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FINAL YEAR PROJECT REPORT ON STUDY OF EARTHQUAKE RESISTANT ANALYSIS AND DESIGN OF MULTI-STOREY BUILDING

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Abstract : : The need for earthquake-resistant buildings in Nepal is of critical importance due to the country's high vulnerability to earthquakes. Nepal is located at the junction of the Indian and Eurasian tectonic plates and has a long history of devastating earthquakes, making it one of the most seismically active countries in the world. The country has experienced several earthquakes of magnitude 6.0 or greater in the past century, and the risk of large earthquakes in Nepal continues to increase due to the active tectonic plate boundary that runs through the region.

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SYMBOL	Meaning
a_x, a_y	BM coefficients for Rectangular Slab Panels
ϕ δ_m	Diameter of Bar, Angle of internal friction of soil Percentage reduction in moment
τ_c	Shear Stress in Concrete
$\tau_{c,max}$	Max. shear stress in concrete with shear reinforcement
τ_{bd} σ_{ac}	Design Bond Stress Permissible Stress in Axial Compression (Steel)
σ_{cbc} σ_{sc}, σ_{st} γ_m	Permissible Bending Compressive Strength of Concrete Permissible Stress in Steel in Compression and Tension respectively Partial Safety Factor for Material
γ_f	Partial Safety Factor for Load
γ	Unit Weight of Material
A_B	Area of Each Bar
A_G A_H	Gross Area of Concrete Horizontal Seismic Coefficient
P_Z	Wind Pressure
Q, Q_U Q_I	Permissible and Ultimate bearing capacity of soil Design Lateral Force in i^{th} Level
SR, R_{MIN}	Slenderness Ratio, (minimum) for structural steel section
R S_a/g	Response Reduction Factor Average Response cceleration Coefficient
S_V T_I	Spacing of Each Bar Torsional Moment due to Lateral Force in i-direction
L.L	Live Load
RCC	Reinforced Cement Concrete
SPT, N	Standard Penetration Test
M25	Grade of Concrete

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1. INTRODUCTION

1.1 Background

The need for earthquake-resistant buildings in Nepal is of critical importance due to thecountry's high vulnerability to earthquakes. Nepal is located at the junction of the Indian and Eurasian tectonic plates and has a long history of devastating earthquakes, making it one of the most seismically active countries in the world. The country has experienced several earthquakes of magnitude 6.0 or greater in the past century, and the risk of large earthquakesin Nepal continues to increase due to the active tectonic plate boundary that runs through the region.

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1.2 Title and Theme of the Project Work

The proposed project is "**Earthquake Resistant Analysis and Design of Multi-Storey Building**". Our project lies in Nepal and it lies in seismic zone 'V' according to its seismic severity. Earthquake load dominates wind load and governs the lateral design loading. The report strictly follows Indian Standards with limit state design philosophy in general. The estimation of live and dead load could be predicted with reasonable accuracy but the loads dueto earthquake can't be accurately predicted. So, statistical and probabilistic approaches are resorted to, considering one of factor economy. The seismic coefficient design method as stipulated in IS 1893:2016 is applied to analyze the building for earthquake. The 3- dimensionalmoment resistance frame is considered as the main structural system of the building.

1.1 Objective

The specific objectives of the project work are:

1. To analyze and design a multi-storey earthquake-resistant building.
2. To study architectural drawings and fix the structural system of the building to

1.2 Scope

The project work aims to provide a comprehensive analysis and design of a multi-storey earthquake-resistant building.

1. METHODOLOGY

In Nepal, design of buildings is mainly based upon the guidelines provided by the Nepal NationalBuilding Codes: 000- 1994. NBC codes are designed referring to IS codes and are less detailed and extensive comparing to IS code. So, it permits use of IS code for design such that building fulfills requirement of NBC codes on doing so. In this project, we are going to use IS codes which follows limit state design method.

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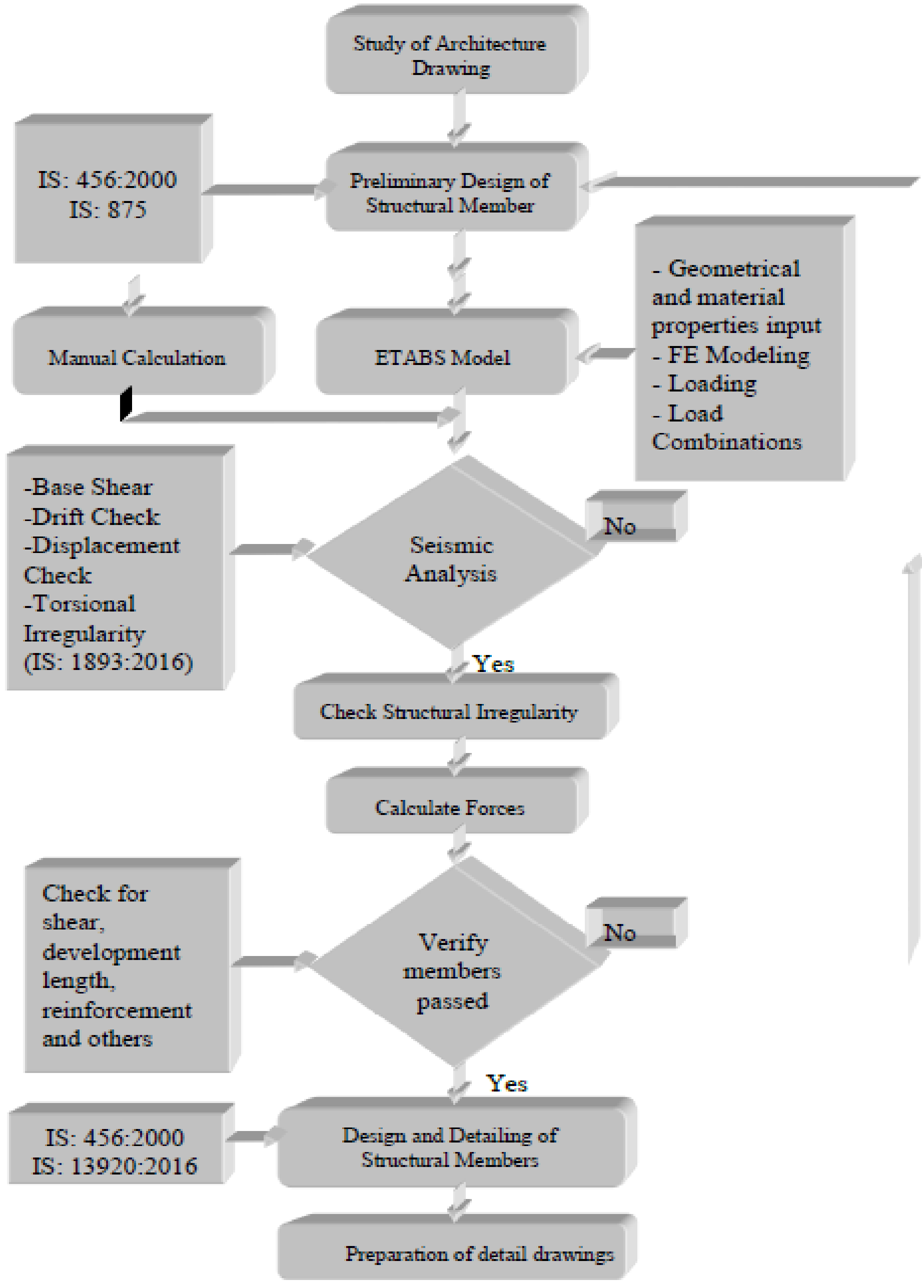

2.1 Planning Phase

Planning of building is grouping and arrangement of different component of a building so as to form a homogenous body which can meet all its function and purposes. Proper orientation, safety, healthy, beautiful and economic construction are the main target of building planning. It is done based on the following criteria:

2.2 Load Assessment

Once the detailed architectural drawing of building is drawn, the buildings subjected to different load are found out and the calculations of load are done. The loads on building are categorized as below

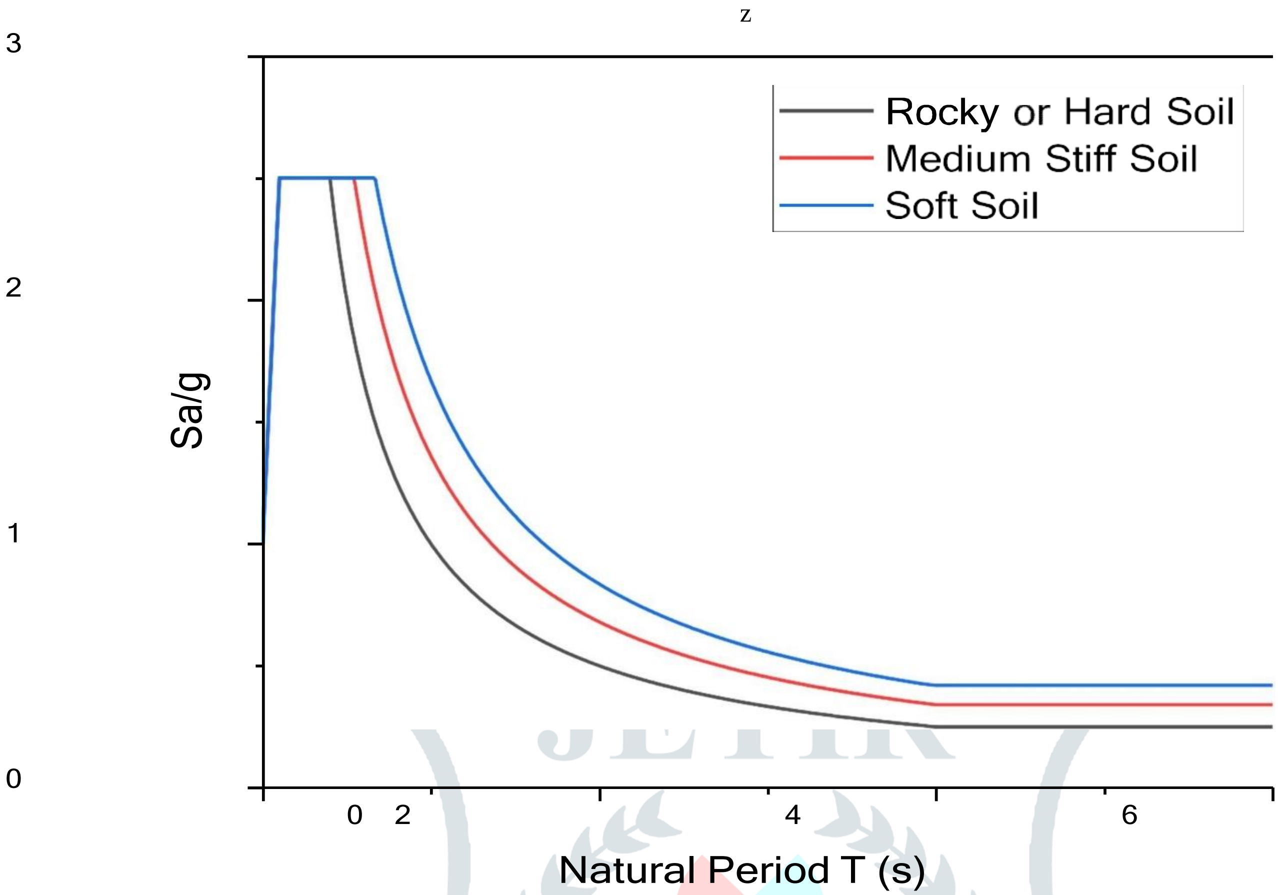

Figure 2:Response spectra for rock and soils for 5% damping

The seismic analysis can be performed using design spectrum. Response spectrum method isdynamic analysis used for the analysis of seismic loads for unsymmetrical buildings.

2.1 Modeling and Analysis of structure

2.1.1 Salient Features of ETABS

ETABS represents one of the most sophisticated and user-friendly release of SAP series of computer programs. Creation and modification of the model, execution of the analysis, and checking and optimization of the design are all done through this single interface. Graphical displays of the results, including real-time display of time-history displacements are easily produced.

2.2 Detailing Principle for Reinforced Concrete and Steel Structures

2.2.1 *Ductile Detailing of Reinforced Concrete Structure*

Ductile detailing of reinforced concrete structure is done based on IS 13920:2016 for theprovision of compliance with earthquake resistant design philosophy. Special consideration is taken in detailing of linear frame elements (BEAMS & COLUMNS) to achieve ductility in the

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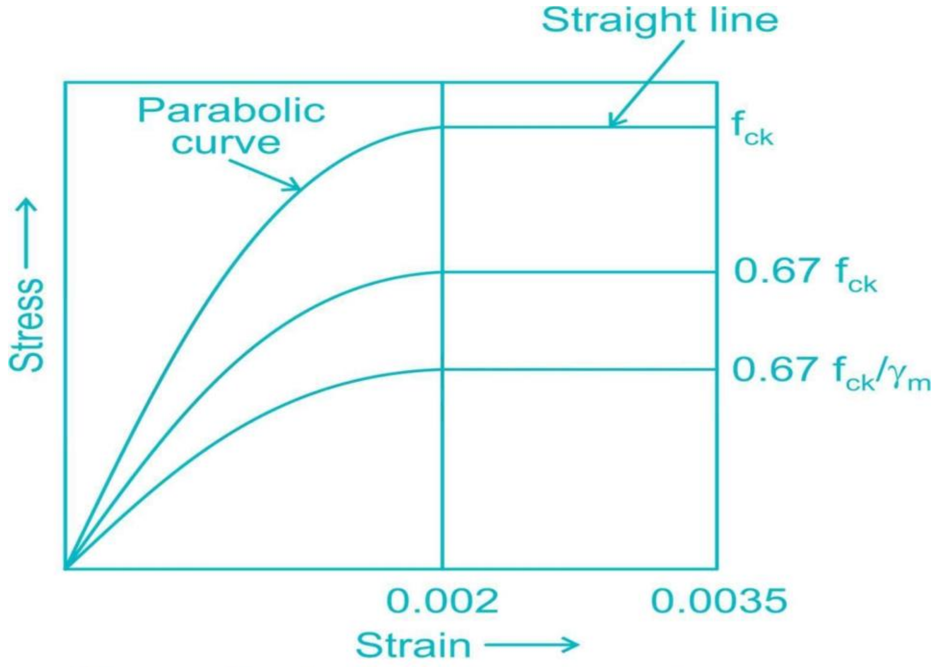

Stress-Strain curve for concrete

2.2.2 *Design and Detailing of Structural Element*

2.2.2.1 **Slab**

Slabs are plate elements forming floors and roofs of buildings and carrying distributed loads primarily by flexure. Inclined slabs may be used as ramps for Multi-storey car parks. A staircasecan be considered to be an inclined slab. A slab may be supported by beams or walls and maybe used as the flange or a T- or L-beam. Moreover, a slab may be simply supported, or cantilever over one or more supports and is classified according to the manner of support.

- One-way slabs spanning in one direction
- Two-way slabs spanning in both direction
- Circular slabs
- Flat slabs resting directly on column with no beams
- Grid floor and ribbed slabs

2.2.2.2 *Beam*

Beam is a flexural member which distributes the vertical load to the column and resists the bending moment. The total effect of all the forces acting on the beam is to produce shear forcesand bending moments within the beam, that in turn induce internal stresses, strains and deflections of the beam. Its mode of deflection is primarily by bending. The loads applied to the beam result in reaction forces at the beam's support points.

2.2.2.3 *Column*

Columns are compression members whose effective length exceeds three times the least lateral dimension. They are subjected to large axial compression force. Any compression member ofa structure, or column in particular, takes the load from flexure and slab members present aboveit and transfers the load to the foundation and consecutively to the earth below. Thus, it is very important to design columns of adequate size and with adequate reinforcement in order to safely transfer the incoming loads.

2.1.1 *Foundation*

The foundation forms a very important part of the structure which transfers the load to the soilon which it rests. Theground surface in contact with the lower surface of the foundation is known to be the base of the foundation

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2.1.1.1 Slab

Slabs are plate elements forming floors and roofs of buildings and carrying distributed loads primarily by flexure.Inclined slabs may be used as ramps for Multi-storey car parks. A staircasecan be considered to be an inclined slab

1. RELIMINARY DESIGN OF STRUCTURAL MEMBERS

Before proceeding for the actual modeling of the building, it is necessary to fix approximate dimensions for the structural elements. This is done through preliminary design and acts as guidelines in analysis which are liable to be changed in future after response evaluation. Drawings received from architect were thoroughly studied and elements at maximum exploited location were chosen for preliminary design.

3.1 Preliminary Design of Slab

Preliminary design of RCC slab for the floor and roof of the proposed building is done in such a way that it complies with deflection control criteria of **IS 456:2000** and behavior of floor slab as a rigid diaphragm. Being equal spacing of columns in both the axes, planar dimensions of all slabs being equal, on ly a single panel is taken for preliminary design.

lx=6000mm

ly=6000mm

<u>Classification of slab</u>

$$\frac{ly}{lx} = \frac{6000}{6000} = 1 < 2$$

So, the slab behaves as two-way slab.

For slab, as per **IS 456:2000 CL 24.1**, the provision for beams app ly to slabs also.

Therefore, from **IS 456:2000 CL 23.2**

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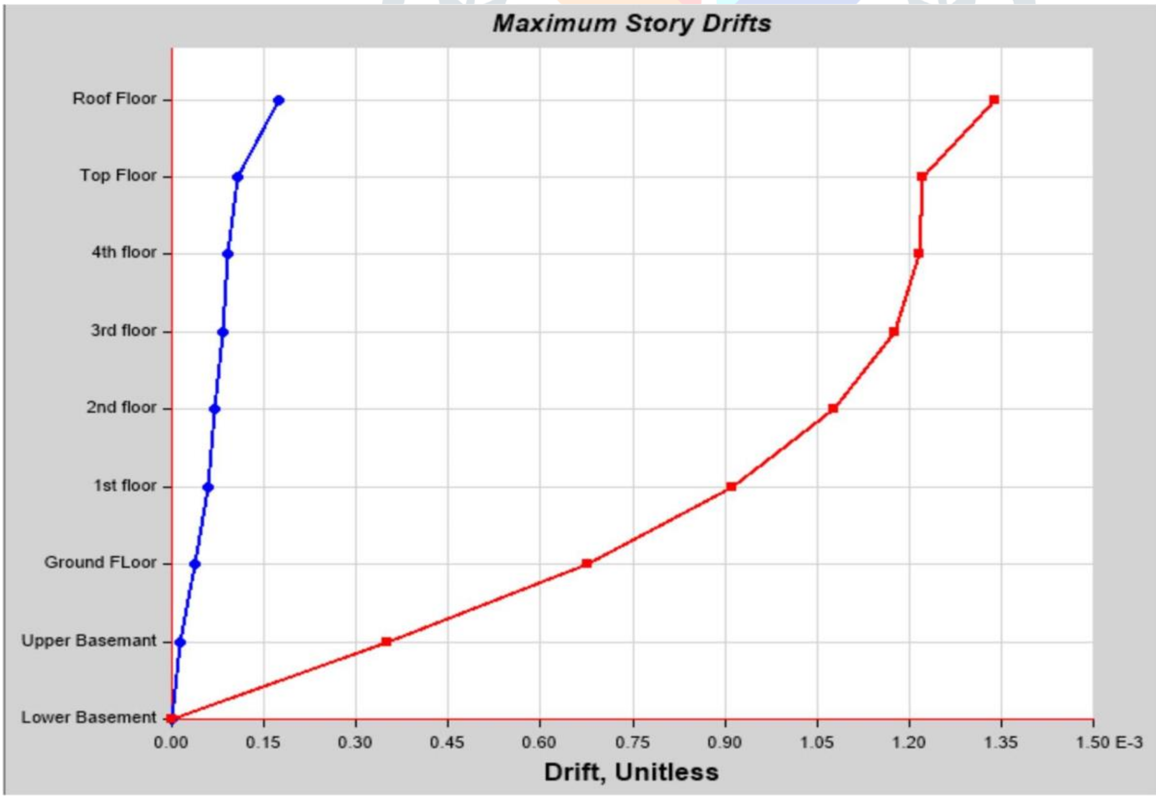
- ## Storey Drift

Storey drift is the relative displacement between the floors above and/or below the storey under consideration. As per **IS 1893:2016** Storey drift in any Storey shall not exceed 0.004 times the storey height. The limitation on storey drift is necessary to avoid discomfort to occupants of the building and to save non-structural elements from damage. ETABS analysis directly generates the drift in form ratio so that the result can be directly compared with the permissible drift ratioof **0.004**.

Table 17: Storey Drift Ratio Storey	Elevation (m)	X-Direction	<0.004	Y-Direction	<0.004
Roof Floor	27.72	0.002098	**OK**	0.001339	**OK**
Top Floor	24.255	0.002268	**OK**	0.001222	**OK**
4th floor	20.79	0.002328	**OK**	0.001216	**OK**
3rd floor	17.325	0.002298	**OK**	0.001177	**OK**
2nd floor	13.86	0.002146	**OK**	0.001078	**OK**
1st floor	10.395	0.001846	**OK**	0.000912	**OK**
Ground Floor	6.93	0.001378	**OK**	0.000676	**OK**
Upper Basement	3.465	0.000669	**OK**	0.000351	**OK**
Lower Basement	0	0	**OK**	0	**OK**



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4 LOAD CALCULATION

Slab:

UPPER BASEMENT:

Slab ID	Length (m)	Breadth(m)	Area (m2)	Unit Weight (kN/m3)	Thickness (m)	Dead Load (kN)	Live Load (kN/m2)	Live Load (kN)	Total Load (kN)
BF26	24	24	576	25	0.14	2016	5	1440	3456
Deduction	4.4	2	-8.8	25	0.14	-30.8	5	-22	-52.8
Deduction	6	6	-36	25	0.14	-126	5	-90	-216
Deduction	1.2		-9.047	25	0.14	-31.6672	5	-22.61946711	-54.286
OTHERS	12	3	144	25	0.14	504	5	360	864
Total									3996.9132

GROUND FLOOR:

Slab ID	Length(m)	Breadth(m)	Area (m2)	Unit Weight (kN/m3)	Thickness (m)	Dead Load (kN)	Live Load (kN/m2)	Live Load (kN)	Total Load (kN)
DE13	9	6	54	25	0.14	189	5	135	324
Deduction	4.4	2	-8.8	25	0.14	-30.8	5	-22	-52.8
BC23	6	6	36	25	0.14	126	3.484029	62.712	188.712
EF23	6	6	36	25	0.14	126	3.1039	55.870	181.8705
AB34	6	3	18	25	0.14	63	3.198055	28.782	91.7825
AB45	6	3	18	25	0.14	63	3	13.5	76.5
BC34	6	6	36	25	0.14	126	3.5313	63.564	189.5642
BC45	6	6	36	25	0.14	126	3.0345	54.621	180.621
CE35	12	12	144	25	0.14	504	4	288	792
EG35	12	9	108	25	0.14	378	4	216	594
BC56	6	6	36	25	0.14	126	40.837	735.06	861.066
CD57	9	6	54	25	0.14	189	4	108	297
DE57	9	6	54	25	0.14	189	3.825625	103.29	292.2918
EF56	6	6	36	25	0.14	126	4	72	198
Total									4214.6090

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5 STRUCTURAL ANALYSIS

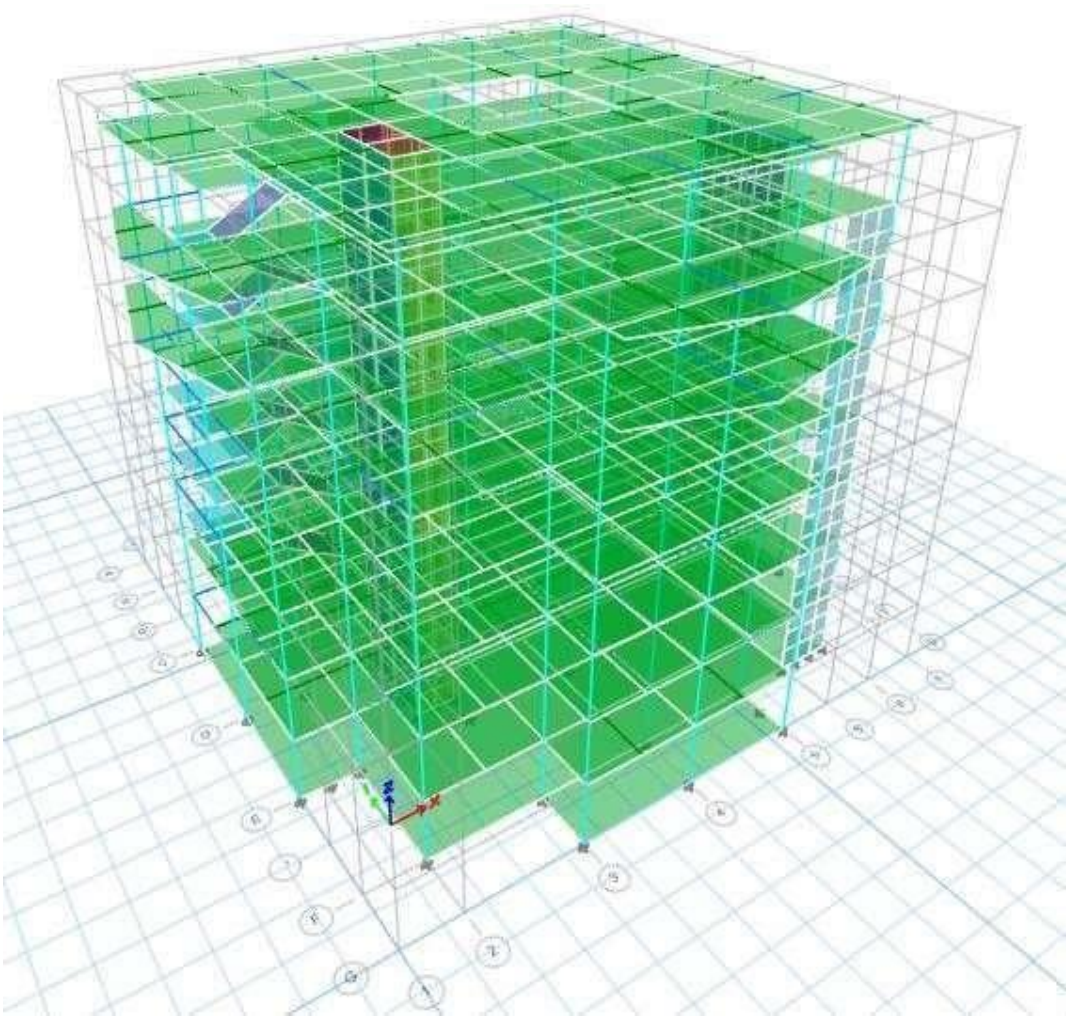

Figure 4 Building Model in ETABS

- Centre of mass and Centre of stiffness:

Centre of mass of each storey was calculated manually, along with the center of rigidity for thepreliminary architectural plan. Additionally, these values were generated from the ETABS model, and compared. Eccentricity thus observed was used in determining changes, to structural configuration.

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- Design of basement wall

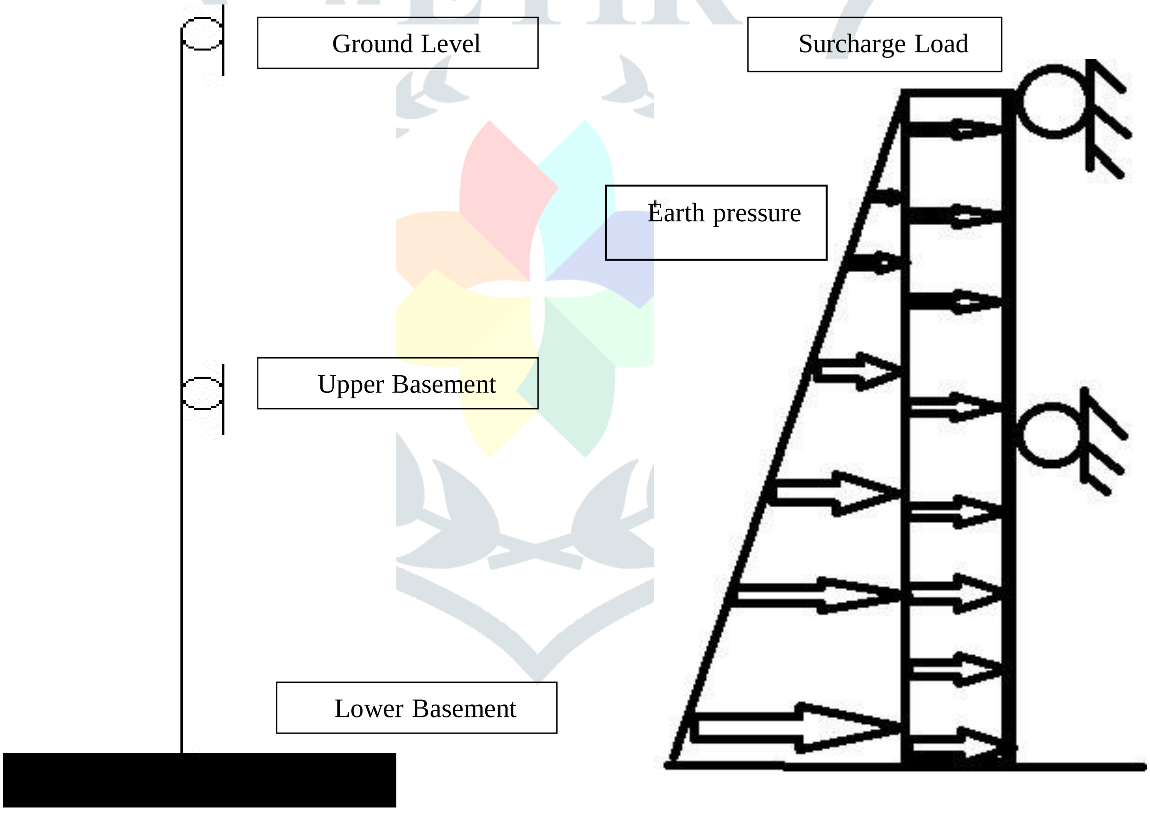
Basement wall is constructed to retain the earth and to prevent moisture from seeping into the building. Since the basement wall is supported by the mat foundation, the stability is ensured and the design of the basement wall is limited to the safe design of vertical stem.

Basement walls are exterior walls of underground structures (tunnels and other earth sheltered buildings), or retaining walls must resist lateral earth pressure as well as additional pressure due to other type of loading. Basement walls carry lateral earth pressure generally as vertical slabs supported by floor framing at the basement level and upper floor level. The axial forces in the floor structures are, in turn, either resisted by shear walls or balanced by the lateral earth pressure coming from the opposite side of the building.

The basement wall is designed as the cantilever wall with the fixity provided by the matfoundation.

Basement wall is idealized as propped cantilever wall assuming that basement wall is rigidly fixed as base and supported hingedly at floor slab.

Modeling of Basement wall



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- Design of beam

Beams are structural members assigned to transmit the loads from slab to the column through it. Specially, flexure is more dominant than shear in the beam.

There are three types of reinforced concrete beams:

1. Singly reinforced beams
2. Doubly reinforced beams
3. Singly or doubly reinforced flanged beams

In singly reinforced simply supported beams, reinforcements are placed at the bottom of the beamwhereas on top in case of cantilever beams.

A doubly reinforced concrete beam is reinforced in both compression and tension regions. The necessity of using steel in compression region arises when depth of the section is restricted due to functional or aesthetic requirements.

A complete design of beam involves consideration of safety under ultimate limit state in flexure, shear, torsion and bond as well as consideration of serviceability limit states of deflection, crack width, durability etc.

Basically, two types of works are performed namely, analysis of section and design of section. In the analysis of a section, it is required to determine the moment of resistance knowing thecross section and reinforcement details.in the design of sections, it is required to determine thecross section and amount of reinforcement knowing the factored design loads.

Concrete Grade = M25Steel Grade = Fe500

1. *Main beam*

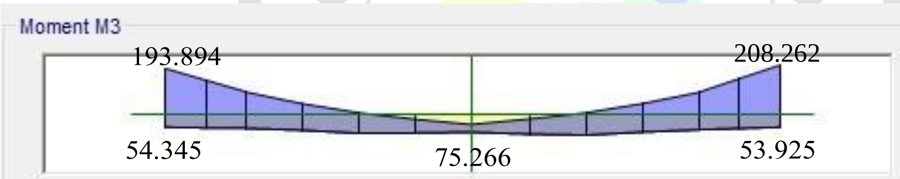

Figure 9: Main beam moment+

Main Beam – B18 Unique No: 492 Floor: Second FloorKnown Data

Concrete Grade= **25 MPa**

Steel Grade= **415 MPa**

Overall depth of beam, **D=550mm**

- Design of lift shear wall

Sample Calculation

The lift shear wall design of wall spanning along Y-axis at lower basement level isshown below.

Table 43: Design parameter for lift shear wall

Length of wall	4475 mm
Thickness of wall, tw	400 mm

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Pier id	L1
Axial Force (compressive) P_-	16974.9kN
Axial Force (tensile) P_+	11335.23 kN
Inplane Moment M_3	11407.6kN-m
Out of Plane Moment M_2	506.2 kN-m
In Plane Shear V_2	4038.1kN
Out of Plane Shear V_3	410.63kN

The Vertical reinforcement, Horizontal reinforcement and Horizontal reinforcement in boundary element is designed as in Shear wall design section above and the result is shown below as:

Table 44: Reinforcement detail in Lift shear wall

Vertical Reinforcement Dia. Φv (mm)	32
Vertical Reinforcement spacing (mm)	120
Horizontal Reinforcement Dia. Φh (mm)	20
Horizontal Reinforcement spacing (mm)	100
Boundary Element tie spacing (sv) (mm)	100
Boundary element Ties dia (mm)	10
Boundary Element size (mm x mm)	895 X 400

As per above reinforcement the provided resistance capacity of wall would be

Force/Moment	M_3 (kNm)	M_2 (kNm)	V_2 (kN)	V_3 (kN)	P_c(kN)	P_t(kN)
Design Forces	11407.6	506.2	4038.1	410.63	16974.9	11335.23
Provided Capacity	19292.34	737.383	8222.13	1643.81	32558.75	19034.5

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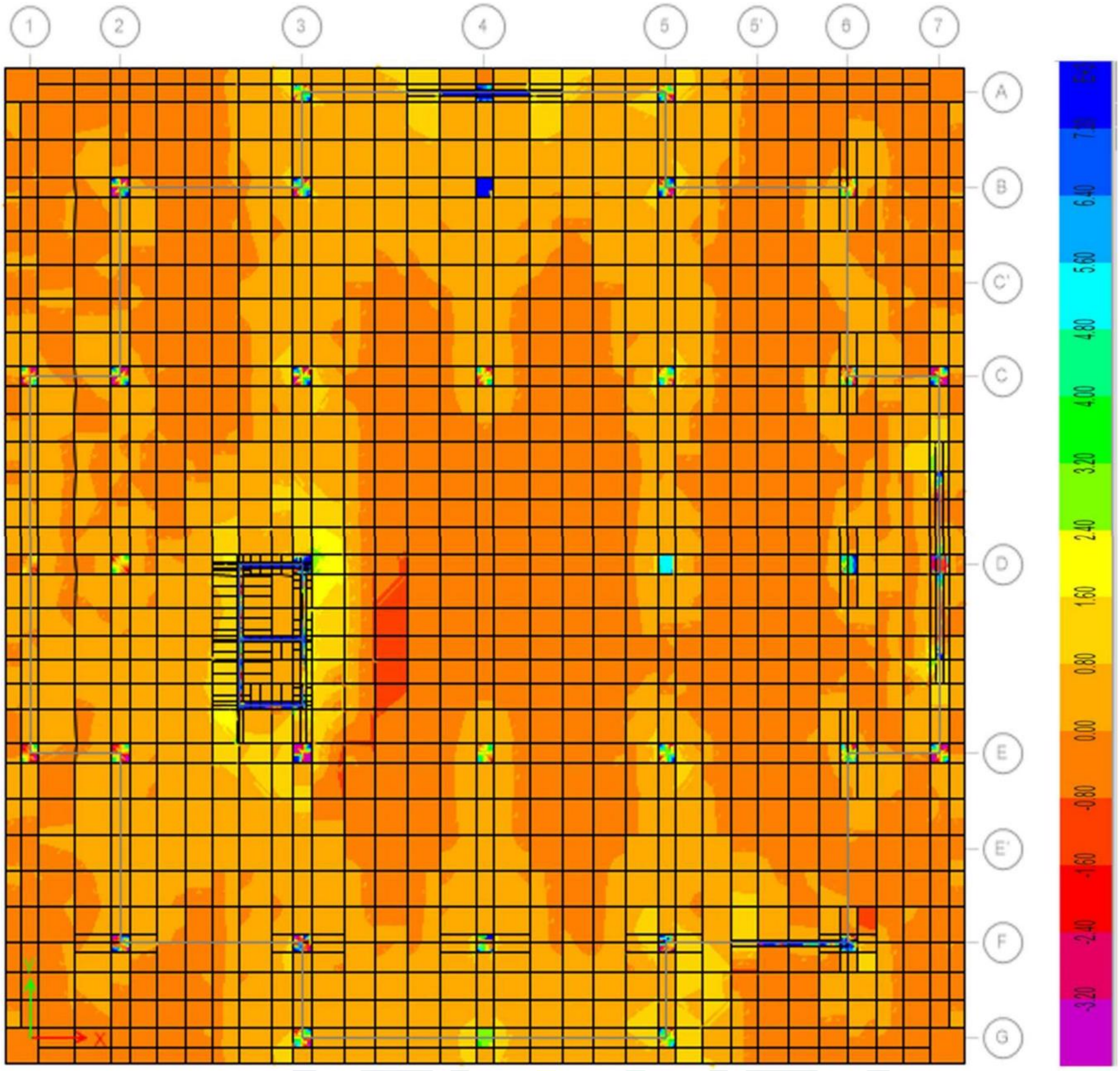

Figure 19: Shell stress M11 at collapse envelope

Upon analyzing, it can be observed that the majority of the maximum moment values occur near the shear wall end and column end of the structure. In contrast, significantly lower moments are observed in other areas of the structure. Taking this into account, the structural design has been optimized for economic efficiency by providing additional reinforcement only in the areas where the maximum moment values are observed, i.e., at the column and shear wall ends. Specifically, the main reinforcement has been designed to withstand a moment value of 1000kNm, which is the maximum moment that can be sustained by the structure as a whole. However, to ensure that the observed maximum moment values near the column and shear wall ends can be safely sustained without requiring unnecessary reinforcement throughout the rest of the structure,

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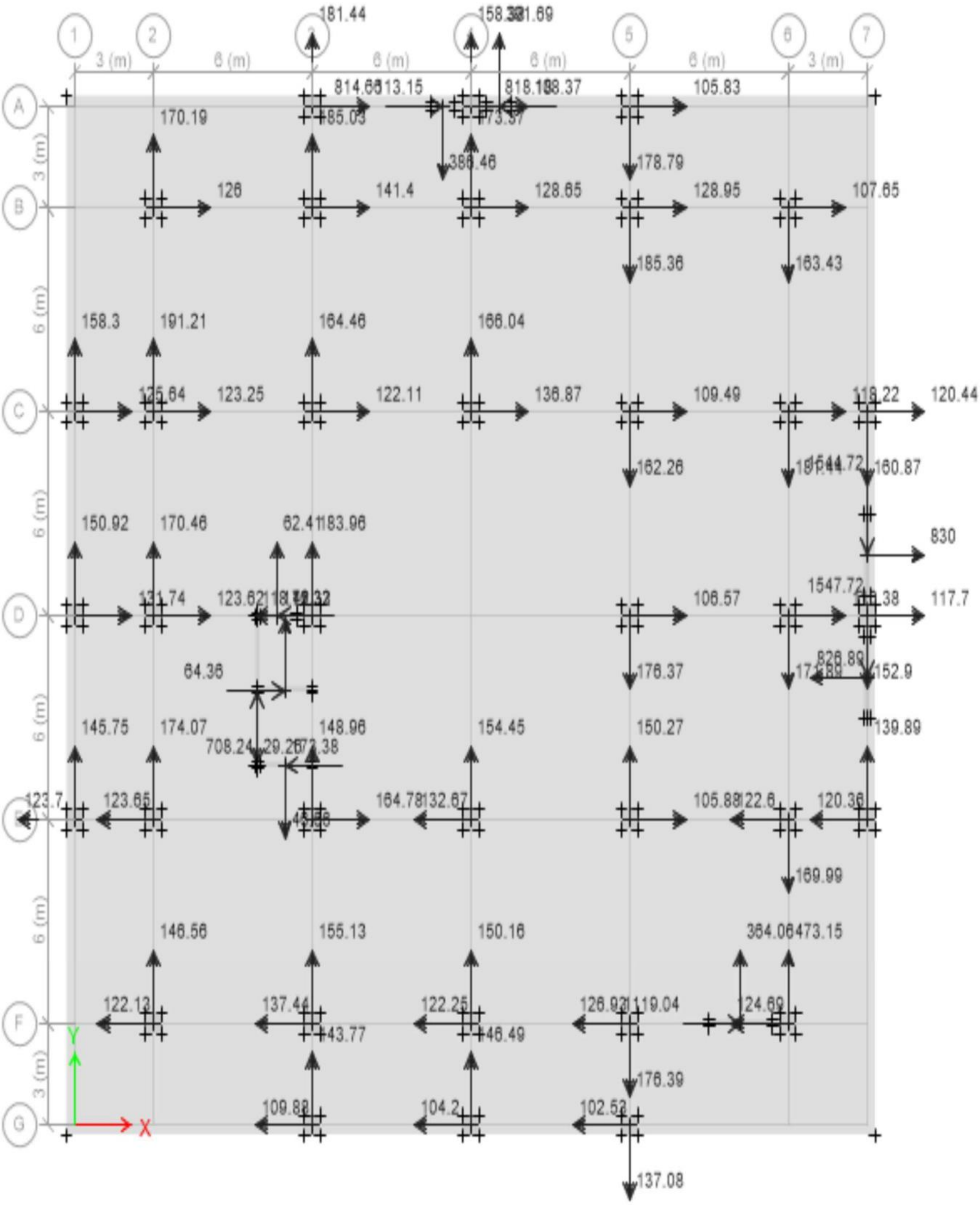
Loads on



Foundation for Ultimate state

7 Conclusion

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In conclusion, this building project has provided us with a valuable learning experience inearthquake resistant design and ductile detailing of concrete structures. As Nepal is located in a seismically active region, it is crucial to consider the safety of structures and human lives during earthquakes. By following the earthquake resistant design code (IS 1983 (Part-I):2016) and ductile detailing of concrete (IS 13920:2016), we have designed a building that is better equipped to withstand lateral earthquake loads and minimize damage. Our team worked together to idealize, analyze, and design the building under the guidance of our respected supervisor, and we hope that our design meets their expectations. We believe that this project has given us a deeper understanding of the transfer mechanism of lateral earthquake loads into vertical members and, finally, into the foundation. Overall, we are grateful for the opportunity to work on this project, and we are confident that the knowledge and skills we have gained will serve us well in our futurecareers as civil engineers.

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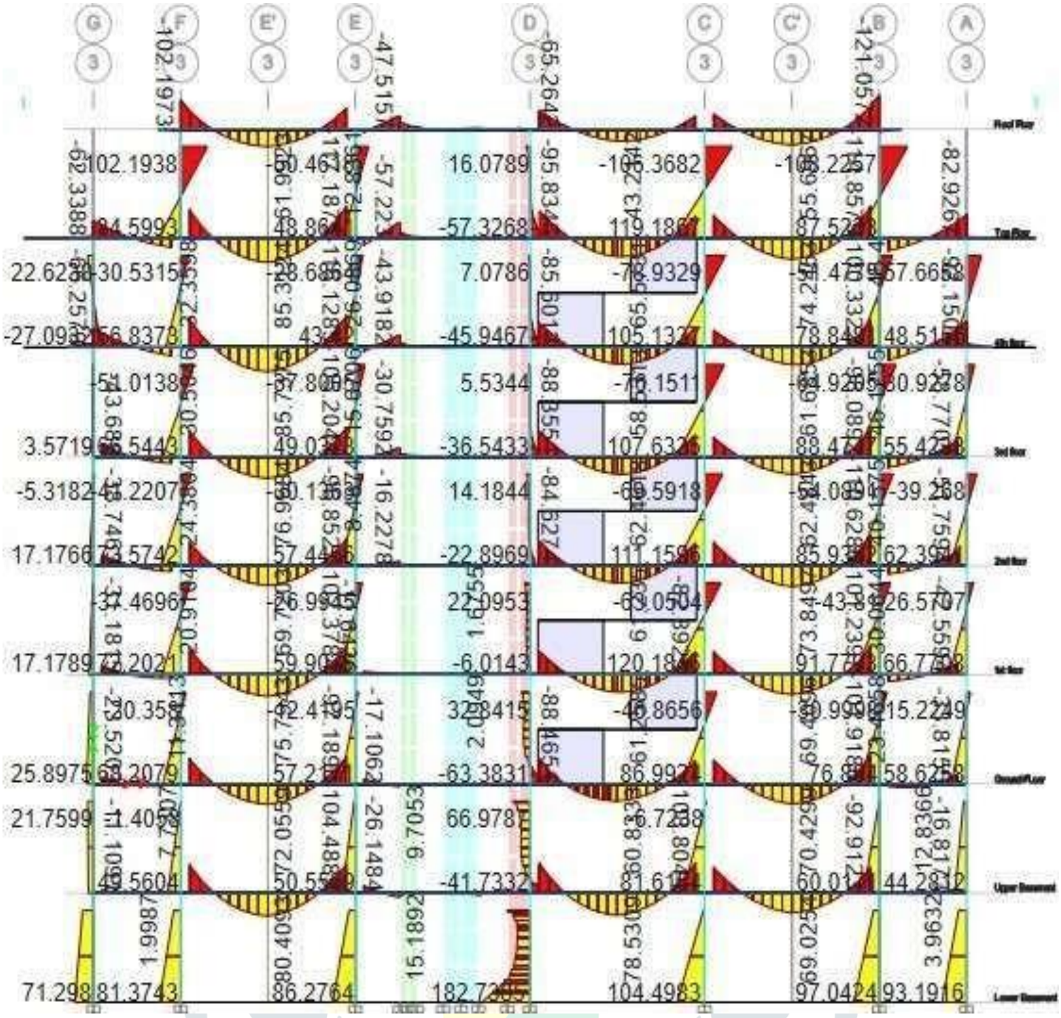
Figure 22 Moment Diagram at 1.2(DL+LL+EQx)



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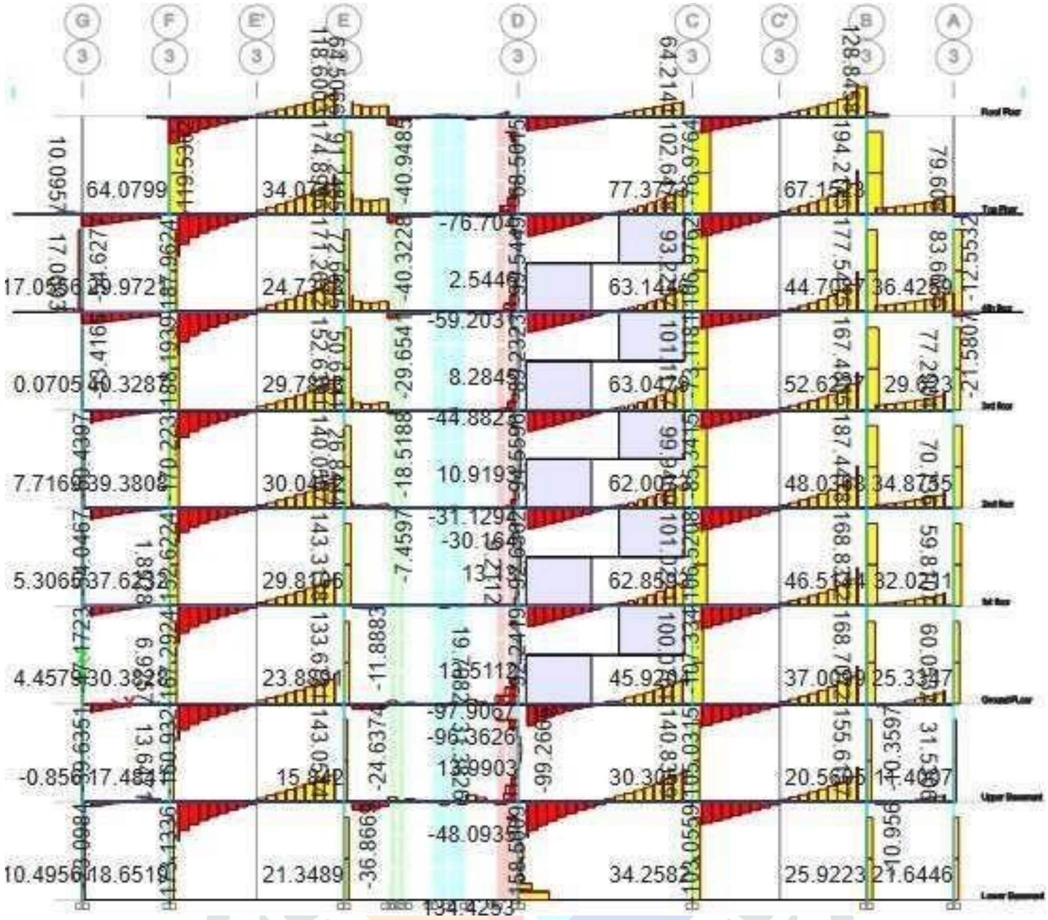

Figure 23 Shear Force Diagram at 1.2(DL+LL+EQx

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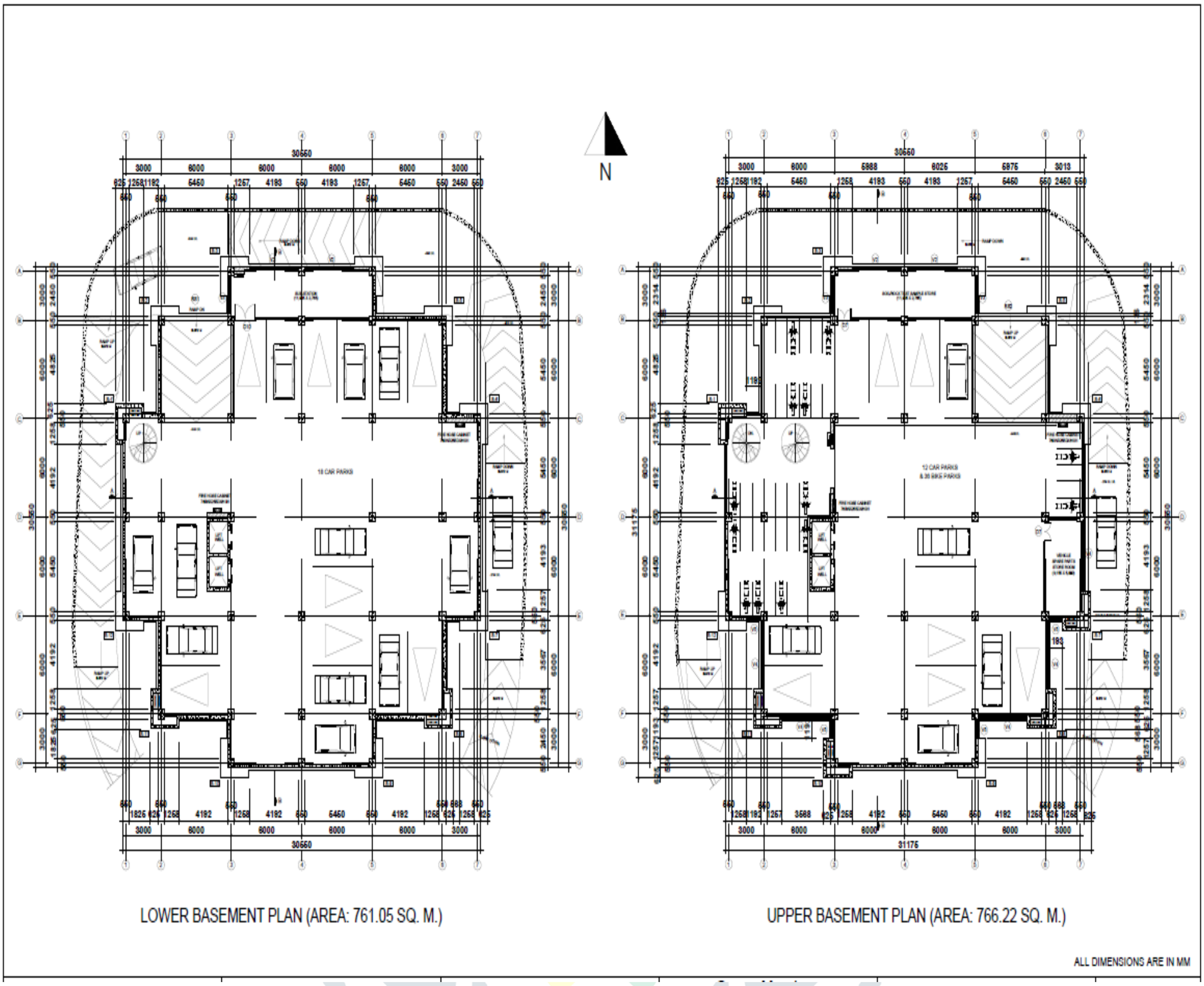
N
LOWER BASEMENT PLAN (AREA: 761.05 SQ. M.)
UPPER BASEMENT PLAN (AREA: 766.22 SQ. M.)
ALL DIMENSIONS ARE IN MM

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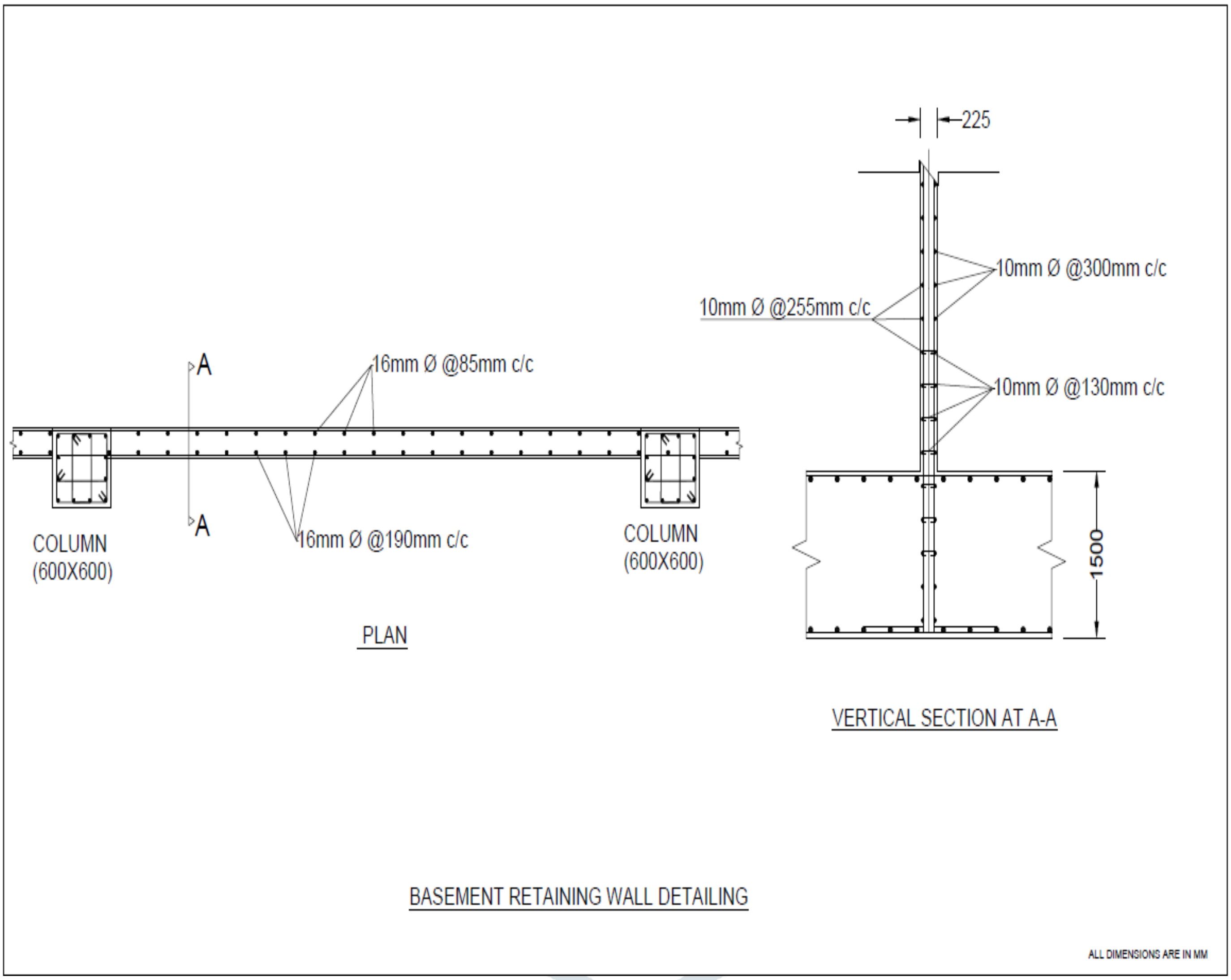
225
10mm Ø @300mm c/c
10mm Ø @255mm c/c
A
16mm Ø @85mm c/c
10mm Ø @130mm c/c
A
16mm Ø @190mm c/c
COLUMN
(600X600)
COLUMN
(600X600)
1500
PLAN
VERTICAL SECTION AT A-A
BASEMENT RETAINING WALL DETAILING
ALL DIMENSIONS ARE IN MM

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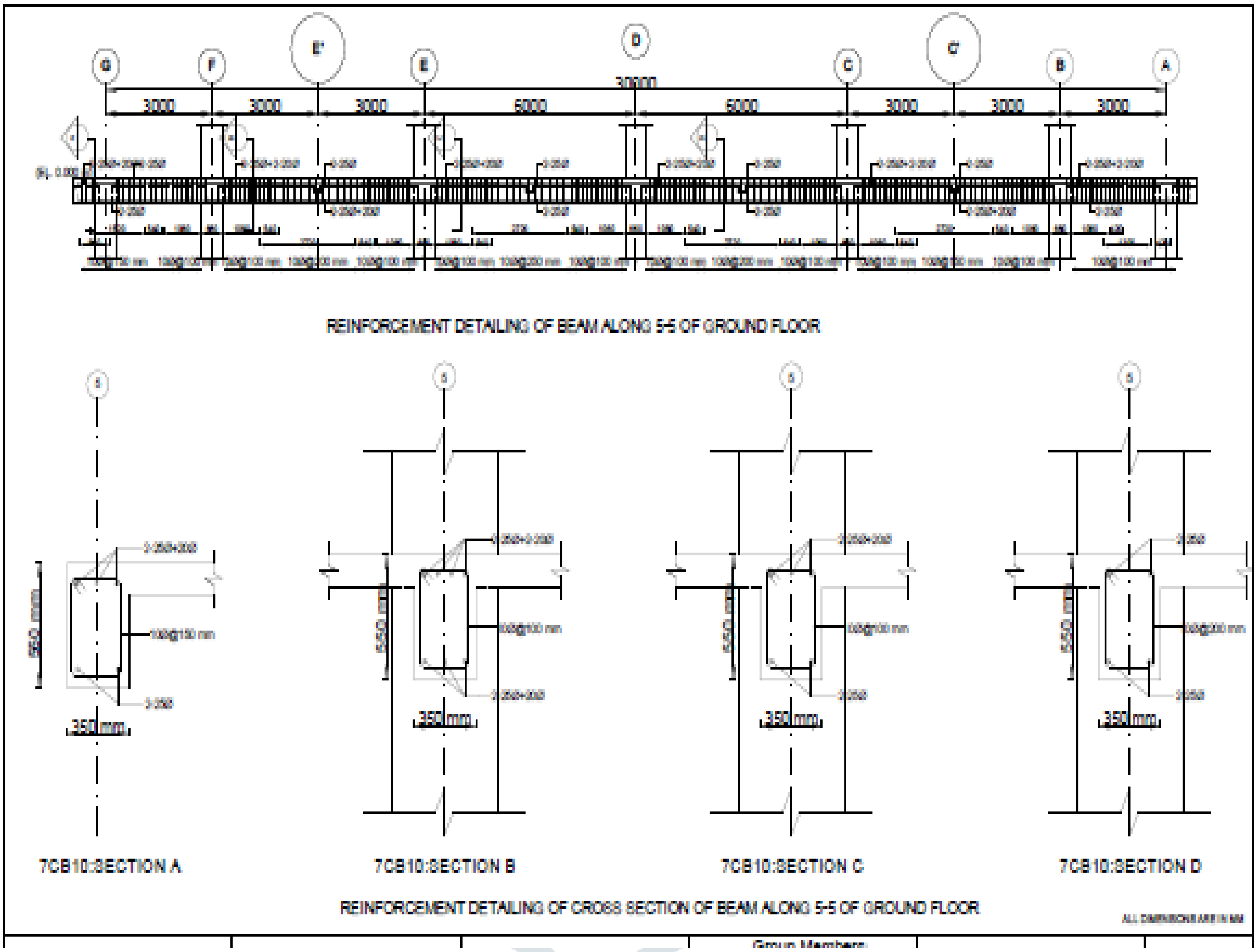
G
F
E'
E
D
C
C'
B
A
30000
3000
3000
3000
6000
6000
3000
3000
3000
REINFORCEMENT DETAILING OF BEAM ALONG 5-5 OF GROUND FLOOR
550 mm
350 mm
7CB10:SECTION A
7CB10:SECTION B
7CB10:SECTION C
7CB10:SECTION D
REINFORCEMENT DETAILING OF CROSS SECTION OF BEAM ALONG 5-5 OF GROUND FLOOR

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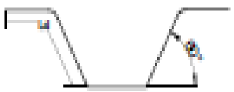
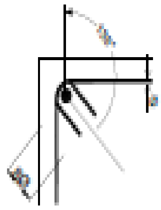
TYPICAL BEAM REINFORCEMENT DETAILING



BENT UP HANGER TYPE BARS



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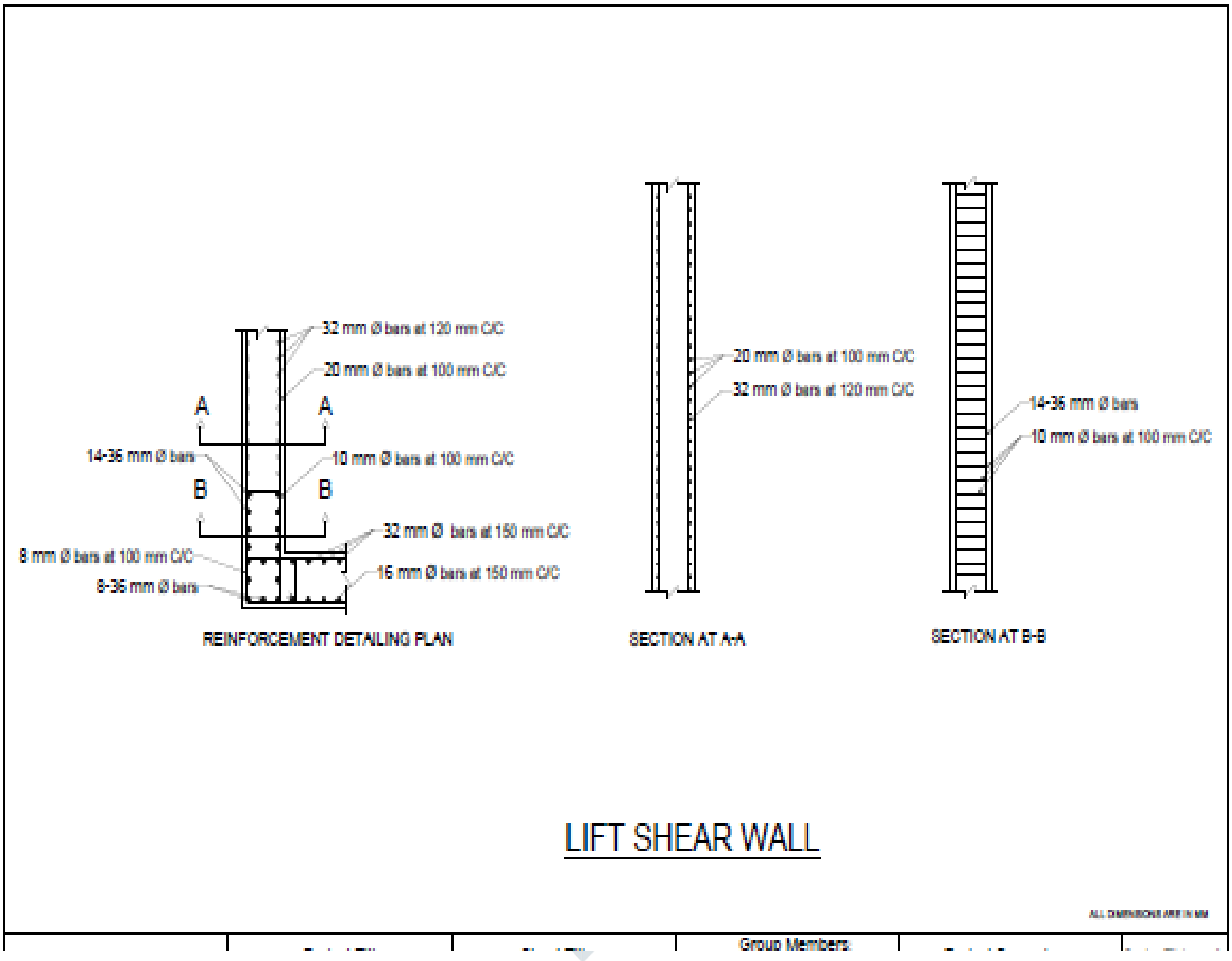
32 mm Ø bars at 120 mm C/C
20 mm Ø bars at 100 mm C/C
A
A
14-36 mm Ø bars
10 mm Ø bars at 100 mm C/C
B
B
32 mm Ø bars at 150 mm C/C
8 mm Ø bars at 100 mm C/C
16 mm Ø bars at 150 mm C/C
8-36 mm Ø bars
REINFORCEMENT DETAILING PLAN
20 mm Ø bars at 100 mm C/C
32 mm Ø bars at 120 mm C/C
SECTION AT A-A
14-36 mm Ø bars
10 mm Ø bars at 100 mm C/C
SECTION AT B-B
LIFT SHEAR WALL
Group Members

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