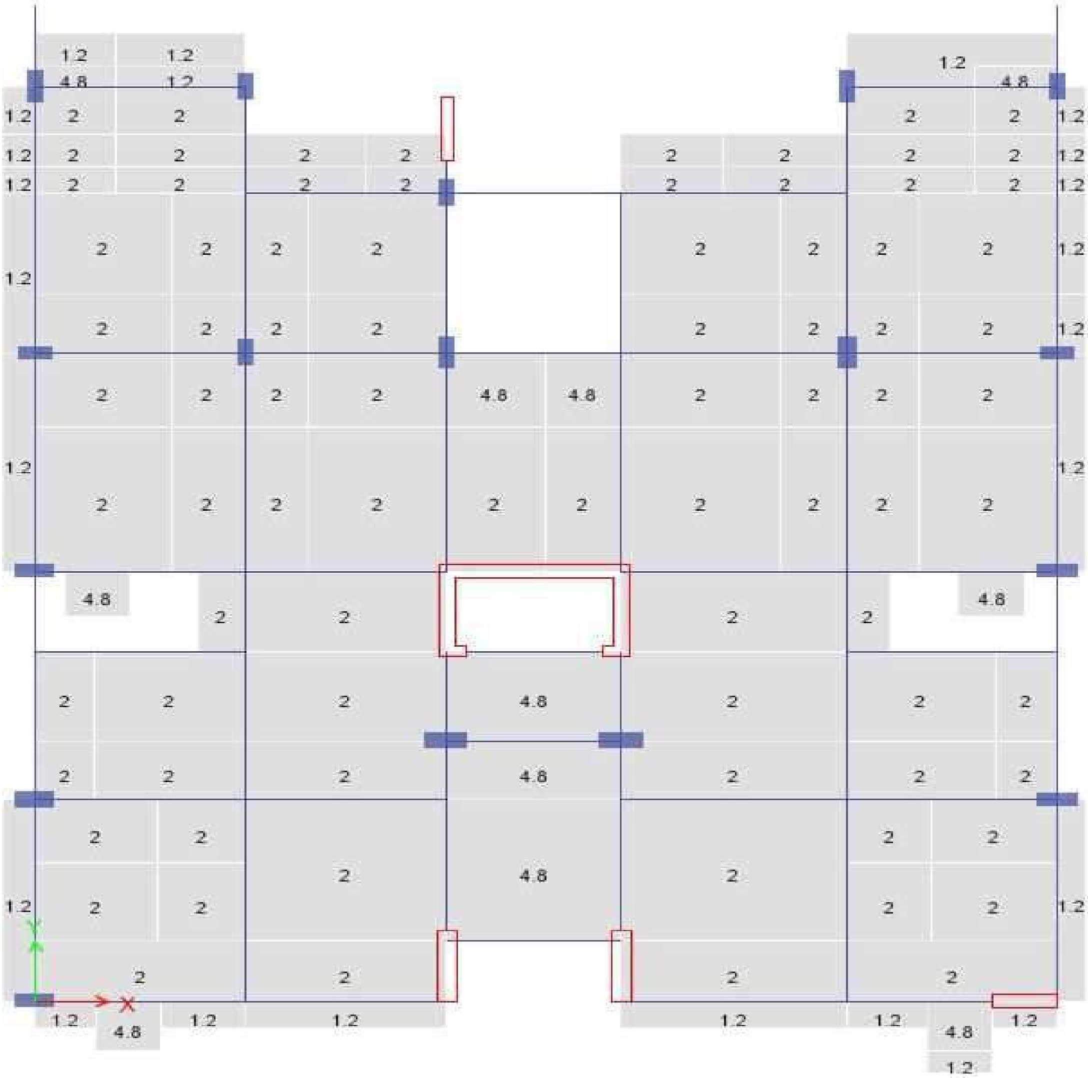
Wall Load in model

11

6.2 Live Loads:

Considered as per BNBC 2020, chapter 2

Floor usages	Live load applied as per BNBC-2020 kPa
Stair	4.8
Toilet	2.0
Dining/Living	2.0
Verandah/Lobby	4.8
Roof	1.5



Live Load in model

12

6.3 WIND PRESSURES

6.3.1 Wind Pressures on Primary Structures

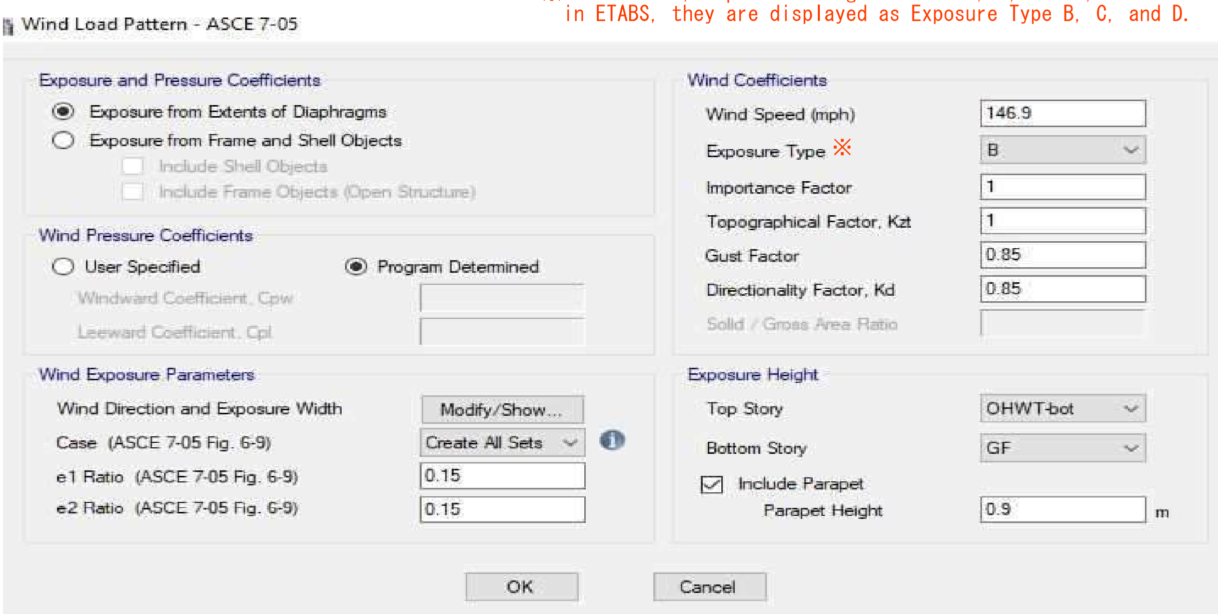
The design of primary structures against wind loading is conducted in accordance with part 6, chapter 2 of BNBC:2020.

The design wind pressures are to be calculated by using the below wind design parameters relevant to the proposed project area.

Basic Wind Speed: 65.7m/s (Return period: 50years / Averaging time: 3sec)
Exposure: Surface Roughness A

Description	Design Parameter	Reference	Notes
Exposure category ※	A	BNBC 2020 Part 6 Cl. 2.4.6	Urban and suburban areas, wooded areas, or other terrain with numerous closely spaced obstructions having the size of single-family dwellings or larger.
Wind Directionality Factor, Kd	0.85	BNBC 2020 Part 6 Cl. 2.4.4.3	
Importance Factor, I	1.0	BNBC 2020 Part 6 Table 6.2.9	Occupancy Category II
Topography Factor, k_{zt}	1.0	BNBC 2020 Part 6 Cl. 2.4.7.2	Flat Terrain
Gust Effect Factor, G_f	0.85	BNBC 2020 Part 6 Cl. 2.4.8.2	

※In BNBC2020, Exposure categories are A, B, and C, but in ETABS, they are displayed as Exposure Type B, C, and D.



Wind Load in model

13

6.3.2 BASIC WIND SPEEDS AS PER SELECTED LOCATIONS IN BANGLADESH

Table 6.2.8: Basic Wind Speeds, V, for Selected Locations in Bangladesh

Location	Basic Wind Speed (m/s)	Location	Basic Wind Speed (m/s)
Angarpota	47.8	Lalmonirhat	63.7
Bagerhat	77.5	Madaripur	68.1
Bandarban	62.5	Magura	65.0
Barguna	80.0	Manikganj	58.2
Barisal	78.7	Meherpur	58.2
Bhola	69.5	Maheshkhali	80.0
Bogra	61.9	Moulvibazar	53.0
Brahmanbaria	56.7	Munshiganj	57.1
Chandpur	50.6	Mymensingh	67.4
Chapai Nawabganj	41.4	Naogaon	55.2
Chittagong	80.0	Narail	68.6
Chuadanga	61.9	Narayanganj	61.1
Comilla	61.4	Narsinghdi	59.7
Cox's Bazar	80.0	Natore	61.9
Dahagram	47.8	Netrokona	65.6
Dhaka	65.7	Nilphamari	44.7
Dinajpur	41.4	Noakhali	57.1
Faridpur	63.1	Pabna	63.1
Feni	64.1	Panchagarh	41.4
Gaibandha	65.6	Patuakhali	80.0
Gazipur	66.5	Pirojpur	80.0
Gopalganj	74.5	Rajbari	59.1
Habiganj	54.2	Rajshahi	49.2
Hatiya	80.0	Rangamati	56.7
Ishurdi	69.5	Rangpur	65.3
Joypurhat	56.7	Satkhira	57.6
Jamalpur	56.7	Shariatpur	61.9
Jessore	64.1	Sherpur	62.5
Jhalakati	80.0	Sirajganj	50.6
Jhenaidah	65.0	Srimangal	50.6
Khagrachhari	56.7	St. Martin's island	80.0
Khulna	73.3	Sunamganj	61.1
Kutubdia	80.0	Sylhet	61.1
Kishoreganj	64.7	Sandwip	80.0
Kurigram	65.6	Tangail	50.6
Kushtia	66.9	Teknaf	80.0
Lakshmipur	51.2	Thakurgaon	41.4

14

6.4 SEISMIC LOADS

6.4.1 Strength Provisions

According to part 6, table 6.2.13, of BNBC:2020, it is observed that the site belongs to SD type soil as N<15, Vs<180 & Su not exist for sandy. For some clay layer Su exist but it is <70 kPa.

.

According to part 6, chapter 2, of BNBC:2020, Bangladesh seismic hazard map is divided into four seismic zones. Dhaka district belongs to zone II, which is a moderate seismic intensity zone.

"According to part 6, table 6.1.1, of BNBC:2020, Occupancy category is II".

Table 6.2.18: Seismic Design Category of Buildings

Site Class	Occupancy Category I, II and III				Occupancy Category IV			
	Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4
SA	B	C	C	D	C	D	D	D
SB	B	C	D	D	C	D	D	D
SC	B	C	D	D	C	D	D	D
SD	C	D	D	D	D	D	D	D
SE, S_1, S_2	D	D	D	D	D	D	D	D

Dead Load (At base)	53041.2547	kN
Live Load (At base)	9484.0106	kN
Base shear force, V (At base)	3823.50	kN

W= 53041.25+0.25*9484 = 55412.25 kN

As per BNBC: 2020, the design base shear (V), is given by;

$$V = S_a W$$

$$S_a = \frac{2}{3}\frac{ZI}{R}C_s$$

T= 0.7 sec, Z = 0.2, I = 1, R = 6.5

From the relation of T and Cs we find that Cs = 3.375

S_a = (2/3*0.2*1*3.4) /6.5 = 0.069

15

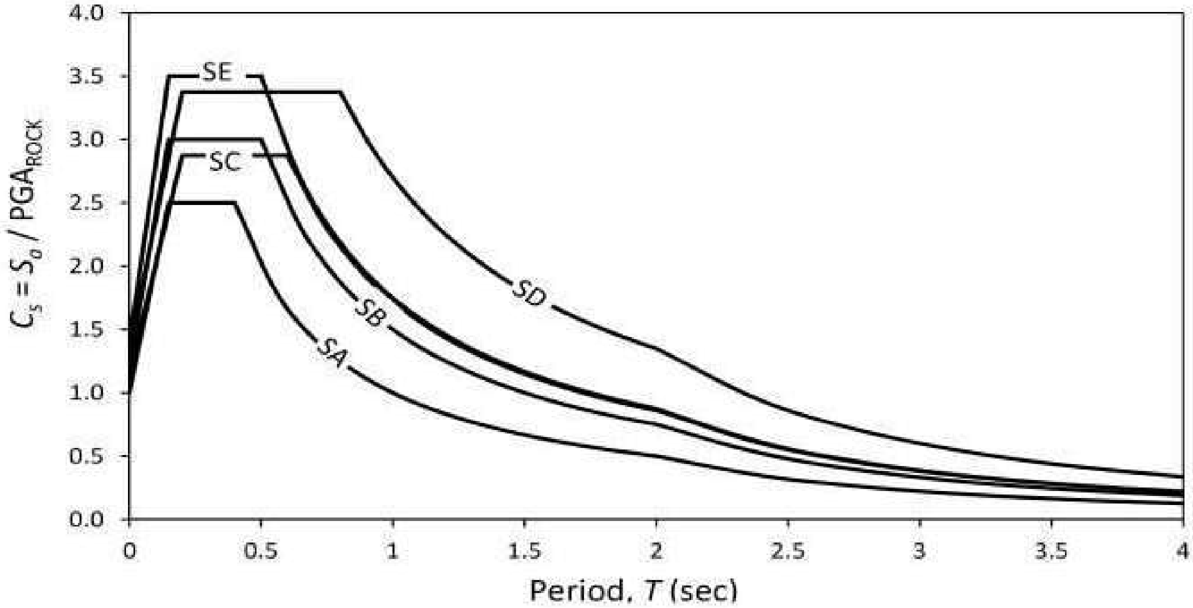
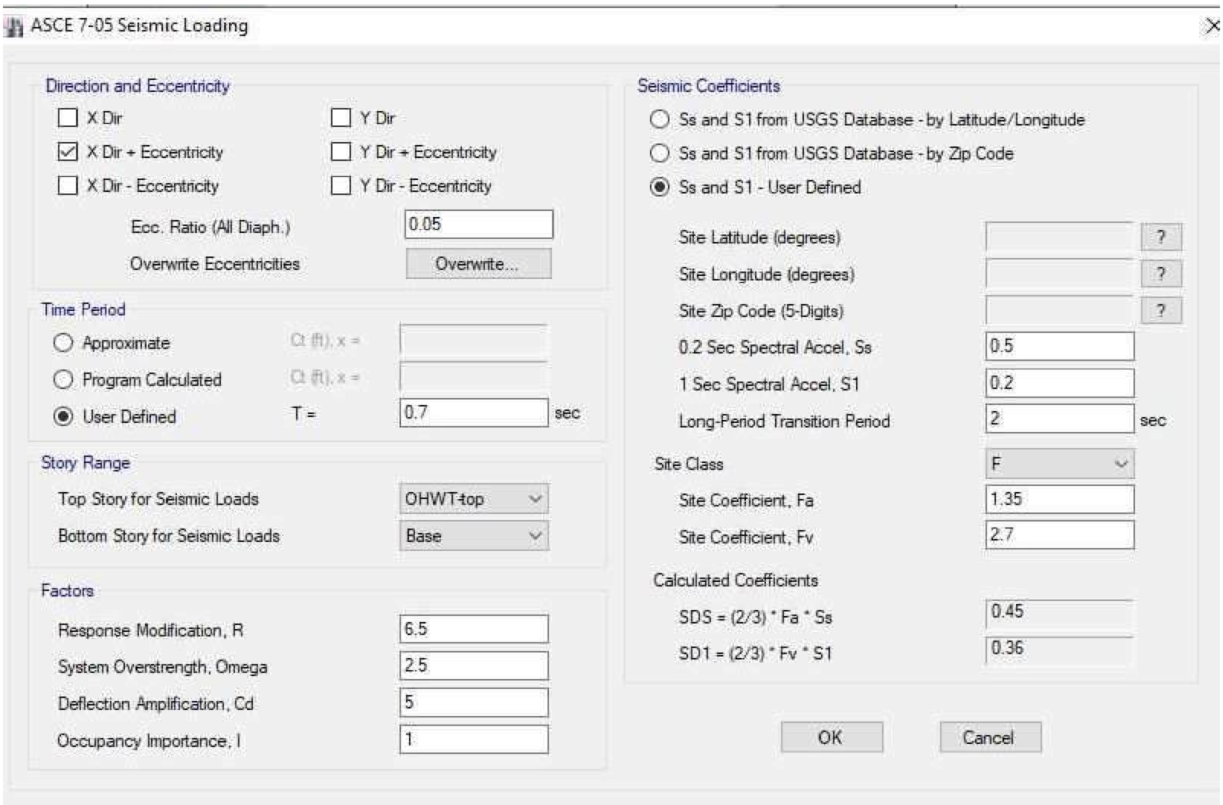
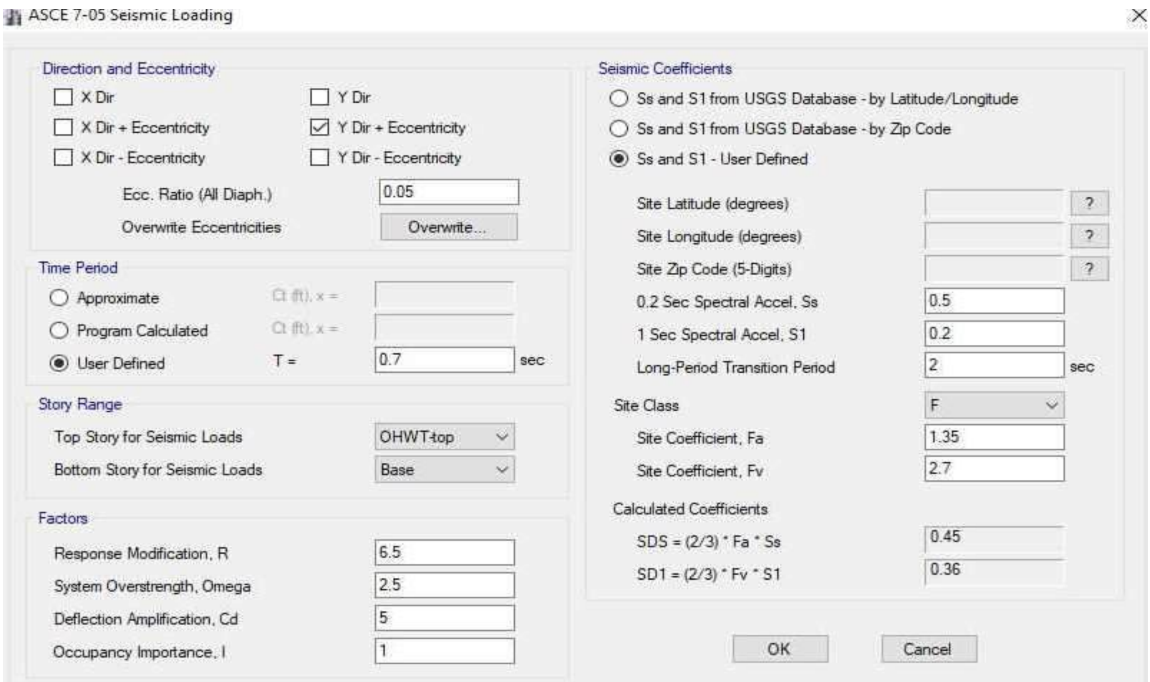


Figure 6.2.26 Normalized design acceleration response spectrum for different site classes.



Earthquake Load in model in X-Direction

16



Earthquake Load in model in Y-Direction

SEISMIC ZONING MAP

17

Description	Design Parameter	Reference	Notes
Seismic Zone Coefficient, Z	0.20	BNBC 2020 Part 6 Table 6.2.14	Location: Dhaka
Importance Factor, I	1.0	BNBC 2020 Part 6 Table 6.2.17	Occupancy Category II
Response Reduction Factor, R	6.5	BNBC 2020 Part 6 Table 6.2.19	E.2 Dual system-special reinforced concrete shear walls
System Overstrength Factor, Ω_o	2.5	BNBC 2020 Part 6 Table 6.2.19	E.2 Dual system-special reinforced concrete shear walls
Deflection Amplification Factor, C_d	5	BNBC 2020 Part 6 Table 6.2.19	E.2 Dual system-special reinforced concrete shear walls
Coefficient to estimate approximate period, C_t	0.0488	BNBC 2020 Part 6 Table 6.2.20	Other structural systems
Coefficient toestimate approximate period, m	0.75	BNBC 2020 Part 6 Table 6.2.20	Other structural systems

Earth Quake Manual Calculation: As per BNBC 2020		
Total height in meter, hn	34.5	m
Structural System Coefficient, Ct	0.0488	
Structure Period in second, T=Ct(hn)^(0.75)	0.694678957	

18

6.5 LOAD COMBINATIONS FOR STRENGTH DESIGN METHOD

When strength design method is used, structural members and foundations shall be designed to have strength not less than that required to resist the most unfavorable effect of the combinations of factored loads listed in the following Sections:

For the design of the building BNBC 2020 load combination has been considered.
BNBC 2020 load combinations are as follows-

1. 1.4(D + F)
2. 1.2(D + F + T) + 1.6(L + H) + 0.5(Lr or R)
3. 1.2D + 1.6(Lr or R) + (L or 0.8W)
4. 1.2D + 1.6W + L + 0.5(Lr or R)
5. 1.2D + 1.0E + 1.0L
6. 0.9D + 1.6W + 1.6H
7. 0.9D + 1.0E + 1.6H

D	=	Dead load;
L	=	Floor live load;
Lr	=	Roof live load
W	=	Wind load;
E	=	Seismic load
F	=	Loads due to weight and pressures of fluids = 0
H	=	Loads due to weight and pressure of soil = 0
T	=	Self-straining forces and cumulative effect of temperature = 0
R	=	Rain load, or related internal moments and forces.

19

7.0 FOUNDATIONS

7.1 GEOTECHNICAL SITE CONDITIONS

Site investigation is a mandatory for any type of building.
Deposits of loose-to-medium cohesion less soil (with or without some soft cohesive layers), or of predominantly soft-to-firm cohesive soil considered as per sub soil investigation report

7.2 FOUNDATIONS

As there is soil test result here, we consider allowable pile capacity= 100 tons for pile foundation design.

20

8.0 STRUCTURAL SCHEME

8.1 RESIDENTIAL FACILITY STRUCTURE

The proposed structure is (B+G+9) storied tall. The floor system is proposed to be RCC beam supported with slab. The slab thickness above ground floor is proposed to be 6 inch and these floors have a general floor to floor height of 3m. Typical floor layout and typical floor sections are provided in the appendix.

8.2 LATERAL LOADS RESISTANCE SYSTEM

For the wind and seismic load, the sway resistance is provided by shear wall & column.

8.3 ANALYSIS PROCEDURE

Equivalent static analysis has been performed for this building.
The structure was modelled using 3-D computer program **ETABS v16.2.1.**

21

9.0 STRUCTURAL PARAMETERS FOR THE ARCHITECTURAL AND LIFT SPECIFICATIONS

9.1 CONCRETE FINISHES

The structural specification is based on BNBC, ACI standard of concrete finish.

The terms used to describe the different types of concrete finish should be used in the Architectural finishes schedule when calling up concrete finishes.

22

Appendix A: Column Layout & Typical Floor Framing Plans

23

Appendix A: Column Layout & Typical Floor Framing Plans

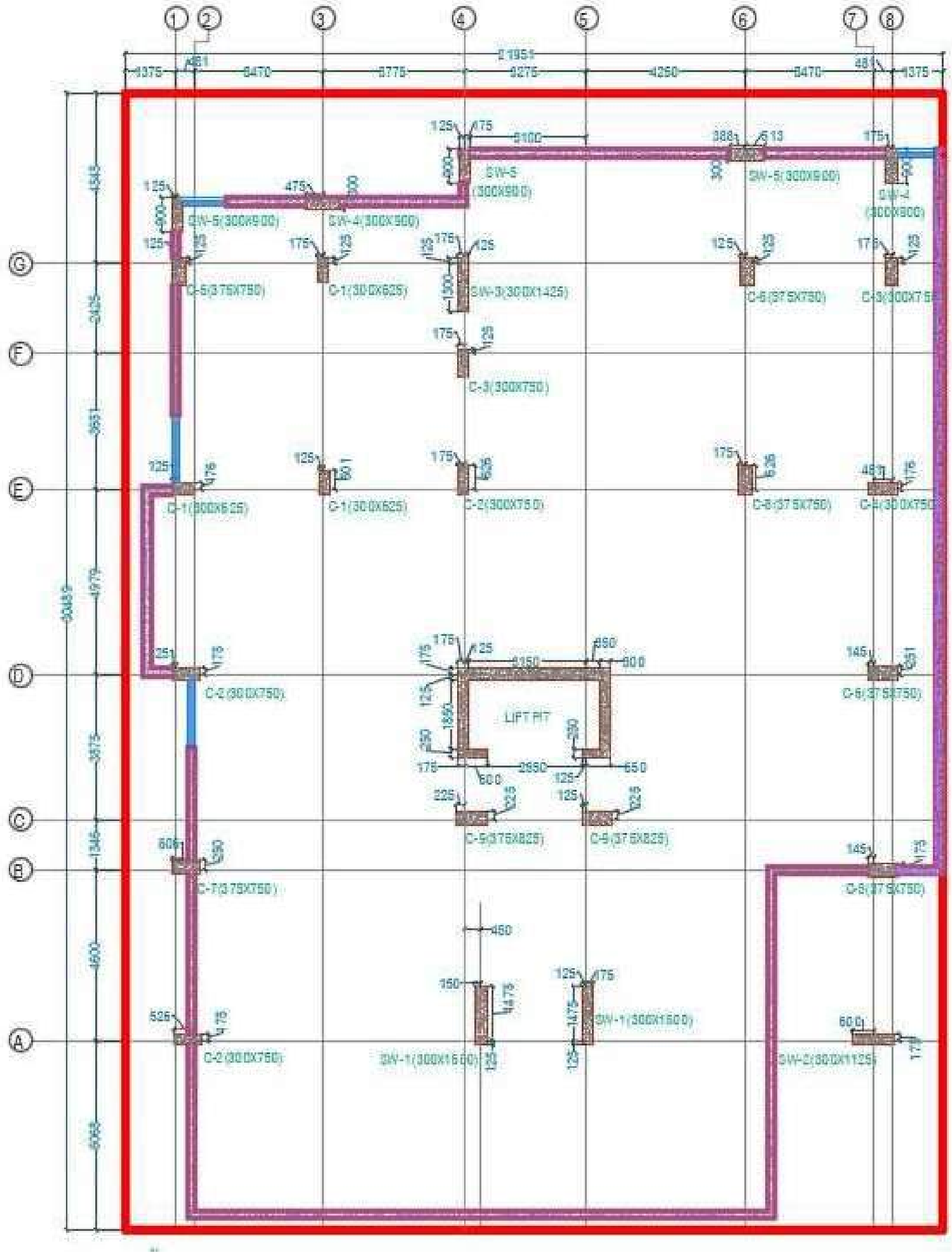
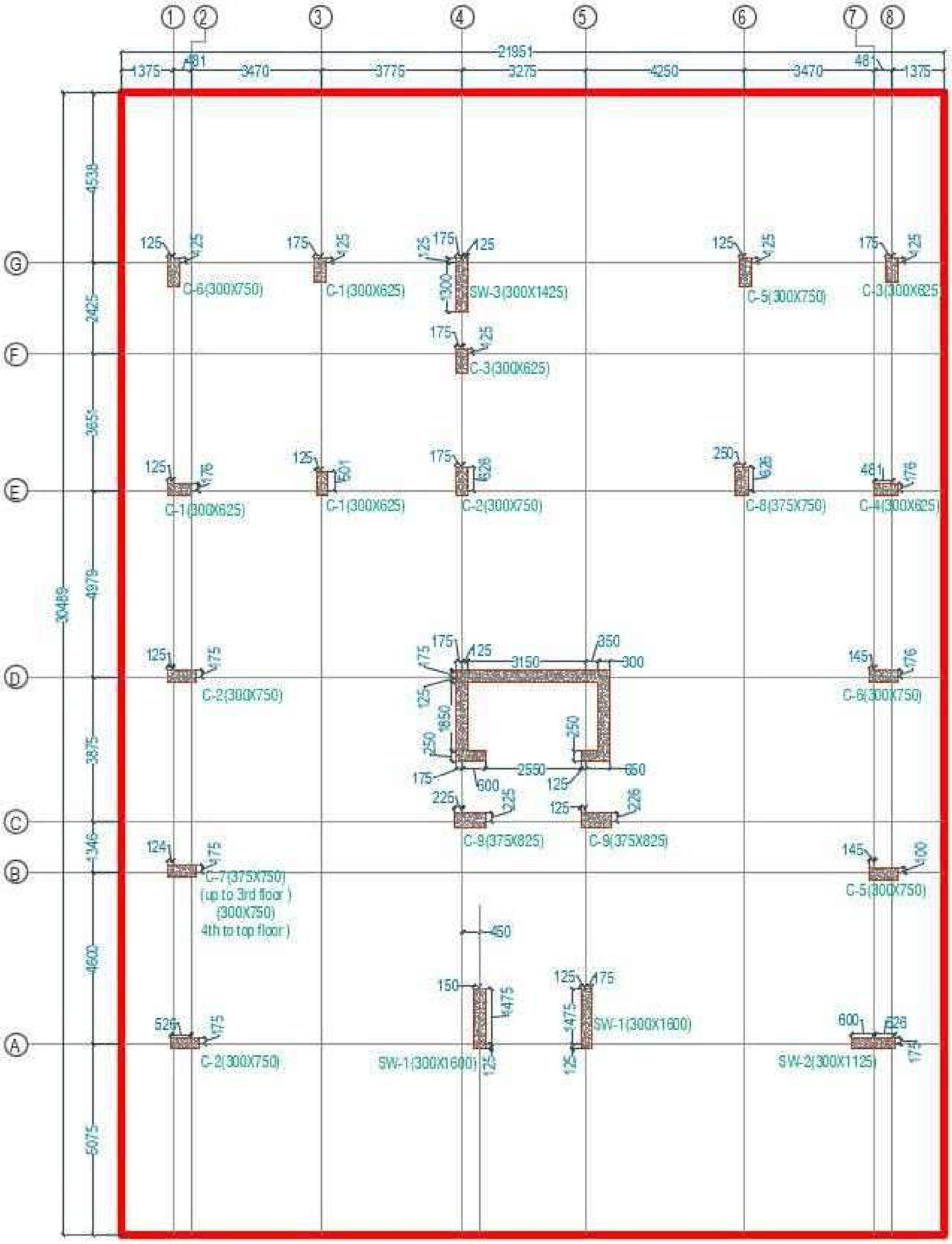


Figure A-0: Column Layout Plan up to 1st Floor)

24

B+G+9 STORIED RESIDENTIAL BUILDING



25

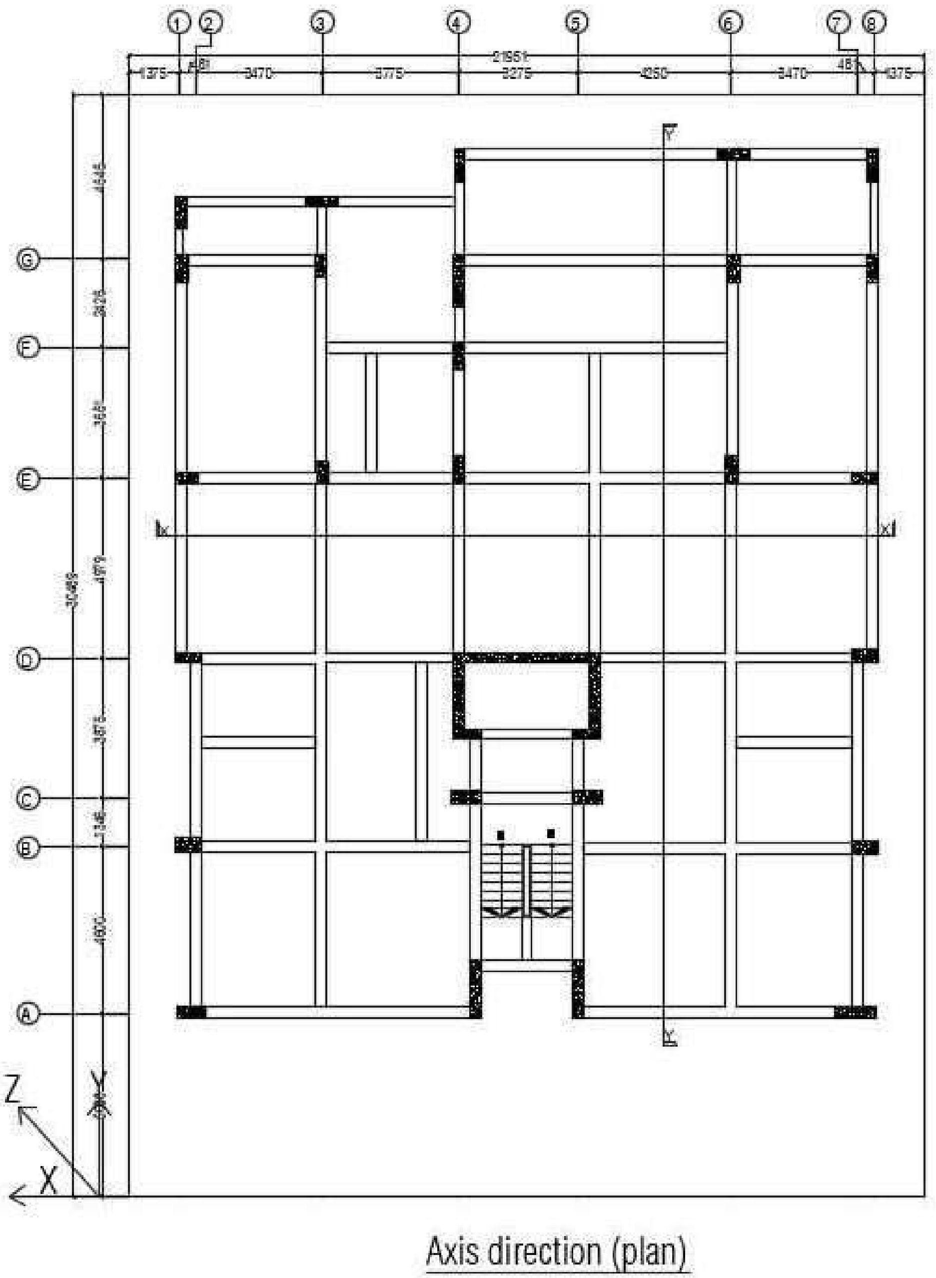


Figure A-2: Axis Direction

26

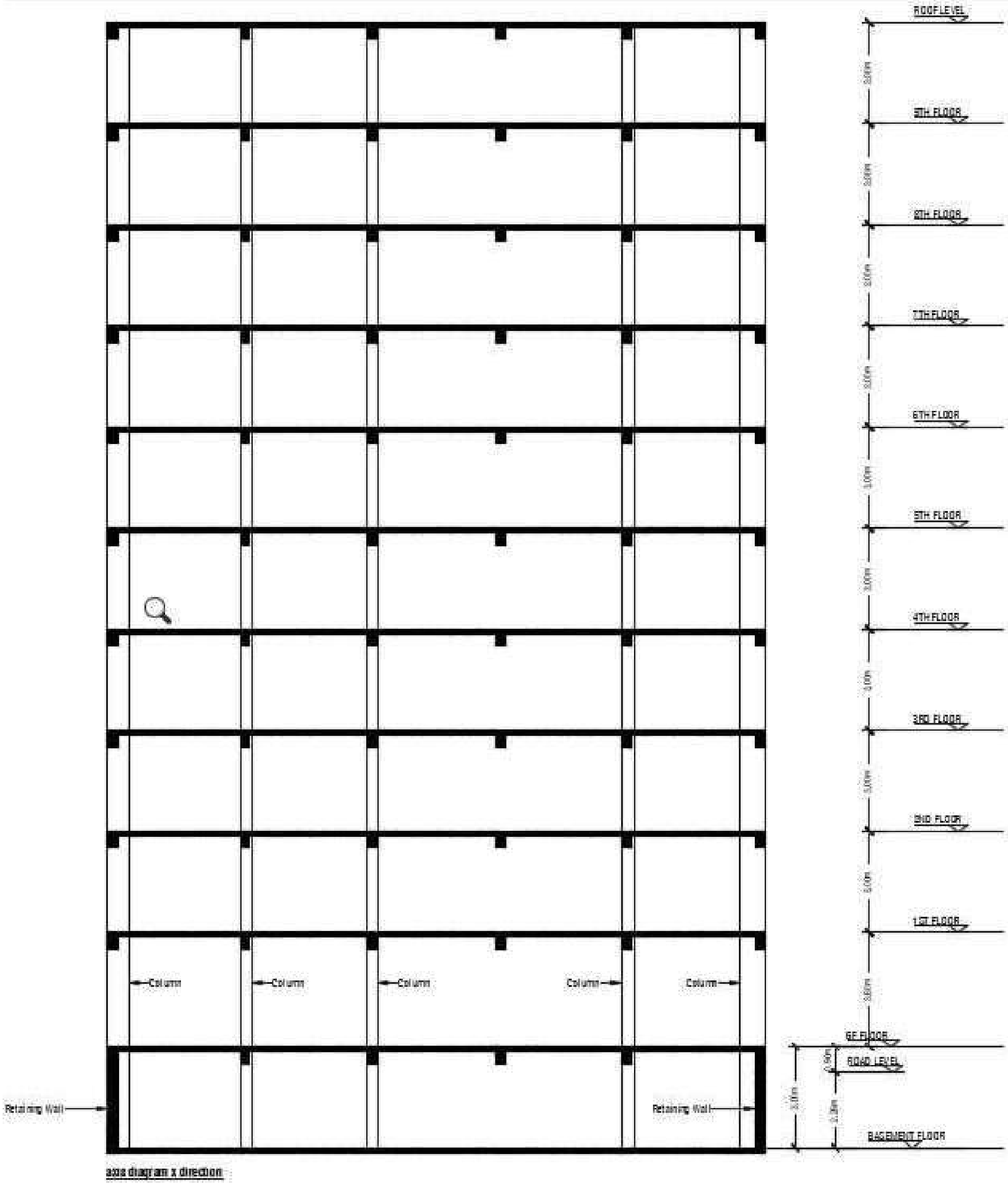


Figure A-3: Axis diagram in X direction

27

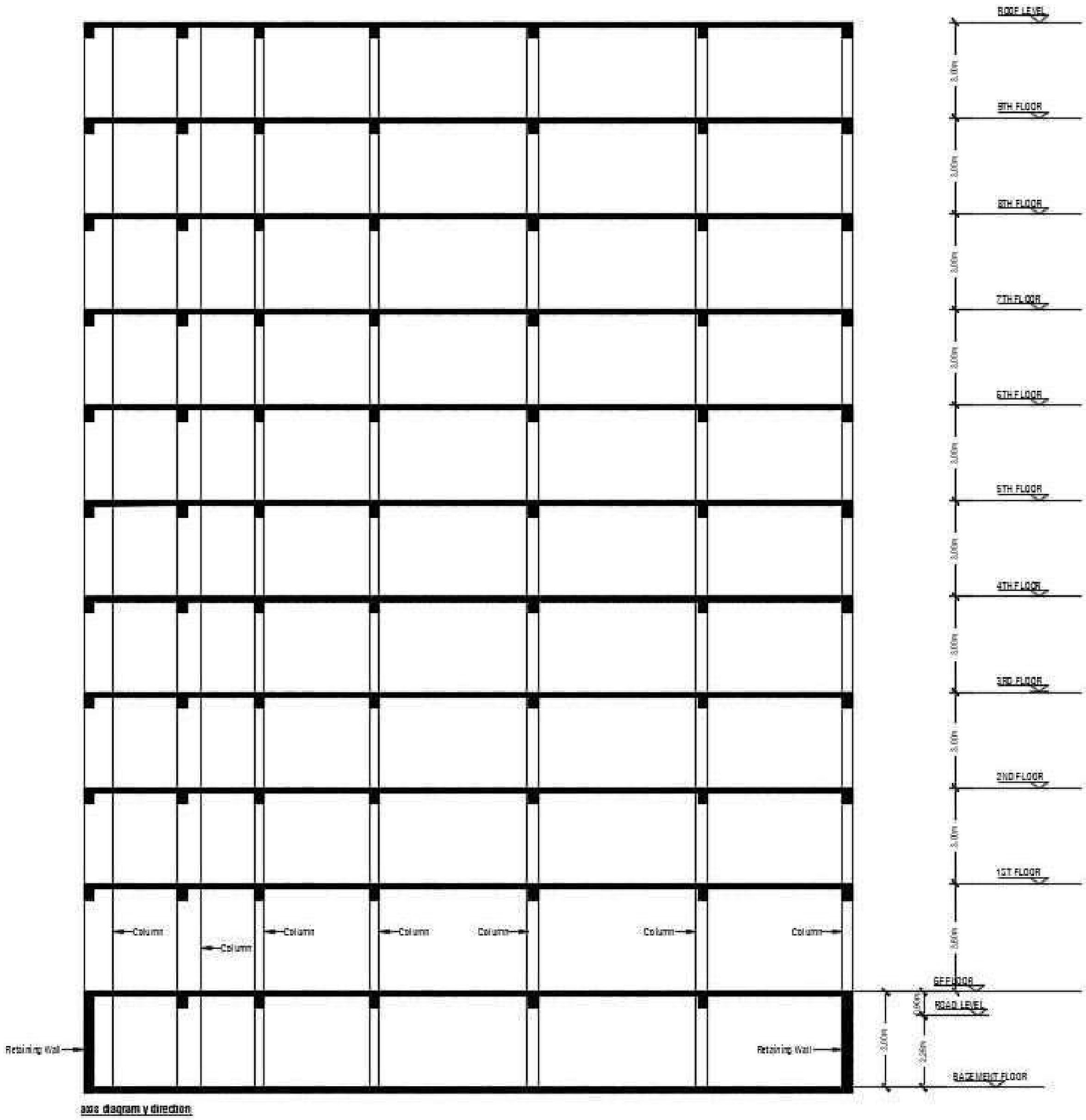


Figure A-3: Axis diagram in Y direction

28

Blue= Column
Red= Shear wall
In general, we use different colors in Etabs for our understanding but in report general practice is to provide same color.

29

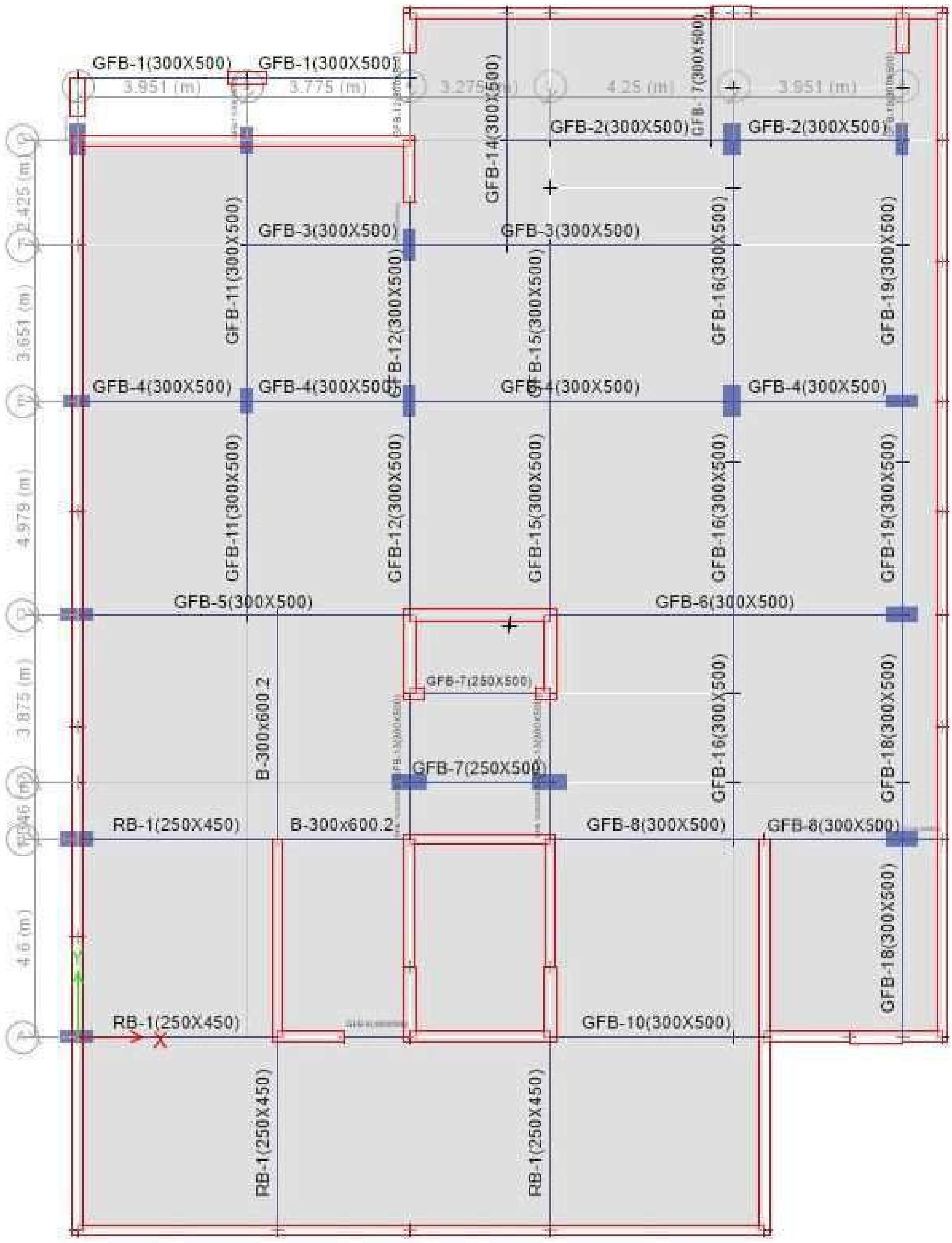


Figure A-4: Ground Floor Beam/Slab Layout

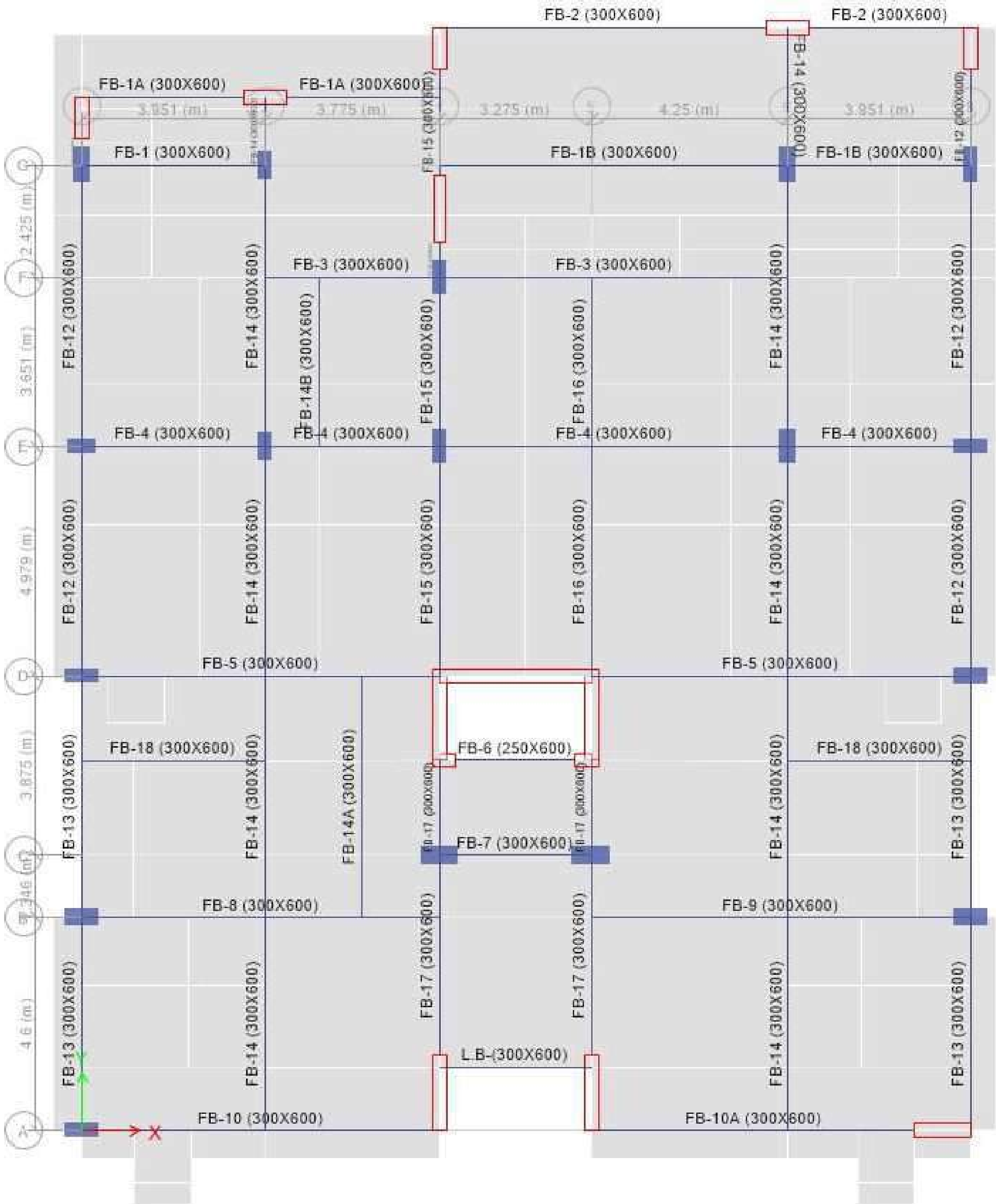


Figure A-5: First Floor Beam/Slab Layout

31

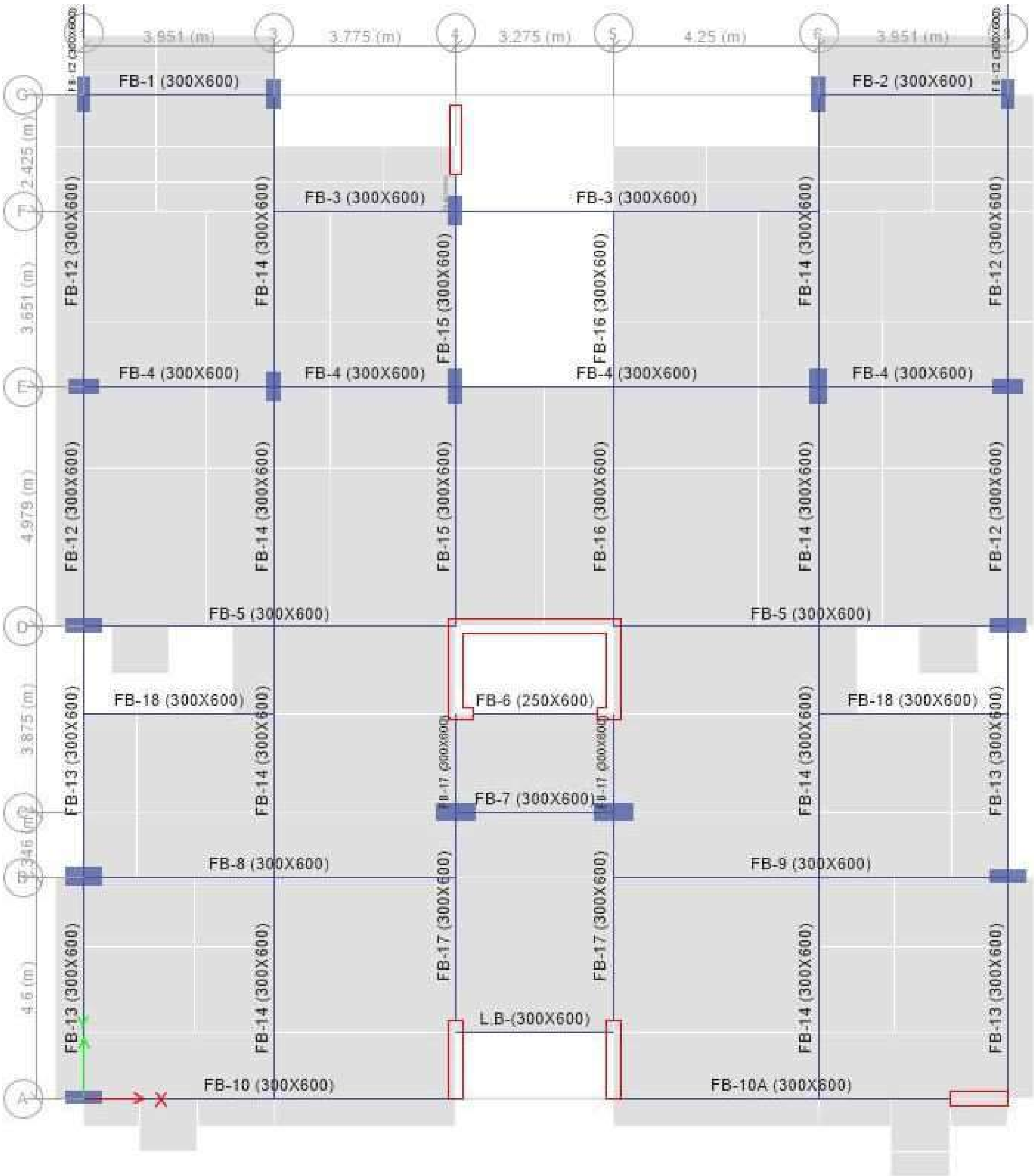


Figure A-6: Second Floor Beam/Slab Layout

32

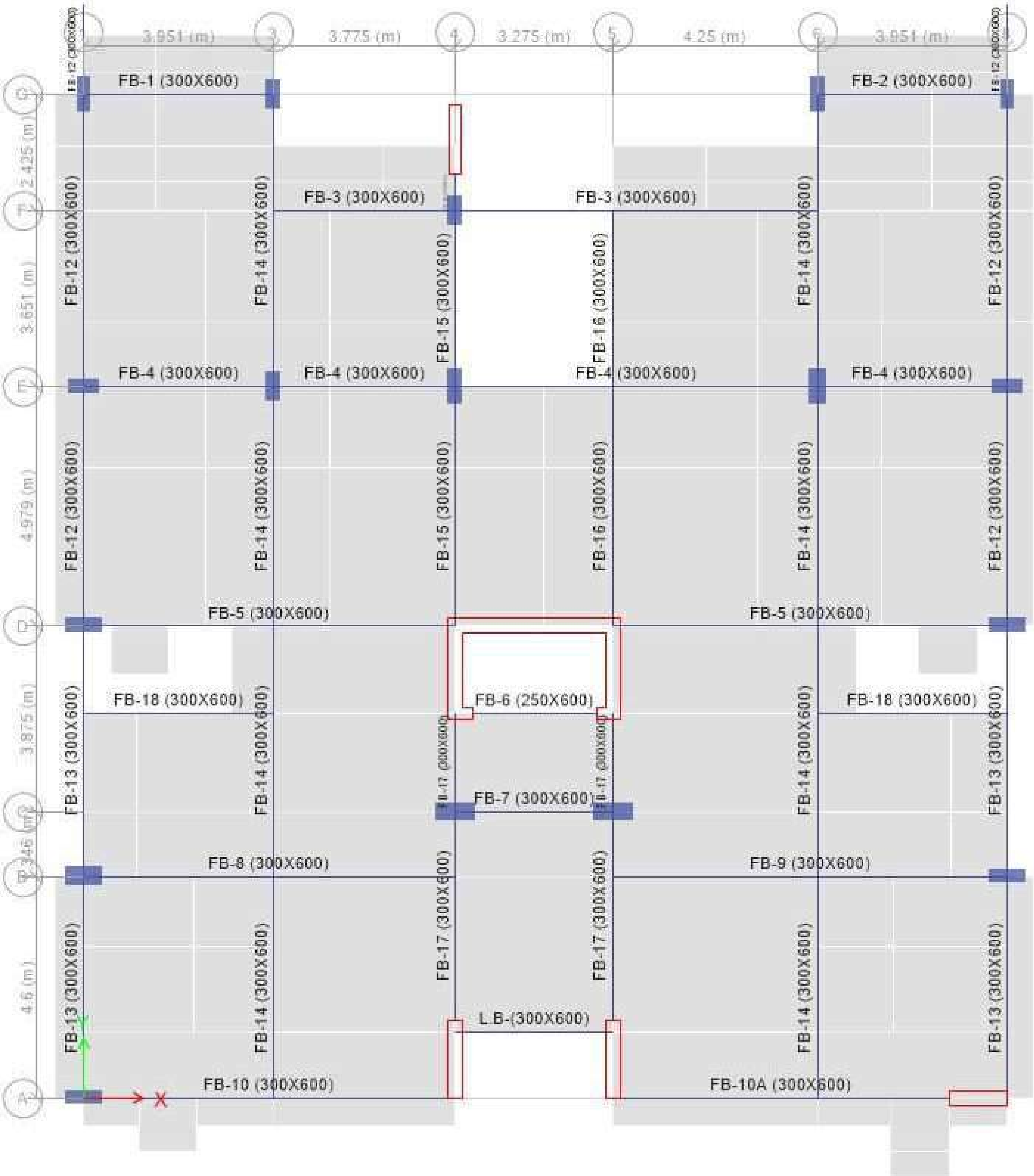


Figure A-7: Third & fourth Beam/Slab Layout

33

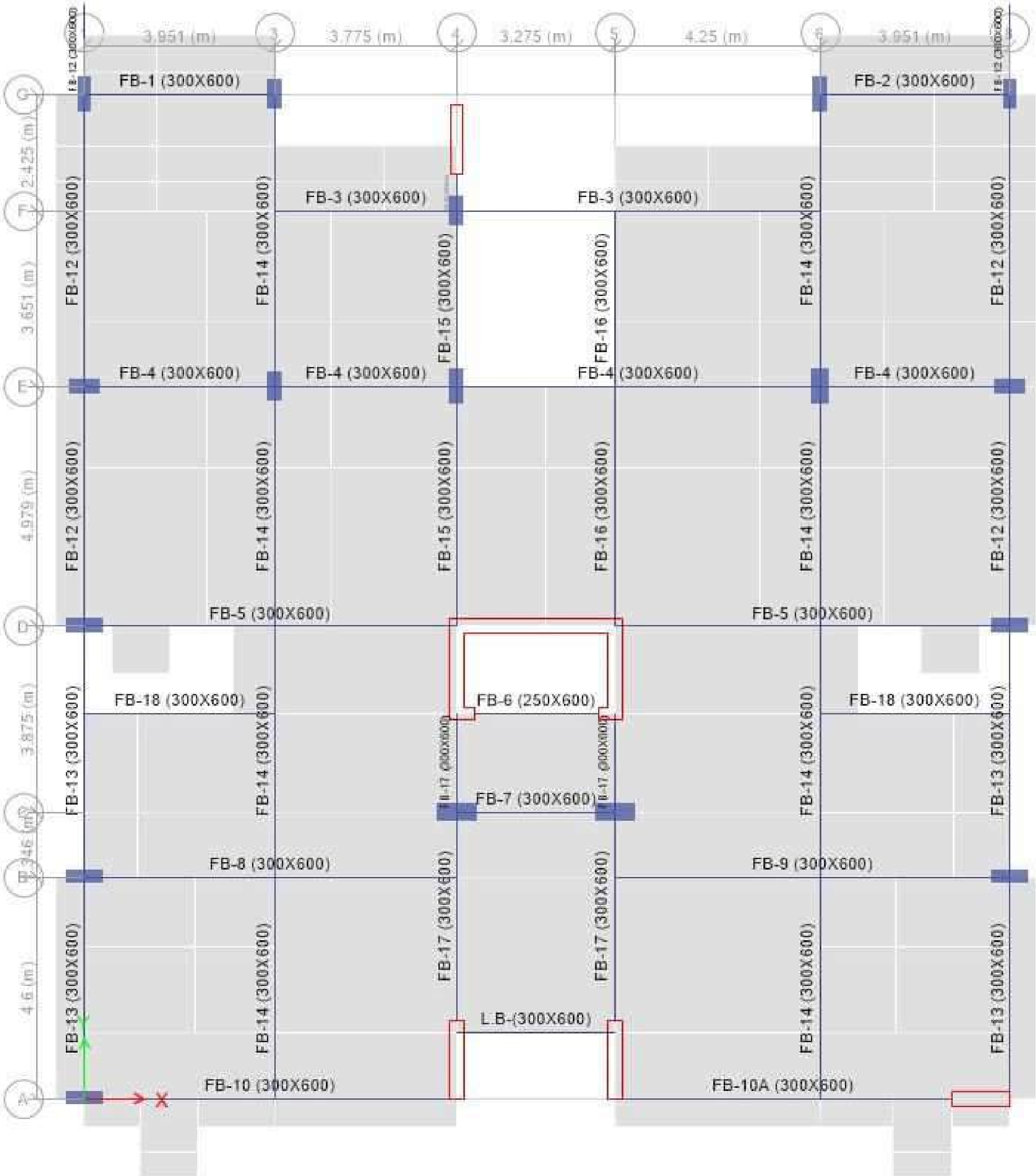


Figure A-8: Fifth & Sixth Beam/Slab Layout

34

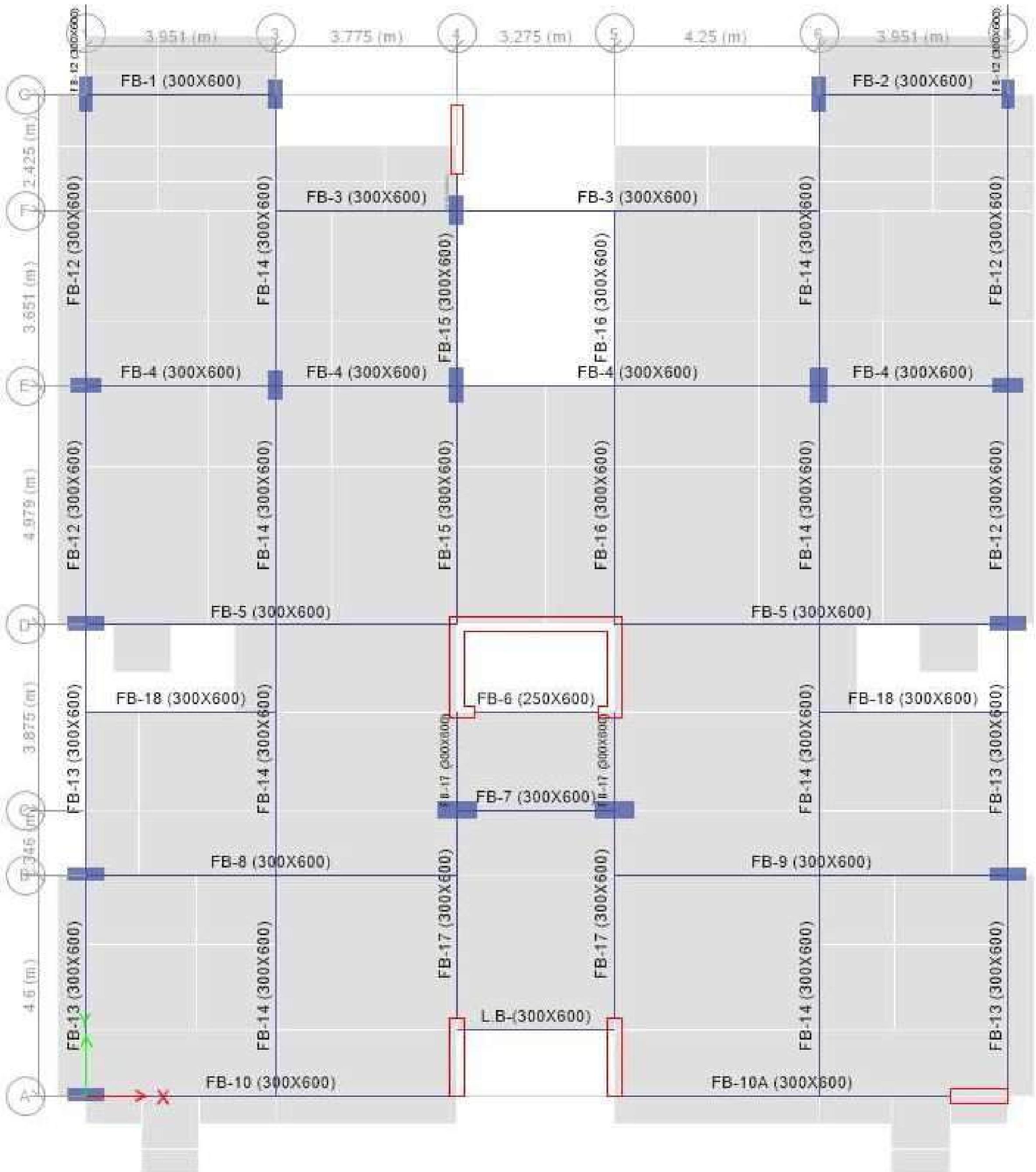


Figure A-9: Seventh Beam/Slab Layout

35

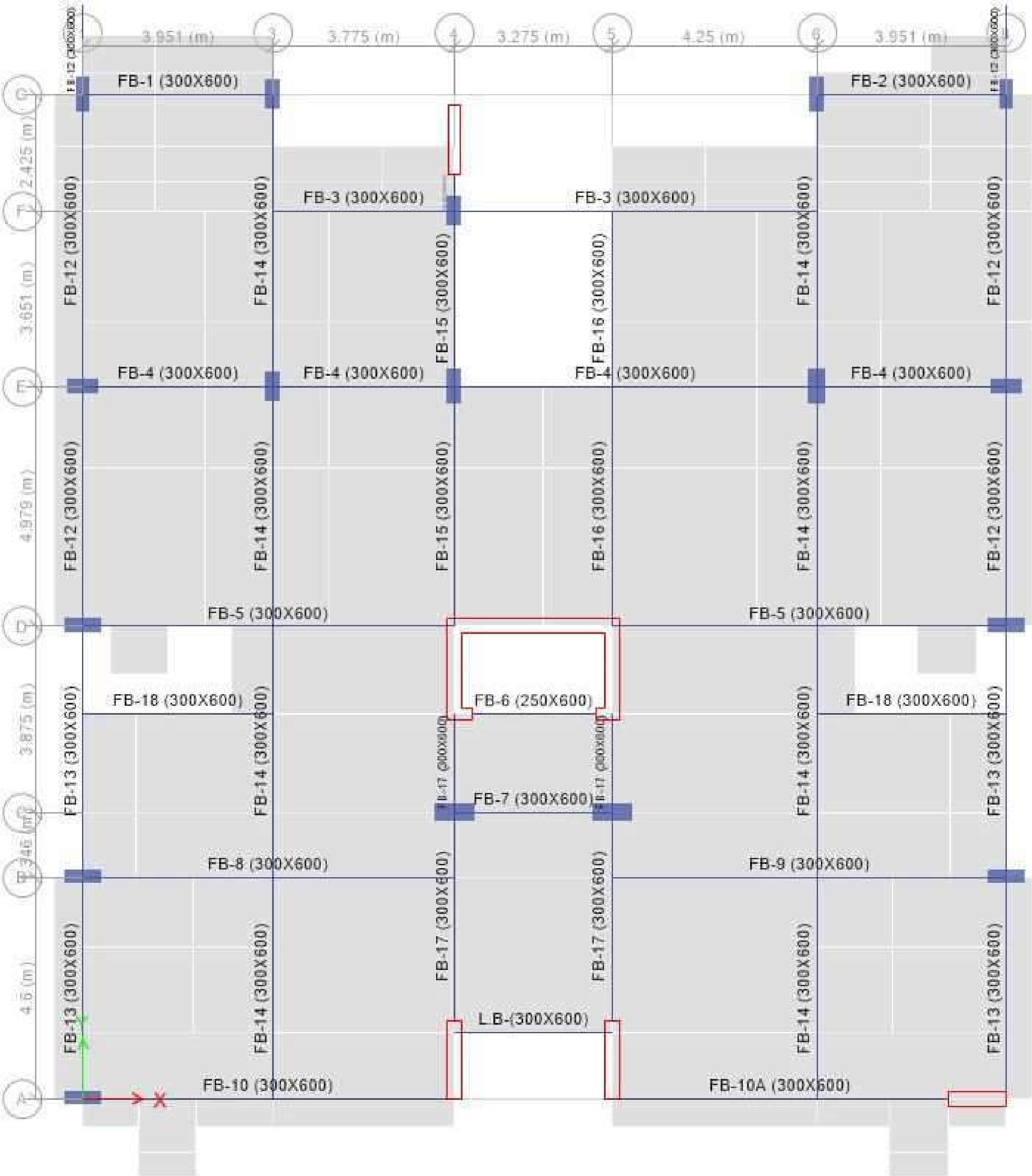


Figure A-10: Eight & Ninth Beam/Slab Layout

36

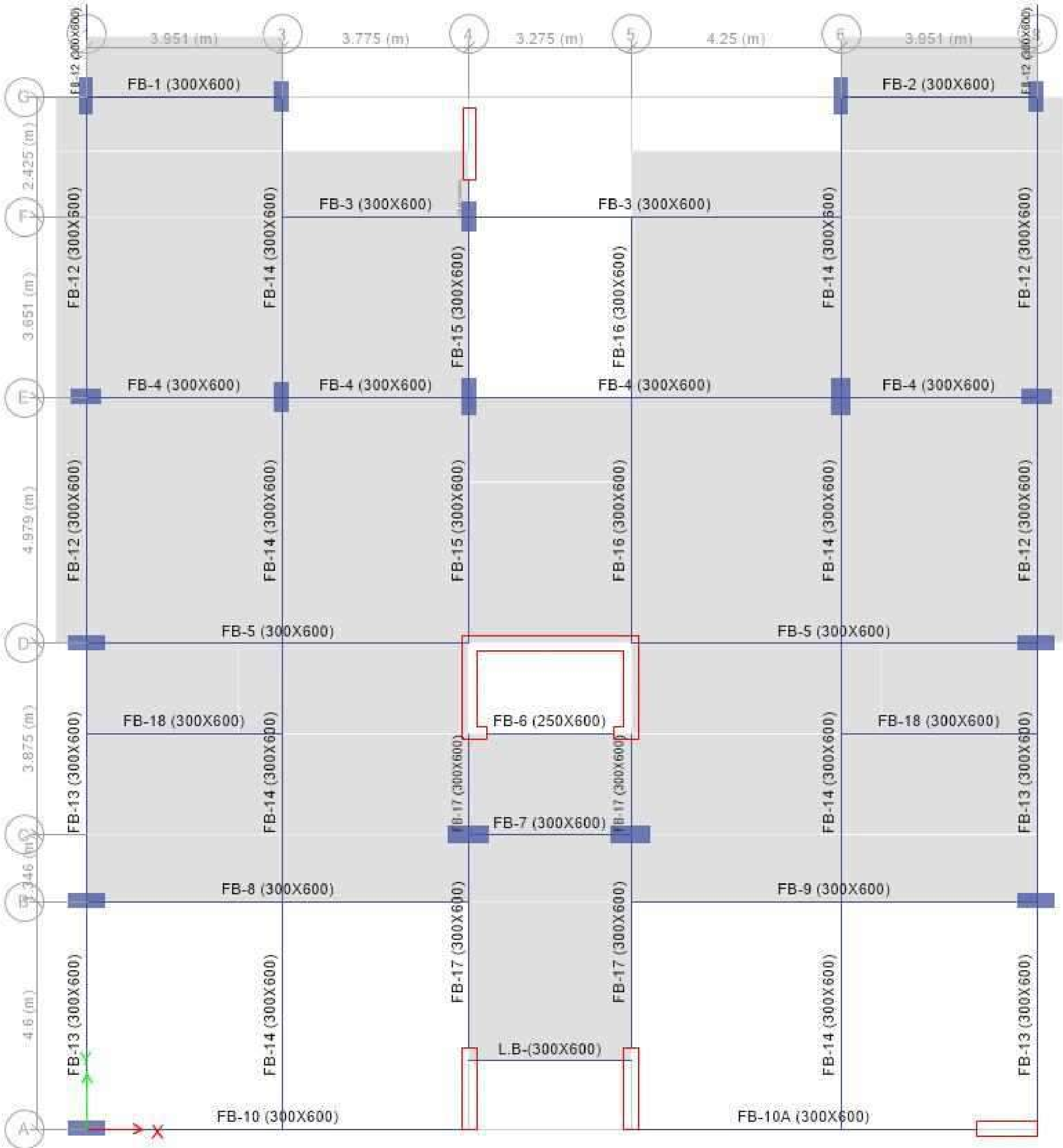


Figure A-11: Roof Beam/Slab Layout

37

Appendix B: Computer Model of the Structure

38

Appendix B: Computer Model of the Structure

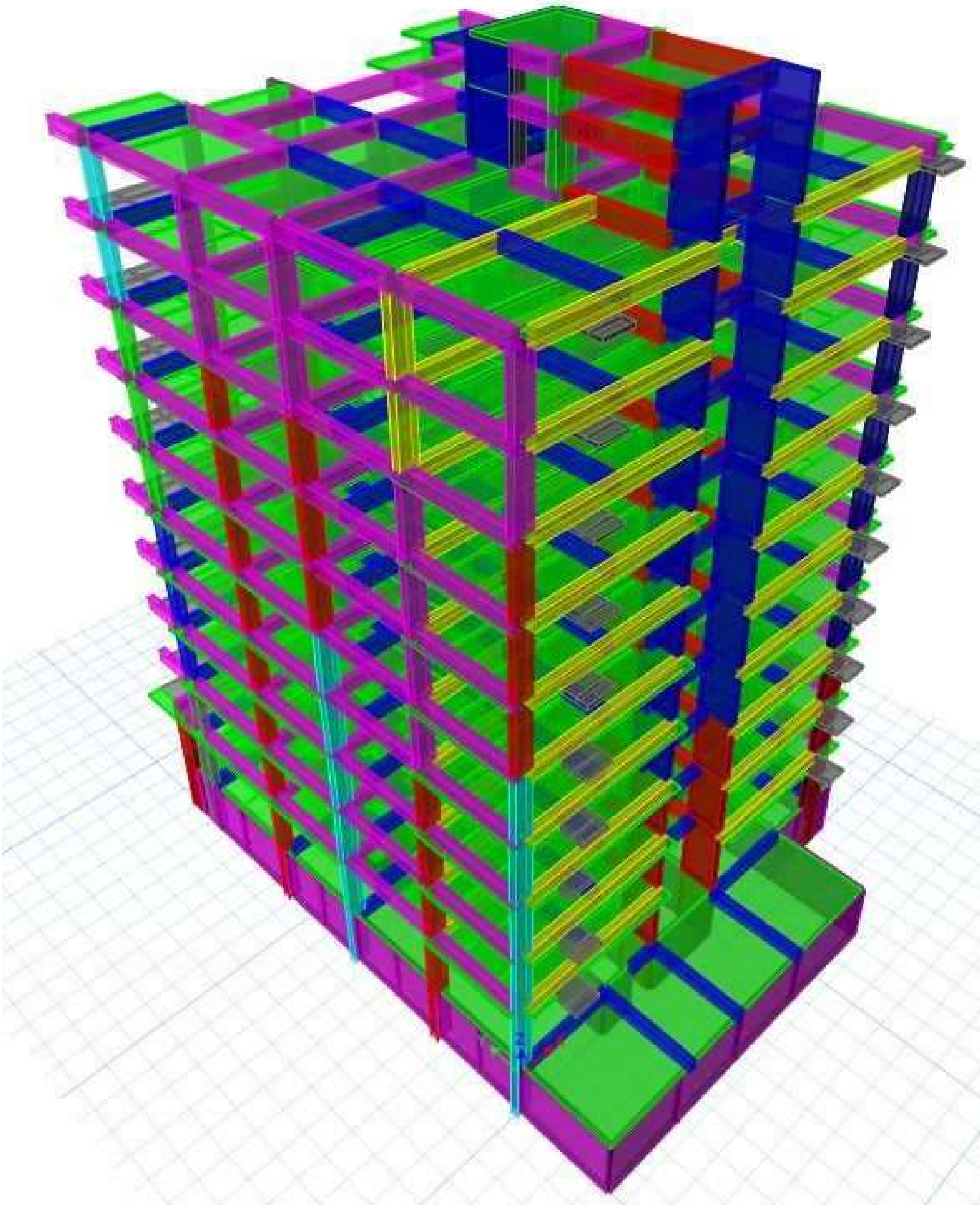


Figure B-1: 3D Model of Structure

Appendix C: Serviceability and Structural Member Check

40

Appendix C: Serviceability and Structural Member Check

C1. Check for Serviceability Requirements:

Table 6.1.4: Vertical Irregularities of Structures

Vertical Irregularity Type	Definition	Reference Section
I	**a. Stiffness Irregularity (Soft Storey):** Soft storey is one in which the lateral stiffness is less than 70 percent of that in the storey above or less than 80 percent of the average stiffness of the three storeys above. **b. Stiffness Irregularity (Extreme Soft Storey):** Extreme soft storey irregularity is defined to exist where there is a story in which the lateral stiffness is less than 60% of that in the story above or less than 70% of the average stiffness of the three stories above.	1.7.3.8, 2.5.5 to 2.5.14 and 2.5.17
II	**Mass Irregularity:** Mass irregularity shall be considered to exist where the effective mass of any storey is more than 150 percent of the effective mass of an adjacent storey. A roof which is lighter than the floor below need not be considered.	2.5.5 to 2.5.14
III	**Vertical Geometric Irregularity:** Vertical geometric irregularity shall be considered to exist where horizontal dimension of the lateral force-resisting system in any storey is more than 130 percent of that in an adjacent storey, one-storey penthouses need not be considered.	2.5.5 to 2.5.14
IV	**In-Plane Discontinuity in Vertical Lateral Force-Resisting Element:** An in-plane offset of the lateral load-resisting elements greater than the length of those elements.	1.7.3.8, 2.5.5 to 2.5.14
Va	**Discontinuity in Capacity (Weak Storey):** A weak storey is one in which the storey strength is less than 80 percent of that in the storey above. The storey strength is the total strength of all seismic-resisting elements sharing the storey shear for the direction under consideration.	2.5.5 to 2.5.14 and 2.5.17
Vb	**Extreme Discontinuity in Capacity (Very Weak Storey):** A very weak storey is one in which the storey strength is less than 65 percent of that in the storey above.	2.5.5 to 2.5.14 and 2.5.17

Table 6.1.5: Plan (Horizontal) Irregularities of Structures

Plan Irregularity Type	Definition	Reference Section
I	**Torsional Irregularity (to be considered when diaphragms are not flexible):** a. Torsional irregularity shall be considered to exist when the maximum storey drift, computed including accidental torsion, at one end of the structure is more than 1.2 times the average of the storey drifts at the two ends of the structure. b. Extreme Torsional Irregularity is defined to exist where the maximum story drift, computed including accidental torsion, at one end of the structure transverse to an axis is more than 1.4 times the average of the story drifts at the two ends of the structure. Extreme torsional irregularity requirements in the reference sections apply only to structures in which the diaphragms are rigid or semirigid.	1.7.3.8, 2.5.5 to 2.5.14
II	**Reentrant Corners:** Plan configurations of a structure and its lateral force-resisting system contain reentrant corners, where both projections of the structure beyond a reentrant corner are greater than 15 percent of the plan dimension of the structure in the given direction.	1.7.3.8, 2.5.5 to 2.5.14
III	**Diaphragm Discontinuity:** Diaphragms with abrupt discontinuities or variations in stiffness, including those having cutout or open areas greater than 50 percent of the gross enclosed area of the diaphragm, or changes in effective diaphragm stiffness of more than 50 percent from one storey to the next.	1.7.3.8, 2.5.5 to 2.5.14
IV	**Out-of-plane Offsets:** Discontinuities in a lateral force path, such as out-of-plane offsets of the vertical elements.	1.7.3.8, 2.5.5 to 2.5.14
V	**Nonparallel Systems:** The vertical lateral load-resisting elements are not parallel to or symmetric about the major orthogonal axes of the lateral force-resisting system.	2.5.5 to 2.5.15

Lateral deflection due to Wind:

For serviceability limit state against lateral deflection of buildings and structures due to wind effect, the following combination shall be used:

3. $D + 0.5L + 0.7W$

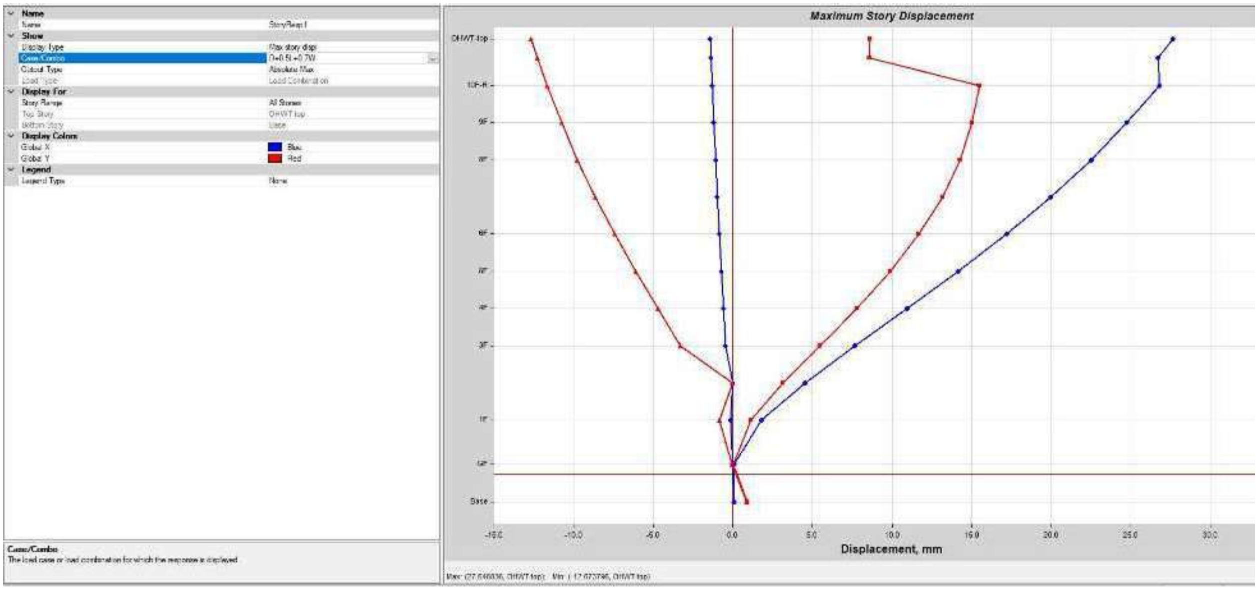


Figure C-1: Lateral deflection due to D+0.5L+0.7W

Maximum lateral deflection due to D+0.5L+0.7W = 27.7 mm

Allowable limit for Lateral deflection due to Wind = H/500 = (34500)/500= 69 mm

Maximum deflection < Allowable deflection (okay)

43

TORSIONAL IRREGULARITY CHECK:

I **Torsional Irregularity (to be considered when diaphragms are not flexible):**

a. Torsional irregularity shall be considered to exist when the maximum storey drift, computed including accidental torsion, at one end of the structure is more than 1.2 times the average of the storey drifts at the two ends of the structure.

b. Extreme Torsional Irregularity is defined to exist where the maximum story drift, computed including accidental torsion, at one end of the structure transverse to an axis is more than 1.4 times the average of the story drifts at the two ends of the structure. Extreme torsional irregularity requirements in the reference sections apply only to structures in which the diaphragms are rigid or semirigid.

Accidental torsional effects:

In order to account for uncertainties in the location of masses and in the spatial variation of the seismic motion, accidental torsional effects need to be always considered. The accidental moment M_{ta} is determined assuming the story mass to be displaced from the calculated center of mass a distance equal to 5 percent of the building dimension at that level perpendicular to the direction of the force under consideration.

$$A_x = \left[\frac{\delta_{max}}{1.2\delta_{avg}}\right]^2 \leq 3.0 \qquad (6.2.44)$$

Where,

δ_{max} = Maximum displacement at level-x computed assuming $A_x = 1$.

δ_{avg} = Average displacements at extreme points of the building at level-x computed assuming $A_x = 1$.

For EX+:

TABLE: Story Max/Avg Drifts					
Story	Load Case/Combo	Direction	Max Drift	Avg Drift	Ratio
			mm	mm	
10F-R	EX	X	8.746	8.114	1.078
9F	EX	X	9.009	8.557	1.053
8F	EX	X	9.168	8.927	1.027
7F	EX	X	9.253	9.2	1.006
6F	EX	X	9.417	9.297	1.013
5F	EX	X	9.407	9.133	1.03
4F	EX	X	9.017	8.651	1.042
3F	EX	X	8.146	7.753	1.051
2F	EX	X	6.554	6.396	1.025
1F	EX	X	4.674	4.54	1.029

44

For EX-:

TABLE: Story Max/Avg Drifts					
Story	Load Case/Combo	Direction	Max Drift	Avg Drift	Ratio
			mm	mm	
10F-R	EX-	X	10.7	8.226	1.301
9F	EX-	X	12.166	8.738	1.392
8F	EX-	X	13.629	9.106	1.497
7F	EX-	X	15.05	9.378	1.605
6F	EX-	X	16.196	9.474	1.709
5F	EX-	X	16.848	9.304	1.811
4F	EX-	X	16.855	8.809	1.913
3F	EX-	X	15.768	7.86	2.006
2F	EX-	X	13.23	6.691	1.977
1F	EX-	X	7.598	4.492	1.691

Since, there is torsional irregularity so Accidental length factor has been multiplied.

For EY+:

TABLE: Story Max/Avg Drifts					
Story	Load Case/Combo	Direction	Max Drift	Avg Drift	Ratio
			mm	mm	
10F-R	EY	Y	4.312	3.667	1.176
9F	EY	Y	5.489	4.504	1.219
8F	EY	Y	6.69	5.338	1.253
7F	EY	Y	7.889	6.134	1.286
6F	EY	Y	8.898	6.772	1.314
5F	EY	Y	9.586	7.157	1.339
4F	EY	Y	9.825	7.184	1.368
3F	EY	Y	9.275	6.692	1.386
2F	EY	Y	7.528	5.47	1.376
1F	EY	Y	4.591	3.493	1.314

Since, there is torsional irregularity so Accidental length factor has been multiplied

45

For EY-:

TABLE: Story Max/Avg Drifts					
Story	Load Case/Combo	Direction	Max Drift	Avg Drift	Ratio
			mm	mm	
10F-R	EY-	Y	4.011	3.661	1.096
9F	EY-	Y	4.877	4.408	1.106
8F	EY-	Y	5.856	5.258	1.114
7F	EY-	Y	6.757	6.029	1.121
6F	EY-	Y	7.481	6.644	1.126
5F	EY-	Y	7.914	7.008	1.129
4F	EY-	Y	7.919	7.02	1.128
3F	EY-	Y	7.405	6.531	1.134
2F	EY-	Y	5.99	5.339	1.122
1F	EY-	Y	3.562	3.411	1.044

Drift Check:

The deflection in the plane of the diaphragm, as determined by engineering analysis, shall not exceed the permissible deflection of the attached elements. Permissible deflection shall be that deflection that will permit the attached element to maintain its structural integrity under the individual loading and continue to support the prescribed loads.

Table 6.2.21: Allowable Storey Drift Limit (Δ_a)

Structure	Occupancy Category		
	I and II	III	IV
Structures, other than masonry shear wall structures, 4 stories or less with interior walls, partitions, ceilings and exterior wall systems that have been designed to accommodate the story drifts.	$0.025h_{sx}$	$0.020h_{sx}$	$0.015h_{sx}$
Masonry cantilever shear wall structures	$0.010h_{sx}$	$0.010h_{sx}$	$0.010h_{sx}$
Other masonry shear wall structures	$0.007h_{sx}$	$0.007h_{sx}$	$0.007h_{sx}$
All other structures	$0.020h_{sx}$	$0.015h_{sx}$	$0.010h_{sx}$

46

Drift

For EX+:

TABLE: Story Response			
Story	Elevation	Location	+X Direction
	m		
10F-R	31.3466	Top	0.002915
9F	28.3466	Top	0.003003
8F	25.3466	Top	0.003056
7F	22.3466	Top	0.003084
6F	19.3466	Top	0.003139
5F	16.3466	Top	0.003136
4F	13.3466	Top	0.003006
3F	10.3466	Top	0.002715
2F	7.3466	Top	0.002185
1F	4.3466	Top	0.0013

For EX-:

TABLE: Story Response			
Story	Elevation	Location	-X Direction
	m		
10F-R	31.3466	Top	0.000709
9F	28.3466	Top	0.00099
8F	25.3466	Top	0.001239
7F	22.3466	Top	0.001552
6F	19.3466	Top	0.001837
5F	16.3466	Top	0.00206
4F	13.3466	Top	0.002199
3F	10.3466	Top	0.002159
2F	7.3466	Top	0.001836
1F	4.3466	Top	0.000737

For EY+:

TABLE: Story Response			
Story	Elevation	Location	+Y Direction
	m		
10F-R	31.3466	Top	0.001421
9F	28.3466	Top	0.001811
8F	25.3466	Top	0.002209
7F	22.3466	Top	0.002606
6F	19.3466	Top	0.00294
5F	16.3466	Top	0.003168
4F	13.3466	Top	0.003248

47

3F	10.3466	Top	0.003067
2F	7.3466	Top	0.00249
1F	4.3466	Top	0.001267

For EY-:

TABLE: Story Response			
Story	Elevation	Location	-Y Direction
	m		
10F-R	31.3466	Top	0.001421
9F	28.3466	Top	0.001811
8F	25.3466	Top	0.002209
7F	22.3466	Top	0.002606
6F	19.3466	Top	0.00294
5F	16.3466	Top	0.003168
4F	13.3466	Top	0.003248
3F	10.3466	Top	0.003067
2F	7.3466	Top	0.00249
1F	4.3466	Top	0.001267

Drift value unit less.

The deflections (δ_x) of level x at the center of the mass shall be determined in accordance with the following equation:

$$\delta_x = \frac{C_d \delta_{xe}}{I} \qquad (6.2.45)$$

Where,

C_d = Deflection amplification factor given in Table 6.2.19

δ_{xe} = Deflection determined by an elastic analysis

I = Importance factor defined in Table 6.2.17

Allowable limit= (0.02*1.0)/5= 0.004

MASS IRREGULARITY CHECK:

II **Mass Irregularity:**

Mass irregularity shall be considered to exist where the effective mass of any storey is more than 150 percent of the effective mass of an adjacent storey. A roof which is lighter than the floor below need not be considered.

48

TABLE: Story Forces					
Story	P	L/L+1	L/L-1	REMARKS	
	KN			FOR L/L+1	FOR L/L-1
9F	10457.8278	-	65.93%	MASS IRREGULARITY EXISTS	NO MASS IRREGULARITY
8F	15862.7985	151.68%	74.52%	MASS IRREGULARITY EXISTS	NO MASS IRREGULARITY
7F	21285.5248	134.19%	79.70%	NO MASS IRREGULARITY	NO MASS IRREGULARITY
6F	26708.2511	125.48%	83.12%	NO MASS IRREGULARITY	NO MASS IRREGULARITY
5F	32130.4118	120.30%	85.73%	NO MASS IRREGULARITY	NO MASS IRREGULARITY
4F	37478.6642	116.65%	87.39%	NO MASS IRREGULARITY	NO MASS IRREGULARITY
3F	42887.1675	114.43%	88.83%	NO MASS IRREGULARITY	NO MASS IRREGULARITY
2F	48280.1029	112.57%	87.32%	NO MASS IRREGULARITY	NO MASS IRREGULARITY
1F	55292.0844	114.52%	90.89%	NO MASS IRREGULARITY	NO MASS IRREGULARITY
GF	60832.4902	110.02%	-	-	-

Mass irregularity exist when effective mass of any story is more than 150%

STIFFNESS IRREGULARITY CHECK (SOFT STORY):

a. Stiffness Irregularity (Soft Storey):

Soft storey is one in which the lateral stiffness is less than 70 percent of that in the storey above or less than 80 percent of the average stiffness of the three storeys above.

b. Stiffness Irregularity (Extreme Soft Storey):

Extreme soft storey irregularity is defined to exist where there is a story in which the lateral stiffness is less than 60% of that in the story above or less than 70% of the average stiffness of the three stories above.

For EX:

Story	Stiffness X	$\frac{K_i}{K_{i+1}}$	check
	kN/m	0.7	
9F	142770.29	-	-
8F	195946.218	1.37	Regular
7F	240705.969	1.23	Regular
6F	281482.158	1.17	Regular

49

5F	323808.128	1.15	Regular
4F	373703.018	1.15	Regular
3F	445317.197	1.19	Regular
2F	645006.564	1.45	Regular
1F	827424.863	1.28	Regular
GF	23313840.23	28.18	Regular

For EY:

Story	Stiffness Y kN/m	$\frac{K_i}{K_{i+1}}$ 0.7	check
9F	271450.29	-	-
8F	326155.449	1.20	Regular
7F	359572.5	1.10	Regular
6F	385125.046	1.07	Regular
5F	412109.987	1.07	Regular
4F	449074.367	1.09	Regular
3F	515163	1.15	Regular
2F	660275.029	1.28	Regular
1F	1072120.523	1.62	Regular
GF	32360903.8	30.18	Regular

Soft story occurs when lateral stiffness is less than 70% of that in the story above.

50

WEAK STORY CHECK:

Discontinuity in Capacity (Weak Storey):

A weak storey is one in which the storey strength is less than 80 percent of that in the storey above. The storey strength is the total strength of all seismic-resisting elements sharing the storey shear for the direction under consideration.

Extreme Discontinuity in Capacity (Very Weak Storey):

A very weak storey is one in which the storey strength is less than 65 percent of that in the storey above.

Since, in this building floor height same and no change in shear wall thickness so there is no possibility of weak story.

Weak story occurs when story strength is less than 80% of that in the story above.

VERTICAL GEOMETRIC IRREGULARITY CHECK:

Vertical Geometric Irregularity:

Vertical geometric irregularity shall be considered to exist where horizontal dimension of the lateral force-resisting system in any storey is more than 130 percent of that in an adjacent storey, one-storey penthouses need not be considered.

There is no vertical geometric irregularity as no horizontal dimension reduction of the lateral force resisting element.

REENTRANT CORNER CHECK:

Reentrant Corners:

Plan configurations of a structure and its lateral force-resisting system contain reentrant corners, where both projections of the structure beyond a reentrant corner are greater than 15 percent of the plan dimension of the structure in the given direction.

There is no reentrant corner in this building.

DIAPHRAGM DISCONTINUITY CHECK:

Diaphragm Discontinuity:

Diaphragms with abrupt discontinuities or variations in stiffness, including those having cutout or open areas greater than 50 percent of the gross enclosed area of the diaphragm, or changes in effective diaphragm stiffness of more than 50 percent from one storey to the next.

There is no diaphragm irregularity in this building

51

OUT-OF-PLANE OFFSETS CHECK:

Out-of-plane Offsets:

Discontinuities in a lateral force path, such as out-of-plane offsets of the vertical elements.

There are no out-of-plane offsets of the vertical elements in this building.

NONPARALLEL SYSTEMS CHECK:

Nonparallel Systems:

The vertical lateral load-resisting elements are not parallel to or symmetric about the major orthogonal axes of the lateral force-resisting system.

There are no non parallel lateral load resisting elements.

52

C2. Column adequacy check

Column layout plan from model snap shot is shown in Figure C-2: Results has been shown based on model grid. Assessment of columns (P-M-M Interaction Ratio) considering prescribed live load. According to standard practice, column with P-M-M value greater than 1.0 is considered as inadequate

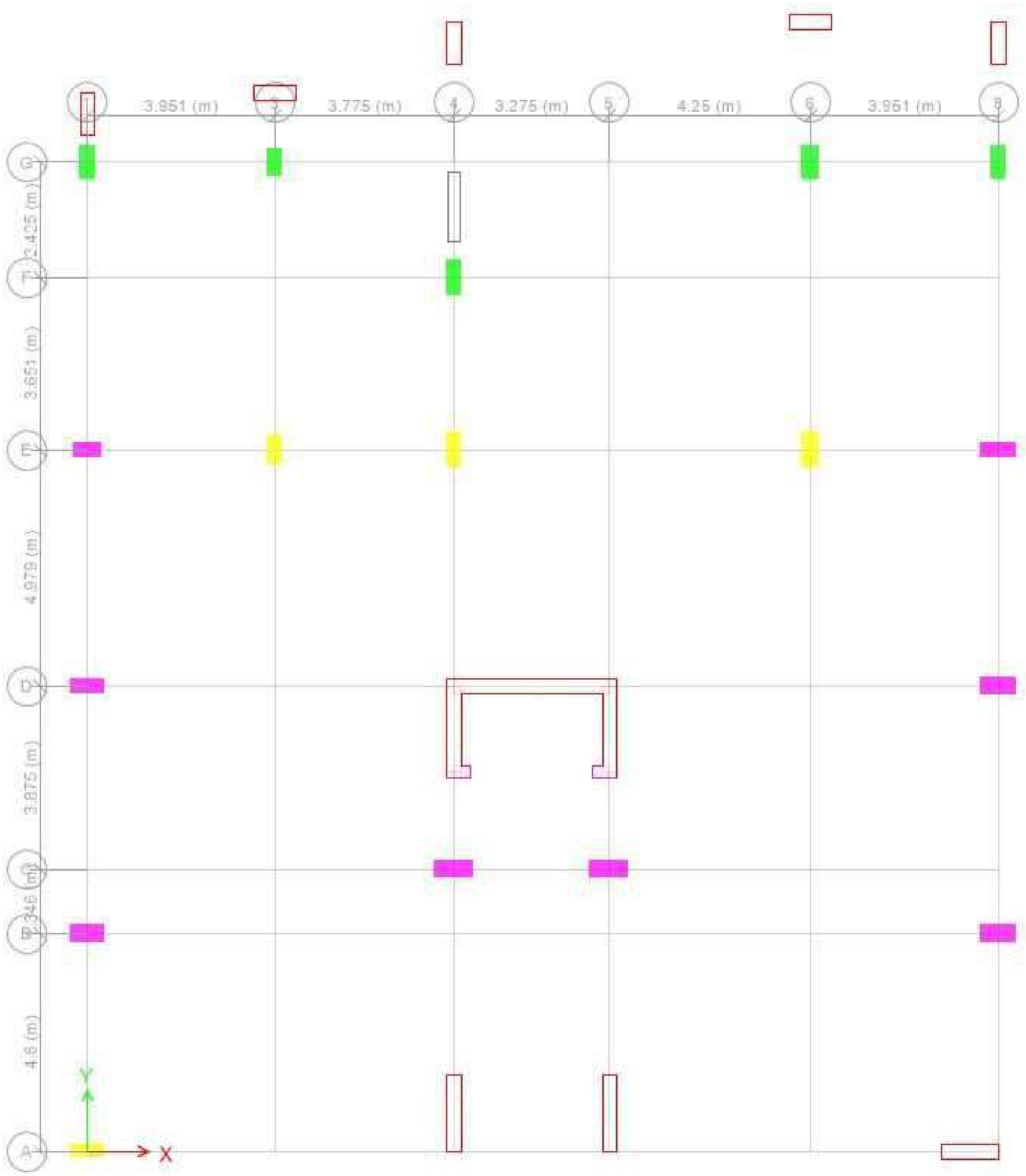


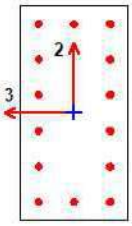
Figure C-2: Column Layout Plan from Model Snapshot.

53

ETABS 2016 Concrete Frame Design

ACI 318-08 Column Section Design

C2 Type Column Grid D-1 at third floor



Column Element Details (Flexural Details) (Part 1 of 2)

Level	Element	Unique Name	Section ID	Combo ID	Station Loc	Length (mm)
3F	C6	265	C2-300x750 2ND TO 4TH	9. 1.2DL+LL-EX+0.3EY+EV	0	3000

Column Element Details (Flexural Details) (Part 2 of 2)

LLRF	Type
0.443	Sway Intermediate

Section Properties

b (mm)	h (mm)	dc (mm)	Cover (Torsion) (mm)
300	750	62.5	27.3

Material Properties

E_c (MPa)	f'_c (MPa)	Lt.Wt Factor (Unitless)	f_y (MPa)	f_{ys} (MPa)
26363.32	31.03	1	414	413.69

Design Code Parameters

Φ_T	Φ_{CTied}	$\Phi_{CSpiral}$	Φ_{Vns}	Φ_{Vs}	Φ_{Vjoint}
0.9	0.65	0.75	0.75	0.6	0.85

Axial Force and Biaxial Moment Design For P_u , M_{u2} , M_{u3}

Design P_u kN	Design M_{u2} kN-m	Design M_{u3} kN-m	Minimum M_2 kN-m	Minimum M_3 kN-m	Rebar % %	Capacity Ratio Unitless
2707.3593	112.5989	-251.8134	65.6264	102.1757	3.06	0.844

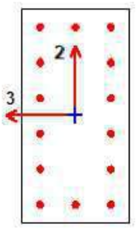
Factored & Minimum Biaxial Moments

	NonSway M_{ns} kN-m	Sway M_s kN-m	Factored M_u kN-m	Minimum M_{min} kN-m	Minimum Eccentricity mm
Major Bending(M_{u3})	-106.3364	-145.477	-251.8134	102.1757	37.7
Minor Bending(M_{u2})	10.8071	101.7918	112.5989	65.6264	24.2

Axial Force and Biaxial Moment Factors

	C_m Factor Unitless	δ_{ns} Factor Unitless	δ_s Factor Unitless	K Factor Unitless	Effective Length mm
Major Bend(M3)	0.422675	1	1	1	2400
Minor Bend(M2)	0.366468	1	1	1	2400

54



Column Element Details (Shear Details) (Part 1 of 2)

Level	Element	Unique Name	Section ID	Combo ID	Station Loc	Length (mm)
3F	C6	265	C2-300x750 2ND TO 4TH	9. 1.2DL+LL-EX+0.3EY+EV	0	3000

Column Element Details (Shear Details) (Part 2 of 2)

LLRF	Type
0.443	Sway Intermediate

Section Properties

b (mm)	h (mm)	dc (mm)	Cover (Torsion) (mm)
300	750	62.5	27.3

Material Properties

E_c (MPa)	f'_c (MPa)	Lt.Wt Factor (Unitless)	f_y (MPa)	f_{ys} (MPa)
26363.32	31.03	1	414	413.69

Design Code Parameters

Φ_T	Φ_{CTied}	$\Phi_{CSpiral}$	Φ_{Vns}	Φ_{Vs}	Φ_{Vjoint}
0.9	0.65	0.75	0.75	0.6	0.85

Shear Design for V_{u2}, V_{u3}

	Rebar A_v /s mm²/m	Design V_u kN	Design P_u kN	Design M_u kN-m	ΦV_c kN	ΦV_s kN	ΦV_n kN
Major Shear(V2)	251.56	151.4356	2707.3593	-251.8134	267.9512	53.659	321.6102
Minor Shear(V3)	0	92.6529	2707.3593	112.5989	231.413	0	231.413

Design Forces (Part 1 of 2)

	Factored V_u kN	Factored P_u kN	Factored M_u kN-m	Factored V_{u*} kN	Factored P_{u*} kN	Factored M_{u*} kN-m
Major Shear(V2)	151.4356	2707.3593	-251.8134	222.8918	2707.3593	-397.2904
Minor Shear(V3)	74.3072	2707.3593	112.5989	141.4842	2707.3593	214.3907

Design Forces (Part 2 of 2)

Capacity V_p kN
125.0861
92.6529

Capacity Shear (Part 1 of 2)

55

	Shear V_p kN	Long.Rebar $A_{s(Bot)}$ %	Long.Rebar $A_{s(Top)}$ %	Cap.Moment M_{posBot} kN-m
Major Shear(V2)	125.0861	3.06	3.06	1025.2834
Minor Shear(V3)	92.6529	3.06	3.06	381.512

Capacity Shear (Part 2 of 2)

Cap.Moment M_{negTop} kN-m	Cap.Moment M_{negBot} kN-m	Cap.Moment M_{posTop} kN-m
1025.2834	1025.2834	1025.2834
381.512	381.512	381.512

Design Basis

Shr Reduc Factor Unitless	Strength f_{ys} MPa	Strength f_{cs} MPa	Area A_g cm²
1	413.69	31.03	2250

Concrete Shear Capacity

	Design V_u kN	Conc.Area A_{cu} cm²	Tensn.Rein A_{st} mm²
Major Shear(V2)	151.4356	2062.5	3437
Minor Shear(V3)	92.6529	1781.3	3437

Shear Rebar Design

	Stress v MPa	Conc.Cpcty v_c MPa	Uppr.Limit v_{max} MPa	Φv_c MPa	Φv_{max} MPa	RebarArea A_v /s mm²/m
Major Shear(V2)	0.73	1.73	5.43	1.3	4.07	251.56
Minor Shear(V3)	0.52	1.73	5.43	1.3	4.07	0

56

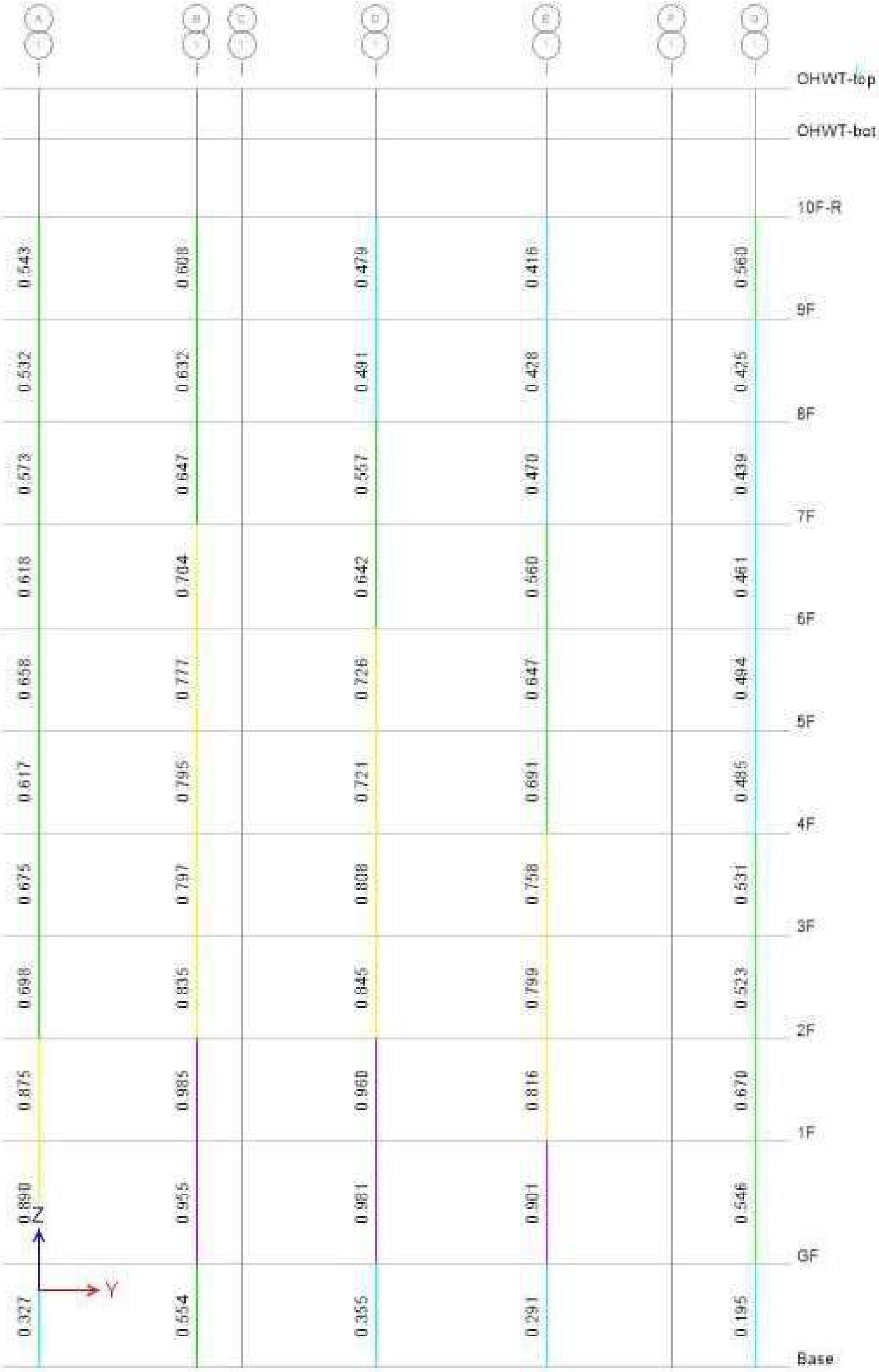


Figure C-3: Condition of Column in Grid 1

Figure C-4: Condition of Column in Grid 3

58

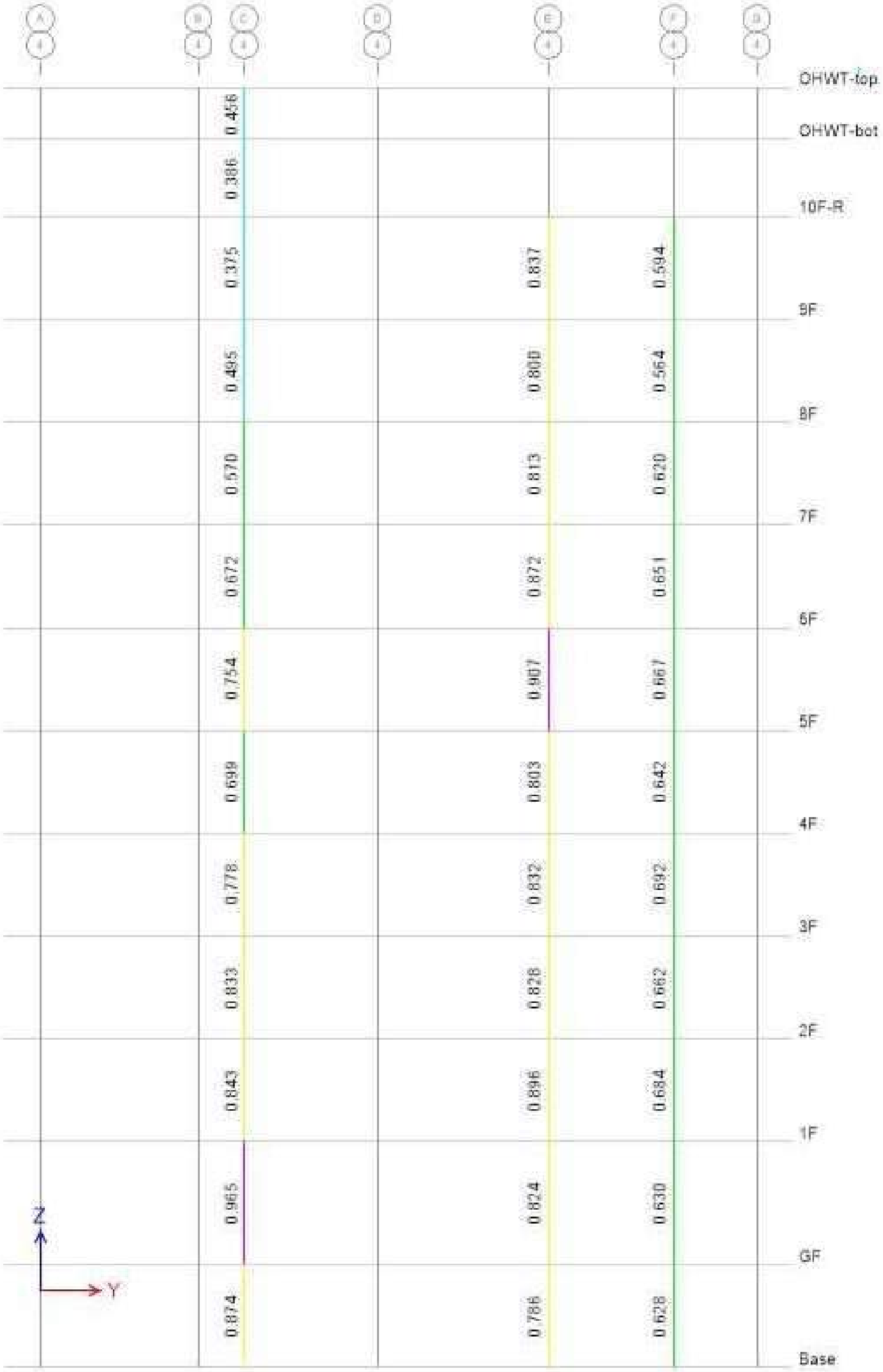


Figure C-5: Condition of Column in Grid 4

59

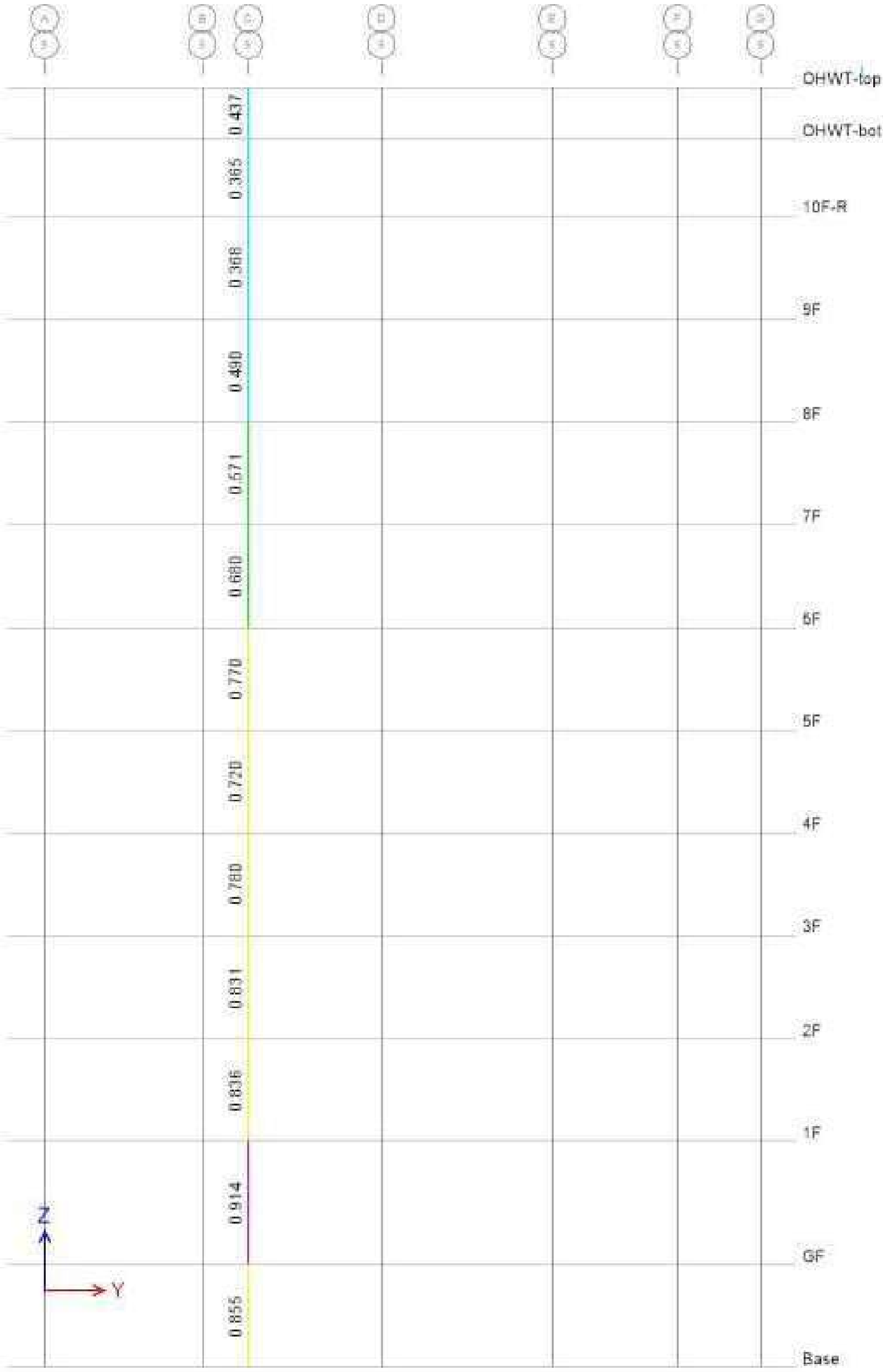


Figure C-6: Condition of Column in Grid 5

60

Figure C-7: Condition of Column in Grid 6

61

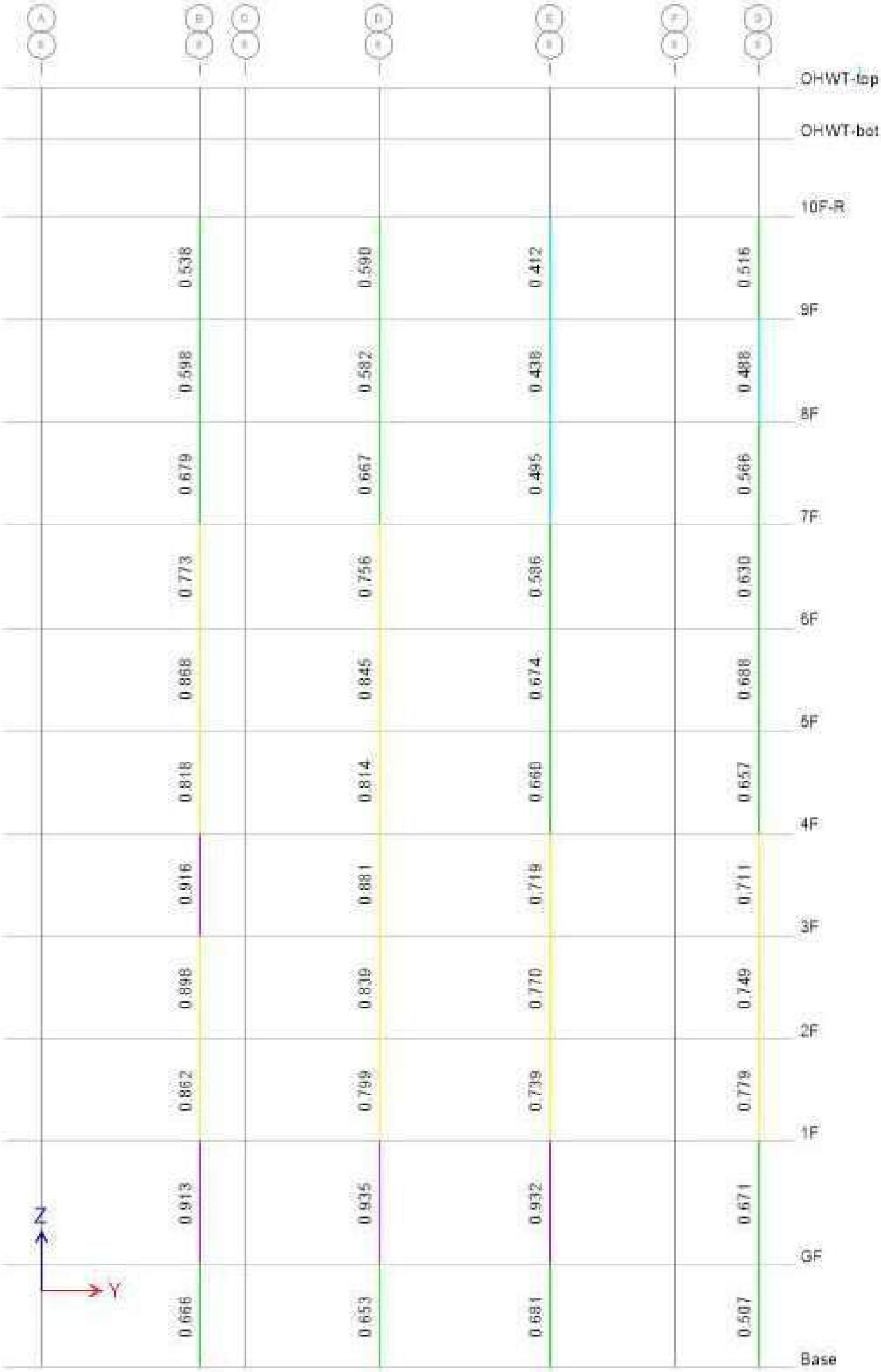


Figure C-8: Condition of Column in Grid 8

All the columns pmm ratio is less than 1.0

62

C.3 Shear Wall Adequacy Check

Following figures represent the condition of shear wall according to prescribed live loading. Represented Figures are showing required reinforcements. Required reinforcement > Provided Reinforcement denotes inadequacy.

ETABS 2016 Shear Wall Design

ACI 318-08 Pier Design

SW1 Grid 4

Pier Details

Story ID	Pier ID	Centroid X (mm)	Centroid Y (mm)	Length (mm)	Thickness (mm)	LLRF
1F	P11	7726	812.3	1624.6	304.8	0.485

Material Properties

E_c (MPa)	f'_c (MPa)	Lt.Wt Factor (Unitless)	f_y (MPa)	f_{ys} (MPa)
26363.32	31.03	1	413.69	413.69

Design Code Parameters

Φ_T	Φ_C	Φ_v	Φ_v (Seismic)	IP_{MAX}	IP_{MIN}	P_{MAX}
0.9	0.65	0.75	0.65	0.04	0.0025	0.8

Pier Leg Location, Length and Thickness

Station Location	ID	Left X_1 mm	Left Y_1 mm	Right X_2 mm	Right Y_2 mm	Length mm	Thickness mm
Top	Leg 1	7726	0	7726	1624.6	1624.6	304.8
Bottom	Leg 1	7726	0	7726	1624.6	1624.6	304.8

Flexural Design for P_u, M_{u2} and M_{u3} (Part 1 of 2)

Station Location	Required Rebar Area (mm²)	Required Reinf Ratio	Current Reinf Ratio	Flexural Combo	P_u kN	M_{u2} kN-m
Top	1238	0.0025	0.0032	17D. 0.9DL-RSY-0.3RSX+EV-	1748.3001	37.3689
Bottom	4019	0.0081	0.0032	16. 0.9DL+EY+0.3EX+EV-	650.9384	-110.8294

Flexural Design for P_u, M_{u2} and M_{u3} (Part 2 of 2)

M_{u3} kN-m	Pier A_g mm²
55.3075	495173
1327.1105	495173

Shear Design

Station Location	ID	Rebar mm²/m	Shear Combo	P_u kN	M_u kN-m	V_u kN	ΦV_c kN	ΦV_n kN
Top	Leg 1	762	11. 1.2DL+LL-EY+0.3EX+EV	4271.0937	139.697	478.7006	297.7322	630.6069
Bottom	Leg 1	762	11. 1.2DL+LL-EY+0.3EX+EV	4325.225	-1582.0168	478.7006	297.7322	630.6069

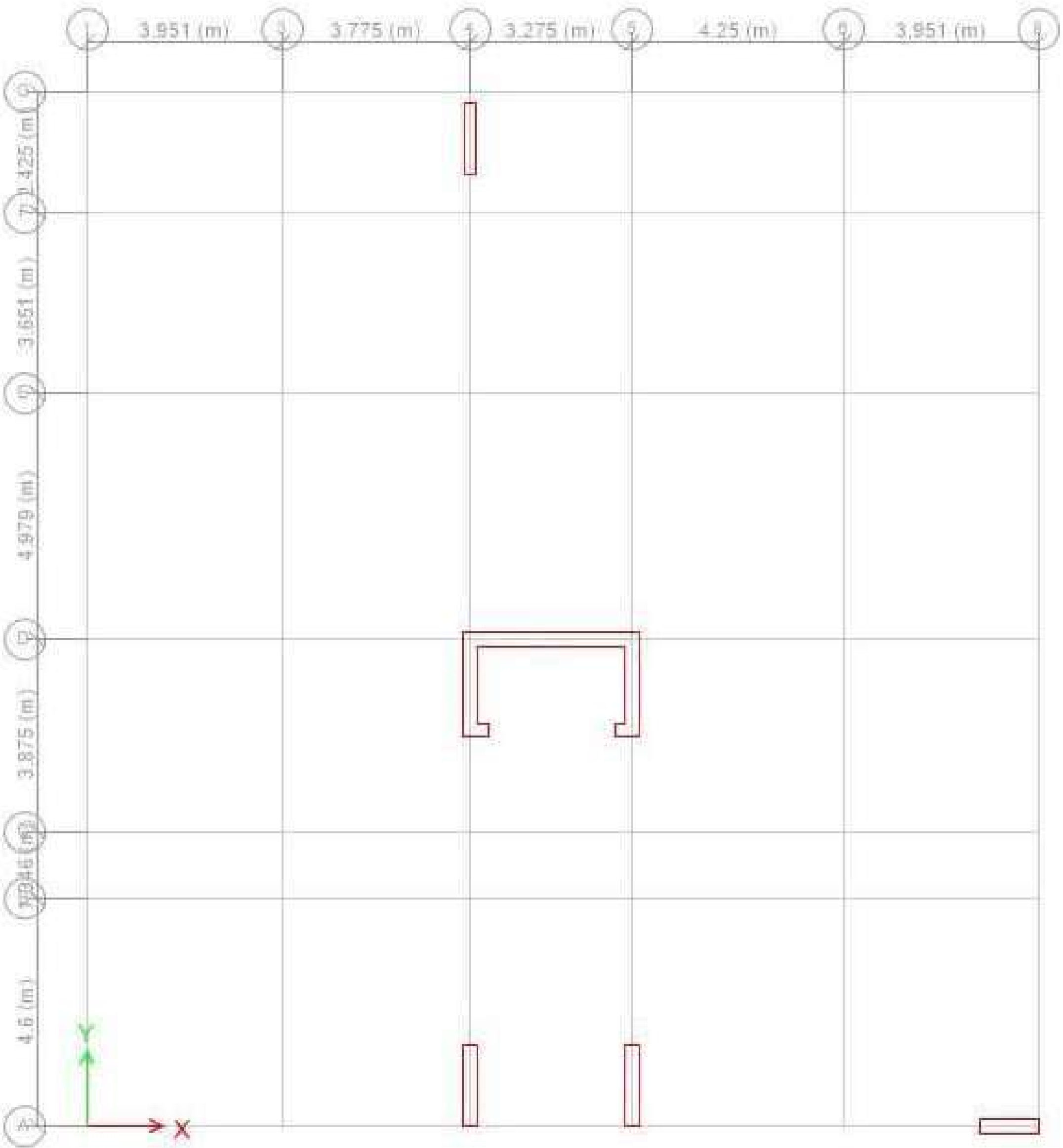
Boundary Element Check (ACI 21.9.6.3, 21.9.6.4) (Part 1 of 2)

Station Location	ID	Edge Length (mm)	Governing Combo	P_u kN	M_u kN-m	Stress Comp MPa
Top–Left	Leg 1	Not Required	10. 1.2DL+LL+EY+0.3EX+EV	1872.4209	13.182	3.68
Top–Right	Leg 1	816.9	10. 1.2DL+LL+EY+0.3EX+EV	4271.0937	139.697	9.67
Bottom–Left	Leg 1	828.5	11. 1.2DL+LL-EY+0.3EX+EV	4325.225	-1582.0168	20.53

Station Location	ID	Edge Length (mm)	Governing Combo	P_u kN	M_u kN-m	Stress Comp MPa
Botttom−Right	Leg 1	324.8	11. 1.2DL+LL-EY+0.3EX+EV	2730.3998	260.9885	7.46

Boundary Element Check (ACI 21.9.6.3, 21.9.6.4) (Part 2 of 2)

Stress Limit MPa	C Depth mm	C Limit mm
6.21	354.7	343
6.21	979.3	327.8
6.21	991	327.8
6.21	487.3	386.8



64

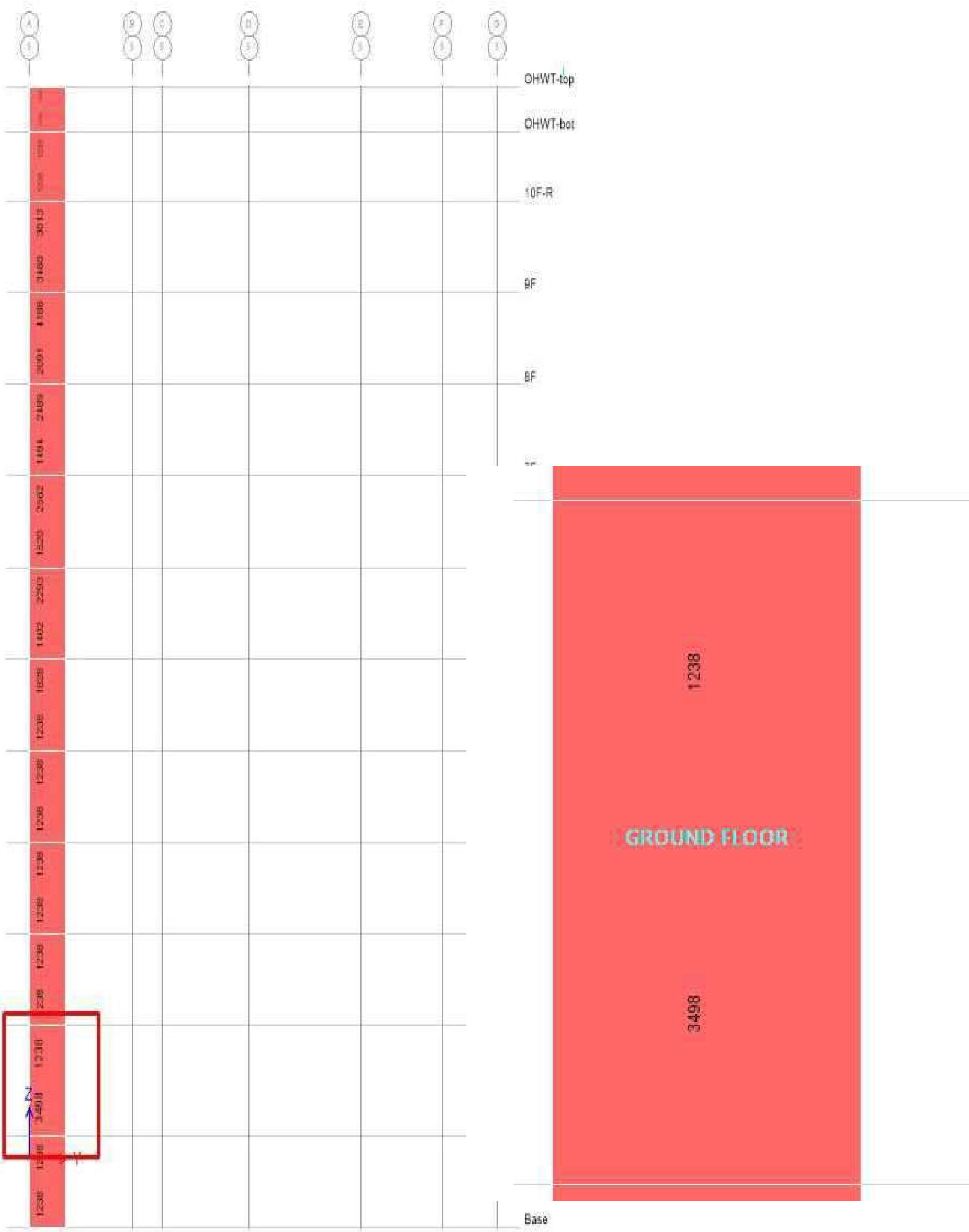


Figure C-9: Reinforcement of SW-1 in Grid 5 (mm^2)

65

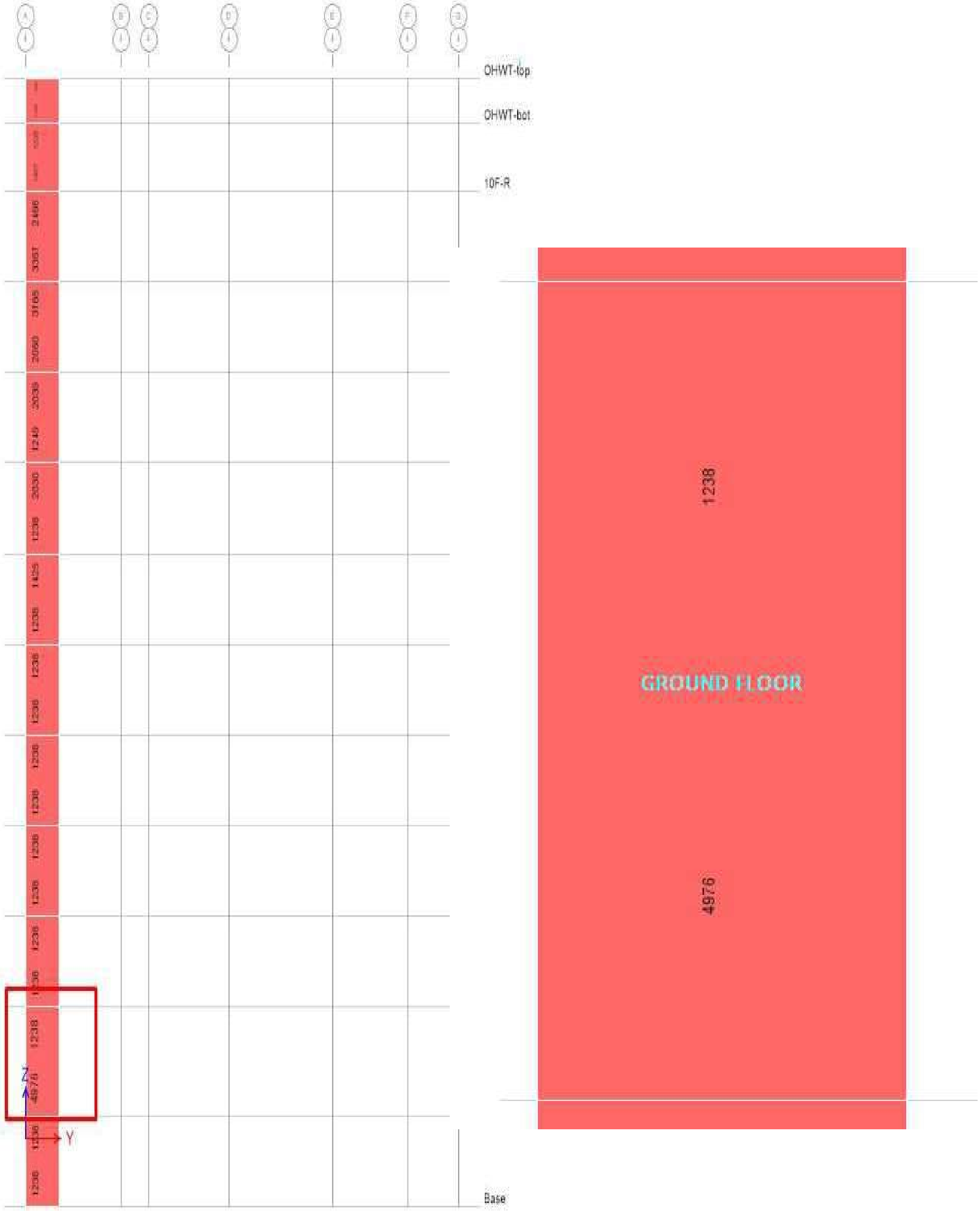


Figure C-10: Reinforcement of SW-1 in Grid 4 (mm^2)

66

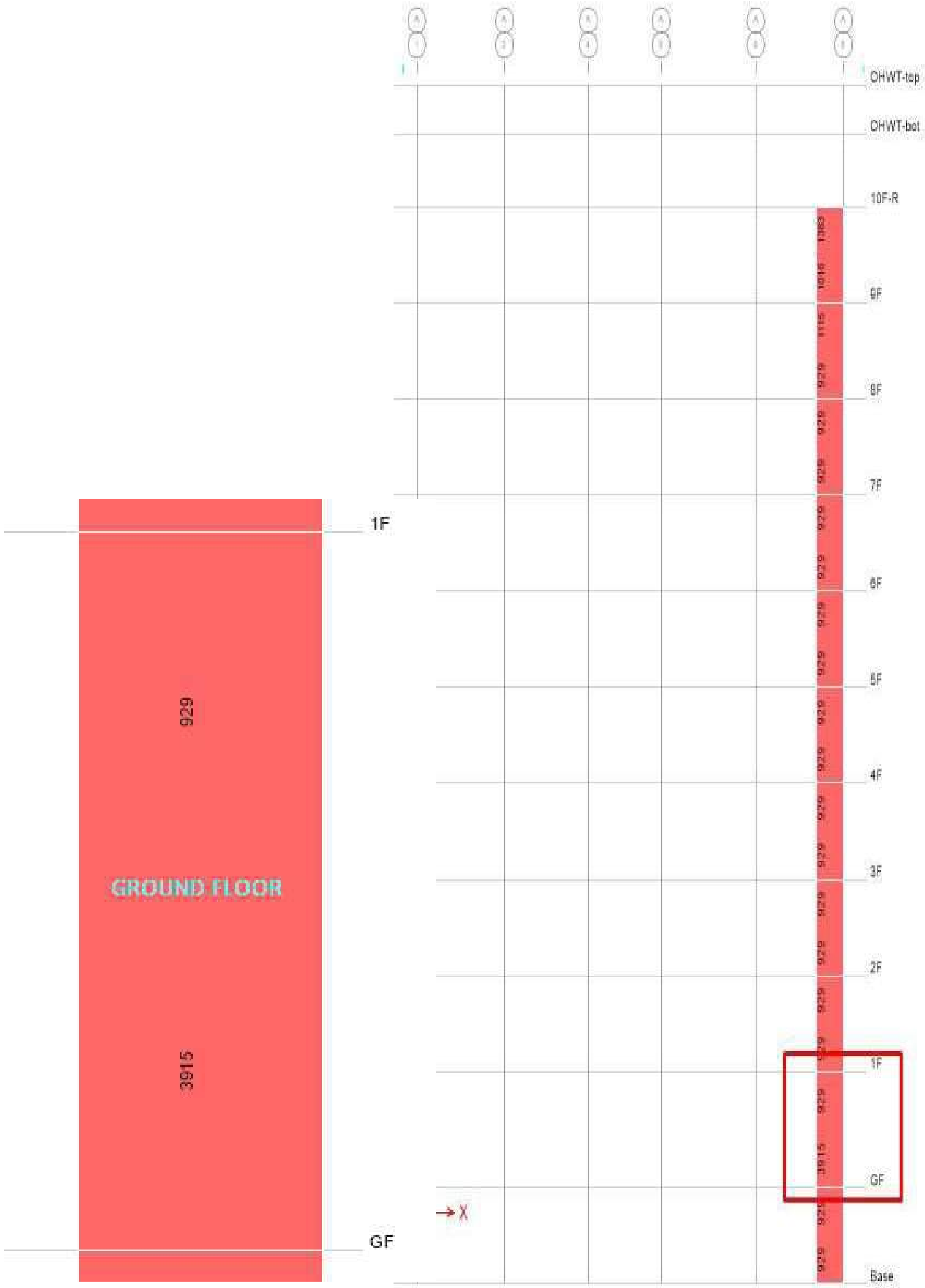


Figure C-11: Reinforcement of SW-2 in Grid A (mm^2)

67

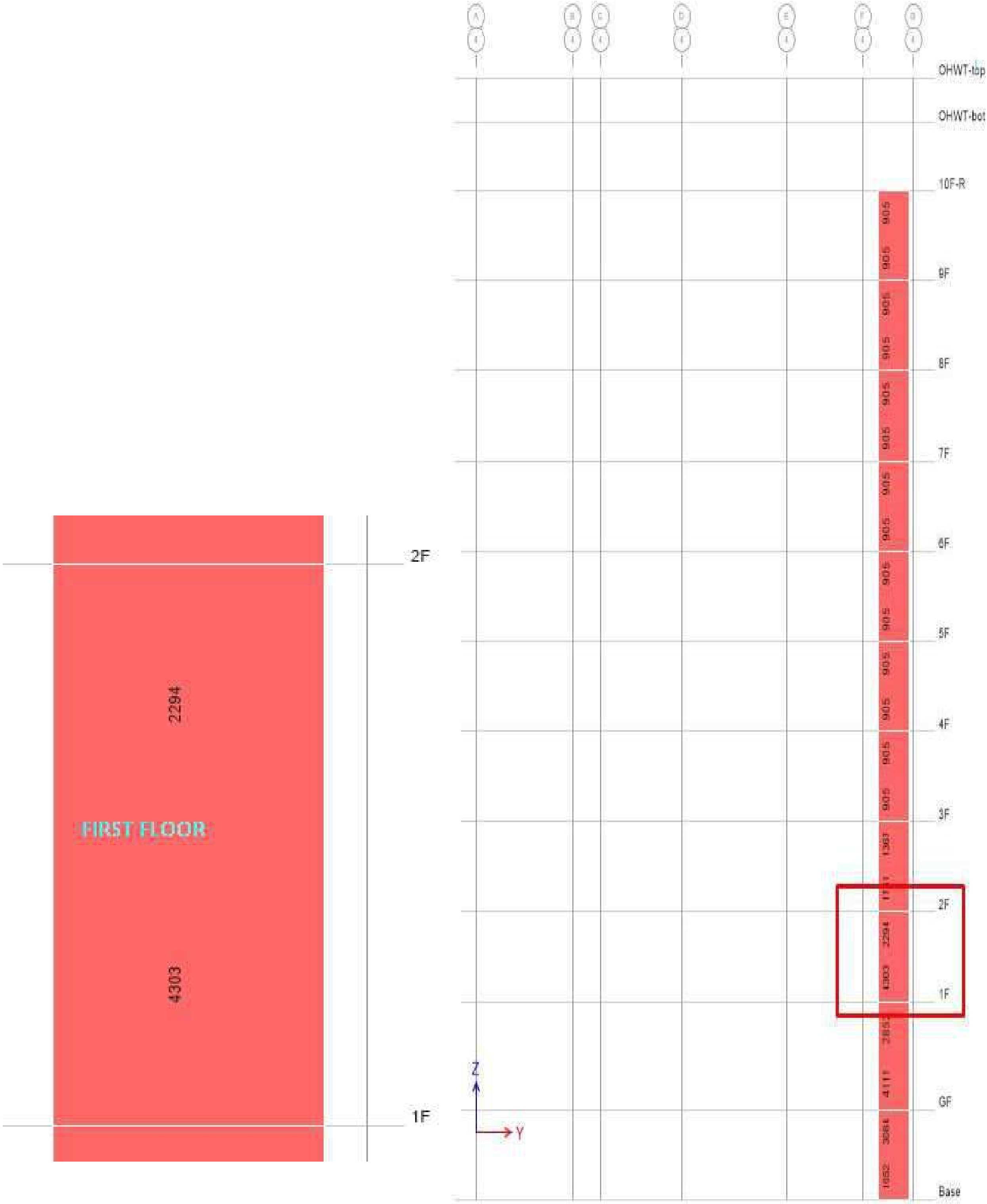


Figure C-12: Reinforcement of SW-3 in Grid 4 (mm^2)

68

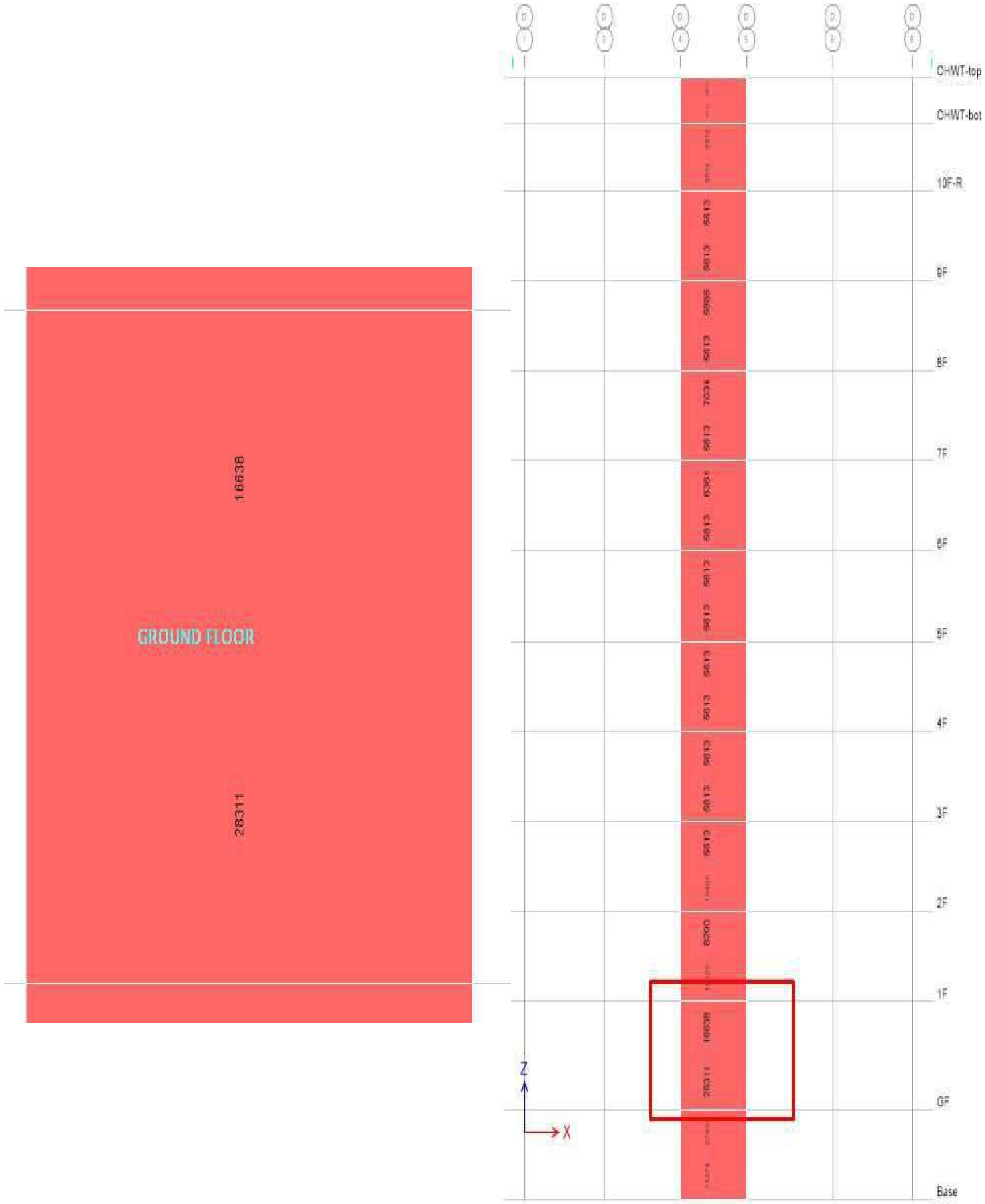


Figure C-13: Reinforcement of Lift Wall in Grid D (mm^2)

69

Table C1: Reinforcement Check of Shear Walls

Shear Wall	Longitudinal Reinforcement (mm^2)			Drawing no.
	Required (Etabs)	Provided (Drawing)	Remarks	
SW-1	4976 (GF)	8616	Adequate	S-15
SW-2	3915 (GF)	7536	Adequate	S-15
SW-3	4303 (1^{ST})	8792	Adequate	S-15
Lift	28311	33964	Adequate	S-16

SW-1 = 26-20+4-12 = 26*314+ 4*113 = 8616 mm^2 (Structural drawing S-15)

SW-2 = 24-20 = 24*314 = 7536 mm^2 (Structural drawing S-15)

SW-3 = 28-20 = 28*314 = 8792 mm^2 (Structural drawing S-15)

Lift = 80-20 + 44-16 = 80*314 + 44*201 = 33964 mm^2 (Structural drawing S-16)

ZOOM VIEW OF SW-1

70

C.4 Ground Floor Beam Adequacy Check

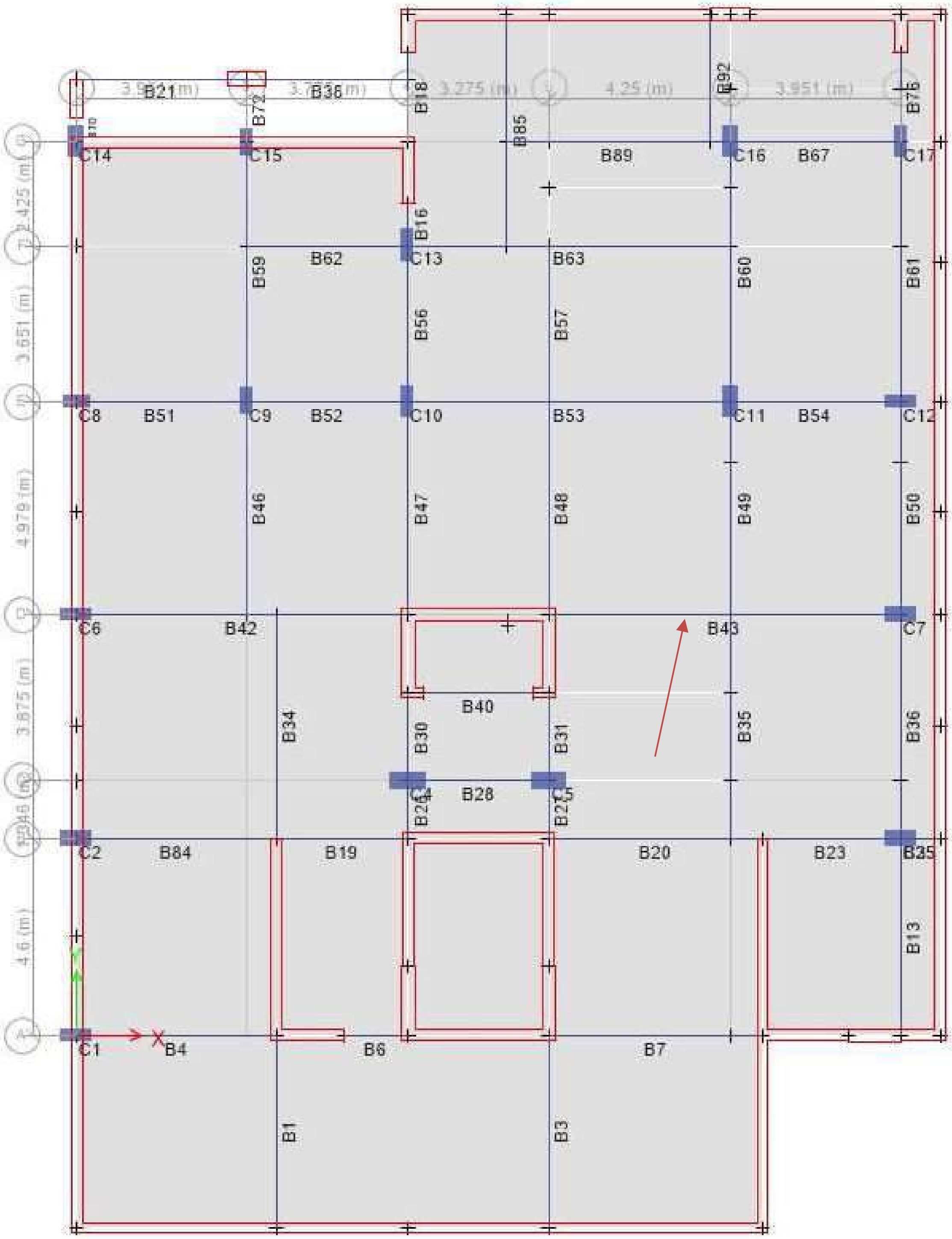


Figure C-14: Beam number layout

71

ETABS 2016 Concrete Frame Design

ACI 318-08 Beam Section Design

G.F.B-6 (300X500)

Beam Element Details (Envelope)

Level	Element	Unique Name	Section ID	Length (mm)	LLRF	Type
GF	B43	192	GFB-6(300X500)	8201	0.936	Sway Intermediate

Section Properties

b (mm)	h (mm)	b_f (mm)	d_s (mm)	d_{ct} (mm)	d_{cb} (mm)
300	500	300	0	76.2	76.2

Material Properties

E_c (MPa)	f'_c (MPa)	Lt.Wt Factor (Unitless)	f_y (MPa)	f_{ys} (MPa)
23250.27	24.13	1	414	413.69

Design Code Parameters

Φ_T	Φ_{CTied}	$\Phi_{CSpiral}$	Φ_{Vns}	Φ_{Vs}	Φ_{Vjoint}
0.9	0.65	0.75	0.75	0.6	0.85

Flexural Reinforcement for Major Axis Moment, M_{u3}

	End-I Rebar Area mm²	End-I Rebar %	Middle Rebar Area mm²	Middle Rebar %	End-J Rebar Area mm²	End-J Rebar %
Top (+2 Axis)	1583	1.06	377	0.25	1081	0.72
Bot (-2 Axis)	479	0.32	1076	0.72	463	0.31

Flexural Design Moment, M_{u3} (Part 1 of 2)

	End-I Design M_u kN-m	End-I Station Loc mm	Middle Design M_u kN-m	Middle Station Loc mm
Top (+2 Axis)	-218.5007	0	-43.7001	5648.7
Combo	9A. 1.2DL+LL-EX-0.3EY+EV		9A. 1.2DL+LL-EX-0.3EY+EV	
Bot (-2 Axis)	72.8336	0	155.3671	4250
Combo	9A. 1.2DL+LL-EX-0.3EY+EV		2. 1.2DL+1.6LL+0.5LR	

Flexural Design Moment, M_{u3} (Part 2 of 2)

End-J Design M_u kN-m	End-J Station Loc mm
-156.08	7826
8A. 1.2DL+LL+EX-0.3EY+EV	
70.4086	6059.7
2. 1.2DL+1.6LL+0.5LR	

Shear Reinforcement for Major Shear, V_{u2}

End-I Rebar A_v /s mm²/m	Middle Rebar A_v /s mm²/m	End-J Rebar A_v /s mm²/m
441.34	250	330.22

72

Design Shear Force for Major Shear, V_{u2} (Part 1 of 2)

End-I Design V_u kN	End-I Station Loc mm	Middle Design V_u kN	Middle Station Loc mm	End-J Design V_u kN
135.8223	0	0.0513	5648.7	121.2113
9A. 1.2DL+LL-EX-0.3EY+EV		11D. 1.2DL+LL-RSY-0.3RSX+EV		8A. 1.2DL+LL+EX-0.3EY+EV

Design Shear Force for Major Shear, V_{u2} (Part 2 of 2)

End-J Station Loc mm
7826

Torsion Reinforcement

Shear Rebar A_t /s mm²/m	Longitudinal Rebar A_l mm²
151.69	584

Design Torsion Force

Design T_u kN-m	Station Loc mm	Design T_u kN-m	Station Loc mm
6.9432	3187.5	6.6423	7826
10. 1.2DL+LL+EY+0.3EX+EV		10. 1.2DL+LL+EY+0.3EX+EV	

73

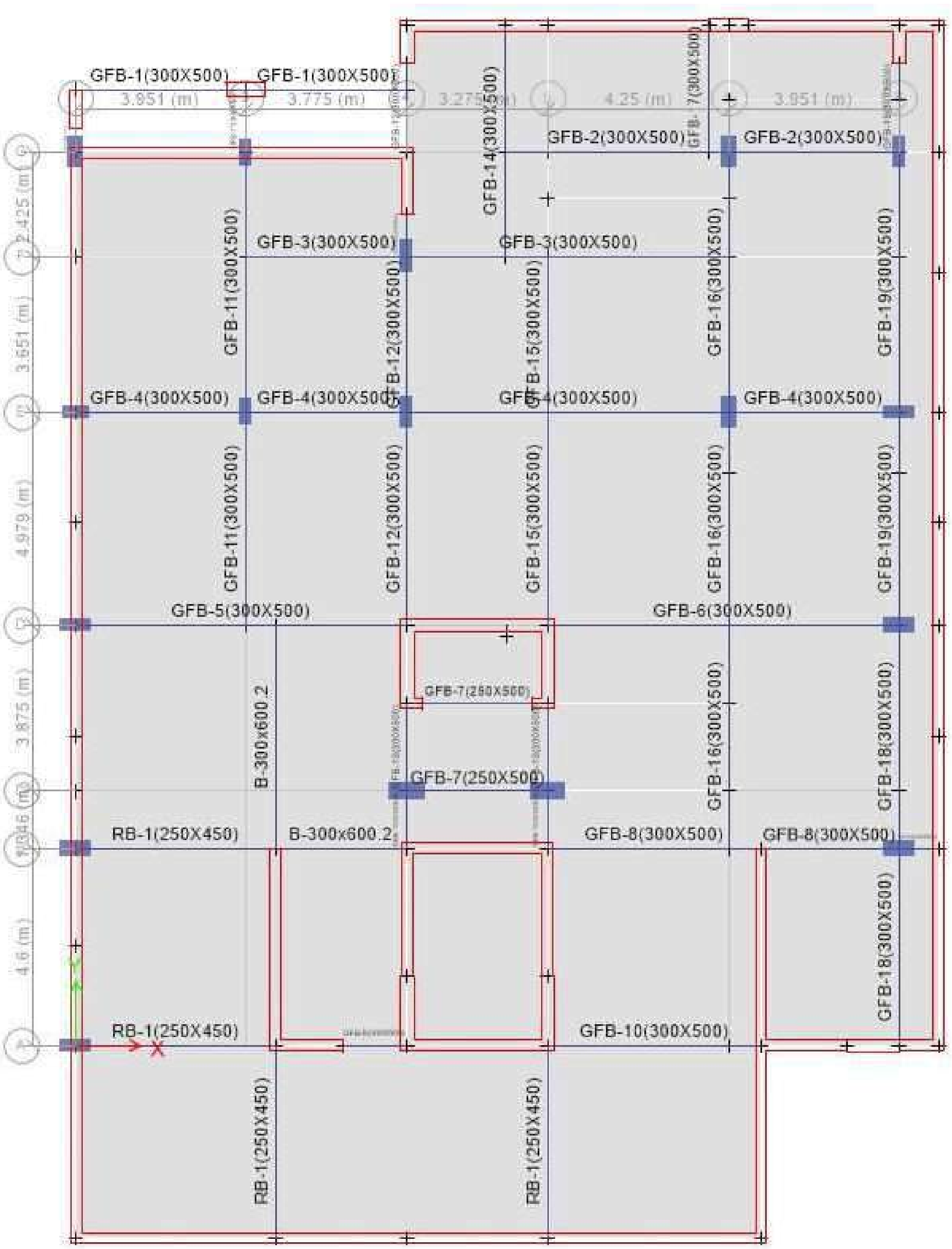


Figure C-15: Ground floor beam layout

74

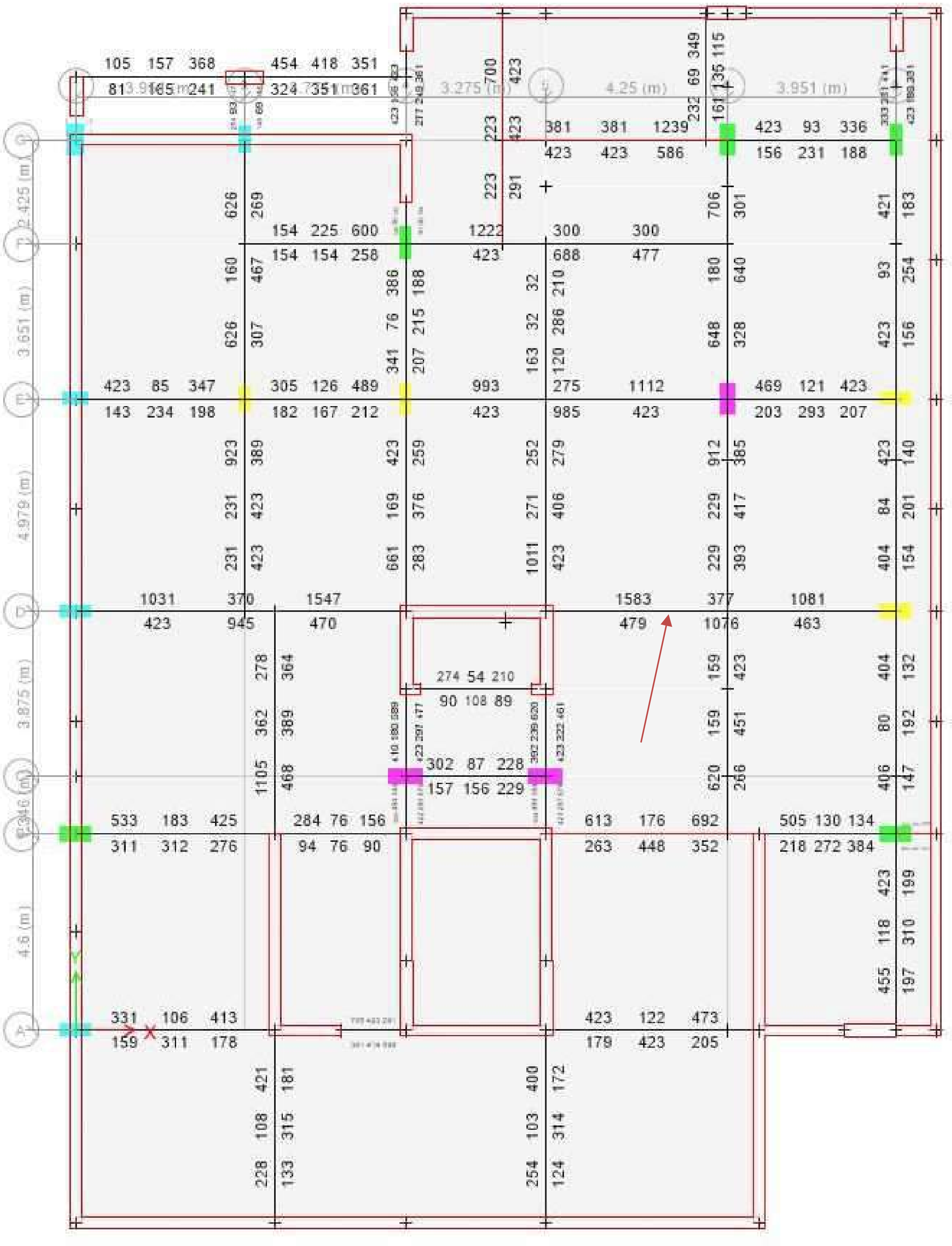


Figure C-16: Reinforcement of Ground Floor Beam (mm^2)

75

Table C2: Reinforcement Check of Ground Floor Beam

Beam ID	Beam Size (mm)	Required Reinforcement(mm^2) Output from etabs		Provided Reinforcement(mm^2) From drawing		Remarks
		Top	Bottom	Top	Bottom	
G.F.B-1	300 x 500	391	204	716	603	Adequate
G.F.B-2	300 x 500	1334	544	1344	603	Adequate
G.F.B-3	300 x 500	1231	685	1570	942	Adequate
G.F.B-4	300 x 500	1110	984	1658	1545	Adequate
G.F.B-5	300 x 500	1551	138	1570	1344	Adequate
G.F.B-6	300 x 500	1583	1076	1884	1344	Adequate
G.F.B-7	250 x 500	306	232	1570	1570	Adequate
G.F.B-8	300 x 500	1099	572	1884	1570	Adequate
G.F.B-9	300 x 500	423	609	628	942	Adequate
G.F.B-10	300 x 500	475	423	942	942	Adequate
G.F.B-11	300 x 500	925	498	1344	942	Adequate
G.F.B-12	300 x 500	966	676	1118	942	Adequate
G.F.B-13	300 x 500	1046	687	1884	1344	Adequate
G.F.B-14	300 x 500	708	423	1884	942	Adequate
G.F.B-15	300 x 500	1014	423	1344	603	Adequate
G.F.B-16	300 x 500	917	639	942	942	Adequate
G.F.B-17	300 x 500	352	166	942	942	Adequate
G.F.B-18	300 x 500	459	310	1118	716	Adequate
G.F.B-19	300 x 500	458	423	1118	716	Adequate

Note: This table has been revised

C.5 Floor Beam Adequacy Check

Following figures represent the condition of floor beams according to prescribed live loading. Represented Figures are showing required reinforcements. Required reinforcement > Provided Reinforcement denotes inadequacy.

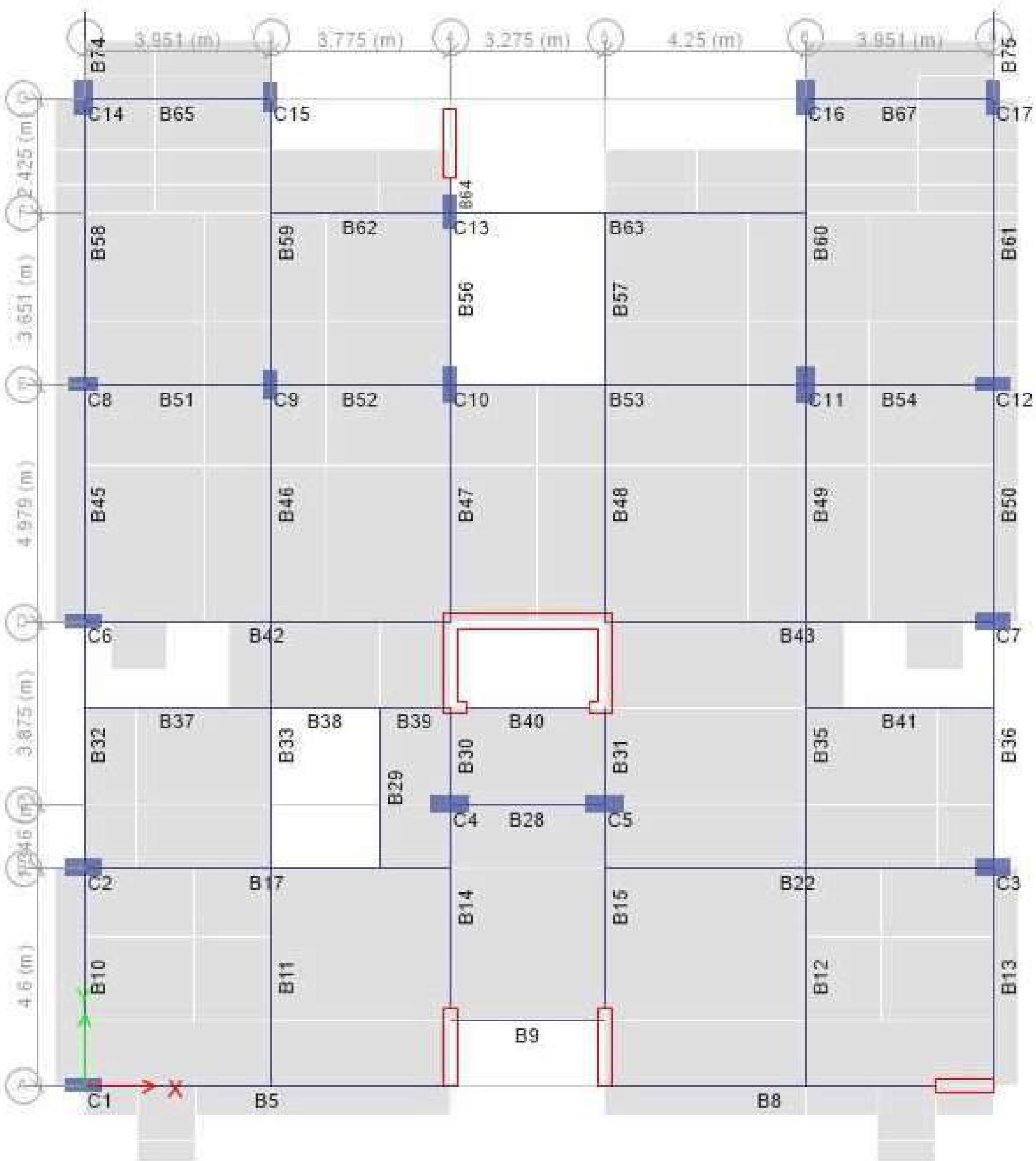


Figure C-17: Beam number layout

77

ETABS 2016 Concrete Frame Design

ACI 318-08 Beam Section Design

1st Floor Beam F.B-4 (300X600)

Beam Element Details (Envelope)

Level	Element	Unique Name	Section ID	Length (mm)	LLRF	Type
1F	B53	125	FB-4 (300X600)	7525	0.963	Sway Intermediate

Section Properties

b (mm)	h (mm)	b_f (mm)	d_s (mm)	d_{ct} (mm)	d_{cb} (mm)
300	600	300	0	76.2	76.2

Material Properties

E_c (MPa)	f'_c (MPa)	Lt.Wt Factor (Unitless)	f_y (MPa)	f_{ys} (MPa)
23250.27	24.13	1	414	413.69

Design Code Parameters

Φ_T	Φ_{CTied}	$\Phi_{CSpiral}$	Φ_{Vns}	Φ_{Vs}	Φ_{Vjoint}
0.9	0.65	0.75	0.75	0.6	0.85

Flexural Reinforcement for Major Axis Moment, M_{u3}

	End-I Rebar Area mm²	End-I Rebar %	Middle Rebar Area mm²	Middle Rebar %	End-J Rebar Area mm²	End-J Rebar %
Top (+2 Axis)	1489	0.83	427	0.24	1771	0.98
Bot (-2 Axis)	557	0.31	1236	0.69	542	0.3

Flexural Design Moment, M_{u3} (Part 1 of 2)

	End-I Design M_u kN-m	End-I Station Loc mm	Middle Design M_u kN-m	Middle Station Loc mm
Top (+2 Axis)	-262.778	150	-61.2629	5278.5
Combo	9. 1.2DL+LL-EX+0.3EY+EV		8. 1.2DL+LL+EX+0.3EY+EV	
Bot (-2 Axis)	104.9008	1837.1	222.0551	3275
Combo	2. 1.2DL+1.6LL+0.5LR		2. 1.2DL+1.6LL+0.5LR	

Flexural Design Moment, M_{u3} (Part 2 of 2)

End-J Design M_u kN-m	End-J Station Loc mm
-306.3144	7337.5
8. 1.2DL+LL+EX+0.3EY+EV	
102.1048	7337.5
8. 1.2DL+LL+EX+0.3EY+EV	

Shear Reinforcement for Major Shear, V_{u2}

End-I Rebar A_v /s mm²/m	Middle Rebar A_v /s mm²/m	End-J Rebar A_v /s mm²/m
736.56	437.76	835.94

78

Design Shear Force for Major Shear, V_{u2}

End-I Design V_u kN	End-I Station Loc mm	Middle Design V_u kN	Middle Station Loc mm	End-J Design V_u kN	End-J Station Loc mm
215.8484	150	0.1673	5278.5	232	7337.5
10A. 1.2DL+LL+EY-0.3EX+EV		8. 1.2DL+LL+EX+0.3EY+EV		8. 1.2DL+LL+EX+0.3EY+EV	

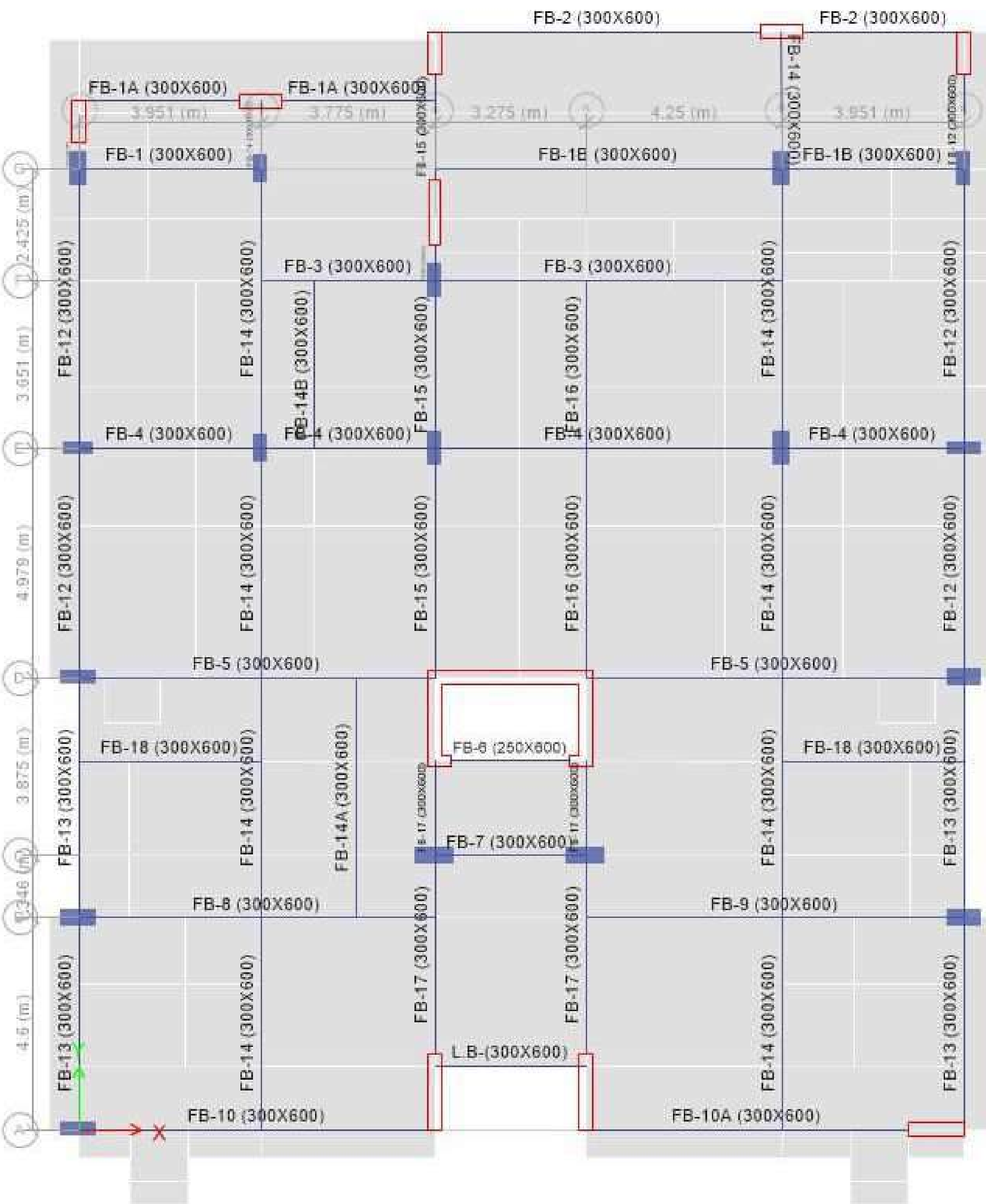
Torsion Reinforcement

Shear Rebar A_t /s mm^2/m	Longitudinal Rebar A_l mm^2
529.17	764

Design Torsion Force

Design T_u kN-m	Station Loc mm	Design T_u kN-m	Station Loc mm
30.1139	3275	30.1139	3275
11A. 1.2DL+LL-EY-0.3EX+EV		11A. 1.2DL+LL-EY-0.3EX+EV	

79



-18: 1st Floor Beam Layout

80

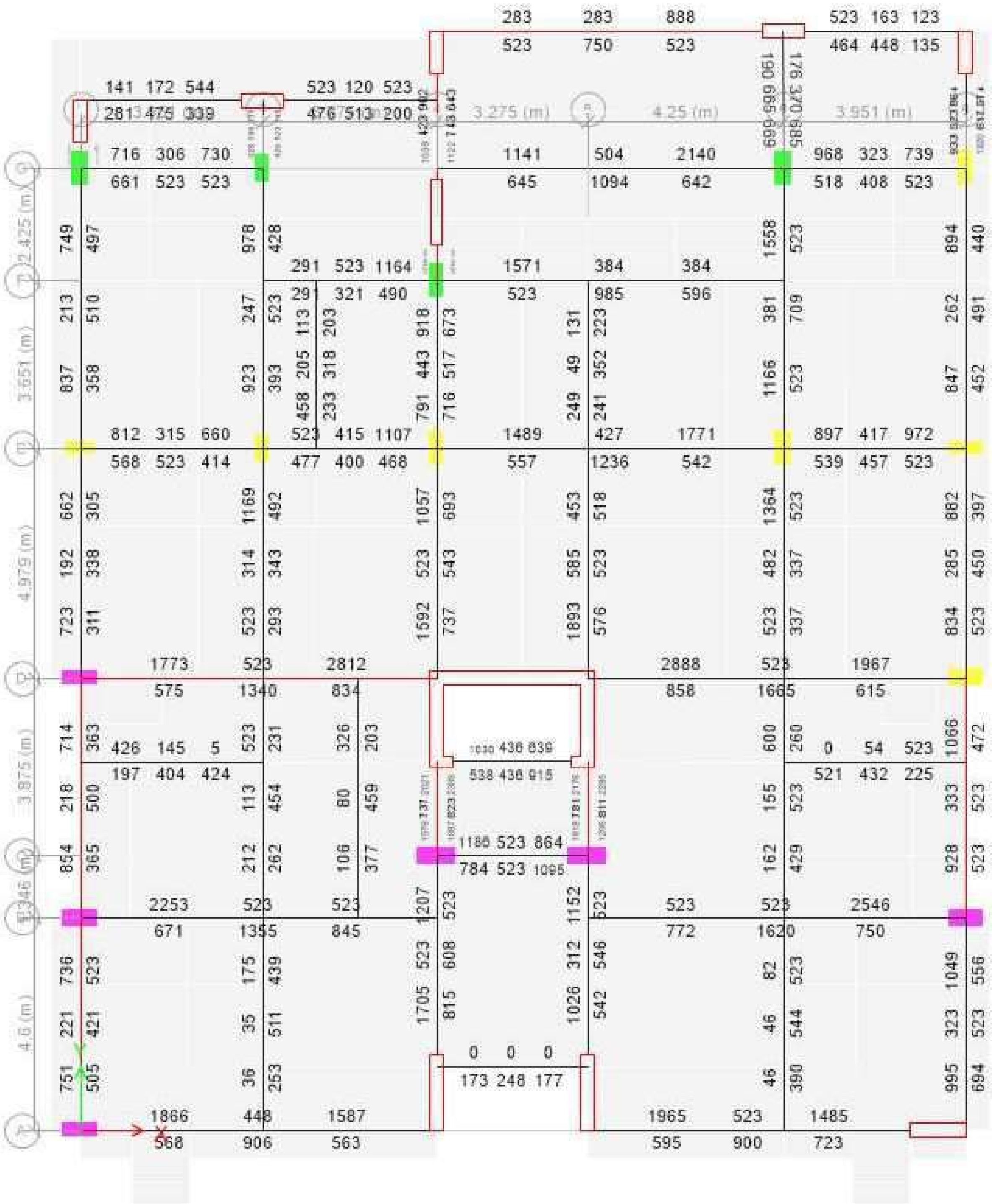


Figure C-19: Reinforcement of 1st Floor Beam (mm^2)

81

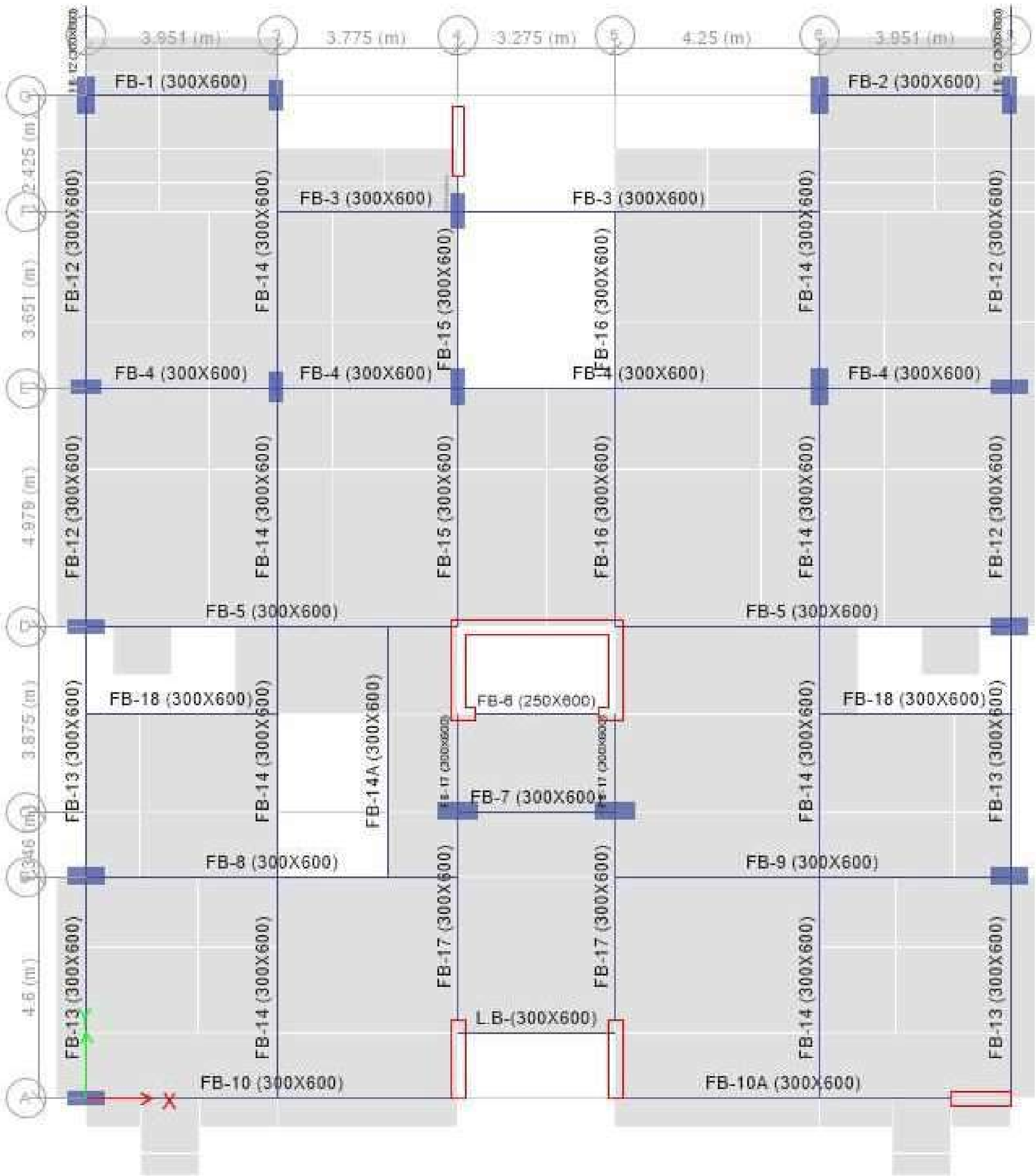


Figure C-20: 2nd Floor Beam Layout

82

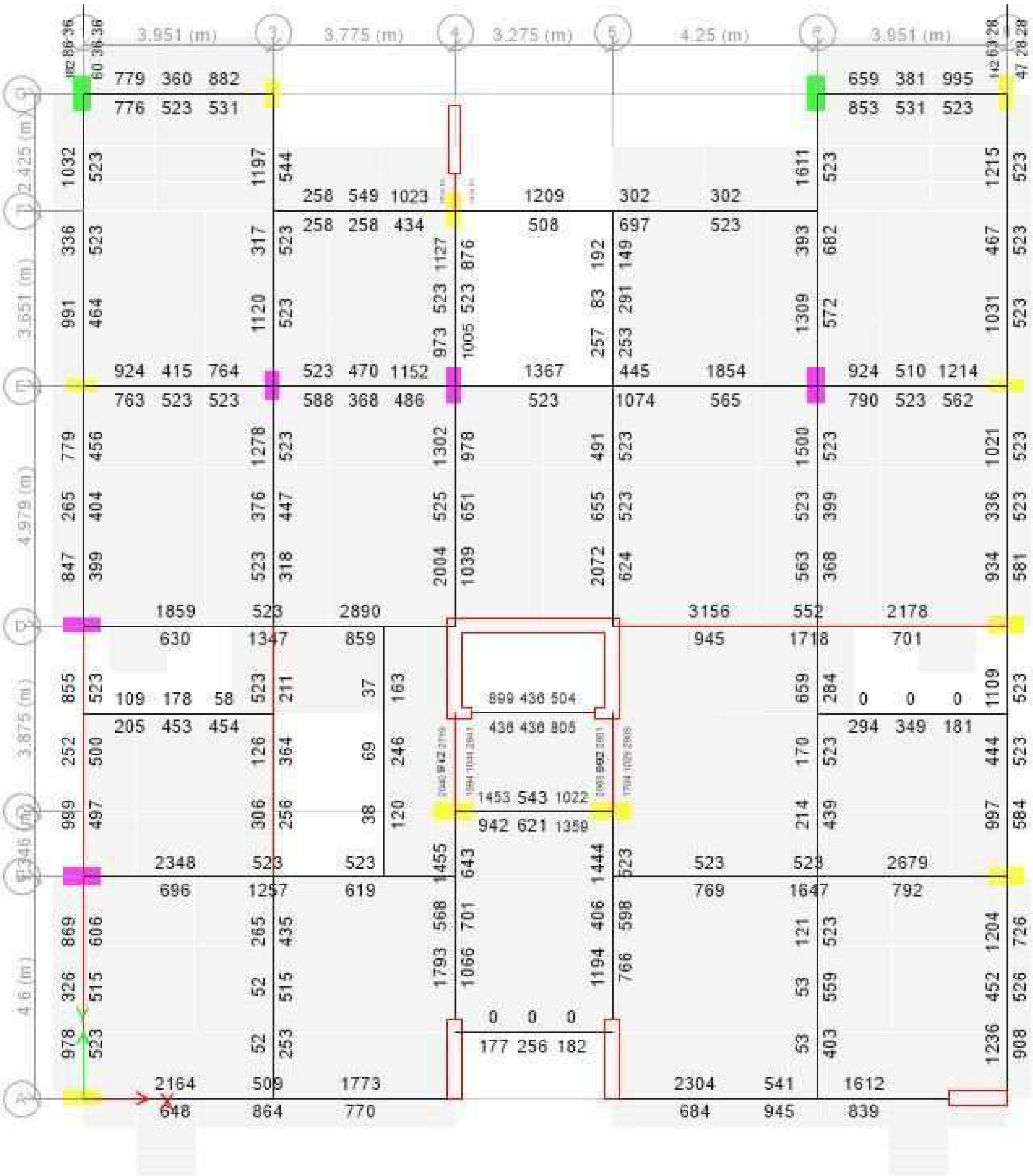


Figure C-21: Reinforcement of 2nd Floor Beam (mm^2)

83

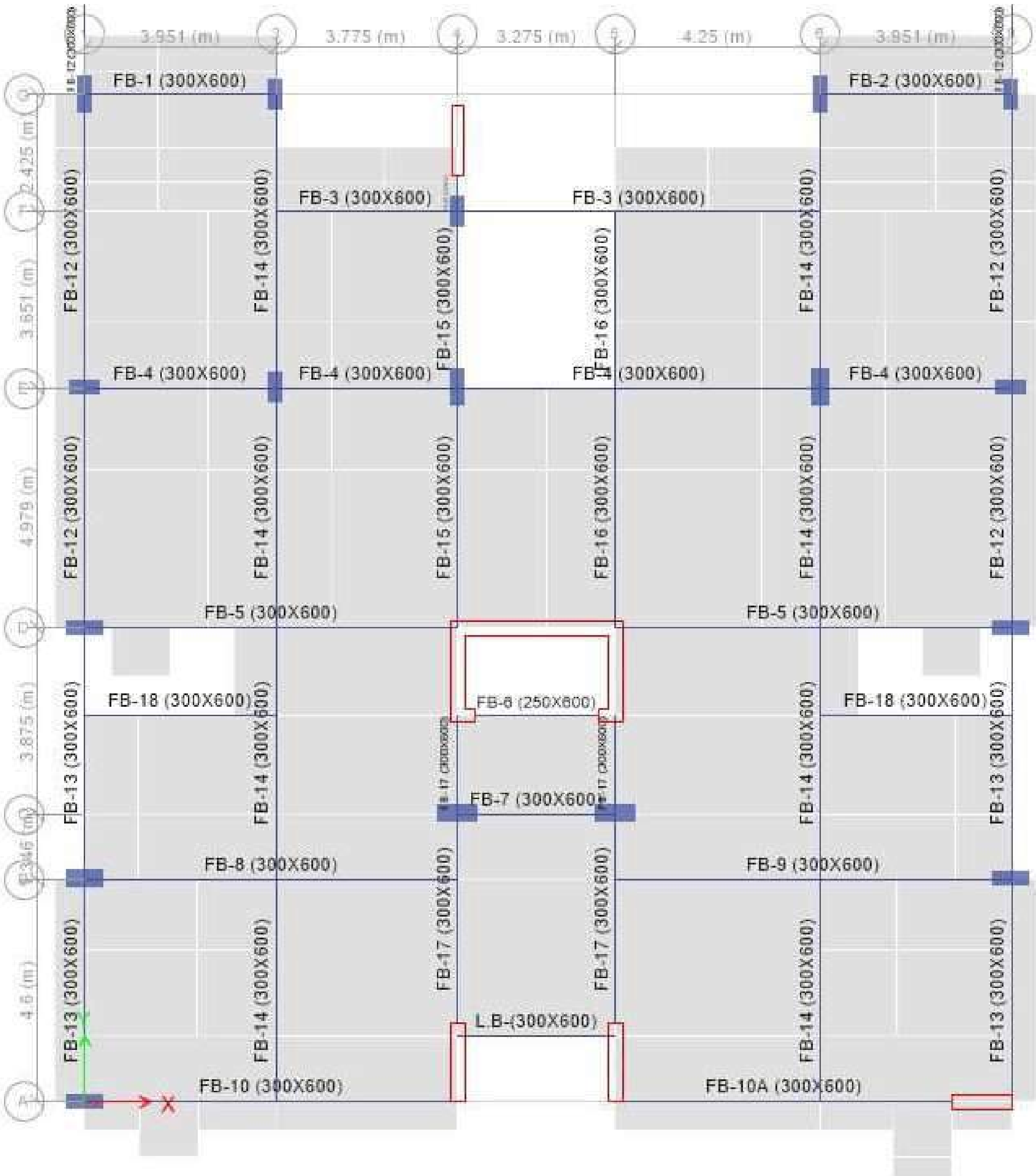


Figure C-22: 3rd & 4th Floor Beam Layout

84

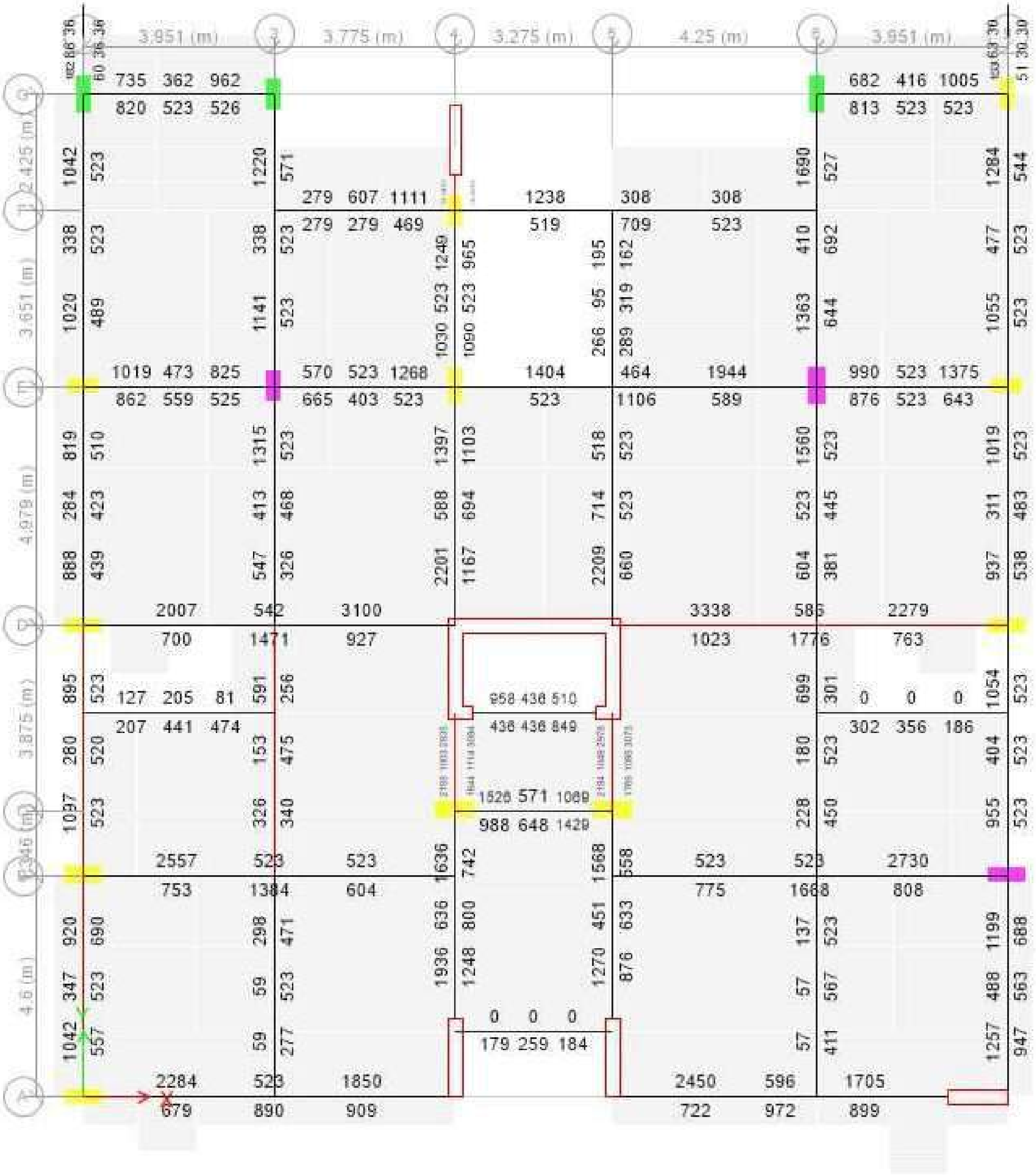


Figure C-23: Reinforcement of 3rd & 4th Floor Beam (mm^2)

85

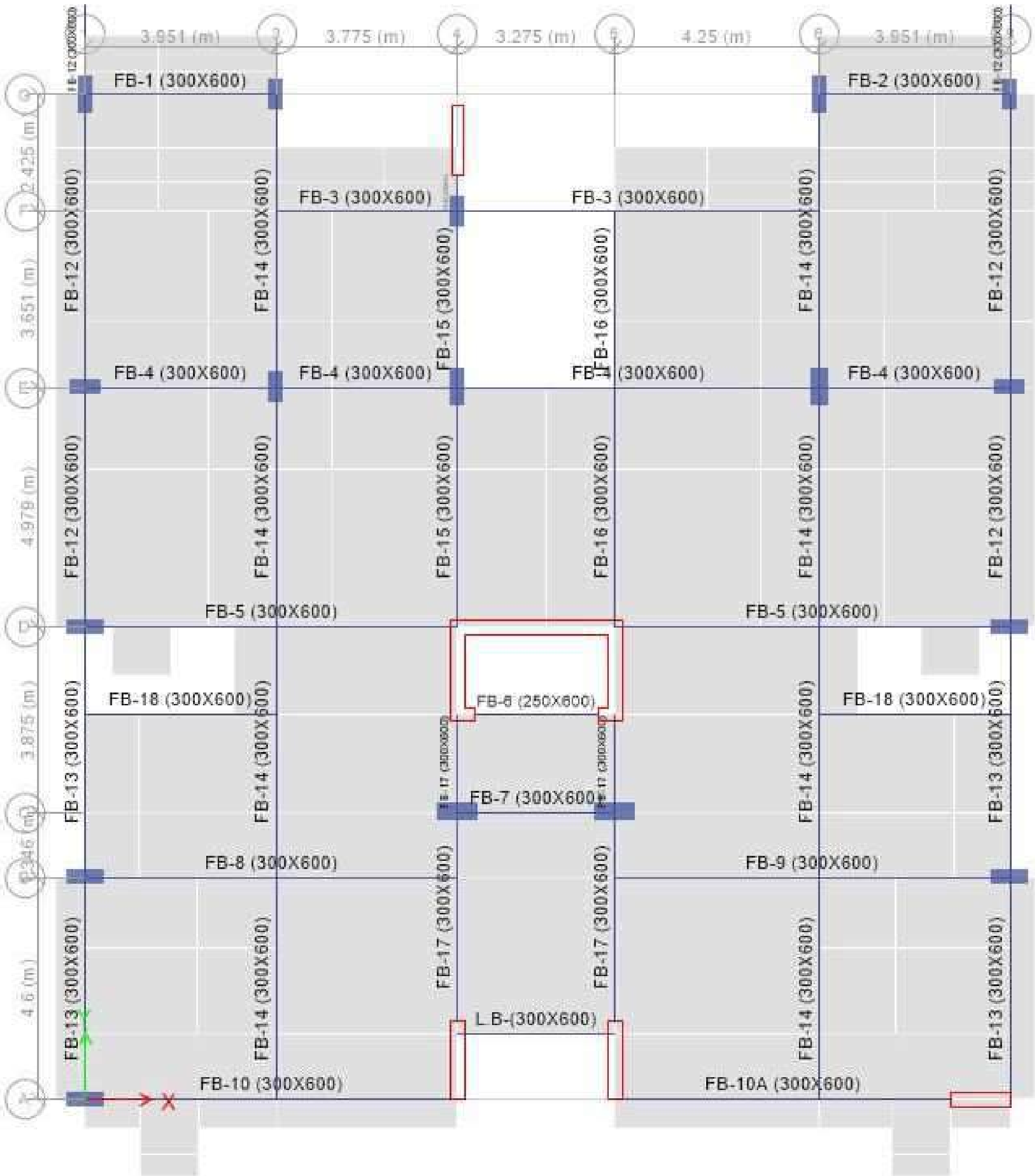


Figure C-24: 5th & 6th Floor Beam Layout

86

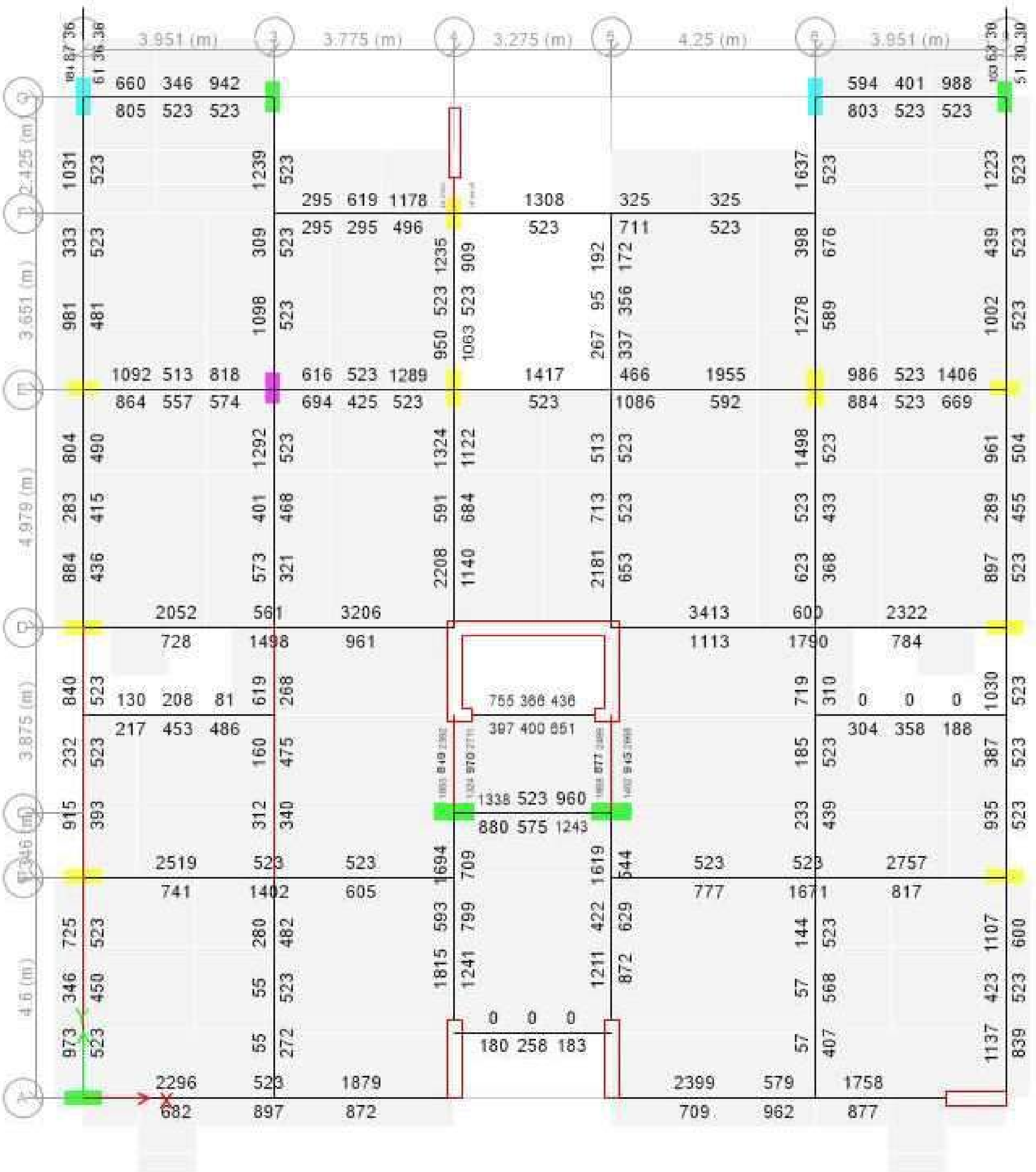


Figure C-25: Reinforcement of 5th & 6th Floor Beam (mm²)

87

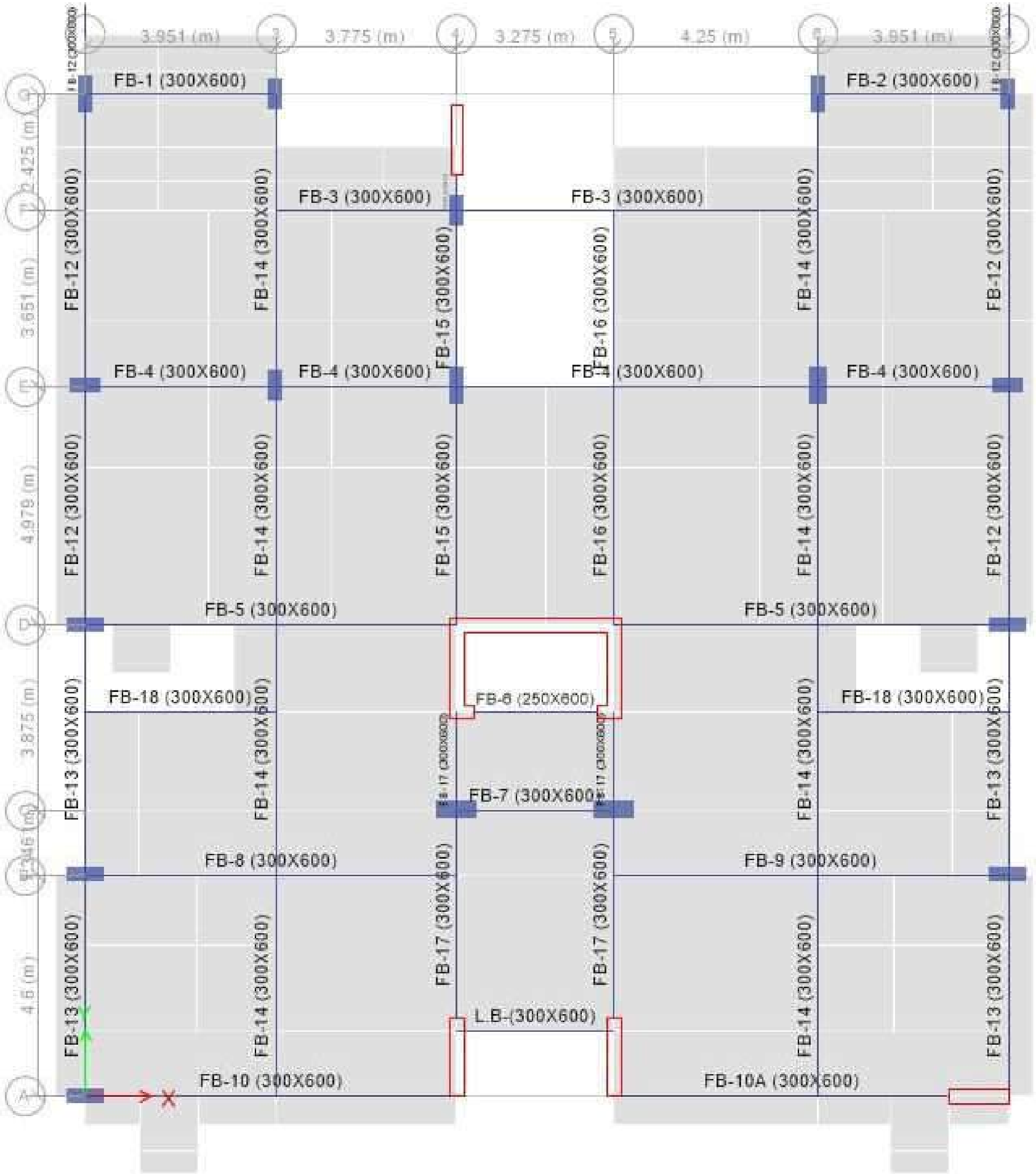


Figure C-26: 7th Floor Beam Layout

88

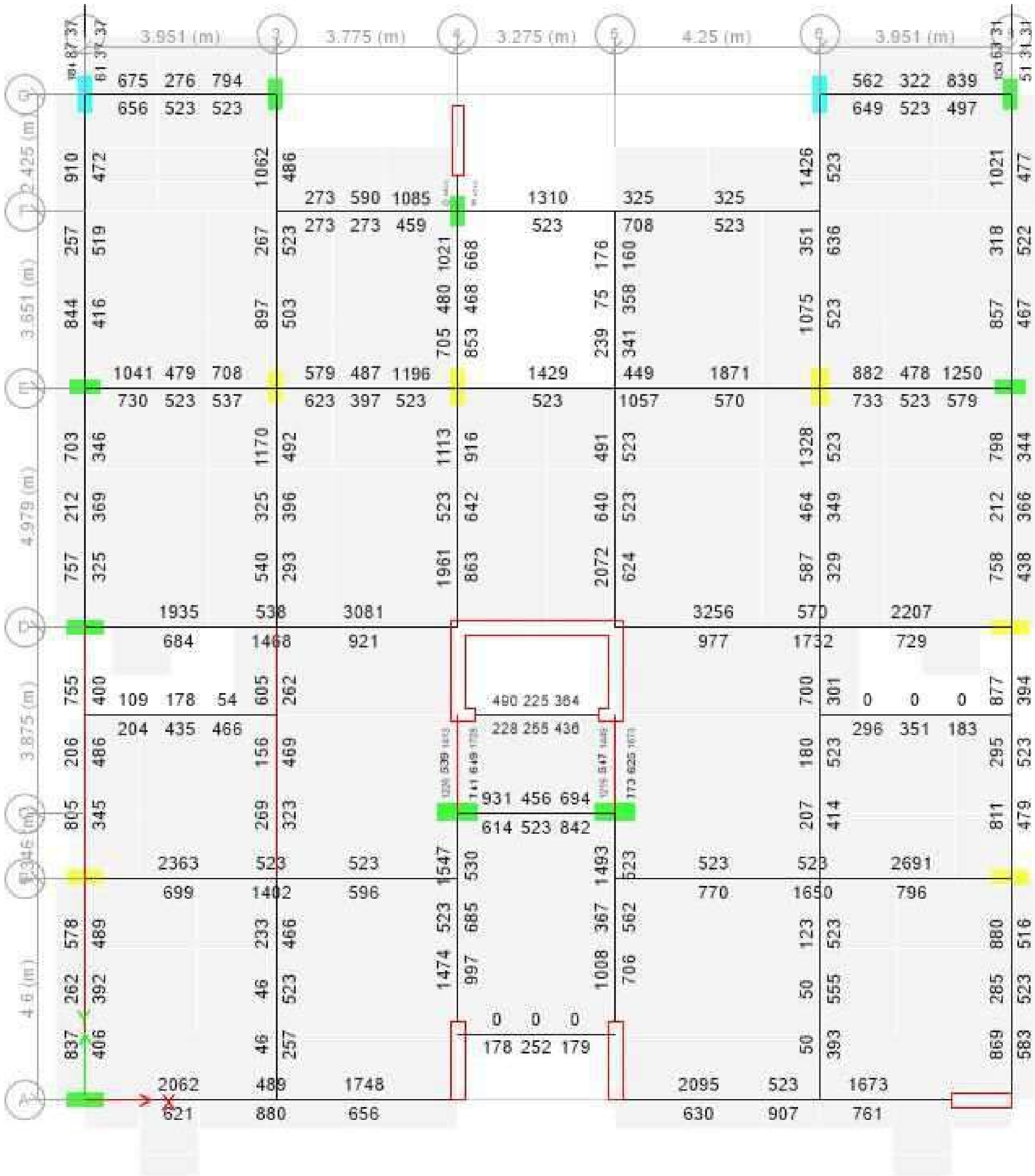


Figure C-27: Reinforcement of 7th Floor Beam (mm^2)

89

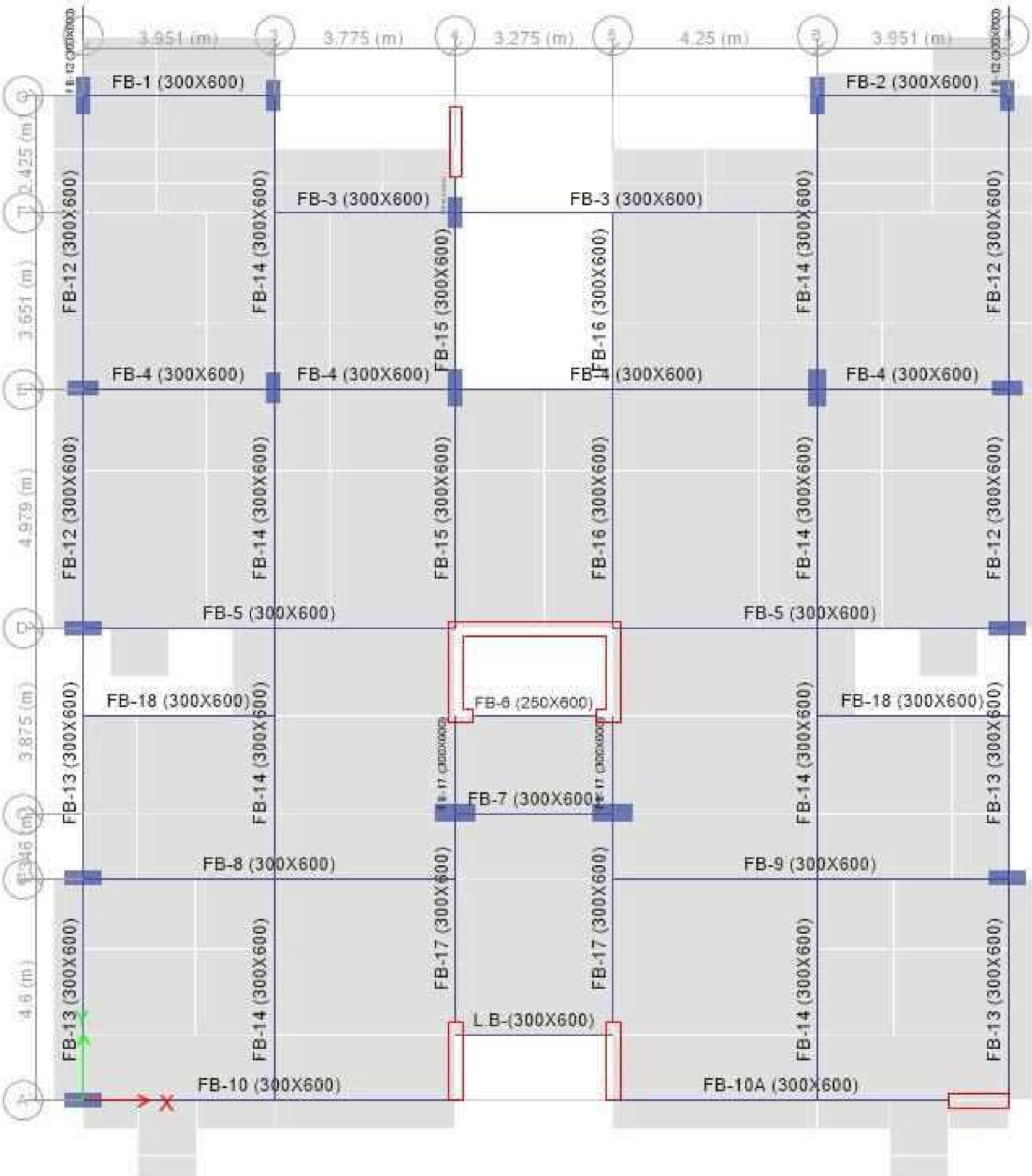


Figure C-28: 8th & 9th Floor Beam Layout

90

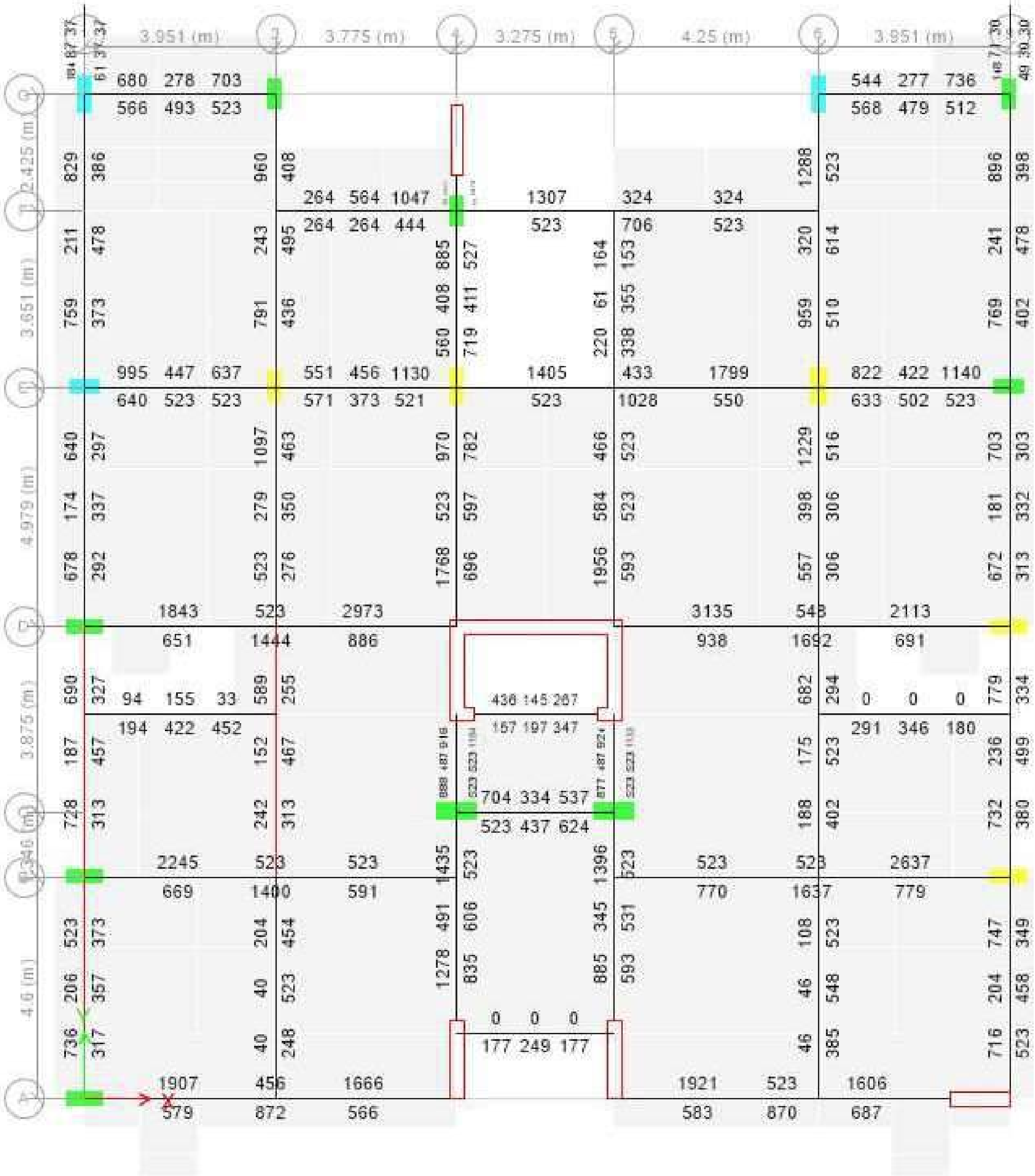


Figure C-29: Reinforcement of 8th & 9th Floor Beam (mm^2)

91

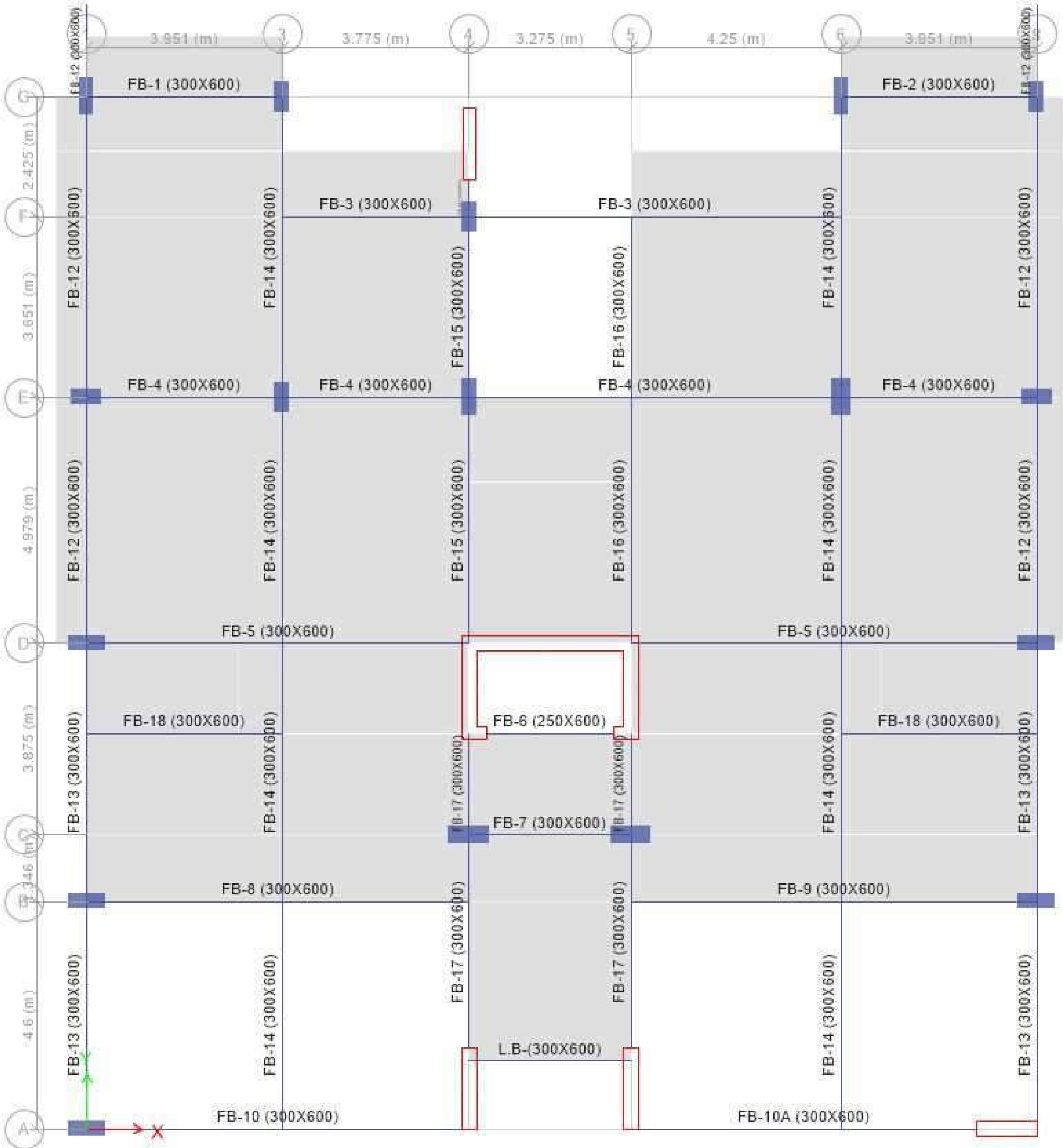


Figure C-30: Roof Floor Beam Layout

92

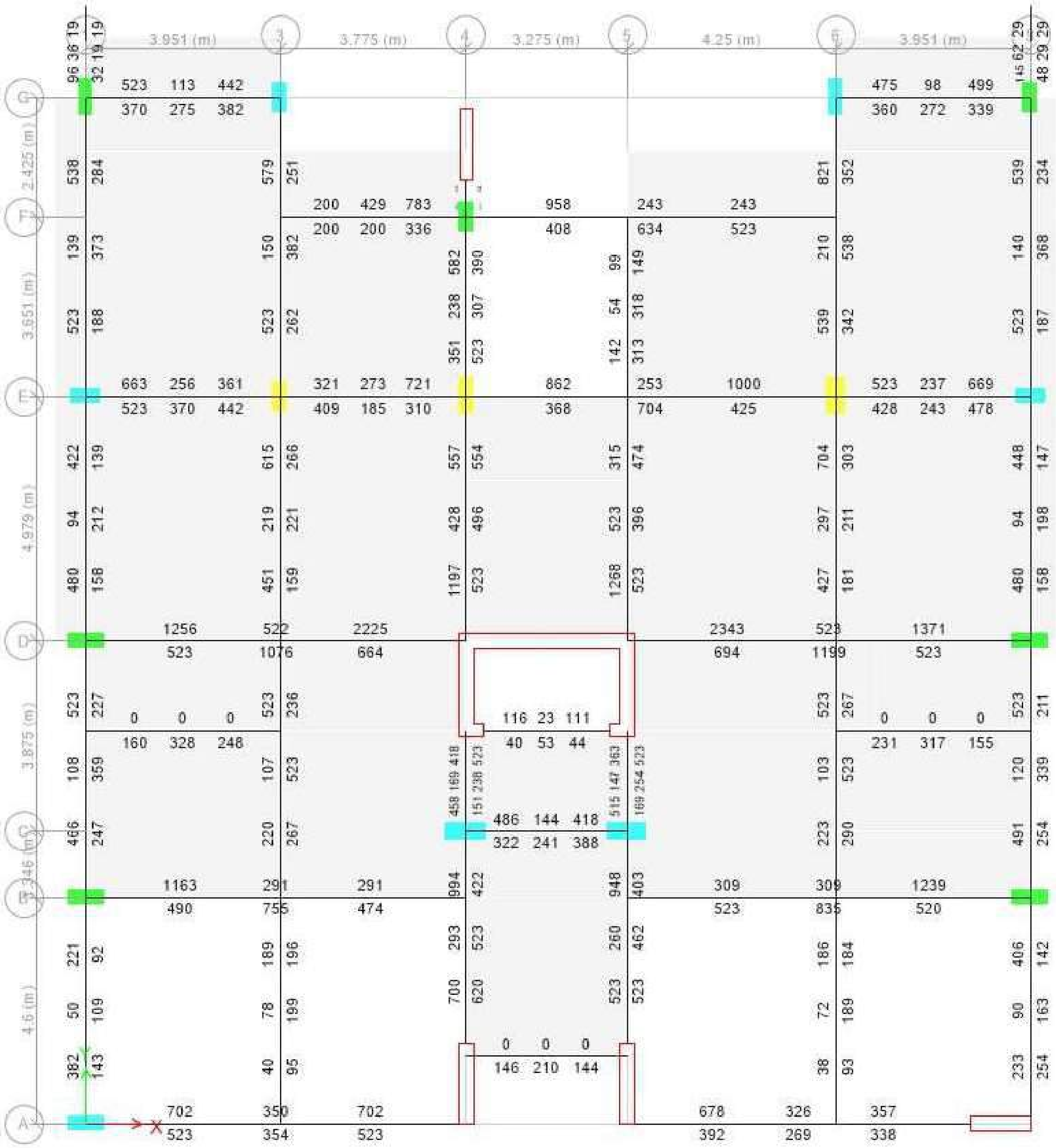


Figure C-31: Reinforcement of Roof Floor Beam (mm^2)

93

Table C3: Reinforcement Check of All Floor Beam

Beam ID	Beam Size (mm)	Required Reinforcement(mm^2) Output from etabs		Provided Reinforcement(mm^2) From drawing		Remarks
		Top	Bottom	Top	Bottom	
FB-1	300X600	962	820	1884	1344	Adequate
FB-1A	300X600	544	513	1884	1344	Adequate
FB-1B	300X600	2140	1094	2415	1884	Adequate
FB-2	300X600	1022	853	1884	1344	Adequate
FB-3	300X600	1571	985	1884	1344	Adequate
FB-4	300X600	1955	1236	2415	1570	Adequate
FB-5	300X600	3413	1790	3437	1884	Adequate
FB-6	250X600	1030	915	1344	1344	Adequate
FB-7	300X600	1526	1429	1570	1570	Adequate
FB-8	300X600	2557	1403	2592	1884	Adequate
FB-9	300X600	2757	1671	2946	1884	Adequate
FB-10	300X600	2329	926	2415	1344	Adequate
FB-10A	300X600	2458	926	2592	1884	Adequate
FB-12	300X600	1284	1320	1884	1344	Adequate
FB-13	300X600	1257	947	1884	1570	Adequate
FB-14	300X600	1694	926	1884	942	Adequate
FB-14A	300X600	326	459	603	942	Adequate
FB-15	300X600	2230	1206	2415	1570	Adequate
FB-16	300X600	2209	660	2415	942	Adequate
FB-17	300X600	2978	3094	3437	3437	Adequate
FB-18	300X600	523	523	603	942	Adequate

Note: This table has been revised

94

C.6 Slab Adequacy Check

Check for span (Grid-D-E, 3-4),

(a) For α_{fm} equal to or less than 0.2, the provisions of Sec 6.2.5.3.2 shall apply;

(b) For α_{fm} greater than 0.2 but not greater than 2.0, h shall not be less than

$$h = \frac{l_n\left(0.8+\frac{f_y}{1400}\right)}{36+5\beta(\alpha_{fm}-0.2)} \quad \geq 125 \text{ mm} \qquad (6.6.5)$$

(c) For α_{fm} greater than 2.0, h shall not be less than

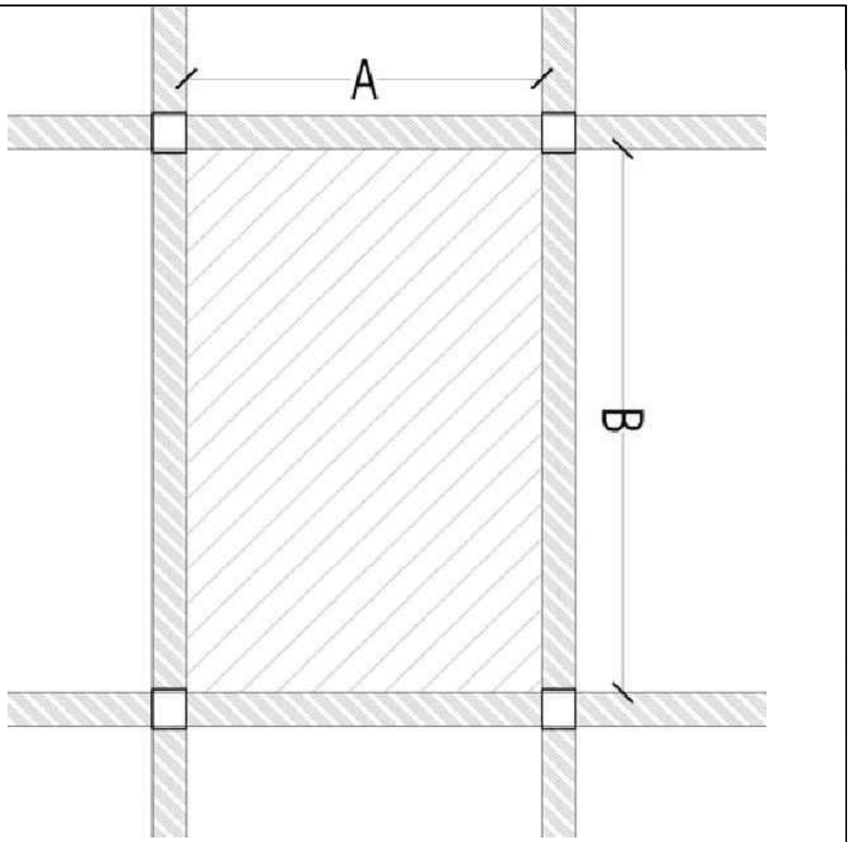
$$h = \frac{l_n\left(0.8+\frac{f_y}{1400}\right)}{36+9\beta} \quad \geq 90 \text{ mm} \qquad (6.6.6)$$

Considering slab thickness = 125 mm
Beam depth = 600 mm
Beam width = 300 mm
Each side of the beam x = y = 600-125 =475 mm < 4*125 = 500mm
Therefore, b_e = 300+2*475 = 1250 mm
Area of flange = 125*1250 = 156250 mm^2
Area of web = 300*475 = 142500 mm^2
Total area = 156250 + 142500 = 298750 mm^2
(156250*125/2+ 142500*(475/2+125) = 298750*ý
ý = 205.6 mm
I_S= 3426*125^3/12 = 557617187.5 mm^4
I_b= 1250*125^3/12 + 156250*$(205.6-125/2)^2$ + 300*475^3/12+ 142500*$(475/2-(205.6-125))^2$ = 9.59*e^9 mm^4
αf_1= 9.59*e^9/557617187.5 = 17.19
I_S= 4650*125^3/12 = 756835937.5 mm^4
αf_2= 9.59*e^9/756835937.5 = 12.67
αf_m= (17.19+ 12.67)/2 = 14.93

Slab Thickness, $h = \frac{\ln\,(0.8+\frac{fy}{1400})}{36+9\beta}, \beta = \text{long clear span/short clear span}$ αfm = 14.93 >2

95

Here,
β=4.65/3.426 = 1.357
ln= 4.65 m
Therefore, Check slab thickness, h= 4.65*1000*(0.8+414/1400)/ (36+9*1.357) = 106.5 mm
Provided slab thickness= 125 mm

Panel Size- CASE 2								
Short Span (A)	3.426 m							
Long Span (B)	4.65 m							
m	0.74							
cover	1.0							
Slab thickness	5							
d	4							
Material Property								
f'c	24.13 MPa							
fy	414 MPa							
Load Data								
Self-weight	3.01 kN/m^2							
Floor finish	1.19 kN/m^2	Moment(kN-m)		Steel Required(mm^2)		Steel Provide(mm^2)		Stability
Other dead load	1.19 kN/m^2	Ma(-ve)	3.3	As(-) short	187	As(-) short	245.2	Ok
Total dead load	5.39 kN/m^2	Mb(-ve)	1.76	As(-) long	187	As(-) long	245.2	Ok
Live load	3.01 kN/m^2	Ma(+ve)	1.67	As(+)Short	96.7	As(+)Short	154.8	Ok
Total factored load	13.30 kN/m^2	Mb(+ve)	0.90	As(+)Long	96.7	As(+)Long	154.8	Ok

96

C.7 Foundation Adequacy Check

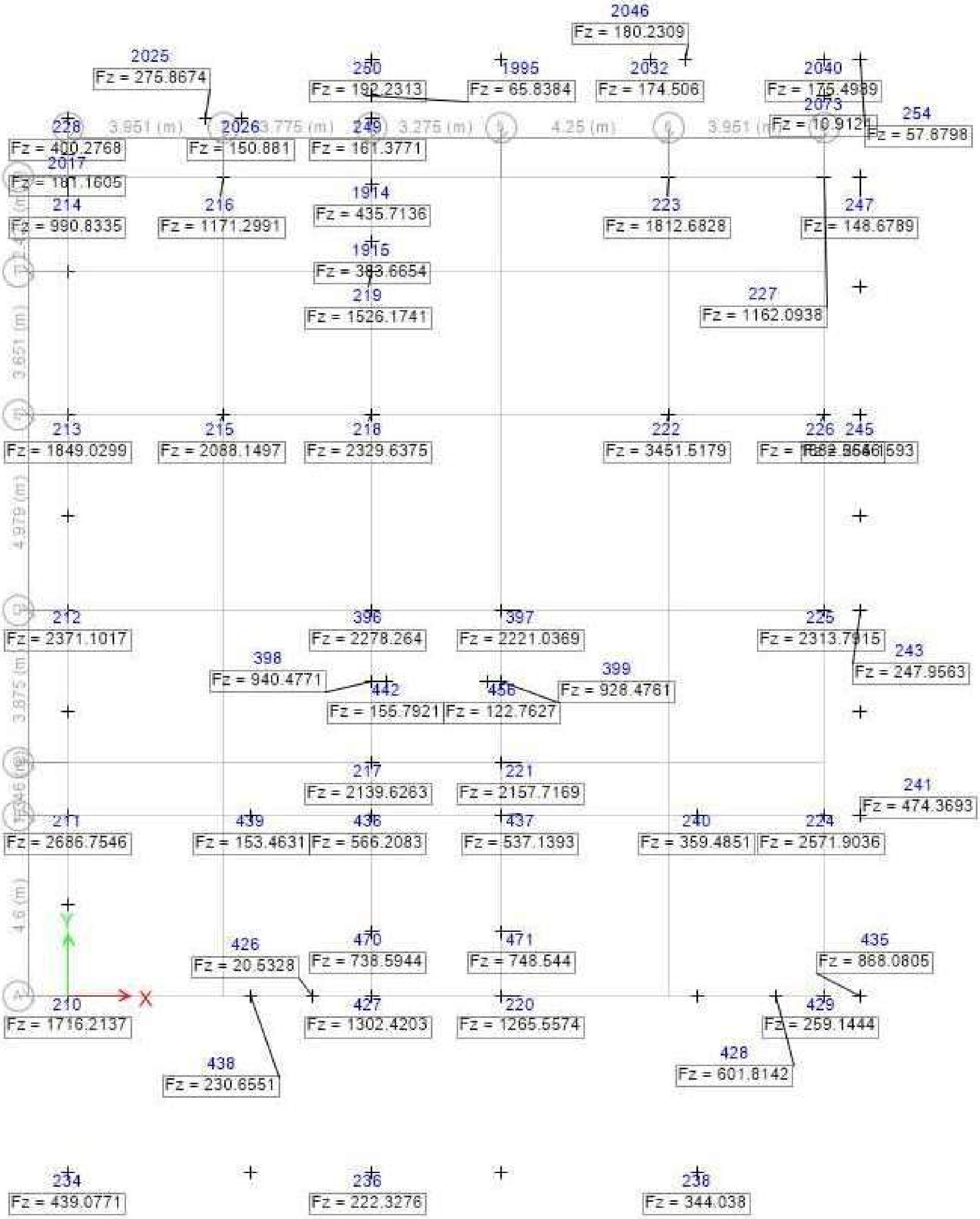


Figure C-26: Dead load from ETABS

97

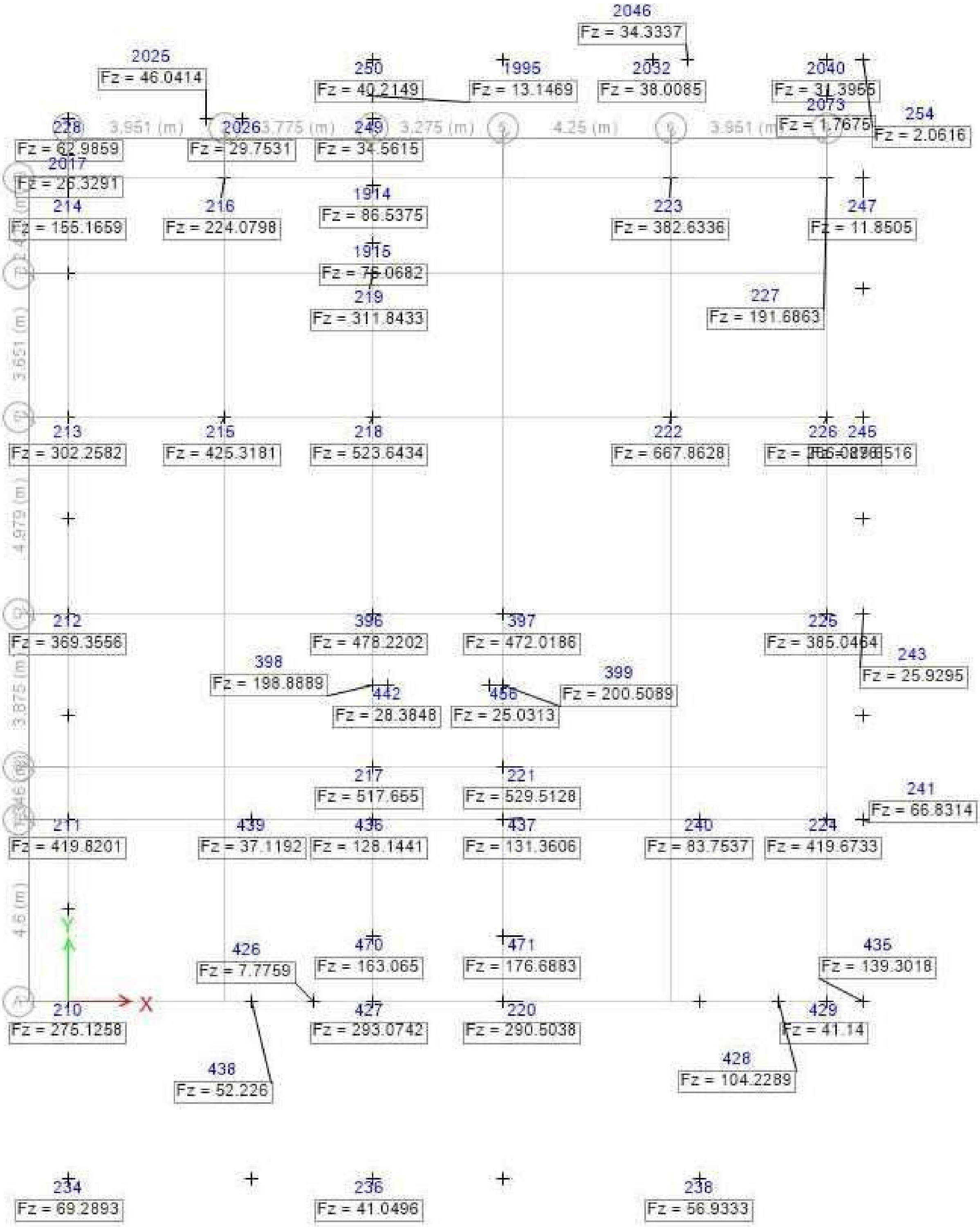


Figure C-27: Live Load from ETABS

Table C4: Factor of Safety check for Prescribed Live Load

Size =	600	mm
Length =	29700	mm
Capacity =	100	Ton
FoS =	2.5	

Pile Cap Type	Pile Nos	Thickness	Ultimate Pile Capacity	Ultimate Pile Capacity 33% increase (kN)
	Nos	mm	kN	
PC1	1	550	2224	2958
PC2	2	550	2224	2958
PC3	3	550	2224	2958
PC3C	3	550	2224	2958
PC4	4	550	2224	2958
PC5	5	550	2224	2958
PC8	8	550	2224	2958
PC8A	8	550	2224	2958
PC20	20	550	2224	2958

Joint Label	Pile Cap Type	Provided Number of Pile	Ultimate Pile Capacity	Reaction	Total Ultimate Pile Capacity	FACTOR OF SAFETY	Remarks (F.S >2.5)
		Nos	kN	kN	kN		
1	**PC1**	1.0	2958	774.87274	2958	**3.82**	**OK**
4	**PC1**	1.0	2958	282.78605	2958	**10.46**	**OK**
6	**PC1**	1.0	2958	559.87866	2958	**5.28**	**OK**
26	**PC3**	3.0	2958	2279.0529	8874	**3.89**	**OK**
30	**PC8A**	8.0	2958	7361.9515	23664	**3.21**	**OK**
31							
32							
33							
49							
50							
37	**PC8**	8.0	2958	6825.6206	23664	**3.47**	**OK**
38							
40							
68							
71							
73							
59	**PC4**	4.0	2958	3447.6804	11832	**3.43**	**OK**

99

63	PC20	20.0	2958	16061.728	59160	**3.68**	**OK**
65							
66							
104							
105							
116							
117							
118							
119							
151							
153							
142	PC4	4.0	2958	2998.5703	11832	**3.95**	**OK**
160	PC4	4.0	2958	3137.3701	11832	**3.77**	**OK**
162							
310	PC3	3.0	2958	2369.8677	8874	**3.74**	**OK**
312	PC3	3.0	2958	2552.0889	8874	**3.48**	**OK**
314	PC8	8.0	2958	6645.4054	23664	**3.56**	**OK**
341							
364							
389							
318	PC5	5.0	2958	4145.4204	14790	**3.57**	**OK**
320	PC3	3.0	2958	2664.6945	8874	**3.33**	**OK**
322							
379	PC3C	3.0	2958	2678.9103	8874	**3.31**	**OK**
396							
404							
381	PC3C	3.0	2958	2462.8087	8874	**3.60**	**OK**
405							
407							
384	PC3	3.0	2958	2668.3419	8874	**3.33**	**OK**
386	PC2	2.0	2958	2058.8902	5916	**2.87**	**OK**
388							
408	PC1	1.0	2958	1158.3259	2958	**2.55**	**OK**
412							
419							
421	PC1	1.0	2958	637.0648	2958	**4.64**	**OK**
423							
413	PC1	1.0	2958	963.84157	2958	**3.07**	**OK**
424							
425							

100

Table C5: Punching Capacity check for Prescribed Live Load

Column Type	Length	Width
	mm	mm
C1	300	625
C2	300	625
C3	300	625
C4	300	625
C5	300	625
C6	300	625
C7	300	625
C8	300	625
C9	300	625

			f'_c=	31	MPa				
			Live Load	2.01	kN/m^2				
Joint Label	Foundation Type	Column Type	Factored Reaction	Foundation Thickness	Column Length, L	Column Width, B	Punching Shear Capacity	DCR for Punching	Remark
			kN	mm	mm	mm	kN		
26	PC3	C2	2929	800	300	625	5533	**0.53**	**OK**
59	PC4	C7	608	800	300	625	5533	**0.11**	**OK**
71	PC8	C5	249	950	300	625	7358	**0.03**	**OK**
142	PC4	C2	3327	800	300	625	5533	**0.60**	**OK**
160	PC4	C6	3278	800	300	625	5533	**0.59**	**OK**
310	PC3	C1	961	800	300	625	5533	**0.17**	**OK**
312	PC3	C1	474	800	300	625	5533	**0.09**	**OK**
314	PC8	C2	1939	950	300	625	7358	**0.26**	**OK**
318	PC5	C8	1442	1150	300	625	10176	**0.14**	**OK**
320	PC3	C4	1452	800	300	625	5533	**0.26**	**OK**
379	PC3C	C6	4259	850	300	625	6114	**0.70**	**OK**
341	PC8	C3	489	950	300	625	7358	**0.07**	**OK**
381	PC3C	C1	1349	850	300	625	6114	**0.22**	**OK**
384	PC3	C5	1284	800	300	625	5533	**0.23**	**OK**
386	PC2	C3	778	650	300	625	3957	**0.20**	**OK**

101

Calculation of Pile Cap:

Check for 3-Pile (Grid G-6)

Maximum load = 2326 kN
Allowable capacity of per pile as per soil report= 100 Ton =890 kN
Ultimate capacity of pile = 890*3 =2670 kN
Factor of Safety= (2670*3)/2326 = 3.44 > 2.5 (ok)

Punching Capacity Check:

Factor Load = 3407 kN
Column Size = 300mmx750mm
Depth, d = 750mm
F'c = 31 MPa
Bo = 2(300+750) +2(750+750) = 5100 mm
$V_c = 0.33\varphi\sqrt{f'_c} b_o d/1000$
=5100 kN >> 3407 kN so ok

One-way Shear Check:

Factor Load = 3407/3=1136 kN per pile
Column Size = 300mmx750mm
Depth, d = 750mm
Column outer to pile center distance=675 mm
Develop shear= 1136/2= 568 kN
Allowable shear=$0.17\varphi\sqrt{f'_c}bd$=0.17*0.75√31*1375*750/1000 =732 kN > 568 kN

Reinforcement Check

Bottom reinforcement

Develop moment = 1246 *675 kN-mm= 841050 kN-mm
Concrete Compressive Strength, f'c=31 MPa
Yield Strength of Reinforcement, fy= 414 MPa
Width, b= 2125 mm
Effective Depth, d= 750 mm
Area of reinforcement, As= Mu/ (Φfyd) = 841050/ (0.8*414*750))
As= 3380 mm^2 so, As= 1629 mm^2/m
Minimum As= (1.4/fy)*bd= (1.4/ 414)*1000*750= 2536 mm^2 > 1629 mm^2
So, As required = 2536 mm^2/m
Required 20 mm @ 120 mm c/c (in both direction)
Provided 20 mm @ 100 mm c/c (in both direction) (ok)
Same principle has been considered for other pile cap design.

102

Conclusion:

The structure was modelled using 3-D computer program **ETABS v16.2.1.** Under the all loading conditions:

- Pile cap size is okay against punching & bearing capacity.
- The column sizes of the building are okay under all loading conditions.
- Beams of the building are okay under all loading conditions.
- The building is safe against lateral deflection.

Recommendation:

- **Column Performance**: Though column sizes are ok under all loading condition, it is recommended to follow the floor load plan properly.
- **Beam, slab and Foundation Performance**: Slab thickness is adequate to resist punching shear. Beams & foundation are also safe in size & reinforcement to carry all possible loads. Further any vertical or horizontal extension should not be added.
- **Vertically Extension**: The building was assessed with a simplified model based calculation. If any vertical extension is needed adequacy should be verified by finite element Model.

103

Soil Report

104

Site Class Based on Soil Properties

Input:

Calculations:

Depth (m)	Field N Value	Shear Wave Velocity, V_{si} (m/s)	Average Shear Wave Velocity, V_s (m/s)	Average N Value
1.5	1	61.00	108.38	2.67
3	2	86.27		
4.5	3	105.66		
6	4	122.00		
7.5	1	61.00		
9	1	61.00		
10.5	2	86.27		
12	2	86.27		
13.5	3	105.66		
15	2	86.27		
16.5	3	105.66		
18	4	122.00		
19.5	8	172.53		
21	5	136.40		
22.5	4	122.00		
24	6	149.42		
25.5	14	228.24		
27	12	211.31		
28.5	12	211.31		
30	49	427.00		

105

PILE LOAD CAPACITY CALCULATION FROM SPT VALUE

Pile Length = 29.7 m; From Level = -2.4 m

Ultimate Capacity of Pile, $Q_u = 40NAp + (\frac{N}{2})As$ (ton)

End bearing of pile = 40NAp

Bore hole -02 at 32 m, SPT = 50+

Corrected SPT = 15+0.5(N-15)

= 15+0.5(50-15)

= 15+17.5

= 32.5

End bearing of pile = $40*32.5*(3.1416*.6^2/4)$ = 367.5 tons

Skin friction $= \frac{N}{2}\ \pi DL$

$$N = \frac{5+5+9+6+5+5+7+8+28+32.5+32.5}{11}$$

= 13

Skin friction $= \frac{13}{2}*\pi*0.6*16.5$

= 202 tons

Total = 367.5+202 = 569.5 tons

For bored pile capacity = 569.5 *0.65 = 370 tons

Considering, F.S = 3

$Q_{allowable} = \frac{370}{3}$

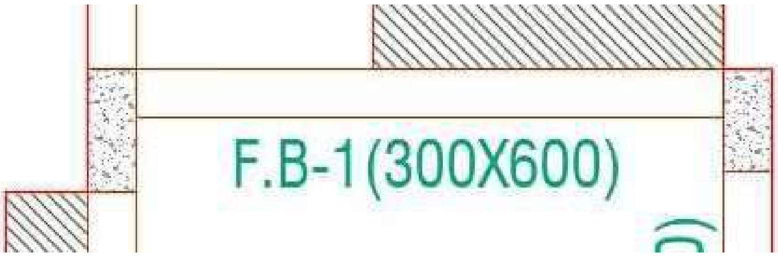
= 123 tons

Considered capacity = 100 tons

106

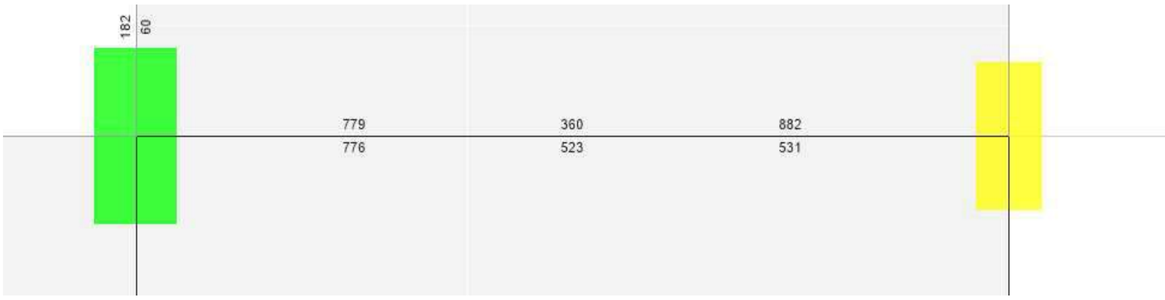
Development length check for exterior column support: 2nd floor

FB-1=300X600

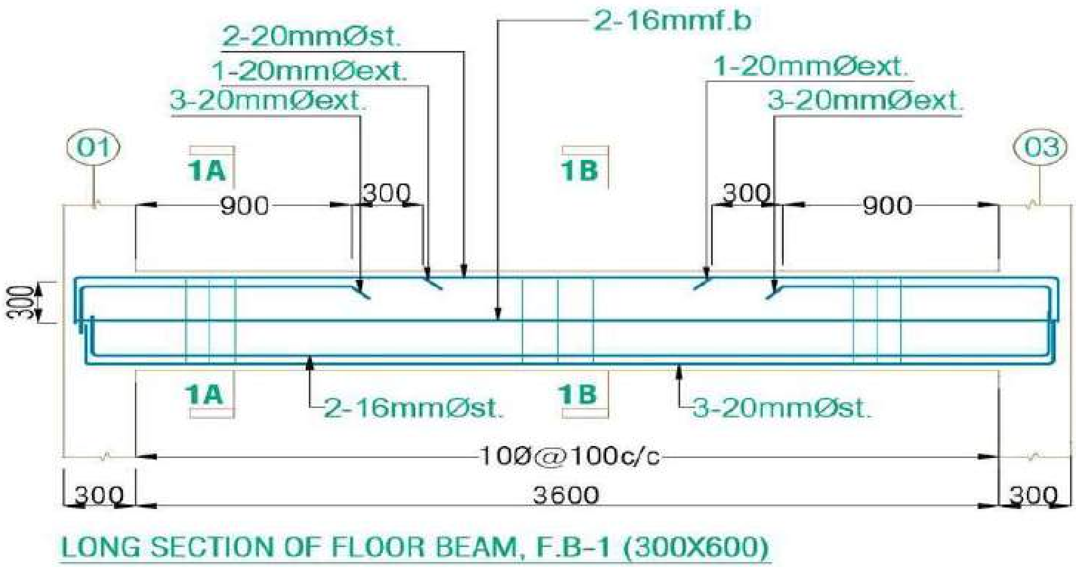


Drawing

Etabs output:



Provided beam rebar:



For fy=414 MPa, db=20mm, f'c= 24.13 MPa

Development length= 0.24*fy*db/√f'c = 0.24*414*20/√24.13 = 404.5 mm

Available width= 300 mm, Clear width for l_{dh}=300-40-20-10 = 230 mm

Number of bar need to increase at first layer = 404.5/230= 1.76 times

Number of bar need to increase at second layer = 404.5/(230-45) = 2.19 times

Top rebar

Provided 1st layer reinforcement 3 nos 20mm bar = 3*314*230/404.5 = 535.6 mm^2

Provided 2nd layer reinforcement 3 nos 20mm bar = 3*314*185/404.5 = 430.8 mm^2

Total provided reinforcement = 535.6+430.8= 966.4 mm^2 > 882 mm^2 (See previous page)