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Review on Comparative Seismic Study of RC Multistoried Structure with Shear Wall at Different Locations and in Different Seismic Zones

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ABSTRACT:

Earthquake is a major concern for the engineers to give stability to the structures. Properly designed and detailed structures with lateral load resisting component i.e. shear walls, bracings etc have shown very good performance in past earthquakes.

Shear Walls are one of the most commonly adopted lateral load resisting systems. Shear Walls possesses very high in-plane stiffness and strength, this allows them to resist large horizontal, gravity and lateral loads caused by seismic and wind loads. Besides that they also carry gravity loads.

This dissertation work was an attempt towards distinguishing that how introduce a shear wall in a structural system which can make in difference in performance of the structure against seismic disturbance. Most of the structures in India are RC frame, and seismic disturbance are felt every now and then in some or the other part of the country. Hence through this dissertation it was tried to appreciate the effectiveness and role of this small extra structural elements that can protect both life and property, at least for most of the earthquakes In this dissertation work we considered 5 models (with & without shear wall) with G+14 storey & 30m x 30m plan area and comparison has been made for following 3 Parameters namely Base Shear, Storey Shear, Interstorey Drift for ground motion in x direction in all Seismic Zones of India. The Seismic Analysis performed according to IS 1893- 2016 (PART I) by Dynamic Response Spectrum method (RSA) using the well known structural analysis and design software Staad.Pro V8i . This analysis will help in understanding the improvement in seismic resistance through the implementation of shear walls and their ideal location in multi storey structures

Keywords-Shear Wall, Response Spectrum method, Staad.Pro V8i ,Base Shear, Storey Shear, Interstorey Drift

1. INTRODUCTION :

An earthquake is the sudden release of strain energy in the Earth's crust, resulting in waves of shaking that radiate outwards from the earthquake source. When stresses in the crust exceed the strength of the rock, it breaks along lines of weakness, either a pre-existing or new fault plane.

Earthquakes are among the most deadly natural hazards. They strike without warning and many of the Earth's earthquake zones coincide with areas of high population density. When large earthquakes occur in such areas the results can be catastrophic, with terrible loss of human lives and untold economic cost.

The multistoried structures requires a lateral load resisting system to maintain the structural stability against the lateral loads are applied to them. Lateral loads from earthquakes and wind are primarily applied to structures.

1.1 Shear Wall :

- It is one of the easiest and effective lateral load resisting systems.
- Shear wall is a **Solid Continuous Vertical Wall** which extends over the full height of the structure.
- Shear walls are very stiff and they resist loads by bending like a vertical cantilever. They have high in-plane stiffness and strength.
- Shear walls need to the fixed at the base level in order to carry the lateral loads effectively. The thickness and the length of the walls are determined as per the design requirements. Typically, shear walls are constructed as lift core walls and around the staircases.
- Shear walls are usually Reinforced Concrete Structures. But the recent advancements in Structural Engineering made it possible to have Steel, Masonry and also wooden Shear walls.

1.2 Dynamic Analysis Method

The dynamic analysis may be performed by either the Time History Method or by the Response Spectrum Method.

1.3 Response Spectrum Method

1] A Response Spectrum is a plot of the Peak or Steady state Response (displacement, velocity or acceleration) of a series of oscillators of varying natural frequency , that are forced into motion by the same vibration or shock.

2] Response spectrum analysis is a special type of dynamic analysis that uses a graphical representation of the maximum response of a single-degree-of-freedom system to a given earthquake ground motion.

3] The maximum response is plotted against the undamped natural period and for various damping values and can be expressed in terms of maximum absolute acceleration, maximum relative velocity or maximum relative displacement.

4] By using a modal analysis technique, the response spectrum can be applied to a multi-degree-of-freedom system, such as a structure, by combining the responses of its individual modes of vibration.

5] Response spectrum analysis is a convenient and efficient way to perform dynamic analysis, as it does not require the full time history of the ground motion or the structure.

6] However, it also has some drawbacks, such as assuming linear and elastic behavior, ignoring phase differences between modes, and requiring a suitable response spectrum for the design situation.

7] As per IS 1893 :2016 (Part 1), Clause 7.6 "Equivalent static method shall be applicable for regular buildings with height less than 15 m in Seismic Zone II."

8] When building not qualifying for Equivalent static method , then first choice is Response Spectrum Analysis. Though Response Spectrum Analysis is involved it is more rational than Equivalent static method but RSA is not sophisticated as much as Time History Method.

2. PROBLEM STATEMENT

In the present work, G+14 storey structure with 30m x 30m plan area is considered. The analysis of RC multistoried structure has been carried out by using STAAD.PRO software by changing the locations of shear walls in the structure .Seven Different loading conditions as per the Indian Standard code for Design are taken.

Seismic Performance of the structures has been computed and compared based on the Parameters namely Base Shear, Storey Shear, Interstory Drift in STAAD.PRO software.

Shear Wall considered is of 200 mm thickness, and placed along the entire height of the structure. Shear wall has been modeled as rectangular column section by increasing width to 5m i.e., the spacing between two columns.

Table 1 : STRUCTURAL PROPERTIES OF RC STRUCTURE

Specifications	Data
Height of Structure	45 m
Storey Height	3.0 m
Plan Size	30m × 30m
No. of bays along X direction	6
No. of bays along Y direction	6
Bay Length along X direction	5m
Bay Length along Y direction	5m
Concrete grade used	M 30
Steel grade used	Fe 415
Columns Size	0.60m X 0.60m
Beams Size	0.45m X 0.45m

Slab Thickness	0.15m
Shear Wall Thickness	0.20 m
Unit Weight of Concrete	25 kN/m^3
Live Load	3.0 kN/m^3
Dead Load	As per calculations
Zone	II, III, IV,V
Soil Conditions	Medium Soil
Damping Ratio, ζ	5%
Importance Factor, I	1.5
Response reduction factor, R	5

Table 2 : The 5 Structural Model Type

Model	**Structural Model Type**
Model 1 [**M1**]	RC Frame Structure Without Shear Wall
Model 2 [**M2**]	RC Frame Structure With Cross Type Shear Wall at Center of Geometry
Model 3 [**M3**]	RC Frame Structure With Box Type Shear Wall at Center of Geometry
Model 4 [**M4**]	RC Frame Structure With Shear Wall on Periphery at Corner
Model 5[**M5**]	RC Frame Structure With Shear Wall on Periphery at Center

3. RESULTS AND DISCUSSION

Following are the results & comparisons are based on the responses of the bare frame model and the changes in the responses after using shear wall at different locations.

The properties which are compared are

1] Base Shear

2]Peak Storey Shear

3] Inter Storey Drift (both in X and Z direction)

The result of above properties were compared for all five models in all four seismic zones and a conclusion was then drawn.

3.1 Comparison of Base Shear for ground motion in X-direction

- It is clearly seen that for all 5 structural models Base Shear inZone II is very less as compared to different types of zones for same soil because base shear depends on type of zone. Base shear increased from Zone II to Zone V, indicating that the earthquakes in these regions are becoming stronger.
- **In all seismic zones for all 5 structural models**
- Base Shear is increasing from Bare Frame (M1) to Frame with Shear Wall (M2, M3, M4, M5) as the stiffness increase due to increase in the structural rigidity contributed by lateral load resisting elements i.e. shear wall.
- The % increment in Base Shear with respect to M1 for model M2, M3, M4 and M5 respectively is exactly same.
- Model M3 (Box type Shear Wall at Center of Geometry) shows the least Base Shear and model M4 **(**Shear Wall on Periphery at Corner) shows highest Base Shear among all the shear wall cases .
- Model M3 (Box type Shear Wall at Center of Geometry) and M5 (Shear Wall Periphery At Center) have approximately equal Base Shear.
- Increasing order of base shear in all seismic zones

M1< M2< M3≈ M5< M4

- The % increment in Base Shear with respect to M1 is 2.24%, 4.49%, 14.87%, 4.49% for model M2, M3, M4 and M5 respectively in zone II.
- The % increment in Base Shear with respect to M1 is 2.24%, 4.49%, 14.87%, 4.49% for model M2, M3, M4 and M5 respectively in zone III.
- The % increment in Base Shear with respect to M1 is 2.24%, 4.49%, 14.87%, 4.49% for model M2, M3, M4 and M5 respectively in zone IV.
- The % increment in Base Shear with respect to M1 is 2.24%, 4.49%, 14.87%, 4.49% for model M2, M3, M4 and M5 respectively in zone V.

3.2 Comparison of Peak Storey Shear for ground motion in X- direction

- It is clearly seen that Storey Shear increases as we move from zone II to zone V for all 5 structural models indicating that the earthquakes in these regions are becoming stronger.
  - **In all seismic zones for all 5 structural models**
  - The Storey Shear decreases with increase in the height of the storey . Storey shear will be more for lower floors, than the higher floors due to the decrease in weight (DL) when we go from bottom to top floors.
  - The % Variation in Storey Shear with respect to model M1to model M2, M3, M4 and M5 is almost same for particular storey.
  - The variation of minimum value of Storey Shear is not constant. Minimum value of Storey Shear for storey G to 2 is for model M1 , for storey 2 to 9 is for model M2 , for storey 10 is for model M5, for storey 11is again for model M1 and for storey 12 to 14 is for model M 3 .
  - Up to storey 12 Peak Storey Shear value is maximum for model M4. For storey 13 and 14 Peak Storey Shear value is maximum for model M2 and M1respectively.
  - Minimum and Maximum value of Top Storey Shear is for model M3 and M1 respectively.
- In seismic zone II , The % increment in 12th Storey Shear with respect to model M1 is 6.63%,-1.02%, 7.07%,4.47% for model M2, M3, M4 and M5 respectively.
- In seismic zone III , The % increment in 12th Storey Shear with respect to model M1 is 6.63%,-1.02%, 7.07%,4.47% for model M2, M3, M4 and M5 respectively.
- In seismic zone IV , The % increment in 12th Storey Shear with respect to model M1 is 6.63%,-1.02%, 7.07%,4.47% for model M2, M3, M4 and M5 respectively.
- In seismic zone V, The % increment in 12th Storey Shear with respect to model M1 is 6.63%,-1.02%, 7.07%, 4.47% for model M2, M3, M4 and M5 respectively.
- In seismic zone II , The % reduction in Top Storey Shear with respect to model M1 is 5.77%,19.99 %, 16.24 %,10.77 % for model M2, M3, M4 and M5 respectively.
- In seismic zone III , The % reduction in Top Storey Shear with respect to model M1 is 5.75%,19.99%, 16.24%,10.77% for model M2, M3, M4 and M5 respectively.
- In seismic zone IV , The % reduction in Top Storey Shear with respect to model M1 is 5.76%,19.99 %, 16.24%,10.77 % for model M2, M3, M4 and M5 respectively.
- In seismic zone V, The % reduction in Top Storey Shear with respect to model M1 is 5.77%,19.99 %, 16.24%,10.77 % for model M2, M3, M4 and M5 respectively.

3.3 Comparison of Interstorey Drift in X and Z direction for ground motion in X-direction

- By using shear wall in the structure the drift is found to be reduced remarkably as significant amount of increase in the lateral stiffness in all models of shear wall frame (M2, M3, M4, M5) as compared to bare frame (M1).
- Interstorey Drift increases as we move from zone II to zone V for all 5 structural models indicating that the earthquakes in these regions are becoming stronger.
- Interstorey Drift in X-direction is comparatively more than in Z-direction for ground motion in X-direction indicating Drift will be greater in the direction in which the seismic force is applied.
- The Interstorey drift is less in bottom stories, high at the middle stories and finally gradually decreases towards the upper stories.
- After observing all the graphs, it can be generally said that drift is increases from ground storey to second storey than continuous decreases up to upper Storey for both in X and Z direction for all structural model in all seismic zones.

- **In all seismic zones for all 5 structural models**
  - Interstorey Drift in X direction is maximum for model M1 and minimum for model M4.
  - Interstorey Drift in Z direction is maximum for model M1 and minimum for model M5.
  - Interstorey Drift both in X & Z direction is maximum for Bare Frame model (M1) in comparison to Frame with Shear Wall (M2, M3, M4, M5) as the stiffness increase than drift decreases due to increase in the structural rigidity contributed by implementation of shear wall in structural system.
  - The % Variation in Interstorey Drift with respect to base model M1 to shear wall model M2, M3, M4 and M5 is approximately same for particular storey.
  - For Bare Frame model M1 storey drift abruptly increases from base to second storey then decreases gradually up to top storey.
  - The shear walls provision makes structure more stable and resistant to lateral forces. From the graph it is clear that shear walls plays an important role in reducing movement of structure under seismic loads.
  - Decreasing order of storey drift in X- direction when ground motion in X-direction

M1 >M2> M5 >M3> M4

  - Decreasing order of storey drift in Z- direction when ground motion in X-direction

M1 >M2> M3 >M4> M5

- In seismic zone II , The % reduction in Interstorey Drift in X & Z direction for top storey w.r.t. model M1 is 5.61 % & 19.56 % ,53.05 % & 48.79 % , 60.23 % & 74.77 % ,23.87 % & 82.95 % for model M2, M3, M4 and M5 respectively.
- In seismic zone III , The % reduction in Interstorey Drift in X & Z direction for top storey w.r.t. model M1 is 6.08 % & 20.07 % ,43.54 % & 49.11 % , 60.44% & 74.93% ,24.02 % & 83.07 % for model M2, M3, M4 and M5 respectively.
- In seismic zone IV , The % reduction in Interstorey Drift in X & Z direction for top storey w.r.t. model M1 is 6.17 % & 20.17 % ,53.33 % & 49.18 % ,60.48 % & 74.96 % ,23.53 % & 83.1 % for model M2, M3, M4 and M5 respectively.
  - In seismic zone V , The % reduction in Interstorey Drift in X & Z direction for top storey w.r.t. model M1 is 6.18 % & 20.18 % ,53.33 % & 49.18 % , 60.44 % & 74.93 % ,23.53 % & 83.08% for model M2, M3, M4 and M5 respectively.
  - The % reduction in Interstorey Drift in Z-direction for top storey in model M5 w.r.t. model M4 is 32.43% , 32.46 % , 32.45 % & 32.43 % in zone II, III, IV & V respectively.

4.0 LITERATURE REVIEW :

Ashraf M. **et.al in (2008)-** The present work deals with a study of seismic analysis of G+7 RCC frame building with the effect of shear wall (at the periphery of the bulding) in high seismic zone V and the analysis as well as structural modeling is done in using STAAD Pro software. This study includes calculating the seismic base shear , storey shear , maximum nodal displacement and maximum combined (both axial and bending) stresses. Result are then interpreted and compared for the two model ,one without and other with shear wall. It is concluded that shear wall greatly reduces the displacement and stresses arises due to seismic forces.

Anil baral et.al in (2015)- In this paper analysis of 10-storey building which is in zone-V is done. The response of building with different positioning of shear wall is presented using Equivalent static method and Response spectrum method. There are five models of RCC building which are considered which are as respectively- model-1 building without shear wall, model-2 building with shear wall on each side in middle portion, model-3 with corner shear wall extending 3m on each side, model-4 with shear wall at central position and model-5 with corner shear wall extending 1.5m on each side. The software which is used for analysis is ETABS. It has been observed that the fundamental period of vibration is higher in model-1 with no shear wall. The displacement was higher in building model-1 with no shear wall and lower in building model with shear wall at corners. The conclusion showed us that providing shear wall results in better performance of building during earthquakes.

Mr. K. LovaRaju et.al (2015)- This paper deals with non-linear analysis of eight-storey building for zone II, III, IV, V with changing shear wall positions. The analysis has been done by using software package ETABS. The various models of eight-storey building involves- model one with bare frame, and other three models with shear wall at three different positions. It has been concluded that provision of a shear wall influences the seismic performance of structure regarding strength and lateral displacement. Shear wall provision in buildings is advantageous in their seismic performance.

Ashwinkumar B Karnale (2015)- In the present work , analysis of RCC framed building to check and compare effect of providing shear wall in 6 storey building as low rise structure and in 14 storey building as high rise structure at different locations. It has been concluded that for Shear wall at corner L shape is effective location. In low rise (6 storey) building, even providing shear wall at different locations the structural parameters not much affected.

Axay Thapa & Sajal Sarkar (2017) - In this study the main focus is to compare the dynamic responses of frame structure with and without shear wall. Three models are generated with varying height with and without shear wall. G+5, G+10 and G+15 R-C frame models with and without shear walls are generated with varying structural member dimensions according to height. The models are analysed by Static Method and Response Spectrum Method considering seismic zone V in STAAD. Pro V8i. Parameters like lateral displacement, story drift, base shear and mode shapes are determined for all the models (with and without shear walls) by the three methods and are compared and the effectiveness of shear walls is enumerated. Also, comparisons are made based on some studies previously done by the other authors.

Sylviya B & P. Eswaramoorthi (2018) -In the present study, analysis of RCC building has been carried out by changing the locations of shear walls in the building. Also, the effect of variations in seismic zones as per IS codes has been presented. The seismic analysis performed is linear dynamic response spectrum analysis using the well known analysis and design software ETABS16.2.0. Seismic performance of the building has been investigated based on parameters such as storey drift, base shear and storey displacements.

Mukesh Sharma (2018) - This study has been done on G+6 multi-storey building. The modeling has been done using STAAD. Pro software package. The focus of the study is to determine the ideal location of shear walls and seismic performance of multi-storey buildings with and without shear walls which is considered to be situated in Chandigarh region in seismic zone-IV. The design of structure is according to IS 1893 (PART–I):2002. The static analysis is performed in this study. The method used for analysis is Equivalent static method. This study involves modeling different models of multi-storey building with and without shear walls on STAAD. Pro and then comparing the results obtained for base shear, storey shear, storey drift, nodal displacements etc. This will help in proper designing of shear walls and their ideal location in multi-storey buildings.

Anil Kumar B (2020) - In this study, analysis of RCC building has been carried out by changing the locations of1shear walls in the building. Also, the effect of variations in seismic zones as per IS codes has been presented. The seismic analysis performed is dynamic response spectrum method as per IS1893-2016 using the well-known analysis and design software ETABS15.0. Seismic performance of the building has been investigated based on parameters such as time period, storey displacements, storey drift & base shear along both the direction of the structure.From the investigation conclude the shear wall impacts in high rise structural system with respective all seismic zones.

Vijender Singh (2021) - In this study, seven models are considered to have suitable various shear walls arrangements. These models are analyzed for Equivalent Static Analysis and Response Spectrum Analysis with the help of platform ETABS 16.2.1. Both the analysis is carried out under the guidelines of IS: 1893 (Part— 1)-2002 in the form various load combinations. Various parameters such as base shear, fundamental natural time period of vibrations are evaluated on the basis of both methods of analysis and the best arrangement of shear wall is suggested.

5.0 CONCLUSION :

The following conclusions were drawn at the end of the dissertation work :

- Implementation of shear wall in RC structure increase the strength and stiffness of the structures. The response of the structures due to seismic disturbance is affected by shear wall locations, where the presence of shear walls was useful in some places and not very much useful in the other places.
- From the analytical result, it is clearly observed that there was a significant increase in Base Shear, Peak Storey Shear and Interstorey Drift with the change in seismic Zone II to Zone V, which shows that the earthquakes in these areas are getting stronger.
- Base Shear increases in the model with shear wall (M2, M3, M4, M5) when compared to the model without shear wall (M1). Structures having greater stiffness attract greater base shear and vice versa. Base shear in all seismic zones is maximum for model M4 **(**Shear Wall on Periphery at Corner). The % increment in Base Shear in model M4 with respect to base model M1is 14.874 % in all seismic zone.
- The variation of minimum value of Storey Shear is not constant. The maximum storey shear up to 12 storey is for model M4 and the storey shear value for storey 13 and 14 is maximum for model M2 and M1respectively. The % increment in Storey Shear in model M4 for 12th storey with respect to model M1 is 7.069 % which is maximum in comparison to all other shear wall model.
- Model without shear wall (M1) showed higher storey drift, than shear walled-frame models. A significant amount of increase in the lateral stiffness has been also observed in all models of shear wall frame as compared to model M1. Model M4 is most effective in reducing drifts along X- direction and MODEL M5 is most effective in reducing drifts along Z-direction, for ground motions in X -direction. The % reduction in Interstorey Drift in X & Z direction for top storey in model M4 & M5 w.r.t. model M1 is near about 60.5% & 75 % and 24 % & 83% in all seismic zones.
- Shear walls are more effective when located along exterior perimeter of the structure (M4,M5), such a layout increases seismic resistance of the structure.
- Hence from our study model M4 with Shear Wall on Periphery at Corner is more effective and efficient than other structural models so this is the optimum position to place shear walls on a multi storey structures.

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