TO STUDY THE DISTRIBUTION OF SEISMIC LOAD IN SHEAR WALL FRAME DUAL SYSTEM USING SAP2000

A PROJECT

Submitted in partial fulfilment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

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CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"To study the distribution of seismic load in shear wall frame dual system using SAP2000 "** in partial fulfilment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering and submitted to the Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat, is an authentic record of work carried out by Yogender Thakur (131658) & Ashvin Elias (131678) during a period from July 2016 to May 2017 under the supervision of *Mr. Bibhas Paul*, Assistant Professor, & *Mr. Niraj Singh Parihar* , Assistant Professor, Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

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Primarily, we submit our gratitude & sincere thanks to our supervisor Mr Bibhas Paul, Assistant Professor, Department of Civil Engineering, for his constant motivation and support during the course of our work. We truly appreciate and value his esteemed guidance. We are indebted to him for having helped us shape the problem and providing insights towards the solution.

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LIST OF ABBREVIATIONS

E	Modulus of elasticity
L	Span Length
V_B	Design Base Shear
S_a/g	Average Response Acceleration
A_h	Design Horizontal seismic coefficient
W	Seismic weight of building
W_i	Seismic weight of floor i
Z	Zone Factor
I	Importance Factor
R	Response Reduction Factor
H	Height of structure in metres
h_i	Height measured from base of building to floor i
Q_i	Lateral force at floor i
T	Undamped Natural period of vibration of structure
S_{co}	Moment resisting frame with Shear Wall at core
S_{cn}	Moment resisting frame with Shear Wall at corner
S_{xy}	Moment resisting frame with Shear Wall parallel to x and y axes
M1	Moment resisting frame having 0.6x0.6 column dimensions
M2	Moment resisting frame having 0.5x0.5 column dimensions
M3	Moment resisting frame having 0.45x0.45 column dimensions

ABSTRACT

Shear wall is one of the most important structural member used to resist the lateral load in high rise building. Shear wall has high in plane stiffness and strength which resist both lateral loads and the gravity loads. Shear wall with frame is known as dual structural system or wall-frame structure which is most effective and adequate in resisting of lateral load like earthquake load. The scope of present work is to study the distribution of seismic forces between the shear wall and moment resisting frame. The residential G+14 building is analyzed for earthquake load by considering two type of structural system. i.e. Frame system and shear wall frame dual system. Analysis is carried out by using SAP2000 in which dynamic analysis has been done using non-linear dynamic (Time History Method) and modal analysis. By using Non Linear analysis, stiffness coefficient ratios have been found for shear wall and moment resisting frame which determines the distribution of earthquake load on the building.

Key words: Dual system, shear wall, moment resisting frame, lateral loads

CHAPTER 1

INTRODUCTION

1.1 MOMENT RESISTING FRAME

Moment-resisting frames are assemblies of beams and columns, with beams connected to columns. Lateral forces are resisted primarily by development of bending moment and shear force in the frame members. Because of the rigid beam-column connections, a moment frame cannot displace laterally without bending the columns or beams. The bending rigidity and strength of the frame members is therefore the primary source of lateral stiffness for the frame. The connections between columns and beams in moment resisting frames are designed to be rigid. This causes bending in beams and columns during earthquake. Hence frame members should be designed to be strong in bending. Frames acts as shear cantilevers, their shear stiffness being constant along the structure's height.

1.2 SHEAR WALLS

Reinforced walls are called shear walls. Acting as a deep beam, a shear wall resists lateral loads on structure. They are normally located inside building and most of time, walls that support lift are designed as shear walls. Shear walls resist two kinds of forces: shear forces and uplift forces. Connections in the structure above transfer the horizontal forces to shear wall. Throughout the height of the wall, shear forces are developed. Well designed shear walls transfer the seismic forces to the other shear walls, foundation walls etc. below them. Other components in the load path may be floors, footing or slabs etc.

1.3 SHEAR WALL FRAME INTERACTION

Possession of minimum lateral stiffness prevents too much swinging during small shaking in earthquake resistant buildings. Moment frame buildings may not always be able to resist large sways. Shear walls help reduce the overall displacement of buildings when the lateral displacement is large in the high rise buildings .Shear walls have large in-plane stiffness and strength. Hence the earthquake resistant building consists of moment resisting frames with specific bays in each direction having shear walls. Shear walls resist lateral forces through combined flexure-axial-shear action. Also, shear walls reduce shear and moment demands on columns and beams in the building, when provided as lateral load resisting system along with the moment resisting frames. Shear walls must be of sufficient height to increase the performance of the building against earthquake. Also, optimum performance is ensured when it rests on hard soil strata.

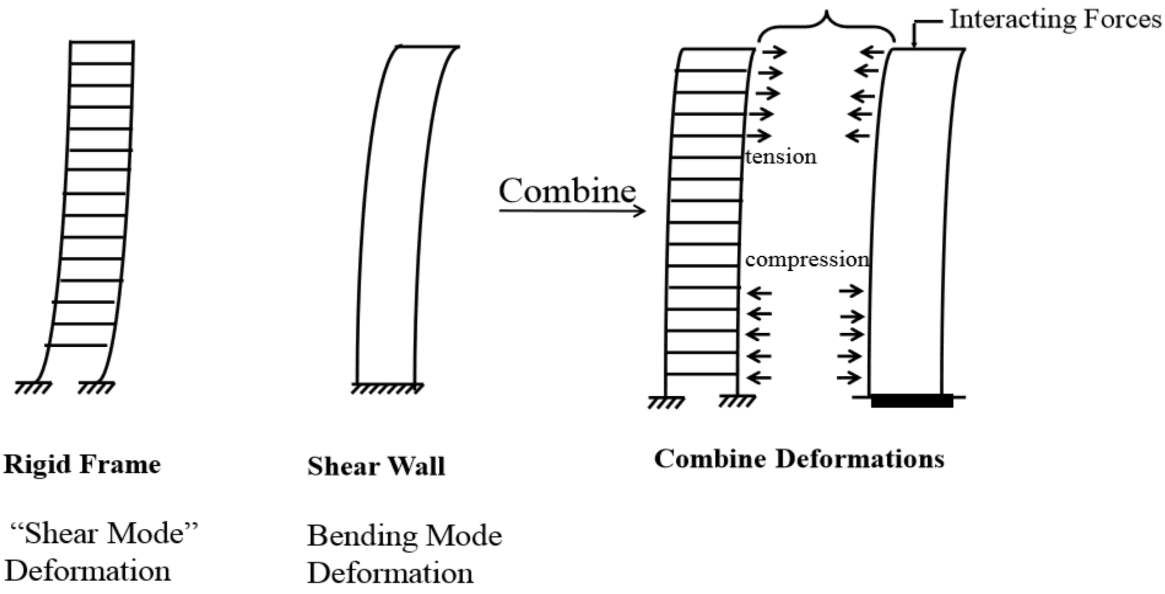


Figure 1.1-Rigid Frame, Shear Wall &Combined Deformation

1.4 SAP2000

Since it’s introduction over 30 years ago, the SAP name is now synonymous with State-of-the-art analytical methods. SAP2000 features a very sophisticated, intuitive and versatile user interface powered by an analysis engine and design tools for engineers working on industrial, transportation, public works and other facilities. SAP2000 allows to create structural models rapidly and intuitively. Complex Models can be generated and meshed with powerful Templates built into interface. The Advanced Analytical Techniques allow for Step-by-Step Multiple P-Delta, Large Deformation Analysis, Ritz and Eigen Analyses, Cable Analysis, Tension or Compression Only Analysis, Base Isolators, Buckling Analysis, Blast Analysis, and Support Plasticity, Fast Nonlinear Analysis for Dampers, Energy Methods for Drift Control and Segmental Construction Analysis. Bridge Designers can use SAP2000 Bridge Templates for generating Bridge Models and can perform Pushover Analysis

1.5 AIM OF PROJECT

The aim of the project is to find out the distribution of seismic forces in shear wall frame dual system. It involves finding the stiffness coefficient of the shear wall and of the frame. It will constitute the following stages

1. Modelling of a moment resisting frame in SAP2000
2. Location of shear wall in the above frame for which deflection is minimum
3. Ductile detailing of the shear wall
4. Study the distribution of earthquake on the shear wall frame dual system

1.6 METHODS OF ANALYSIS

Equivalent Lateral Force Method

The Equivalent lateral force method is the simplest analysis method requiring least computational effort as forces depend on the code based fundamental time period of structures with some empirical modifier. The design base shear is first computed as a whole and then it is distributed along the height of buildings based on simple formulae appropriate for buildings with regular distribution of stiffness and mass. The design lateral force obtained at each floor level is to be distributed to individual lateral load resisting elements. The design base shear or design lateral force and the distribution are given by some formulas given in the IS 1893.

Time History Analysis

It is also called nonlinear dynamic analysis as it involves analysis of the dynamic response of the structure at each time increment, when its base is subjected to a certain ground motion. Recorded ground motions database from past natural earthquake events called accelerogram files are the source for time histories. Recorded ground motions are randomly selected from distance, magnitude and soil condition; three main parameters in time history generation. Adding more constraints to characteristics of each category makes it more accurate and similar to site characteristics.

CHAPTER 2

EARTHQUAKE AND SEISMICITY

2.1 EARTHQUAKES

An earthquake is the sudden movement of the earth’s surface resulting from the release of energy in the earth’s crust. This energy could be generated by sudden dislocations or by volcanic eruptions or magnetic activity. An earthquake is also known as quake, tremor. The sudden release of the energy creates seismic waves. Frequency, type and size of earthquakes experienced over a time period determine the seismicity, seismism or seismic activity of an area.

2.2 CAUSE OF EARTHQUAKES

Earthquakes are oscillations caused by a temporary disturbance of the elastic equilibrium of the rocks beneath the earth’s surface. The disturbance and movements give rise to elastic impulses or waves. Two theories explains the causes of the earthquake

Plate Tectonic Theory This theory states that the earth’s crust consists of crustal plates. These plates bear loads of water bodies, land masses or both and are in constant motion on viscous mantle

Elastic Rebound Theory This theory says that the earthquake are generated when there is sudden displacement of ground on both sides of fault

2.3 EFFECTS OF EARTHQUAKES

Landslides

Ground motion also creates landslides. Care must be taken before constructing a building in a location that can be affected by landslides.

Tsunamis and Seiche

A tsunami is caused by landslides, volcanic eruptions or an earthquake on sea floor. During an earthquake, powerful seismic waves are produced in the ocean. These waves are very deep. “Seiche” refers to the oscillation of water in a closed space which can cause collapse of dams and can damage structures in the vicinity of water bodies.

Direct Effects

Seismic waves through surface rock layers result in strong ground motion. Such motion can damage and can destroy buildings. Ground shaking may increase problem in areas with very wet ground in filled land, coastal areas or in locations having high water table.

2.4 BUILDING CHARACTERISTICS

Several important characteristics of buildings affect performance during an earthquake. Below are some of the important characteristics of a building which determine their performance during an earthquake.

1. Natural Time Period: As seismic waves moving through the ground has its natural time period. If the time period of the ground is the same as that of the building causes resonance which is highly destructive.

Height is a major factor governing time period. A taller building will have a greater time period as compared to that of a shorter one. A taller building often suffers more damage because the natural period of the ground tends to match that of buildings eight stories or taller.

2. Ductility and Strength: Ductility is another factor affects performance of a building during an earthquake. Materials like steel bend or deform before failing. These ductile materials absorb energy and prevent collapse. In fact reinforced concrete improves ductility and strength.

3. Damping: The damping of resonance reduces the vibration of a building during earthquakes. In short damping is the retardation or termination of the motion or vibration of a structure. Connections of non-structural elements like ceilings and exterior walls can dampen building’s vibration.

4. Stiffness: The building is made up of both flexible and rigid elements. Less rigid building elements have a greater capacity to absorb several cycles of ground motion before failure. Stiff elements fail and shatter suddenly during an earthquake. Earthquake loads have greater effect on the stiffer, rigid elements of a building. Hence buildings should be constructed of components having same level of flexibility.

5. Drift*:* It means the extent to which a building sways or bends. Limits are often put on drift so that resulting sway during an earthquake does not cause excessive damage to the building. If the drift is too high, a building may pound into the building next to it or non structural components, such as ceilings and walls could be ripped away from their attachments causing injury to people inside.

2.5 SEISMIC ZONING OF INDIA

The varying geology at different locations in the country creates that the likelihood of differnt extent of damage at different locations in India. A map of seismic zones identifies these regions. Based on the intensities of damages due to past earthquakes, the zone map has been subdivided India into four zones – II, III, IV and V. Zone I &II have been merged together under the name of zone II.

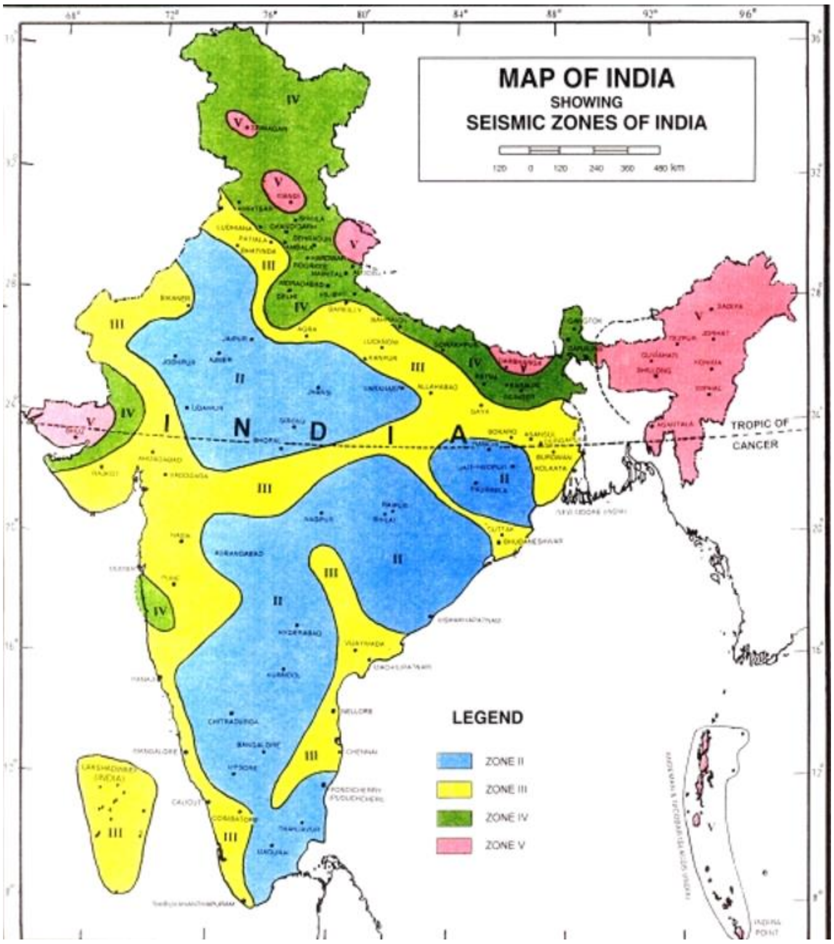


Figure 2.1-Seismic Zone Map

CHAPTER 3
LITERATURE REVIEW

This chapter presents a brief summary of the literature review.

3.1. Stability and Dynamics of Shear Wall Frame Structures

It was written by Riko Rosman and published in 1974 in Britain. He considered the frames as shear cantilevers, i.e. cantilevers working under shear, their shear stiffness being constant along the height of the building. The shear stiffness is dependent on the bending stiff nesses of its columns and lintels and on the geometry of the frame. He proposed a model consisting of a bending cantilever, i.e. a cantilever working under bending only, and a shear cantilever, both of them being connected by rigid hinged bars. The bending cantilever represents the wall system, whereas the shear cantilever represents the frame system. Applying the shear-cantilever concept to describe the relationship between load and deflection of the frames, simple formulas have been derived for free vibrations periods and the buckling loads.

3.2. Evaluation of Shear Wall RC Frame Interaction of High-rise Buildings using 2-D Model Approach

This research paper was published by J. A. Amin and Dipali Patel and published in July 2015. In their research, shear wall and RCC frame interaction of 20, 30 and 35 storey of a building with shear wall is investigated using 2 dimensional modelling of respective frames. Analysis of 2-D model of building having RCC frame and shear wall shows that shear wall and RCC frame assist each other in carrying the external load at the intermediate and lower floors. From analysis results of all considered RC frame, it is observed that the contribution of shear wall in resisting lateral force at top is almost negligible and the entire lateral load at top 2 to 3 storey is taken by RC frame only. But at storey level 1 to 3 from bottom, more than 75% of the lateral load is taken by shear wall and remaining 25% lateral load is resisted by the RC frame. Almost 40 % of lateral load is resisted by frame with shear wall, whereas remaining 60% load is resisted by frame without shear wall at intermediate storey levels. However higher forces are resisted by exterior frame with shear wall as compared to internal frame without shear wall as the storey height decreases.

3.3 A seismic design lateral force distribution based on inelastic state of structures

This research paper was published by Shih-Ho Chao, Subhash C.Goel and Soon-Sik Lee. In this paper results have been obtained from nonlinear dynamic analysis of various example structures by reviewing current seismic codes. It concludes the unpredictable and undesirable behaviour of structures under seismic load due to the results obtained from seismic design codes which are limited to elastic response studies. It is well known that the structures designed as per seismic codes undergo large inelastic deformations during major earthquakes. It has developed a new lateral force distribution using relative distribution of maximum storey shears considering the inelastic behaviour of the structures when subjected to a wide variety of earthquake ground motions. The results show that the suggested lateral force distribution is more accurate and satisfies inelastic seismic demands at both elemental and global levels.

3.4 Studies on Behaviour of Wall-Frame Structure Subjected to Lateral Load

It was written by Md. Irshad Ali and Vishwanath B. Patil and was published in 2013 in India. They have conducted a study on the effect of seismic loading on various placements of shear wall in medium rise building. The office building of medium raised is analyzed for earthquake force by considering two type of structural system. i.e. Dual system and Frame system. They considered total ten models in which five are of six stories and five are of twelve stories. They studied the effectiveness of shear wall with the help of three different models of six stories and twelve stories. Model one and six are bare frame structural system, model two and seven are full masonry infill and other three models of six story and twelve story are dual type structural system. Analysis has been done using ETAB. They observed that the lateral stiffness in different models were increasing with the addition of infill walls and by providing shear wall at different location in building plan compared to bare frames. The storey drift for all models were satisfying the permissible limit 0.004*h where h is the storey height, as per IS 1893. They concluded that provision of infill wall and shear wall enhances the performance in terms of drift control and storey displacement besides increasing lateral stiffness of the building.

CHAPTER 4

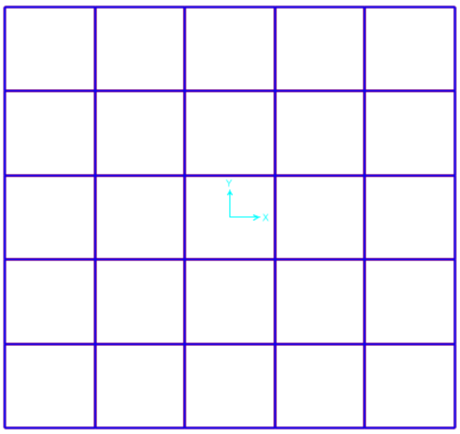
MOMENT RESISTING FRAME

4.1 GENERAL DETAILS

G+14 Community building in zone 4 with medium soil site condition. Total height of the building = 52.5m. Wind load is not considered in the given study. Further details are as follows:

Table 4.1-Storey details

Number of Stories	15	Storey Height	3.5m
Number of Bays (X)	5	Bay Width (X)	3.5m
Number of Bays (Y)	5	Bay Width (Y)	3.5m



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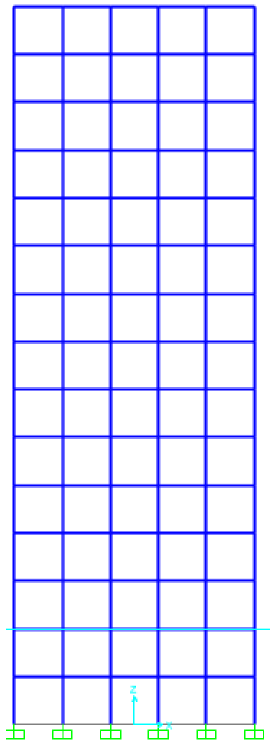

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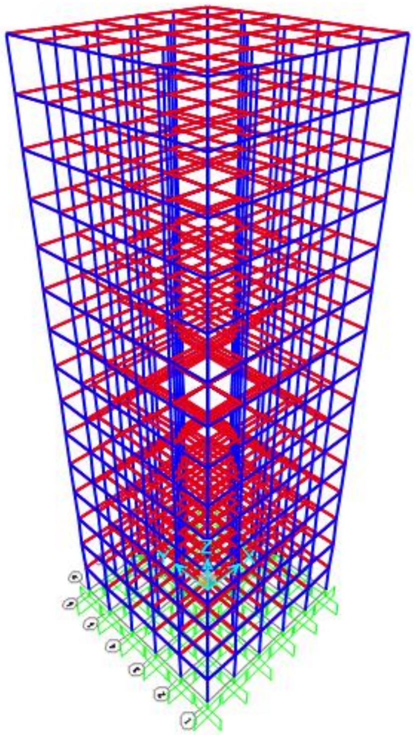


(c)

Figure 4.1-Building (a) Plan , (b) Elevation & (c) 3d model.

4.2 MEMBER DETAILS

Table 4.2-Schedule of members

MEMBER	SIZE	MATERIAL
Column 1	450mm × 450mm	M30
Column 2	500mm × 500mm	M30
Column 3	600mm × 600mm	M30
Beam	350mm × 500mm	M30
Slab thickness : 150mm , Material : M20		

4.3 LOADS ASSIGNED

Dead Load

- Dead load refers to the self weight of the structure covering the weight of each and every element of the structure like the beam, column, slab and the walls.
- The unit weight of various building material are given in IS: 875 (part 1).

Imposed Load

- The term 'imposed load' is used instead of 'live load' to emphasize the effects of nature of occupancy and not only the physical contribution due to people.
- The IS 875 (part 2) gives specification of various live loads.

Table 4.3-Loads assigned

LOADS ASSIGNED	kN/m^2	IS CODE
Dead load	4.5	IS 875 (Part 1)
Imposed load	2.5	IS 875 (Part 2)
Imposed load on roof	0.75	IS 875 (Part 2)

4.4 IS 1893 PROVISIONS USED

- For different buildings the importance factor is given in Table 6 and the response reduction factor, R is given in Table 7.
- Imposed Loads for seismic force calculation

  For various loading classes as specified in IS 875(Part 2), the earthquake force shall be calculated for the full dead load plus the percentage of imposed load as given in Table8.

  For calculating the design seismic forces of the structure, the imposed load on roof need not be considered.

- The seismic weight of each floor is its full dead load plus some amount of imposed load, as per in clause 7.3.1 and 7.3.2. When computing the seismic weight of each floor, the weight of columns and walls in any storey shall be equally distributed to the floors above and below the storey.

- The seismic weight of the whole building is the sum of the seismic weights of all the floors.

- The fundamental natural period of vibration in seconds, of a moment-resisting frame building without brick infill panels is calculated using the following formula.

$$T_a = 0.075\, h^{0.75} \quad \text{for RC frame building}$$
$$= 0.085\, h^{0.75} \quad \text{for steel frame building}$$

where

h = Height of building, in m. This excludes the basement storeys, where basement walls are connected with the ground floor deck or fitted between the building columns. But, it includes the basement storeys, when they are not so connected.

- The fundamental natural time period (T), in seconds, of all other buildings, including moment-resisting frame buildings with brick infill panels, is estimated using the following expression

$$T_a = \frac{0.09}{\sqrt{d}}$$

where

h = Height of building, in m, as defined in 7.6.1; and

d = Base dimension of the building at the plinth level, in m, along the considered direction of the lateral force.

- The design horizontal seismic coefficient Ah for a structure is to be determined by the following formula

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

Provided that for any structure with T <0.1 s, the value of A should not be taken less than Z/2 whatever be the value of I/R

Z = Zone factor given in Table 2, is for the Maximum Considered Earthquake (MCE) and service life of structure in a zone. The factor 2 in the denominator of Z is used so as to reduce the Maximum Considered Earthquake (MCE) zone factor to the factor for Design Basis Earthquake (DBE).

I = Importance factor, depending upon the functional use of the structures, characterised by hazardous consequences of its failure, post-earthquake functional needs, historical value, or economic importance (Table 6).

R = Response reduction factor, depending on the perceived seismic damage performance of the structure, characterised by ductile or brittle deformations. However, the ratio (I/R) shall not be greater than 1.0 (Table 7). The values of R for buildings are given in Table 7.

S_a/g = Average response acceleration coefficient

For rocky, or hard soil sites

$$\frac{S_a}{g} = \begin{cases} 1 + 15\,T; & 0.00 \le T \le 0.10 \\ 2.50 & 0.10 \le T \le 0.40 \\ 1.00/T & 0.40 \le T \le 4.00 \end{cases}$$

For medium soil sites

$$\frac{S_a}{g} = \begin{cases} 1 + 15\,T; & 0.00 \le T \le 0.10 \\ 2.50 & 0.10 \le T \le 0.55 \\ 1.36/T & 0.55 \le T \le 4.00 \end{cases}$$

For soft soil sites

$$\frac{S_a}{g} = \begin{cases} 1 + 15\,T; & 0.00 \le T \le 0.10 \\ 2.50 & 0.10 \le T \le 0.67 \\ 1.67/T & 0.67 \le T \le 4.00 \end{cases}$$

- Design Seismic Base Shear*:* The total design lateral force or design seismic base shear (V_B) along any principal direction is determined using the following formula:

$$V_B = A_h W$$

where

A_h = Design horizontal acceleration spectrum value as per **6.4.2**, using the fundamental natural period T_a as per **7.6** in the considered direction of vibration; and

W = Seismic weight of the building as per **7.4.2**.

- Distribution of Design Force :The design base shear (V_B) computed is distributed along the height of the building as per the following expression:

$$Q_i = V_B \frac{W_i h_i^2}{\sum_{j=1}^{n} W_j h_j^2}$$

where

Q_i = Design lateral force at floor i,

W_i = Seismic weight of floor i,

h_i = Height of floor i measured from base, and

n = Number of storeys in the building is the number of levels at which the masses are located.

Shear wall dual frame system consists of shear wall in a moment resisting frame. The two are designed to resist the total design lateral force in proportion to their lateral stiffness.

The moment resisting frame is designed to independently resist at least 25 percent of the design base shear.

4.5 STEPS FOR CALCULATING DESIGN LATERAL FORCE

1. Find the seismic weight of building, W … (cl 7.4.2)
2. Find the Natural Time Period of vibration of the building, T … (cl 7.6.1 / cl 7.6.2)
3. Find the Average Response Acceleration coefficient, S_a/g … (cl 6.4.5)
4. Find the Design Horizontal Seismic Coefficient of the structure, A_h … (cl 6.4.2)
5. Find the Design Seismic Base Shear, V_B …(cl 7.5.3)
6. Find the Design Lateral Force at the floors, Q_i …(cl 7.7.1)

4.6 CALCULATIONS

4.6.1. Calculation of Base Shear V_B

Equivalent Lateral Force Method:

A. Load per unit area of storey (except roof) (w_1)

= DL + .25 LL

$= 4.5 + .25*2.5$

$= 5.125\ kN/m^2$

Load per unit area of roof (w_2)

$= 4.5\ kN/m^2$

Floor Area (A)

$= 17.5*17.5\ m^2$

$= 306.25\ m^2$

Seismic Weight of a Floor (W_i)

$= 5.125*306.25$

$= 1569.53\ kN$

Seismic Weight of the building,(W)

$= 1569.53 * 14 + 4.5 * 306.25$

$= 23351.5\ KN$

B. Natural Time Period of the building, (T)

$= 0.075*h^{0.75}$

$=0.075*(52.5)^{0.75}$

$=1.4627s$

C. Average Response Acceleration coefficient,(S_a/g)

$= 1.36/T$

$= 0.9297$

D. Design Horizontal Seismic Coefficient, A_h

$= (Z*I*S_a)/(2*R*g)$

= (0.24*1.5*0.9297) / (2*3)

= 0.055782

E. Design Seismic Base Shear, V_B

= A_h * W

=0.055782 * 23351.5

=1302.59 kN

Therefore, V_B =1302.59 kN .Design lateral forces in the floors are as follows:

Table 4.4-Design lateral forces on the frame

Floor no.	Design lateral force(kN)
1	1.2
2	4.8
3	10.8
4	19.2
5	30.04
6	43.3
7	58.9
8	76.9
9	97.33
10	120.16
11	145.39
12	173
13	203
14	235
Roof	270

The following three models of the building are analysed in SAP2000 by applying the lateral forces.

Table 4.5-Moment resisting frame models

MODELS	COLUMN DIMENSIONS (mm)	BEAM DIMENSIONS (mm)
M1	600 x 600	350 x 500
M2	500 x 500	350 x 500
M3	450 x 450	350 x 500

4.7 ANALYSIS RESULT AND DISCUSSION

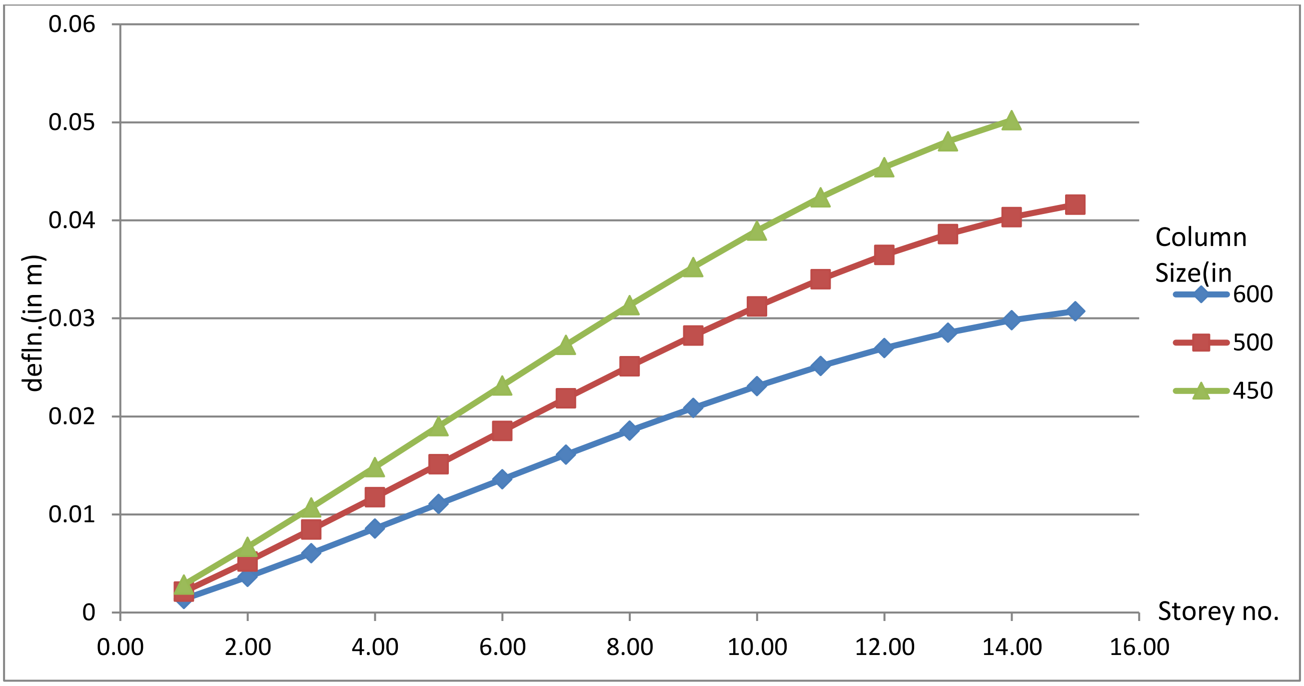


Figure 4.2-Storey displacement

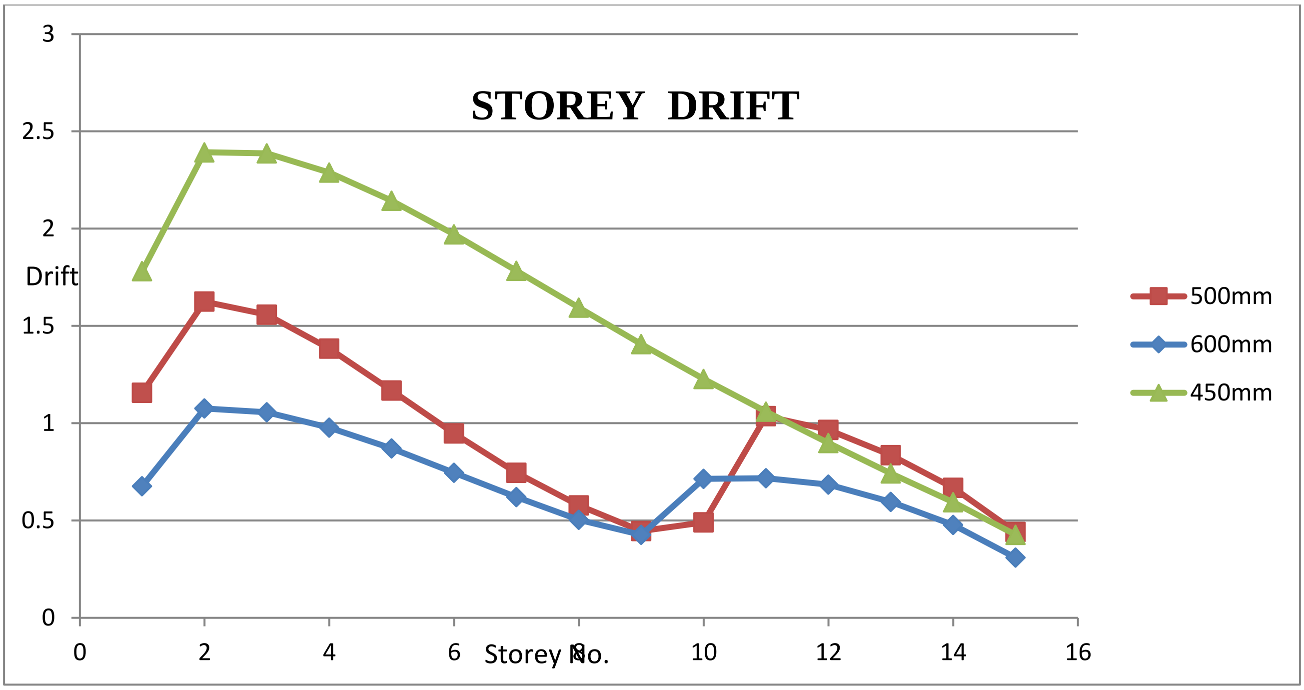


Figure 4.3-Storey drift

As per clause 7.11.1 of IS 1893: 2000, storey drift in any storey should not exceed 0.004 times the storey height. Here the storey drift limitation is 14 mm which is satisfied by all the three models. The storey displacement of M2 is in between that of storey displacement of the other two models. Hence considering the safety and economy of the building model M2 is chosen as the moment resisting frame designed to bear 30% of the total base shear.

CHAPTER 5

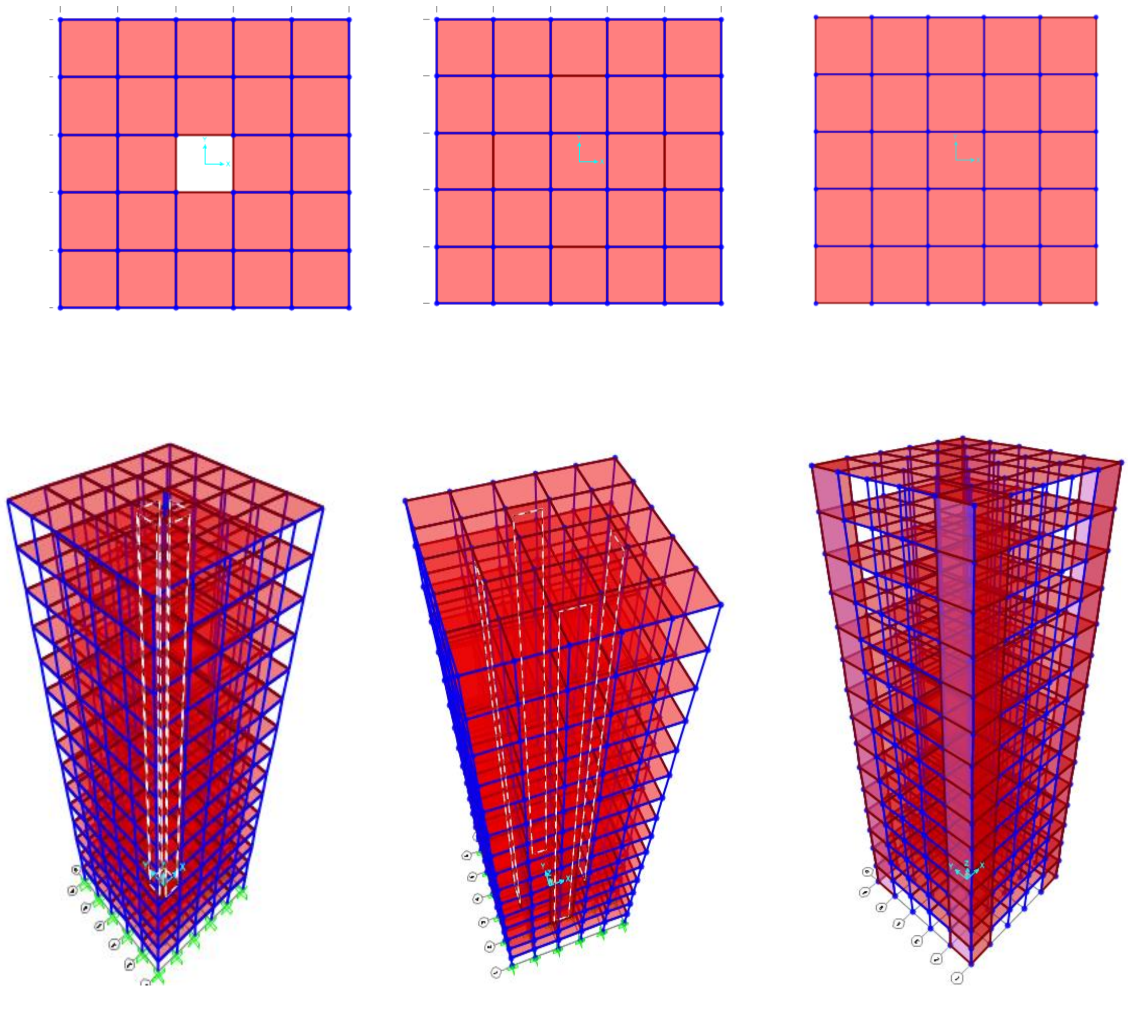
LOCATION OF SHEAR WALL

To find the location of the shear wall for which the deflection of our structure is minimum,we have taken following three models with different locations of the shear wall :

S_{co} = Moment resisting frame with shear wall at the core

S_{cn} = Moment resisting frame with shear wall at corner

S_{xy} = Moment resisting frame with shear wall parallel to the X and Y axis



(a) (b) (c)

Figure 5.1-Plan and 3d view of frame with shear wall at (a) core, (b) parallel to X and Y axis & (c) corner

5.1 SHEAR WALL DETAILS

Shear wall type: Linear

Thickness: 250mm

Height: 52.4m

Material: M30

5.2 CALCULATIONS

By using modal analysis of the above three models on SAP2000, natural time period of the structures is obtained. To find the lateral force at the floors, equivalent lateral force method is used. Tables of design lateral forces for the considered locations of shear wall have been tabulated using equivalent lateral force method.

Table 5.1-Time period and Base shear

MODEL	TIME PERIOD (T)	BASE SHEAR (V_B)
S_{co}	1.14439	1346
S_{cn}	1.12122	1374
S_{xy}	1.23259	1250

Table 5.2- Design lateral forces for shear wall at core

Floor no.	Design lateral force(kN)
1	1.09
2	4.34
3	9.76
4	17.34
5	27.14
6	39.08
7	53.19
8	69.5

9	87.9
10	108.5
11	131.34
12	156.3
13	183.44
14	212.75
Roof	244.2

Table 5.3- Design lateral forces for shear wall at corner

Floor no.	Design lateral force(kN)
1	1.08
2	4.43
3	9.97
4	17.73
5	27.7
6	39.89
7	54.3
8	70.92
9	89.75
10	110.8
11	134.07
12	159.56
13	187.26
14	217.18
Roof	249.31

Table 5.4-Design lateral forces for shear wall parallel to X & Y axis

Floor no.	Design lateral force(kN)
1	1.008
2	4.03
3	9.07
4	16.12
5	25.2
6	36.29
7	49.4
8	64.52
9	81.65
10	100.8
11	121.97
12	145.16
13	170.36
14	197.58
Roof	226.81

5.3 ANALYSIS, RESULT AND DISCUSSION

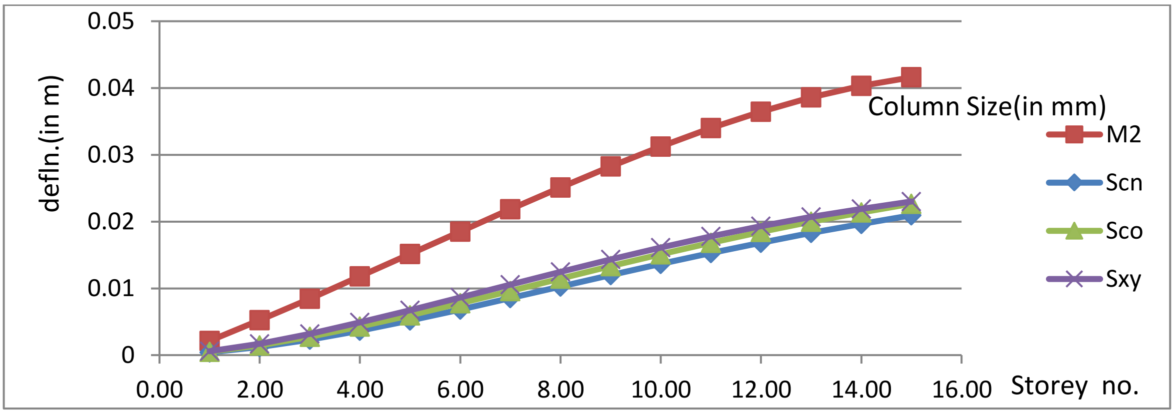


Figure 5.2-Lateral displacement of stories for different locations of shear wall

This graph shows that the shear walls have reduced the storey displacement and are found to be effective in enhancing the overall seismic capacity characteristics of the structure. From the comparison of lateral displacement of above models, it can be observed that maximum reduction in storey displacement values are obtained when shear walls are provided at corners of the building

CHAPTER 6

DESIGN OF NONLINEAR SHEAR WALL

As per clause 6.4.2 of IS 1893 part 1:2002, shear wall is to be designed for 70% of Bhuj Earthquake.

6.1 PROCEDURE AS PER IS 13920:1993

1. Obtain factored shear force for the combined building and shear walls
2. Assume shear walls to take 70% of the seismic load and obtain design shear force for a single shear wall
3. Assume thickness of the wall not less than 150 mm and find nominal shear stress such that it is greater than the design shear strength of concrete τ_c and less than $\tau_{c\ max}$. [cl 9.1.2 & cl 9.2.1]
4. Find the maximum spacing of the bars in both the directions [cl 9.1.7]
5. Find the minimum reinforcement in both the directions [cl 9.1.4]
6. Assume suitable dia of bars for vertical reinforcements and calculate the horizontal spacing of the bars.
7. Assume suitable dia of bars for the horizontal reinforcements.
8. Find the shear to be resisted by the horizontal reinforcements and calculate the vertical spacing of the bars.[cl 9.2.5]
9. Check if boundary elements are to be provided [cl 9.4.1]

6.2 CALCULATION

A. Nominal shear stress

Factored Shear force for the combined building and shear walls, V_B

= 5450 kN

Here,

τ_c = 0.37N/mm^2

& $\tau_{c\ max}$ =3.5N/mm [Table 19, IS 456:2000]

Design shear force for a single shear wall,

V_u = (0.7*5450)/ 4

= 953.75 kN

Let thickness of shear wall be 300 mm

Therefore, thickness,

T =300 mm

Horizontal length of wall,

l_w =3000mm

& effective depth of wall section,

d_w = 0.8 l_w

=0.8*3000

=2400 mm

Therefore, nominal shear stress

τ_V = $V_u/(t^* d_w)$

τ_V = 1.3246 N/mm^2

B. Maximum spacing of bars

Minimum of:
$L_w/5$ = 600 mm
$3t_w$ =900 mm
& 450mm

Therefore, Maximum spacing of the bars is 450 mm

C. Vertical reinforcements

Wall thickness, t>200 mm, therefore provide two curtains of reinforcement.

Provide minimum reinforcements = 0.0025*300*1000

A_{st} = 750 mm^2

Assume 14mm dia bars, $A_{st\phi}$ =153.93 mm^2

Horizontal spacing of bars = 1000*2*153.93/750

= 410.48 < 450

Hence provide 14 mm diameter bars @ 410mm c/c in two curtains.

D. Horizontal reinforcements

Wall thickness, t>200 mm, therefore provide two curtains of reinforcement.

$\tau_c < \tau_V < \tau_{c\,max}$

Shear to be resisted by the horizontal reinforcements

$V_{us} = V_u - \tau_c * t_w * d_w$

$= 953750 - 0.37*300*2400$

$= 687350N$

Assume 14mm dia bars

Therefore

$A_{st\phi} = 153.93\ mm^2$

$A_h = 2*153.93$

$V_{us} = 0.87*f_y*A_h*d_w/S_v$

$= 0.87*415*2*153.93*2400/S_v$

$S_v = 388\ mm$

Hence provide 14 mm dia bars @ 380 mm c/c in two curtains

E. Boundary element

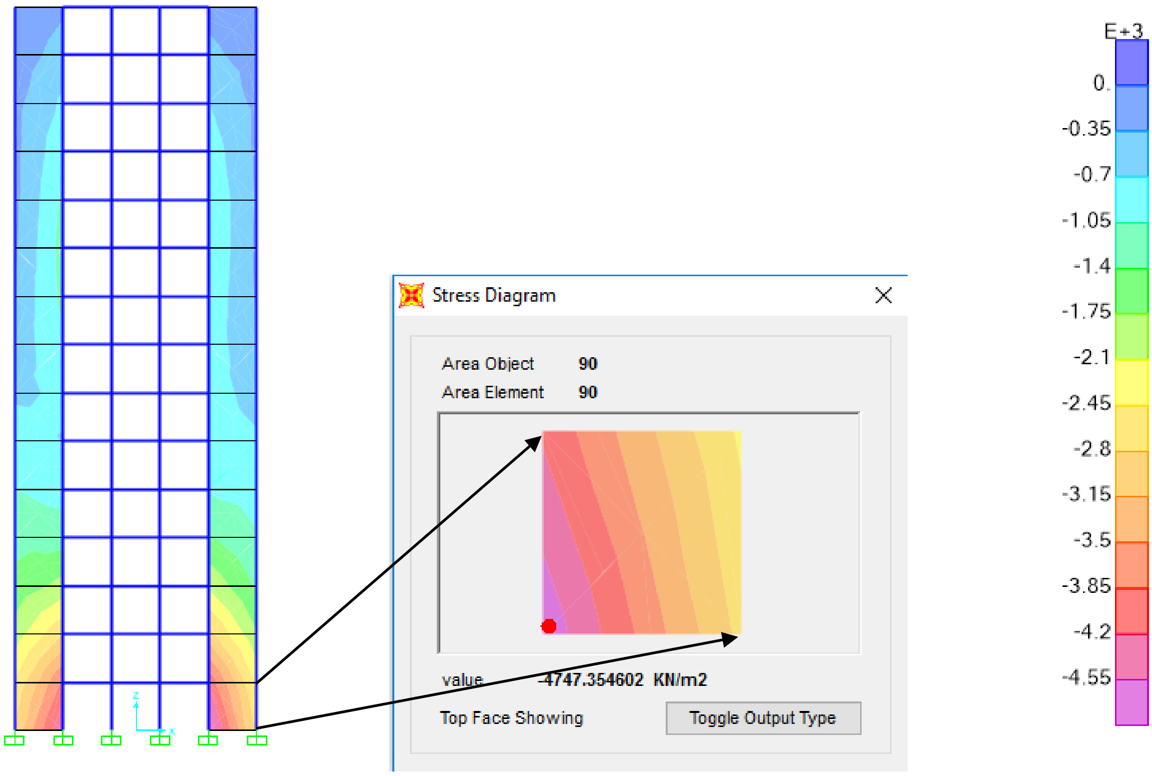


Figure 6.1-Compressive stress in shear wall

As per clause 9.4.1 of IS 13920: 1993, boundary elements shall be provide when the compressive stress in the extreme fibre exceeds $0.2f_{ck} = 6N/mm^2$

Maximum compressive stress in the shear wall = $4.74N/mm^2 < 6N/mm^2$

Therefore, there is no need to provide boundary elements.

6.3 Shear wall details

Length = 3000 mm

Thickness = 300mm

Height = 51.2 m

Concrete used = M30

Yield strength of rebars = $415N/mm^2$

Vertical reinforcement

Diameter = 14mm Spacing = 410mm c/c

Horizontal reinforcement

Diameter = 14mm Spacing = 380mm c/c

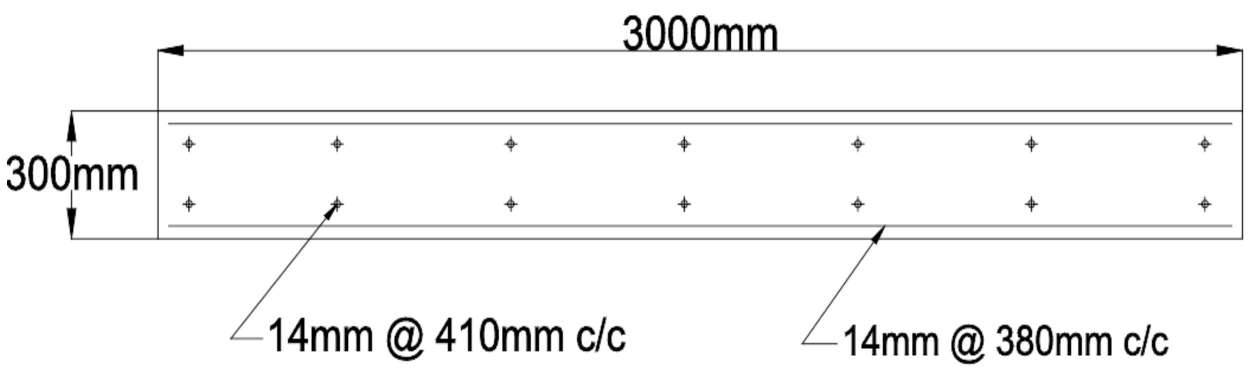


Figure 6.2-Top view of shear wall

CHAPTER 7

STUDY OF SHEAR WALL FRAME INTERACTION

7.1 TIME HISTORIES CONSIDERED FOR THE STUDY

1. BHUJ 2001

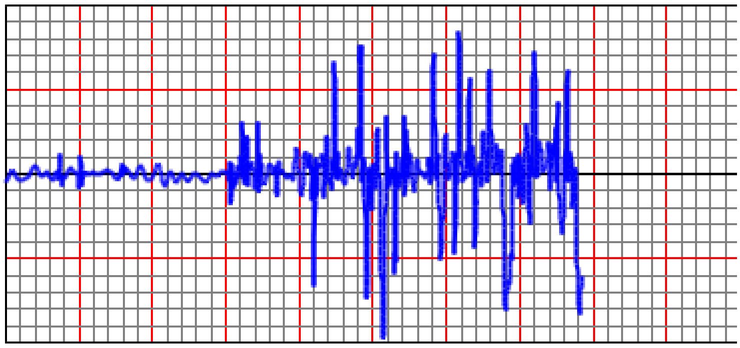


Figure 7.1-Bhuj earthquake time history graph

Magnitude = 7.7
Peak acceleration = 0.78236 m/s2

2. CHAMOLI 1999

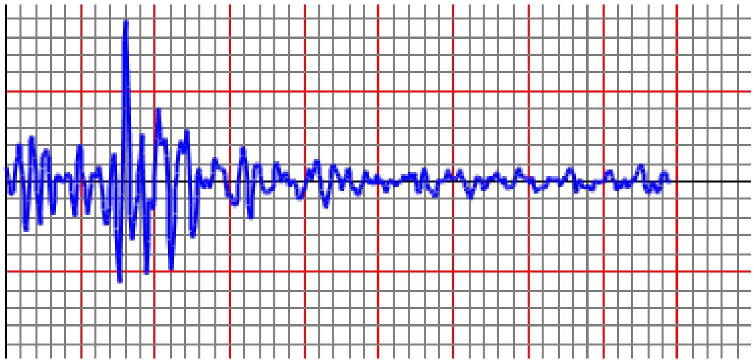


Figure 7.2-Chamoli earthquake time history graph

Magnitude = 6.8
Peak acceleration = 0.35559 m/s2

3. DHARMSHALA 1986

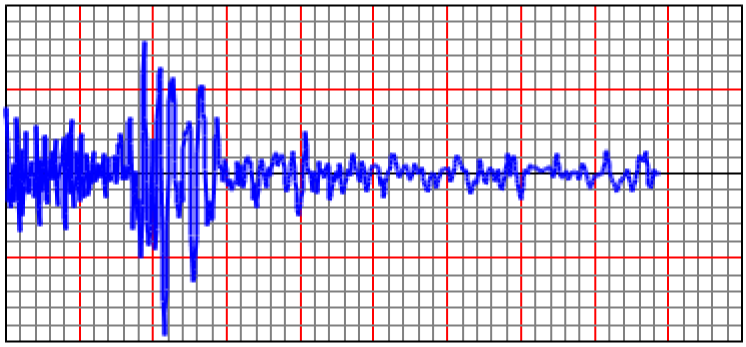


Figure 7.3-Dharamshala earthquake time history graph

Magnitude = 5.7
Peak acceleration = 0.3820 m/s2

4. INDIA BURMA BORDER 1988

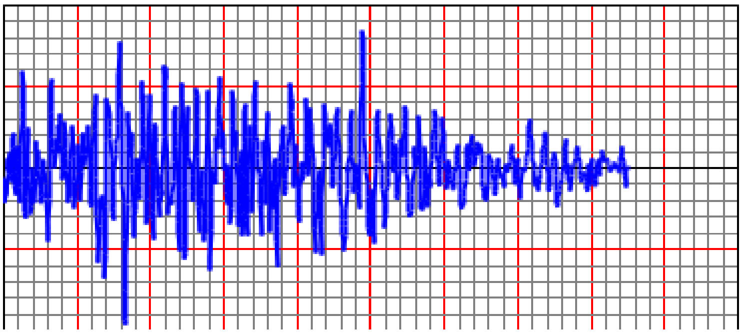


Figure 7.4-India-Burma border earthquake time history graph

Magnitude = 7.2
Peak acceleration = 0.482 m/s2

5. UTTARKASHI 1991

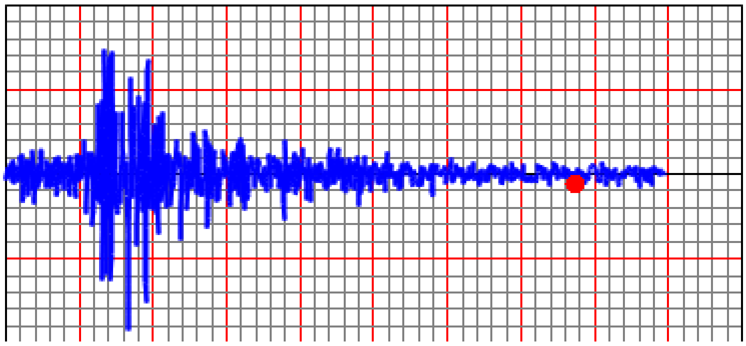


Figure 7.5-Uttarkashi earthquake time history graph

Magnitude = 6.8

Peak acceleration = 0.739 m/s2

7.2 CALCULATIONS

From various earthquake loads applied in previous chapters, base shear borne by shear wall has been found through SAP2000 as shown in table below

Table 7.1-Base shear resisted by shear walls

EARTHQUAKE	MAGNITUDE IN RICHTER SCALE	BASE SHEAR RESISTED (kN)	LOAD CASE	TOTAL BASE SHEAR (kN)
Chamoli 1999	6.8	727.35	1.5(DL+EL)	1119
Dharmshala 1986	5.7	717	1.5(DL+EL)	1066.23
India-Burma Border 1988	7.2	2958.63	1.5(DL+EL)	4322.952
Uttarkashi 1991	6.8	1442.36	1.5(DL+EL)	2091.35

Let α = stiffness coefficient of shear wall,

β = stiffness coefficient of moment resisting frame

From the data shown above, stiffness coefficient of shear wall has been found as

$$\alpha = \sum \text{BASE SHEAR RESISTED} / \sum \text{TOTAL BASE SHEAR}$$

$$\alpha = (727.35+717+2958.63+1442.36) / (1119+1056.23+4322.952+20$$

$$\alpha = 0.681$$

As sum of stiffness coefficient of shear wall and moment resisting frame has to be equal to one hence stiffness coefficient ratio of moment resisting frame is calculated as shown

$$\beta = 1-\alpha = 1-0.681 = 0.319$$

Hence stiffness coefficient ratio of shear wall is 0.681 and that of moment resisting frame is 0.319.

CONCLUSION

From the present investigation and the results obtained it can be concluded as following:

1) In our analysis results we found that by shear walls are found to be effective in enhancing the overall seismic capacity characteristics of the structure.

2) From the comparison of lateral displacement of above models, it can be observed that maximum reduction in storey displacement values are obtained when shear walls are provided at corners of the building

3) By using Time history analysis, stiffness coefficient ratios have been found to be 0.681 for shear wall and 0.319 for moment resisting frame. This means that approximately 68% of earthquake load will be borne by shear wall and 32% of earthquake load will be borne by moment resisting frame.

REFERENCES

1. Riko Rosman (1974), “Stability and Dynamics of Shear-Wall Frame Structures”, *Build.Sci.Vol.9.pp.55-63*
2. IS 875 (Part 1) : 1987, “Design loads (other than earthquake) for buildings and structures [Dead loads]”
3. IS 875 (Part 2) : 1987 ,”Design loads (other than earthquake) for buildings and structures [Imposed loads]”
4. IS 13920: 1993, “Ductile detailing of reinforced concrete structures subjected to seismic forces”
5. IS 1893 part 1:2000, “Criteria for earthquake resistant design of structures”
6. IS 456: 2000, “Plain and Reinforced concrete”
7. Md. Irshad Ali and Vishwanath B. Patil (2013), “Studies on Behaviour of Wall-Frame Structure Subjected to Lateral Load”, *Volume 2, Issue 11.*
8. J. A. Amin and Dipali Patel (July 2015), “Evaluation of Shear Wall-RC Frame Interaction of High-rise Buildings using 2-D Model Approach”, *Journal of materials and engineering structures 2.*
9. *SAP2000* Ultimate version 18.2.0, (Computer software), Computers and Structures Inc (US).
10. C.V.R Murthy, Rupen Goswami, A.R Vijaynarayanan, Vipul V. Mehta, *Some concepts in earthquake behaviour of buildings.*
11. Shih-Ho Chao, Subhash C.Goel and Soon-Sik Lee, “A seismic design lateral force distribution based on inelastic state of structures”, *Earthquake Spectra, Volume 23, No. 3, pages 547–569.*
12. “Center for engineering strong motion data.” Data for latest earthquakes, <https://www.strongmotioncenter.org>.