Study on Dynamic Behaviour of Irregular R.C Framed Structures with Different Location of Shear Walls

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Abstract. In the recent researches it was found to be the most appropriate loads resisting system in recent and present years is shear walls system. In the high rise building shear walls are of the most achievable and hence commonly used lateral load resisting components. It is supplied in building from foundation level to through the height of the building. The scope of the present work is to find the optimum location of the shear walls in plan irregular structures with shear walls such as in I frame, L frame, T frame for different zones in G+17 stories each storey height of 3.2 m, Shear walls are given at corners and at periphery of the building. And also, the outcome of results in seismic zones as per IS CODE 1893(Part1): 2016 has been presented. The seismic analysis performed is linear dynamic response spectrum analysis utilizing the well-known analysis and design software ETABS 18.1.0. Seismic performance of the building has been examined based on specification such as storey displacement, Storey drift, Storey Shear, Base shear, Time period of modes.

Key Words: Shear walls, Irregular plan, Response spectrum, Seismic zones, ETABS.

1. Introduction

1.1. General

India is developing country around the globe; the cities are also growing but due to movements towards city it arises in population addition in most of the cities. In the development it is mandatory to build multi-storied structures, because scarcity of space and by this sort of development work advance will be rapid. By increasing the height of building it becomes capable to resist lateral loads such earthquake and wind loads. Hence, we have to consider the structure protection rather than economy. Multi-storied structures were known for withstanding against the vertical and also lateral loads when analysis and designed with earthquake resisting parameters. By the establishment of shear walls the building become durable, Stable, safe and it increase rigidity for the lateral loads that may be generate
the effect of wind and earthquakes. Shear walls usually begins from the foundation level and continuous throughout the building height. They are basically provided along both length and width of the building and are located at the corners, periphery, and in the form core at lifts. Shear walls can easily execute on the site and which also cost-effective functional technique to minimizing the earthquake injury. Shear walls in multi-storied building it depends on location and thickness of shear walls and type of building constructed and the seismic zones of the building which has been discussed in detailed below.

1.2. Shear walls

The walls in a building, which resist lateral loads origins from the wind or earthquake in plane of the wall along the shear and bending is termed as the shear walls as shown in the Figure 1. Shear walls obtain normally in High rise building, where effect of the wind and seismic forces is mostly. Shear walls are provided because they are in easy in construction, It helps in minimizing the earthquake damage, Large in-plane stiffness, orientation in the direction of strength, Automatically reduces the lateral sway, Installing of shear walls is very easy.

![Figure 1. Shear walls](image)

1.3 Plan irregularities

Building is termed as irregular if the its any one of the conditions is applicable such as

- Torsion irregularities
- Re-entrant corner
- Floor slabs having excessive cut-outs
- Out of the plane offset in vertical elements
- Non parallel forces system

1.3.1. Re-entrant corner

In this project 3 types are considered such as I, L, T these shapes are coming under re-entrant corner type plan irregularity. The Figure 2 shows the L frame of a re-entrant corner. Plan configuration of the structure and lateral load resisting system contain re-entrant corners, while both the projections of the structures beyond the re-entrant corners are more than 15% of its project dimension in the given direction.
2. Objectives

2.1. Objectives of the study

Objectives of the present work is to determine the performance of G+17 Storey building utilizing different irregular plan with shear walls and without shear walls is analyzed in ETABS software using the linear dynamic analysis method.

- Determine the storey displacement, Storey drift, Storey shear, Storey stiffness, Base shear, time period of modes for the models.
- Compare the seismic response of different irregular plan with shear walls and without subjected to lateral load in different zones.
- To identify the suitable irregular plan building with shear walls to resist the seismic loads.
- Finally identify the optimum location of shear walls.

3. Literature review

Tarun Magendra, Abhyuday Titisk, A.A Qureshi (May-Jun 2016) [1]

“Optimum Positioning of shear walls in Multi-storey Buildings” In this paper, A study has been carried out to find the optimum construction framing of a tall building by locating the shear walls in radically. Four different models were created, for G+10 storey structure along with zero eccentricity through the mass center and hardness center. In this they have analyzed using the ETABS software. The seismic loading on the building is as per I S codes. They concluded that Shear walls located at periphery has the greater values of storey shear as compared to other models. Overturing moments are less in normal structures. Finally, they as concluded that building with Box-type Shear wall at the Centre of the geometry is the best framing technique for tall buildings.

Kusuma B (2017) [2]

“Seismic Analysis of a High -rise RC Framed structure with irregularities” In this paper for G+49 stories of RC Framed building having height of each floor 3m, along with irregular floor plan in zone IV for soil type III and the type of analysis is equivalent Static lateral loads. She has analyzed in ETABS (V 13.1) software in the response spectrum method for each irregular and regular building. After analysis of the building a study has done for the response parameters like, Storey displacement, Storey drift, etc. The author has concluded that storey drift is higher in irregular structure when considered to regular building, then story displacement is founded higher in the re-entrant corner building considered to the other irregular building and stiffness in irregular building and re-entrant building decreased when considered with vertical irregular.
Prem Shankar Singh, Jay Kumar Sah, Chinmay Kumar Kundu (2018) [3]

“The Optimum location of the shear wall in irregular plan multi-storey RC frame Structure under lateral load” In this paper for G+19 stories having the height of each storey 3m and shear wall thickness of 300mm for zone V, along with medium type of soil using response spectrum method analysis is done. Analysis is done according to earthquake IS:1893(Part-1), wind loads by the I S:875 (Part-III):1987. They have concluded that the seismic nature of RC frame structure can be increased by lay outing the shear walls which directly decreases storey displacement and storey drift. Increase the strength and stiffness of the building. Irregular plan along the shear walls it gives lesser drift and lesser displacement as considered to irregular plan without shear wall. And finally concluded that the shear wall at the Centre core and corner is the best position.

Jawid Ahmed Tajzadah, Proff A. N Desai, Proff .Vimlesh V. Agrawal (April 2019) [4]

“Optimum Location of shear wall in RC Building” In this paper G+9 stories having the height of 3.5m for the ground level and 3m for the other storey. Building is of square type in Zone V and the shear wall thickness is of 250mm. Analysis is done by utilizing the response spectrum method in ETABS software. Shear wall given at the periphery, inner bays, corners, at the core of building. Finally, they have concluded that the shear wall at building of core has the grater base shear when considered with the other models. Lateral displacement, Storey drift it obeys the permissible limits according to I S codes. The torsional resistance of the buildings provided along with shear walls it acts as the most possible part from Centre of mass of the building. Then they concluded that the inner bays of the buildings are best positioning place.

Sandesh M O, Chetan Gonni S (April 2020) [5]

“A Comparative Study on Behavior of shear walls with and without openings in RC Framed Structure by Dynamic Analysis” In this paper G+13 Stories structure having height of 3m and shear wall thickness of the 300mm. Analysis is done by utilizing the Response spectrum analysis in Zone II by utilizing the ETABS software. Finally, they have concluded that the base shear value for shear walls at the middle is more when considered with the other models, base shear values for equally in the equivalent static analysis and response spectrum analysis. Storey displacement is maximal for regular building in the both the directions and the displacement increases for the successive stories from base to the top storey.

4. Methodology

In this project study has been carried out in two different zones by utilizing different Models having plan irregularities (Re-entrant corners) as per I S Codes.

- Modelling of Multi-storied commercial building is done by utilizing FEM software ETABS.
- Eighteen different models are used owing the different Re-entrant corners.
- I Frame in Zone 5 and Zone 3 for the bare frame, Shear walls at corners and the Shear walls at periphery.
- L Frame in Zone 5 and Zone 3 for the bare frame, Shear walls at corners and the Shear walls at periphery.
- T Frame in Zone 5 and Zone 3 for the bare frame, Shear walls at corners and the Shear walls at periphery.

After Modelling the irregular frames, these frames are analyzed by using two different linear dynamic analysis Method, they are mentioned below.
a) Response Spectrum Analysis
The nature of all the eighteen models is then studied in different zones by changing the seismic zones factor as per IS 1893:2016. Comparison, Interpretation, Validation of the results obtained from different types of analysis and for different zones.

4.1. Model Description
The building composition details considered in this study are listed in Table.1. For the same building composition the ETABS Model details are listed in Table.2. Further the earthquake load details are given in Table.3 respectively.

| Table 1. Building Composition details |
|--------------------------------------|
| **Type of Building** | Commercial |
| **Number of stories** | G+17(18) |
| **Floor to Floor Height** | 3.2m |
| **Height of Building** | 57.6m |
| **Grade of Concrete** | M25 |
| **Grade of Steel** | Fe500 |
| **Thickness of Shear walls** | 250mm |
| **Beam Size** | 300mm*500mm |
| **Base to 9th Storey Column Size** | 850*850mm |
| **9th to 18th Storey Column Size** | 450*600mm |
| **Slab Thickness** | 150mm |
| **Live load** | 3 KN/m2 |
| **Floor Finish** | 1 KN/m2 |

| Table 2. ETABS Model details |
|--------------------------------|
| **Type of Irregularities** | Re-entrant Corner |
| **Plan** | Irregular Plan |
| **R.C.C frames** | I, L, T |
| **Number of Bays in X-Direction** | 11 |
| **Number of Bays in Y- Direction** | 11 |
| **Spacing of bays** | 5m |
| **Shear wall type** | R.C Shear walls |
| **Method of assigning Shear walls** | Uniform reinforcing |

| Table 3. Earthquake Load Details |
|-----------------------------------|
| **Importance Factor** | 1.2 |
| **Response Reduction Factor** | 5 |
| **Seismic Zone factor** | Zone 2: 0.10 |
| | Zone 3: 0.16 |
| | Zone 4: 0.24 |
| | Zone 5: 0.36 |
| **Type of Soil** | Medium |
| **Time Period** | Program Calculated |
5. Results

5.1. Introduction

The project is conducted out in the Finite Element Method software ETABS. In this project performance the analysis is done by utilizing the Equivalent Static Method and Response Spectrum Analysis. On the whole Eighteen Models are prepared by utilizing the various specification like Base Shear, Storey displacement, Storey drift, Storey shear, Storey Stiffness. All the models continued to analyzed for the distinct seismic zones by considering the distinct zone factor. The three irregularity model results are compared with the Zone 3 and Zone 5. The frame models for L-Frame, I-frame, and T-Frame are depicted in Figure 3, Figure 4, and Figure 5 respectively.

**Figure 3. L Frame Models**

**Figure 4. I Frame Models**
5.2. Discussions

SC - Shear walls at Corners
SP - Shear walls at Periphery
BF - Bare Frame

**Base Shear**

![Figure 5. T Frame Models](image)

**Figure 5.** T Frame Models

**Figure 6.** Base Shear of Irregular Buildings

**Base Shear**

Base shear will also be increasing gradually. Base Shear on the irregularities, Structurally the Base Shear depended on the Mass and Stiffness the buildings. A Comparability of base Shear for the Response Spectrum Analysis among all the Models. From the above Chart of the irregular buildings,
from the Figure 6, X-axis specify distinct seismic Zones and Y-axis specify Base Shear for Irregularities.

As well for Zone 3 also the Shear walls at periphery and at corners increased.

Finally, from all the above results of Chart it is observed as the Zone factor increases then the Base Shear too will increase. Base Shear for I, L, T frame Shear walls buildings appropriately shows increments by the above percentages as shown in the frames particularly when considered along the Base Shear of I, L, T Frames of bare frame buildings.

- Base shear will be increasing as the Zone factors increases. For the irregular building R.C frame in Zone-3 is 3450.386 KN and in the Zone-5 is 7763.3688 KN which means that base shear shows increments by 35.70%.
- Bare frame has the lowest base shear when considered with R.C Frame with shear walls.
- L frame has the Highest base shear when compared with the I and T frame, then Zone 3 also it has highest in the L frame.
- Shear walls with corners has the highest base shear in all the R.C frames.

**Storey Displacement**

The Lateral load withstanding structure can limit the extra displacement of building. Storey displacement will also be increasing gradually based on the height of the structure, Storey Displacement in Irregularities, A comparability of Storey displacement for the response spectrum analysis among all the models. From the above chart of irregular buildings, from Figure 7, X-axis specify distinct seismic zones and Y-axis specify storey displacement for irregularities.

| Storey Displacement,mm | I Frame Zone 5 | I Frame Zone 3 | L Frame Zone 5 | L Frame Zone 3 | T Frame Zone 5 | T Frame Zone 3 |
|-------------------------|---------------|---------------|---------------|---------------|---------------|---------------|
| SC                      | 91.193        | 40.74         | 85.897        | 38.315        | 90.493        | 40.27         |
| SP                      | 94.371        | 42.157        | 86.34         | 38.602        | 91.722        | 40.833        |
| BF                      | 106.206       | 45.917        | 107.716       | 47.958        | 104.477       | 46.52         |

**Figure 7.** Storey Displacement of Irregular Buildings

For Zone 5 and Zone 3, also the Shear walls at periphery and at corners decreased and Bare frame is showing increased values. As the stories increased the Displacement also increased along the both the directions. As referred the I S Code bare frame irregular building obey the permissible limits (H/500). Finally, from all the above results of Chart it is observed as the Zone factor increases then the Story displacement will be increased. Storey displacements for I, L, T frame Shear walls buildings
appropriately shows decrements by the above percentages as shown in the frames particularly when considered along the Storey displacement of I, L, T Frames of the bare frame buildings.

- The storey displacement increases with the zone factors from the analysis it has been found Zone 3 to Zone 5 values will show increments.
- The maximum storey displacement appears in the last storey and minimum storey displacement at the starting storey.
- As observed the height of the irregular plan R.C frame buildings increasing, storey displacement will also increase L frame storey displacement shows the reduction in storey displacement as observed it has the least storey displacement.
- I frame has been observed as the higher storey displacement considered with the other R.C frames.
- Shear walls at corners is the optimum location and positioning of shear walls.

L frame is considered as the best R.C. frame with the shear walls at Corners. Because it shows shear walls buildings has decreased by the 19.84%,20.26% individually when considered along the bare frame irregular frame.

**Storey drift**

Proportion of displacement in Height of the floor to two successive floors. Storey drift is evaluated depending on the storey drift separated from the storey height. Storey drift will show increments structurally depending on the height of the structure. And then Zone factor also plays a prime role, as the Zone factor increases the Storey drift will also increases. A Comparability of storey drift for response Spectrum analysis among all the Models. From the above Chart of the irregular buildings, from Figure 8, X-axis specify distinct seismic Zones and Y-axis specify Storey drift Irregularities.

![Storey Drift Chart](image)

**Figure 8.** Storey Drift of Irregular Buildings

As the stories increase the storey drift also shows increments along the both the directions. As referred the I S Code bare frame irregular building obey the permissible limits 0.0004 times storey height. Storey drift will be increasing structurally depending on the height of the structure. But for I, L, T frame the irregular plans at the 9th Storey it will be decreased and at the 10th storey it is increased then again, the curve decreased as Shown in Storey drift of I, L, T frame of Zone 5 and Zone 3. Finally,
from all the above results of chart it is observed as the Zone factor increases then the storey drift will show increments and the decrements at its specific stories. Storey Drift for I, L, T frame Shear walls buildings appropriately shows decrements by the above percentages as shown in the frames particularly along the storey drift of I, L, T Frames of the bare frame.

- The storey drift increases with the zone factors from the analysis it has been found Zone 3 to Zone 5 values will show increments.
- Storey drift will be increasing structurally depending on the height of the structure. But for I, L, T frame the irregular plans at the 9th Storey it will be decreased and at the 10th storey it is increased then again, the curve decreased as Shown in Storey drift of I, L, T frame of Zone 5 and Zone 3.
- L frame storey drift shows the reduction in storey displacement as observed it has the least storey drift.
- Bare frame has been observed as the higher storey drift considerd with the other R.C frames.
- L frame is considered as the best R.C. frame with the shear walls at Corners. Because it shows shear walls buildings has decrements, individually when considered along the bare frame irregular frame.

**Storey Shear**

In the storey shear, we can see the lateral forces on the absolute floor in a given direction. Storey Shear graph will layout the height wise arrangement of storey shear and the lateral loads. Storey shear as observed from of I, L, T frames the storey shear is more in the starting storey and at the ending of stories it is observed decrements. Storey shear in Irregularities, A comparability of storey shear for the response spectrum analysis among all the Models. From the whole Chart of storey shear from Figure 9. X-axis specify distinct seismic Zones and Y-axis specify storey shear for the irregularities.

![Storey Shear Graph](image)

**Figure 9.** Storey Shear of Irregular Buildings

For Zone 5 and Zone 3, also Shear walls at periphery and at corners the Storey shear is increased when considered with the Bare frame. As the stories increased the storey shear along the both the directions will decreased. Finally, from the above results of the chart it is observed as the Zone factor increases then the Storey shear will be increased. Storey shear for the I, L, T frame Shear walls buildings appropriately shows increments by the above percentages as shown in the frames particularly when considered along the storey shear of I, L, T frames of the bare frame buildings.

- I frame storey shear is the lowest of all when considered with the other R.C frames.
• Bare frame has the lowest storey shear when considered along with the other R.C frames.
• L frame has observed the highest storey shear in the shear walls at corners.
• In the starting of stories, it has the high storey shear and at the ending of stories it has the low storey shear.
• As the height of stories increases the storey shear will show decrements. As the Zone factor increases the Storey shear will also be increases respectively.

**Time Period**

A comparability of time period for the response spectrum analysis among all the Models. From the on the Chart of time period from Figure 10, X-axis specify distinct irregular building frames and Y-axis specify time period for the irregularities.

- Natural time period is inversely proportional to the square root of stiffness.
- In the starting Modes it has more time period and then the last modes it has the less time periods.
- In this time period we can see that I frame has the highest time period in the bare frame then for the T frame the time period has the lowest time period in Shear walls at Corners. Because shear wall provided large stiffness to the building so the value of natural time period is decreases.

![Time Period Chart](chart.png)

**Figure 10. Time Period of Irregular Buildings**

### 6. Conclusions

In the project, Response spectrum analysis was accomplished by taking the G+17 storey buildings utilizing different irregular plan with shear walls and without shear walls (Bare frame) is analysed in the ETABS software utilizing the linear dynamic analysis method.

**Base Shear**

- Bare frame has the lowest base shear when considered with R.C Frame with shear walls.
- L frame has the highest base shear when considered with the other R.C frame irregular buildings.
- T frame has the Lowest base shear when considered with the other R.C frame irregular buildings.

**Storey displacement**

- T frame storey displacement shows the reduction in storey displacement as observed it has the least storey displacement, so L frame is considered as the best storey displacement.
The storey displacement increases with the zone factors from the analysis it has been found Zone 3 to Zone 5 values will show increments. As observed the height of the irregular plan R.C frame buildings increasing, storey displacement will also increase spontaneously.

**Storey Drift**

- The storey drift increases with the zone factors from the analysis it has been found Zone 3 to Zone 5 values will show increments in its respective directions.
- Bare frame has the highest storey drift in all the R.C frames.
- Storey drift shows less reduction in the Shear walls at corners so it is recognized as the best storey drift.

**Storey Shear**

- In the staring of stories, it has the high storey shear and at the ending of stories it has the low storey shear.
- I frame storey shear is the lowest of all when considered with the other R.C frames.
- Bare frame has the lowest storey shear when considered along with the other R.C frames.
- L frame has observed the highest storey shear in the shear walls at corners so it is recognized as the best Storey shear frame among all the R.C frames.

**Time Period**

- I bare frame has the highest time period in the R.C framed structures.
- In the Starting modes it has more time period and then the last modes it has the less time periods.

From this project building with the shear walls has proven to be the best choice methods for the R.C frame irregular plans. Shear walls at corners is found as the best optimum location and positioning of shear walls.

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