# Quantificationof Damage Due to Earthquakeon RCC Multistoried Building with Different Shear Wall Locations

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**Abstract**— The quantification of damage to reinforced concrete buildings due to earthquakes has utmost importance in earthquake engineering community. This can be achieved with the help of damage indices like Vulnerability Index. These damage indices evaluate structural stability under seismic loading and quantify local and global structural damage of buildings, subject to base excitations. Shear walls are commonly used as a vertical structural element for resisting the lateral loads that may be induced by the loads due to wind and earthquake. A well designed system of shear wall in building frame improves

**Index Terms**—Performance Range,pushoverAnalysis,SeismicDamage Indices, Shear Wall, Vulnerability Index

## 1INTRODUCTION

The assessment of seismic risk involves the estimation of consequences of an earthquake in the chosen area in terms of the expected damage and loss from a given hazardto given elements at risk. For the risk assessment involves evaluation of seismic hazard, vulnerability of structures, exposure and finally loss estimation·

The seismicvulnerability quantifies the tendency of buildings to be damaged due to specifiedground motions. Different buildings vary in their degree ofvulnerability to earthquake ground motions as a function of geometrical or qualitativecharacteristics (such as height, plandimensions,elevation,configurations, age etc.), andstructural characteristics (such as material of construction, mass, stiffness, quality ofconstruction, strength, intrinsic ductility, state of stress, seismic displacements, non-linearbehaviour parameters and other structural information). Vulnerability assessment thusprovides an important input to seismic risk assessment.

### 1.1 Function of shear wall

Use of shear wall gives a structurally efficient solution to stiffen a building. The main function of shear wall is to increase the rigidity for lateral load resistance in the tall buildings. Shear walls are commonly used as a vertical structural element for resisting the lateral loads that may be induced by the loads due to wind and earthquake. Besides they also carry gravity loads. A well designed system of shear wall in building frame improves seismic performance significantly.

### 1.2 Seismic Damage Indices

The quantification of damage to reinforced concrete buildings due to earthquakes has utmost importance. Seismic damage indices are widely used to predict possible damage. These damage indices have been formulated using response parameters of the structure that are obtained through analytical evaluation of structural response. The damage index typically normalizes the damage on a scale of 0 to 1, where zero represents undamagedstate while unity represents collapse state of the building. The seismic damage indices are used in the field of vulnerability assessment, post earthquake damage assessment, decision regarding retrofitting of structures and performance evaluation of structure.

The damage indices have been classified as local damage indices and global damage indices based on their use in quantifying damage in individual members or entire building, respectively. The damage indices based on member-type model are classified as deformation-based damage indices, energy-based damage indices and combined damage indices.

## 2. NUMERICAL FORMULATION

The increase or the distribution in local hazard can be determined by a Vulnerability Index which is derived from the formation of hinges.

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$$VI_{bldg} = \frac{1.5\sum N_i^c x_i + \sum N_i^h x_i}{\sum N_i^c + \sum N_i^h} \quad (1)$$

Here, $N_i^c$ and $N_i^h$ are the numbers of hinges in columns and beams, respectively, for the ith performance range. $VI_{bldg}$ is a measure of the overall vulnerability of the building. A high value of $VI_{bldg}$ reflects poor performance of the building components (i.e., high risk) as obtained from the pushover analysis.

## 3. NUMERICAL INVESTIGATION

A static pushover analysis using SAP2000 is to be performed on a low-rise 6storey building.3 different models are considered by varying their shear wall location. Plastic hinge formation is one of the primary data analyzed to identify location of the buildingwhere larger potential damage mayoccur. Assigned plastic hinges reach a specifichinge rotation limit and go through different damage states. The weight age factor for various performance ranges are shown in Table 3.1

**Table 3.1 Weightage Factors for Performance Range**

| Serial no. | Performance Range (i) | Weightage Factor (xi) |
|---|---|---|
| 1 | < B | 0 |
| 2 | B-IO | 0.125 |
| 3 | IO-LS | 0.375 |
| 4 | LS-CP | 0.625 |
| 5 | CP-C | 0.875 |
| 6 | C-D,D-E,> E | 1 |



### 3.1 Description of the building

Plan dimension: 29m X 23.5m
Floor height: 3.5m
Thickness of shear wall: 0.2m
Thickness of slab: 0.15m
Beam and Column sizes:
All Beams= 0.23m X 0.4m
All Columns= 0.23m X 0.65m
Concrete mix = M25, M30 Steel = Fe500

3.2 Dead Load [IS 875 (Part1)-1987]

Wall load = 15.3 kN/m

Sunken slab load = 2 kN/m²

Lift slab load = 10 kN/m²

Load due to parapet wall of height 1 m and thickness 10 cm = 2 kN/m

Floor finish = 1kN/m2 3.3 Live Load [IS 875 (Part2)-1987]

For classrooms = 3 kN/m²

For staff room = 2.5 kN/m²

For toilets = 2 kN/m²

For balconies, corridors, stair = 4 kN/m²

For terrace = 1.5kN/m²

## 4. MODELS

Three models are considered by varying the shear wall locations.

Model 1- Shear wall at the centre

Model 2- Shear wall at the outer bay

Model 3 - Shear wall at the corners

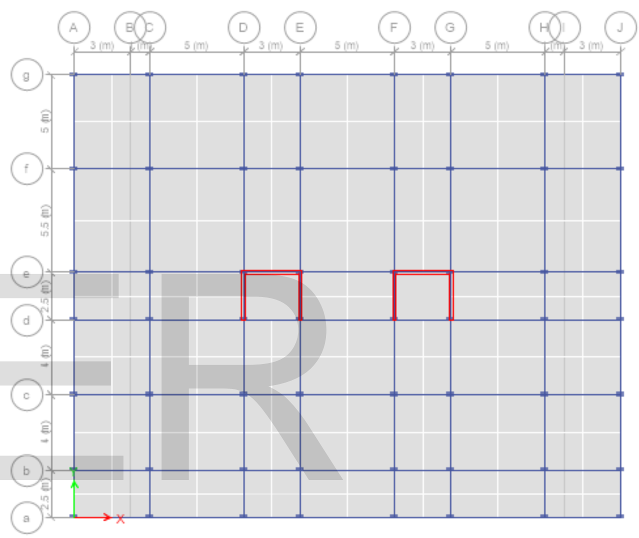


**Fig 4.1 Plan View - Model1**

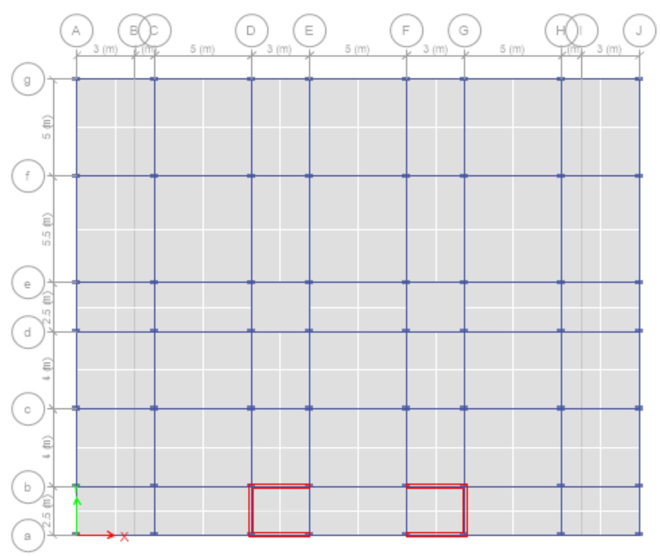


**Fig.4.2 Plan View-Model2**

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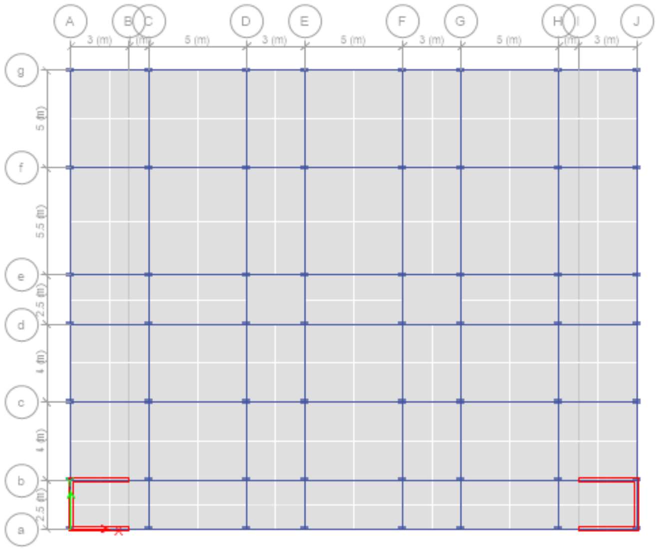


Fig 4.3 Plan View-Model 3

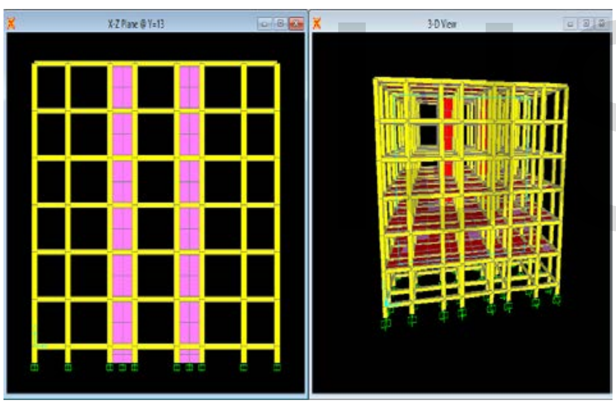


Fig 4.4 3D View- Model 1

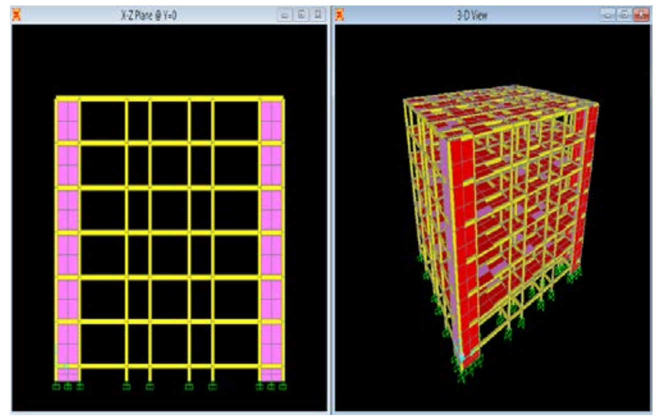


Fig 4.5 3D View-Model 2

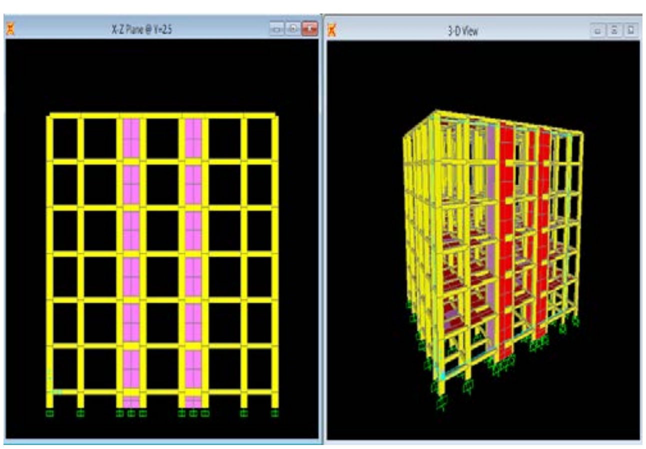


Fig 4.6 3D View-Model 3



## 5. TYPE OF ANALYSIS

Pushover Analysis is performed in SAP 2000.Pushover analysis is one of the methods available for evaluating buildings against earthquake loads. As the namesuggests, a structure is induced incrementally with a lateral loading pattern until a target displacement is reached oruntil the structure reaches a limit state. For this analysis, nonlinear plastic hinges are assigned to all of the primary elements. Default moment hinges (M3-hinges) have been assigned to beam elements and default axial-moment 2-moment 3 hinges (PMM-hinges) have been assigned to column elements. The structure is subjected to the load until some structural members yield.

The model is then modified to account for the reduced stiffness of the building and is once again applied with alateral load until additional members yield. A base shear vs. displacement capacity curve and a plastic hinging modelis produced as the end product of the analysis which gives a general idea of the behaviour of the building.

The building analyzed goes through various performance levels which describes a limiting damage condition for a building. The performance levels are commonly defined as follows:

 Immediate Occupancy IO: Damage is light and structure retains most of its original strength and stiffness. There may be minor cracking on the structural members.

 Life Safety LS: Substantial damage to the structure and the structure may have lost a large portion of itsstrength and stiffness.

 Collapse Prevention CP: Severe damage and little strength and stiffness remains. Building is unstable and isnear collapse.

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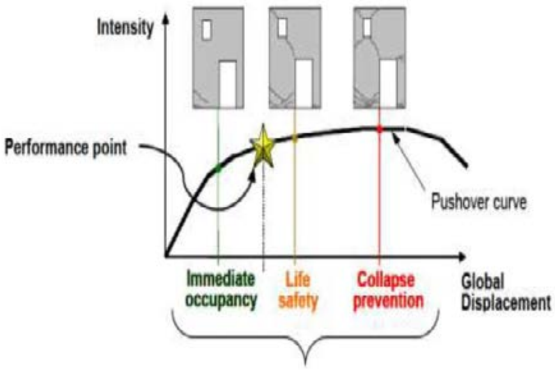



**Fig.5.1 Performance levels**

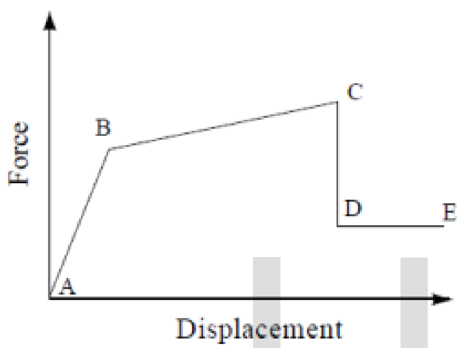



**Fig.5.2 Generalised Force Displacement Characteristics of Frame Element**

In the above figure, Point A shows to unloaded states and point B shows yielding of the element. The ordinate at C corresponds to optimum strength & on x-axis at C it shows the deformation at which significant decrease in strength starts. The line from C to D shows the starting failure of the component/element. The resistance from D to E shows that the frame elements sustain only gravity loads. After point E the maximum deformation occurs.

## 6. RESULTS

### 6.1 General

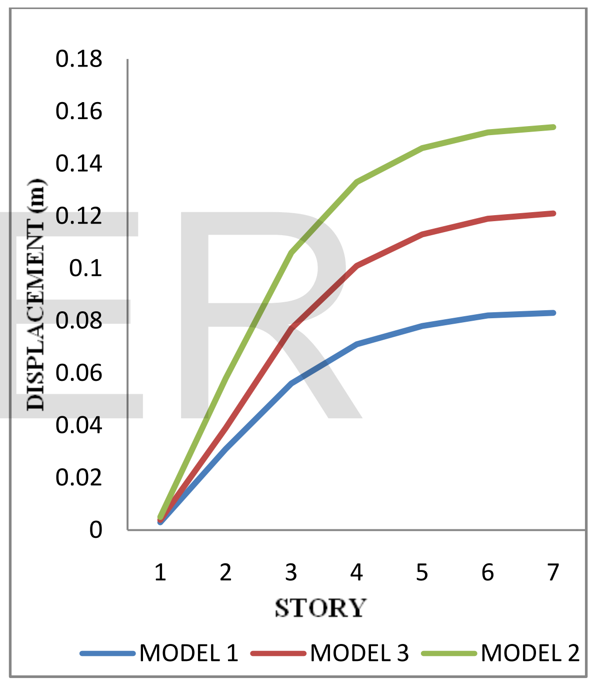
SAP 2000 is used to compute the response of the structures using pushover analysis. Pushover curves and capacity spectrum curve results have been used to observe and compare the displacements of the building at the performance point. Vulnerability Index (VI) is then calculated for the three models using the plastic hinge count obtained after pushover analysis.

### 6.2 Comparison of Base Shear and displacement at Performance Point

**Table 6.1 Base Shear and displacement of Models**

| MODEL | BASE SHEAR (kN) | DISPLACEMENT (m) |
|---|---|---|
| 1 | 5576 | 0.099 |
| 2 | 7073 | 0.102 |
| 3 | 5858 | 0.051 |

### 6.3 Comparison of Story Drift




### 6.4Damage Quantification of Models

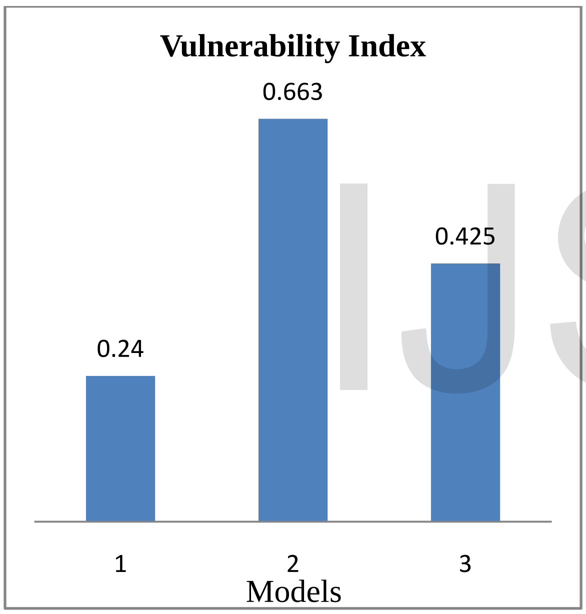
**Table 6.2 Plastic Hinge Count**

| MODEL | MEMBER | B-IO | IO-LS | LS-CP | C-D | D-E | >E |
|---|---|---|---|---|---|---|---|
| 1 | BEAM | 266 | 194 | 2 | _ | _ | _ |
| | COLUMN | 30 | _ | _ | 4 | _ | _ |
| 2 | BEAM | 114 | 150 | 50 | 274 | 54 | _ |
| | COLUMN | 48 | _ | _ | 20 | _ | 2 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| 3 | BEAM | 116 | 283 | 15 | 88 | _ | _ |
| | COLUMN | 35 | 12 | _ | 2 | _ | _ |

This hinge count is substituted in the damage index formula along with their weight age factors and corresponding damage index for the three models are calculated.Vulnerability Index for 3 models are shown in the following chart.

### 6.5 Comparison of Vulnerability Index




## 7. DISCUSSION

The results are plotted to get actual behaviourof the structures and to judge the objectives of study. The results and their significance are discussed here briefly.

From table 6.1 of base shear for the 3 models, itis clear that thebase shear is maximum for model 2 which is having shear wall at outer bay of the structure. Model 1 with shear wall at the core has least base shear.

The graph of story drift reflects that for structure havingcore shear wall (Model 1),the displacement is least. It is maximum for the Model 2.

Damage expressed in terms of Vulnerability Index indicates a higher value for Model 2 and least for Model 1.

## 8. CONCLUSION

Location of shear wall affects the structural parameters significantly. Shear wall located at the centre (Model 1) and corner (Model 3) of the structure gives lesser base shear than the model with shear wall at the outer bay (Model 2).Base shear of Model 2 is 27% higher than Model 1 and 21 % higher than Model 3.Accordingly, VulnerabilityIndex (V.I) of Model 2 is 76.25% higher thanModel 1 and 56% higher than Model 2.Therefore, the best location of shear wall is at the centre and corner of the structure.

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## REFERENCES

[1] Fredrick and Oretaa, "Seismic Vulnerability Assessment of Soft Story Irregular Buildings Using Pushover Analysis", Procedia Engineering, Vol. 125,2015,pp 925 – 932

[2] Olteanu,Barbat,Mihai,"VulnerabilityAssessment of Reinforced Concrete Framed Structures Considering the Effect of Structural Characteristics", The Open Civil Engineering Journal,Vol. 9, 2015, pp 321-329

[3] Ashwinkumar B &Shinde D N (2015)"Seismic Analysis of RCC Building with Shear Wall at Different Locations" Journal of Civil Engineering and Environmental Technology,Vol.2,2015 pp.65-68

[4] Thakur R.S, Patil P.S, Keshav K.S, "Evaluation of Damage Index of High Rise Building Using Nonlinear Static Seismic Analysis",International Journal of Emerging Technology and Advanced Engineering,Vol.2,2012,pp 595-600

[5] Sinha R. &Shiradhonkar S.R, "Seismic Damage Index for Classification of Structural Damage", ISET Journal of Earthquake Technology, Vol. 49, 2012, pp 112- 123

[6] Lakshmanan N., "Seismic Evaluation and Retrofitting of Buildings and Structures", ISET Journal of Earthquake Technology,Vol. 43, 2006, pp. 31-48