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ORIGINAL CONTRIBUTION

Building Design for Lateral Earthquake Forces on a Multi-Story Reinforced Cement Concrete (RCC) Structure Including a Shear Wall

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***Abstract*— The primary goal of this research was to determine how modifying the Shear Walls may improve the design of a multi-story skyscraper. Under static and dynamic load, four possible shear wall orientations for a 25-story skyscraper have been studied in line with BNBC 1993 rules using the analytical programme ETABS. Forces on columns and beams are seen to grow on the grid in the direction opposite to the movement of the Shear Wall from the building's centre of mass. Members' twisting moments are found to increase when the eccentricity between the geometric centre of the structure and the position of the shear wall is larger. Elements of the Shear Wall that are perpendicular to the displacement direction of the Shear Wall are less affected by the stress than those that are parallel to it. The building's lateral movement is constant in a zero-eccentricity example. However, if the Shear Wall is positioned erratically, the drift will be more pronounced on one side of the grid than the others. It is determined that the optimal location for the shear wall is where the building's centre of mass and centroid meet. Also this study Insights into eccentricity and its effect on lateral drift provided by the study offer recommendations for mitigating building sway and vibrations. By broadening the scope of the investigation to encompass the distinct consequences of seismic forces on various shear wall orientations, the significance of the research could be heightened, particularly in areas prone to earthquakes.**

***Index Terms*— Lateral earthquake forces , Reinforced Cement Concrete (RCC) , Shear wall**

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I. INTRODUCTION

Bangladesh is encircled by highly seismic areas. According to historical records, several devastating earthquakes have ravaged various portions of Bangladesh at various periods. The Great India Earthquake struck on June 12, 1897, with a magnitude of 8.7, killing 545 people and severely damaging masonry structures in Sylhet town. The crumbling masonry structures were to blame for this. Chittagong, Bangladesh, had a magnitude 5.0 earthquake on November 22, 1997, and Maheshkhali Island, Bangladesh, experienced a magnitude 5.0 earthquake on July 22, 1999 [1]. The area also saw a high number of minor earthquakes. This makes Bangladesh a very earthquake-prone country. An earthquake is a potentially devastating natural disaster. It's a one-of-a-kind challenge for engineers to solve. All civil engineering structures are potentially vulnerable to damage from a powerful earthquake. Large numbers of people are killed or injured whenever an earthquake is reported anywhere in the world. This tragedy poses a threat to both human life and the economy [2]. The goal of structural engineering is to create buildings that can withstand even the most devastating earthquakes without collapsing or suffering significant damage throughout the course of their useful lifetimes. The primary function of a building is to accommodate its intended occupants [3]. Therefore, the supply of a suitable internal layout of buildings is one of the primary design needs. Once the functional layout is finalised, the next step is to create a structural system that meets the predetermined design requirements in the most effective, inexpensive manner feasible without compromising the integrity of the architectural design. Critical structural criteria include sufficient failure margin, sufficient lateral stiffness, and effective performance during the building's useful life [4].

Since a shear wall's primary purpose is to improve stiffness for lateral load resistance, including one into a building's structural system is a structurally efficient option for stiffening the system. Shear walls are a typical vertical structural feature in contemporary high-rise structures because of their effectiveness in mitigating lateral stresses caused by wind and earthquakes. Cross sections for shear walls can range from the standard square or rectangle to more complex geometries like a channel, T, L, barbell, box, etc. Walls are useful for sectioning off an area, whereas cores are useful for housing and transporting utilities like lifts. Windows on outside walls, entrances and corridors inside walls and lift lobbies all necessitate gaps in the walls. From an architectural and practical standpoint, the size and placement of apertures might vary[5].

A. Fundamental ideas

A wall-frame is a building type in which the shear walls and rigid frames (or braced bents and rigid frames) work together to withstand horizontal loads. Floor systems are supported by shear walls or braced bents, which are often located in the lift and service cores, and by frames that are laid

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out in accordance with the walls [6]. (Fig. 1)

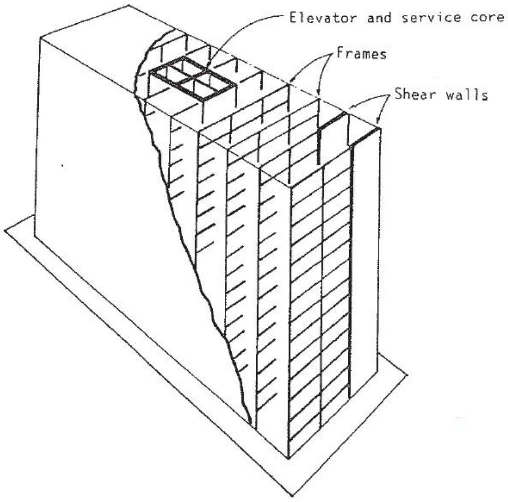


Fig. 1. Representative wall-frame structure

The benefits of a wall-frame construction are determined by the horizontal interaction between the walls and the frames, which in turn is controlled by the building's height. The interaction is stronger as the building is taller and, in normally proportioned structures, the frames are stiffer [6]. Assuming the shear walls or cores will resist all lateral stress and designing the frames for gravity loading solely used to be standard practice in the construction of tall buildings. Although this assumption would have resulted in little mistake for buildings with flexible frames under 20 stories in height, it is probable that possibilities were lost in the design of more logical and cost-effective structures in many situations where the frames were rigid and the buildings were higher. Frames are represented by similar assemblies of beam components, while shear walls and shear-wall cores are represented by simple column cantilevers with appropriate moments of inertia [?]. In the planar model, the in-plane rigidity of the floor slabs imposes constraints on the cantilever columns and frames at each floor level via the nodal constraint option of the analysis programme, if available, or via axially rigid links, causing equal horizontal displacement of the bents. The horizontal loads can be supported by any column or frame nodes that are easily accessible [7].

From the building's blueprints, walls and frames are crafted to create a high-rise wall-frame construction. In most cases, the gravity loading is used to establish the starting member sizes, with an arbitrary increase added to account for the impacts of horizontal loading. Recognizing the increased lateral stiffness due to the interaction and allowing the wall and frame members to be designed more correctly and economically is the advantage of including the wall-frame interaction in the lateral load analysis as opposed to assuming that the wall carries all the lateral loading [8]. The tensile stress in the walls and cores due to horizontal loading is reduced by sizing the combination of walls and cores appropriately during the preliminary design phase so that they can carry their assigned gravity loading and two-thirds of the total horizontal loading. The next step is to look for any drift in the wall and core system. The walls and cores should be strengthened if the maximum total drift or story drift under total horizontal stress is greater than double the permitted value [9]. The most beneficial sizing modifications are made to the bottom walls and cores.

B. Problem statement

Bangladesh's population, and that of its capital city of Dhaka in particular, has exploded in recent decades. This massive population has significant requirements, including those related to employment, housing, and basic amenities. People in the countryside are leaving to find work in the big cities. Since there are now more people living in cities than ever before, there is a lot of competition for available housing. The impact on farmland and intermediate-sized cities from this population boom will be enormous. Since rapid urbanization calls for greater space, taller structures are the way to go.

Dhaka, like other cities in Bangladesh, is experiencing horizontal and random urban growth at the moment. Additionally, because to land limitations, vertical growth is required. This is crucial for protecting farmland from being converted into residential or commercial real estate or a highway. Rising home prices can be attributed to a number of factors, including the high cost of land, the need to prevent a continuous urban spread, and the necessity to protect key agricultural output.

These days, most Dhaka apartment structures are thrown up without sufficient planning or design. However, authorities do not review or analyse the structural designs or the reinforcing details. During an earthquake, this might cause a catastrophic loss of life and property. Significant damage was incurred in the broader Rangpur area of Bangladesh as a result of the 1934 earthquake near Dhubri, Assam, India [10].

C. Study aims and objectives

Typically, a building's shear walls can be found around the building's edges or organized into a central core that contains the building's escalators and lifts. Most buildings' structural behavior is not taken into account when deciding on shear wall dimensions and placement. Therefore, the study's primary aims are:

- To study the effects of static loads and dynamic loads behavior for eccentric positions of shear walls.
- To evaluate the displacements for eccentric positions of shear walls for earthquake forces in X and Y direction.
- To observe the difference between the results of the following types of the comparison of various measures for eccentric positions of shear walls.
  (i) Beam Moments
  (ii) Beam Torsions
  (iii) Column Axial Forces
  (iv) Column Moments

D. Scope of the study

Shear Wall has a lot of issue to study. The scope of this study was limited to the following:

- The study is carried out only for earthquake forces.
- The study has further opportunity for analysis with wind forces.
- For the study purpose, shear wall location is changed for same opening size.
- The design load combinations are used according to BNBC 1993 for static analysis and dynamic analysis
- The structural analysis accomplished by ETABS and some other by hand calculations.

II. LITERATURE REVIEW

Shear walls are used to resist the effects of lateral stress on a structure and are made up of braced panels (also called shear panels) in structural engineering. The most frequent types of loads that braced wall lines are built to resist are wind and earthquake. All external wall lines in wood or steel frame construction are required to be braced by numerous building codes. This is referred to as a "braced wall line" in the International Building Code. Some of the internal walls may need bracing as well, depending on how large the structure is. A vertical diaphragm that is inflexible and may transfer lateral stresses from the outside walls, floors, and roofs to the ground foundation perpendicular to the planes of these structural elements. The reinforced concrete wall and the vertical truss are two such examples. Strong twisting (torsional) forces are generated by the weight of the building and its occupants, as well as by the lateral pressures created by wind, earthquake, and uneven settlement loads. A structure can be torn (sheared) apart by these pressures. Attaching or inserting a stiff wall into a frame helps it keep its form and stops the joints from twisting. The importance of shear walls cannot be overstated in tall buildings that must withstand lateral wind and seismic stresses. Shear walls are a sort of structural system used to increase a building's lateral strength. They are strong against vertical (or "in-plane") loads. It is common practice to use a diaphragm, collector, or drag component to transmit the applied load to the wall. Wood, concrete, and masonry (CMU) are used in their construction.

A. previous studies

Azamand Ashish Develop a Shear walls guard against in-plane lateral forces induced by wind and seismic stresses. The international residential and construction codes in many countries dictate shear wall design. Shear walls can support plane-level loads. Drag members, or collectors, transport diaphragm shear to shear walls and other vertical seismic force-resisting system components. This research uses STAAD Pro to analyse seismic zone v of a G+5 RCC structure with shear walls. Analysis concerns the G+5 multistory structure. Shear wall and building 3D models are created using STAAD Pro, Designing and Analysis software. We reinforced the nodes with a shear wall since seismic and wind stresses on buildings made them fragile. After adding the building's shear wall and basic STAAD Pro analysis. After analysing the effect and shear wall's position on the building and comparing results with old building design without shear wall, it was found that adding and placing shear walls in multistory structures strengthens their weak points and allows them to withstand lateral, wind, and earthquake loads [11].

(Reshma) conducted a study the longitudinal and transverse behaviour of a structure with a distinct shear wall position under various seismic zones is explored. IS code and ETABS design software analyse dynamic response spectrum. A 20-story RCC building's base shear, time-period, drift ratio, and displacement are analysed. Comparisons are made with and without shear walls at various sites. Our research emphasise the ideal shear wall location [12].

Soni analyse studies on enhancing shear walls and their behaviour under lateral stresses. Shear walls withstand lateral stresses in lower areas while frames support higher portions, making them ideal for soft layer high-rise structures often built in India [13].

(Ragi) Stability by ensuring structural ductility and enhancing resistance to oblique stresses. They are strengthened braces that guarantee towering constructions can bear loads. Position and rigidity strongly influence load attraction for each component. The size, height, and geometry of the shear wall system should be addressed for structural benefits, particularly in irregular constructions. Shear wall type and features should be examined before construction. This review is suggested for future investigations on lateral load-resisting structural stability. This study analyses the research trend on the stability of buildings with diverse shear wall conditions on the issue and the poll results. It concludes with all-inclusive findings that create the concepts of the extra study [14].

B. Shear wall positioning

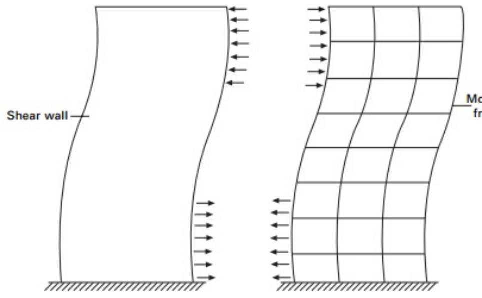
Each floor, including the basement and the attic, needs to have shear walls. Shear walls of same length should be evenly spaced along all four external walls to create a strong box construction. When the outer walls cannot offer enough strength and stiffness, or when the span-width ratio for the floor or roof diaphragm is exceeded, shear walls should be added to the inside of the structure [15].

C. Shear wall resistance

Shear walls withstand uplift and shear. Connections to the superstructure provide the shear wall horizontal pressures. Shear stresses between the top and bottom shear wall connections traverse the wall height due to this movement. Without strong timber, sheathing, and fasteners, the wall will "shear" apart. Since shear walls encounter uplift pressures, horizontal forces on top must be resisted. These upward forces lower one wall end and boost the other. Sometimes upward force may topple a wall. Uplift forces are greater on high, short walls than low, long barriers. Bearing walls endure less rise than non-bearing walls due to gravity forces. Both ends of a shear wall need hold down devices when gravity loads are inadequate to prevent complete elevation. The retaining mechanism then resists the rise.

D. Frame-shear wall behavior

When exposed to a horizontal force, rigid frames and short shear walls mostly deform in a pure shear way, with concave in the top section. Deformation of cantilever shear walls occurs convexly throughout the whole height of the wall, a property known as flexure. Deformation of short, linked shear walls looks like a cross between a flexure and a shear.



21.3 Shear wall frame interaction.

Fig. 2. Frame-shear wall behavior

The walls and the frame of a symmetrical structure will bend in the direction of the horizontal load. Due of the flooring' high in-plane stiffness, the walls and frame must conform to the same deflection profiles. The load attracted by frames and walls does not remain constant as their height increases. A stiff frame can draw a large fraction of the load towards its top, but it will attract much less near its flexible base, as seen by the forms of the deflection curves. When shear walls are arranged asymmetrically, the building twists clockwise around its vertical axis. The axis of rotation will shift from level to level, and it won't grow uniformly up the building's height. It is necessary to perform a three-dimensional analysis [16].

E. Shear wall failures

Possible shear wall failure modes due to horizontal loads are:

- Flexural

- Horizontal shear
- Vertical shear

The figure below shows the failure modes of the shear walls:

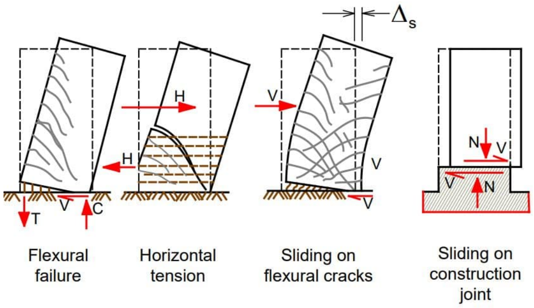


Fig. 3. Shear wall failures

F. Shear wall types and efficiency

Whether or not a shear wall also supports gravity loads determines whether or not it is considered a load-bearing wall. Brick, concrete, reinforced concrete, unreinforced concrete, single-way, multi-way, solid, perforated, rectangular, flanged, cantilever, linked, etc. are all examples of masonry and construction types that may be used to categorise these structures. Rectangular or flanged shear walls are the most prevalent kind. Figure 4 depicts several shear walls [17].

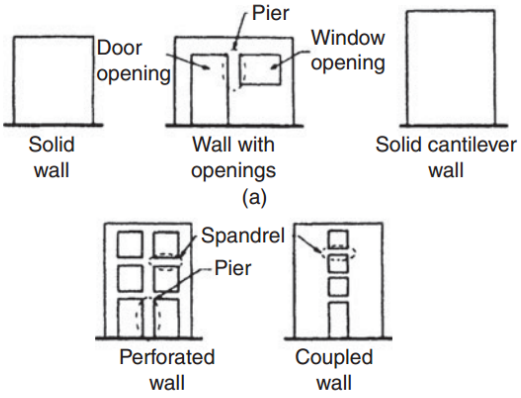


Fig. 4. Types of shear wall, (a) single story, (b) Multi-story

Rigidity (or stiffness) is a measure of the effectiveness of shear walls. Because of their superior efficiency, solid shear walls are much sought after. Shear walls that have gaps in them for practical reasons (such as doors and windows) are called perforated walls. A pier is the section of shear wall that is between two adjacent openings, whereas a spandrel or beam is the section of shear wall that lies above those openings. A windowed shear wall can be viewed as a framework made up of individual struts. Shear walls often need a systematic arrangement of windows, doors, or both for practical reasons [18]. Coupled shear walls can be created when the walls between the apertures are linked with spandrels (or beams). For shear to be transferred from one section of a connected shear wall to another, horizontal and vertical reinforcing of the connecting parts (i.e. beams) is commonly used. Non-coupled shear walls are those in which the connecting components do not transmit shear from one shear wall to the other, allowing the walls to be analyses as cantilevers fixed at the base. By strategically placing openings in shear walls, highly efficient structural systems may be designed, making them ideal for a ductile response and excellent energy dissipation. However, shear walls are less sturdy when there are apertures in them [19] .

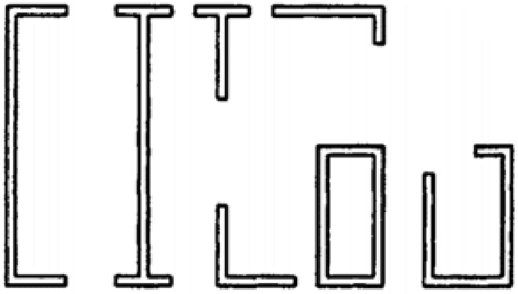


Fig. 5. Openings in shear walls

There are several examples where the wall has been cut through. The connecting beams or slabs allow these walls to function as if they were separate, continuous pieces, thus the name "coupled shear walls" [20].

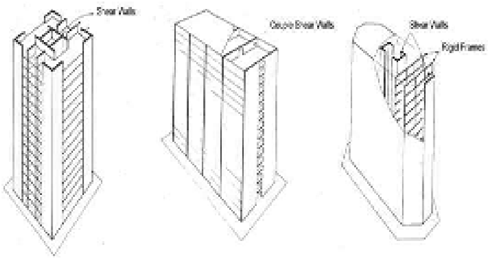


Fig. 6. Coupled shear walls

In a typical building, the walls are bolted straight to the footings. They can be supported on columns connected by a transfer beam to offer clean space most of the time, but in a few circumstances when the lateral loads are quite minor and there are no notable dynamic effects [21].

G. Structural forms of shear walls

Monolithic shear walls are classified as short, squat or cantilever according to their height to depth ratio [22].

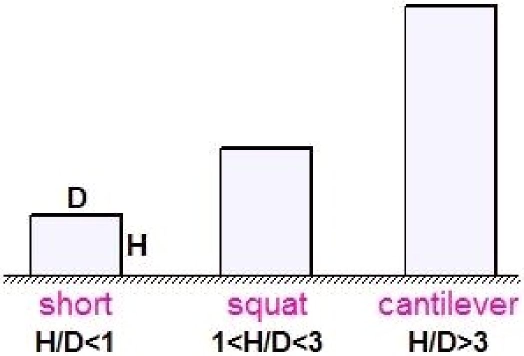


Fig. 7. Structural Forms of Shear Walls

III. DEVELOPMENT OF STRUCTURAL MODEL

A. The finite element packages

ETABS is used in this study for its relative ease of use and flexibility. The version of the ETABS used is ETABS Nonlinear version 9.6

B. Description of structural model

The structure under examination was a 25-story tower with a shear wall located near the building's centre of gravity, as seen in Figure-3.1. Studies have been conducted for shear wall displacements of 25 feet, 50 feet, and 75 feet eccentric from the mass centre in order to apply loading. Here, ETABS was used to do a full three-dimensional study of the building under both gravity and lateral loads. The figure-3.1 diagram depicts the building's layout, which consists of seven bays measuring 25 feet in length and five bays measuring 21 feet in width. The structure is made up of 3050 line components and 525 plate elements, with a total of 1378 joints. Figure-3.2 depicts the maximum eccentricity of the shear wall to be 75 feet in the X-direction.

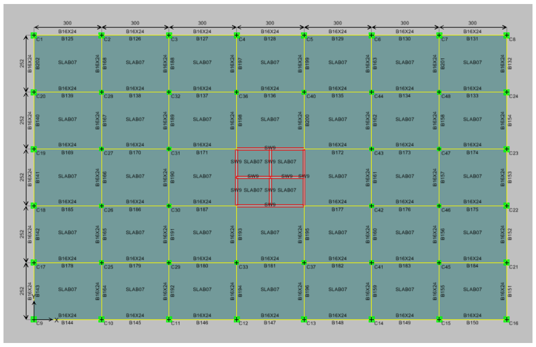


Fig. 8. Plan of Building (shear wall at center of mass)

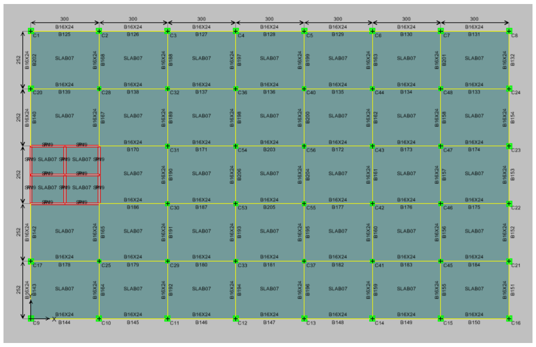


Fig. 9. Plan of building (Shear wall displaced 75 ft. in x direction)

1) *Column sizes*

TABLE I
COLUMN SIZE IN DIFFERENT STOREY LEVEL

Story Levels	Sizes
From Base to Story Level 13	34"x34"
From Story Level 13 to Story Level 16	30"x30"
From Story Level 16 to Story Level 19	26"x26"
From Story Level 19 to Story Level 22	22"x22"
From Story Level 22 to Story Level 25	18"x18"
Column around the periphery	24"x24"

2) *Beam sizes and slab thickness*

All beams are uniform size of 16”x24” and having 7” thick slab for all the spans. Storey height is kept as 11 ft. for all the floors.

3) *Shear wall thickness*

TABLE II
SHEAR WALL THICKNESS IN DIFFERENT STOREY LEVEL

Story Levels	Thickness
From Base to Story Level 2	24"
From Story Level 2 to Story Level 4	21"
From Story Level 4 to Story Level 6	18"
From Story Level 6 to Story Level 8	15"
From Story Level 8 to Story Level 10	12"
From Story Level 10 to Story Level 25	9"

Two-noded frame elements with six degrees of freedom per node were employed for the columns in this investigation. The web of T-beams (monolithic beam and slab) has been modelled using comparable components with node offset capabilities. Standard four-noded shell components have been used to represent the floor slab and shear wall.

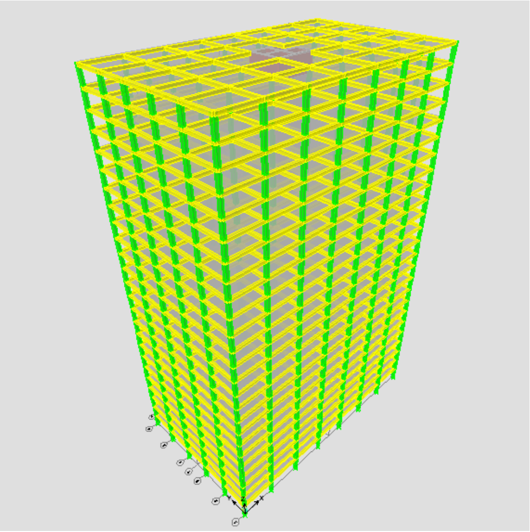


Fig. 10. 3D View of building

C. Materials properties

It is suggested that hot rolled deformed steel of grade 60 be utilised. For the walls, beams, and slabs, a concrete with a cylinder strength of 3000 psi is required. However, 4000 psi cylinder strength concrete is required for the column construction.

D. Loading and boundary condition

1) *Gravity loading*

Dead and active loading are both types of gravity loading. The planned member sizes and material densities allow for reasonable predictions of dead loads. The self-weight and superimposed dead loads of the structure were as follows: Self weight of slab = 87.5 psf Dead load for typical floors = 40 psf Dead load for roof = 60 psf

The amount of live loads was assessed using ANSI standards for the workplace. Reducing beam loading and column loading, respectively, increases the likelihood that not all beam-supported floor sections and column-supported floor sections will experience full live loads at the same time. Here are some examples of normal daily loads: Live load at typical floors = 50 psf Live load at roof = 30 psf

2) Lateral loading

Only earthquakes may cause lateral loading. The software has determined the earthquake loading, and it has been applied to the building's mass centre . The total base shear was calculated as follows since the building in question was located in a zone A with a standard occupancy:

Equivalent Static Load as per BNBC 1993 Seismic zone coefficient in Dhaka, Z=0.20 Structural importance coefficient for residential building, I =1.0 Response modification coefficient for IMRF (concrete), R=9.0 Site coefficient for soil type, S=1.2

3) Modeling of the supports

The building's pillars have been modelled with a focus on restricting all degrees of freedom at the foundation's nodes. All model walls and columns will appear fixed at this point.

E. Analysis methods

The seismic reaction of structures has been studied and compared using both the equivalent static force technique (ESFM) and the response spectrum method (RSM). Response spectral analysis relies on modal Eigen value analysis as a prerequisite. The number of retrieved modes in this research was equal to double the number of stories. As can be seen in Fig.11 , RSM makes use of the normalized BNBC response spectrum as a proxy for a more generic response spectrum. The findings of the response spectrum approach need to be correctly scaled since, in modal studies, mode shapes are often acquired in normalized form. In this investigation, we scale from ESFM to RSM using the same base shear to adhere to BNBC recommendations. Modal combination has traditionally been accomplished through the CQC (Complete Quadratic Combination) technique.

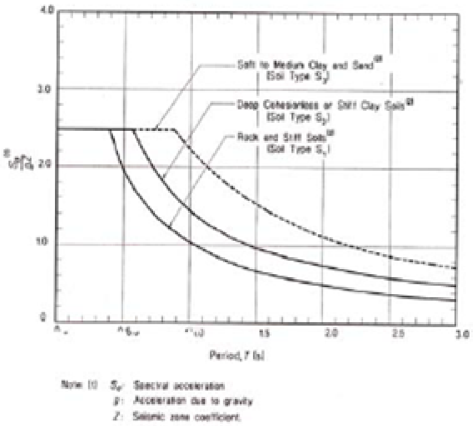


Fig. 11. Normalized response spectra for 5% damping ratio (BNBC 1993)

F. Strength requirements

The required strength 'U' of the structural members to resist dead load (D.L), live load (L.L), and equivalent earthquake load (E.L) should be the envelop value computed from analysis subjected to the following combination of loads according to ACI 318-99.

1) For static analysis

U = 1.4 D.L
U = 1.4 D.L + 1.7 L.L
U = 1.05 D.L + 1.275 L.L ± 1.4025 E.L
U = 1.05 D.L ± 1.4025 E.L
U = 0.9 D.L ± 1.43 E.L

2) For dynamic analysis

U = 1.05 D.L + 1.275 L.L + 1.4025 E.L Spectra
U = 0.9 D.L + 1.43 E.L Spectra

IV. ANALYSIS AND EVALUATION OF RESULT

A. Introduction

Shear walls are a sort of structural system used to increase a building's lateral strength. They are strong against vertical (or "in-plane") loads. It is common practice to use a diaphragm, collector, or drag component to transmit the applied load to the wall. In addition to axial pressures, shear forces, and bending moments, the analysis also accounts for vertical and horizontal node displacements and out-of-plane node rotations. The critical forces and displacements of beams, columns, and shear walls from the static and dynamic studies are reported in tabular form for each of the following four construction instances:

- Case 1 - When shear wall is placed at center of building
- Case 2 - When shear wall is placed 25ft. from the centroid in X-direction.
- Case 2 - When shear wall is placed 50ft. from the centroid in X-direction.
- Case 2 - When shear wall is placed 75ft. from the centroid in X-direction.

1) Effect of beam moments for different positions of shear wall by using static analysis

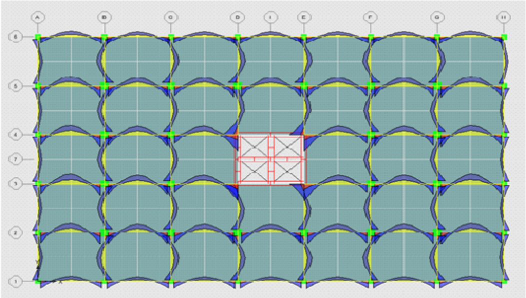


Fig. 12. Plan view of storey 1 with beam moments diagram

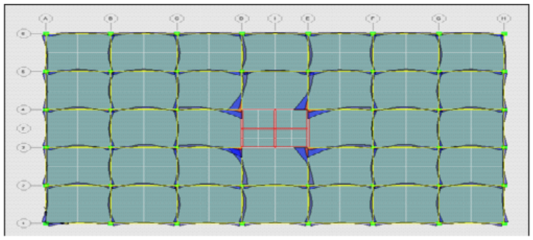


Fig. 13. Plan view of storey 25 with beam moments diagram

Remarks

Table 2 compares negative bending moments at column faces due to gravity and lateral loading to the zero eccentricity scenario of shear wall location and highlights the following essential features:

- At grid H, G and F bending moment is found to increase with the increase in eccentricity in case of storey 1 of the building. On the other hand, for storey 25 of the building the opposite is true.

- The difference in moment at grid H varies between 54% to 150% for 1st storey for case 2 to case 4 of the shear wall location. Whereas, this is found to decrease for these cases between 1% to 4% for storey 25.

2) *Graphical presentation of beam moments for static analysis*

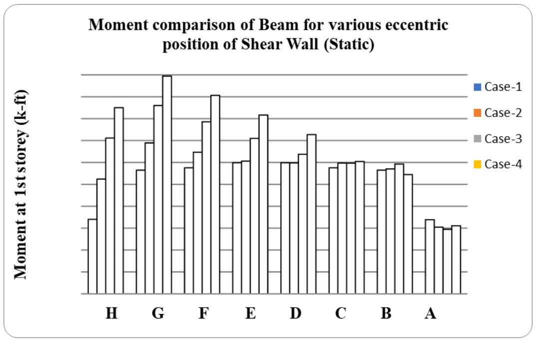


Fig. 14. Beam moments at storey 1 for various eccentric position of shear wall

The beam moments at same grid are progressively increasing for Grid H to E. And beam moments at Grid D to A remain similar in same grid.

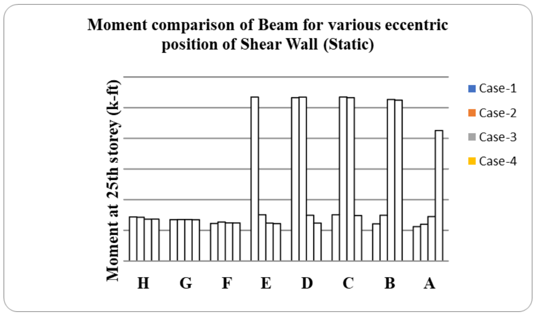


Fig. 15. Beam moments at storey 25 for various eccentric position of shear wall

Beam moments at Grid H to F remain similar in same grid. And a dissimilarity is found for others Grid.

3) *Effect of beam torsions for different positions of shear wall by static analysis*

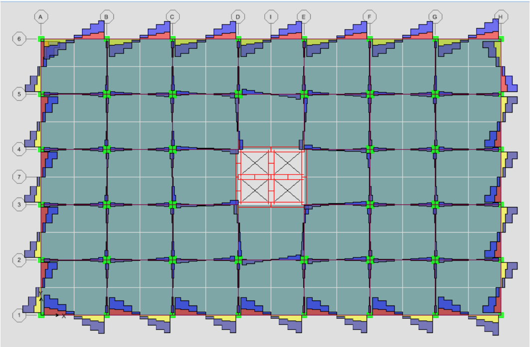


Fig. 16. Plan view of storey 1 with beam torsion diagram

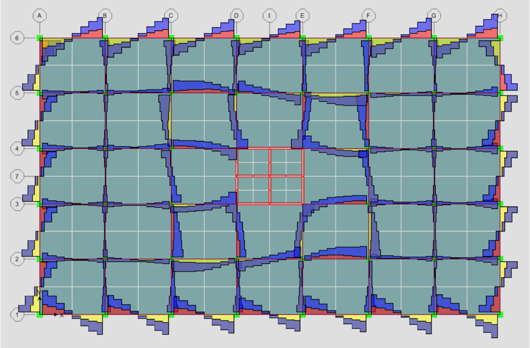


Fig. 17. Plan view of storey 25 with beam torsion diagram

TABLE III
THE COMPARISON OF BEAM TORSIONS FOR VARIOUS ECCENTRIC POSITION OF SHEAR WALL (STATIC ANALYSIS)

Grid Line	Shear Wall placed at C.G.		Shear Wall 25-ft eccentric from centroid				Shear Wall 50-ft eccentric from centroid				Shear Wall 75-ft eccentric from centroid			
	Story-1	Story-25	Story-1		Story-25		Story-1		Story-25		Story-1		Story-25	
	Moment kip-ft	Moment kip-ft	Moment kip-ft	Diff. %	Moment kip-ft	Diff. %	Moment kip-ft	Diff. %	Moment kip-ft	Diff. %	Moment kip-ft	Diff. %	Moment kip-ft	Diff. %
H	35.06	40.08	35.07	0	40.5	-1	35.09	0	40.67	-1	35.26	-1	43.08	-7
	-31.07	-33.14	-31.08	0	33.54	201	-31.1	0	33.67	202	-31.27	1	-35.88	-8
	±31.03	±32.17	±31.05	0	±32.70	-2	±31.07	0	±32.83	-2	±31.23	-1	±35.02	-9
	31.07	33.14	31.08	0	-33.54	201	31.1	0	-33.67	202	31.27	-1	35.88	-8
	-35.06	-40.08	-35.07	0	-40.5	-1	-35.09	0	-40.67	-1	-35.26	1	-43.08	-7
G	3.29	9.92	3.21	2	10.97	-11	-3.6	209	11.45	-15	-4.01	222	15.82	-59
	3.62	-4.77	-3.45	195	-5.11	-7	-3.91	208	-5.3	-11	-4.17	215	-7.23	-52
	±3.69	±4.18	±3.47	6	±4.02	4	±3.44	7	±4.26	-2	±3.23	12	±6.02	-44
	-3.62	4.77	3.45	-195	5.11	-7	3.91	-208	5.3	-11	4.17	-215	7.23	-52
	-3.29	-9.92	-3.21	-2	-10.97	-11	3.6	-209	-11.45	-15	4.01	-222	-15.82	-59
F	2.99	-13.04	2.89	3	-9.87	24	3.5	-17	9.9	176	4.29	-43	14.6	212
	3.91	-23.27	2.8	28	-5.45	77	2.97	24	-4.63	80	3.74	4	-6.4	72
	±5.25	±18.47	±2.85	46	±6.90	63	±2.71	48	±4.39	76	±3.01	43	±6.27	66
	-3.91	23.27	-2.8	-28	5.45	77	-2.97	-24	4.63	80	-3.74	-4	6.4	72
	-2.99	13.04	-2.89	-3	9.87	24	-3.5	17	-9.9	176	-4.29	43	-14.6	212
E	-2.89	-11.13	3.02	-204	-13.61	-22	-3.48	20	-10.04	10	4.25	-247	14.74	232
	8.89	21.15	3.93	56	-23.09	209	-2.99	134	-5.05	124	3.72	58	6.59	69
D	2.89	11.11	-2.88	200	-11.61	205	-3.52	222	-13.51	222	4.29	-48	14.43	-30
	-8.81	-21.07	8.63	-198	19.19	191	3.92	-144	-22.84	-8	3.61	-141	-6.34	70
C	-2.98	13.02	2.88	-197	11.34	13	-3.5	17	-11.45	188	-7.77	161	11.67	10
	-3.9	23.22	-8.61	121	-19.12	182	8.62	-321	18.95	18	3.6	-192	-20.96	190
B	-3.29	-9.94	-3.37	2	9.7	198	3.77	-215	9.44	195	8.27	-351	-11.51	-16
	-3.62	4.78	-4.69	30	22.39	-368	-9.8	171	16.8	-251	8.08	-323	17.75	-271
A	-35.07	-40.1	-35	0	-40.17	0	-34.9	0	-37.84	6	-35.17	0	-38.8	3
	31.07	33.16	30.93	0	32.93	1	30.24	3	25.68	23	27.07	13	29.33	12

Remarks

Torsion is observed to increase with shear wall eccentricity when comparing findings due to gravity and lateral stress to the zero eccentricity scenario of shear wall placement. For instance 4, the largest twisting moment is generated at the 25th floor, grid H.In the most wacky of all possible scenarios, this equates to almost 43 080 feet. Except for grid A, all other grids have negligibly tiny torsion.

4) *Graphical presentation of torsion comparisons for static analysis*

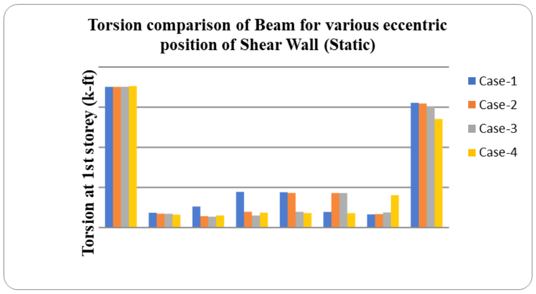


Fig. 18. Beam torsions at storey 1 for various eccentric position of shear wall

The value of torsion moment at Grid H and A is higher than others grid for all position of shear wall. For Grid G to B torsion moment remain almost same.

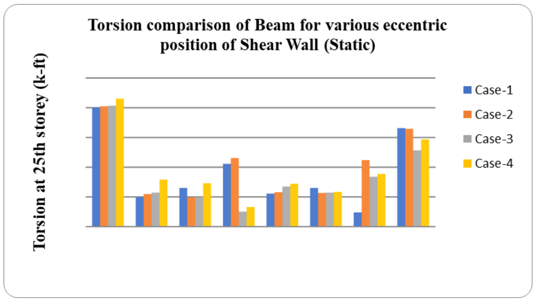


Fig. 19. Beam torsions at storey 25 for various eccentric position of shear wall

The value of torsion moment at Grid H and A is higher than others grid for all position of shear wall. For Grid G to B torsion moment remain almost same.

5) *Effect of column axial forces for different positions of shear wall by static analysis*

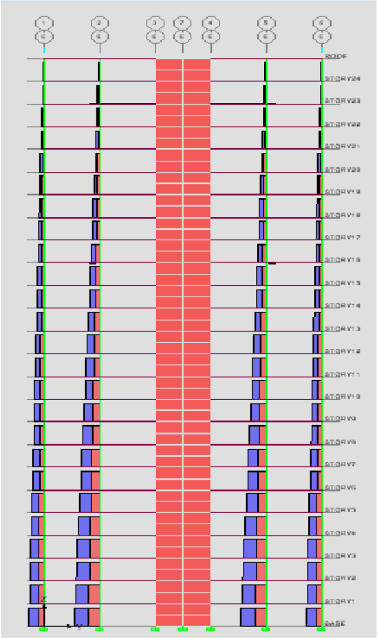


Fig. 20. Elevation of Grid E with column axial forces diagram

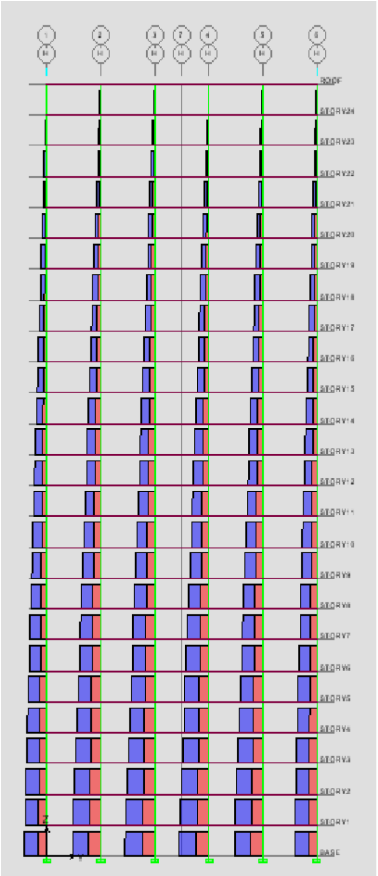


Fig. 21. Elevation of Grid H with column axial forces diagram

TABLE IV
THE COMPARISON OF COLUMN AXIAL FORCES FOR VARIOUS ECCENTRIC POSITION OF SHEAR WALL (STATIC ANALYSIS)

Grid Line	Shear Wall placed at C.G.		Shear Wall 25-ft eccentric from centroid				Shear Wall 50-ft eccentric from centroid				Shear Wall 75-ft eccentric from centroid			
	Story-1	Story-25	Story-1		Story-25		Story-1		Story-25		Story-1		Story-25	
	Moment kip-ft	Moment kip-ft	Moment kip-ft	Diff. %	Moment kip-ft	Diff. %	Moment kip-ft	Diff. %	Moment kip-ft	Diff. %	Moment kip-ft	Diff. %	Moment kip-ft	Diff. %
H	-1761.3	-70.18	-1764.1	0	-70.9	1	-1770.1	0	-71.1	1	-1826.1	4	-73.95	5
	-2239.9	-90.14	-2243.1	0	-90.3	0	-2249.3	0	-90.43	0	-2307	3	-92.72	3
	-2321.9	-94.36	-2325.8	0	-94.67	0	-2332.1	0	-94.76	0	-2389.9	3	-96.98	3
	-2321.9	-94.36	-2325.8	0	-94.67	0	-2332.1	0	-94.76	0	-2389.9	3	-96.98	3
	-2239.9	-90.14	-2243.1	0	-90.3	0	-2249.3	0	-90.43	0	-2307	3	-92.72	3
G	-1761.3	-70.18	-1764.1	0	-160	128	-1770.1	0	-71.1	1	-1826.1	4	-73.95	5
	-2276.8	-94.2	-2284.8	0	-94.38	0	-2287.2	0	-93.48	-1	-2298.1	1	-94.85	1
	-4499.5	-160.12	-4523.6	1	-159.11	-1	-4528.2	1	-159.2	-1	-4546.1	1	-159.03	-1
	-4461.1	-169.11	-4504.9	1	-165.71	-2	-4510.2	1	-165.96	-2	-4527.3	1	-165.63	-2
	-4461.1	-169.11	-4504.9	1	-165.71	-2	-4510.2	1	-165.96	-2	-4527.3	1	-165.63	-2
F	-4499.5	-160.12	-4523.6	1	-159.11	-1	-4528.2	1	-159.2	-1	-4546.1	1	-159.03	-1
	-2276.8	-94.2	-2284.8	0	-94.38	0	-2287.2	0	-93.48	-1	-2298.1	1	-94.85	1
	-2310.5	-97.71	-2341	1	-97.83	0	-2348.8	2	-97.98	0	-2351.8	2	-98.09	0
	-4351.5	-154.92	-4503.7	3	-164.1	6	-4527.4	4	-163.59	6	-4532.3	4	-163.7	6
	-4013.3	-139.18	-4424.8	10	-172.05	24	-4467.5	11	-168.15	21	-4472.9	11	-168.35	21
E	-4013.3	-139.18	-4424.8	10	-172.05	24	-4467.5	11	-168.15	21	-4472.9	11	-168.35	21
	-4351.5	-154.92	-4503.7	3	-164.1	6	-4527.4	4	-163.59	6	-4532.3	4	-163.7	6
D	-2310.5	-97.71	-2341	1	-97.83	0	-2348.8	2	-97.98	0	-2351.8	2	-98.09	0
	-2257.2	-101.07	-2319.8	3	-97.97	-3	-2350.1	4	-98.04	-3	-2357.8	4	-98.19	-3
C	-3830.7	-122.15	-4356.7	14	-154.24	26	-4508	18	-163.66	34	-4531.6	18	-163.07	33
	-3830.7	-122.15	-4356.7	14	-154.24	26	-4508	18	-163.66	34	-4531.6	18	-163.07	33
B	-2257.2	-101.07	-2319.8	3	-97.97	-3	-2350.1	4	-98.04	-3	-2357.8	4	-98.19	-3
	-2257.2	-101.04	-2257.7	0	-101.02	0	-2319.7	3	-97.96	-3	-2349.6	4	-98.01	-3
A	-2257.2	-101.04	-2257.7	0	-101.02	0	-2319.7	3	-97.96	-3	-2349.6	4	-98.01	-3
	-3830.7	-122.31	-3834.3	0	-122.44	0	-4357.1	14	-154.36	26	-4507.3	18	-163.64	34

Remarks

Axial loads in columns due to gravity and lateral loading for four shear wall locations show the following:

- Axial forces are usually higher in lower storeys and lower in upper stories.
- Geometrically, column forces at level 1 and 25 are insignificant.
- Grid E axial pressures at storey 25 fall from 128% (example 2) to 5% (case 4) compared to instance 1. Storey 1 rise from 10% (case 3) to 28% (case 4) compared to instance 1.
- At grid G, axial forces reach 4546.1 kips. Storey 25 is onlyb159.03kips.

6) Graphical presentation of axial forces for static analysis

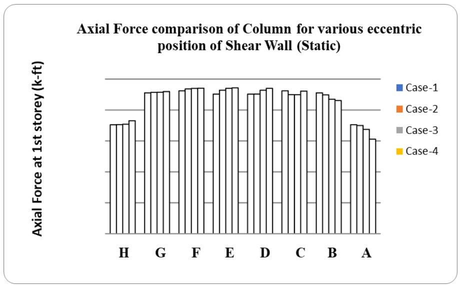


Fig. 22. Axial forces at storey 1 for various eccentric position of shear wall

For storey 1 the value of axial forces of column is remain almost same in grid G to B. Axial forces in Grid H and A is comparatively lower with others grid for all position of shear wall.

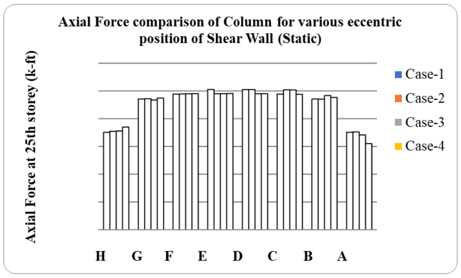


Fig. 23. Axial forces at storey 25 for various eccentric position of shear wall

For storey 25 the value of axial forces of column is remain almost same in grid G to B. Axial forces in Grid H and A is comparatively lower with others grid for all position of shear wall.

7) *Effect of column moments for different positions of shear wall by static analysis*

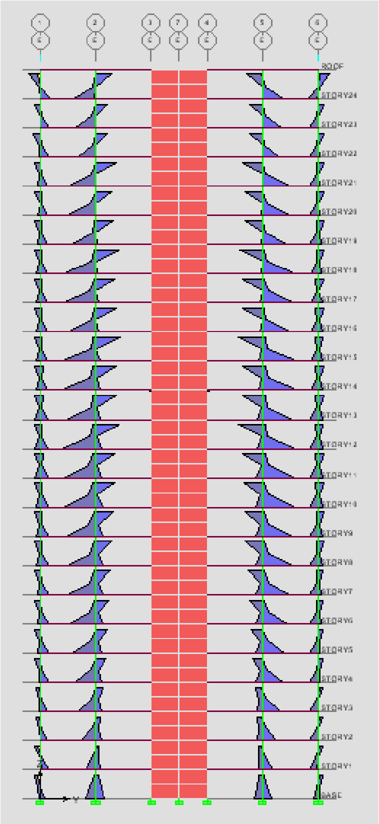


Fig. 24. Elevation of Grid E with column moments diagram

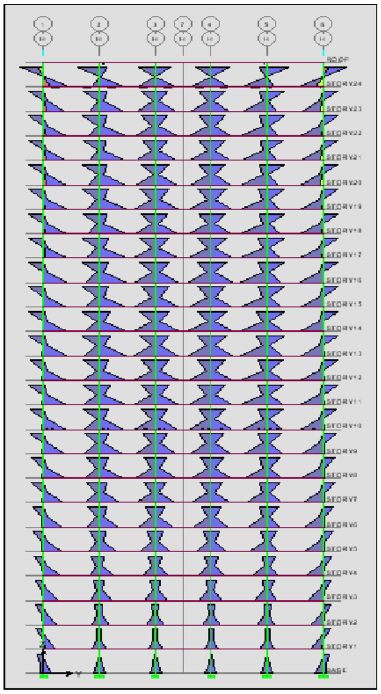


Fig. 25. Elevation of Grid H with column moments diagram.

TABLE V
THE COMPARISON OF COLUMN MOMENTS FOR VARIOUS ECCENTRIC POSITION OF SHEAR WALL (STATIC ANALYSIS)

Grid Line	Shear Wall placed at C.G.		Shear Wall 25-ft eccentric from centroid				Shear Wall 50-ft eccentric from centroid				Shear Wall 75-ft eccentric from centroid			
	Story-1	Story-25	Story-1		Story-25		Story-1		Story-25		Story-1		Story-25	
	Moment kip-ft	Moment kip-ft	Moment kip-ft	Diff. %	Moment kip-ft	Diff. %	Moment kip-ft	Diff. %	Moment kip-ft	Diff. %	Moment kip-ft	Diff. %	Moment kip-ft	Diff. %
H	50.06	148.55	108.53	-117	155.96	-5	164.29	-228	155.99	-5	202.27	-304	156.45	-5
	36.81	148.75	104.21	-183	154.02	-4	168.13	-357	136.71	8	211.96	-476	126.28	15
	36.9	120.33	104.31	-183	125.33	-4	167.97	-355	110.7	8	211.61	-473	102.98	14
	-36.9	-120.33	-104.31	183	-125.33	4	-167.97	355	-110.7	-8	-211.66	474	-102.98	-14
	-36.81	-148.75	-104.21	183	-154.02	4	-168.13	357	-136.71	-8	-211.97	476	-126.27	-15
G	-50.06	-148.55	-108.53	117	-155.96	5	-164.29	228	-155.99	5	-202.29	304	-156.45	5
	-62.34	179.94	107.98	-273	186.48	-4	156.43	-351	186.39	-4	192.14	-408	185.72	-3
	-115.77	83.34	-291.94	152	83.77	-1	-468.99	305	75.05	10	-599.38	418	69.01	17
	115.74	-77.93	291.22	-152	-76.71	-2	468.65	-305	-69.76	-10	599.3	-418	-65.95	-15
	-115.74	77.93	-291.22	152	76.71	2	-468.65	305	69.76	10	-599.33	418	65.95	15
F	115.77	-83.34	291.94	-152	-83.77	1	468.99	-305	-75.05	-10	599.35	-418	-69.01	-17
	62.34	-179.94	-107.98	273	-186.48	4	-156.43	351	-186.39	4	-192.15	408	-185.72	3
	-61.12	159.65	93.55	-253	175.2	-10	133.39	-318	176.07	-10	165.91	-371	175.88	-10
	-114.29	-83.98	-240.61	111	76.31	-191	-385.93	238	70.18	-184	-504.56	341	64.62	-177
	-113.07	-98.89	-239.52	112	-81.93	-17	-385.19	241	-74.16	-25	-504.1	346	-70.19	-29
E	113.07	98.89	239.52	-112	81.93	17	385.19	-241	74.16	25	504.08	-346	70.19	29
	114.29	83.98	240.61	-111	-76.31	191	385.93	-238	-70.18	184	504.54	-341	-64.62	177
D	61.12	-159.65	-93.55	253	-175.2	10	-133.39	318	-176.07	10	-165.93	371	-175.88	10
	-59.73	-141.97	79.29	-233	161.21	-214	110.6	-285	172.95	-222	139.94	-334	173.82	-222
C	-121.37	-263.98	-189.74	56	-84.07	-68	-302.87	150	70.51	-127	-409.76	238	66.9	-125
	121.37	263.98	189.74	-56	84.07	68	302.87	-150	-70.51	127	409.74	-238	-66.9	125
B	59.73	141.97	-79.29	233	-161.21	214	-110.6	285	-172.95	222	-139.94	334	-173.82	222
	-59.73	-142.01	64.76	-208	-141.53	0	87.72	-247	161.31	-214	113.98	-291	173.06	-222
A	-59.73	-142.01	64.76	-208	-141.53	0	87.72	-247	161.31	-214	113.98	-291	173.06	-222
	-121.14	-264.35	-145.19	20	-262.73	-1	-220.35	82	-80.98	-69	-315.02	160	69.33	-126

Remarks

- The 1st floor moment difference at grid H ranges from 117% to 304% for cases 2 to 4 of the shear wall placement. Storey 25 remains unchanged.
- Grid G moment at storey 1 increases from 152% (case 2) to 418% (case 4). Storey 25 moments rise from 1% (example 2) to 17% (case 4).
- Grids opposite shear wall shifting minimise column moment.

8) *Graphical presentation of column moments for static analysis*

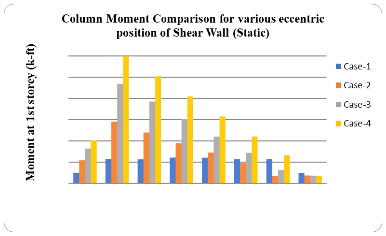


Fig. 26. Column moments at storey 1 for various eccentric position of shear wall

The column moments at same grid are progressively increasing for Grid H to D. And column moments remain similar at grid A.

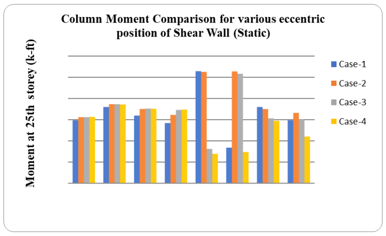


Fig. 27. Column moments at storey 25 for various eccentric position of shear wall

Column moments at Grid H to E remain almost similar in same grid. And a dissimilarity is found for Grid D to A.

B. Scaling of dynamic base shear

For dynamic segment firstly we have to make a pre analysis for getting the value of static base shear on both directions with Scale Factor 1. To equalize these values with corresponding static analysis result another scale factor has defined. Then a further dynamic analysis has done to find the final equal static base shear

1) *Effect of beam moments for different positions of shear wall by dynamic analysis*

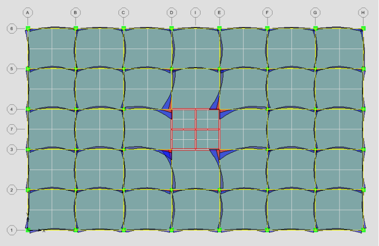


Fig. 28. Plan view of storey 1 with beam moments diagram

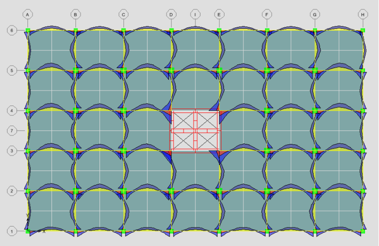


Fig. 29. Plan view of storey 25 with beam moments diagram

2) Graphical presentation of beam moments for dynamic analysis

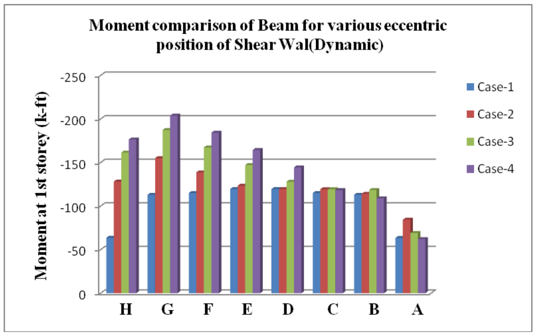


Fig. 30. Beam moments at storey 1 for various eccentric position of shear wall

The beam moments at same grid are progressively increasing for Grid H to E. And beam moments at Grid D to A remain almost similar in same grid.

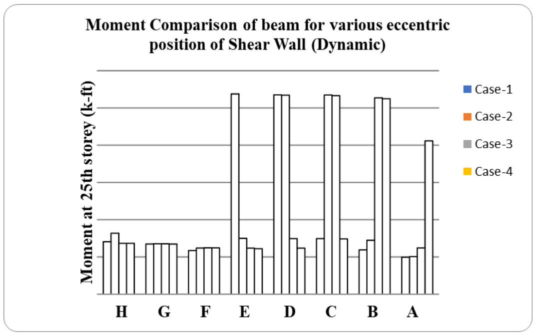


Fig. 31. Beam moments at storey 25 for various eccentric position of shear wall

Beam moments at Grid H to F are remain similar in same grid. And a dissimilarity is found for others Grid.

3) Effect of column moments for different positions of shear wall by dynamic analysis

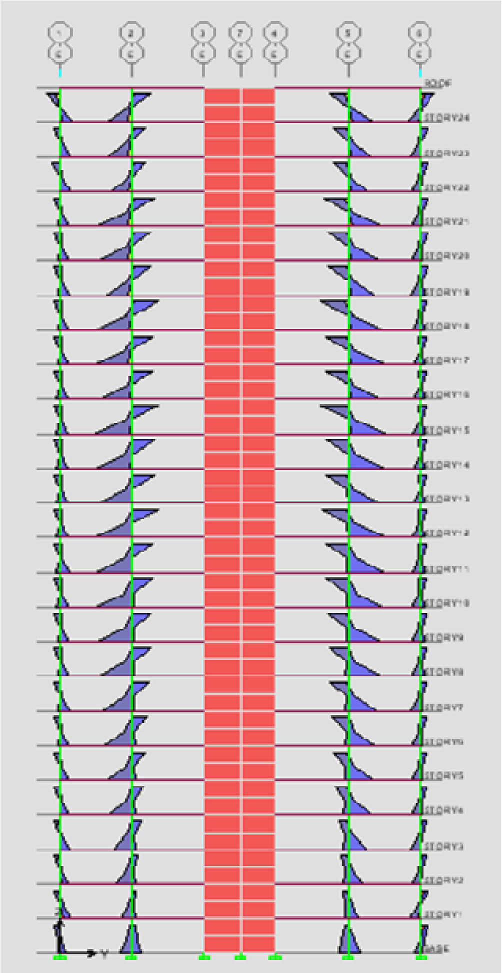


Fig. 32. Elevation of grid E with column moment diagram

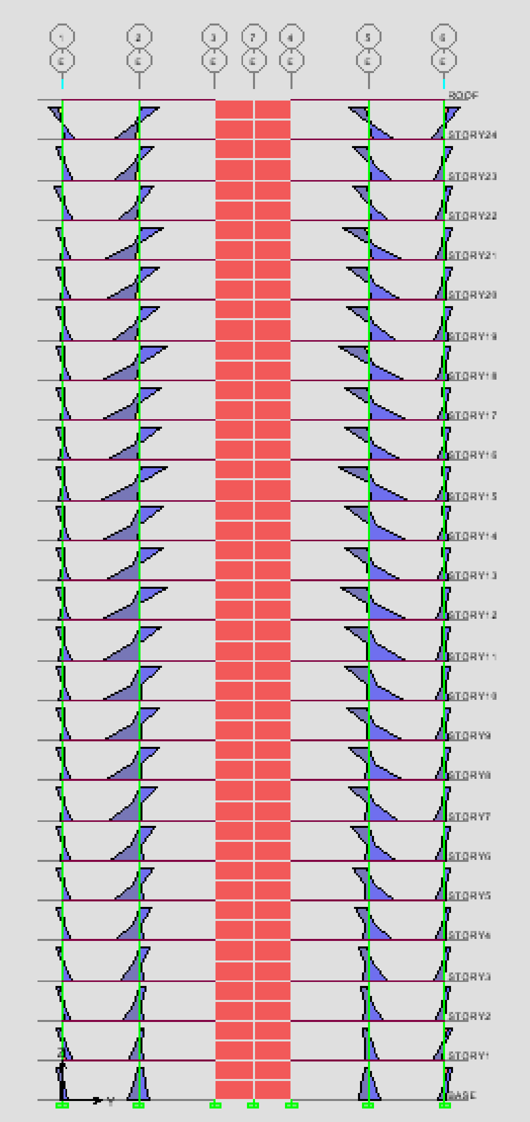


Fig. 33. Elevation of grid H with clumn moment diagram

4) *Graphical presentation of column moments for dynamic analysis*

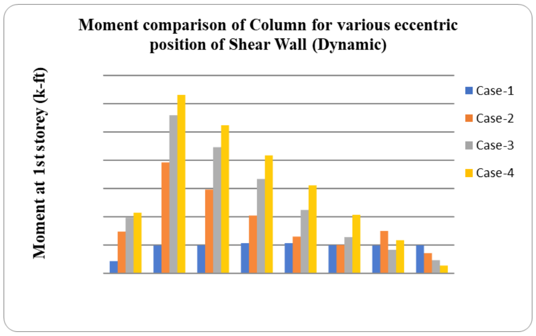


Fig. 34. Column moments at storey 1 for various eccentric position of shear wall

The column moments at same grid are progressively increasing for Grid H to D. And column moments are gradually decreasing at grid A.

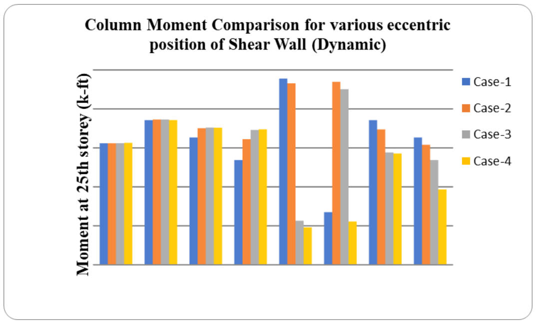


Fig. 35. Column moments at storey 25 for various eccentric position of shear wall

Column moments at Grid H to F remain similar in same grid. And a dissimilarity is found for Grid E to B. But column moments are gradually decreasing at grid A.

5) *Displacement/drift for various eccentric positions of shear wall*

TABLE VI
THE COMPARISON OF DISPLACEMENT/DRIFT FOR VARIOUS ECCENTRIC POSITIONS OF SHEAR WALL FOR EARTHQUAKE FORCES IN – "Y" DIRECTION STATIC

Building Case	Building Location	Displacement in X-Direction (in)	Displacement in Y-Direction (in)	Drift-X (ft)	Drift-Y (ft)
Case-1	Right	0	2.712	0	0.000884
	Left	0	2.712	-	-
Case-2	Right	0.256	3.202	0.000027	0.000818
	Left	0.256	2.347	0.000027	0.000908
Case-3	Right	0.466	3.71	0.000037	0.000759
	Left	0.466	2.158	0.000037	0.000882
Case-4	Right	0.601	4.161	0.000033	0.000734
	Left	0.601	2.158	0.000033	0.000843

Remarks

Table 8 shows that the building floor at storey 25 for Case 1 is unidirectional and symmetric. For earthquake force in Y direction, building displaces solely in Y direction and vice versa. Case 4 has a maximum X-displacement of 0.601 inch and Y-displacement of 4.161 inch due to the off-center shear walls. Storey drift is greater for Case-3.

TABLE VII
THE COMPARISON OF DISPLACEMENT/DRIFT FOR VARIOUS ECCENTRIC POSITIONS OF SHEAR WALL FOR EARTHQUAKE FORCES IN – "Y" DIRECTION DYNAMIC

Building Case	Building Location	Displacement in X-Direction (in)	Displacement in Y-Direction (in)	Drift-X (ft)	Drift-Y (ft)
Case-1	Right	0.0041	1.707	0	0.000613
	Left	0.0041	1.701	0	0.000613
Case-2	Right	0.7602	2.666	0.000111	0.000521
	Left	0.7602	1.512	0.000111	0.000649
Case-3	Right	0.9007	3.151	0.000157	0.000505
	Left	0.9007	1.453	0.000157	0.000605
Case-4	Right	0.88	3.404	0.000618	0.000418
	Left	0.88	1.361	0.000618	0.000591

Remarks

Table 9 shows that the building floor at storey 25 for Case 1 displaces in X and Y directions for earthquake force in Y direction. The structure displaces in both X and Y directions due to the off-center shear walls, with a maximum value of 0.9007 inch for case 3 and 3.404 inch for case 4. Storey drift is highest in Case-4 in X direction and Case-2 in Y direction.

V. CONCLUSION

A. Findings in Brief

Studying the 25-story structure with asymmetrically arranged shear walls throughout its length yields the following results:

- As the eccentricity of shear walls is increased, the moment in beams from static and dynamic analysis also rises. At lower levels, beam moments rise in edge grids, whereas moments drop in edge grids at higher storeys.
- Beam torsion grows when eccentricity of shear walls is increased. The effect of seismic stress on beam torsion, as measured by an increase in eccentricity, is greatest at the building's upper floors. It is most effective for members joining shear walls and at the outer grid of the structure, away from the displacement direction of shear walls.
- Seismic loading is observed to increase column axial forces with increasing eccentricity towards the edge grid in the direction perpendicular to the displacement of shear walls.
- Static and dynamic analyses show that the eccentricity of a column grows in the direction perpendicular to the displacement of shear walls.
- Force analysis of shear walls reveals that eccentricity has a significant impact on these structures. Where exactly in the building it is is a factor. The displaced shear walls have the greatest influence on the pier members in that direction for a given scenario.
- In the situation of zero eccentricity for seismic loading, building displacement is unidirectional and uniform across all grids. As the eccentricity of the structure increases, the right and left sides begin to shift in different ways as a result of torsion.
- Building receives more drifts with the increase in eccentricity.
- The research shows that moving the shear wall has major impacts on axial and shear stresses, as well as bending and twisting moments, of beams and columns at various floors of the structure. Most of the members' forces increased as the shear wall was moved farther from the structure's centre of gravity. Therefore, shear walls should be positioned so that the building's centroid is directly above its centre of gravity.
- In addition to increasing beam and column moments due to their off-center positions, the study shows that torsion is introduced into the structure when stiff parts are not placed uniformly.

B. Recommendations for future study

The following suggestions are provided for further research in order to obtain the true reactions of the structures: The study only examined one type of shear wall, thus further research should be done on other types. For the present study, the analyses were performed for the symmetrical buildings with shear walls at central frames. The further investigations should be made by locating the shear walls at exterior frames. In frame-shear wall systems, shear walls with variable aspect ratios (h/L) should be studied. A flexible foundation reduces effective lateral stiffness, affecting building stability. Thus, soil-structure interaction should be studied. Earthquakes favour ductile shear wall structures. Thus, geometric and material nonlinear behaviour of members should be considered in further investigation. Time series analysis instead of response spectrum analysis may be used to represent the real earthquake analysis.

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