

**PUSHOVER ANALYSIS OF BUILDING WITH FLOATING COLUMN  
STRENGTHENED BY SHEAR WALL**

**PROJECT REPORT**



Submitted by,

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**A. P. J. ABDUL KALAM TECHNOLOGICAL UNIVERSITY**

**2022**

**DEPARTMENT OF CIVIL ENGINEERING**

**T.K.M. College of Engineering, Kollam**



**CERTIFICATE**

Certified that this report entitled 'PUSHOVER ANALYSIS OF BUILDING WITH FLOATING COLUMN STRENGTHENED BY SHEAR WALL' is the report of the project presented by **BINSA S B**, Roll No: **TKM20CESCO9** during **2021-2022** in partial fulfilment of the requirements for the award of the Degree of Master of Technology in Structural Engineering & Construction Management of the A P J Abdul Kalam Technological University.

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I undersigned hereby declare that the project report “Pushover analysis of building with floating column strengthened by shear wall”, submitted for partial fulfillment of the requirements for the award of degree of Master of Technology of the APJ Abdul Kalam Technological University, Kerala, is a bonafide work done by me under supervision of Prof. Mohammed Thowsif, Assistant Professor, Department of Civil engineering, TKM College of Engineering. This submission represents my ideas in my own words and where ideas or words of others have been included, I have adequately and accurately cited and referenced the original sources. I also declare that I have adhered to ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or fact or source in my submission. I understand that any violation of the above will be a cause for disciplinary action by the institute and/or the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been obtained. This report has not been previously formed the basis for the award of any degree, diploma or similar title of any other University.

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## ABSTRACT

In a constructive world of emerging high-rise buildings, due to the lack of space, floating column adds as an advantage for proper functioning. Floating column introduced in seismic prone areas is found to be hazardous. Stability of such structures seems to be an important factor. Shear wall is one of the efficient lateral load resistors. Therefore, proper analysis can help the structure to attain column free space and strength. Pushover analysis is a non-linear static analysis in which the ultimate load, deflection capability and the critical members can be determined.

In this study, pushover analysis is being done on six-storey building with floating columns provided at ground storey. Pushover analysis is being done in ETABS software. Comparison on building with and without shear wall is done. Influence of shear wall at different locations, ie, at core, periphery and corner are analysed. Shear wall with opening of size 1x1m is provided to study the influence of opening in stability of the structure.

From the study it is clear that building with shear wall performs well and could reduce the displacement about 80%. In a building without a shear wall even though target displacement is high, load carrying capacity is found to be low. Shear wall fails prior to structural member, which resist the building from collapse. In the last step of pushover analysis, the collapse of building without shear wall occurred on first floor, which can lead to total collapse of building. In the case of models with shear wall collapse occurred on the upper floor, shows better performance than the building without shear wall.

*Keywords: floating column, shear wall, pushover analysis, ETABS*

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## **NORMS AND ABBREVIATIONS**

A	Unloaded
A-B	Members undergo yielding
B-C	Reduction in stiffness
C-D	Reduction in load resistance
D-E	Severe damage
>E	Collapse
IO	Immediate occupancy
LS	Life safety
CP	Collapse prevention

# CHAPTER - 1

## INTRODUCTION

### 1.1 GENERAL

In a developing nation like India, high-rise construction has been coming up everywhere. Buildings can become more susceptible to damage as they go taller because their vibrations last longer than those of shorter structures. As a result, it is essential to develop structures with sufficient lateral strength and stability against seismic loads.

Floating columns, or columns without a footing, are used in multi-story buildings to enable parking on the ground floor or open hallways on higher stories. The floating column is a vertical member that is supported by a primary beam but does not transmit load to the foundation. It acts as a point load on the beam and this beam transfers the load to the columns below it. Nowadays it is common to have floating columns to provide large obstruction free area. Proper analysis should be done for such structures, since they are more susceptible to destruction by seismic loads.

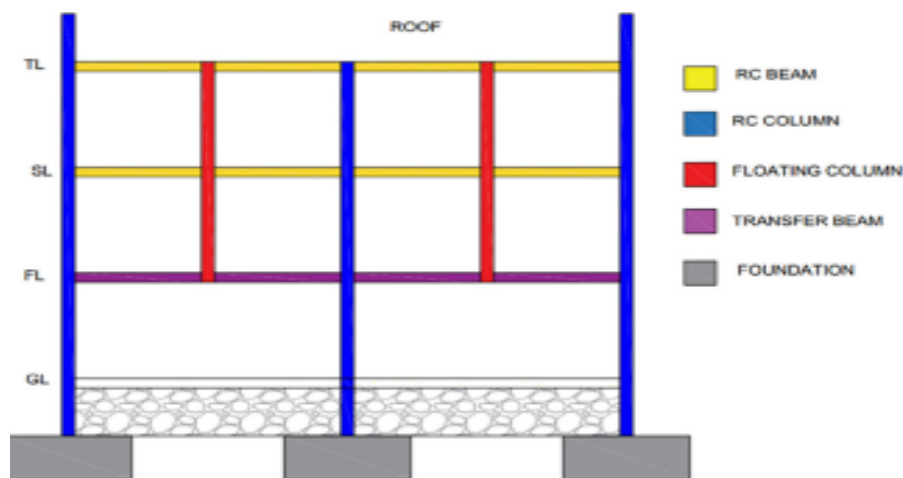


Fig 1. Floating column

Lingeshwaran et.al (2021)

Shear walls are therefore introduced to high-rise RC frame buildings as one of the simple and effective ways to resist lateral loads in order to meet the strength and stability aspect of the structure. Buildings made of materials like concrete that are massive, high-rise, or located in seismically active or windy regions are very vital for having shear walls. This wall could withstand lateral loads that the structure could experience as a result of wind, an earthquake, or lateral ground pressure.

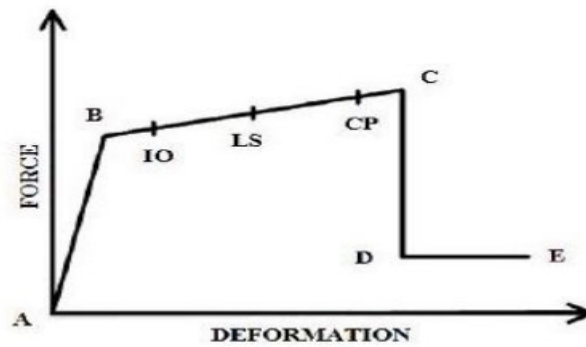


Fig 2: Pushover curve with Acceptance Criteria

Madhusudan et.al (2019)

Pushover analysis, a non-linear static analysis in which deflection capability of structure and the ultimate load is determined. The target displacement ie, displacement at which building is found to be safe without collapse, and the behaviour of the structure is observed for different models. In a pushover curve point, A denotes the unloading condition. AB denotes members undergoing yielding. From B to C, there is a reduction in stiffness. BC involves three acceptance criteria: Immediate Occupancy, Life Safety and Collapse prevention. In immediate occupancy the structure experience light damage. Original strength and stiffness of the building retains and only minor cracking to partitions and ceilings.

Life safety level shows probability of danger to life is low. Non-structural damages can occur. In shear wall building, shear wall with yield or buckle, but do not fail. Beams and partition wall can get damaged. Building is beyond economical repair. In collapse prevention, structure will not collapse, but undergoes structural damages. Damage is irreparable. CD marks the reduction in load resistance, thereby initial failure of structure. DE denotes collapse of building.

In this study, a building with a floating column is subjected to pushover analysis reinforced by an RC shear wall. A shear wall could have numerous apertures because of the utilitarian necessities like doors and windows, which may significantly influence the overall building's reaction to earthquakes. Effect of the opening in a building with a shear wall and floating column is examined. The behaviour of the shear wall is influenced by its position and shape of the structure considerably. The impact of the placement of a floating column and a shear wall in analysis of structure performance is done.

## **1.2 PROBLEM STATEMENT**

Tall building with floating column seems to be a common trait in many of the existing buildings. These buildings can become seismically deficient with change in seismic zones. And the existing buildings may not obey the code provisions. In order to ensure the durability and safety of structure ie, to know the deflection capability of existing structures pushover analysis is found to be an accurate solution. Since these building is found to be hazardous in earthquake-prone regions, in order to resist the lateral load acting on structures, shear wall seems to be one of the easy and efficient way. Proper analysis helps to mitigate the damage caused to high rise structures due to seismic loads. So, this analysis is significant for evaluating the performance level for the structures.

## **1.3 OBJECTIVE OF THE STUDY**

- To study the behaviour of a building with floating column using non-linear static analysis
- To study on effect of position of shear wall in building with floating column
- To study on impact of opening in shear wall for building with floating column

## **1.4 NEED OF THE STUDY**

- With changes in seismic zones, existing structures may become seismically unsound, and many do not follow code requirements. For analysis of such structures, this study is necessary
- To evaluate the behaviour and deficiency of building with change in seismic zones
- To mitigate damage to high rise RC buildings during earthquakes
- To determine the progress of failure and weak members
- To mitigate damage to high rise RC buildings during earthquakes
- To evaluate the advantage of providing shear wall in building with shear wall

## **1.5 SCOPE OF THE STUDY**

The projects aim to do pushover analysis of building with floating column strengthened by shear wall to evaluate the performance level of structures. The analytical study is done in

ETABS software. Study is limited for buildings which are regular in plan. Storey height is kept constant ie, G+5 storeys. Floating column is provided only in one storey.

## **1.6 ORGANIZATION OF THE REPORT**

The thesis is structured into seven main chapters. Chapter one describes the background of the study, problem statement, significance of the research, objectives of the study and the scope and limitations of the study.

Chapter two reviews about the studies conducted on pushover analysis of building, floating column and shear wall in the past. It focuses on the literature about different types of shear wall, important influencing parameters, floating column, pushover analysis etc. Detailed reporting of the methodology adopted for the study is done in chapter three.

Chapter four describes about software validation of ETABS. It details about the comparison of results obtained through reference journal and the results obtained through analytical analysis of simulated model.

Chapter five presents the displacement, storey shear and store drift of building at different shear wall locations. Chapter six presents the results of studies and the inferences obtained from them. It mainly includes hinge results, ultimate load and target displacement of building at different shear wall locations.

Chapter seven presents the results of studies obtained from building with openings. It mainly includes hinge results, ultimate load and target displacement of building at different shear wall locations.

Chapter eight presents the inferences, conclusions and future scope of the study.

## CHAPTER-2

### LITERATURE REVIEW

#### 2.1 GENERAL

Ms. Waykule.S. B (2016): The analysis of a G+5 building in seismic zone V includes and excludes floating columns. Four models were created, with and without floating columns in the first, second, and third floors of the buildings. For each of the four models, linear static and time history analysis is performed. All earthquake characteristics, including time period, base shear, storey displacement, and storey drift, are compared across all models. For a building with a floating column, the displacement of the floors is greater. They could conclude that the presence of floating columns results in lower base shear. Additionally, foundation shear is significantly lower on the first floor of a building with floating columns than in other locations.

Nikhil N. Varma (2016): In this study pushover analysis is being done on RC building with floating column. Push over analysis is chosen because this analysis will help to find deflection capability, ultimate load and determination of actual performance of the structure. In this study, two RC structures of four storey is evaluated and the base force and displacement of RC structure is compared. Columns near to floating column seems to be critical. It is sure that the section of beam below floating column has to be increased in order to fulfill the demand of safety. There is a 50% increase in column forces of columns below and around girder supporting floating column are compared with column force in building without floating column, as compared to building without floating column. Increasing these sections could fulfil safety. Moments in column drastically increased in building with floating column. Increase in base shear, displacement, drift is found in building with floating column

Allacheruvu Raghavendra (2016): The goal of the study is to employ bracings to strengthen the floating columns building in order to lower the possibility that an earthquake will have an adverse effect on the structures. In this study, four models ie, normal RC building, floating column building, and floating column building with bracings at corner and at centre are seismically analysed. Analysis is done in two zones III and V. Analysis of time period, maximum displacement, storey shears and storey drifts for all models are done. Introducing bracing could reduce the movement in building with floating column. Floating column building with bracings at centre shows better outcomes as compared to other models, its

performance is observed using pushover analysis. The building with bracings at centre shows less time period which reflects its strength towards lateral loads.

Hemanth et.al (2016): The main objective of the paper is to evaluate the behaviour and performance of the structure for the plan in a building with reentrant corners in the presence of a short leg shear wall. Performance levels, displacement, and base shear are analysed in this study. For all models, the base shear determined by equivalent static analysis is higher than that determined by response spectrum analysis. The huge ratio of pushover base shear to elastic base shear for shear wall models in 5-storey models shows that a significant amount of reserve strength is underutilised. Due to its lower ductility as compared to short leg shear wall, a shear wall model collapses earlier than one of a short leg shear wall (spandrel type).

Trupanshu Patel et.al (2017): In this study impact of the floating column on RCC building with and without infill wall is analysed. When compared to other scenarios, the use of floating columns at corners or on any floor displays inferior performance. Corner provisions of floating columns should be seen as a critical case as a result. There is a reduction in the value of displacements when the position of floating columns shifts from the corner to the centre. graphical comparison demonstrates that there is a sharp increase in the value of displacements in cases of without infills. Design of structural components after installing infill walls suggests that doing so tends to use less steel and concrete. As a result, it will not only lessen the seismic response but also increase the structure's efficiency.

Nikam (2021): This study will carry out a non-linear static pushover analysis to evaluate the performance level of a reinforced concrete building. The demand and capacity curves' junction, as well as the distribution of hinges in the beams and columns, show the importance of reinforced concrete frame structures with clearly defined behaviours. Though with only minor damage, the bulk of the hinges developed in the beams and a small number in the columns. The pushover study was used to examine the performance of reinforced concrete frames. The following is inferred from the analysis, The use of a shear wall lengthens the construction process fundamentally because it raises the building's overall rigidity. An easy method to investigate the nonlinear behaviour of buildings is the pushover analysis. The placement of hinges in the beams and columns, as well as the intersection of the demand and capacity curves, demonstrate the suitable behaviour of reinforced concrete frame buildings with properly specified construction. Fewer hinges developed in the columns and most in the beams, although there was only minor damage.

Parishith J (2017): In this study, RC frame models with and without shear walls are subjected to pushover analysis. Analysis of the structure's behaviour and comparison of performance metrics for several models with and without shear walls are conducted. Installation of shear wall has proven to be one of the good lateral load resisting systems from the observation of target displacement among the models. The building is analysed by varying the position of shear wall ie, shear wall at external mid-span, at corners, and at core. The model with shear wall at core shows higher performance point, which behaves better as compared to other models. Shear wall at core shows less displacement and also base shear was found to be greater than other models.

Rakesh Kumar Pandey (2020): In this study roof displacement and base shear for symmetrical and unsymmetrical buildings is analysed. Shear wall position is also changed to observe its strength. Base shear is found to decrease by 7.55 percent in symmetrical building when shear wall is provided in one bay of structure. About 63.30 percent in roof displacement is observed while introducing shear wall. For unsymmetrical building, the base force capacity is decreased by 4.3 percent when shear wall is provided on the larger side of the building frame, whereas 7.9 percent decrease of base shear capacity when it is provided on the smaller side. In unsymmetrical building roof displacement was reduced by 59.09 percent, when shear wall was provided in larger side and decrease of 58.92 percent on provision of shear wall on smaller side.

Ozlem Caviar (2017) : In this study, nonlinear static analysis and nonlinear dynamic analysis were used to examine the seismic behaviour of a reinforced concrete shear-wall building that collapsed during the Bingol earthquake in 2003. Bingol, Turkey is the location of the chosen reinforced-concrete shear-wall construction. The pushover method, code procedures, and nonlinear dynamic analysis were used to evaluate the performance objectives of the reinforced-concrete shear-wall construction.

Dona Mary Daniel and Shemin (2016): In this study, displacement controlled pushover analysis is used to analyse the seismic response of a ten story reinforced concrete building. It is believed to be in seismic zone three. To obtain the pushover curve, displacement is increased incrementally up to the limiting displacement. Failure of beams and columns as well as the creation of plastic hinges were also seen. The order in which the hinges formed demonstrated that columns collapse before beams. The structure is determined to be secure

for the assumed level earthquake because 77.6% and 84.56% of the hinges were formed inside the life safety standard.

Hanafiah et. al (2017): The behaviour study of shear wall on concrete structure by pushover analysis. This paper used four models of 10 floors building of each floor 18 m x 18 m with three variations of shear wall position. The purpose of this study is to analyse building performance, curve capacity and plastic hinge distribution from pushover analysis. In this without shear wall, shear wall at corners, at periphery and at core is analysed. After pushover analysis we could infer that first plastic hinge occurred at storey 3-4 for model without shear wall, which also shows that building is more susceptible to destruction. For model, shear wall at periphery and at core, first plastic hinge occurred at storey 7-9, and for shear wall at core storey 8-9. An office building was analysed and the result of pushover analysis was that the building performance of all model is immediate occupancy.

Mohit et.al (2017): In this study pushover analysis of asymmetric steel building is done. The objective also involves assessing the impact of eccentricity on a building's performance by shifting the location of its shear walls. The base shear capacity diminishes and displacement rises as the percentage of eccentricity increases. The placement of shear walls has a considerable impact on base shear capacity. The structure approaches the point of collapse as the building's eccentricity increases.

Waykule. S.B et al (2017) : In this study, a five-story structure in India's zone v with and without floating columns on the first and second floors is examined in accordance with the code. Under seismic and gravity loads, buildings underwent linear static analysis. Then compare each building's base shear and storey displacement. When a floating column is added to a building's first floor, base shear of such building diminishes in comparison to a building without a floating column. It was found that floating column buildings cause more displacement between each storey than non-floating column buildings do.

Sreevidya M G et.al (2018): In this study RC building is analysed with floating column and with bracings. static analysis is being done for all the models. Time period, base shear and storey displacements are compared for all the models. From the present study, we could infer that introducing floating column increases the displacement of the building. It is because the stiffness of the building reduces, which make the building more flexible. When floating column buildings is retrofitted with bracings it shows good performance than a normal

building without a floating column. X bracings and inverted V bracings were provided and analysed. Building with X bracings shows good performance than in all the cases. Provision of floating column tends to oscillate the building, thereby increases the time period than normal building.

Akansha Dwivedi (2020): RCC and composite columns are used in this study's analysis of a 20-story high rise skyscraper. Shear walls could lessen displacement and drift while increasing the building's rigidity. More lateral force could be resisted by a composite column building with a shear wall. Shear walls can reduce top displacement in RCC and composite column buildings by 40% in static study and 47% in response spectrum analysis, respectively. A composite column is used, which approximately decreases movement. 20% less than a typical building. There was less storey-drift. When shear walls are introduced, the drift at the top is reduced by 13% in the case of static analysis and by 23% in the case of response spectrum analysis. Adding composite columns approximately minimises drift. 25% more than RCC column structures while also demonstrating an increase in rigidity

Sreadha A R et.al (2020): This study compares a multi-story building with and without floating columns when subjected to earthquake stresses. This analysis concentrates on analysing the structure seismically and utilising software to compare it to a building without a floating column because floating columns are important in high-rise buildings. In addition to these numerous characteristics, base shear and its impact on the number of storeys on drift are also investigated. According to the study, structures with floating columns exhibit the most displacement when compared to structures without floating columns. Displacement also increases as the number of stories rises. An upward-shifted floating column demonstrates an increase in storey lateral displacement. Structure without floating column displays minimum base shear while with floating column shows maximum base shear. In seismically active areas, buildings with floating columns show higher storey drift and storey displacement.

N. Lingeshwaran et.al (2021): In this study analysis of high-rise building with and without floating columns and shear wall is done. Study shows the importance the addition of floating Column along with the presence of shear wall in high- rise structures. Time history method is used for analysing the structure The floor displacement, inter storey drift, base shear are measured for analysing the performance of structure on both the building with presence of floating column and building with absence of floating column. Building with floating column shows greater displacement as compared to other two cases. Provision of introducing shear

wall along with floating column could reduce the displacement as compared with building without floating column.

## **2.2 GAPS FROM LITERATURE REVIEW**

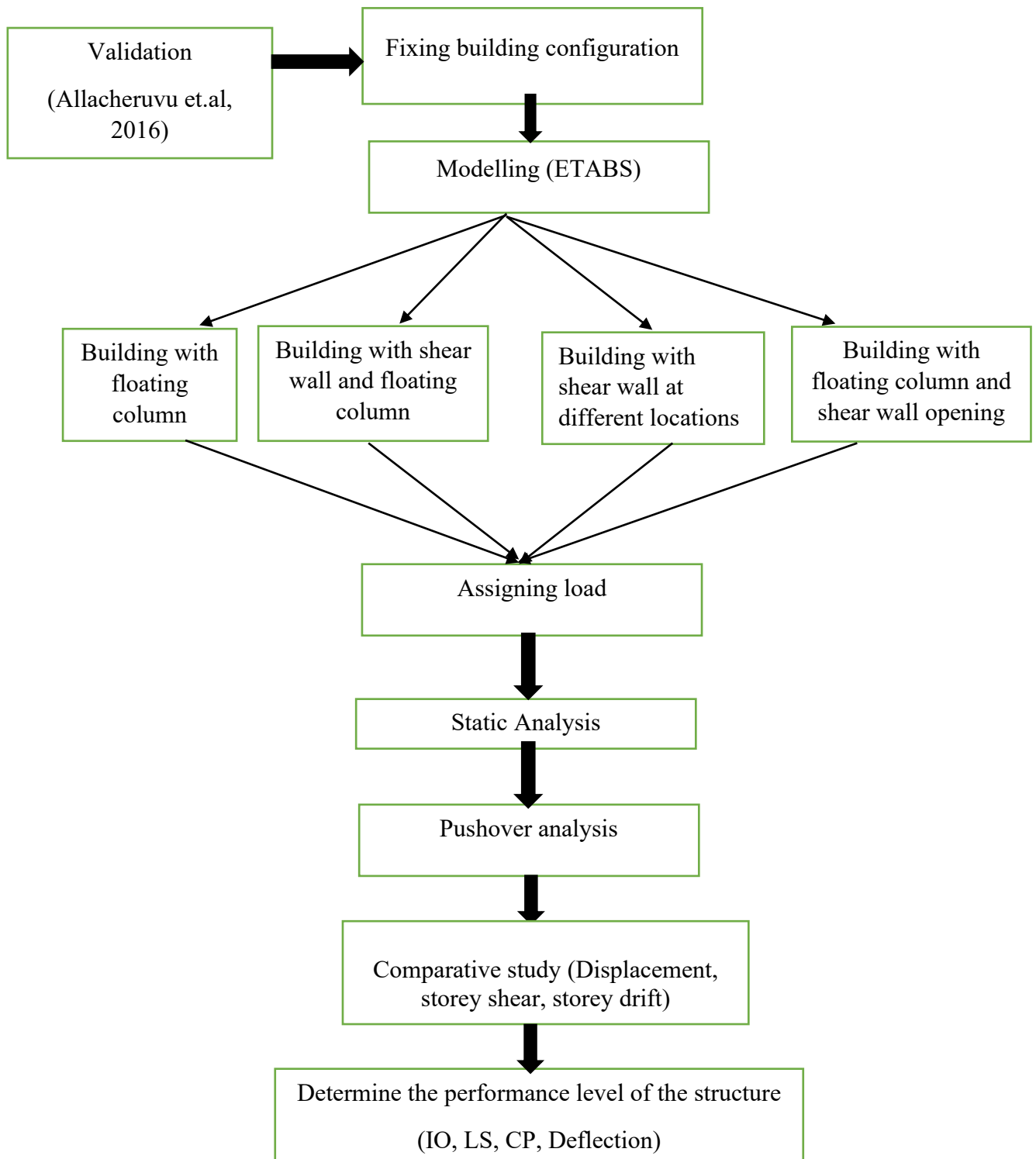
From the literature review, we could infer that seismic analysis of shear wall building with floating column is done. Gaps from the literature review is provided below

- Nonlinear static analysis of shear wall structures with floating column
- Pushover analysis of shear wall opening building with floating column
- Analysis of building with floating column by varying the position of shear wall
- Analysis of shear wall building with composite column
- Analysis of shear wall building with composite floating column
- Non-linear static analysis RC irregular shear wall structures with floating column
- Analysis of RC structure with steel plate shear wall and floating column

## CHAPTER -3 METHODOLOGY

### 3.1 Flowchart showing methodology

Methodology of the study is shown in fig 3.1. Methodology starts from validation of ETABS software and end up in getting results.



**Fig 3.1: Flowchart showing methodology**

Analysis is done on ETABS software. For validation, as per the journal seismic analysis of ten storey building is done. Displacement, storey shear and storey drift is observed. Journal values and observed values is found to be approx. equal. A building from III seismic zone is analysed by providing eight floating columns at the base. After the modelling of building ie, building with floating column, building with floating column and shear wall at different positions and shear wall with opening are modelled.

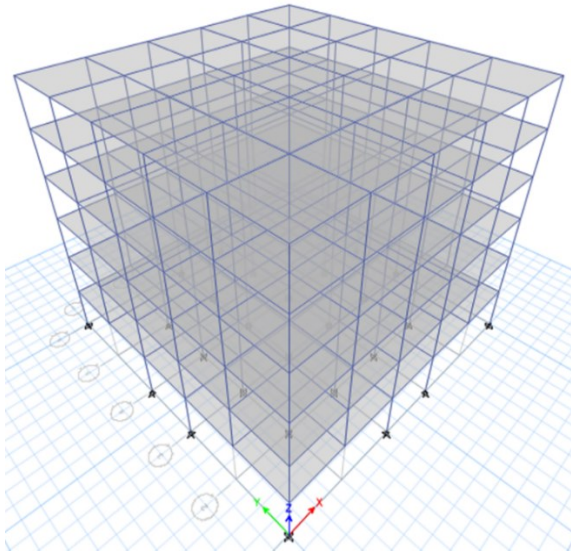
### **3.2 Building Configuration**

Description of building

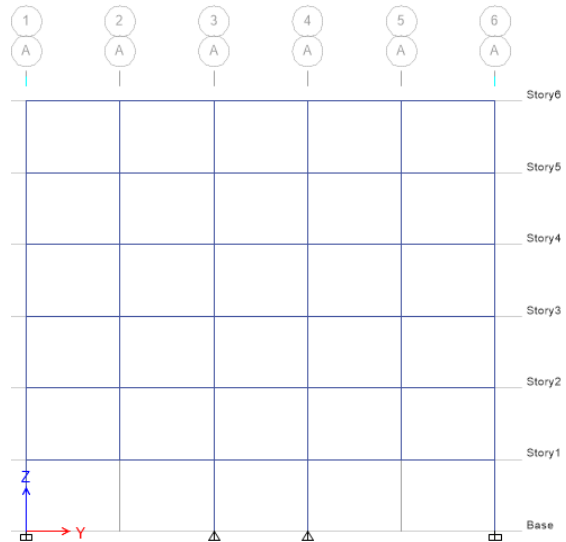
- Dimension of building: 20m x 20m
- No of storey- G+5
- Size of column- 0.5 x 0.5 m
- Size of beam- 0.230 x 0.550 m
- Transfer beam – 0.4 x 0.6m
- Base column- 0.6 x 0.6m
- Slab thickness- 0.150 m
- Concrete – M30
- Steel – Fe415

Seismic data of G + 5 building

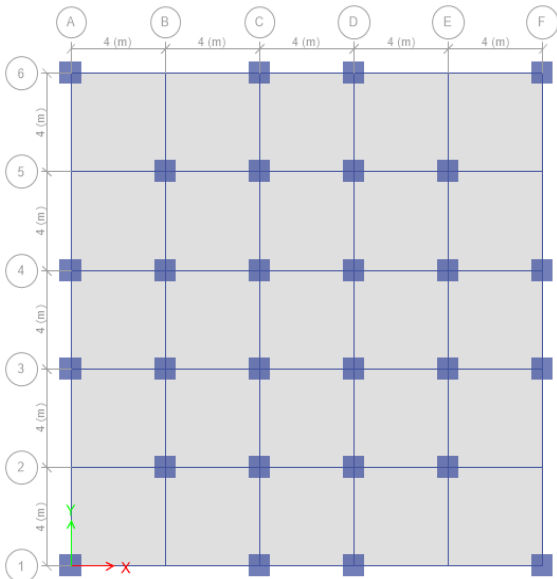
- Location zone III
- Importance factor- 1
- Soil type- hard soil (Type I)
- Live load- 3KN/m<sup>2</sup>
- Total height of building- 18 m



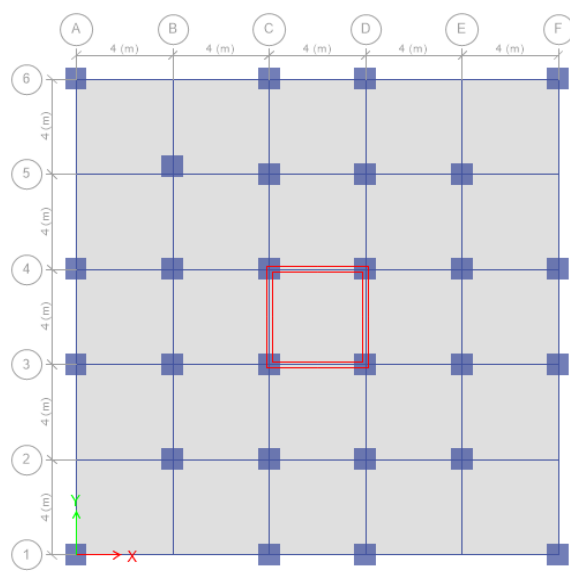
**Fig 3.2: 3-D view of building**



**Fig 3.3: Elevation of building**

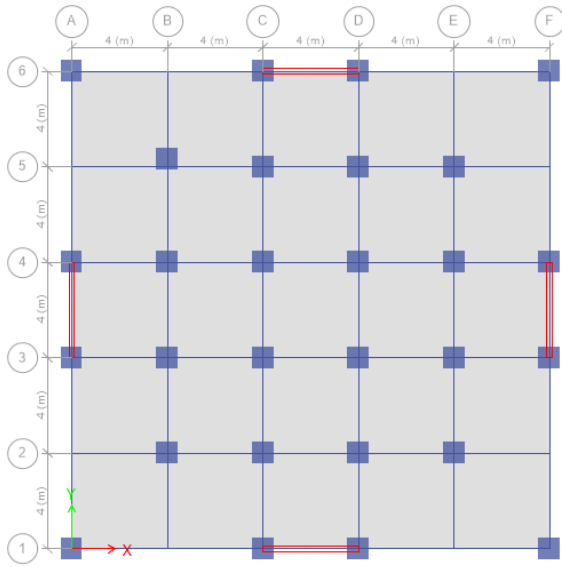


**Fig 3.4: 1<sup>st</sup> storey plan of building without shear wall**

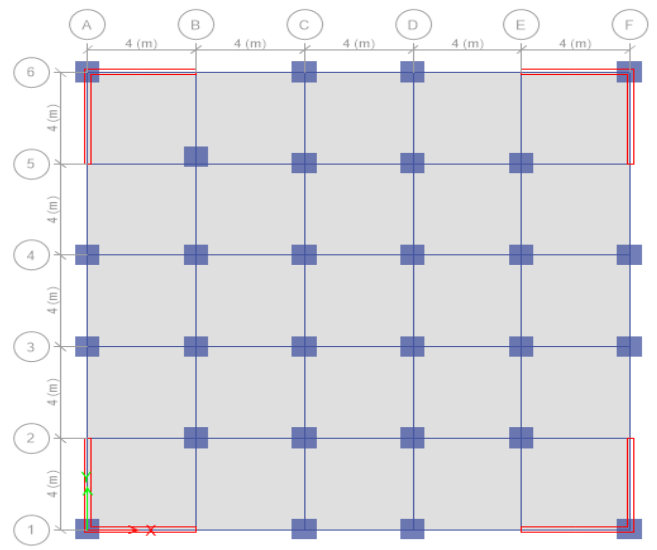


**Fig 3.5: 1<sup>st</sup> storey plan of building with shear wall at core**

Fig 3.3 shows the elevation of the building. As the building shows, eight columns in first floor is given as floating column leaving behind column-free space in ground storey. Fig 3.4, 3.5, 3.6, 3.7 shows first storey plan view of building without shear wall, shear wall at core, periphery and at corner respectively.



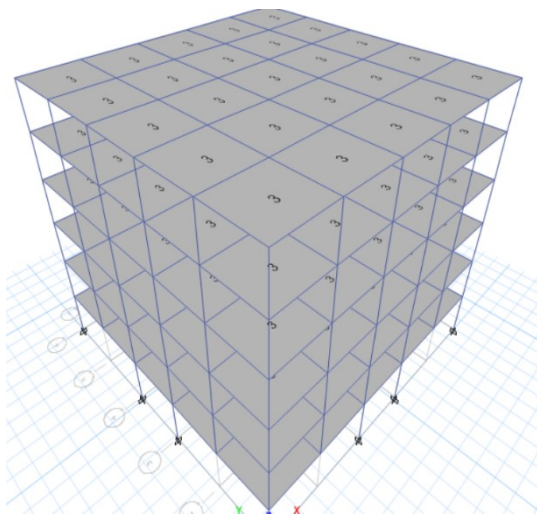
**Fig 3.6 : 1<sup>st</sup> storey plan of building with shear wall at periphery**



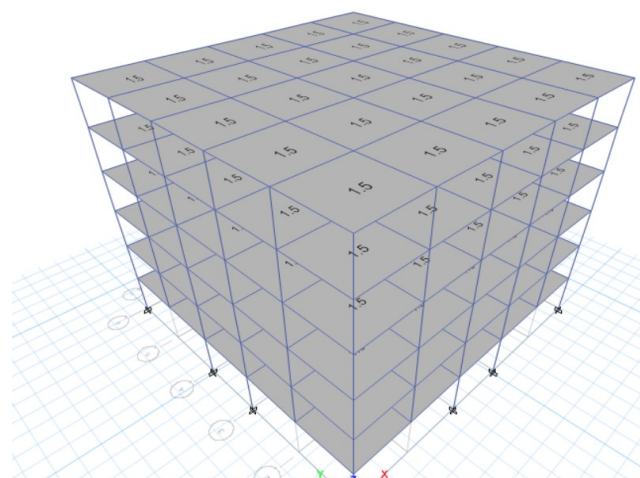
**Fig 3.7 : 1<sup>st</sup> storey plan of building with shear wall at corner**

### 3.3 Load cases

After creating a basic computer model, define properties and load cases. Dead load is given as 1.5kN plus self-weight. Self-weight of each component depends upon its dimension. In addition to linear analysis loads, for pushover analysis, two loads push X and Push Y is assigned, such that it makes required displacement.



**Fig 3.8: live load in building**



**Fig 3.9: dead load in building**

### 3.4 Analysis

Static analysis is done after assigning load like dead load, live load, earthquake load etc. The structural system is subjected to load and load combinations as per IS: 456-2000 and IS: 1893- 2016. After the static analysis unlock the model. Then push displacement value ie, displacement up to which nonlinear behaviour has to be observed, is given. As per ATC 40, the buildings are pushed to a controlled displacement of 4% of the height of the structure. Therefore, the push displacement is given as 720mm. Consider the corner joint label of top floor for target displacement. Hinges are assigned at a distance of 0.05 and 0.95 of the length of the member, to view the weak members. Change the load cases from linear to nonlinear. Set the load cases to run.

After running analysis, deformed shape for nonlinear behaviour along x & y direction can be observed. The number of hinges in each stage and the pushover curve is determined. The intersection of the bilinear force-displacement curve(red) and the capacity curve (green) represents the performance point for a given set of values. Pushover displaced shape and hinge formation sequence is observed step by step. Hinge results, whether they arrive in IO, LS, CP, etc., can also be identified. Comparative studies are carried out on storey displacement, storey shear, storey drift, and building performance.

## CHAPTER-4

### VALIDATION

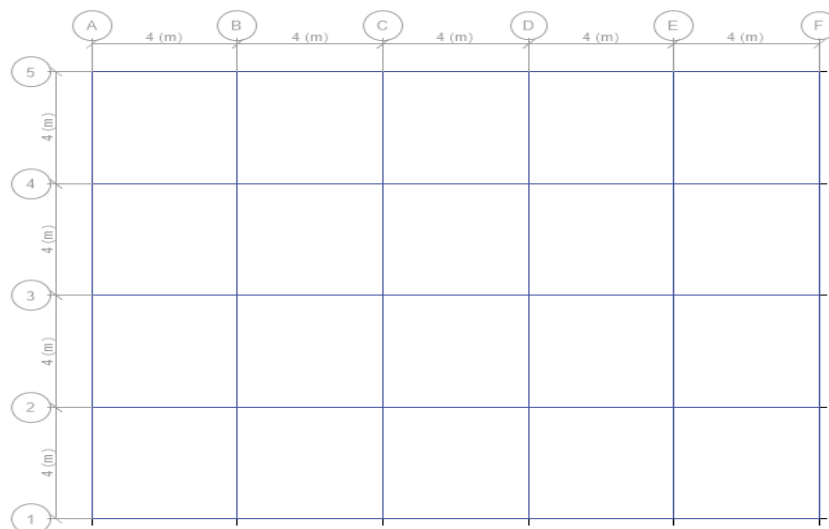
Ten storey building is modelled in ETABS with the following data. Seismic analysis of building is done to validate the observed data with the journal (Allacheruvu et.al, 2016).

#### Description of building

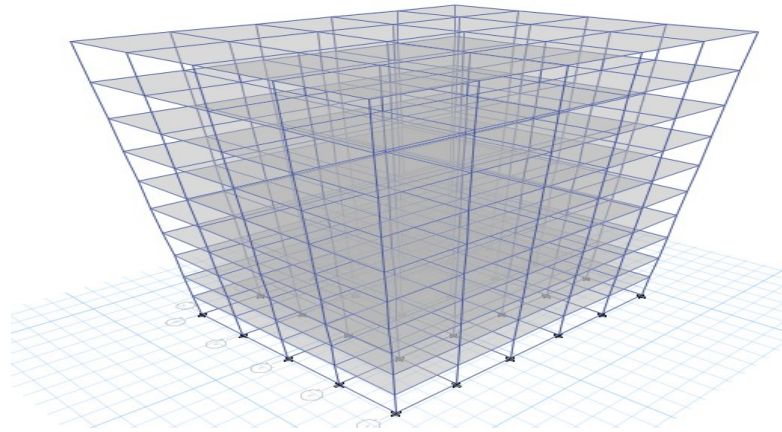
- Dimension of building: 20m x 16m
- No of storey-10
- Size of column- 0.4 x 0.4m
- Size of beam- 0.3m x 0.25m
- Slab thickness- 0.125m
- Concrete – M25
- Steel – Fe415

#### Seismic data of G + 9 building

- Location- zone III
- Importance factor- 1
- Response reduction factor-3
- Soil type- hard soil (Type I)
- Live load- 3KN/m<sup>2</sup>
- Total height of building-30m



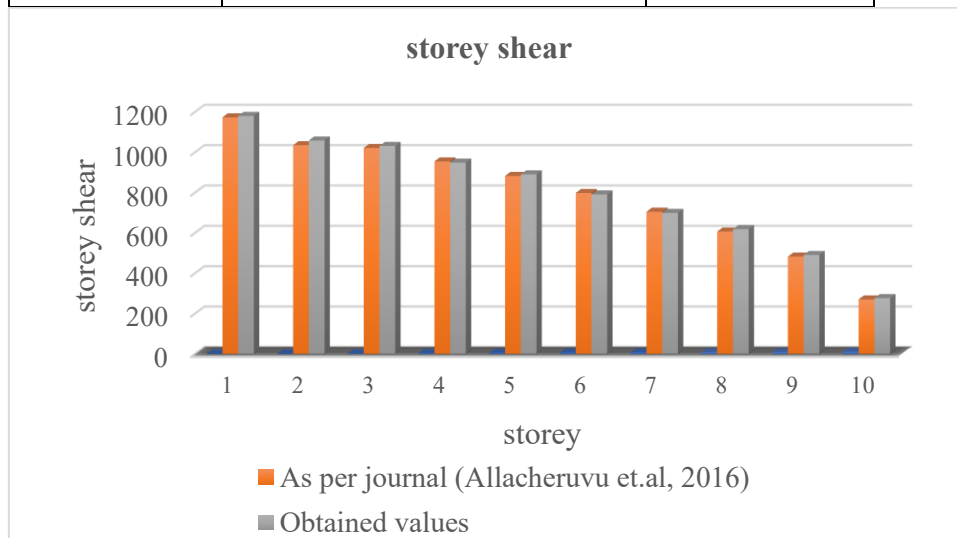
**Fig 4.1: Plan of building**



**Fig 4.2: Elevation of building**

**Table 4.1: Storey shear of building**

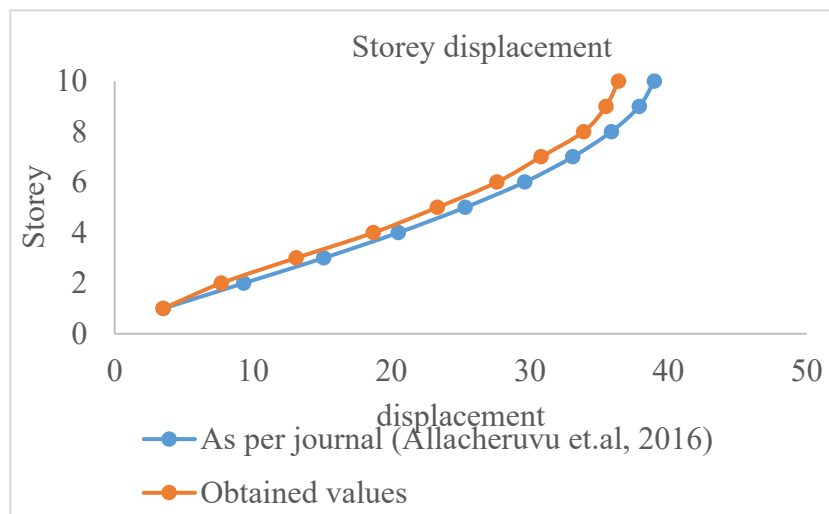
Storey	As per journal (Allacheruvu et.al, 2016)	Obtained values
9	270.42	276.527
8	482.56	490.647
7	606.71	618.73
6	705.11	699.309
5	798.22	790.918
4	882.83	890.091
3	954.83	948.362
2	1021.16	1031.264
1	1000.04	1058.33
Ground floor	1173.14	1180.09



**Fig 4.3. Storey shear of building**

**Table 3.2: Displacement in each storey**

Storey	As per journal (Allacheruvu et.al, 2016)	Obtained values
9	39	36.4
8	37.9	35.5
7	35.89	33.89
6	33.1	30.8
5	29.62	27.62
4	25.32	23.32
3	20.49	18.7
2	15.11	13.11
1	9.32	7.7
Ground floor	3.51	3.5



**Fig 3.4: graph showing storey displacement of the building**

Analysis is done on ETABS software. For validation, as per the journal seismic analysis of ten storey building is done. Displacement and storey shear are observed. Variation from analysis result= 2%. Journal values and observed values is found to be approx. equal. So, the software is said to be validated.

## CHAPTER-5

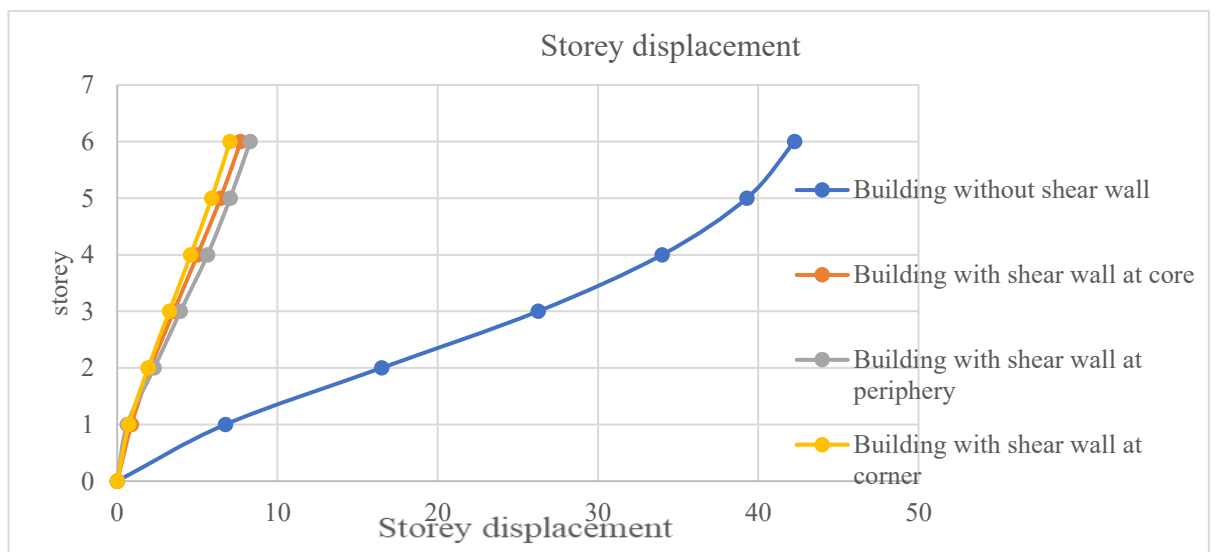
### RESULTS AND DISCUSSION

#### 1. Storey displacement

Storey displacement is the deviation of a single story with respect to the structure's foundation or ground level. As we progress up the structure, we can naturally expect observing higher total displacement values.

**Table 5.1: Storey displacement of building in different shear wall position**

Storey displacement	Building without shear wall (mm)	Building with shear wall at core (mm)	Building with shear wall at periphery (mm)	Building with shear wall at corner (mm)
Storey 6	42.272	7.706	8.3	7.044
Storey 5	39.291	6.455	7.05	5.892
Storey 4	34.009	5.016	5.64	4.59
Storey 3	26.263	3.534	3.95	3.254
Storey 2	16.499	2.074	2.313	1.935
Storey 1	6.751	0.892	0.631	0.735
Base	0	0	0	0



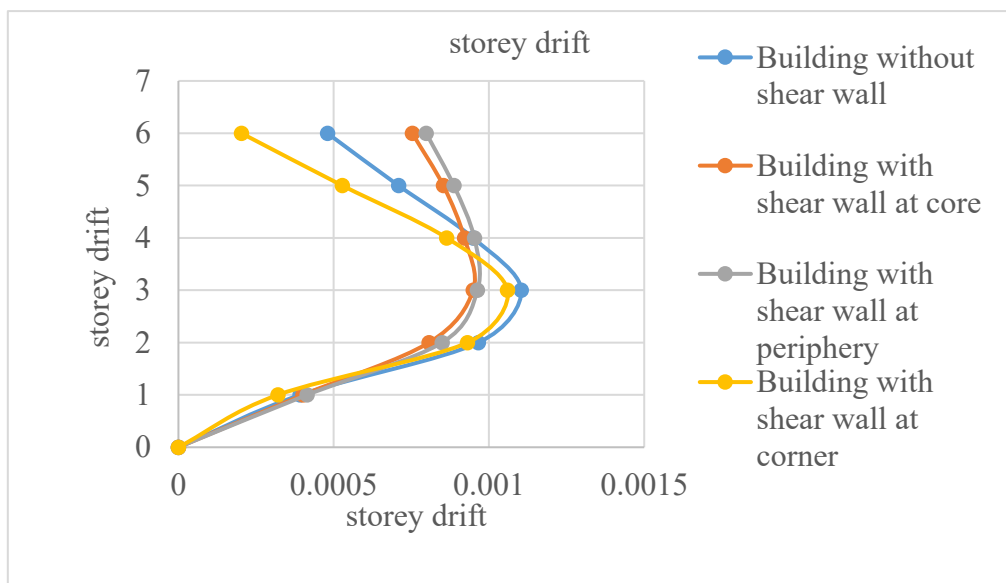
**Fig 5.1: Graph showing storey displacement in different storey with respect to building without shear wall**

Table 5.1 shows the storey displacement of building with and without shear wall. A drastic difference is made in lateral load carrying capacity. storey displacement by varying the shear wall position is also observed. Building with shear wall at corner shows less displacement than other locations.

## 2. Storey drift

**Table 5.2: Storey drift of building in different shear wall position**

	Building without shear wall	Building with shear wall at core	Building with shear wall at periphery	Building with shear wall at corner
Storey 6	0.00048	0.000753	0.000798	0.000203
Storey 5	0.000709	0.000853	0.000887	0.000528
Storey 4	0.000949	0.000921	0.000953	0.000864
Storey 3	0.001104	0.000949	0.000963	0.00106
Storey 2	0.000966	0.000807	0.000849	0.000931
Storey 1	0.000392	0.000401	0.000414	0.00032

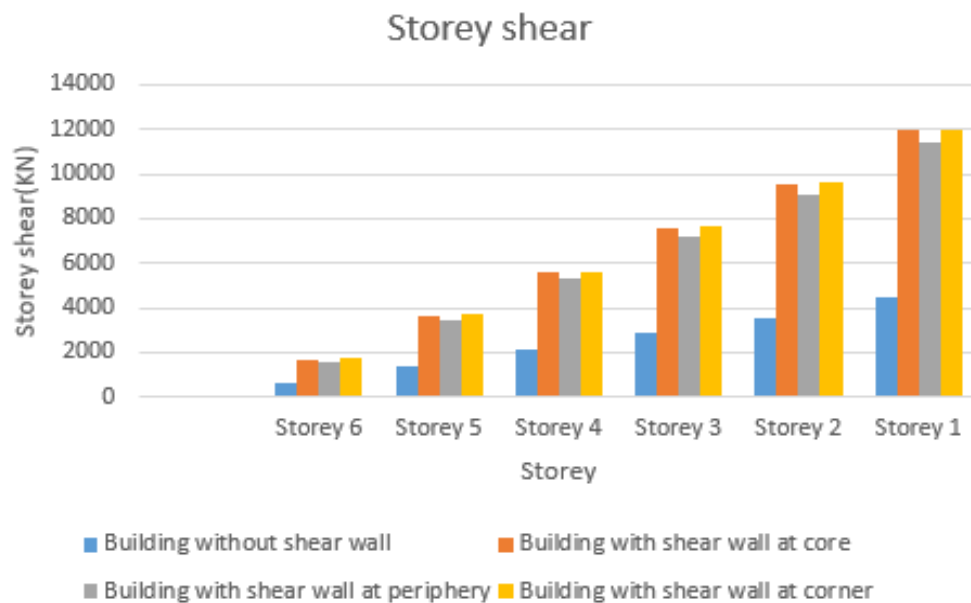


**Fig 5.3: Graph showing storey drift with respect to building without shear wall**

### 3. Storey shear

**Table 5.3: Storey shear of building in different shear wall positions**

storey shear (KN)	Building without shear wall	Building with shear wall at core	Building with shear wall at periphery	Building with shear wall at corner
Storey 6	626.62	1628.25	1548.4161	1749.30
Storey 5	1366.06	3606.86	3430.01	4422.42
Storey 4	2105.50	5585.47	5311.61	5633.968
Storey 3	2844.94	7564.08	7193.21	7645.52
Storey 2	3584.38	9542.70	9074.81	9757.06
Storey 1	4505.75	11573.81	11386.73	11988.28



**Fig 5.3: Graph showing base shear at different shear wall positions**

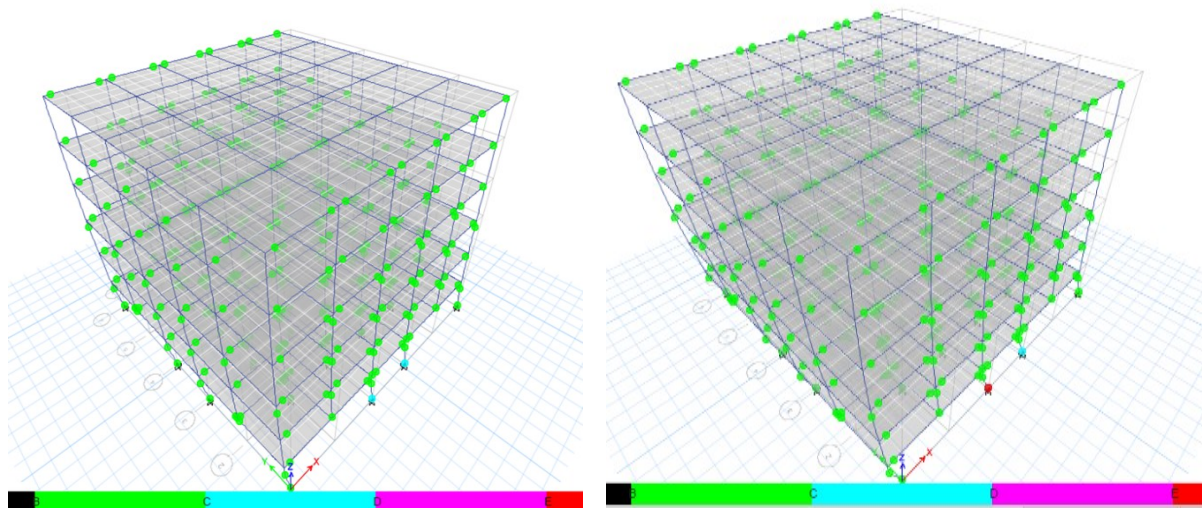
## CHAPTER- 6

### PERFORMANCE OF BUILDING

The curve plotted between the base shear and roof displacement is known as the Pushover curve. It displays the structure's overall reaction to incrementing seismic loads. A triangular loading is given to the structure which is gradually raised in small increments until any level of the structure has failed. Base shear is a measurement of the maximum expected lateral force from seismic activity on the base of the structure. It is calculated using the lateral force equations for the seismic zone, soil type, and building code.

#### 6.1 Building without shear wall

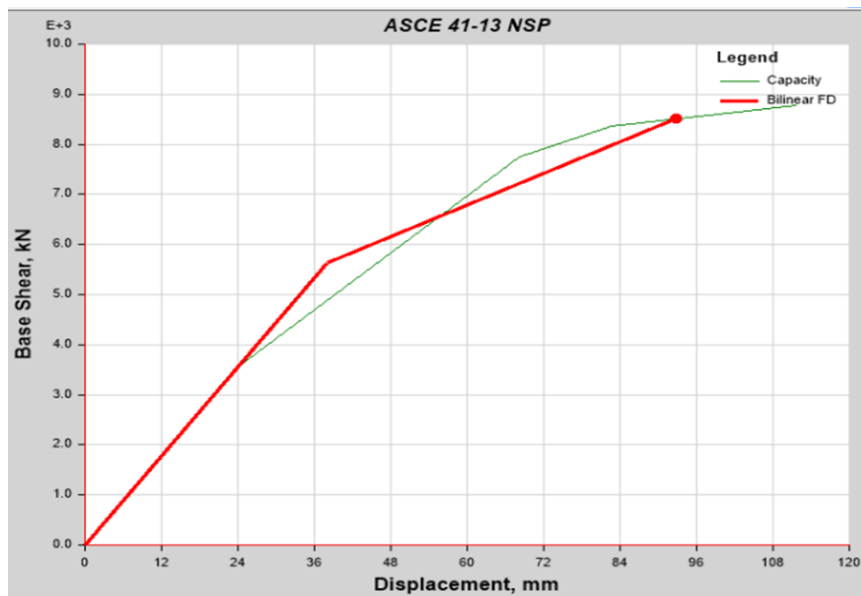
Fig 6.1 and table 6.1 shows the performance of plastic hinges in building in different loading conditions. While incrementing load, colour of hinges changes depending on the members load resisting capacity. The green colour indicates reduction in stiffness, blue indicates reduction in load resistance, red indicates collapse. In figure 6.1, at a displacement of 111.624mm, one of the base columns in the ground floor shows reduction in load resistance, which is indicated as blue colour. On subsequent increase in load, ie, at displacement of 111.75 mm one of the base columns got collapsed as shown in fig 6.2, which is indicated in red colour. From table 6.1, we could also determine, the number of hinges in different acceptance criteria, ie, Immediate occupancy, life safety and collapse prevention.



**Fig6.1: plastic hinges in building at stage 4    Fig 6.2: plastic hinges in building at stage 5**

**Table 6.1: No. of hinges in different stages**

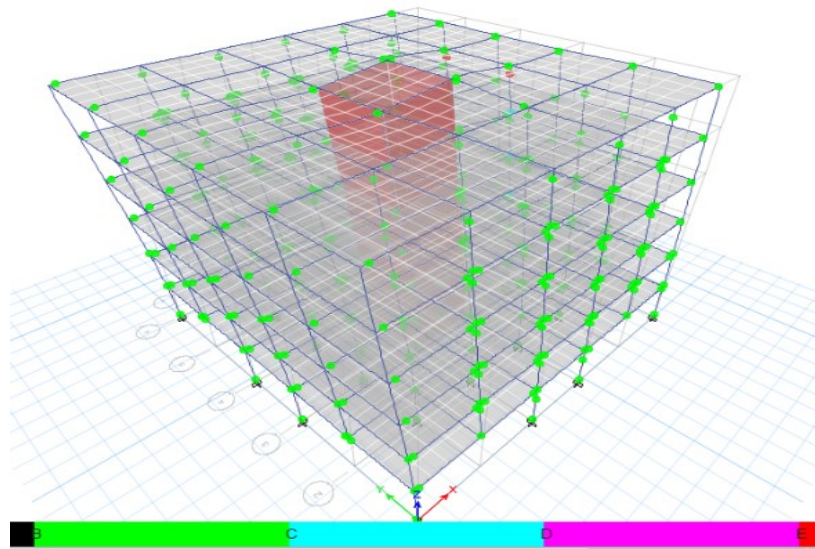
Stage	Base shear (KN)	Displacement (mm)	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP
1	3547.356	23.897	2264	8	0	0	0	2272	0	0
2	7746.75	68.183	2148	124	0	0	0	2272	0	0
3	8372.770	82.659	2120	152	0	0	0	2256	0	0
4	8773.170	111.624	2112	152	8	0	0	2160	56	56
5	8773.541	111.75	2112	152	8	0	2	2160	56	52



**Fig 6.3: pushover curve of building without shear wall**

Base shear v/s displacement graph is obtained. The green colour indicates capacity curve, which is superimposed by bilinear force-displacement curve. The bilinear curve consists of two straight lines. Intersecting point of these two curves indicates the performance point, indicates the ultimate load and target displacement of the structure. Fig 6.2 indicate ultimate load as 8512.64KN and target displacement as 92.78mm.

## 6.2 Building with shear wall at core



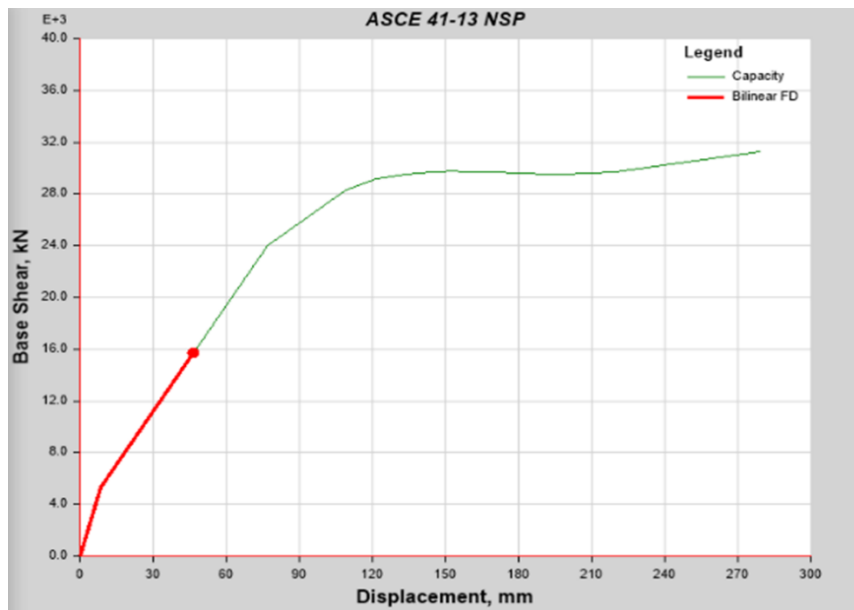
**Fig6.4: plastic hinges in building at stage 4**

**Table 6.2: No. of hinges in different stages**

Stage	Base shear	displacement	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP
1	4323.940	7.694	2296	0	0	0	0	2296	0	0
2	30404.89	80.078	2085	211	0	0	0	2296	10	0
3	48109.52	153.195	1477	819	0	0	0	2272	24	0
4	62402.93	235.952	1320	972	0	0	0	2085	175	36
5	62113.45	235.959	1316	976	0	0	4	2085	175	32
6	62256.95	236.607	1316	976	0	0	4	2085	175	32
7	63224.66	242.51	1308	972	12	0	4	2081	167	44

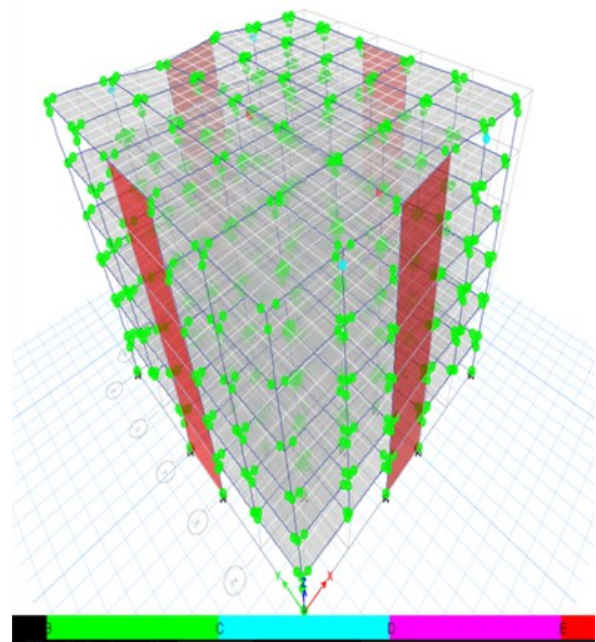
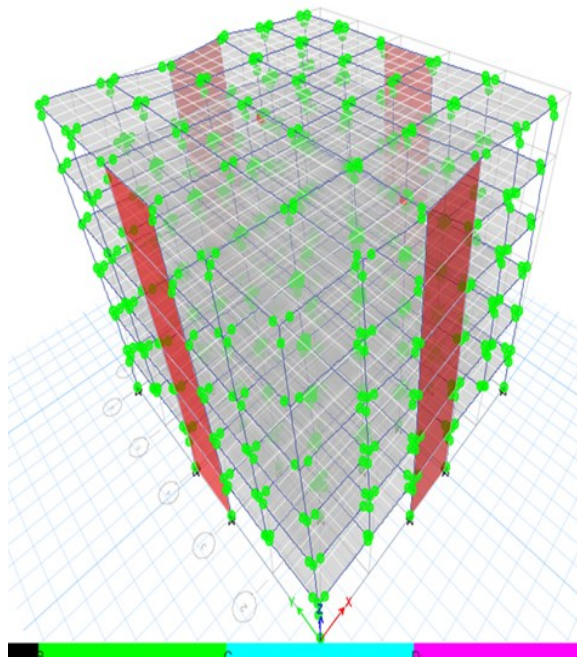
In this shear wall is provided at the core and analysed its performance. Introducing a shear wall to the structure shows an increase in load carrying capacity in the building. As the fig 6.3 shows, members first to get damaged is at upper storey. It is evident that shear wall act as

a barrier to resist the lateral load that is acting upon the structure. Target displacement is the displacement up to which a building is found to be safe. The target displacement obtained is 51.427mm and the ultimate load is 20081.64kN.



**Fig 6.5: pushover curve of building with shear wall at core**

### 6.3 Shear wall at periphery

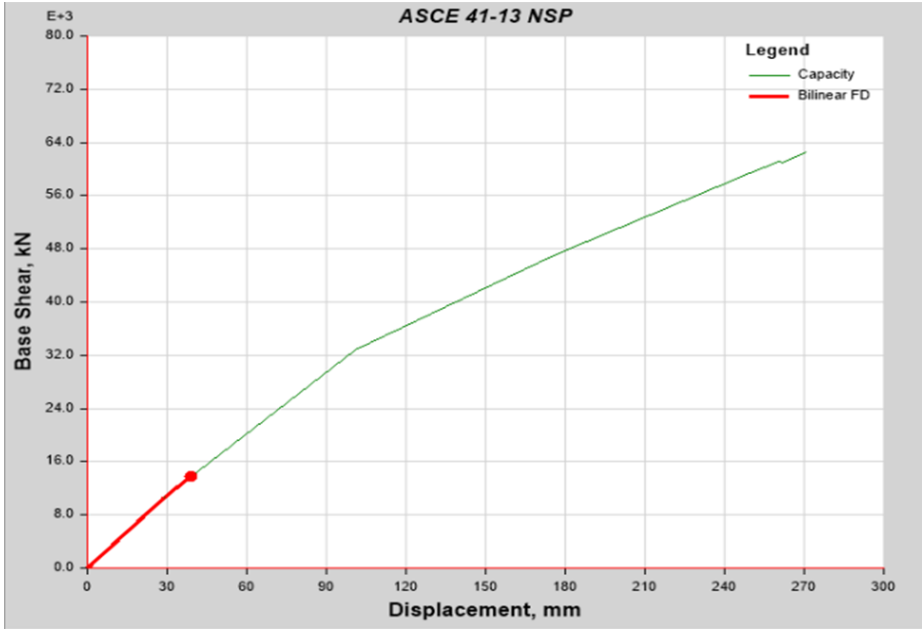


**Fig 6.6: plastic hinges in building at stage 6 Fig 6.7: plastic hinges in building at stage 7**

Shear wall is provided at the periphery and analysed its performance. Fig 6.6 and 6.7 shows the hinge result in stage 6 and 7. As fig 6.7 shows, some of the hinges in upper storey turned to red colour, showing the collapse of such members at a displacement of 270.632mm. Also some of members, which shown reduction in stiffness in stage 4 was converted to reduction in load resistance in stage 5.

**Table 6.3: No. of hinges in different stages**

Stage	Base shear	displacement	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP	>CP
1	10644.9805	28.777	2288	8	0	0	0	2296	0	0	0
2	32811.3495	100.896	1866	426	0	0	4	2292	0	0	4
3	46957.69	175.395	1504	788	0	0	4	2274	18	0	4
4	59408.6158	249.747	1376	916	0	0	4	1974	310	8	4
5	61196.0247	260.715	1324	964	4	0	4	1950	334	8	4
6	61005.7062	261.611	1320	968	0	0	8	1950	330	8	8
7	62478.63	270.632	1312	970	4	0	10	1938	334	16	8



**Fig 6.8: pushover curve showing target displacement**

Fig 6.8 shows the pushover curve of building with shear wall at periphery, indicating ultimate load as 15779.85kN and target displacement as 38.976 mm.

#### 6.4 Shear wall at corner

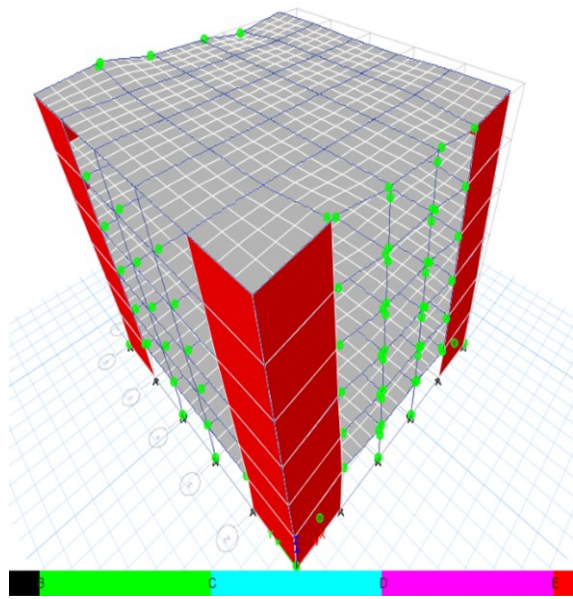


Fig 6.9: plastic hinges in building at stage

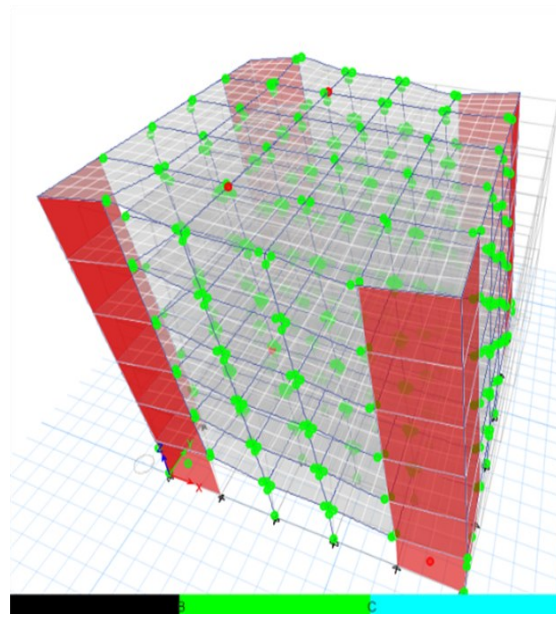
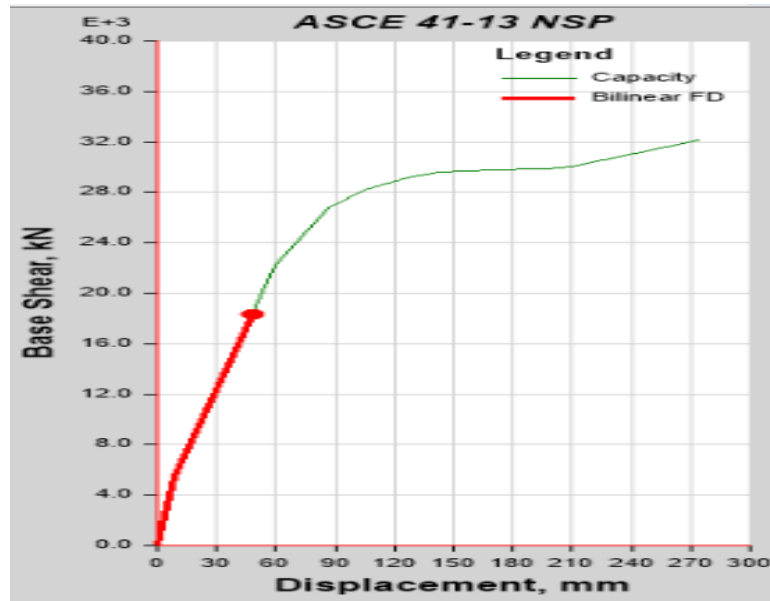


Fig 6.10: plastic hinges in building at stage 7

Shear wall is provided at corners to analyze its performance. Eight shear walls were provided and loaded. On increasing the load, shear wall at the lower storey and upper storey members undergo failure at a displacement of 278.794mm. From the figure it is evident that shear walls fail prior to structural members, thereby ensuring the safety of the whole structure.

Table 6.4 : No. of hinges in different stages

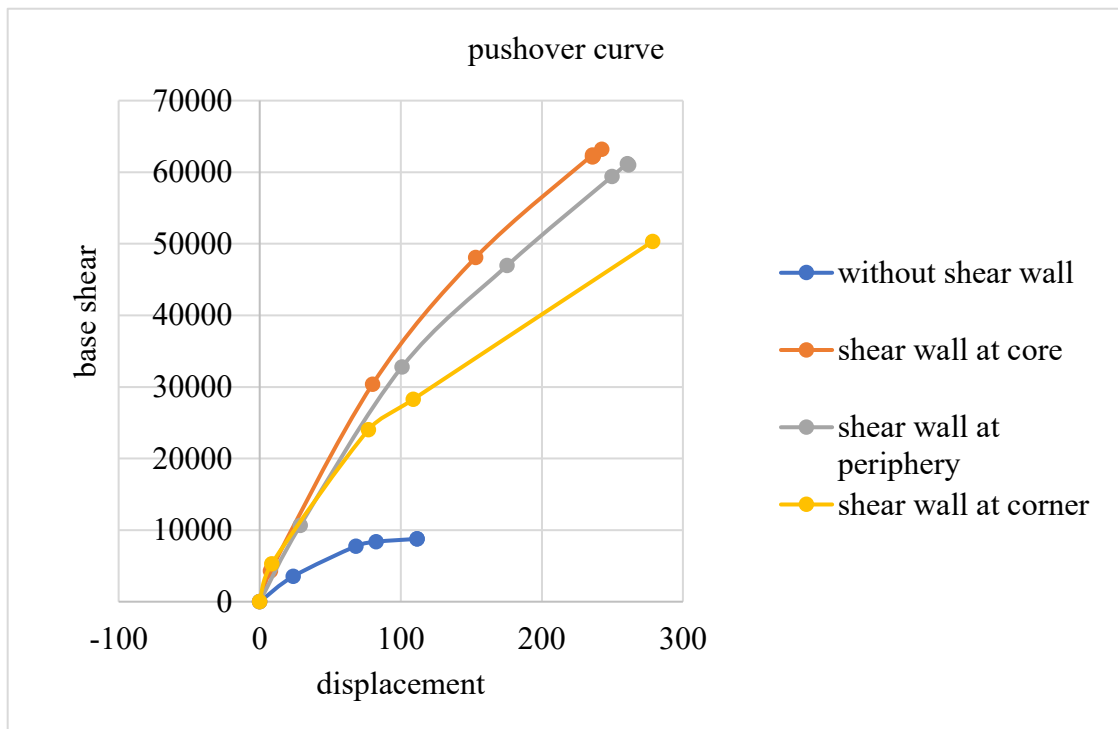
Stages	Base shear (KN)	Displacement (mm)	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP
1	5314.0188	8.609	2320	0	0	0	0	2320	0	0
2	24012.085	77.08	2110	210	2	0	0	2320	1	0
3	28276.196	108.846	1890	430	0	0	2	2318	2	0
4	29145.434	121.735	1690	628	0	0	2	2318	2	0
5	29523.455	133.276	1630	688	0	0	2	2318	0	2
6	29701.719	144.428	1594	724	0	0	2	2316	2	2
7	31287.67	278.794	1458	854	6	0	10	1868	432	14



**Fig 6.11: pushover curve showing target displacement**

Table 6.4 shows base shear, displacement and the number of hinges in each stage of loading. Fig 6.11 shows the pushover curve of a building with shear wall at corner, indicating ultimate load as 18045.05 kN and target displacement as 48.251 mm.

### 6.5 Comparison of pushover curve



**Fig 6.12: Comparison of pushover curve**

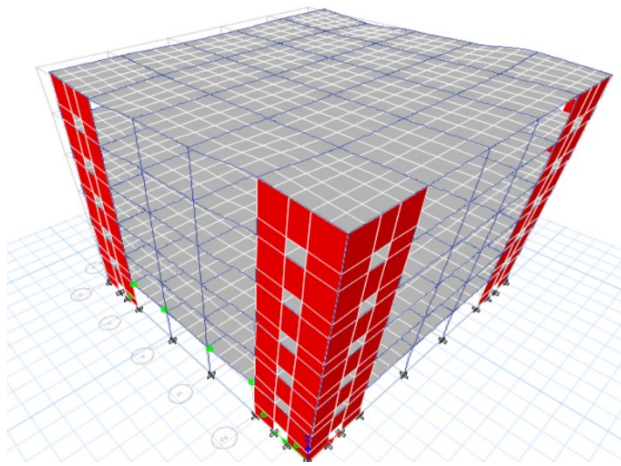
Fig 6.12 shows the comparison of the pushover curve. As the lateral load increases deformation increases. In building without shear wall, building fails faster as compared to building with shear wall. The shear wall at the core shows the ultimate load carrying capacity with ultimate load of 20081.64 kN and target displacement of 51.427mm. Load carrying capacity of building without shear wall is far less than the building with shear wall. It itself shows the resisting power of lateral loads by the shear wall.

## CHAPTER-7

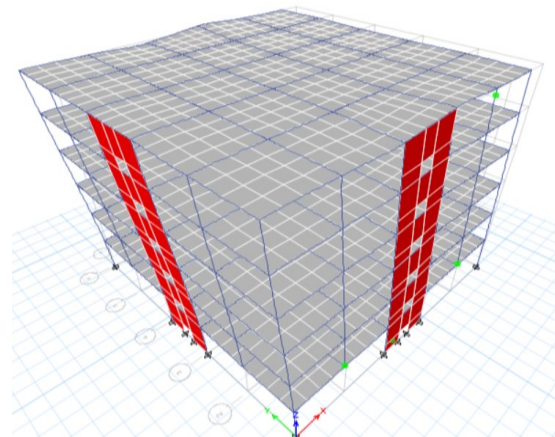
### SHEAR WALL WITH OPENING

#### 7.1 Introduction

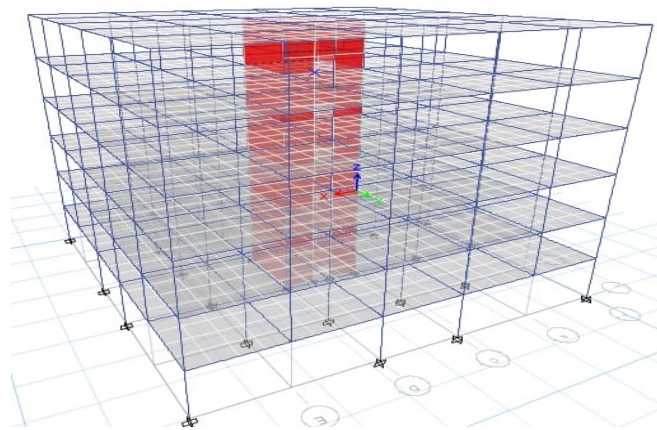
Shear walls have been used for building framing for a very long time. An effective lateral force-resisting system can be created by strategically placed walls within a structure while also serving other functional purposes. In apartment buildings, shear walls will be provided with rows of apertures for windows in external walls and doorways or corridors in internal walls. However, in a shear wall system, seismic reactions may be negatively impacted by the size and position of apertures in the shear wall. Due to the presence of apertures in the shear wall, which vary in size and shape, the strength and stiffness of the shear wall reduces. As the size of the apertures rises, the stiffness of the shear wall diminishes, increasing the column moment and axial forces. So proper analysis helps to fulfil functional and strength requirements.



**Fig 7.1: Shear wall at corner with opening**



**Fig 7.2: Shear wall at periphery with opening**

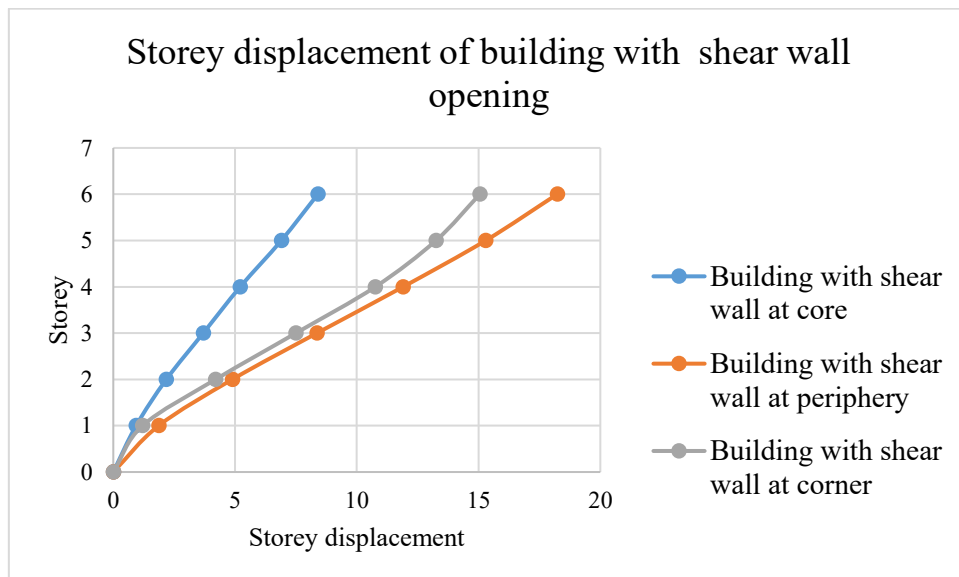


**Fig 7.3: Shear wall at core with opening**

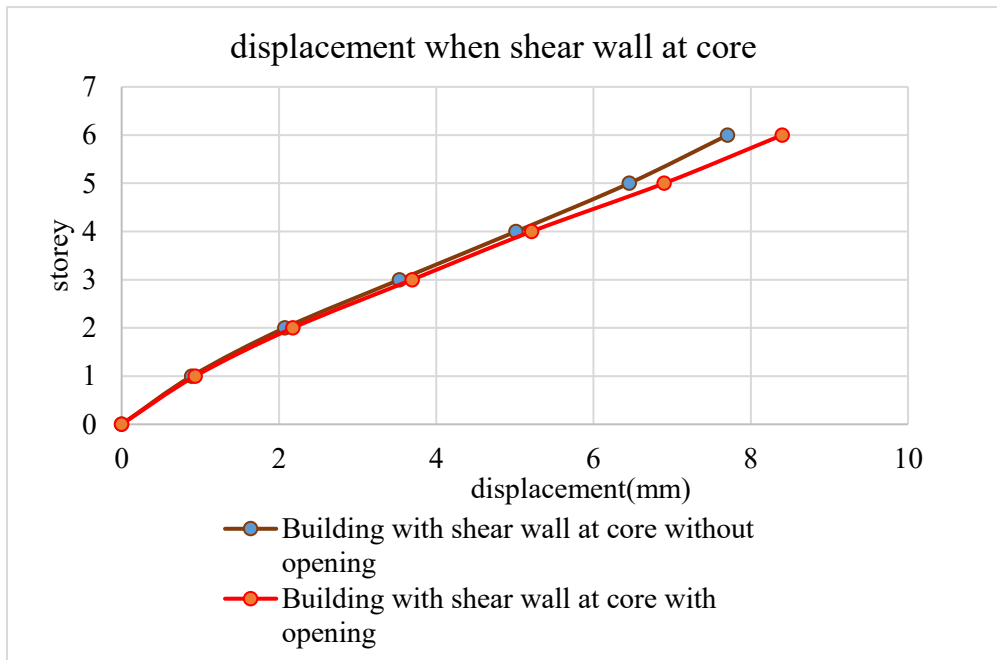
### 7.3 Storey displacement

**Table 7.1: Storey displacement of building with opening**

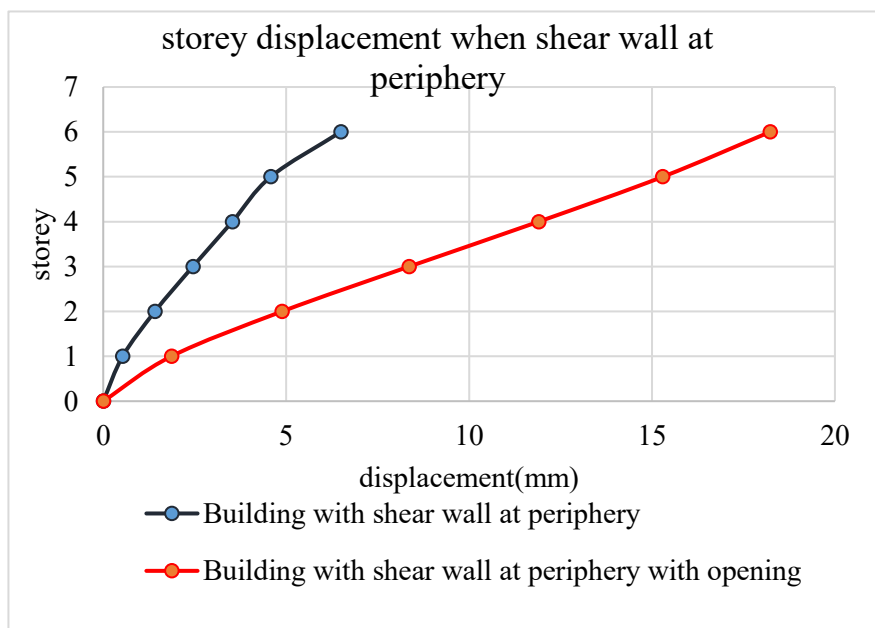
Storey displacement	Building with shear wall at core (mm)	Building with shear wall at periphery (mm)	Building with shear wall at corner (mm)
Storey 6	8.4	18.229	15.053
Storey 5	6.9	15.293	13.25
Storey 4	5.212	11.904	11.336
Storey 3	3.694	8.363	8.01
Storey 2	2.179	4.889	4.2
Storey 1	0.937	1.864	1.2
Base	0	0	0



**Fig 7.4: Storey displacement of building with opening**

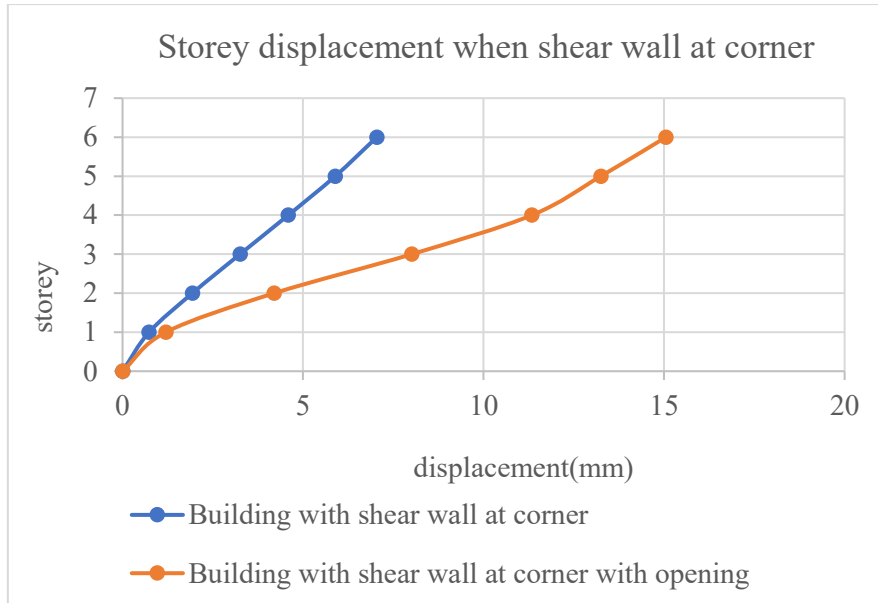


**Fig 7.5: Graph showing storey displacement in building with shear wall at the core, with and without opening**



**Fig 7.6: Graph showing storey displacement in building with shear wall at periphery, with and without opening**

Fig 7.6, 7.7 and 7.8 is the graph showing storey displacement in building with shear wall at core, periphery and corner with and without opening. It indicates the reduction of load carrying capacity as opening is provided in shear wall. Fig 7.6, storey displacement in building with shear wall at the periphery, shows a great difference when openings were provided

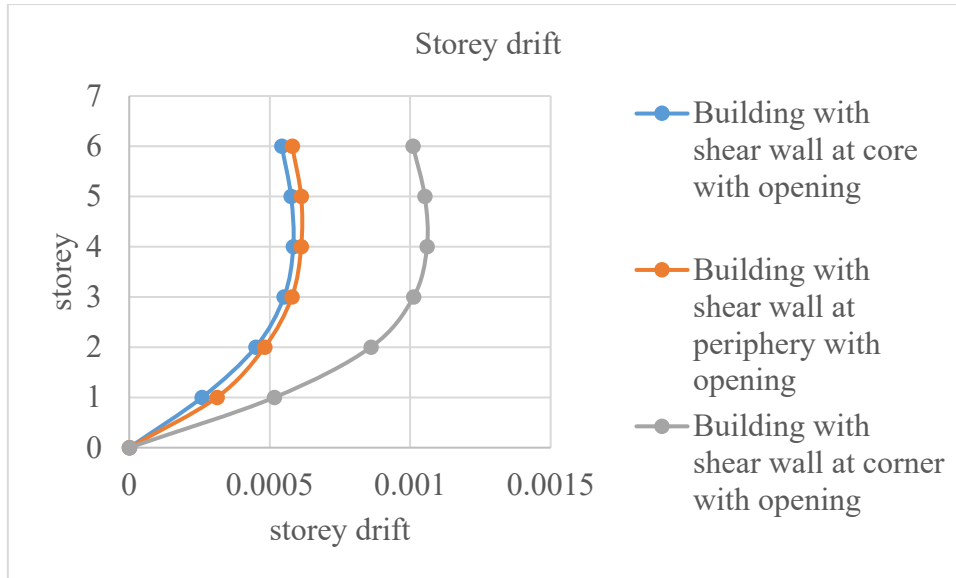


**Fig 7.8 : Graph showing storey displacement in building with shear wall at corner, with and without opening**

## 2. Storey drift

**Table 7.2: Storey drift of building with opening**

Storey drift	Building with shear wall at core (mm)	Building with shear wall at periphery (mm)	Building with shear wall at corner (mm)
Storey 6	0.00058	0.000543	0.00101
Storey 5	0.000612	0.000576	0.001052
Storey 4	0.000612	0.000584	0.00106
Storey 3	0.000579	0.000551	0.001012
Storey 2	0.000482	0.00045	0.00086
Storey 1	0.000312	0.000259	0.000517
Base	0	0	0



**Fig 7.9: Storey drift of building with an opening at different shear wall locations**

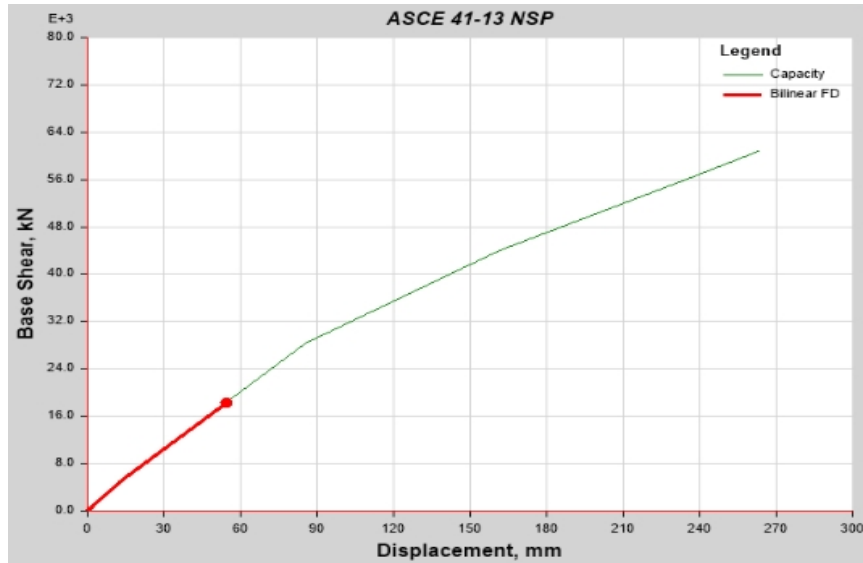
Table 7.9 depicts storey drift of building with shear wall at different locations with opening. Since the opening provided for corner is greater, from the graph, it is clear that building with shear wall at corner shows more storey drift as compared to other positions.

**Performance of building with shear wall opening**

**7.3 Shear wall at periphery with opening**

**Table 7.3 : No. of hinges in different stages**

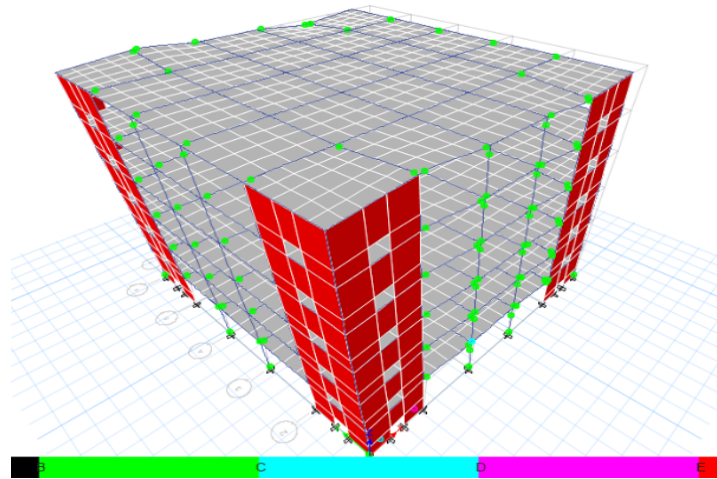
Stage	Base shear (kN)	Displacement (mm)	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP
1	4955.2635	13.013	2392	0	0	0	0	2392	0	0
2	28384.988	85.292	2102	250	2	0	0	2392	0	0
3	43985.034	161.721	1638	754	2	1	0	2378	0	0
4	56404.932	236.415	1610	880	1	3	4	2120	14	4
5	60725.350	263.199	1436	950	4	2	6	2042	268	8



**Fig 7.11: pushover curve of building with shear wall at the periphery with opening**

Table 7.3 shows base shear, displacement and the number of hinges in each stage of loading. Fig 6.11 shows the pushover curve of a building with shear wall at periphery with opening, indicating the performance point. The building is found to be safe for a displacement of 54.363 mm and an ultimate load of 17359.25 kN.

**7.4 Shear wall at corner with opening**

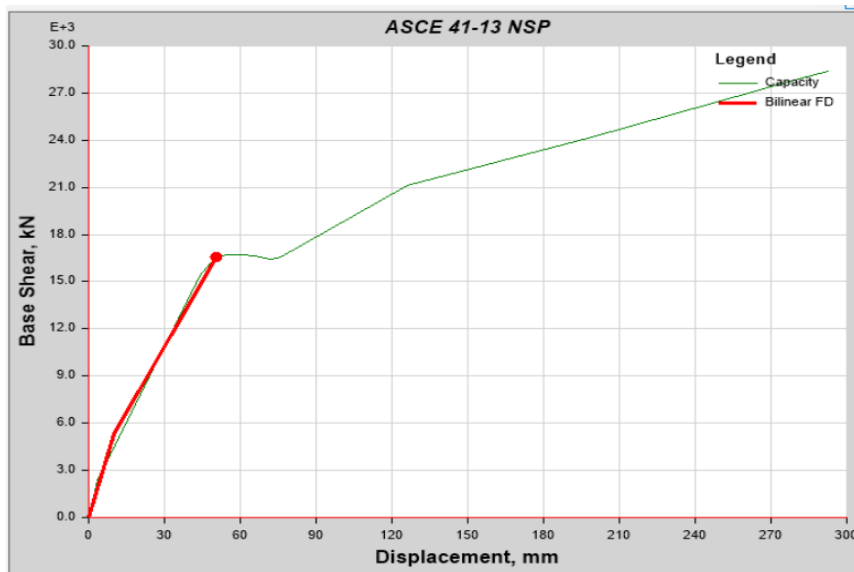


**Fig 7.12 Shear wall at corner with opening**

Fig 7.12 shows the shear wall at the corner with opening. Opening of size 1x1m is provided in each storey, in each shear wall. As the fig 7.12 shows, some of the hinges provided at the shear wall got damaged at the initial stage than that of structural members. Table 7.4 shows the load resisting capacity and deformation of building in each stage of loading.

**Table 7.4 : No. of hinges in different stages**

Stages	Base shear (KN)	Displacement (mm)	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP
1	2385.053	3.695	2512	0	0	0	0	2512	0	0
2	15395.222	43.822	2430	82	0	0	0	2512	0	0
3	16421.81	49.34	2422	90	0	0	0	2512	0	0
4	16574.711	50.729	2422	90	2	0	0	2508	4	0
5	16652.68	52.102	2418	94	2	1	0	2508	4	0
6	16721.309	58.69	2390	120	0	0	3	2508	2	2
7	21141.438	125.984	1896	610	2	0	4	2506	0	4



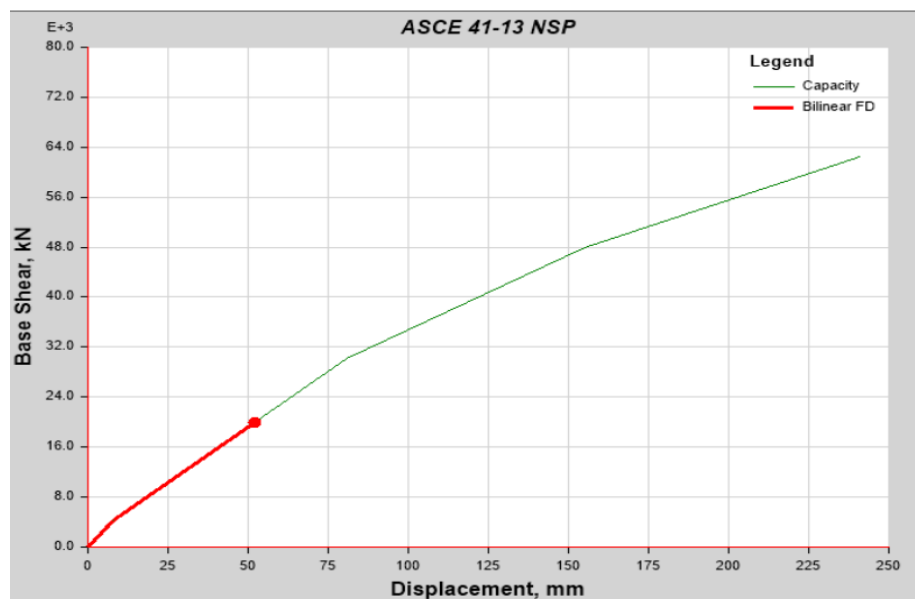
**Fig 7.13: pushover curve of building with shear wall at the periphery with opening**

Table 7.4 shows the load resisting capacity and deformation of building in each stage of loading. Pushover curve of the building shows the performance point. The building is found to be safe for a displacement of 48.251mm and an ultimate load of 18045.05 kN.

## 7.5 Shear wall at the core with opening

**Table 7.4: No. of hinges in different stages**

Stages`	Base shear (KN)	Displacement (mm)	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP
1	6534.07	18.686	1444	8	0	0	0	1452	0	0
2	22608.6	95.044	770	682	1	0	0	1452	0	0
3	39108.5	176.804	705	747	2	0	0	1452	0	0
4	64817.2	322.37	687	761	0	0	4	1448	2	2
5	76819.1	394.237	683	765	0	0	4	1445	3	4



**Fig 7.14: pushover curve of building with shear wall at the core with opening**

Table 7.4 shows the load resisting capacity and deformation of building in each stage of loading. Pushover curve of the building shows the performance point. The building is found to be safe for a displacement of 52.215 mm and an ultimate load of 19985.8 kN.

## 7.5 Target displacement and ultimate load

**Table 7.5: Target displacement and ultimate load of different models**

	Without shear wall	Shear wall at core	Shear wall at periphery	Shear wall at corner	Shear wall at core with opening	Shear wall at periphery with opening	Shear wall at corner with opening
Target displacement (mm)	92.78	51.427	38.976	48.251	52.215	54.363	50.443
Ultimate load (KN)	8512.64	20081.64	15779.85	18045.05	19985.8	14359.25	16543.31

Table 7.5 shows the target displacement and ultimate load of different models. As the lateral load increases deformation increases. In building without shear wall, even though target displacement is more, ultimate load carrying capacity is less and it fails faster as compared to building with shear wall. The shear wall at the core shows the ultimate load carrying capacity with ultimate load of 20081.64 kN and target displacement of 51.427mm. Load carrying capacity of building without shear wall is far less than the building with shear wall. Opening in shear wall decreases the load carrying capacity in shear wall.

## CHAPTER-8

### INFERENCES AND CONCLUSION

From the study, we could infer that shear wall is one of the most effective building components for mitigating lateral seismic forces. In places that are prone to earthquakes, floating columns that were added to many buildings for aesthetic reasons and parking spaces is hazardous. Pushover analysis, a nonlinear static analysis performed on a shear wall building with a floating column, aids in assessing the building's performance level. This study helps to identify the critical members, storey displacement, storey drift, storey shear and the number of hinges that comes under various acceptance criteria.

From the study following inferences are obtained

- Building with shear wall performs well and could reduce the displacement about 80%
- Building with shear wall at corner shows less displacement as compared to other positions
- Storey shear is found to be greater in building with a shear wall at the corner
- In a building without a shear wall even though target displacement is high, load carrying capacity is found to be low
- Ultimate load carrying capacity is greater for building with a shear wall at the core with a deflection of 51.427mm
- In the last step of pushover analysis, the collapse of building without shear wall occurred on the first floor, which can lead to total collapse of building.
- The collapse of models with shear wall occurred on the upper floor, shows better performance than the building without shear wall.
- In shear wall with opening, shear wall at core shows less displacement than other positions. As the opening increases, the load carrying capacity of the building decreases.
- Shear wall fails prior to structural member, which resist the building from collapse

The study can be extended to linear and nonlinear static analysis of composite column building with floating columns. Pushover analysis of composite column building strengthened by bracings, analysis on steel plate shear wall with floating column is yet to be studied.

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