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Effect of Openings in Shear Wall

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Abstract - *In modern high rise buildings, shear walls are generally used as a vertical structural element for resisting the lateral loads that is induced by the effect of wind and earthquakes. A shear wall may contain many openings due to the functional requirements such as doors and windows, which may largely affect the overall seismic response of the structure. This study is carried out on a seven story frame-shear wall building, using linear elastic analysis, with the help of finite element software ETABS, using time history method. The objective is to study time period, displacement, base shear, storey drift and storey acceleration of shear wall with openings arranged in vertical, horizontal and zigzag manner and by varying percentage of opening in zigzag manner. The comparative results showed that the time period, displacement, base shear, storey drift and storey acceleration and around the openings depend on the arrangement of openings. Finally, the zigzag arrangement of openings in shear walls is suggested to be applied in practice, since it provides comparatively 4% better performance than other arrangement of opening. Also structure with shear wall having openings arranged in zigzag manner having opening area less than 16.67% as compared to shear wall area is founded to be approximately 4% better performance in the base shear, storey displacement, time period, storey drift and storey acceleration than opening area greater than 16.67% as compared to shear wall area*.

Key Words: **Shear Wall, Time history method, ETABS, Openings, Percentage of openings**

1. INTRODUCTION

Shear walls are vertical structural elements for resisting the lateral loads that may be induced by the effect of wind and earthquakes. Shear wall is a structure considered to be one, whose resistance to horizontal loading is provided entirely by them. Introduction of shear walls in a building is a structurally efficient solution to stiffen the building because they provide the necessary lateral strength and stiffness to resist horizontal forces. Shear walls generally start at the foundation level and are continuous throughout the building height. They are generally provided along both length and width of the building and are located at the sides of the buildings or arranged in the form of core. Shear walls may have one or more openings for functional reasons.

The size and location of shear walls is extremely critical. They must be symmetrically located in plan to reduce the effect of twisting in buildings. Properly designed and detailed building with shear wall has shown good performance in past earthquakes. Also the strong earthquakes recorded worldwide in the past have shown that the damages and certain failure mechanisms of shear walls depend on a series of factors such as, the shape in plan, dimensions of the walls and openings, reinforcement and the openings layout, site condition, type of earthquake and strain rates. Even if failure modes have been extensively researched, there are still certain failure modes which have to be investigated further.

Shear walls are generally located at the sides of buildings or arranged in the form of core that houses stairs and lifts. Shear walls in a building is a structurally efficient solution to stiffen the building because they provide the necessary lateral strength and stiffness to resist horizontal forces. They are generally provided along both length and width of the building and are located at the exterior, interior sides of the buildings. Shear walls are vertical structural elements for resisting the lateral loads that may be induced by the effect of wind and earthquakes acting on tall structure. To reduce the effect of earthquake reinforced concrete shear walls are used in the building. These can be used for improving seismic response of buildings. The provision of shear wall in building to achieve rigidity has been found effective and economical. Shear walls are usually used in tall building to avoid collapse of buildings. When shear wall are situated in advantageous positions, they can form an efficient lateral force resisting system.

Shear walls may have one or more openings for functional reasons such as doors, windows, and other types of openings in shear wall. The size and location of openings may vary depending on purposes of the openings. The size and location of shear walls is extremely critical. Properly designed and detailed buildings with shear walls have shown good performance in past earthquakes.

Shear walls in high seismic regions require special detailing. However, in past earthquakes, even buildings with sufficient amount of walls that were not specially detailed for seismic performance (but had enough well distributed reinforcement) were saved from collapse. Shear walls are efficient, both in terms of construction cost and effectiveness in minimizing earthquake damage in structural and nonstructural elements (like glass windows and building contents).

For this study residential type of structure, with G+6 building are considered which one of the frame, with or without opening in shear wall by using finite element software (ETABS) under earthquake loads. Structure with shear wall having no openings and openings arranged in

horizontal, vertical and zigzag manner are used for the study. Time history method is taken for analysis.

1.1 Objectives

The main objectives of this study are

- To analyze the structure using ETABS
- To study the base shear, storey displacement, storey drift, storey acceleration and time period of the building with opening or without opening in shear wall
- To study the behavior in base shear, storey displacement, storey drift, storey acceleration and time period of the structure with shear wall having openings arranged in horizontal, vertical and zigzag manner using time history method and to find the best arrangement of openings
- To study the base shear, storey displacement, storey drift, storey acceleration and time period of best arrangement of opening by varying percentage of opening

2. MODELING AND ANALYSIS OF THE STRUCTURE

In this Project, the model was meshed in order to obtain results with higher accuracy. The earthquake load and load combinations were applied as per IS 1893 – 2002 and the seismic analysis was done by time history method. The model description, preliminary load considered and the seismic data required for the analysis are given in table1, table2, table 3 respectively.

Table -1: Model description

Parameter	Value
No. of storey	7
Floor plan dimension	16x12m
Bays	4x3
Floor height	3m
Thickness of the shear wall	250 mm
Size of beam and column	250x500mm
Thickness of slab	150mm
Grade of beam, column, wall and slab	M25
Opening size	1mx1m

Table -2: Preliminary load considerations

Parameter	Value
Live load	2KN/m²
Floor finish	Typical floor 1KN/m², Top floor 3KN/m²

Table -3: Seismic data required for analysis

Parameter	Value
Seismic zone	V
Zone factor	0.36
Type of soil	Medium
Importance factor	1
Response reduction factor	5

To study the structure with shear wall having openings

2.1 Models used for analysis

Model preparation done by using etab. Structure with shear wall having openings arranged in horizontal, vertical and zigzag manner are prepared and then seven models are created by varying percentage of opening in structure with shear wall having openings arranged in zigzag manner by providing 9%, 10.66%, 11.16%, 16.67%, 18%, 20% and 22% opening. The grid plan, modeling of the structure with shear wall having no openings, modeling of the structure with shear wall having openings arranged in vertical direction, horizontal direction and in zigzag manner are given in fig 1, 2,3, 4, 5 respectively.

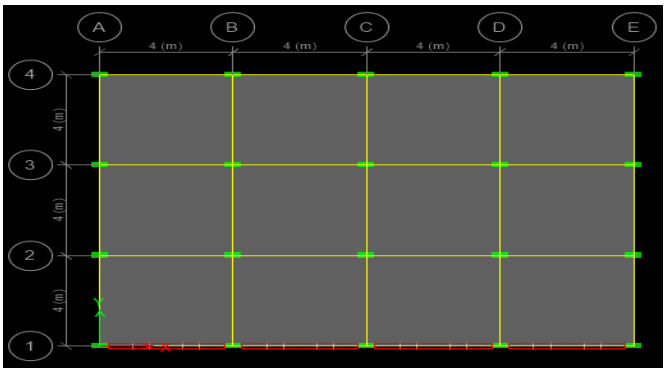

Fig -1: Grid plan

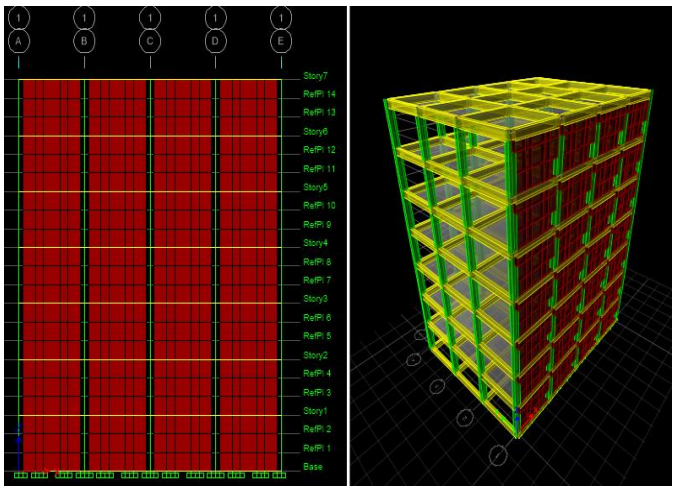

Fig -2: Modeling of structure with shear wall having no openings

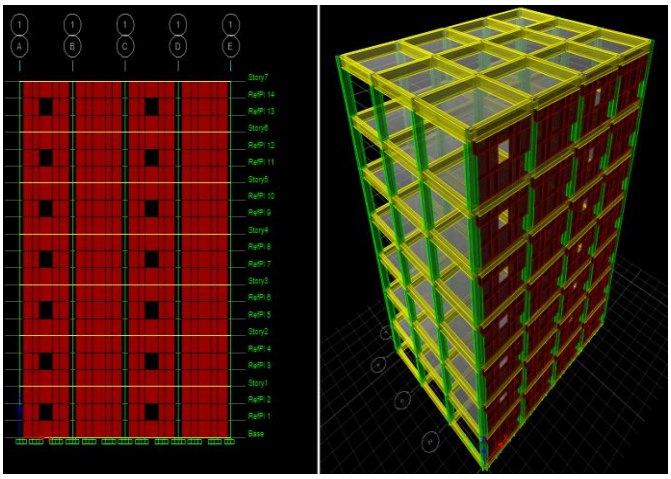

Fig -3: Modeling of structure with shear wall having openings arranged in vertical direction

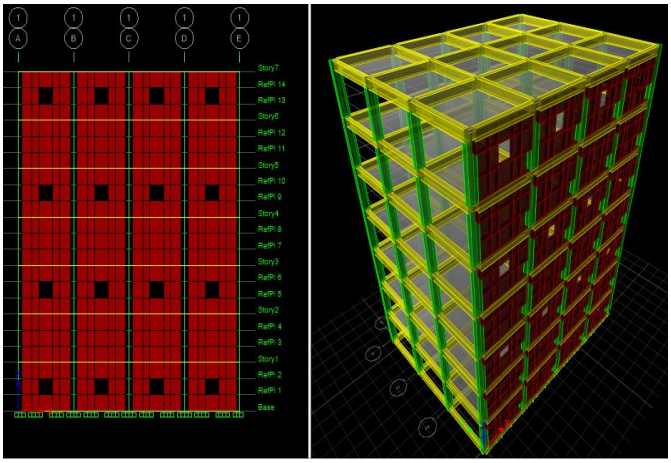

Fig -4: Modeling of structure with shear wall having openings arranged in horizontal direction

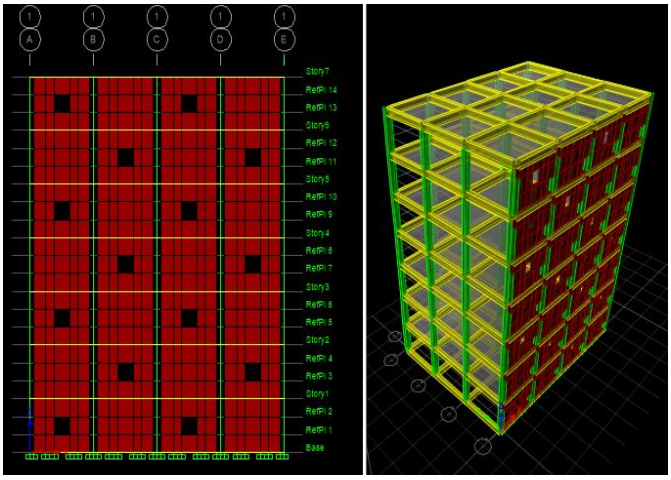

Fig -5: Modeling of structure with shear wall having openings arranged in zigzag manner

2.2 Analysis of the structure

Dynamic analysis is classified as linear dynamic and non linear dynamic analysis. Response spectrum method is the linear dynamic analysis method. In that method the peak response of structure during an earthquake is obtained directly from the earthquake response, but this is quite accurate for structural design applications. Nonlinear dynamic analysis is known as time history analysis. It is an important technique for structural seismic analysis especially when the evaluated structural response is nonlinear. To perform such an analysis, a representative earthquake time history is required for a structure being evaluated. Time history analysis is a step-by step analysis of the dynamic response of a structure to a specified loading that may vary with time. Time history analysis is used to determine the seismic response of a structure under dynamic loading of representative earthquake. In this method of analysis, a selected earthquake motion is applies directly to the base of the structure. For the full duration of the earthquake. Time history record of Sylamar earthquake occurred at California in february 9, 1971 is used for analysis. The magnitude of sylmar earthquake is 6.5 to 6.7 Mw and the peak ground acceleration is 1.25g.

3. RESULTS AND DISCUSSIONS

Structure with shear wall having openings arranged in horizontal, vertical and zigzag manner are prepared and then seven models are created by varying percentage of opening in structure with shear wall having openings arranged in zigzag manner. Models are created by providing 9%, 10.66%, 11.16%, 16.67%, 18%, 20% and 22% opening and results are tabulated based on base shear, storey displacement, storey drift, time period and storey acceleration of the structure.

3.1 Base shear

Base shear for structure with shear wall having openings arranged in different manner and base shear for structure with shear wall having openings arranged in zigzag manner by varying percentage of opening are given in chart 1 and chart 2 respectively.

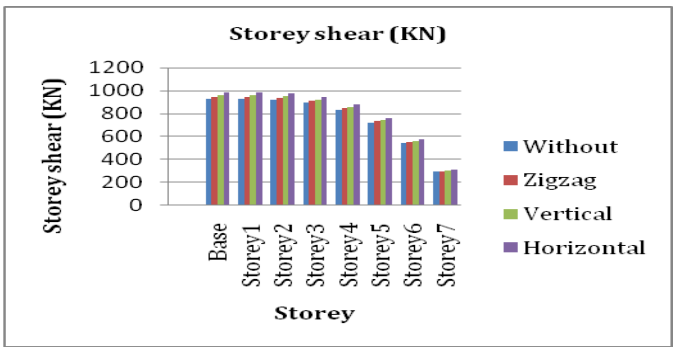

Chart -1: Base shear for structure with shear wall having openings arranged in different manner

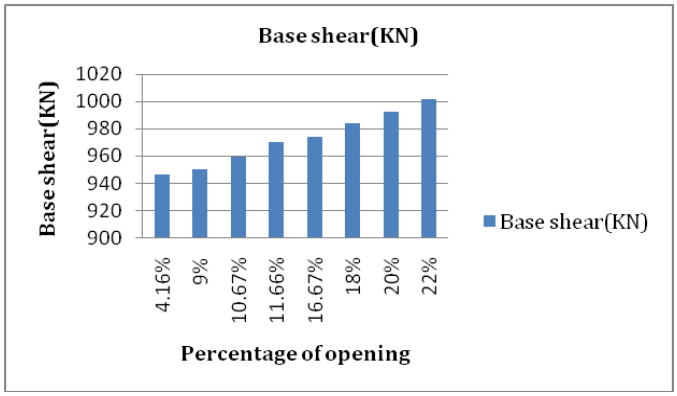

Chart -2: base shear for structure with shear wall having openings arranged in zigzag manner by varying percentage of opening

The base shear is found to be 1.25% lesser for structure with shear wall having openings arranged in zigzag manner when compared to structure with shear wall having openings arranged in vertical direction and 3.67% lesser when compared with openings arranged in horizontal direction. When the percentage of opening is increased from 4.16 to 22%, the structure with shear wall having openings arranged in zigzag manner having opening area less than 16.67% as compared to shear wall area is founded to be approximately 4% better performance in the base shear than opening area greater than 16.67% as compared to shear wall area.

3.2 Storey displacement

The storey displacement for structure with shear wall having openings arranged in different manner and storey displacement for structure with shear wall having openings arranged in zigzag manner by varying percentage of opening are given in chart 3 and chart 4 respectively.

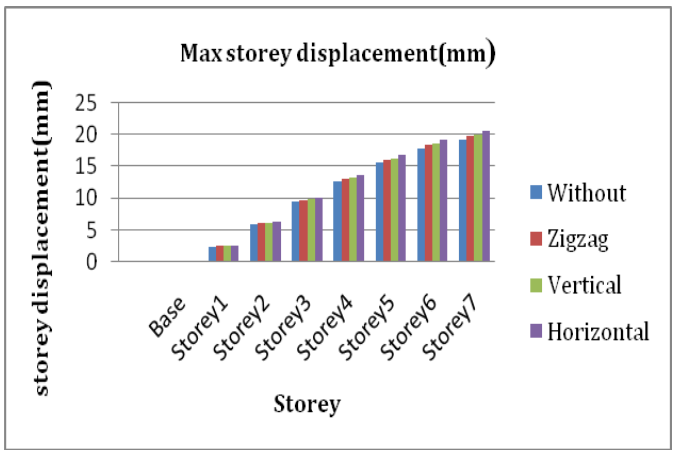

Chart -3: Storey displacement for structure with shear wall having openings arranged in different manner

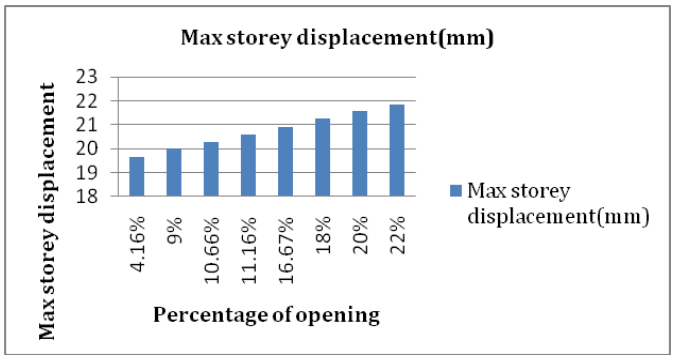

Chart -4: Storey displacement for structure with shear wall having openings arranged in zigzag manner by varying percentage of opening

The structure with shear wall having openings arranged in vertical direction experiences 1.5% higher displacement than openings arranged in zigzag manner and shear wall with openings arranged in horizontal direction experiences 4.5% higher displacement than shear wall with openings arranged in zigzag manner. When the percentage of opening is increased from 4.16 to 22%, the structure with shear wall having openings arranged in zigzag manner having opening area less than 16.67% as compared to shear wall area is founded to be approximately 4% better performance in the storey displacement than opening area greater than 16.67% as compared to shear wall area.

3.3 Storey drift

The storey drift for structure with shear wall having openings arranged in different manner and storey drift for structure with shear wall having openings arranged in zigzag manner by varying percentage of opening are given in chart 5 and chart 6 respectively.

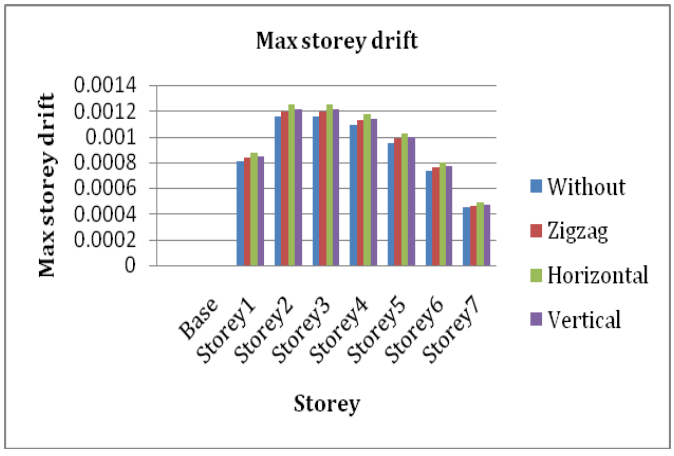

Chart -5: Storey drift for structure with shear wall having openings arranged in different manner

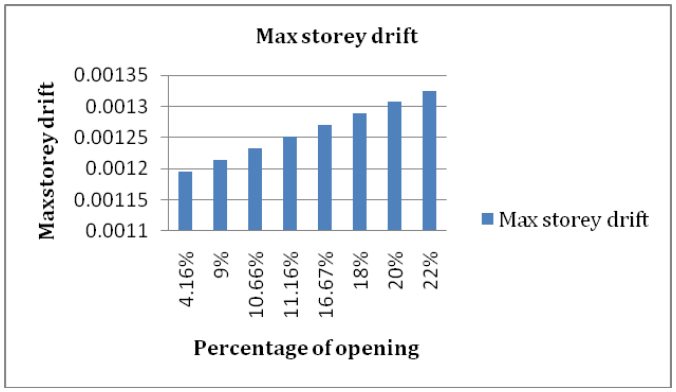

Chart -6: Storey drift for structure with shear wall having openings arranged in zigzag manner by varying percentage of opening

According to IS: 1893 (Part I) - 2002, the story drift for buildings is limited to 0.004 times the story height, which was not exceeded in this analytical study for all the models. In case of story drift, the structure with shear wall having openings arranged in vertical and horizontal direction experiences a storey drift of approximately 4% greater than shear wall with openings arranged in zigzag manner. When the percentage of opening is increased from 4.16 to 22%, the structure with shear wall having openings arranged in zigzag manner having opening area less than 16.67% as compared to shear wall area is founded to be approximately 4% better performance in the storey drift than opening area greater than 16.67% as compared to shear wall area.

3.4 Time period

The time period for structure with shear wall having openings arranged in different manner and time period for structure with shear wall having openings arranged in zigzag manner by varying percentage of opening are given in chart 7 and chart 8 respectively.

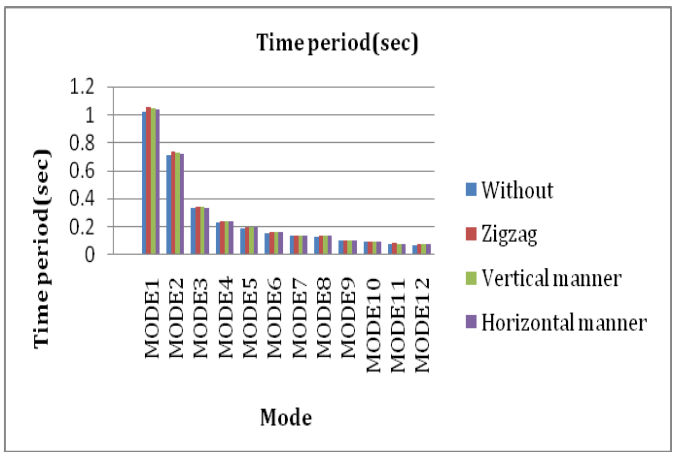

Chart -7: Time period for structure with shear wall having openings arranged in different manner

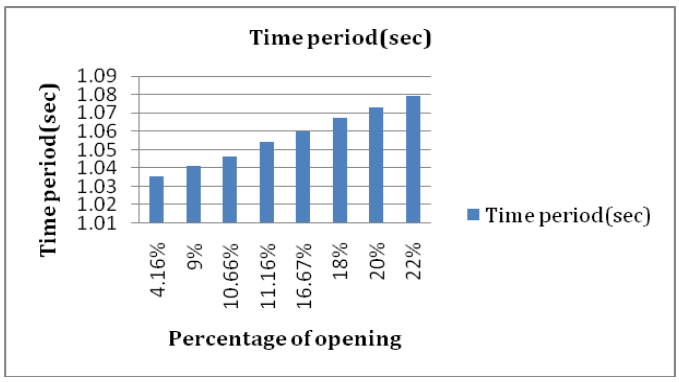

Chart -8: Time period for structure with shear wall having openings arranged in zigzag manner by varying percentage of opening

It can be seen that the structure with shear wall having openings provided in zigzag manner exhibited 1.35% higher value of time period when compared to shear wall with openings arranged in vertical and horizontal manner and approximately 3% higher value of time period when compared to shear wall without opening. When the percentage of opening is increased from 4.16 to 22%, the structure with shear wall having openings arranged in zigzag manner having opening area less than 16.67% as compared to shear wall area is founded to be approximately 4% better performance in the time period than opening area greater than 16.67% as compared to shear wall area.

3.5 Storey acceleration

The storey acceleration for structure with shear wall having openings arranged in different manner and storey acceleration for structure with shear wall having openings arranged in zigzag manner by varying percentage of opening are given in chart 9 and chart 10 respectively.

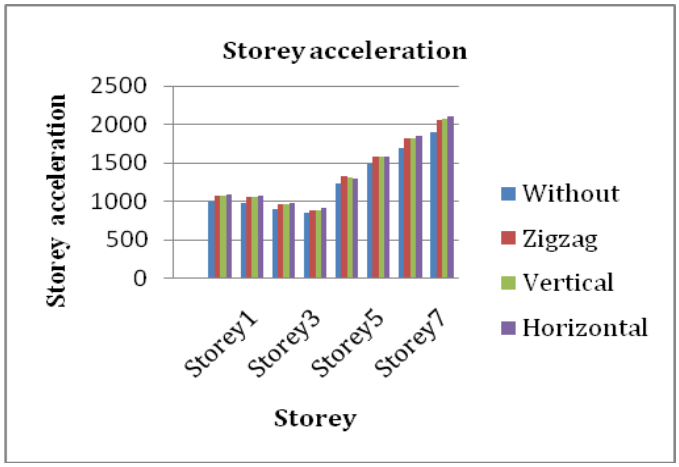

Chart -9: Storey acceleration for structure with shear wall having openings arranged in different manner

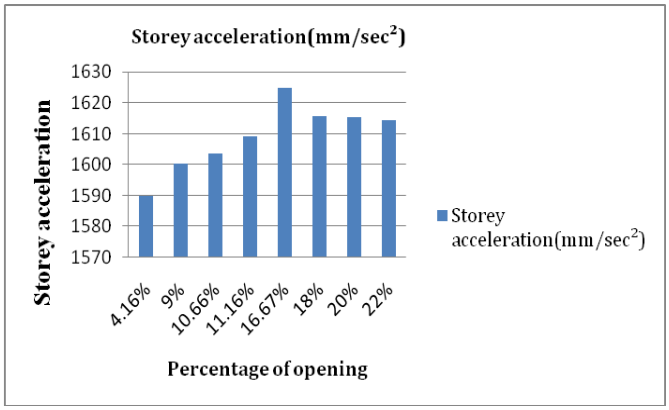

Chart -10: Storey acceleration for structure with shear wall having openings arranged in zigzag manner by varying percentage of opening

It can be seen that the structure with shear wall having openings provided in zigzag manner exhibited 1.5% lesser value of acceleration when compared to shear wall with openings arranged in vertical and horizontal manner and approximately 3% lesser value of acceleration when compared to shear wall without opening. When the percentage of opening is increased from 4.16 to 22%, the structure with shear wall having openings arranged in zigzag manner having opening area less than 16.67% as compared to shear wall area is founded to be approximately 4% better performance in the storey acceleration than opening area greater than 16.67% as compared to shear wall area.

4. CONCLUSIONS

In this study the structure with shear wall having openings arranged in vertical, horizontal and zigzag manner are analyzed by using ETABS software by using time history method of analysis. The results are compared based on the parameters base shear, storey displacement, storey drift, time period and storey acceleration. Also the best arrangement of opening is selected from the analysis and responses of the structure with varying the percentage of openings are studied in terms of the same parameters. Few prominent conclusions are as follows:

- This study reveals that the time period, displacement, drift, base shear and the overall seismic response of the structure is affected by the location of openings in shear wall.
- The base shear is found to be 1.25% lesser for shear wall with openings arranged in zigzag manner when compared to shear wall with openings arranged in vertical direction and 3.67% lesser when compared with openings arranged in horizontal direction.
- The shear wall with openings arranged in vertical direction experiences 1.5% higher displacement

Than openings arranged in zigzag manner and shear wall with openings arranged in horizontal direction experiences 4.5% higher displacement than shear wall with openings arranged in zigzag manner.

- In case of story drift, the shear wall with openings arranged in vertical and horizontal direction experiences a storey drift of approximately 4% greater than shear wall with openings arranged in zigzag manner.
- Shear wall with openings provided in zigzag manner exhibited 1.35% higher value of time period and storey acceleration when compared to shear wall with openings arranged in vertical and horizontal manner and approximately 3% higher value of time period and storey acceleration when compared to shear wall without opening.
- From the comparative study it is founded that the occurrence of storey shear, storey displacement, storey drift and storey acceleration in structure with shear wall having openings arranged in zigzag manner is approximately 4% lesser as compared to vertical and horizontal arrangement of openings.
- When the percentage of opening is increased from 4.16 to 22%, the structure with shear wall having openings arranged in zigzag manner having opening area less than 16.67% as compared to shear wall area is founded to be approximately 4% better performance in the base shear, storey displacement, time period, storey drift and storey acceleration than opening area greater than 16.67% as compared to shear wall area.

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