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Seismic Performance Evaluation and Retrofitting of Unreinforced Masonry: A case study of the Hostel Block at IOE, Thapathali Campus

In the partial fulfillment of requirements for the Bachelor's

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INSTITUTE OF ENGINEERING

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THAPATHALI CAMPUS

LETTER OF APPROVAL

This is to certify that this project work entitled "Seismic Performance Evaluation and Retrofitting of Unreinforced Masonry: A case study of the Hostel Block at IOE, Thapathali Campus" has been examined and it has been declared successful for the fulfillment of the academic requirements towards the completion of the Bachelor's Degree in Civil Engineering.

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ABSTRACT

Retrofitting is conducted on structures to enhance their strength and performance. This study focuses on retrofitting to bolster the seismic resilience and performance of the hostel building situated at Thapathali Campus, which suffered significant damage during the Gorkha earthquake. Various established theoretical methods are employed to assess the seismic vulnerability of the structure. The structure is modeled using SAP2000 software, incorporating appropriate load parameters. Based on the modeling results, two retrofitting options are proposed, considering material selections. We recommend retrofitting methods that employ seismic bands, incorporating wire mesh and TOR bars.

LIST OF ABBREVIATIONS AND SYMBOLS

FEM: Finite Element Method

URM: Unreinforced Masonry

RC: Reinforced Concrete

ASCE: American Society of Civil Engineers

FEMA: Federal Emergency and Management Agency

E: Modulus of Elasticity

G: Shear Modulus

3D: Three Dimension

2D: Two Dimension

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1 INTRODUCTION

1.1 Background

Masonry is a construction material that has been used throughout the years as a structural or non-structural component in buildings. Masonry can be described as a composite material made up of different units, diverse types of arrangements with or without mortar, and used in many ancient public buildings as well as with the latest new technologies being applied in construction. (Tanja, 2019).

Normally thick walled URM buildings were designed for vertical loads, since masonry has adequate compressive strength, the structure behaves well if the loads are vertical. When such a masonry structure is subjected to lateral inertial loads during an earthquake, the walls develop shear and flexural stresses. The strength of masonry under these conditions often depends on the bond between brick and mortar. A masonry wall can also undergo in-plane shear stresses if the lateral forces are in the plane of the wall. Shear failure in the form of diagonal cracks is observed due to this.

Masonry structures are complex systems that require thorough and detailed knowledge and information regarding their behavior under seismic loading. Appropriate modeling of a masonry structure is a prerequisite for a reliable earthquake resistant design or assessment. However, modeling a real structure to a with accurate representation is a very difficult, complex, and computationally demanding task.

Despite all its drawbacks, masonry still has many advantages over RC for low-height residential building construction. Contrary to RC structures, masonry buildings save in overall construction time and cost by eliminating the need for expensive formwork, heavy machinery, and special equipment for concrete pouring.

1.2 Need for Study

Nepal lies in a highly seismically vulnerable region by virtue of its proximity to the young Himalayan range and the ongoing neo-tectonic activities in the region. The seismicity of the country is attributed to the location of region in the sub-duction zone of Indian and Eurasian tectonic plate. (Khadka, 2013).

Throughout history, Nepal has witnessed several significant earthquakes (Ambraseys and Douglas, 2004; Bilham, 2004). Figure 1 displays a map of Nepal, indicating the locations of major historical seismic events. In 1505, Western Nepal experienced a Mw8.2 event, west of the rupture zone of the 2015 earthquake. Strain has been accumulating in this seismic gap region since then, suggesting a high potential for future large earthquakes in the western region. In Eastern Nepal, major earthquakes occurred in 1833 and 1934. The 1934 Mw8.1 Bihar–Nepal earthquake was highly destructive and resulted in a significant number of fatalities (over 10,000 deaths). The 2015 Gorkha earthquake ruptured a fault section that overlaps with the fault rupture plane of the 1934 earthquake (Figure 1). It's noteworthy that the rupture planes of the 1934 and 2015 earthquakes are directly beneath Kathmandu, despite their hypocenters being east and west of Kathmandu, respectively.

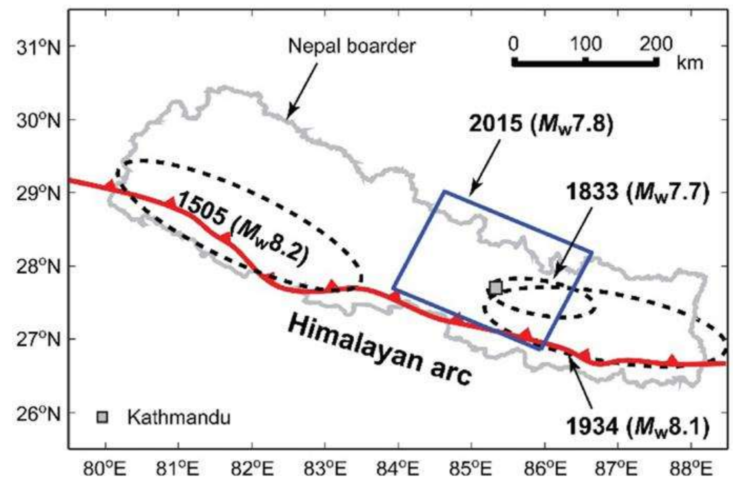


Figure 1 Seismic Map of Nepal

According to the 2011 data from the National Population and Housing Census, Nepal has a total of 5,423,297 individual households, with a population of 26,494,504. Research conducted by Pokhrel, Goda, Kiyota, and Sharma in 2015 reveals that mud-bonded brick/stone masonry structures are predominant across all geographical regions of Nepal (44.2%), followed by wooden buildings (24.9%).

The Post Disaster Needs Assessment of 2015 reports that the total number of buildings damaged during the 2015 Gorkha earthquake was 755,549, with 498,852 fully damaged and 256,697 partially damaged. Among fully damaged structures, low-strength masonry constituted 95% (474,025), while for partially damaged buildings, it accounted for 67.7%

(173,867). In contrast, cement-based masonry buildings represented 3.7% (18,214) of fully damaged structures and 25.6% (65,859) of partially damaged ones. The remaining damage was to reinforced concrete buildings. Notably, low-strength masonry buildings experienced the most significant structural damage (Assessment, 2015).

It is thus important to take control on the factors that would tend to help minimize the earthquake damage from earthquakes in future. For this firstly, modelling of the masonry building is done using 3D simplified macro modelling approach using SAP2000. Then, nonlinear links have been introduced according to the predefined. Then, linear static analysis is performed. Now, our aim is to assess the seismic vulnerability of this building and provide appropriate retrofitting measures, if necessary.

1.3 Objectives

The main objective of the project is:

1. To assess the seismic vulnerability of the Hostel Block at IOE, Thapathali Campus and recommend appropriate retrofitting measures if needed.

1.4 Scope of Work

Scope of work includes:

1. Conducting a thorough seismic performance evaluation of the Hostel Block at IOE, Thapathali Campus.
2. Analyzing structural vulnerabilities and weaknesses of unreinforced masonry.
3. Developing retrofitting strategies and designs tailored to the specific building characteristics.

1.5 Assumptions And Limitations

1. Although masonry walls which are composed of mortar and brick units show heterogeneous and anisotropic behavior, masonry is assumed as a homogenous and isotropic medium.
2. A more detailed micro-modeling approach or damage models could provide better representation of the failure patterns and capacity curves, a limitation for FE modeling using SAP2000.

2 Literature Review

In this chapter, we examine the existing literature that informs our study. We discuss the characteristics of unreinforced masonry, the historical evidence of earthquake-induced damage to unreinforced masonry buildings, the common failure mechanisms of URM, the methods of modelling and analyzing URM and some related works in the Nepalese context.

URM structures are vulnerable to various loading conditions, such as compression, bending, shear, and torsion. Compression is the most common load acting on URM walls, and it affects the stability and strength of the structure. URM walls have a low tensile strength and a high compressive strength, which results in cracking and crushing failure modes. The compressive behavior of URM walls depends on many factors, such as the properties of the units and mortar, the bond strength, the slenderness ratio, the presence of openings, and the loading eccentricity (Hendry, 1998). The design of URM walls under compression requires the use of empirical formulas or analytical methods that account for these factors, as well as the comparison with the experimental results and the design codes (Abrahem A. Ali Blash, 2023)

Seismic forces can seriously impact the performance of URM structures. These structures, with low flexibility and high stiffness, are prone to cracking and collapsing during earthquakes. To enhance their seismic resistance, various techniques have been developed, including reinforcing corners and wall intersections, connecting walls, and using horizontal and vertical ties (Tomazevic, 2007). Analyzing URM structures under seismic loads requires the use of nonlinear models that account for material damage, plasticity, and torsional effects caused by structural irregularities (Garbin, 2020) It is crucial to validate these models with experimental data to ensure accurate and reliable predictions.

2.1 Failure Modes in URM Structures

Seismic evaluation procedures, like FEMA 356 (2000) and ASCE 41 (2006), typically consider four failure modes for unreinforced masonry walls. These modes are based on the observed behavior of such walls in earthquakes and experimental tests. The main assumption is that the masonry wall's behavior is governed by the failure mode with the lowest capacity. These failure modes are categorized as either deformation-controlled (involving bed-joint sliding and rocking) or force-controlled (involving diagonal tension cracking and toe compression failure).

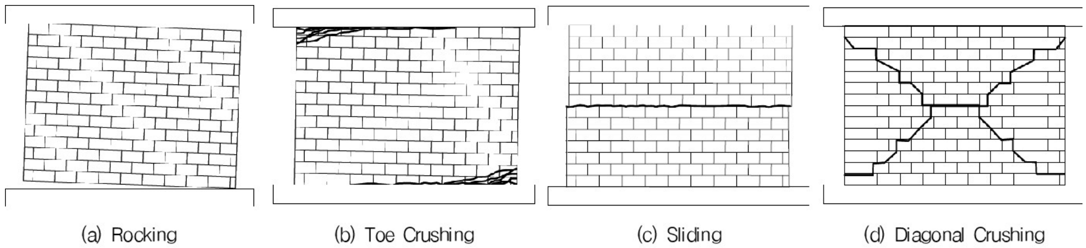


Figure 2 Failure modes of URM

Deformation-controlled actions are expected to result in ductile behavior without significant strength loss, while force-controlled actions are expected to exhibit brittle behavior with a sudden loss of strength. In earthquake-resistant design, force-controlled members are not allowed to reach the yield stress. Seismic evaluation guidelines, like FEMA 356 (2000) and ASCE 41 (2006), use lower bound strengths and expected strengths of materials to determine the capacity of force-controlled and deformation-controlled actions, respectively (Bahmin Ghiassi, 2012)

2.2 Stress-Strain Curves for Brick Units

The tests conducted in this study were carried out in accordance with standards, namely ASTM C 67-00 and IS 3495. Stress-strain curves for four types of bricks were generated by averaging data from ten samples of each type, revealing a linear behavior up to approximately one-third of the ultimate failure load, beyond which the behavior became highly nonlinear. An average stress-strain curve encompassing all brick types studied was also presented. The relationship between Eb and fb, showed Eb varied between 150 and 500 times fb. An average value of Eb was determined as:

$$Eb \sim 300fb$$

But it was found to have a weak correlation (Cr=0.39) between Eb and fb, as evidenced by significant data scattering in Figure 4. Thus, the equation should be used cautiously. (Kaushik, Rai, & Jain, 2007)

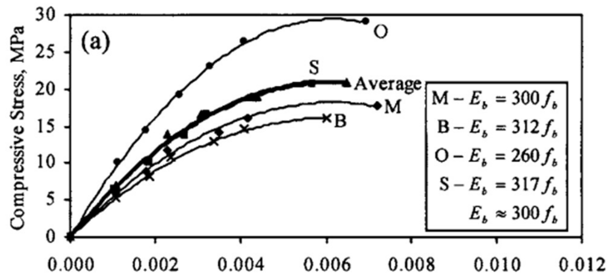


Figure 3 Stress-Strain curves for brick units

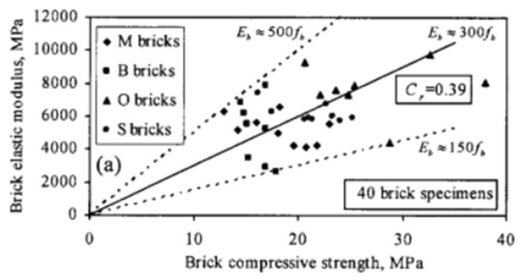


Figure 4 Relationship between Eb and fb

2.3 Stress-Strain Curves for Masonry Prism

Sometimes, it is essential to consider the property of masonry rather than individual brick units. So, masonry prisms were assembled using combinations of four brick types and three mortar grades, with stress-strain curves derived from averaging data from seven specimens of each combination as shown in figure 5.

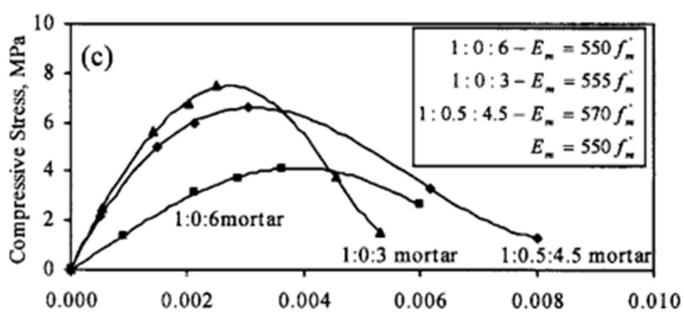


Figure 5 Stress-Strain Curves for Masonry prism

The stress-strain curve indicated linear behavior up to about one-third of fm, after which cracks began to form in the bricks, introducing nonlinearity.

The relationship between Em and fm was explored, with Em varying between 250 and 1,100 times fm. An average value of Em was determined as:

$$Em = 550fm$$

A relatively good coefficient of correlation (Cr=0.63) was observed between experimentally observed Em values and those estimated using the proposed equation, aligning with internationally accepted documents and codes.

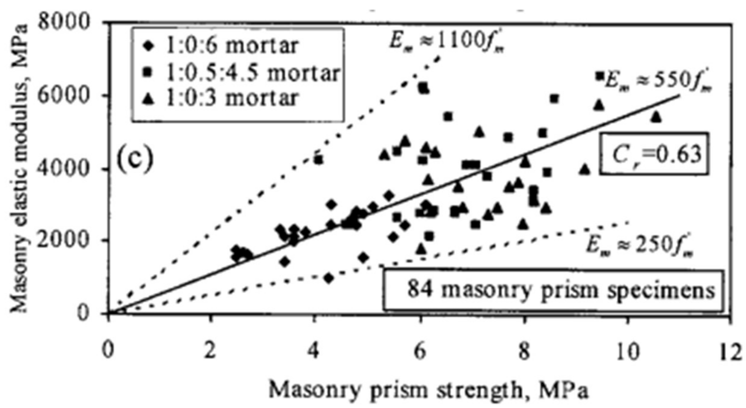


Figure 6 Relationship between Em and fm

Furthermore, the study highlighted the performance of masonry prisms constructed with different mortar types, emphasizing the role of lime content in improving ductility without compromising compressive strength. Additionally, the compressive behavior of masonry was examined concerning the strengths and stiffnesses of bricks and mortar, challenging the commonly held belief regarding their go-between behavior.

Finally, the relationship between fm, brick strength (fb), and mortar strength (fj) was explored, with fm increasing with fb and fj, particularly pronounced when weaker mortar was used. This behavior aligns with past studies and suggests considerations beyond strength alone, such as workability and deformability, in selecting appropriate mortar for masonry construction. (Kaushik, Rai, & Jain, 2007)

2.4 Analytical Modelling Techniques of Masonry Structures

2.4.1 Detailed Micro-Modeling

In this type of modeling, the bricks and mortar are modeled as continuous elements with specific failure criteria. Special elements that represent the discontinuities are used to model the interface between bricks and mortar. The shape of the wall is fully reproduced in this case. This model can capture most masonry failure modes because of its level of detail.

2.4.2 Simplified Micro-Modeling

The bricks are the same as in the detailed micro model in simplified micro-modeling, but the mortar joints and interface elements are replaced by distinct elements that represent a contact area. The overall shape is maintained, but the individual elements that represent joints and interfaces cannot account for the Poisson's effect of mortar on bricks. Some types of failure modes cannot be replicated in this kind of model.

2.4.3 Macro-Modeling

The masonry panel (or part of it) is treated as a uniform element in this situation. This kind of model should be able to reproduce the basic structural behavior of a masonry panel based on its properties, but it will not be able to simulate all kinds of failure phenomena.

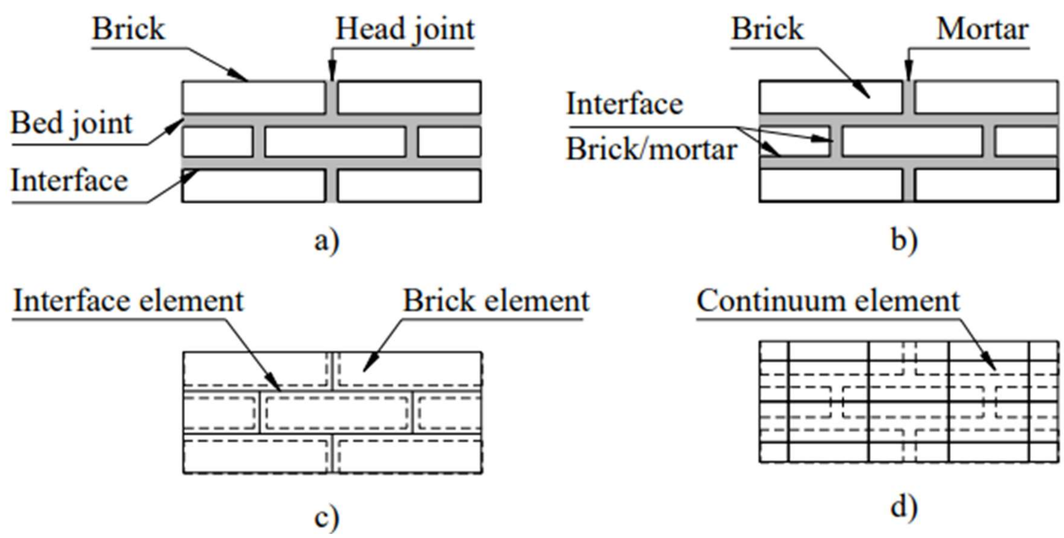


Figure 7 Masonry modeling strategies: a) masonry sample; b) detailed micro modeling; c) simplified micro modeling; d) macro modeling.

3 Methodology

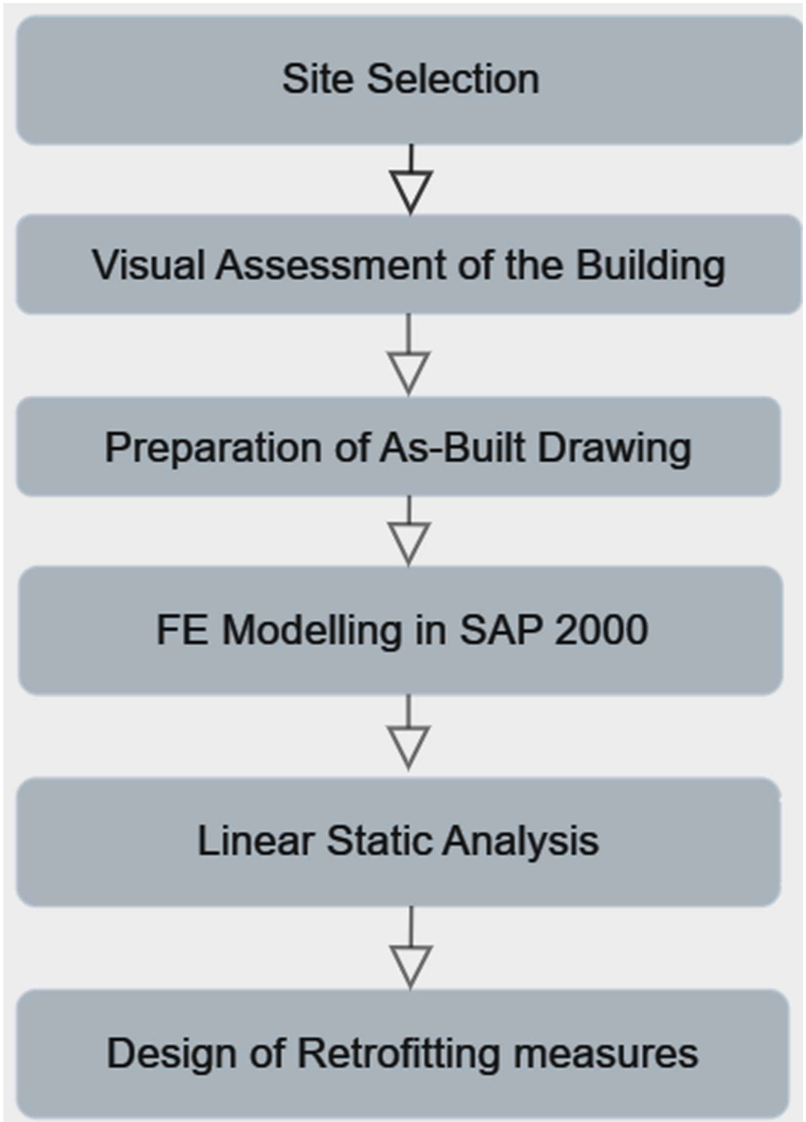


Figure 8 Work Methodology

3.1 Site Selection

After completion of reconnaissance survey, the hostel block of IOE, Thapathali Campus, a masonry building, which has been abandoned after the 2015 Gorkha earthquake was selected. This building is in the IOE, Thapathali Campus premises in Thapathali, Kathmandu.

3.2 Visual Assessment of The Building

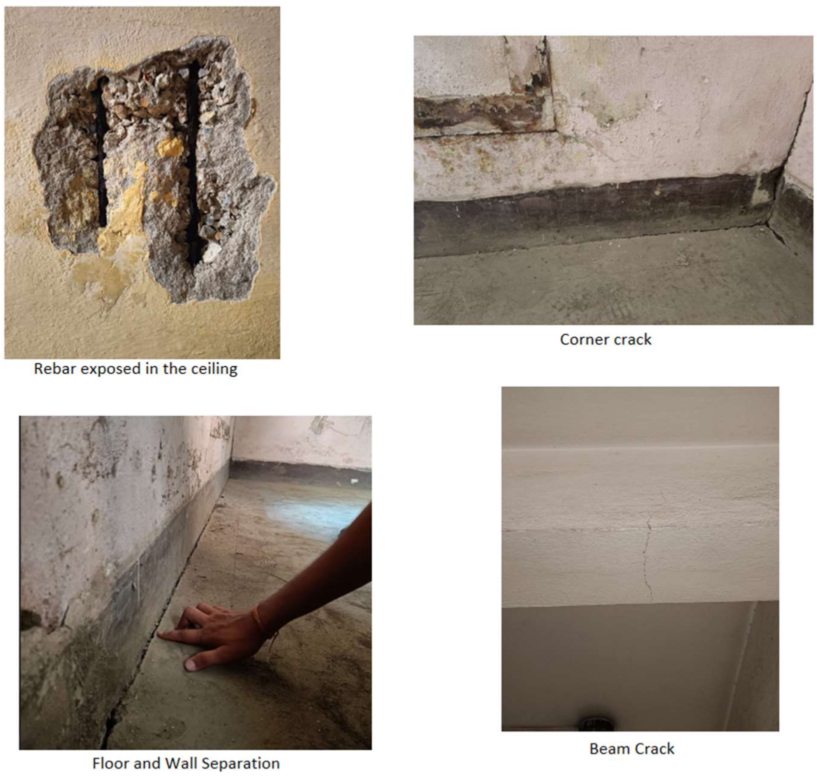


Figure 9 Damages in the Hostel Block of IOE, Thapathali Campus

During the preliminary survey, various aspects of the structure are visually examined. Essential building parameters necessary for evaluating its vulnerability are measured and documented. Additionally, photographs capturing the current state of the structure are taken to serve as a reference during the creation of as-built drawings. Any damage incurred in the aftermath of the Gorkha 2015 Earthquake are also identified.

Table 1 General Building Description

Building Type	Accommodation Building
No. of Stories	3.00
Story height	2.71m, 2.935m, 3.007m
Wall	480mm, 470mm, 360mm
Floor/Slab	135(G),190(F),170(S)
Parapet wall height	1m
Earthquake Zone	I
Importance Factor	1.50
Floor	RCC, M20
Mortar Grade	M2
Beam Section	632.2mm*254mm
Building Dimension	13.760m X 20.515m

3.3 Checklist

3.3.1 Building System

Table 2 Checklist

LOAD PATH	C
REDUNDANCY	C
GEOMETRY	C
MEZZANINES/LOFT/SUBFLOORS	N/A
WEAK STORY	N/K
SOFT STORY	N/K
VERTICAL DISCONTINUITIES	N/C
MASS	C
TORSION	N/K
ADJACENT BUILDINGS	C
DETERIORATION OF CONCRETE	N/C
MASONRY UNITS	N/C
MASNORY JOINTS	C
UNREINFORCED MASONRY WALL CRACKS	N/K

3.3.2 Lateral Load Resisting System

SHEAR STRESS IN SHEAR WALLS	N/A
HEIGHT TO THICKNESS RATIO	C
MASONRY LAY UP	N/A
WALL ANCHORAGE	N/A
CONNECTIONS	N/A
OPENINGS IN DIAPHRAGMS NEAR SHEAR WALLS	N/A
OPENINGS IN DIAPHRAGMS NEAR EXTERIOR MASONRY SHEAR WALLS	N/A
PLAN IRREGULARITIES	N/K
VERTICAL REINFORCEMENT	N/K
HORIZONTAL BANDS	N/K
CORNER STITCH	N/C
GABLE BAND	N/A
DIAGONAL BRACING	N/A
LATERAL RESTRAINERS	N/C

3.4 Preparation of As-Built Drawing

During the site visit, measurements were taken to prepare the as-built architectural drawing. The ground floor plan is shown below in figure 8.

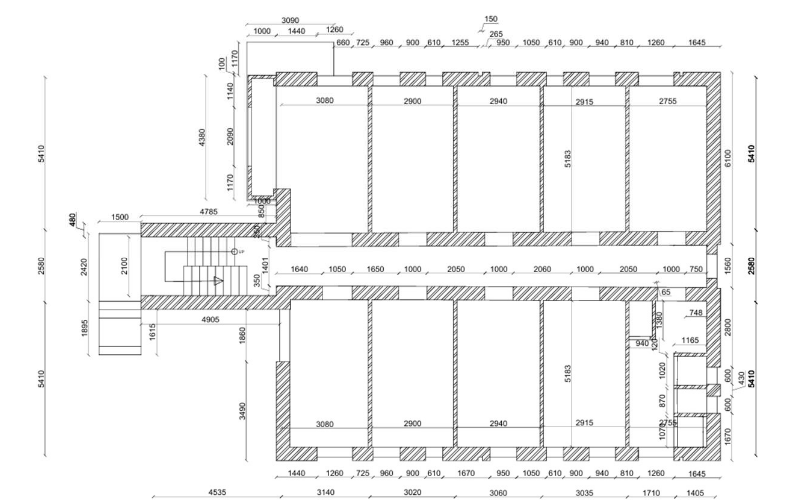


Figure 10 Ground Floor Plan

3.5 Modeling

The Finite Element Software SAP 2000 v20.0.0 is employed for modeling and analysis. The 3D macro-modeling approach is utilized to represent the current building under investigation. Masonry wall elements and roof slabs are represented as thin shell area elements. This validated modeling technique is applied to develop the Finite Element (FE) model for the chosen building typology. Although finite element models are the most reliable among all, the best method might be defined as "the method that provides the sought information in a reliable manner, i.e., within an acceptable error, with the least cost" (Oliveira, 2003).

Due to the absence of field data and material testing, mechanical properties are derived from relevant literature for the present study. The foundation is assumed to be hinge support at ground level.

The complexity of historical masonry structures renders linear analyses unsuitable. These structures, exhibiting anisotropic behavior and distinct responses in tension and compression, make linear models less accurate, especially considering the almost negligible tensile strength of masonry. Even at low loads, linear analysis may prove inaccurate. Despite these limitations, linear models effectively highlight the overall tendencies in building behavior, modal characteristics, and stress concentration areas that can disrupt masonry continuity.

In recent decades, linear analyses have been employed to simulate the structural behavior of numerous culturally significant masonry buildings. However, nonlinear analysis is now recommended as the more appropriate method for historical masonry structures. This advanced approach captures the complete structural response, encompassing elastic stages, cracking, dislocation, and eventual collapse. To conduct nonlinear analysis, one must define the elastic and inelastic mechanical properties of masonry. Various nonlinearities, including material, geometrical, and contact-related factors, can be considered in this comprehensive computational method.

3.5.1 Material Properties

Table 3 Material Properties

Compressive Strength of Mortar	3 MPa (Table 1 of IS 1905:1987)
Young's Modulus	1543.882 (Calculated using IS 1893 Part I: 2016)
Poisson's ratio	0.15
Modulus of Rigidity	671.260 MPa
Shear Strength	0.1 MPa-0.5 MPa

4 MANUAL CALCULATIONS

4.1 Design Loads Considerations

Table 4 Design load calculation

Dead Loads	(IS 875 PART I)
Masonry Wall	19.1kN/m^3
RCC Slab	25kN/m^3
Live loads	(IS 875 PART II)
Passage/Staircase live load	3kN/m^2
Roof live load(inaccessible)	1.5kN/m^2
Roof live load(accessible)	0.75kN/m2
Bathroom/Toilet live load	2.0kN/m2
Bedroom live load	2.0kN/m2

4.2 Unit Weight of The Elements

Table 5 Unit Weight of the Element

S.N.	**Description**	**Thickness(m)**	**Density (kN/m^3)**	**FF Thickness (m)**	**FF Density (kN/m^3)**	**Intensity (kN/m^2)**
1.000	**Self-weight of slab**					
1.100	Ground Floor	0.135	25.000	0.050	20.000	4.375
1.200	1st floor	0.190	25.000	0.050	20.000	5.750
1.300	2nd floor	0.170	25.000	0.050	20.000	5.250
2.000	**Wall**					
2.100	Ground Floor	0.480	19.100	0.025	20.000	9.668
2.200	1st Floor	0.470	19.100	0.025	20.000	9.477
2.300	2nd floor	0.360	19.100	0.025	20.000	7.376

4.3 Load Calculation for Ground Floor

Table 6 Load Calculation for Ground Floor

Floor	Description	Weight (kN/m3)	Height (m)	Area(m^2)	X(m)	Y(m)	Weight (KN)
G.F.	Walls	19.100	2.710	35.347	7.030	6.835	1829.573
G.F.	Walls above window	19.100	0.720	8.795	7.923	6.473	120.946
G.F.	Slab	25.000	0.135	220.945	7.695	6.974	745.689
G.F. LL	Toilet/bathroom live load	2.000		38.926			77.851
G.F. LL	Room live load	2.000		153.924			307.849
G.F. LL	Passage live load	3.000		23.595			70.785

4.4 Load Calculation for First Floor

Table 7 Load Calculation for First Floor

Floor	Description	Weight (kN/m3)	Height(m)	Area(m^2)	X(m)	Y(m)	Weight (KN)
1 F	Walls	19.100	2.935	33.393	5.861	6.943	1871.964
1 F	Walls above window	19.100	0.650	9.273	9.444	6.636	115.119
1 F	Walls below window	19.100	0.570	9.273	9.444	6.636	100.951
1 F	Slab	25.000	0.190	216.445	7.865	6.88	1028.113
1 F LL	Toilet/bathroom live load	2.000		39.273			78.546
1 F LL	Room live load	2.000		151.689			303.379
1 F LL	Passage live load	3.000		25.483			76.448

4.5 Load Calculation for Second Floor

Table 8 Load Calculation for Second Floor

Floor	Description	Weight (kN/m3)	Height	Area	X	Y	Weight (KN)
2 F	Walls	19.100	3.070	28.509	6.204	6.880	1671.682
2 F	Walls above window	19.100	0.620	8.374	8.686	6.880	99.160
2 F	Walls below window	19.100	0.750	8.374	8.686	6.880	119.952
2 F	Parapet Wall	19.100	1.000	18.610	8.177	6.880	355.447
2 F	Slab	25.000	0.170	216.445	7.865	6.880	919.890
2 F	Roof live load(accessible)	1.500		216.445			324.667

4.6 Lumped Mass Calculation

4.6.1 Load Calculation For 1st Lump

Table 9 Load Calculation for first lump

	Weight kN	X (m)	Y (m)	W*X kN-m	W*Y kN-m
G.F Walls (50%)	914.786	7.030	6.835	6430.948	6252.564
F.F. Walls (50%)	935.982	5.861	6.943	5485.791	6498.524
GF wall above windows	120.946	7.923	6.473	958.256	782.884
1F Walls below Windows	100.951	9.444	6.636	953.379	669.909
G.F. Slab	745.689	7.695	6.974	5738.075	5200.433
Total Dead Load	**2818.354**			**19566.448**	**19404.315**
Mass Center		**6.943**	**6.885**		
Live Load (30%)	**136.945**	**(30% As per NBC 105:2020)**			

4.6.2 Load Calculation For 2nd Lump

Table 10 Load Calculation for second Lump

	Weight kN	X (m)	Y (m)	W*X kN-m	W*Y kN-m
1F Walls(50%)	935.982	5.861	6.943	5485.791	6498.524
2F. Walls(50%.)	835.841	6.204	6.880	5185.558	5750.587
1F wall above windows	115.119	9.444	6.636	1087.187	763.932
2F. Walls below Windows	119.952	8.686	6.880	1041.902	825.269
1F. Slab	1028.113	7.865	6.880	8086.107	7073.416
Total Dead Load	**3035.007**			**20886.545**	**20911.727**
Mass Center		**6.882**	**6.890**		
Live Load (30%)	**137.512**	**(30% As per NBC 105:2020)**			

4.6.3 Load Calculation For 3rd Lump

Table 11 Load Calculation for 3rd lump

	Weight kN	X (m)	Y (m)	W*X kN-m	W*Y kN-m
2F Walls (50%)	835.841	6.204	6.880	5185.558	5750.587
2F wall above windows	99.160	8.686	6.880	861.305	682.222
Parapet Wall	355.447	8.177	6.880	2906.492	2445.477
2F. Slab	919.890	7.865	6.880	7234.938	6328.846
Dead Load	**2210.339**			**16188.293**	**15207.131**
Mass Center		**7.324**	**6.880**		
Live Load (30%)	**Nil**	**Roof live load not considered in lump mass calculation**			

4.7 Horizontal Shear Coefficient Calculation

4.7.1 Earthquake Load Calculation

Base Shear= $W_{seismic}$*Earthquake Coefficient

According to NBC 105:2020

From clause no. 4.1.1 of NBC 105:2020

C(T)= Ch(T)ZI

Where,

C(T) = Elastic Site Spectrum for horizontal loading

Ch(T)= Spectral Shape Factor as per 4.1.2

Z= Seismic Zoning Factor as per 4.1.4

I= Importance Factor as per 4.1.5

Now,

We use the graph of **Figure 4-1 Spectral Shape Factor from NBC 105:2020**,

Time period of vibration from Cl. 5.1.2 for masonry building with Height of Building as 8.715m

$T' = 0.05H^{0.75} = 0.05*8.7150.75 = 0.2736$sec

$T=1.25*T'=1.25*0.2736=0.342$sec. (From clause 5.1.3 of NBC 105:2020)

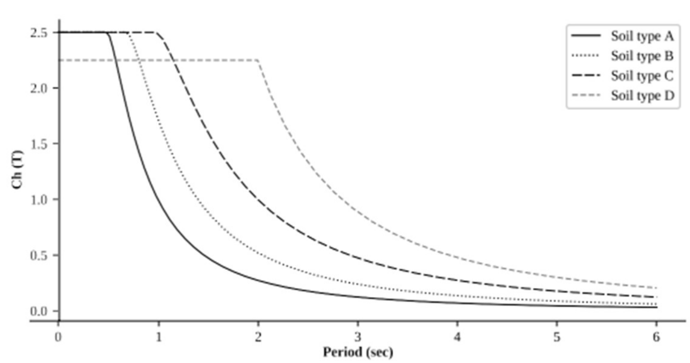


Figure 11 Spectral Shape Factor Ch(T) for equivalent static method

∴ Ch (T) = 2.25 from the graph

Z= 0.35 for Kathmandu

I= 1.25 for Educational Buildings

∴ C(T) = 2.25*0.35*1.25 = 0.984375

Horizontal Base Shear Coefficient:

For Ultimate Limit State

For the ultimate Limit State,

Hz. Base shear coefficient from Cl.6.1.1

Cd (T1) = $\frac{C(T1)}{R\mu \times \Omega u}$

$R\mu$= Ductility Factor (as per 5.3) = 2.0

Ω_u= Over Strength Factor for ULS(as per 5.4) = **1.2**

∴Cd (T1) = 0.984375/ (2x1.2) = 0.41

For Serviceability limit state

For the Serviceability limit state, Hz base shear coefficient from 6.1.2

Cd (T1) = $\frac{C_s(T_1)}{\Omega_s}$

Where, Ωs = Over strength Factor for SLS (as per 5.4) = 1.1

Cs(T)= 0.20C(T)

Cs(T)= 0.20*0.984375= 0.196875

∴ Cd (T1) = (0.2*0.984375)/1.1= 0.1789

4.8 Base Shear and Lateral Force Calculation

4.8.1 Lumped Weight of The Building at Story Level

Table 12 Lumped weight of Building at Story Level

Storey	Dead Load(kN)	Live load (kN)	Total W_i (KN)
3	2210.34	0	2210.34
2	3035.007	137.512	3172.52
1	2818.354	136.945	2955.30
Summation			**8338.16**

4.8.2 Horizontal Seismic Base Shear

Base Shear = Wseismic x Earthquake Coefficient

let us take Base Shear Coefficient Cd (T1) = 0.41

Total Base Shear, Vb =3418.64437

The lateral seismic force (Fi) induced at each level 'i' shall be calculated as:

$$F_i = \frac{W_i h_i^k}{\sum W_i h_i^k} \times V \quad \text{(From clause 6.3 of NBC 105:2020)}$$

Where,

Wi = seismic weight of the structure assigned to level 'i'

hi= height (m) from the base to level 'i'

n= total number of floors/levels

V= horizontal seismic base shear calculated as per 6.2

k= an exponent related to the structural period as follows:

For structure having time period T≤0.5sec, k=1

4.8.3 Story Shear at Different Stories of The Building

Table 13 15 Story Shear at Different Stories of The Building

Storey	Total W_i (kN)	h_i (m)	W_i h_i (kNm)	Design lateral force,Qi(kN)	Shear Force, Vi(kN)
3	2210.340	8.715	19263.104	1457.558	1457.558
2	3172.520	5.645	17908.870	1355.089	2812.647
1	2955.300	2.710	8008.860	605.997	3418.644
	Summation		45180.834	3418.644	

4.9 Stiffness Center Calculation

i. Calculation of center of stiffness of walls along X-direction:

Modulus of elasticity of masonry wall,

E = 2400MPa (NBC 201, cl 4.2.l)

Stiffness Ky = $(12EIyy/h^3)/(1+3d^2/h^2)$

Stiffness center Yk = ∑ (Ky Y /∑Ky)

ii. Calculation of center of stiffness of walls along Y-direction:

Stiffness Kx = $(12EIxx/h3)/(1+3d^2/h^2)$

Stiffness center Xk = ∑ Kx X /∑Kx

4.9.1 For Ground Floor

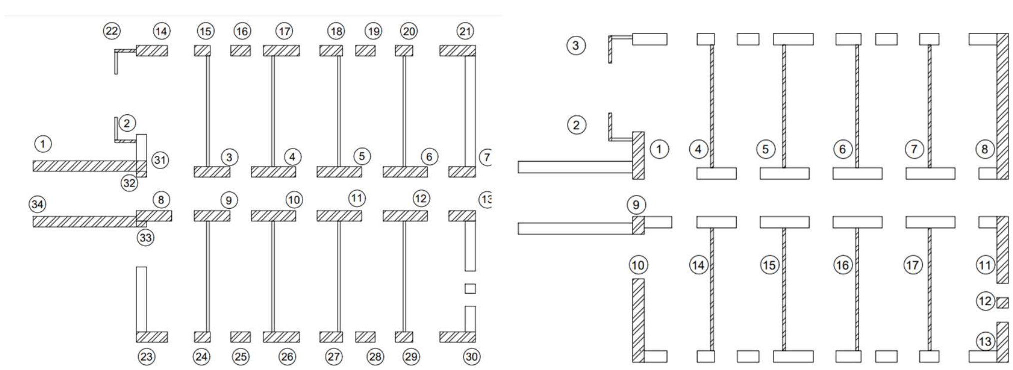


Table 14 Calculation of Center of Stiffness along Y for Ground Floor

wall ID	h(m)	b(m)	d(m)	Iyy(m^4)	Stiffness Ky	Relative Stiffness	Y(m)	Yk
1	2.710	0.480	4.785	4.380	612.530	0.084	7.930	0.663
2	2.710	0.120	1.000	0.010	10.270	0.001	8.080	0.011

3	2.100	0.480	1.650	0.180	195.930	0.027	7.660	0.205
4	2.100	0.480	2.050	0.340	277.710	0.038	7.660	0.290
5	2.100	0.480	2.060	0.350	279.770	0.038	7.660	0.292
6	2.100	0.480	2.050	0.340	277.710	0.038	7.660	0.290
7	2.100	0.480	1.230	0.070	114.070	0.016	7.660	0.119
8	2.100	0.480	1.640	0.180	193.910	0.027	5.620	0.149
9	2.100	0.480	1.650	0.180	195.930	0.027	5.620	0.150
10	2.100	0.480	2.050	0.340	277.710	0.038	5.620	0.213
11	2.100	0.480	2.060	0.350	279.770	0.038	5.620	0.215
12	2.100	0.480	2.050	0.340	277.710	0.038	5.620	0.213
13	2.100	0.480	1.230	0.070	114.070	0.016	5.620	0.087
14	1.355	0.480	1.440	0.120	315.090	0.043	13.280	0.571
15	1.355	0.480	0.725	0.020	94.930	0.013	13.280	0.172
16	1.355	0.480	0.900	0.030	145.280	0.020	13.280	0.263
17	1.355	0.480	1.670	0.190	388.100	0.053	13.280	0.703
18	1.355	0.480	1.050	0.050	191.350	0.026	13.280	0.347
19	1.355	0.480	0.900	0.030	145.280	0.020	13.280	0.263
20	1.355	0.480	0.810	0.020	118.770	0.016	13.280	0.215
21	1.355	0.480	1.645	0.180	380.200	0.052	13.280	0.689
22	2.575	0.120	1.000	0.010	11.610	0.002	13.280	0.021
23	1.355	0.480	1.440	0.120	315.090	0.043	0.240	0.010
24	1.355	0.480	0.725	0.020	94.930	0.013	0.240	0.003
25	1.355	0.480	0.900	0.030	145.280	0.020	0.240	0.005
26	1.355	0.480	1.670	0.190	388.100	0.053	0.240	0.013
27	1.355	0.480	1.050	0.050	191.350	0.026	0.240	0.006
28	1.355	0.480	0.900	0.030	145.280	0.020	0.240	0.005
29	1.355	0.480	0.810	0.020	118.770	0.016	0.240	0.004
30	1.355	0.480	1.645	0.180	380.200	0.052	0.240	0.012
31	2.100	0.480	0.480	0.000	11.890	0.002	7.930	0.013
32	2.100	0.270	0.480	0.000	6.690	0.001	7.555	0.007
33	2.710	0.480	4.785	4.380	612.530	0.084	5.350	0.447
34	1.355	0.270	0.480	0.000	20.930	0.003	5.245	0.015
				Total	7328.77	1.00		6.682

Table 15 Calculation of Center of Stiffness along X for Ground Floor

wall ID	h(m)	b(m)	d(m)	Ixx(m^4)	Stiffness Kx	Relative Stiffness	X(m)	Xk
1	2.100	1.980	0.480	0.310	834.750	0.019	0.240	0.004
2	1.220	1.170	0.120	0.020	246.860	0.006	-0.940	-0.005
3	1.220	1.140	0.120	0.010	228.350	0.005	-0.940	-0.005
4	2.710	5.140	0.120	1.360	1953.560	0.044	3.320	0.145
5	2.710	5.140	0.120	1.360	1953.560	0.044	6.340	0.276
6	2.710	5.140	0.120	1.360	1953.560	0.044	9.400	0.410
7	2.710	5.140	0.120	1.360	1953.560	0.044	12.435	0.542
8	2.710	6.100	0.480	9.080	12008.000	0.268	15.490	4.152
9	1.355	0.750	0.480	0.020	141.920	0.003	0.240	0.001

10	1.355	3.490	0.480	1.700	14300.310	0.319	0.240	0.077
11	2.710	2.800	0.480	0.880	1161.330	0.026	15.490	0.402
12	2.710	0.430	0.480	0.000	4.210	0.000	15.490	0.001
13	2.710	1.670	0.480	0.190	246.390	0.006	15.490	0.085
14	2.710	5.140	0.120	1.360	1953.560	0.044	3.320	0.145
15	2.710	5.140	0.120	1.360	1953.560	0.044	6.340	0.276
16	2.710	5.140	0.120	1.360	1953.560	0.044	9.400	0.410
17	2.710	5.140	0.120	1.360	1953.560	0.044	12.435	0.542
				Total	44800.60	1.00		7.458

4.9.2 For First Floor

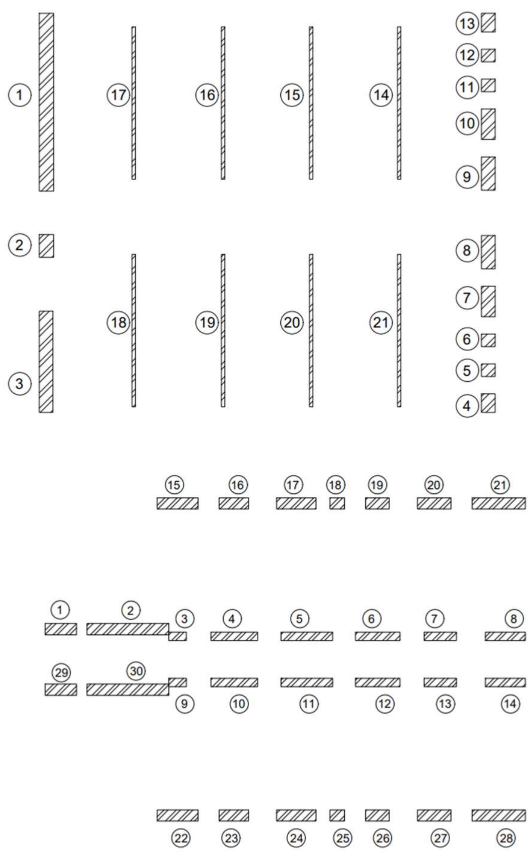


Table 16 Calculation of Center of Stiffness along Y for First Floor

wall ID	h(m)	b(m)	d(m)	Iyy(m^4)	Stiffness Ky	Relative Stiffness	Y(m)	Yk
1	2.935	0.480	1.340	0.100	67.450	0.012	7.935	0.094
2	2.935	0.480	3.490	1.700	369.500	0.065	7.935	0.514
3	2.100	0.355	0.750	0.010	28.070	0.005	7.627	0.038
4	2.100	0.355	2.000	0.240	197.790	0.035	7.627	0.265
5	2.100	0.355	2.200	0.320	228.210	0.040	7.627	0.305
6	2.100	0.355	1.900	0.200	182.600	0.032	7.627	0.244
7	2.100	0.355	1.380	0.080	105.330	0.019	7.627	0.141

8	2.100	0.355	1.705	0.150	153.140	0.027	7.627	0.205
9	2.100	0.355	0.750	0.010	28.070	0.005	5.663	0.028
10	2.100	0.355	2.000	0.240	197.790	0.035	5.663	0.197
11	2.100	0.355	2.200	0.320	228.210	0.040	5.663	0.227
12	2.100	0.355	1.900	0.200	182.600	0.032	5.663	0.181
13	2.100	0.355	1.380	0.080	105.330	0.019	5.663	0.105
14	2.100	0.355	1.705	0.150	153.140	0.027	5.663	0.152
15	1.715	0.470	1.750	0.210	290.630	0.051	13.290	0.678
16	1.715	0.470	1.255	0.080	169.590	0.030	13.290	0.395
17	1.715	0.470	1.685	0.190	274.600	0.048	13.290	0.640
18	1.715	0.470	0.620	0.010	38.280	0.007	13.290	0.089
19	1.715	0.470	1.005	0.040	111.810	0.020	13.290	0.261
20	1.715	0.470	1.435	0.120	213.140	0.037	13.290	0.497
21	1.715	0.470	2.275	0.460	419.340	0.074	13.290	0.978
22	1.715	0.470	1.750	0.210	290.630	0.051	0.235	0.012
23	1.715	0.470	1.255	0.080	169.590	0.030	0.235	0.007
24	1.715	0.470	1.685	0.190	274.600	0.048	0.235	0.011
25	1.715	0.470	0.620	0.010	38.280	0.007	0.235	0.002
26	1.715	0.470	1.005	0.040	111.810	0.020	0.235	0.005
27	1.715	0.470	1.435	0.120	213.140	0.037	0.235	0.009
28	1.715	0.470	2.275	0.460	419.340	0.074	0.235	0.017
29	2.935	0.480	1.340	0.100	67.450	0.012	5.355	0.063
30	2.935	0.480	3.490	1.700	369.500	0.065	5.355	0.347
				Total	5698.97	1.00		6.707

Table 17 Calculation of Center of Stiffness along X for First Floor

wall ID	h(m)	b(m)	d(m)	Ixx(m^4)	Stiffness Kx	Relative Stiffness	X(m)	Xk
1	2.935	6.130	0.470	9.020	9542.860	0.304	0.235	0.071
2	1.715	0.780	0.470	0.020	86.610	0.003	0.235	0.001
3	1.715	3.490	0.470	1.660	7757.920	0.247	0.235	0.058
4	2.935	0.640	0.470	0.010	10.860	0.000	15.495	0.005
5	2.935	0.430	0.470	0.000	3.290	0.000	15.495	0.002
6	2.935	0.430	0.470	0.000	3.290	0.000	15.495	0.002
7	2.935	1.050	0.470	0.050	47.960	0.002	15.495	0.024
8	1.540	1.150	0.470	0.060	367.130	0.012	15.495	0.181
9	1.540	1.150	0.470	0.060	367.130	0.012	15.495	0.181
10	2.935	1.050	0.470	0.050	47.960	0.002	15.495	0.024
11	2.935	0.430	0.470	0.000	3.290	0.000	15.495	0.002
12	2.935	0.430	0.470	0.000	3.290	0.000	15.495	0.002
13	2.935	0.640	0.470	0.010	10.860	0.000	15.495	0.005
14	2.935	5.250	0.120	1.450	1640.110	0.052	12.420	0.649
15	2.935	5.250	0.120	1.450	1640.110	0.052	9.385	0.491

16	2.935	5.250	0.120	1.450	1640.110	0.052	6.345	0.332
17	2.935	5.250	0.120	1.450	1640.110	0.052	3.260	0.170
18	2.935	5.250	0.120	1.450	1640.110	0.052	3.360	0.176
19	2.935	5.250	0.120	1.450	1640.110	0.052	6.345	0.332
20	2.935	5.250	0.120	1.450	1640.110	0.052	9.385	0.491
21	2.935	5.250	0.120	1.450	1640.110	0.052	12.420	0.649
				Total	31373.36	1.00		3.846

4.9.3 For Second Floor

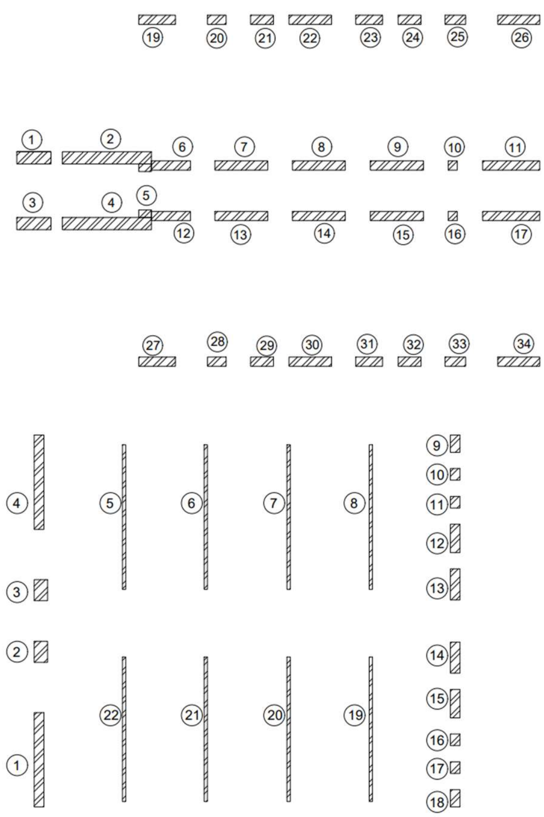


Table 18 Calculation of Center of Stiffness along Y for Second Floor

wall ID	h(m)	b(m)	d(m)	Iyy(m^4)	Stiffness Ky	Relative Stiffness	Y(m)	Yk(m)
1	3.07	0.48	1.34	0.10	60.96	0.008	7.990	0.067
2	3.07	0.48	3.49	1.70	347.03	0.048	7.990	0.381

3	3.07	0.48	1.34	0.10	60.96	0.008	5.410	0.045
4	3.07	0.48	3.49	1.70	347.03	0.048	5.410	0.258
5	2.1	0.3	0.495	0.00	8.08	0.001	5.800	0.006
6	2.1	0.36	1.535	0.11	129.64	0.018	7.690	0.137
7	2.1	0.36	2.07	0.27	211.37	0.029	7.690	0.223
8	2.1	0.36	2.075	0.27	212.14	0.029	7.690	0.224
9	2.1	0.36	2.085	0.27	213.69	0.029	7.690	0.226
10	2.1	0.36	0.355	0.00	3.84	0.001	7.690	0.004
11	2.1	0.36	2.24	0.34	237.59	0.033	7.690	0.251
12	2.1	0.36	1.535	0.11	129.64	0.018	5.710	0.102
13	2.1	0.36	2.07	0.27	211.37	0.029	5.710	0.166
14	2.1	0.36	2.075	0.27	212.14	0.029	5.710	0.167
15	2.1	0.36	2.085	0.27	213.69	0.029	5.710	0.168
16	2.1	0.36	0.355	0.00	3.84	0.001	5.710	0.003
17	2.1	0.36	2.24	0.34	237.59	0.033	5.710	0.187
18	2.1	0.3	0.495	0.00	8.08	0.001	7.600	0.008
19	1.7	0.36	1.44	0.09	166.57	0.023	13.400	0.307
20	1.7	0.36	0.725	0.01	43.36	0.006	13.400	0.080
21	1.7	0.36	0.9	0.02	69.64	0.010	13.400	0.128
22	1.7	0.36	1.67	0.14	210.28	0.029	13.400	0.387
23	1.7	0.36	1.05	0.03	94.93	0.013	13.400	0.175
24	1.7	0.36	0.9	0.02	69.64	0.010	13.400	0.128
25	1.7	0.36	8.1	15.94	1352.38	0.186	13.400	2.492
26	1.7	0.36	1.645	0.13	205.52	0.028	13.400	0.379
27	1.7	0.36	1.44	0.09	166.57	0.023	0.180	0.004
28	1.7	0.36	0.725	0.01	43.36	0.006	0.180	0.001
29	1.7	0.36	0.9	0.02	69.64	0.010	0.180	0.002
30	1.7	0.36	1.67	0.14	210.28	0.029	0.180	0.005
31	1.7	0.36	1.05	0.03	94.93	0.013	0.180	0.002
32	1.7	0.36	0.9	0.02	69.64	0.010	0.180	0.002
33	1.7	0.36	8.1	15.94	1352.38	0.186	0.180	0.033
34	1.7	0.36	1.645	0.13	205.52	0.028	0.180	0.005
				Total	7273.33	1.00		6.754

Table 19 Calculation of Center of Stiffness along X for Second Floor

wall ID	h(m)	b(m)	d(m)	Ixx(m^4)	Stiffness Kx	Relative Stiffness	X(m)	Xk(m)
1	1.7	3.49	0.36	1.28	6589.10	0.2570	0.18	0.046
2	1.7	0.78	0.36	0.01	73.56	0.0029	0.18	0.001
3	1.7	0.78	0.36	0.01	73.56	0.0029	0.18	0.001
4	1.7	3.49	0.36	1.28	6589.10	0.2570	0.18	0.046
5	3.07	5.35	0.12	1.53	1517.23	0.0592	3.32	0.196
6	3.07	5.35	0.12	1.53	1517.23	0.0592	6.34	0.375
7	3.07	5.35	0.12	1.53	1517.23	0.0592	9.4	0.556
8	3.07	5.35	0.12	1.53	1517.23	0.0592	12.435	0.736

9	3.07	0.64	0.36	0.01	7.52	0.0003	15.55	0.005
10	3.07	0.43	0.36	0.00	2.28	0.0001	15.55	0.001
11	3.07	0.43	0.36	0.00	2.28	0.0001	15.55	0.001
12	3.07	1.05	0.36	0.03	33.20	0.0013	15.55	0.020
13	3.07	1.15	0.36	0.05	43.62	0.0017	15.55	0.026
14	3.07	1.15	0.36	0.05	43.62	0.0017	15.55	0.026
15	3.07	1.05	0.36	0.03	33.20	0.0013	15.55	0.020
16	3.07	0.43	0.36	0.00	2.28	0.0001	15.55	0.001
17	3.07	0.43	0.36	0.00	2.28	0.0001	15.55	0.001
18	3.07	0.64	0.36	0.01	7.52	0.0003	15.55	0.005
19	3.07	5.35	0.12	1.53	1517.23	0.0592	12.435	0.736
20	3.07	5.35	0.12	1.53	1517.23	0.0592	9.4	0.556
21	3.07	5.35	0.12	1.53	1517.23	0.0592	6.34	0.375
22	3.07	5.35	0.12	1.53	1517.23	0.0592	3.32	0.196
				Total	25640.97	1.00		3.928

4.10 Direct Shear Force in Pier

4.10.1 For Ground Floor

i. In X-direction wall due to Horizontal loading

Vb=3418.6444 kN

Table 20 Direct Shear Stress in X dir. wall for ground Floor

SN.	Wall ID	Relative Stiffness	Direct Shear Stress(kN)
1	1	0.0836	285.80
2	2	0.0014	4.79
3	3	0.0267	91.28
4	4	0.0379	129.57
5	5	0.0382	130.59
6	6	0.0379	129.57
7	7	0.0156	53.33
8	8	0.0265	90.59
9	9	0.0267	91.28
10	10	0.0379	129.57
11	11	0.0382	130.59
12	12	0.0379	129.57
13	13	0.0156	53.33
14	14	0.043	147.00
15	15	0.013	44.44
16	16	0.0198	67.69

17	17	0.053	181.19
18	18	0.0261	89.23
19	19	0.0198	67.69
20	20	0.0162	55.38
21	21	0.0519	177.43
22	22	0.0016	5.47
23	23	0.0432	147.69
24	24	0.013	44.44
25	25	0.0198	67.69
26	26	0.053	181.19
27	27	0.0261	89.23
28	28	0.0198	67.69
29	29	0.0162	55.38
30	30	0.0519	177.43
31	31	0.0016	5.47
32	32	0.0009	3.08
33	34	0.0836	285.80
34	33	0.0029	9.91

ii. In Y-direction Wall due to Horizontal loading:

Vb= 3418.6444 kN

Table 21 Direct Shear Stress in Y dir. wall for ground Floor

SN.	Wall ID	Relative Stiffness	Direct Shear Force(kN)
1	1	0.0186	63.59
2	2	0.0055	18.80
3	3	0.0051	17.44
4	4	0.0436	149.05
5	5	0.0436	149.05
6	6	0.0436	149.05
7	7	0.0436	149.05
8	8	0.268	916.20
9	9	0.0032	10.94
10	10	0.3192	1091.23
11	11	0.0259	88.54

12	12	0.0001	0.34
13	13	0.0055	18.80
14	14	0.0436	149.05
15	15	0.0436	149.05
16	16	0.0436	149.05
17	17	0.0436	149.05

4.10.2 For First Floor

i. In X-direction wall due to Horizontal loading

Vb=2812.6475 kN

Table 22 Direct Shear Stress in X dir. wall for First Floor

SN.	Wall ID	Relative Stiffness	Direct Shear Stress(kN)
1	1	0.0118	33.19
2	2	0.0648	182.26
3	3	0.0049	13.78
4	4	0.0347	97.60
5	5	0.04	112.51
6	6	0.032	90.00
7	7	0.0185	52.03
8	8	0.0269	75.66
9	9	0.0049	13.78
10	10	0.0347	97.60
11	11	0.04	112.51
12	12	0.032	90.00
13	13	0.0185	52.03
14	14	0.0269	75.66
15	15	0.051	143.45
16	16	0.0298	83.82
17	17	0.0482	135.57
18	18	0.0067	18.84
19	19	0.0196	55.13
20	20	0.0374	105.19
21	21	0.0736	207.01
22	22	0.051	143.45
23	23	0.0298	83.82
24	24	0.0482	135.57
25	25	0.0067	18.84
26	26	0.0196	55.13
27	27	0.0374	105.19

28	28	0.0736	207.01
29	29	0.0118	33.19
30	30	0.0648	182.26

ii. In Y-direction Wall due to Horizontal loading:

Vb=2812.6475 kN

Table 23 Direct Shear Stress in Y dir. wall for First Floor

SN.	Wall ID	Relative Stiffness	Direct Shear Force(kN)
1	1	0.3042	855.61
2	2	0.0028	7.88
3	3	0.2473	695.57
4	4	0.0003	0.84
5	5	0.0001	0.28
6	6	0.0001	0.28
7	7	0.0015	4.22
8	8	0.0117	32.91
9	9	0.0117	32.91
10	10	0.0015	4.22
11	11	0.0001	0.28
12	12	0.0001	0.28
13	13	0.0003	0.84
14	14	0.0523	147.10
15	15	0.0523	147.10
16	16	0.0523	147.10
17	17	0.0523	147.10
18	18	0.0523	147.10
19	19	0.0523	147.10
20	20	0.0523	147.10
21	21	0.0523	147.10

4.10.3 For Second Floor

i. In X-direction wall due to Horizontal loading

Vb=1457.5584 kN

Table 24 Direct Shear Stress in X dir. wall for Second Floor

SN.	Wall ID	Relative Stiffness	Direct Shear Stress(kN)
1	1	0.0084	12.24
2	2	0.0477	69.53
3	3	0.0084	12.24

4	4	0.0477	69.53
5	5	0.0011	1.60
6	6	0.0178	25.94
7	7	0.0291	42.41
8	8	0.0292	42.56
9	9	0.0294	42.85
10	10	0.0005	0.73
11	11	0.0327	47.66
12	12	0.0178	25.94
13	13	0.0291	42.41
14	14	0.0292	42.56
15	15	0.0294	42.85
16	16	0.0005	0.73
17	17	0.0327	47.66
18	18	0.0011	1.60
19	19	0.0229	33.38
20	20	0.006	8.75
21	21	0.0096	13.99
22	22	0.0289	42.12
23	23	0.0131	19.09
24	24	0.0096	13.99
25	25	0.1859	270.96
26	26	0.0283	41.25
27	27	0.0229	33.38
28	28	0.006	8.75
29	29	0.0096	13.99
30	30	0.0289	42.12
31	31	0.0131	19.09
32	32	0.0096	13.99
33	33	0.1855	270.38
34	34	0.0283	41.25

ii. In Y-direction Wall due to Horizontal loading:

Vb=1457.5584 kN

Table 25 Direct Shear Stress in Y dir. wall for Second Floor

SN.	Wall ID	Relative Stiffness	Direct Shear Force(kN)
1	1	0.257	374.59
2	2	0.0029	4.23
3	3	0.0029	4.23
4	4	0.257	374.59

5	5	0.0591	86.14
6	6	0.0591	86.14
7	7	0.0591	86.14
8	8	0.0591	86.14
9	9	0.0003	0.44
10	10	0.0001	0.15
11	11	0.0001	0.15
12	12	0.0013	1.89
13	13	0.0017	2.48
14	14	0.0017	2.48
15	15	0.0013	1.89
16	16	0.0001	0.15
17	17	0.0001	0.15
18	18	0.0003	0.44
19	19	0.0592	86.29
20	20	0.0592	86.29
21	21	0.0592	86.29
22	22	0.0592	86.29

4.11 Eccentricity Calculation

Table 26 Eccentricity Calculation

Storey	Mass Centre		Stiffness Centre	
	X(m)	Y(m)	X(m)	Y(m)
1	6.943	6.885	6.683	7.458
2	6.882	6.89	6.705	3.847
3	7.324	6.88	6.755	3.928

For Effective Mass,

X = W1*x1+W2*x2+W3*x3

Y=W1*y1+W2*y2+W3*y3

Table 27 Mass center at different storey level

Storey	Seismic Weight(kN)	Mass Centre	
		X(m)	Y(m)
1	2955.3	6.943	6.885
2	3172.52	6.882	6.89
3	2210.34	7.324	6.88

Torsional Eccentricity Calculation

Storey 1 :

ex = |Xm- Xk | = |7.021-6.683| = 0.338

ey = |Ym- Xk | = |6.885-7.458| = 0.573

Similarly,

Storey 2:

ex = 0.9505

ey = 3.039

Storey 3:

ex = 0.266

ey = 2.958

4.12 Torsional Moment Calculation

4.12.1 For Ground Floor:

For Loading along X-Direction:

Base Shear in the building, Vb =3418.6444

Eccentricity between centre of mass and stiffness, ey (m) =0.573

Dimension along Y direction = 13.76

Accidental eccentricity of minimum 10% =1.376

Now,

Torsional Moment =4704.054694

Similarly,

For Loading along Y-Direction:

Eccentricity between centre of mass and stiffness, ex (m) =0.338

Dimension along X direction =20.515

Accidental eccentricity of minimum 10% =2.0515

So,

Torsional Moment =7013.348987

4.12.2 For First Floor:

For Loading along X-Direction:

Base Shear in the building, Vb =2812.6475

Eccentricity between centre of mass and stiffness, ey (m) =3.038

Dimension along Y direction = 13.76

Accidental eccentricity of minimum 10% =1.376

Now,

Torsional Moment =3870.20296

Similarly,

For Loading along Y-Direction:

Eccentricity between centre of mass and stiffness, ex (m) =0.316

Dimension along X direction =20.515

Accidental eccentricity of minimum 10% =2.0515

So,

Torsional Moment =5770.146346

4.12.3 For Second Floor:

For Loading along X-Direction:

Base Shear in the building, Vb =1457.5584

Eccentricity between centre of mass and stiffness, ey (m) =2.957

Dimension along Y direction =13.76

Accidental eccentricity of minimum 10% =1.376

Now,

Torsional Moment =2005.600358

Similarly,

For Loading along Y-Direction:

Eccentricity between centre of mass and stiffness, ex (m) =0.266

Dimension along X direction =20.515

Accidental eccentricity of minimum 10% =2.0515

So,

Torsional Moment =2990.181058

4.13 Distribution Of Torsional Shear Force

4.13.1 For Ground Floor

Loading along X-direction

Table 28 Torsional Shear Force along X for Ground Floor

SN.	Wall ID	Relative Stiffness	dy	Ri*dy	Ri*dy^2	Torsional Force(kN)
1	1	0.084	0.712	0.060	0.042	12.43
2	2	0.001	1.862	0.003	0.005	0.54
3	3	0.027	0.442	0.012	0.005	2.46
4	4	0.038	0.442	0.017	0.007	3.50

5	5	0.038	0.442	0.017	0.008	3.53
6	6	0.038	0.442	0.017	0.007	3.50
7	7	0.016	0.442	0.007	0.003	1.44
8	8	0.027	1.598	0.042	0.068	8.84
9	9	0.027	1.598	0.043	0.068	8.91
10	10	0.038	1.598	0.061	0.097	12.65
11	11	0.038	1.598	0.061	0.098	12.75
12	12	0.038	1.598	0.061	0.097	12.65
13	13	0.016	1.598	0.025	0.040	5.21
14	14	0.043	6.062	0.261	1.580	54.44
15	15	0.013	6.062	0.079	0.478	16.46
16	16	0.020	6.062	0.120	0.728	25.07
17	17	0.053	6.062	0.321	1.948	67.10
18	18	0.026	6.062	0.158	0.959	33.05
19	19	0.020	6.062	0.120	0.728	25.07
20	20	0.016	6.062	0.098	0.595	20.51
21	21	0.052	6.062	0.315	1.907	65.71
22	22	0.002	6.062	0.010	0.059	2.03
23	23	0.043	7.218	0.312	2.251	65.13
24	24	0.013	7.218	0.094	0.677	19.60
25	25	0.020	7.218	0.143	1.032	29.85
26	26	0.053	7.218	0.383	2.761	79.90
27	27	0.026	7.218	0.188	1.360	39.35
28	28	0.020	7.218	0.143	1.032	29.85
29	29	0.016	7.218	0.117	0.844	24.42
30	30	0.052	7.218	0.375	2.704	78.24
31	31	0.002	0.712	0.001	0.001	0.24
32	32	0.001	0.337	0.000	0.000	0.06
33	33	0.084	1.973	0.165	0.325	34.45
34	34	0.003	1.868	0.005	0.010	1.13
			Summation		22.522	

Loading along Y-direction:

Table 29 Torsional Shear Force along Y for Ground Floor

SN.	Wall ID	Relative Stiffness	dx	Ri*dx	Ri*dx^2	Torsional Force(kN)
1	1	0.019	6.443	0.120	0.772	19.76
2	2	0.006	7.623	0.042	0.320	6.91
3	3	0.005	7.623	0.039	0.296	6.41
4	4	0.044	3.363	0.147	0.493	24.18
5	5	0.044	0.343	0.015	0.005	2.47

6	6	0.044	2.717	0.118	0.322	19.54
7	7	0.044	5.752	0.251	1.443	41.36
8	8	0.268	8.807	2.360	20.787	389.24
9	9	0.003	6.443	0.021	0.133	3.40
10	10	0.319	6.443	2.057	13.251	339.16
11	11	0.026	8.807	0.228	2.009	37.62
12	12	0.000	8.807	0.001	0.008	0.15
13	13	0.006	8.807	0.048	0.427	7.99
14	14	0.044	3.363	0.147	0.493	24.18
15	15	0.044	0.343	0.015	0.005	2.47
16	16	0.044	2.717	0.118	0.322	19.54
17	17	0.044	5.752	0.251	1.443	41.36
			Summation		42.527	

4.13.2 For First Floor

Loading along X-direction:

Table 30 Torsional Shear Force along X for First Floor

SN.	Wall ID	Relative Stiffness	dy	Ri*dy	Ri*dy^2	Torsional Force(kN)
1	1	0.012	4.319	0.051	0.220	5.93
2	2	0.065	4.319	0.280	1.209	32.54
3	3	0.005	4.012	0.020	0.079	2.29
4	4	0.035	4.012	0.139	0.558	16.19
5	5	0.040	4.012	0.160	0.644	18.66
6	6	0.032	4.012	0.128	0.515	14.93
7	7	0.019	4.012	0.074	0.298	8.63
8	8	0.027	4.012	0.108	0.433	12.55
9	9	0.005	2.047	0.010	0.021	1.17
10	10	0.035	2.047	0.071	0.145	8.26
11	11	0.040	2.047	0.082	0.168	9.52
12	12	0.032	2.047	0.065	0.134	7.61
13	13	0.019	2.047	0.038	0.078	4.40
14	14	0.027	2.047	0.055	0.113	6.40
15	15	0.051	9.679	0.494	4.778	57.40
16	16	0.030	9.679	0.288	2.792	33.54
17	17	0.048	9.679	0.467	4.516	54.25
18	18	0.007	9.679	0.065	0.628	7.54
19	19	0.020	9.679	0.190	1.836	22.06
20	20	0.037	9.679	0.362	3.504	42.09
21	21	0.074	9.679	0.712	6.895	82.83
22	22	0.051	3.621	0.185	0.669	21.47
23	23	0.030	3.621	0.108	0.391	12.55

24	24	0.048	3.621	0.175	0.632	20.29
25	25	0.007	3.621	0.024	0.088	2.82
26	26	0.020	3.621	0.071	0.257	8.25
27	27	0.037	3.621	0.135	0.490	15.75
28	28	0.074	3.621	0.267	0.965	30.99
29	29	0.012	1.739	0.021	0.036	2.39
30	30	0.065	1.739	0.113	0.196	13.10
			Summation		33.284	

Loading along Y-direction

Table 31 Torsional Shear Force along Y for First Floor

SN.	Wall ID	Relative Stiffness	dx	Ri*dx	Ri*dx^2	Torsional Force(kN)
1	1	0.304	6.445	1.961	12.636	370.08
2	2	0.003	6.445	0.018	0.116	3.41
3	3	0.247	6.445	1.594	10.272	300.86
4	4	0.000	8.790	0.003	0.023	0.50
5	5	0.000	8.790	0.001	0.008	0.17
6	6	0.000	8.790	0.001	0.008	0.17
7	7	0.002	8.790	0.013	0.116	2.49
8	8	0.012	8.790	0.103	0.904	19.41
9	9	0.012	8.790	0.103	0.904	19.41
10	10	0.002	8.790	0.013	0.116	2.49
11	11	0.000	8.790	0.001	0.008	0.17
12	12	0.000	8.790	0.001	0.008	0.17
13	13	0.000	8.790	0.003	0.023	0.50
14	14	0.052	5.715	0.299	1.708	56.42
15	15	0.052	2.680	0.140	0.376	26.46
16	16	0.052	0.365	0.019	0.007	3.60
17	17	0.052	3.450	0.180	0.623	34.06
18	18	0.052	3.450	0.180	0.623	34.06
19	19	0.052	0.365	0.019	0.007	3.60
20	20	0.052	2.680	0.140	0.376	26.46
21	21	0.052	5.715	0.299	1.708	56.42
			Summation		30.5681	

4.13.3 For Second Floor

Loading along X-direction

Table 32 Torsional Shear Force along X for Second Floor

SN.	Wall ID	Relative Stiffness	dy	Ri*dy	Ri*dy ^2	Torsional Force(kN)

1	1	0.0084	4.182	0.03513	0.1469	1.93
2	2	0.0477	4.182	0.19948	0.8342	10.98
3	3	0.0084	1.602	0.01346	0.0216	0.74
4	4	0.0477	1.602	0.07642	0.1224	4.20
5	5	0.0011	2.052	0.00226	0.0046	0.12
6	6	0.0178	3.942	0.07017	0.2766	3.86
7	7	0.0291	3.942	0.11471	0.4522	6.31
8	8	0.0292	3.942	0.11511	0.4537	6.33
9	9	0.0294	3.942	0.11589	0.4569	6.38
10	10	0.0005	3.942	0.00197	0.0078	0.11
11	11	0.0327	3.942	0.1289	0.5081	7.09
12	12	0.0178	1.962	0.03492	0.0685	1.92
13	13	0.0291	1.962	0.05709	0.112	3.14
14	14	0.0292	1.962	0.05729	0.1124	3.15
15	15	0.0294	1.962	0.05768	0.1132	3.17
16	16	0.0005	1.962	0.00098	0.0019	0.05
17	17	0.0327	1.962	0.06416	0.1259	3.53
18	18	0.0011	3.852	0.00424	0.0163	0.23
19	19	0.0229	9.652	0.22103	2.1334	12.16
20	20	0.006	9.652	0.05791	0.559	3.19
21	21	0.0096	9.652	0.09266	0.8943	5.10
22	22	0.0289	9.652	0.27894	2.6924	15.35
23	23	0.0131	9.652	0.12644	1.2204	6.96
24	24	0.0096	9.652	0.09266	0.8943	5.10
25	25	0.1859	9.652	1.79431	17.319	98.72
26	26	0.0283	9.652	0.27315	2.6365	15.03
27	27	0.0229	3.748	0.08583	0.3217	4.72
28	28	0.006	3.748	0.02249	0.0843	1.24
29	29	0.0096	3.748	0.03598	0.1349	1.98
30	30	0.0289	3.748	0.10832	0.406	5.96
31	31	0.0131	3.748	0.0491	0.184	2.70
32	32	0.0096	3.748	0.03598	0.1349	1.98
33	33	0.1855	3.748	0.69525	2.6058	38.25
34	34	0.0283	3.748	0.10607	0.3975	5.84
			Summation		36.453	

Loading along Y-direction:

Table 33 Torsional Shear Force along Y for Second Floor

SN.	Wall ID	Relative Stiffness	dx	Ri*dx	Ri*dx^2	Torsional Force(kN)
1	1	0.26	6.58	1.69	11.11	173.79

2	2	0.00	6.58	0.02	0.13	1.96
3	3	0.00	6.58	0.02	0.13	1.96
4	4	0.26	6.58	1.69	11.11	173.79
5	5	0.06	3.44	0.20	0.70	20.88
6	6	0.06	0.42	0.02	0.01	2.52
7	7	0.06	2.65	0.16	0.41	16.08
8	8	0.06	5.68	0.34	1.91	34.53
9	9	0.00	8.80	0.00	0.02	0.27
10	10	0.00	8.80	0.00	0.01	0.09
11	11	0.00	8.80	0.00	0.01	0.09
12	12	0.00	8.80	0.01	0.10	1.18
13	13	0.00	8.80	0.01	0.13	1.54
14	14	0.00	8.80	0.01	0.13	1.54
15	15	0.00	8.80	0.01	0.10	1.18
16	16	0.00	8.80	0.00	0.01	0.09
17	17	0.00	8.80	0.00	0.01	0.09
18	18	0.00	8.80	0.00	0.02	0.27
19	19	0.06	5.68	0.34	1.91	34.58
20	20	0.06	2.65	0.16	0.41	16.10
21	21	0.06	0.42	0.02	0.01	2.53
22	22	0.06	3.44	0.20	0.70	20.91
			Summation		29.0732	

4.14 Total Shear in Pier

4.14.1 For Ground Floor:

For loading in X- direction

Table 34 Total Shear Force along X for Ground Floor

SN.	Wall ID	Direct Shear(kN)	Torsional Shear Force(kN)	Total Shear(kN)
1	1	285.8	-12.43	285.800
2	2	4.79	-0.54	4.790
3	3	91.28	-2.46	91.280
4	4	129.57	-3.50	129.570
5	5	130.59	-3.53	130.590
6	6	129.57	-3.50	129.570
7	7	53.33	-1.44	53.330
8	8	90.59	8.84	99.435
9	9	91.28	8.91	100.191
10	10	129.57	12.65	142.220
11	11	130.59	12.75	143.340
12	12	129.57	12.65	142.220

13	13	53.33	5.21	58.537
14	14	147	-54.44	147.000
15	15	44.44	-16.46	44.440
16	16	67.69	-25.07	67.690
17	17	181.19	-67.10	181.190
18	18	89.23	-33.05	89.230
19	19	67.69	-25.07	67.690
20	20	55.38	-20.51	55.380
21	21	177.43	-65.71	177.430
22	22	5.47	-2.03	5.470
23	23	147.69	65.13	212.817
24	24	44.44	19.60	64.038
25	25	67.69	29.85	97.540
26	26	181.19	79.90	261.091
27	27	89.23	39.35	128.577
28	28	67.69	29.85	97.540
29	29	55.38	24.42	79.803
30	30	177.43	78.24	255.672
31	31	5.47	-0.24	5.470
32	32	3.08	-0.06	3.080
33	34	285.8	34.45	320.250
34	33	9.91	1.13	11.041

For loading in Y- direction

Table 35 Total Shear Force along Y for Ground Floor

SN.	Wall ID	Direct Shear(kN)	Torsional Shear Force(kN)	Total Shear(kN)
1	1	63.59	-19.76	63.590
2	2	18.8	-6.91	18.800
3	3	17.44	-6.41	17.440
4	4	149.05	-24.18	149.050
5	5	149.05	-2.47	149.050
6	6	149.05	19.54	168.586
7	7	149.05	41.36	190.409
8	8	916.2	389.24	1305.440
9	9	10.94	-3.40	10.940
10	10	1091.23	-339.16	1091.230
11	11	88.54	37.62	126.157
12	12	0.34	0.15	0.485
13	13	18.8	7.99	26.788
14	14	149.05	-24.18	149.050
15	15	149.05	-2.47	149.050

16	16	149.05	19.54	168.586
17	17	149.05	41.36	190.409

4.14.2 For First Floor:

For loading in X- direction

Table 36 Total Shear Force along X for First Floor

SN.	Wall ID	Direct Shear(kN)	Torsional Shear Force(kN)	Total Shear(kN)
1	1	33.19	5.93	39.12
2	2	182.26	32.54	214.80
3	3	13.78	2.29	16.07
4	4	97.6	16.19	113.79
5	5	112.51	18.66	131.17
6	6	90	14.93	104.93
7	7	52.03	8.63	60.66
8	8	75.66	12.55	88.21
9	9	13.78	-1.17	13.78
10	10	97.6	-8.26	97.60
11	11	112.51	-9.52	112.51
12	12	90	-7.61	90.00
13	13	52.03	-4.40	52.03
14	14	75.66	-6.40	75.66
15	15	143.45	57.40	200.85
16	16	83.82	33.54	117.36
17	17	135.57	54.25	189.82
18	18	18.84	7.54	26.38
19	19	55.13	22.06	77.19
20	20	105.19	42.09	147.28
21	21	207.01	82.83	289.84
22	22	143.45	-21.47	143.45
23	23	83.82	-12.55	83.82
24	24	135.57	-20.29	135.57
25	25	18.84	-2.82	18.84
26	26	55.13	-8.25	55.13
27	27	105.19	-15.75	105.19
28	28	207.01	-30.99	207.01
29	29	33.19	-2.39	33.19
30	30	182.26	-13.10	182.26

For loading in Y- direction

Table 37 Total Shear Force along Y for First Floor

SN.	Wall ID	Direct Shear(kN)	Torsional Shear Force(kN)	Total Shear(kN)
1	1	855.61	-370.08	855.610
2	2	7.88	-3.41	7.880
3	3	695.57	-300.86	695.570
4	4	0.84	0.50	1.338
5	5	0.28	0.17	0.446
6	6	0.28	0.17	0.446
7	7	4.22	2.49	6.709
8	8	32.91	19.41	52.323
9	9	32.91	19.41	52.323
10	10	4.22	2.49	6.709
11	11	0.28	0.17	0.446
12	12	0.28	0.17	0.446
13	13	0.84	0.50	1.338
14	14	147.1	56.42	203.520
15	15	147.1	26.46	173.558
16	16	147.1	-3.60	147.100
17	17	147.1	-34.06	147.100
18	18	147.1	-34.06	147.100
19	19	147.1	-3.60	147.100
20	20	147.1	26.46	173.558
21	21	147.1	56.42	203.520

4.14.3 For Second Floor:

For loading in X- direction

Table 38 Total Shear Force along X for Second Floor

SN.	Wall ID	Direct Shear(kN)	Torsional Shear Force(kN)	Total Shear(kN)
1	1	12.24	1.93	14.173
2	2	69.53	10.98	80.505
3	3	12.24	-0.74	12.240
4	4	69.53	-4.20	69.530
5	5	1.6	-0.12	1.600
6	6	25.94	3.86	29.801
7	7	42.41	6.31	48.721
8	8	42.56	6.33	48.893
9	9	42.85	6.38	49.226
10	10	0.73	0.11	0.838
11	11	47.66	7.09	54.752
12	12	25.94	-1.92	25.940
13	13	42.41	-3.14	42.410
14	14	42.56	-3.15	42.560
15	15	42.85	-3.17	42.850
16	16	0.73	-0.05	0.730
17	17	47.66	-3.53	47.660
18	18	1.6	0.23	1.833
19	19	33.38	12.16	45.541
20	20	8.75	3.19	11.936
21	21	13.99	5.10	19.088
22	22	42.12	15.35	57.467
23	23	19.09	6.96	26.047
24	24	13.99	5.10	19.088
25	25	270.96	98.72	369.680
26	26	41.25	15.03	56.278
27	27	33.38	-4.72	33.380
28	28	8.75	-1.24	8.750
29	29	13.99	-1.98	13.990
30	30	42.12	-5.96	42.120
31	31	19.09	-2.70	19.090
32	32	13.99	-1.98	13.990
33	33	270.38	-38.25	270.380
34	34	41.25	-5.84	41.250

For loading in Y- direction

Table 39 Total Shear Force along Y for Second Floor

SN.	Wall ID	Direct Shear(kN)	Torsional Shear Force(kN)	Total Shear(kN)
1	1	374.59	-173.79	374.590
2	2	4.23	-1.96	4.230
3	3	4.23	-1.96	4.230
4	4	374.59	-173.79	374.590
5	5	86.14	-20.88	86.140
6	6	86.14	-2.52	86.140
7	7	86.14	16.08	102.217
8	8	86.14	34.53	120.665
9	9	0.44	0.27	0.711
10	10	0.15	0.09	0.240
11	11	0.15	0.09	0.240
12	12	1.89	1.18	3.066
13	13	2.48	1.54	4.018
14	14	2.48	1.54	4.018
15	15	1.89	1.18	3.066
16	16	0.15	0.09	0.240
17	17	0.15	0.09	0.240
18	18	0.44	0.27	0.711
19	19	86.29	34.58	120.874
20	20	86.29	16.10	102.395
21	21	86.29	-2.53	86.290
22	22	86.29	-20.91	86.290

4.15Shear Force Distribution According To Grid

Table 40 Shear Force Distribution at grid 1

Total Shear Distribution at Grid 1:

SN.	Wall ID	Direct Shear(kN)
1	23	212.82
2	24	64.04
3	25	97.54
4	26	261.09
5	27	128.58
6	28	97.54
7	29	79.80
8	30	255.67
	Total	1197.08

Table 41 Shear Force Distribution at grid 2&3

Total Shear Distribution at Grid 2:

SN.	Wall ID	Direct Shear(kN)
1	34	320.25

Total Shear Distribution at Grid 3:

SN.	Wall ID	Direct Shear(kN)
1	8	99.43
2	9	100.19
3	10	142.22
4	11	143.34
5	12	142.22
6	13	58.54
	Total	685.94

Table 42 Shear Force Distribution at grid 4&5

Total Shear Distribution at Grid 4

SN.	Wall ID	Direct Shear(kN)
1	3	91.28
2	4	129.57
3	5	130.59
4	6	129.57
5	7	53.33
	Total	534.34

Total Shear Distribution at Grid 5:

SN.	Wall ID	Direct Shear(kN)
1	1	285.8

Table 43 Shear Force Distribution at grid 6

Total Shear Distribution at Grid 6:

SN.	Wall ID	Direct Shear(kN)
1	14	147
2	15	44.44
3	16	67.69
4	17	181.19
5	18	89.23
6	19	67.69
7	20	55.38
8	21	177.43
	Total	830.05

Table 44 Shear Force distribution at grid A,C&E

Table 45 Shear Force distribution at grid B,D&F

Total Shear Distribution at Grid A:

SN.	Wall ID	Direct Shear(kN)
1	1	63.59
2	9	10.94
3	10	1091.23
	Total	1165.76

Total Shear Distribution at Grid B:

SN.	Wall ID	Direct Shear(kN)
1	4	149.05
2	14	149.05
	Total	298.1

Total Shear Distribution at Grid C:

SN.	Wall ID	Direct Shear(kN)
1	5	149.05
2	15	149.05
	Total	298.1

Total Shear Distribution at Grid D:

SN.	Wall ID	Direct Shear(kN)
1	6	168.586
2	16	168.586
	Total	337.172

Total Shear Distribution at Grid E:

SN.	Wall ID	Direct Shear(kN)
1	7	190.409
2	17	190.409
	Total	380.818

Total Shear Distribution at Grid F:

SN.	Wall ID	Direct Shear(kN)
1	8	1305.44
2	11	126.157
3	12	0.485
4	13	26.79
	Total	1458.872

4.16Lateral Force Distribution According to Grid

Table 46 Lateral Force distribution at grid 1

Distribution of Lateral Force at Grid 1

SN.	Level	Lateral Force(kN)	Wi(kN)	h_i(m)	Wi*hi(kN-m)
1	3	510.38	2210.34	8.715	19263.1
2	2	474.50	3172.52	5.645	17908.9
3	1	212.20	2955.3	2.71	8008.86
	Total	1197.08			45180.8

Table 47 Lateral Force distribution at grid 2

Distribution of Lateral Force at Grid 2

SN.	Level	Lateral Force(kN)	Wi(kN)	h_i(m)	Wi*hi(kN-m)
1	3	136.54	2210.339	8.715	19263.1
2	2	126.94	3172.519	5.645	17908.9

Distribution of Lateral Force at Grid 3:

SN.	Level	Lateral Force	Wi	hi	Wi*hi
1	3	292.45	2210.34	8.715	19263.1
2	2	271.89	3172.52	5.645	17908.9
3	1	121.59	2955.3	2.71	8008.86
	Total	685.94			45180.8

3	1	56.77	2955.299	2.71	8008.86
	Total	320.25			45180.8

Distribution of Lateral Force at Grid 6

SN.	Level	Lateral Force(kN)	Wi(kN)	h_i(m)	Wi*hi(kN-m)
1	3	353.90	2210.339	8.715	19263.1
2	2	329.02	3172.519	5.645	17908.9
3	1	147.14	2955.299	2.71	8008.86
	Total	830.05			45180.8

Distribution of Lateral Force at Grid 4:

SN.	Level	Lateral Force	Wi	hi	Wi*hi
1	3	227.82	2210.339	8.715	19263.1
2	2	211.80	3172.519	5.645	17908.9
3	1	94.72	2955.299	2.71	8008.86
	Total	534.34			45180.8

Table 48 Lateral Force distribution at grid 5

Distribution of Lateral Force at Grid 5

SN.	Level	Lateral Force(kN)	Wi(kN)	h_i(m)	Wi*hi(kN-m)
1	3	121.85	2210.34	8.715	19263.1
2	2	113.29	3172.52	5.645	17908.9
3	1	50.66	2955.3	2.71	8008.86
	Total	285.80			45180.8

Table 49 Lateral Force distribution at grid 6

SN.	Level	Lateral Force(kN)	Wi(kN)	h_i(m)	Wi*hi(kN-m)
1	3	127.10	2210.34	8.715	19263.1
2	2	118.16	3172.52	5.645	17908.9
3	1	52.84	2955.3	2.71	8008.86
	Total	298.10			45180.8

Table 50 Lateral Force distribution at grid A

SN.	Level	Lateral Force(kN)	Wi(kN)	h_i(m)	Wi*hi(kN-m)
1	3	497.03	2210.34	8.715	19263.1
2	2	462.09	3172.52	5.645	17908.9
3	1	206.65	2955.3	2.71	8008.86
	Total	1165.76			45180.8

Table 51 Lateral Force distribution at grid B

Distribution of Lateral Force at Grid B

SN.	Level	Lateral Force(kN)	Wi(kN)	h_i(m)	Wi*hi(kN-m)
1	3	127.10	2210.339	8.715	19263.1
2	2	118.16	3172.519	5.645	17908.9
3	1	52.84	2955.299	2.71	8008.86
	Total	298.10			45180.8

Table 52 Distribution of Lateral Force at Grid C

Table 53 Distribution of Lateral Force at Grid D

SN	Level	Lateral Force(kN)	Wi(kN)	h_i(m)	Wi*hi(kN-m)
1	3	143.76	2210.339	8.715	19263.1
2	2	133.65	3172.519	5.645	17908.9
3	1	59.77	2955.299	2.71	8008.86
	Total	337.17			45180.8

Table 54 Distribution of Lateral Force at Grid E

SN	Level	Lateral Force(kN)	Wi(kN)	h_i(m)	Wi*hi(kN-m)

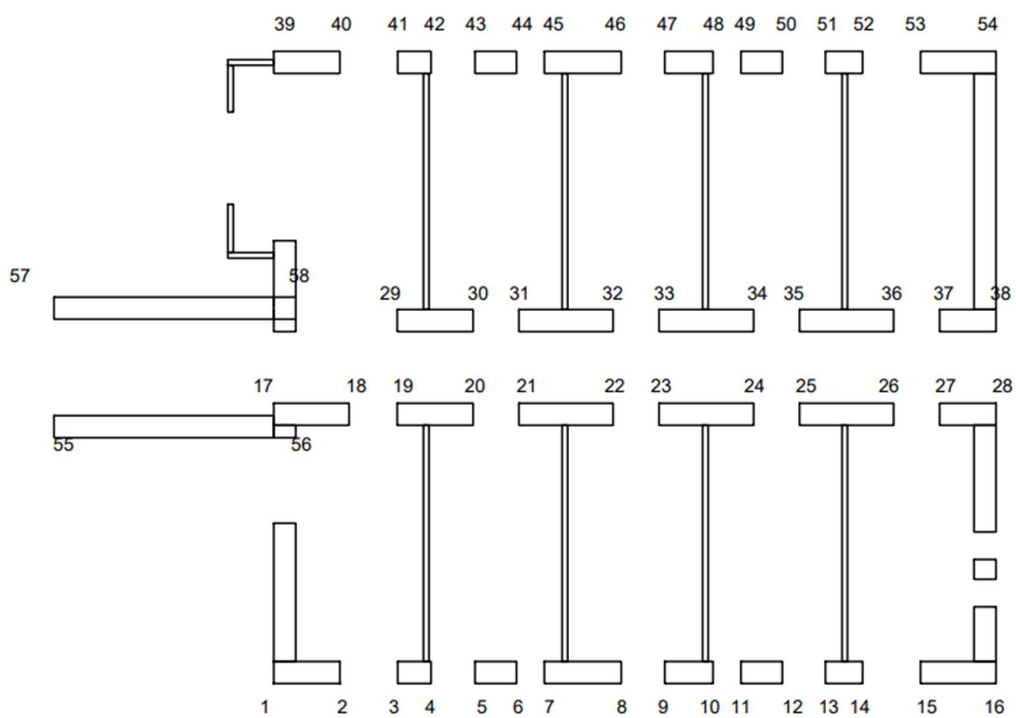
1	3	162.36	2210.34	8.715	19263.1
2	2	150.95	3172.52	5.645	17908.9
3	1	67.50	2955.3	2.71	8008.86
	Total	380.82			45180.8

Table 55 Distribution of Lateral Force at Grid F

SN.	Level	Lateral Force(kN)	Wi(kN)	h_i(m)	Wi*hi(kN-m)
1	3	622.00	2210.339	8.715	19263.1
2	2	578.27	3172.519	5.645	17908.9
3	1	258.60	2955.299	2.71	8008.86
	Total	1458.87			45180.8

4.17 Overturning Stress(fe) Calculation

4.17.1 For Ground Floor Along X-Direction



i. **For outer walls**

Table 56 Overturning Stress Calculation along the X for ground Floor

Name of wall section(pier)	**B(m)**	**D(m)**	**MoI(m^4)**	**Centroid of individual area from A**	**Area(m^2)**	**X(m)**	**Moi about centroid of the wall(m^4)**
1-2/39-40	0.48	1.44	0.119	0.720	0.691	7.211	36.056
3-4/41-42	0.48	0.725	0.015	3.063	0.348	4.868	8.262
5-6/43-44	0.48	0.9	0.029	4.835	0.432	3.096	4.169
7-8/45-46	0.48	1.67	0.186	6.730	0.802	1.201	1.342
9-10/47-48	0.48	1.05	0.046	9.040	0.504	-1.109	0.667
11-12/49-50	0.48	0.9	0.029	10.625	0.432	-2.694	3.166
13-14/51-52	0.48	0.81	0.021	12.420	0.389	-4.489	7.858
15-16/53-54	0.48	1.645	0.178	14.908	0.790	-6.977	38.614
OVERALL CENTROID ABOUT A					7.930		
MOI of whole wall							100.132

Calculation for overturning moment for ground floor sill level

Mo=212.20(2.643-0.635)+474.50(5.540-0.635)+510.38(8.630-0.635)=6834.0082 kNm

Table 57 Overturning Stress Calculation along X for Ground Floor sill level

Point	**Y(m)**	**Mo(KN-m)**	**Ic(m^4)**	**fe(KN/m^2)**
1	7.931	6834.008	100.133	541.256
2	6.491	6834.008	100.133	442.977
3	5.231	6834.008	100.133	356.983
4	4.506	6834.008	100.133	307.502
5	3.546	6834.008	100.133	241.982
6	2.646	6834.008	100.133	180.558
7	2.036	6834.008	100.133	138.926
8	0.366	6834.008	100.133	24.949
9	-0.584	6834.008	100.133	-39.888
10	-1.634	6834.008	100.133	-111.550
11	-2.244	6834.008	100.133	-153.182
12	-3.144	6834.008	100.133	-214.607
13	-4.084	6834.008	100.133	-278.762
14	-4.894	6834.008	100.133	-334.044
15	-6.154	6834.008	100.133	-420.038
16	-7.799	6834.008	100.133	-532.308

Point	Y(m)	Mo(KN-m)	Ic(m^4)	fe(KN/m^2)
39	7.931	3085.635	100.133	244.384
40	6.491	3085.635	100.133	200.009
41	5.231	3085.635	100.133	161.182
42	4.506	3085.635	100.133	138.841
43	3.546	3085.635	100.133	109.258
44	2.646	3085.635	100.133	81.524
45	2.036	3085.635	100.133	62.726
46	0.366	3085.635	100.133	11.265
47	-0.584	3085.635	100.133	-18.010
48	-1.634	3085.635	100.133	-50.366
49	-2.244	3085.635	100.133	-69.164
50	-3.144	3085.635	100.133	-96.898
51	-4.084	3085.635	100.133	-125.864
52	-4.894	3085.635	100.133	-150.825
53	-6.154	3085.635	100.133	-189.652
54	-7.799	3085.635	100.133	-240.344

ii. For entrance walls

Table 58 Overturning Stress Calculation along X for ground Floor for the entrance walls

Name of wall section(pier)	B(m)	D(m)	MoI(m^4)	Centroid of individual area from A	Area(m^2)	X(m)	Moi about centroid of the wall(m^4)
55-56/57-58	0.48	4.785	4.382	2.392	2.296	0	4.382
Centroid of the wall				2.392	**MOI of whole wall about its centroid**		4.382

Point	Y(m)	Mo(KN-m)	Ic(m^4)	fe(KN/m^2)
57	2.393	1828.268	4.382	998.128
58	-2.393	1828.268	4.382	-998.127

Point	Y(m)	Mo(KN-m)	Ic(m^4)	fe(KN/m^2)
55	2.393	1631.606	4.382	890.762
56	-2.393	1631.606	4.382	-890.762

iii. For partition walls

Table 59 Overturning Stress Calculation along the X for ground Floor the partition walls

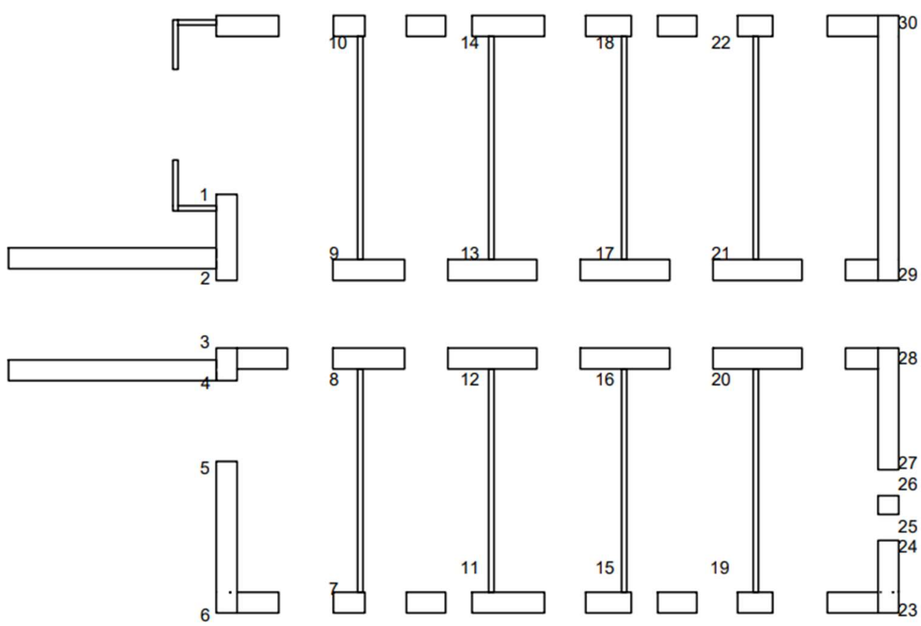
Name of wall section(pier)	B(m)	D(m)	MoI(m^4)	Centroid of individual area from A	Area(m^2)	X(m)	Moi about centroid of the wall(m^4)
17-18	0.48	1.64	0.176	0.820	0.787	7.023	39.003
19-20	0.48	1.65	0.180	3.515	0.792	4.328	15.015
21-22	0.48	2.05	0.345	6.365	0.984	1.478	2.494
23-24	0.48	2.06	0.350	9.420	0.989	-1.577	2.809
25-26	0.48	2.05	0.345	12.475	0.984	-4.632	21.457
27-28	0.48	1.23	0.074	15.115	0.590	-7.272	31.296
Centroid of the wall				7.842	**MOI of whole wall about its centroid**		112.073

Point	Y(m)	Mo(KN-m)	Ic(m^4)	fe(KN/m^2)
17	7.843	3915.943	112.074	274.040
18	6.203	3915.943	112.074	216.737
19	5.153	3915.943	112.074	180.050
20	3.503	3915.943	112.074	122.397
21	2.503	3915.943	112.074	87.457
22	0.453	3915.943	112.074	15.828
23	-0.547	3915.943	112.074	-19.113
24	-2.607	3915.943	112.074	-91.091
25	-3.607	3915.943	112.074	-126.031
26	-5.657	3915.943	112.074	-197.660
27	-6.657	3915.943	112.074	-232.601
28	-7.887	3915.943	112.074	-275.578

Point	Y(m)	Mo(KN-m)	Ic(m^4)	fe(KN/m^2)
29	5.153	3450.249	112.074	158.638
30	3.503	3450.249	112.074	107.842
31	2.503	3450.249	112.074	77.056
32	0.453	3450.249	112.074	13.946
33	-0.547	3450.249	112.074	-16.840
34	-2.607	3450.249	112.074	-80.258

35	-3.607	3450.249	112.074	-111.043
36	-5.657	3450.249	112.074	-174.154
37	-6.657	3450.249	112.074	-204.939
38	-7.887	3450.249	112.074	-242.805

4.17.2 For Ground Floor Along Y-Direction



i. For back face outer walls

Table 60 Overturning Stress Calculation along the Y for ground Floor for back face of outer walls

Name of wall section(pier)	B(m)	D(m)	MoI(m^4)	Centroid of individual area from A	Area(m^2)	X(m)	Moi about centroid of the wall(m^4)
23-24	0.48	1.67	0.186	0.835	0.802	6.518	34.243
25-26	0.48	0.43	0.003	2.485	0.206	4.868	4.895
27-28	0.48	2.88	0.956	4.740	1.382	2.613	10.395
29-30	0.48	6.18	9.441	10.671	2.966	-3.318	42.096
Overall centroid about A					7.353		
MOI of whole wall							91.628

Point	Y(m)	Mo(KN-m)	Ic(m^4)	fe(KN/m^2)
23	7.353	8328.569	91.629	668.360
24	5.683	8328.569	91.629	516.566
25	5.083	8328.569	91.629	462.029
26	4.653	8328.569	91.629	422.945
27	4.053	8328.569	91.629	368.408
28	1.173	8328.569	91.629	106.632
29	-0.228	8328.569	91.629	-20.712
30	-6.408	8328.569	91.629	-582.440

ii. For partition walls

Table 61 Overturning Stress Calculation along the Y for ground Floor for the partition walls

Name of wall section(pier)	B(m)	D(m)	MoI(m^4)	Centroid of individual area from A	Area(m^2)	X(m)	Moi about centroid of the wall(m^4)
7-8	0.12	5.14	1.358	2.570	0.617	3.830	10.406
9-10	0.12	5.14	1.358	10.230	0.617	-2.877	6.463
Overall centroid about A					6.4		
MOI of whole wall							16.868

Point	Y(m)	Mo(KN-m)	Ic(m^4)	fe(KN/m^2)
7	6.4	1708.778	91.629	119.353

8	1.26	1708.778	91.629	23.498
9	-1.26	1708.778	91.629	-23.498
10	-6.4	1708.778	91.629	-119.353

Point	**Y(m)**	**Mo(KN-m)**	**Ic(m^4)**	**fe(KN/m^2)**
11	6.4	1708.778	91.629	119.353
12	1.26	1708.778	91.629	23.498
13	-1.26	1708.778	91.629	-23.498
14	-6.4	1708.778	91.629	-119.353

Point	**Y(m)**	**Mo(KN-m)**	**Ic(m^4)**	**fe(KN/m^2)**
15	6.4	1924.885	91.629	134.447
16	1.26	1924.885	91.629	26.469
17	-1.26	1924.885	91.629	-26.469
18	-6.4	1924.885	91.629	-134.447

Point	Y	Mo	Ic	fe
19	6.4	2174.056	91.629	151.851
20	1.26	2174.056	91.629	29.896
21	-1.26	2174.056	91.629	-29.896
22	-6.4	2174.056	91.629	-151.851

iii. For front face outer walls

Table 62 Overturning Stress Calculation along the X for ground Floor for the front face outer walls

Name of wall section(pier)	**B(m)**	**D(m)**	**MoI(m^4)**	**Centroid of individual area from A**	**Area(m^2)**	**X(m)**	**Moi about centroid of the wall(m^4)**
6-5	0.148	3.49	0.524	1.745	0.517	4.655	11.717
4-3	0.148	0.75	0.005	5.725	0.111	1.628	0.299
2-1	0.148	1.98	0.096	8.65	0.293	-8.650	22.022
Overall centroid about A					4.422		
MOI of whole wall							12.016

Point	**Y(m)**	**Mo(kN-m)**	**Ic(m^4)**	**fe(kN/m^2)**

6	4.423	6655.219	12.016	2449.672
5	0.933	6655.219	12.016	516.722
4	-0.927	6655.219	12.016	-513.446
3	-1.677	6655.219	12.016	-928.836
2	-3.237	6655.219	12.016	-1792.848
1	-5.217	6655.219	12.016	-2889.479

4.18Bending Stress Calculation

4.18.1 For Walls In X-Direction

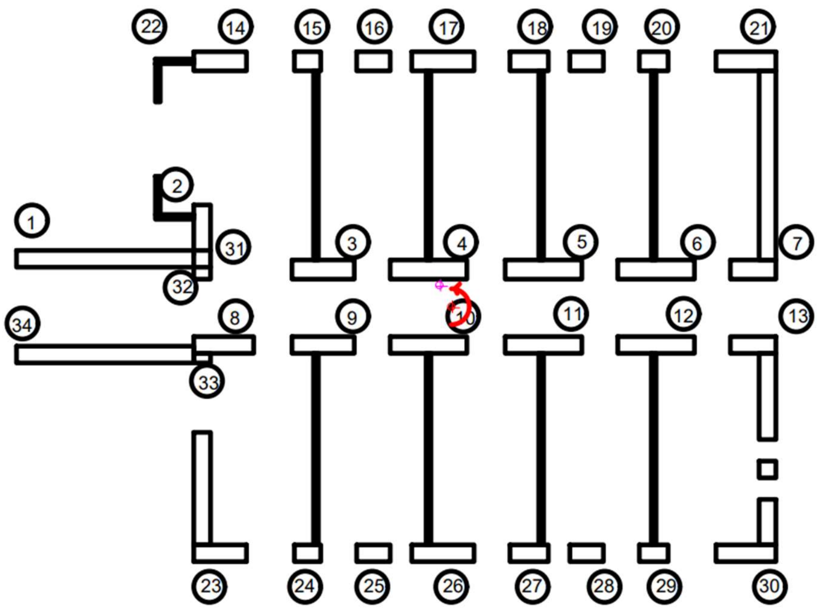


Table 63 Bending Stress Calculation along X

SN	Wall ID	Total Shear	H(m)	M(kN-m)	t(m)	L(m)	Iyy (m^4)	Z(m^3)	fb(M/Z)
1	1	285.800	2.710	387.259	0.480	4.785	4.382	1.832	211.421
2	2	4.790	2.710	6.490	0.120	1.000	0.010	0.020	324.523
3	3	91.280	2.100	95.844	0.480	1.650	0.180	0.218	440.055
4	4	129.570	2.100	136.049	0.480	2.050	0.345	0.336	404.665
5	5	130.590	2.100	137.120	0.480	2.060	0.350	0.339	403.901
6	6	129.570	2.100	136.049	0.480	2.050	0.345	0.336	404.665
7	7	53.330	2.100	55.997	0.480	1.230	0.074	0.121	462.659
8	8	99.435	2.100	104.406	0.480	1.640	0.176	0.215	485.232
9	9	100.191	2.100	105.201	0.480	1.650	0.180	0.218	483.016
10	10	142.220	2.100	149.331	0.480	2.050	0.345	0.336	444.172
11	11	143.340	2.100	150.507	0.480	2.060	0.350	0.339	443.334
12	12	142.220	2.100	149.331	0.480	2.050	0.345	0.336	444.172
13	13	58.537	2.100	61.463	0.480	1.230	0.074	0.121	507.829
14	14	147.000	1.355	99.593	0.480	1.440	0.119	0.166	600.360

15	15	44.440	1.355	30.108	0.480	0.725	0.015	0.042	716.007
16	16	67.690	1.355	45.860	0.480	0.900	0.029	0.065	707.716
17	17	181.190	1.355	122.756	0.480	1.670	0.186	0.223	550.200
18	18	89.230	1.355	60.453	0.480	1.050	0.046	0.088	685.412
19	19	67.690	1.355	45.860	0.480	0.900	0.029	0.065	707.716
20	20	55.380	1.355	37.520	0.480	0.810	0.021	0.052	714.829
21	21	177.430	1.355	120.209	0.480	1.645	0.178	0.216	555.283
22	22	5.470	2.710	7.412	0.120	1.000	0.010	0.020	370.593
23	23	212.817	1.355	144.183	0.480	1.440	0.119	0.166	869.160
24	24	64.038	1.355	43.386	0.480	0.725	0.015	0.042	1031.770
25	25	97.540	1.355	66.083	0.480	0.900	0.029	0.065	1019.802
26	26	261.091	1.355	176.889	0.480	1.670	0.186	0.223	792.826
27	27	128.577	1.355	87.111	0.480	1.050	0.046	0.088	987.655
28	28	97.540	1.355	66.083	0.480	0.900	0.029	0.065	1019.802
29	29	79.802	1.355	54.066	0.480	0.810	0.021	0.052	1030.067
30	30	255.672	1.355	173.218	0.480	1.645	0.178	0.216	800.150
31	31	5.470	2.100	5.744	0.480	0.480	0.004	0.018	311.605
32	32	3.080	2.100	3.234	0.270	0.480	0.002	0.010	311.921
33	33	320.250	1.335	213.767	0.480	4.785	4.382	1.832	116.704
34	34	11.041	2.710	14.961	0.270	0.480	0.002	0.010	1443.013

4.18.2 For Walls In Y-Direction

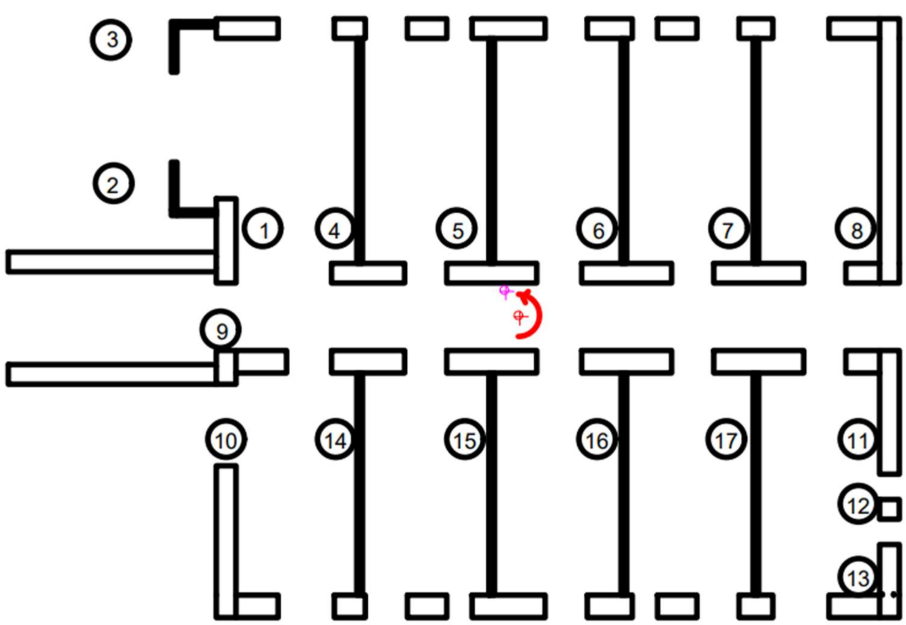


Table 64 Bending Stress Calculation along Y

SN	Wall ID	Total Shear	H(m)	M(kN-m)	t(m)	L(m)	Iyy (m^4)	Z(m^3)	fb(M/Z) (KN/m2)
1	1	63.590	2.100	66.770	0.480	1.980	0.310	0.314	212.891

2	2	18.800	1.220	11.468	0.120	1.170	0.016	0.027	418.877
3	3	17.440	1.220	10.638	0.120	1.140	0.015	0.026	409.295
4	4	149.050	2.710	201.963	0.120	5.140	1.358	0.528	382.221
5	5	149.050	2.710	201.963	0.120	5.140	1.358	0.528	382.221
6	6	168.586	2.710	228.434	0.120	5.140	1.358	0.528	432.319
7	7	190.409	2.710	258.004	0.120	5.140	1.358	0.528	488.281
8	8	1305.445	2.710	1768.878	0.480	6.100	9.079	2.977	594.221
9	9	10.940	1.355	7.412	0.480	0.750	0.017	0.045	164.708
10	10	1091.230	1.355	739.308	0.480	3.490	1.700	0.974	758.726
11	11	126.157	2.710	170.943	0.480	2.800	0.878	0.627	272.550
12	12	0.485	2.710	0.658	0.480	0.430	0.003	0.015	44.450
13	13	26.788	2.710	36.298	0.480	1.670	0.186	0.223	162.690
14	14	149.050	2.710	201.963	0.120	5.140	1.358	0.528	382.221
15	15	149.050	2.710	201.963	0.120	5.140	1.358	0.528	382.221
16	16	168.586	2.710	228.434	0.120	5.140	1.358	0.528	432.319
17	17	190.409	2.710	258.004	0.120	5.140	1.358	0.528	488.281

4.19 Calculation Of Total Stress

4.19.1 For Walls In X-Direction

Table 65 Calculation of Total Stress along X

Point	Bending Stress(fb)(KN/m2)	Axial stress(fy)(KN/m2)	Overturning Stress(fe)(KN/m2)	Net stress(N/mm2)
1	869.160	-0.304	541.256	1.410
2	-869.160	-0.304	442.977	-0.426
3	1031.770	-0.304	356.983	1.388
4	-1031.770	-0.304	307.502	-0.725
5	1019.802	-0.304	241.982	1.261
6	-1019.802	-0.304	180.558	-0.840
7	792.826	-0.304	138.925	0.931
8	-792.826	-0.304	24.949	-0.768
9	987.655	-0.304	-39.888	0.947
10	-987.655	-0.304	-111.550	-1.100
11	1019.802	-0.304	-153.182	0.866
12	-1019.802	-0.304	-214.607	-1.235
13	1030.067	-0.304	-278.762	0.751
14	-1030.067	-0.304	-334.044	-1.364
15	800.150	-0.304	-420.038	0.380
16	-800.150	-0.304	-532.308	-1.333
17	485.232	-0.304	274.040	0.759
18	-485.232	-0.304	216.737	-0.269
19	483.016	-0.304	180.050	0.663
20	-483.016	-0.304	122.397	-0.361
21	444.172	-0.304	87.457	0.531
22	-444.172	-0.304	15.828	-0.429
23	443.334	-0.304	-19.113	0.424

24	-443.334	-0.304	-91.091	-0.535
25	444.172	-0.304	-126.031	0.318
26	-444.172	-0.304	-197.660	-0.642
27	507.828	-0.304	-232.601	0.275
28	-507.828	-0.304	-275.578	-0.784
29	440.055	-0.304	158.638	0.598
30	-440.055	-0.304	107.842	-0.333
31	404.665	-0.304	77.056	0.481
32	-404.665	-0.304	13.946	-0.391
33	403.901	-0.304	-16.840	0.387
34	-403.901	-0.304	-80.258	-0.484
35	404.665	-0.304	-111.043	0.293
36	-404.665	-0.304	-174.154	-0.579
37	462.659	-0.304	-204.939	0.257
38	-462.659	-0.304	-242.805	-0.706
39	600.360	-0.304	244.384	0.844
40	-600.360	-0.304	200.009	-0.401
41	716.007	-0.304	161.182	0.877
42	-716.007	-0.304	138.841	-0.577
43	707.716	-0.304	109.258	0.817
44	-707.716	-0.304	81.524	-0.626
45	550.200	-0.304	62.726	0.613
46	-550.200	-0.304	11.265	-0.539
47	685.412	-0.304	-18.010	0.667
48	-685.412	-0.304	-50.366	-0.736
49	707.716	-0.304	-69.164	0.638
50	-707.716	-0.304	-96.898	-0.805
51	714.829	-0.304	-125.864	0.589
52	-714.829	-0.304	-150.825	-0.866
53	555.283	-0.304	-189.652	0.365
54	555.283	-0.304	-240.344	0.315
55	-1443.013	-0.304	998.127	-0.445
56	-1443.013	-0.304	-998.127	-2.441
57	211.421	-0.304	890.762	1.102
58	-211.421	-0.304	-890.762	-1.102

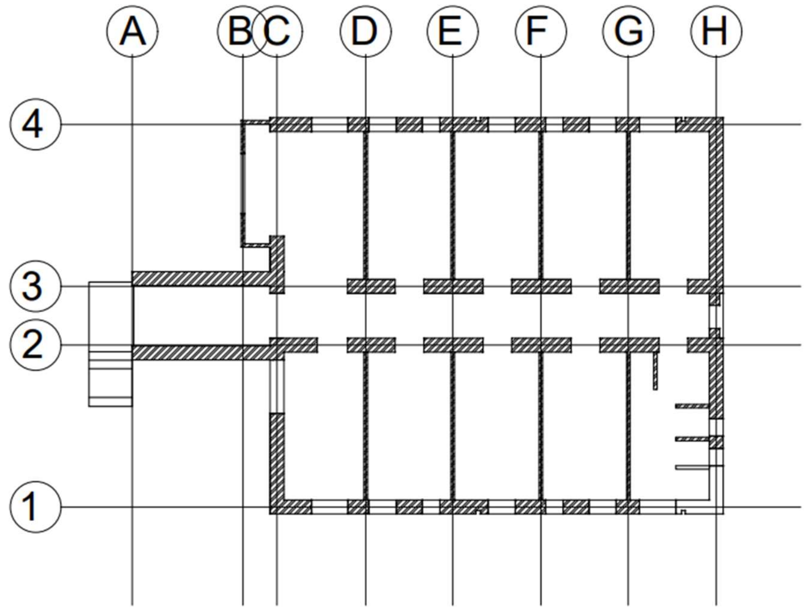
4.19.2 For Walls In Y-Direction

Table 66 Calculation of Total Stress along Y

Point	**Bending Stress(fb) (KN/m2)**	**Axial stress(fy) (KN/m2)**	**Overturning Stress(fe) (KN/m2)**	**Net stress(N/mm2)**
1	212.891	-0.277	2449.672	2.662
2	-212.891	-0.277	516.722	0.304
3	164.708	-0.277	-513.446	-0.349
4	-164.708	-0.277	-928.836	-1.094

5	758.726	-0.277	-1792.848	-1.034
6	-758.726	-0.277	-2889.479	-3.648
7	404.665	-0.277	119.353	0.524
8	-404.665	-0.277	23.498	-0.381
9	600.360	-0.277	-23.498	0.577
10	-600.360	-0.277	-119.353	-0.720
11	403.901	-0.277	119.353	0.523
12	-403.901	-0.277	23.498	-0.381
13	716.007	-0.277	-23.498	0.692
14	-716.007	-0.277	-119.353	-0.836
15	404.665	-0.277	134.447	0.539
16	-404.665	-0.277	26.469	-0.378
17	707.716	-0.277	-26.469	0.681
18	-707.716	-0.277	-134.447	-0.842
19	462.659	-0.277	151.851	0.614
20	-462.659	-0.277	29.896	-0.433
21	550.200	-0.277	-29.896	0.520
22	-550.200	-0.277	-151.851	-0.702
23	485.232	-0.277	668.360	1.153
24	-485.232	-0.277	516.566	0.031
25	443.334	-0.277	462.029	0.905
26	-443.334	-0.277	422.945	-0.021
27	444.172	-0.277	368.408	0.812
28	-444.172	-0.277	106.632	-0.338
29	507.828	-0.277	-20.712	0.487
30	-507.828	-0.277	-582.440	-1.091

5 ANALYSIS OUTPUT



5.1 Inplane force (F22) for Design of Vertical Splints

Table 67 Inplane force for Design of Vertical Splints

Load Combination	**Wall ID**	**F22 (kN/m)**	**Remarks**
DL+0.3LL+EQy	1	531.84	T
		-451.65	C
	2	410.75	T
		-616.18	C
	3	377.24	T
		-523.52	C
	4	579.42	T
		-452.35	C
Load Combination	Wall ID	F22 (kN/m)	Remarks
DL+0.3LL+EQx	C	278.23	T
		-601.60	C
	D	301.089	T
		-102.301	C
	E	313.77	T

		-49.55	C
	F	209.48	T
		-99.25	C
	G	202.24	T
		-100.52	C
	H	683.46	T
		-378.89	C

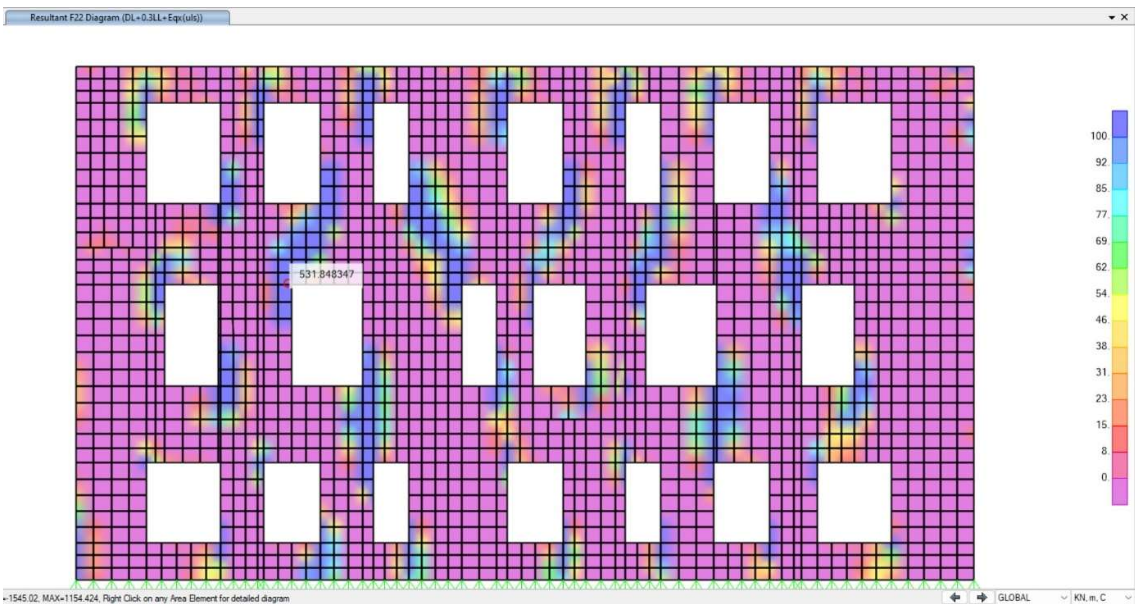


Figure 12 F22 for grid1 in tension

Maximum value = 531.84 kN/m

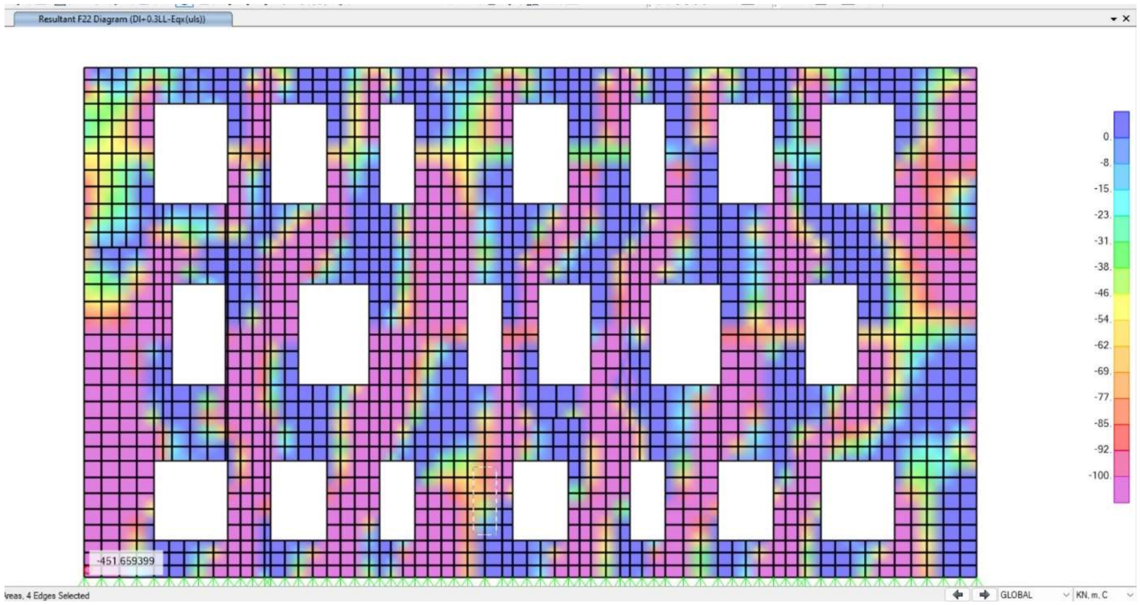


Figure 13 F22 for grid1 in compression

Maximum value = -451.66 kN/m

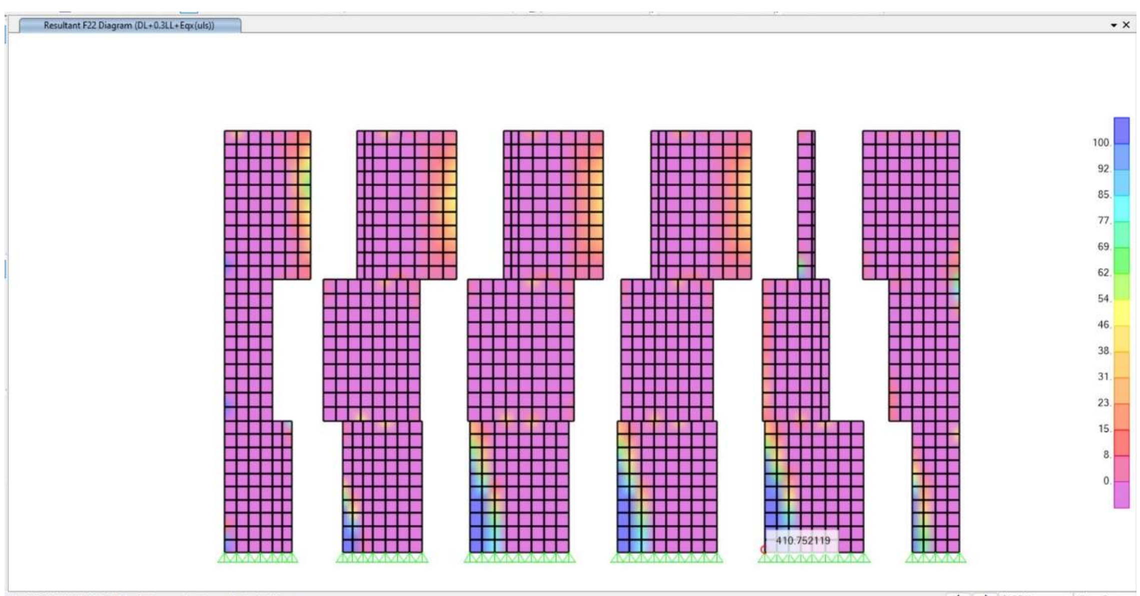


Figure 14 F22 for grid2 in tension

Maximum value = 410.75kN/m

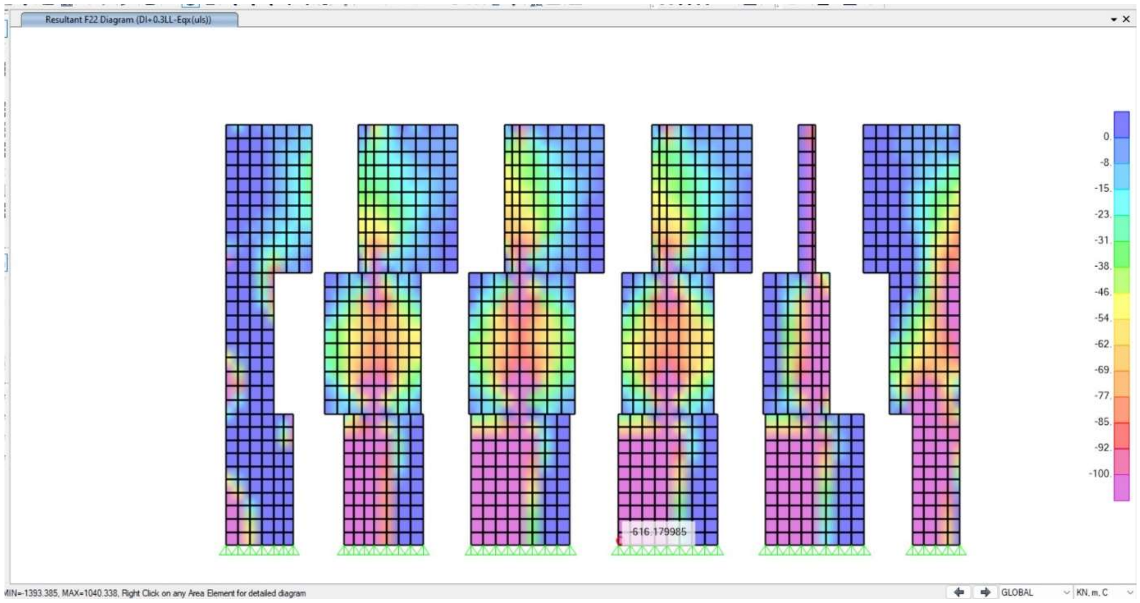


Figure 15 F22 for grid2 in compression

Maximum value = -616.18kN/m

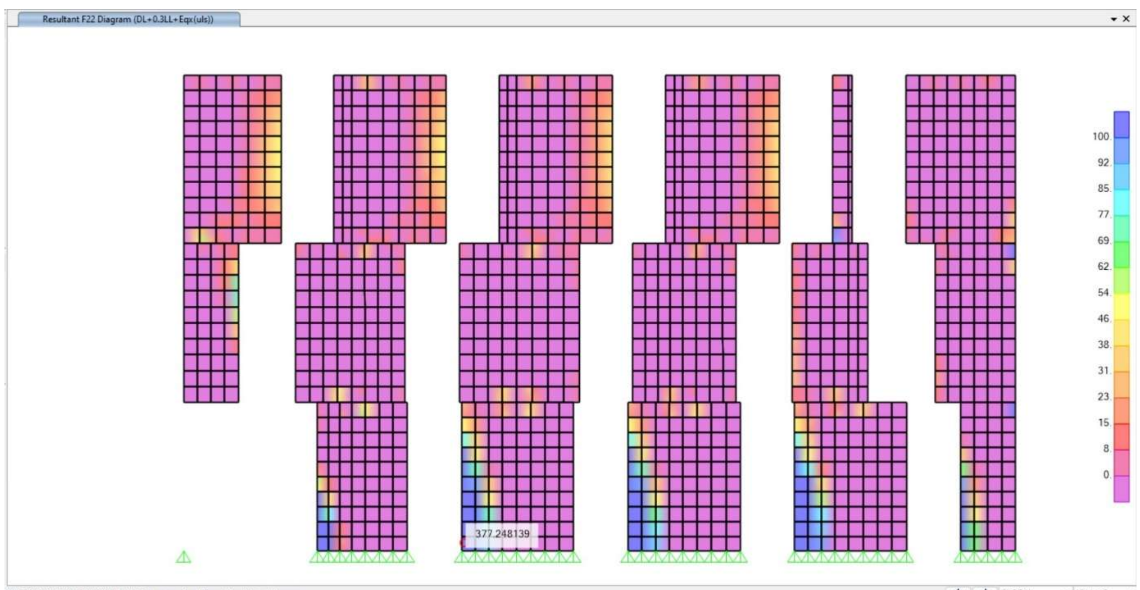


Figure 16 F22 for grid3 in tension

Maximum value = 377.25kN/m

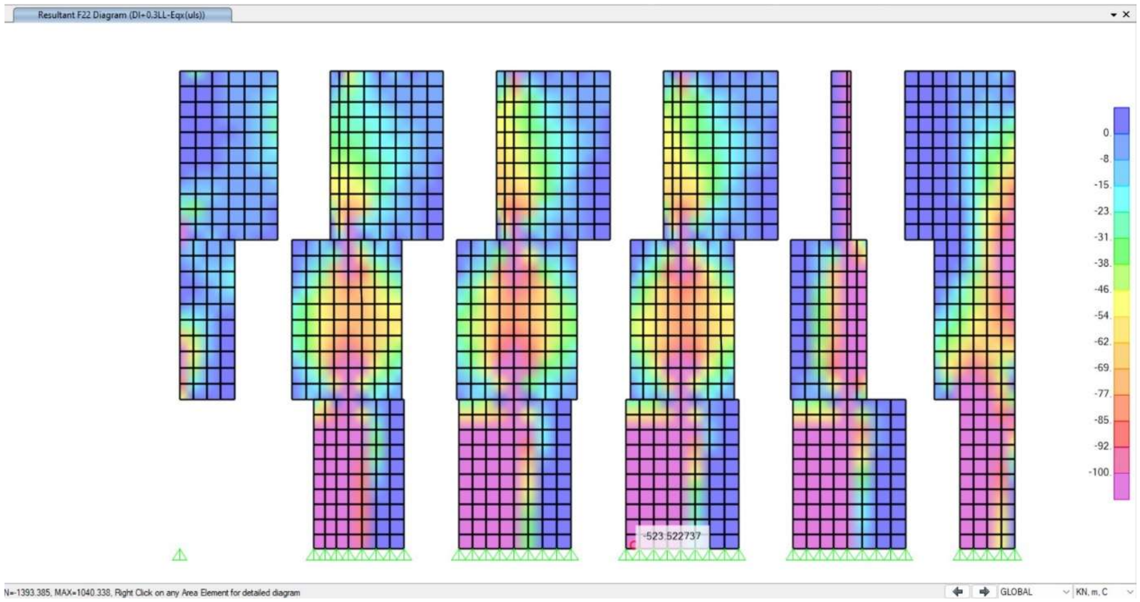


Figure 17 F22 for grid3 in compression

Maximum value = -523.52kN/m

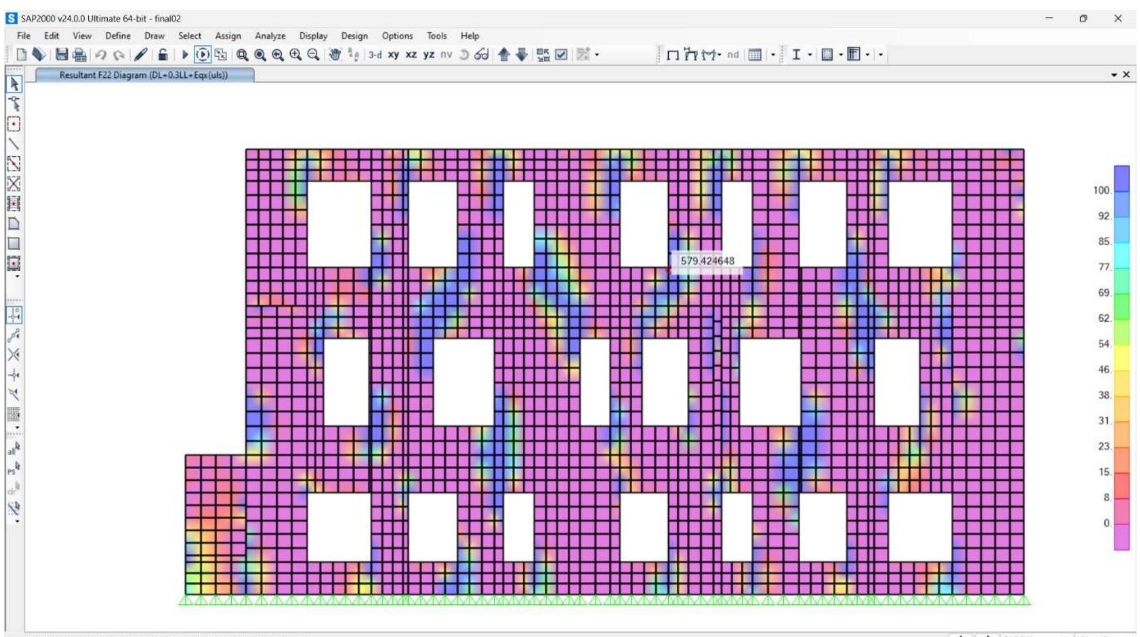


Figure 18 F22 for grid4 in Tension

Maximum value = 579.42kN/m

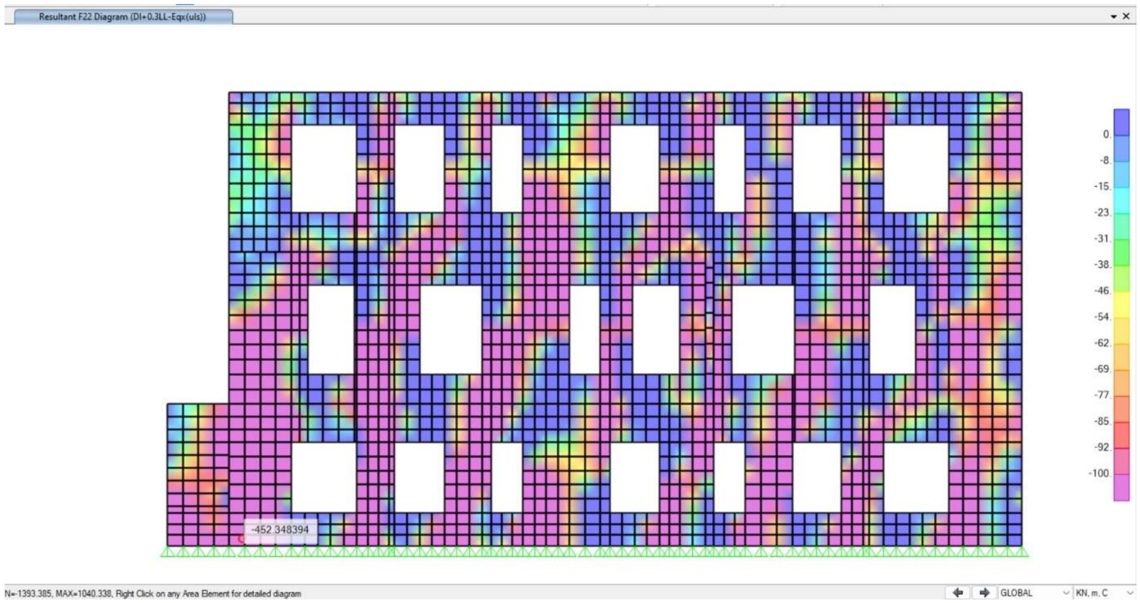


Figure 19 F22 for grid4 in compression

Maximum value = -452.35kN/m

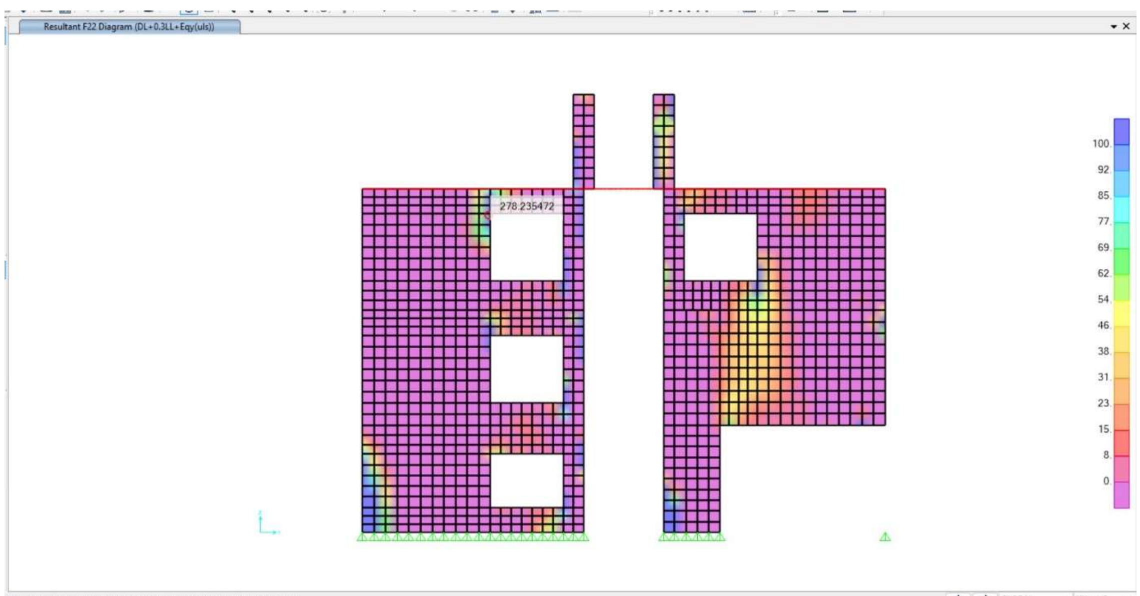


Figure 20 F22 for grid C in tension

Maximum value = 278.24kN/m

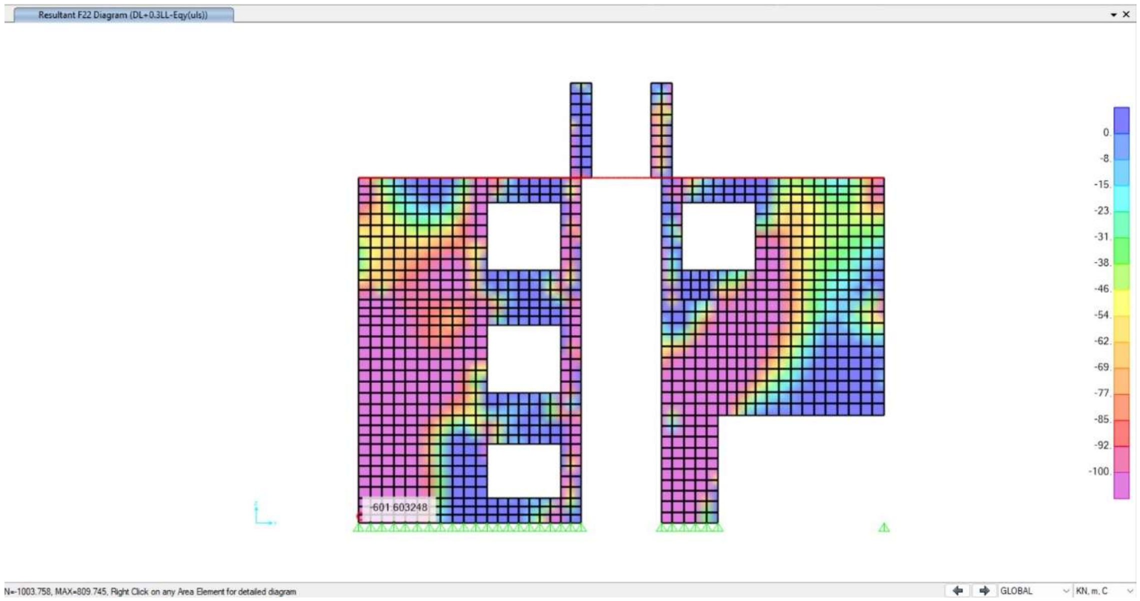


Figure 21 F22 for grid C in compression

Maximum value = -601.6kN/m

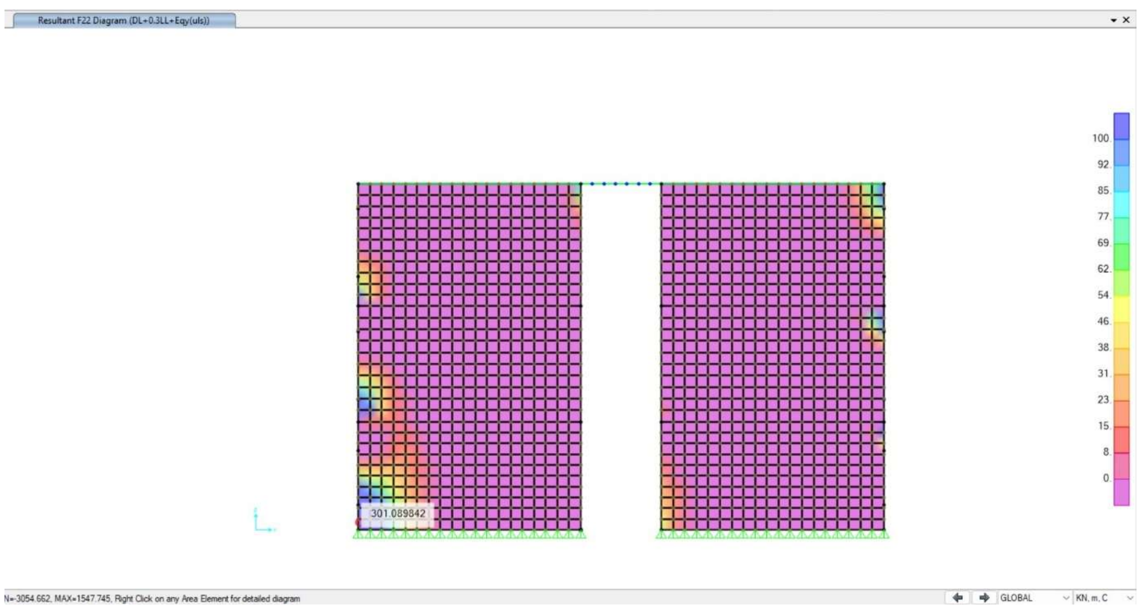


Figure 22 F22 for grid D in tension

Maximum value = 301.09kN/m

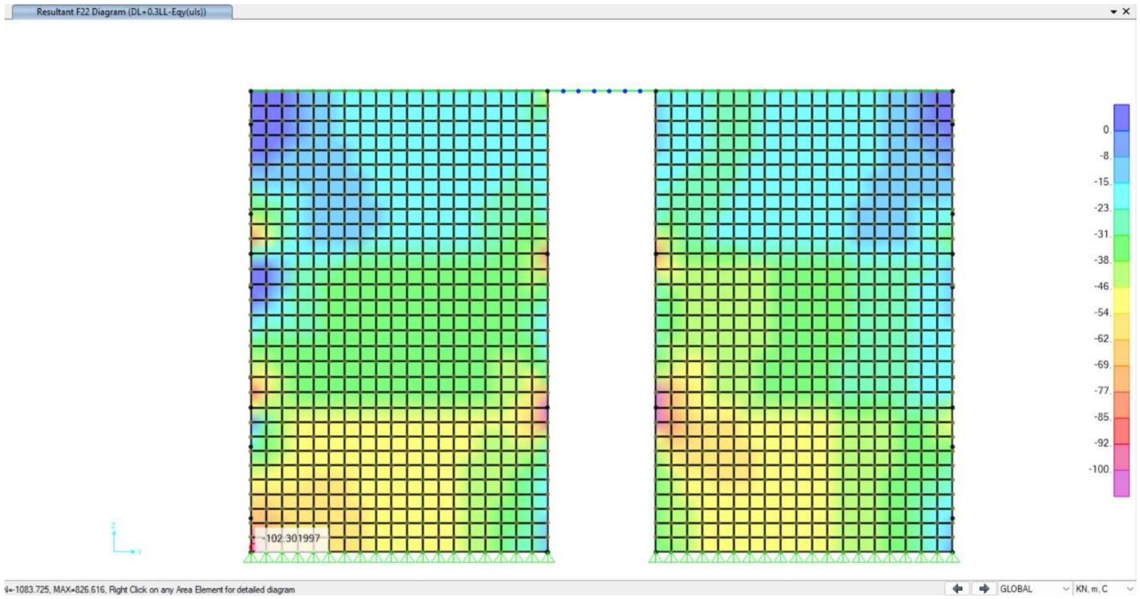


Figure 23 F22 for grid D in compression

Maximum value = -102.3kN/m

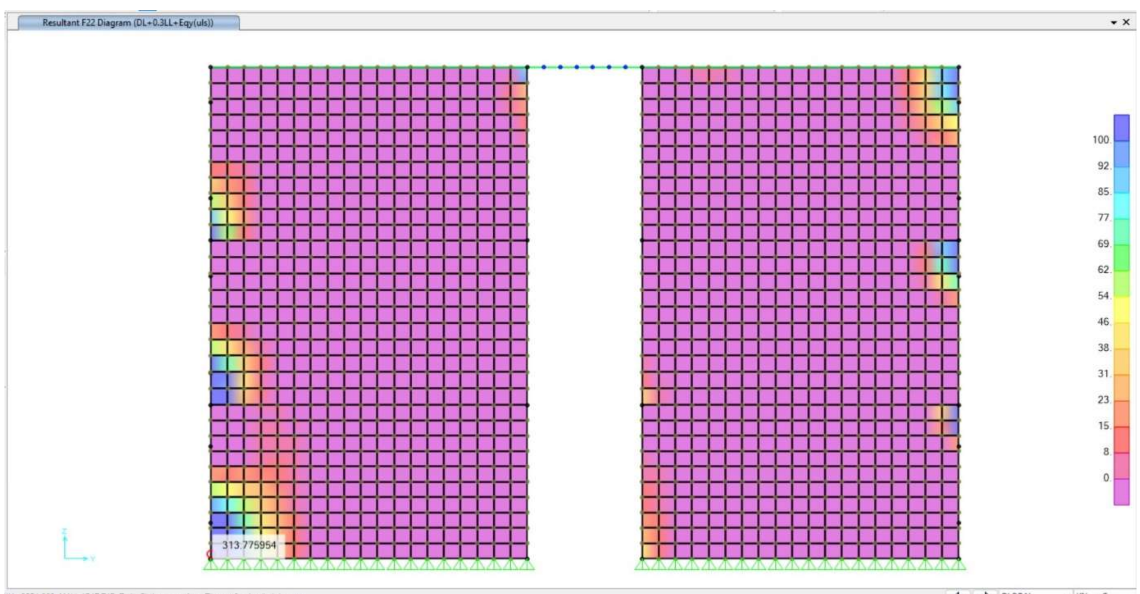


Figure 24 F22 for grid E in tension

Maximum value = 313.77kN/m

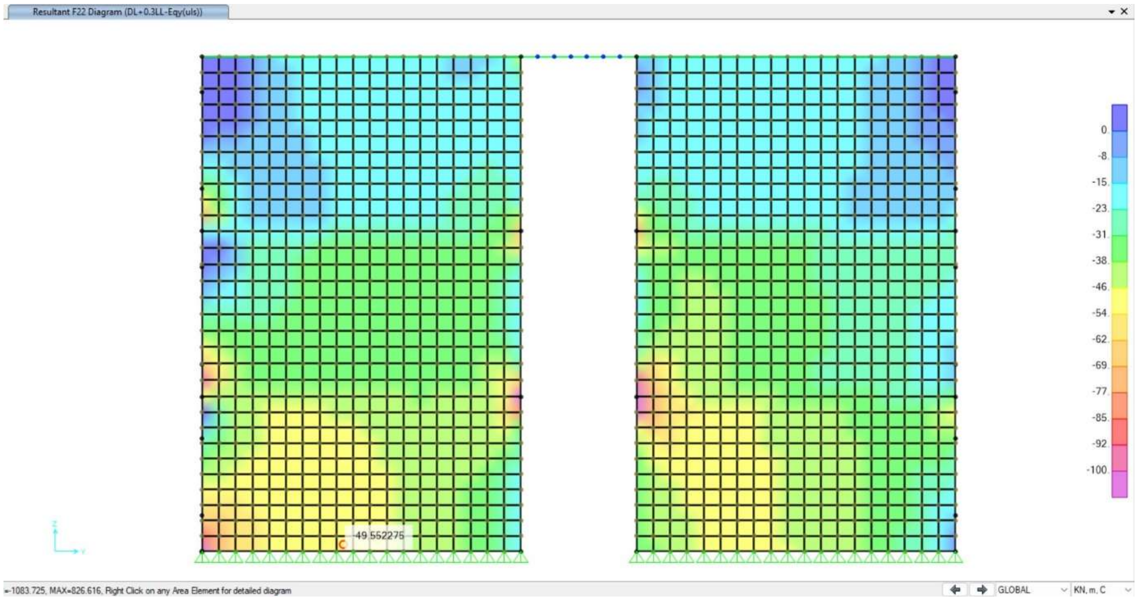


Figure 25 F22 for grid E in compression

Maximum value = -49.55kN/m

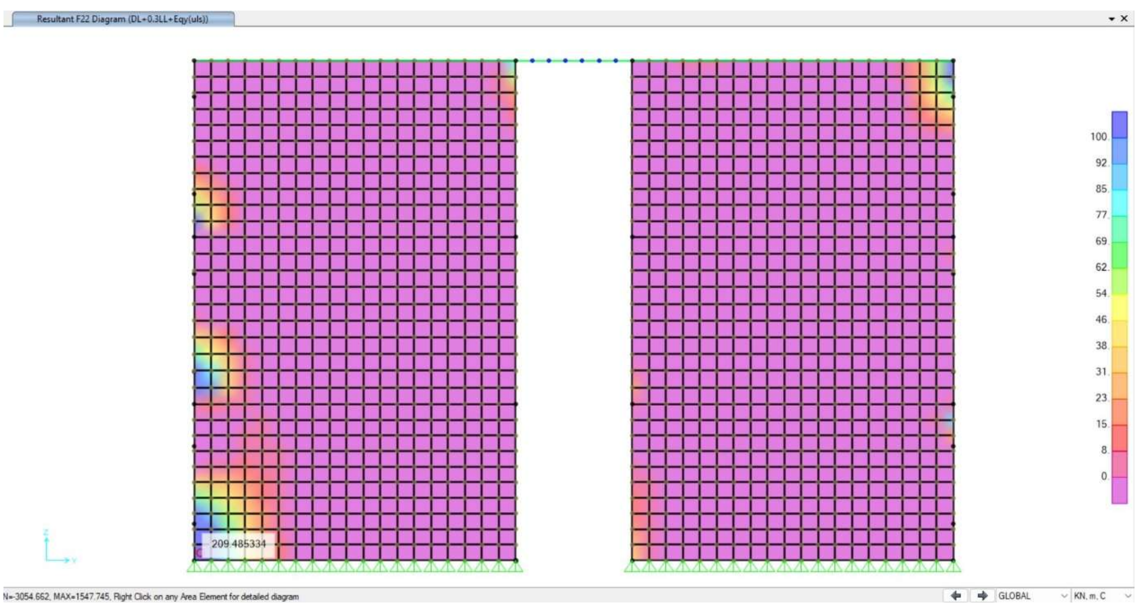


Figure 26 F22 for grid F in tension

Maximum value = 209.48kN/m

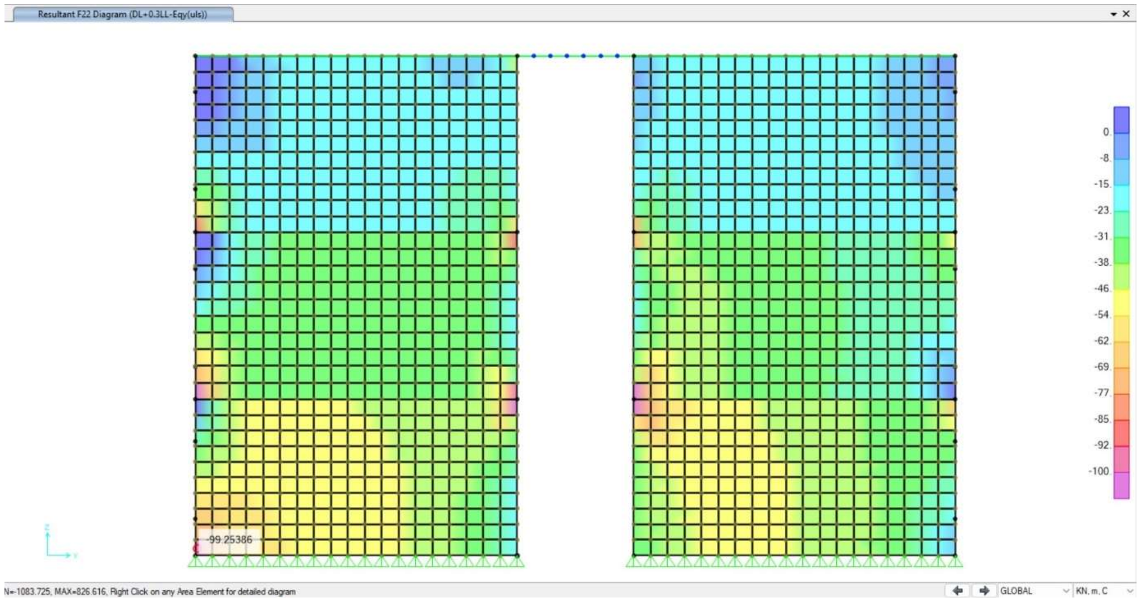


Figure 27 F22 for grid F in compression

Maximum value = -99.25kN/m

Figure 28 F22 for grid G in tension

Maximum value = 202.24kN/m

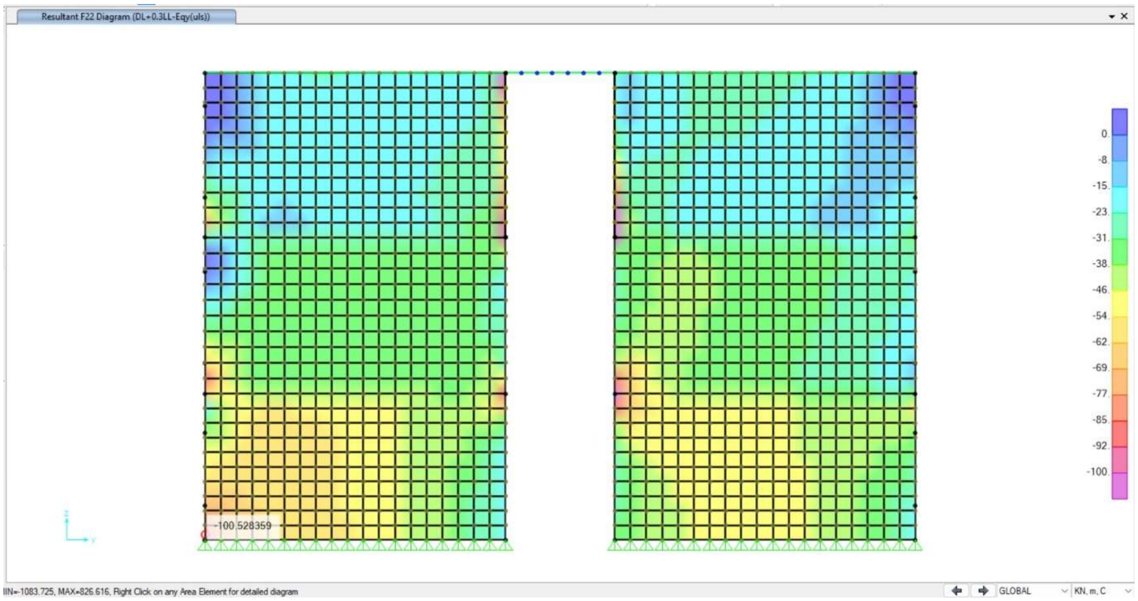


Figure 29 F22 for grid G in compression

Maximum value = -100.52kN/m

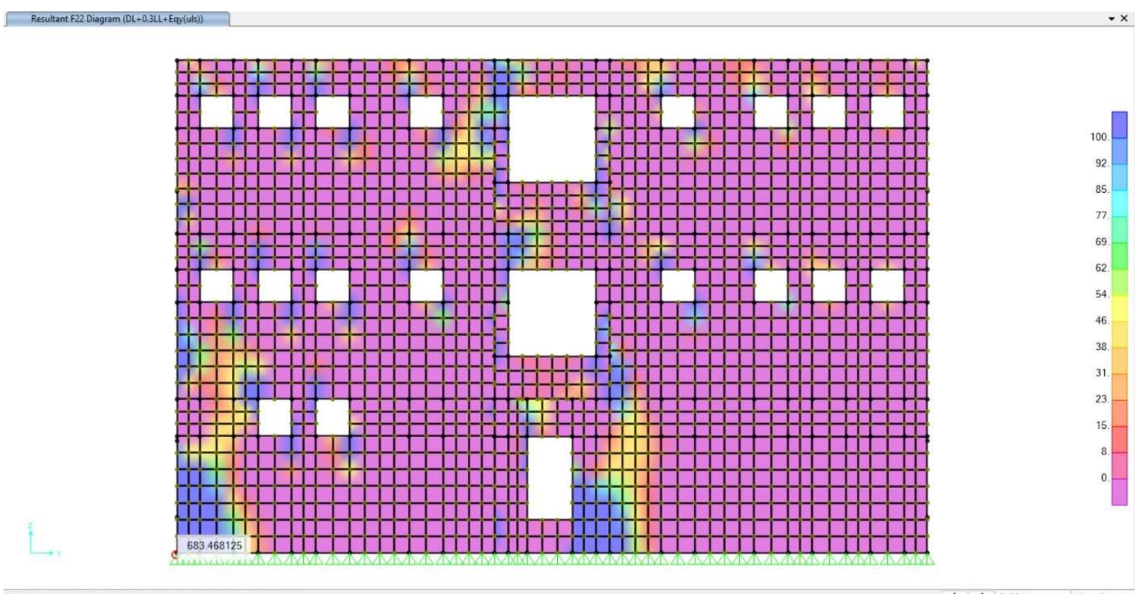


Figure 30 F22 for grid H in tension

Maximum value = 683.47kN/m

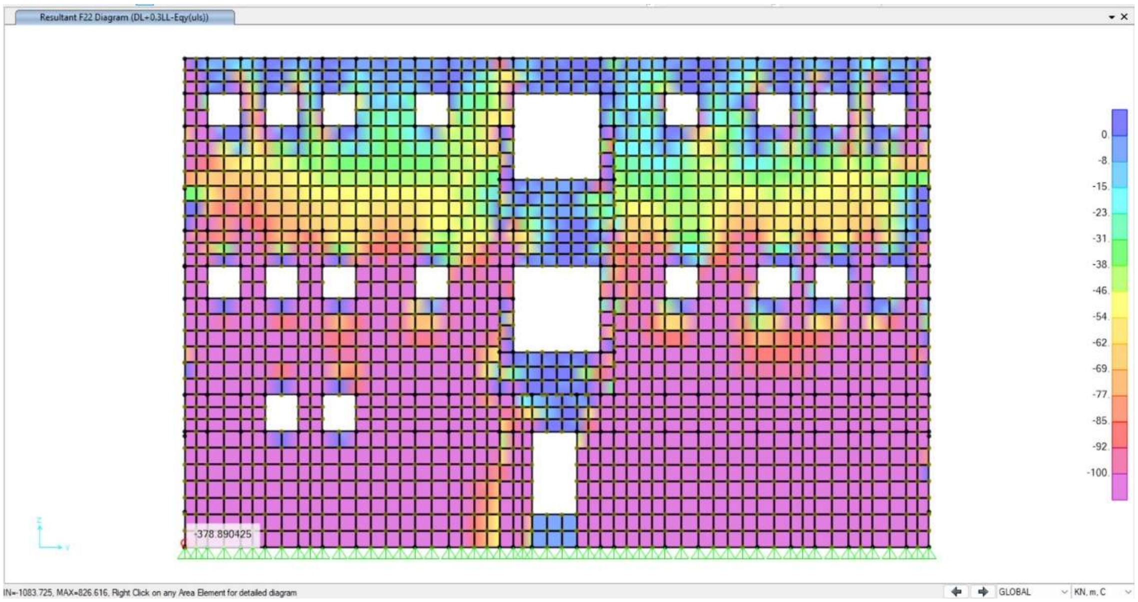


Figure 31 F22 for grid H in compression

Maximum value = -378.89kN/m

5.2 Out of plane Bending Moment (M11) for Design of Horizontal Bandages

Table 68 M11 for the Design of Hz. Bandages

Load Combination	Wall ID	M11 (kN-m/m)
DL+0.3LL+EQy	1	14.56
	4	17.78
DL+0.3LL+EQx	C	17.60
	H	6.5

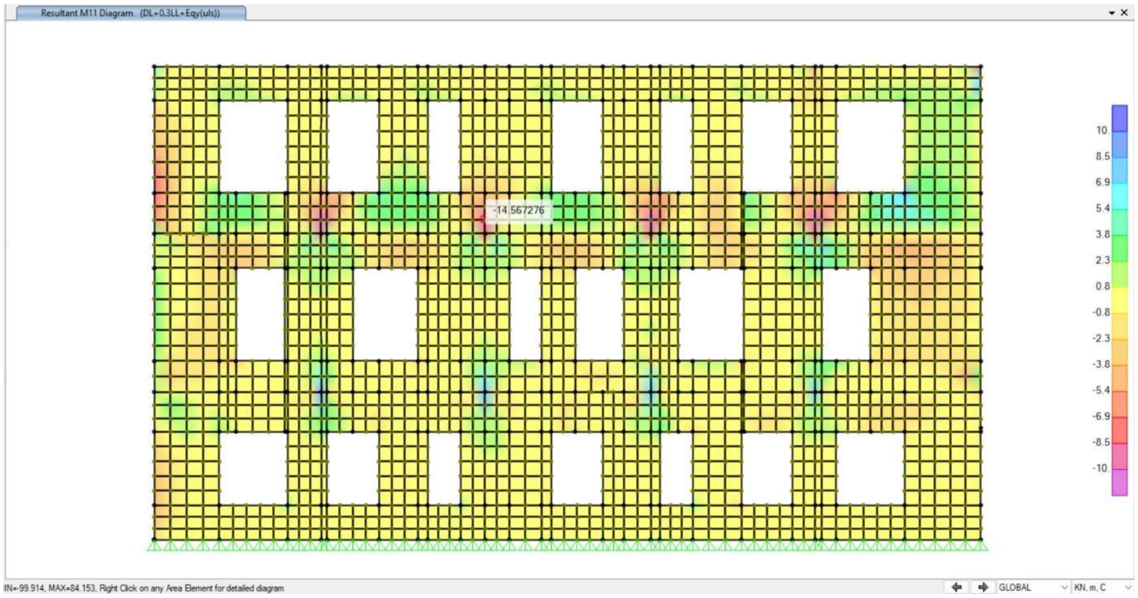


Figure 32 M11 for grid1

Maximum value = -14.57kNm^2/m

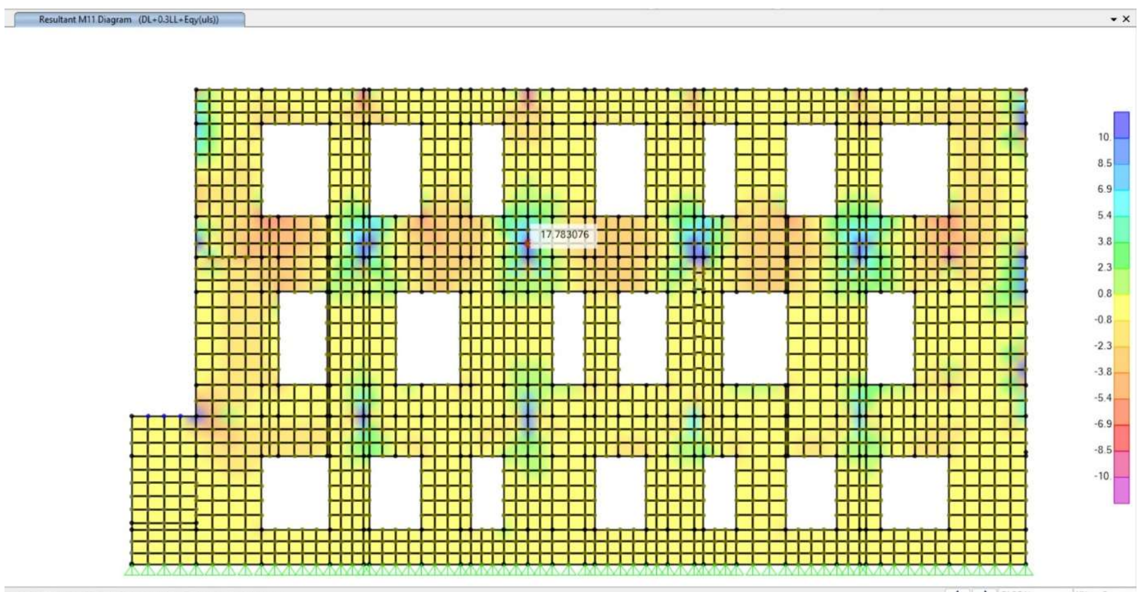


Figure 33 M11 for grid4

Maximum value = 17.78kNm^2/m

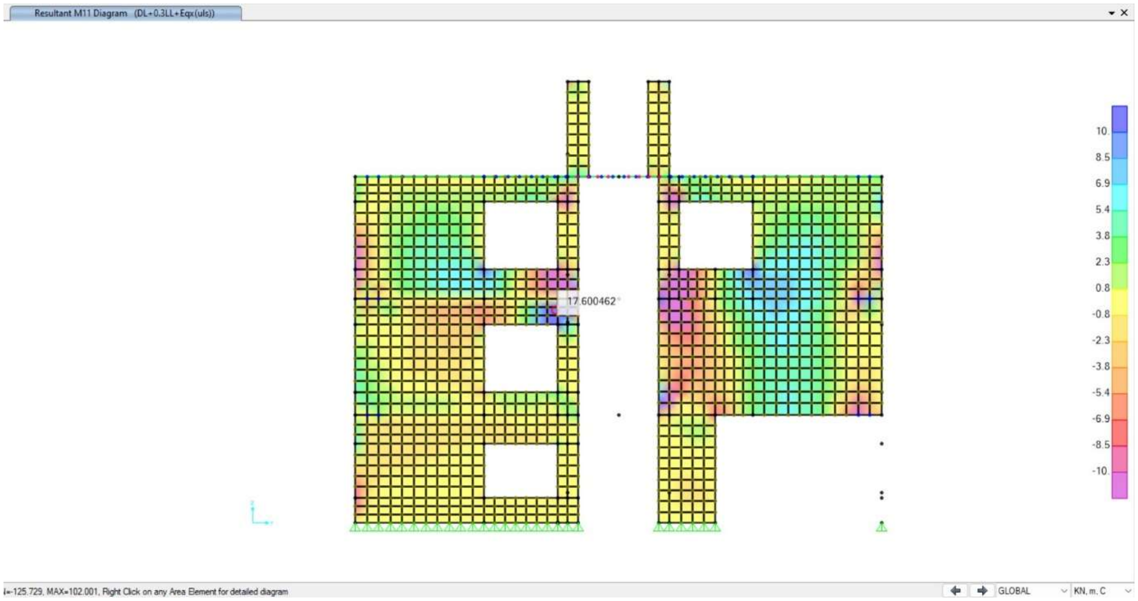


Figure 34 M11 for grid C

Maximum value = 17.6kNm^2/m

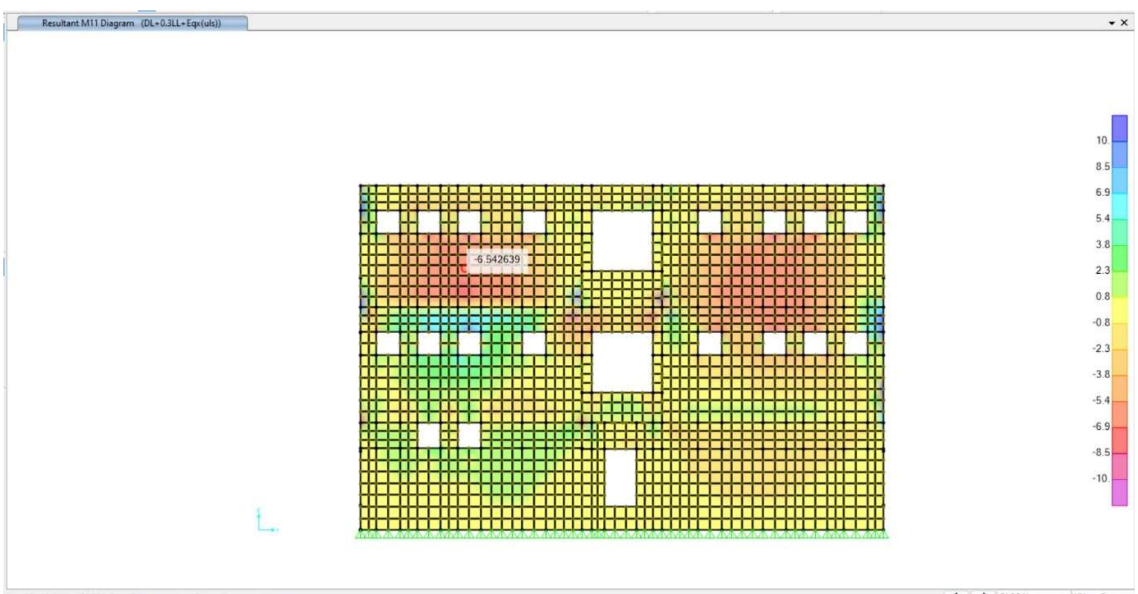


Figure 35 M11 for grid H

Maximum value = -6.54kNm^2/m

5.3 Comparison of Results from Modelling and Manual Calculations

5.3.1 Check for shear forces

Table 69 Comparison of Shear forces from Modelling and Manual Calculations

Grid	**Modelling(F in kN)**	**Shear forces(F in kN)**	**Manual calculations(F in kN)**
1	559.38	319.104	270.38
4	468.17	347.652	369.679
C	254.018	190.256	350.54
H	264.39	225.56	385.345

5.3.2 Check for Axial Forces

Table 70 Comparison of Axial forces from Modelling and Manual Calculations

Grid	**Modeling(F in kN)**	**Manual Calculation(F in kN)**
1	531.84	215.419
2	616.17	341.086
3	523.52	507.640
4	579.42	507.640
C	601.6	1313.45
D	301.089	188.55
E	313.77	137.32
F	209.48	207.57
G	202.24	259.20
H	683.46	188.27

5.4 Wire Mesh Retrofitting Options

5.4.1 Capacity Calculation

Option 1

Using 2mm @ 5mm c/c wire mesh for Retrofitting

Table 71 Wire Mesh Retrofitting Option 1

Wire mesh Grade	Fe250
No. of Horizontal wires per m Strip	201
Total area of wires, mm2	631.14
Yield Strength of wires,Mpa	250
Allowable Strength of wires,Mpa	140
Permissible increase in strength of wires	0.33
Total Allowable tensile force,kN	117.518
Allowable Compressive Strength in Masonry,Mpa	0.81

Capacity of the 480mm wall with GI wire mesh jacketing for out of plane bending per m strip,

Thickness of Jacketing, mm	50
Overall Depth,mm	580

Leaving 10mm clear cover on either side and effective thickness as 560mm,

Assuming triangular distribution for stress distribution,

We get the neutral axis as x,mm	290.169
Lever Arm	463.277
Moment of Resistance per m Strip , kN-m/m	54.444
Moment of Resistance per 0.4m Strip , kN-m/m	21.777
Moment of Resistance per 0.8m Strip , kN-m/m	43.555

Summary of Calculation:

Table 72 Summary of Calculation Option 1

Allowable Tensile Strength of the wall of all wires per m strip	117.518
For 480mm wall , Wall area per m Strip	480000
Allowable tensile stress in 480mm wall ,N/mm2	0.244

Option 2

Using TOR Steel bar of 8mm @ 150mm c/c

Table 73 Wire Mesh Retrofitting Option 2

Bar Grade	Fe415
No. of Horizontal wires per m Strip	8
Total area of wires, mm2	402.124
Yield Strength of wires,Mpa	415
Allowable Strength of wires,Mp	232.4
Permissible increase in strength of wires	0.33
Total Allowable tensile force,kN	124.293
Allowable Compressive Strength in Masonry,Mpa	0.96

Capacity of the 480mm wall with GI wire mesh jacketing for out of plane bending per m strip,

Thickness of Jacketing, mm	50
Overall Depth,mm	580

Leaving 10mm clear cover on either side and effective thickness as 560mm,

Assuming triangular distribution for stress distribution,

We get the neutral axis as x, mm	258.944
Lever Arm	473.685
Moment of Resistance per m Strip , kN-m/m	58.875
Moment of Resistance per 0.4m Strip , kN-m/m	23.550
Moment of Resistance per 0.8m Strip , kN-m/m	47.100

Summary of Calculation:

Table 74 Summary of Calculation Option 2

Allowable Tensile Strength of the wall of all wires per m strip	124.293
For 480mm wall, Wall area per m Strip	480000
Allowable tensile stress in 480mm wall ,N/mm2	0.258

Hence, the summary of the above calculations is:

Table 75 Summary of Calculations of different options

OPTIONS	MATERIAL CHOICE

Option 1	**Fe250**
Option 2	**Fe415**

5.5 Design of Retrofitting Measures

(i) Design of Vertical Bands

Vertical Tensile and Compression force, F22, DL+0.3LL+Eqx loading,

Table 76 Design of Verical Bands for Tensile and Compression Forces

Maximum Tension due to pier action , KN/m	579.42
Maximum Compression due to pier action , KN/m	452.35
Length if Tension Zone, mm	300
Average Tensile Strength, KN/m	289.71
Total Tensile Force, kN	86.913

Considering OPTION 1

2mm diameter wire with 5mm mesh size, fy = 250Mpa. Vertical bands are provided for pier ends and openings on both sides.

Tensile Strength per m strip on both faces , N/mm2	0.48

Tensile Strength of 1m wide wall strip with both faces having vertical bands is 230.4 kN

Required width of the vertical band , m	0.377

Therefore, use 2mm dia. Wire with wire 5mm wire mesh, fy 250Mpa in vertical band of width 400mm at both inner and outer faces of the wall.

Considering OPTION 2

8mm dia. TOR bar @ 150mm c/c, fy = 415Mpa. Vertical bars are provided for piers ends and openings on both sides.

Tensile Strength per m strip on both faces, N/mm2	0.52

Tensile Strength of 1m wide wall strip with both sides having vertical bands is 249.6 kN.

Required width of the vertical band, m	0.348

Therefore, use 8mm dia. Bar @ 150mm c/c in vertical bands of width 400mm at both inner and outer faces of the wall. For 1000mm strip with c/c spacing of 150mm, nos of bars required is 8.

So, use 4-8mm dia. TOR bar in 400mm width vertical band at both inner and outer faces of the wall.

(ii) Out-of-plane bending Moment Distribution for Horizontal Strip

For load combination of DL+0.3LL+Eqy

Table 77 Design of Horizonatal Strip for the out of plane bending Moment

Maximum bending moment intensity in wall ,kN-m/m	17.78
Distance between maximum and minimum intensity, m	0.3
Bending moment, kN/m	5.334

Considering OPTION 1

2mm dia. Wire with 5mm mesh size, fy = 250Mpa

Moment of Resistance of 1m band strip, kN-m/m	54.44
Width of the band for resisting bending moment	0.097

Adopt, the width of the band as 150mm. Thus, use 2mm diameter wire with 5mm mesh size, fy = 250Mpa of 100mm horizontal band on both sides.

Considering OPTION 2

8mm diameter TOR bar @ 150mm c/c, fy = 451Mpa

Moment of Resistance of 1m band strip, kN-m/m	58.87
Width of the band for resisting bending moment	0.0906

Adopt, the width of the band as 150mm. Thus, use 2-8mm diameter bars in 100mm horizontal band in both direction.

(iii) Check for Shear Stress

For load Combination DL+0.3LL+Eqx

Table 78 Check for the Capacity of Bands against Shear Stress

Total Shear Force in the wall, kN	167.814
Length of the wall, m	15.73
Thickness of the wall, m	0.48
Shear Stress in the wall, N/mm2	0.022

Assuming the total shear stress to be carried by wire mesh in horizontal and vertical bands,

Considering OPTION 1

2mm diameter wire with 5mm mesh size, fy = 250Mpa

Table 79 Check for the Capacity of Bands against Shear Stress considering Option 1

Shear Strength per m of the vertical band , kN/m	117.52
Shear Strength per 400mm width of band, kN	47.008
Number of vertical bands along the wall	8
Total shear strength of bands, kN	2224.65
Minimum expected shear strength of masonry, N/mm2	0.1
Total Shear Strength of Masonry Unit, kN	755.04
Ratio of Shear Strength to shear force	17.755

Considering OPTION 2

8mm dia. TOR bar @ 150mm c/c, fy = 451Mpa

Table 80 Check for the Capacity of Bands against Shear Stress considering Option 2

Shear Strength per m of the vertical band , kN/m	124.3
Shear Strength per 400mm width of band, kN	49.72

Number of vertical bands along the wall	8
Total shear strength of bands, kN	2353
Minimum expected shear strength of masonry, N/mm2	0.1
Total Shear Strength of Masonry Unit, kN	755.04
Ratio of Shear Strength to shear force	18.520

Figure 36 F12 for grid 1

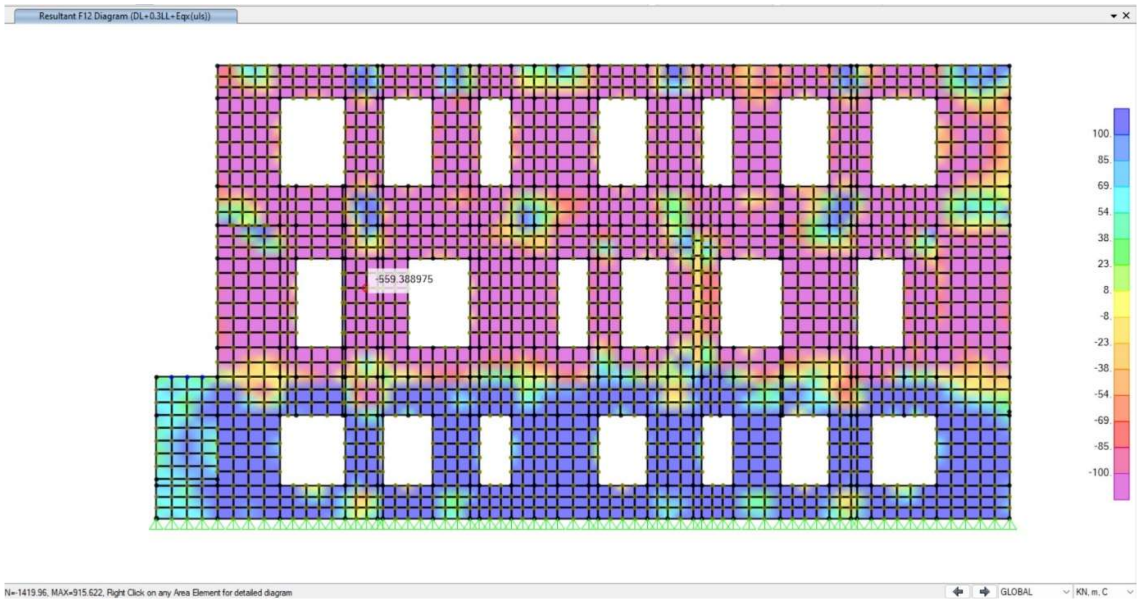


Figure 37 F12 for grid 4

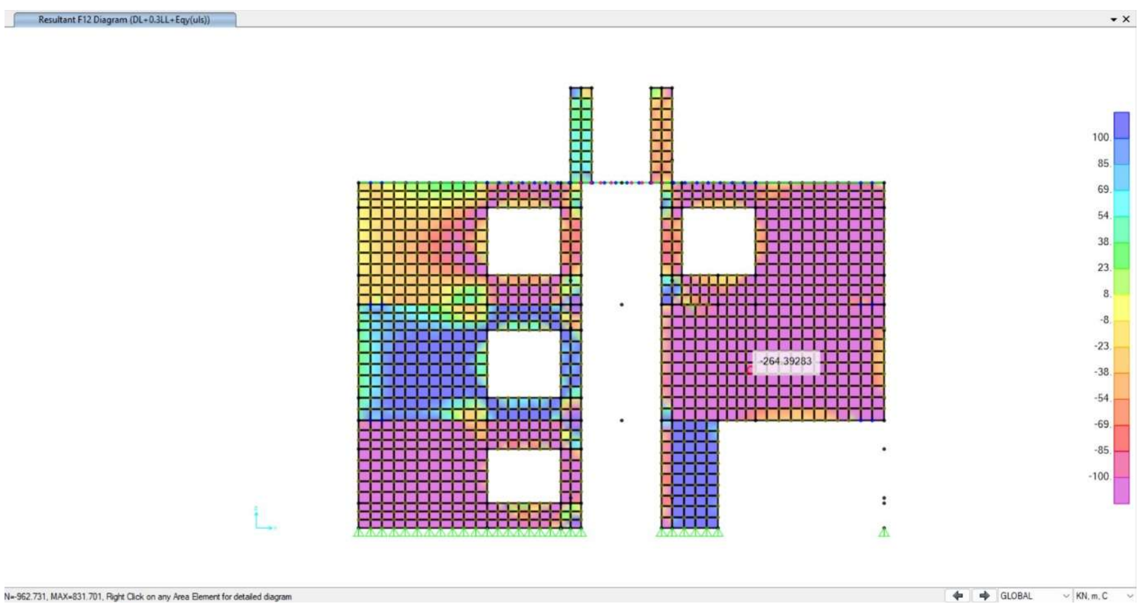


Figure 38 F12 for grid C

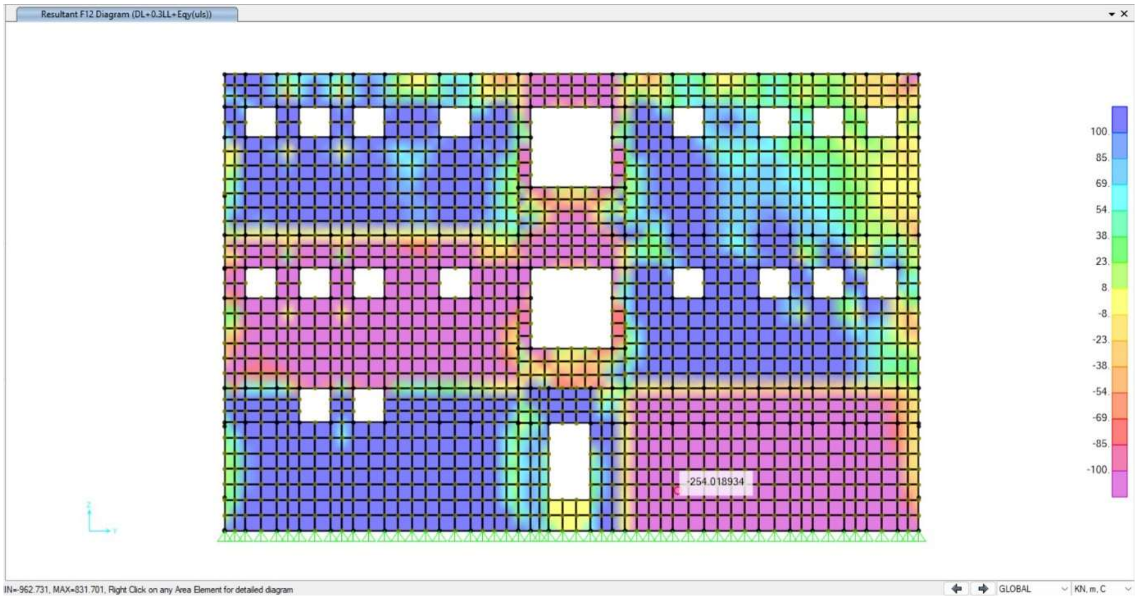


Figure 39 F12 for grid H

6 CHECK FOR SHEAR FORCE

Table 81 Check for the Shear Force

Load Combination	Wall ID	F12 (Kn/m)
DL+0.3LL+EQx	1	-468.17
	4	-559.38
DL+0.3LL+EQy	C	-264.39
	H	-254.02

7 DESIGN SUMMARY

Table 82 Design Summary

Wall ID	Option 1 (2mm wire with 5mm mesh size)		Option 2 (8mm TOR @ 150mm c/c)	
	Vertical band	Horizontal band	Vertical band	Horizontal band
1	Width 400mm	Depth 200mm	Width 400mm	Depth 200mm
2	Width 300mm	Depth 200mm	Width 300mm	Depth 200mm
3	Width 300mm	Depth 200mm	Width 300mm	Depth 200mm
4	Width 400mm	Depth 200mm	Width 400mm	Depth 200mm
C	Width 200mm	Depth 200mm	Width 200mm	Depth 200mm
D	Width 200mm	Depth 200mm	Width 200mm	Depth 200mm
E	Width 210mm	Depth 200mm	Width 200mm	Depth 200mm
F	Width 150mm	Depth 200mm	Width 150mm	Depth 200mm
G	Width 150mm	Depth 200mm	Width 150mm	Depth 200mm
H	Width 450mm	Depth 200mm	Width 450mm	Depth 200mm

8 CONCLUSION

In summary, our project focused on making old masonry hostel building safer during earthquakes. We studied how this building behave during quakes and came up with ways to strengthen it. By using advanced tools, we learned a lot about how this building react to shaking. We then developed practical ways to make it stronger so it can better withstand earthquakes.

• Utilized SAP2000 software to analyze internal forces, stresses, and deformations under various loads, with a focus on seismic events.

• Evaluated the building response to earthquakes and gained insights into earthquake engineering principles.

• Successfully investigated retrofitting strategies for unreinforced masonry hostel building located at Thapathali campus.

• Enhanced understanding of building analysis and reinforced the importance of integrating seismic design strategies in civil engineering education.

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