# SEISMIC REACTION OF RC FRAMED MASS ECCENTRIC BUILDING

Sudesna Baliarsingha
Department of Civil Engineering, Gandhi Institute for Education & Technology, Khurda, Odisha-752060, India.

**ABSTRACT**

Five reinforced concrete frame structures with various anomalies are used as test cases in this study, and they are all designed using IS codes. These structures are subjected to modal, response spectrum, and push-over analysis, which are compared to regular structures. Shear forces and modal properties of regular buildings cause these structures to behave differently, which is thought to be a major factor in the catastrophic destruction of irregularly planned multi-story buildings during earthquakes. According to the study, the asymmetric buildings demonstrate that the maximum base shear for these various structures is about equal. This is because all of these structures base eras are almost identical. This indicates that the second asymmetric variant building is more acceptable than the first asymmetric variant building in every case examined. The maximum roof displacement results for symmetric building variants are found to be less differentiable with the two asymmetric buildings. Although the code requirement for plan asymmetry buildings suggests altering the size of the buildings or the structures parts, it makes no mention of how eccentricity in the opposite direction as the preceding one might lessen plan asymmetry. For such buildings, altering the stiffness distribution can help lower eccentricity.

**Keywords:** Pushover Analysis, Plastic Hinge, Response Spectrum Analysis, Modal Analysis.

## 1 INTRODUCTION

An earthquake or temblor is a disruption in the earth's strength caused by internal forces that induce vibrations or quavers in the outer layer of the earth. Because earthquakes are unpredictable and catastrophic natural disasters, they create low-to-high waves that vibrate the building's base in different ways and orientations, producing lateral strain on the structure. oscillation In structural systems, vibration—motion that repeats in a regular cycle—occurs as a result of wind, earthquakes, height, and other factors[3][26].

Building damage, collapse and landslides in the case of loose soil, and liquefaction in sandy soil are all caused by earthquakes or temblors, which are caused by movements on the earth's surface that produce multi-level vibrations.

Due to various architectural criteria, asymmetrical or irregular building plans are most appropriate in current construction. The seismic torsional vibration in asymmetric building structures is investigated using the torsional coupling caused by eccentricity between the center of mass (CM) and center of rigidity (CR). The resistive force acts through the center of rigidity and the inertia force acts through the center of mass when the structure is seismically vulnerable [26].

There are no buildings that are perfectly symmetrical or regular. Whether in elevation or layout, every building has an irregular shape. The general rules outlined in design codes, however, are only intended for symmetrical or regular buildings. Design rules prescribe specific design criteria for structures that exhibit vertical irregularities and multiple asymmetries in their plans [7]. Understanding the unique design requirements outlined in building rules for the safe design of irregular buildings is crucial, as is researching how these structures behave. The purpose of this study is to examine mass eccentric structures (which fall under the plan irregularity category) in order to determine how they behave seismically differently from comparable regular buildings.

In this study, a single-story, two-story RC-framed building is examined. Only mass eccentricity is taken into account in this analysis. Here, the building's rigidity eccentricity is regarded as the current work's scope. The asymmetric buildings in this study are determined for unidirectional or unilateral loading, and their eccentricity (mass eccentricity) is only taken into consideration in one direction and is only given in the horizontal direction.

In non-linear structures, only plastic flexural hinges are examined, which accounted for the shear failure caused by flexural failure in all code-designed buildings. The end of the column is regarded as fixed at the support. The reciprocity of soil-structure is not taken into account in this investigation.

## 2 COMPUTATIONAL MODEL

Building modeling entails gathering various load-bearing components. Ideal mass distribution, strength, stiffness, and deformability must all be reflected in the structure. The next section discusses or explains the modeling of the structural components and material attributes used in this investigation.

### 2.1 Material Properties

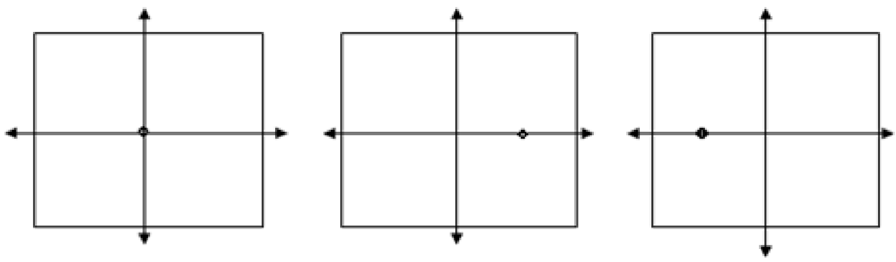
All the frame models having grade of concrete M-25 and grade of reinforcing steel Fe-415 are used in this study. According to Indian Standard IS 456: 2000, the elastic material properties of these materials are taken [9]. The modulus of elasticity (Ec) of concrete is taken as:

$$E_c = 5000\sqrt{f_{ck}}\,\text{MP}a$$

fck is the characteristic compressive strength of concrete cube in MPa at 28-day (25 MPa in this case). For the steel rebar, yield stress (fy) and modulus of elasticity (Es) is taken as per IS 456: 2000.

## 3 BUILDING GEOMETRY

Using IS 1893:2002 (part-1) and IS 456:2000, a single-story, two-story RC-framed building with various irregularities is designed. Each story of the building is the same height, at four meters. In this analysis, all frames and all stories use cross-sections of the structural parts (beams 230×300 mm and columns 300×300 mm). IS 1893:2002 (Part 1) was used to represent the symmetric building variant (SYM), which included eccentricity in the center of the building's plan dimensions. For two asymmetric buildings, eccentricity was achieved by moving the center of masses (CM) by 1.5 meters in both the positive and negative X directions or axis.



(Plan for SYM building) (Plan for ASYM1 building) (Plan for ASYM2 building)

In single storey building, it has been taken two types of buildings, one is regular (SYM) and another is irregular (ASYM). In SYM building, eccentricity is provided at the middle of the structure and in ASYM building, eccentricity is provided in the positive X direction by 1.5 m. In 2-storey building, there are 3 types of buildings are considered. In SYM building, eccentricity is provided at the middle of the structure and in ASYM-1 building, eccentricity is provided in the positive X direction by 1.5 m in all stories. In ASYM-2 building, eccentricity is provided in the positive X direction by 1.5 m in 1st storey and eccentricity is provided in the negative X direction by 1.5 m in 2nd storey.

For each frame the most unfavorable position of the CM is considered. The design is for medium soil (Type II), with a ground acceleration of 0.36g (Zone V) was used. The response reduction factor (R) was taken 3 (ordinary moment resisting frame). In all stories, the storey masses taken as 400 KN. The design base shear was equal to 0.15 times the total weight[12].

## 4 RESULT AND SIMULATION

### 4.1 Modal Analysis

A building's regularity can be observed via modal analysis. The modal characteristics should alter somewhat as a result of the asymmetry. Therefore, the three building models (SYM, ASYM1, and ASYM2) were initially examined in order to determine the changes in elastic modal characteristics. The time period and matching mass participation ratios for the first three modes in the Y-direction are shown in Table 1-4. The main variation between two asymmetric buildings is the design of the reinforcement; otherwise, the mass and stiffness distributions are nearly identical. As a result, the two asymmetric structures' modal characteristics underwent minor modifications. The time durations for all three modes indicate a little decrease in the asymmetric construction versions (Table 1-4). It is discovered that the existence of asymmetry causes the cumulative mass involvement to decline in the first three types. It demonstrates that the augmentation of higher mode is slightly more in the case of asymmetric structures.

It is evident from the tables that the building's elastic modal characteristics do not significantly alter as a result of the asymmetry. Modal analysis is a linear dynamic technique that describes displacement patterns by estimating and evaluating the forms of free-vibration modes. The compositions that a building would naturally upset are explained by mode forms. Lower mode forms often retain the most augmentation to structural response when expressed mathematically.

**Table 1:** Modal Properties of the Single Storey Buildings for first three Modes

| MODE | SYM1 (regular) | | | | ASYM1 (irregular) | | | |
|---|---|---|---|---|---|---|---|---|
| | T(s) | f(Hz) | UY(%) | Sum UY(%) | T(s) | f(Hz) | UY(%) | Sum UY(%) |
| 01 | 0.50 | 1.98 | 100 | 100 | 0.55 | 1.79 | 74.73 | 74.73 |
| 02 | 0.50 | 1.98 | 0 | 100 | 0.50 | 1.98 | 0 | 74.73 |
| 03 | 0.47 | 2.12 | 0 | 100 | 0.40 | 2.48 | 25.263 | 100 |

Bijily B and P. Sarkar[26] have designed a four-storied reinforced concrete frame building with various irregularities and found that there is no modification in the modal properties of the two structures. It has been also found that the translational behavior of SYM building in Y-direction(sum UY%) is not 100% in all modes, but within first three modes it gave 100%. In case of ASYM1 and ASYM2 building, within first three modes it did not give 100%.

From modal analysis of single storey buildings, it has been found that the translational behavior of SYM1 (regular) building in Y-direction (sum UY%) is 100% in all modes but in case of ASYM1 building within first three modes it gives 100%. The time period and frequency of both SYM1 and ASYM1 building are nearly same. So, ASYM1 building will not get severe harm during earthquake.

**Table 2:** Modal Properties of the Two Storey Symmetric Building for important three modes

| MODE | SYM | | | |
|---|---|---|---|---|
| | T(s) | f(Hz) | UY(%) | Sum UY(%) |
| 01 | 1.009 | 0.99 | 87.1 | 87.1 |
| 03 | 0.907 | 1.102 | 0 | 87.1 |
| 04 | 0.286 | 3.493 | 12.56 | 99.66 |

From modal analysis, it has been found that in SYM building, the 1st, 3rd & 4th mode is important and within these three modes it gives 99.66% but in five mode it gives 100%.

**Table 3:** Modal Properties of the Two Storey Asymmetric-1 Building for important three modes

| MODE | ASYM1 | | | |
|---|---|---|---|---|
| | T(s) | f(Hz) | UY(%) | Sum UY(%) |
| 01 | 1.103 | 0.906 | 69.3 | 69.3 |
| 03 | 0.790 | 1.26 | 17.9 | 87.2 |
| 04 | 0.318 | 3.13 | 9.19 | 96.39 |

**Table 4:** Modal Properties of the Two Storey Asymmetric-2 Building for important three modes

| MODE | ASYM2 | | | |
|---|---|---|---|---|
| | T(s) | f(Hz) | UY(%) | Sum UY(%) |
| 01 | 1.063 | 0.94 | 64.9 | 64.9 |
| 03 | 0.849 | 1.177 | 23.7 | 88.6 |
| 04 | 0.295 | 3.38 | 7.5 | 96.1 |

The modal features of a two-story ASYM2 building indicate that the structure's time period is steadily decreasing while its frequency is gradually increasing. It displays the ASYM2 building's deformed shape (translational and rotational) behavior for modes 1 and 3. Likewise, there are other modes with multiple deformed ASYM2 building forms that demonstrate the building's bending, translation in the X-direction, etc. Each mode shape's independent and normalized displacement pattern is amplified and overlaid to produce the final displacement pattern.

### 4.2 Pushover Analysis

Pushover analysis is a nonlinear static analysis in which the magnitude of the lateral force is gradually increased along with the height of the building[28].

By using non-linear static (pushover) analysis, all the three building models were examined. The gravity pushover under displacement control came after the lateral pushover analysis (in the Y-direction). The structures are pushed laterally until they collapse, according to pushover study. The relationship between base shear and roof displacement is derived from the investigation.

Five points A, B, C, D and E are defined the force deflection behavior of the flexural hinge and these points labeled A to B – Elastic state, B to IO- below immediate occupancy, IO to LS – between immediate occupancy and life safety, LS to CP- between life safety to collapse prevention, CP to C – between collapse prevention and ultimate capacity, C to D- between C and residual strength, D to E- between D and collapse, E – collapse[28]. In SAP 2000 those points could be identified by color bands to understand how plastic hinges form in each stage Figure 1 where IO, LS and CP mean immediate occupancy, life safety and collapse prevention respectively.

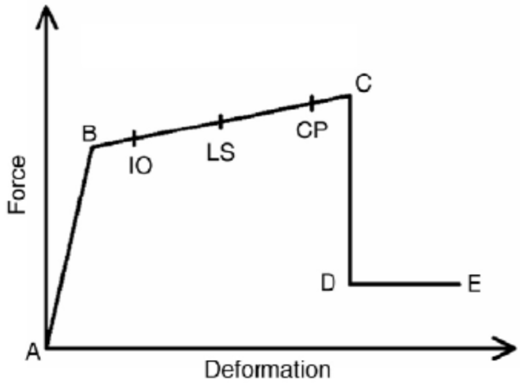



**Fig. 1:** Force-Deformation for Pushover Analysis

Pushover analysis can calculate the behavior of a building, including the ultimate load and the maximum inelastic deflection. At each and every step, the base shear and the roof displacement can be plotted to generate the pushover curve.

Calculation of base shear ( $V_B$ ) depend on soil conditions at the site[12].

Here, Z= Zone Factor, I= Importance Factor, R= Response Reduction Factor, $S_a$/g= Spectral Acceleration Coefficient (It depends on the type of soil)

Calculation of Base shear,

$$V_B = A_h \times W$$

$$= \left[\frac{Z}{2} \times \frac{I}{R} \times \frac{S_a}{g}\right] \times W$$

$$= \left[\frac{0.36}{2} \times \frac{1}{3} \times 2.5\right] \times 400$$

$$= 0.15 \times 400$$

$$= 60 \text{ KN}$$

**Table 8:** Displacement and Base Force values of Two Storey Symmetric Building from Pushover Analysis

| DISPLACEMENT (m) | BASE FORCE (KN) |
|---|---|
| 0 | 0 |
| 0.014142 | 37.474 |
| 0.022059 | 48.41 |

| | |
|---|---|
| 0.032204 | 53.447 |
| 0.064204 | 54.197 |
| 0.096204 | 54.946 |
| 0.128204 | 55.696 |
| 0.160204 | 56.445 |
| 0.192204 | 57.194 |
| 0.211047 | 57.636 |
| 0.22005 | 57.637 |
| 0.252046 | 56.854 |
| 0.284043 | 56.074 |
| 0.291845 | 55.889 |
| 0.319992 | 54.516 |

**Table 9:** Displacement and Base Force values of Two Storey Asymmetric-1 Building from Pushover Analysis

| DISPLACEMENT (m) | BASE FORCE (KN) |
|---|---|
| 0 | 0 |
| 0.013028 | 31.375 |
| 0.020422 | 43.396 |
| 0.025047 | 47.335 |
| 0.029236 | 49.408 |
| 0.039925 | 52.051 |
| 0.071922 | 53.495 |
| 0.103827 | 54.321 |
| 0.13558 | 55.061 |
| 0.167359 | 55.814 |
| 0.19911 | 56.553 |
| 0.206153 | 57.042 |
| 0.219263 | 57.463 |
| 0.228785 | 57.527 |
| 0.233003 | 57.506 |

| | |
|---|---|
| 0.265001 | 56.732 |
| 0.279536 | 56.387 |
| 0.311533 | 55.213 |
| 0.319145 | 54.885 |

**Table 10:** Displacement and Base Force values of Two Storey Asymmetric-2 Building from Pushover Analysis

| DISPLACEMENT (m) | BASE FORCE (KN) |
|---|---|
| 0 | 0 |
| 0.013431 | 33.403 |
| 0.020117 | 43.921 |
| 0.026852 | 50.059 |
| 0.029241 | 51.112 |
| 0.036404 | 52.868 |
| 0.06837 | 53.988 |
| 0.099975 | 53.794 |
| 0.131856 | 55.503 |
| 0.163456 | 55.266 |
| 0.195341 | 57.013 |
| 0.207837 | 57.41 |
| 0.217333 | 57.603 |
| 0.220719 | 57.604 |
| 0.228863 | 57.504 |
| 0.260863 | 56.743 |
| 0.302274 | 55.571 |
| 0.318752 | 54.76 |

The creation of the pushover curve and the computation of displacement from the pushover curve are the two main components of this study. Despite this, the current analysis only produces the capacity curve for the buildings that were chosen [23]. Until the "control node" achieves "target displacement" or the structure collapses, buildings will move or come to an end. Throughout the process, the structural components' failure, plastic hinges, and cracking are seen. The relationship between base shear and displacement for all pushover analyses is shown by the following curve.

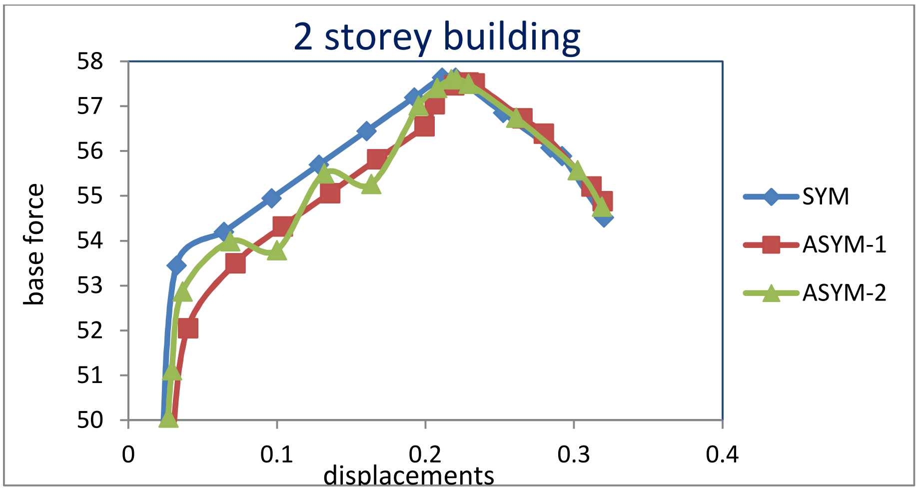



**Figure 2:** Displacement versus Base Force of Two Storey Buildings

In the present study, the figure 2 defines the displacement versus base force curve of two storey building. Here, the seismic vulnerability curve of two asymmetric buildings (ASYM1, ASYM2) compared with symmetric building and found that in between two asymmetric buildings the curve of ASYM2 is nearer to SYM curve that than of ASYM1 and the behavior of ASYM2 is better than ASYM1. Hence, concluded that the seismic vulnerability resisting capacity of ASYM2 is better than ASYM1.

### 4.3 Response Spectrum Analysis

One of the key analysis used in earthquake engineering to monitor how well structures respond during seismic activity is the response spectrum analysis. An elastic structure's maximum seismic response may be determined by measuring the contribution of each vibrational mode using response spectrum analysis, a linear dynamic statistical study. By determining the structure's inherent frequency, one may assess its peak response. With the exception of extremely basic or intricate structures, this is required in many constructions [30]. From the design spectrum and from the modal frequency, modal mass and from the combination of all, the total response of the structure is obtained [31]. In this analysis, the magnitude of forces in all directions is obtained and the corresponding effects on the building is also observed.

**Table 14:** Shear Forces of Two Storey Buildings due to Response Spectrum Analysis

| COLUMNS | SYM (KN) | ASYM1 (KN) | ASYM2 (KN) |
|---|---|---|---|
| 1C1 | 101.38 | 67.16 | 98.05 |

| | | | |
|---|---|---|---|
| 1C2 | 101.38 | 67.16 | 98.05 |
| 1C3 | 101.38 | 112.06 | 87.19 |
| 1C4 | 101.38 | 112.06 | 87.19 |
| 2C1 | 69.89 | 45.89 | 75.68 |
| 2C2 | 69.89 | 45.89 | 75.68 |
| 2C3 | 69.89 | 75.84 | 50.76 |
| 2C4 | 69.89 | 75.84 | 50.76 |

By comparing the shear forces of two-storey building from response spectrum analysis, it has been found that the sum of shear forces of both 1-storey and 2-storey of ASYM2 building is nearer to the SYM building rather than ASYM1 building. So, ASYM2 building is more acceptable building than ASYM1.

## 5 CONCLUSIONS AND FUTURE WORK

### 5.1 Conclusions and Recommendations

The following conclusions are drawn from the present study:

1) Nonlinear static analyses reveals that after design with code provision, the plan asymmetry in the building makes it non-ductile.

2) For both the asymmetric buildings, the base shear – roof displacement curves are found to be similar with translational/rotational shift.

3) From modal analysis, it concluded that for single storey, within 3 modes the irregular building gives 100% of modal participating mass ratio.

4) For two storey it reveals that ASYM2 gives better result than ASYM1.

5) From response spectrum analysis, it concluded that the value of shear forces of ASYM2 is more closer to SYM than ASYM1.

6) The push over curve indicates that the curve of ASYM2 is more preferable than ASYM1.

7) Hence, it concluded that the ASYM2 is more acceptable building than ASYM1.

8) During earthquake, all the building structures will undergo inelastic deformation. So, it will be meaningless if it relate to the design criterion.

9) According to IS 1893:2002 (Part-1), design criterion regarding plan irregularity is not very efficient.

10) Code criterion for plan asymmetry recommends that changing in the size of members of the structure or in the building but it has not mentioned that by giving eccentricity in opposite direction of the previous one, it can reduce the plan asymmetry or it does not look for changing the stiffness distribution of the building. To reduce eccentricity, change in the stiffness distribution can be very useful for such buildings.

**5.2 Scope for Future Work**

1) The present study is based on a case study of a single storeyed and two-storeyed RC framed building. Only mass eccentricity is considered in the present study. This research can be developed by considering stiffness eccentricity of building. Also this study can be developed by changing the height and plan dimensions of the building.

2) In the present research, eccentricity is considered only in one direction but it can be extended by considering various possible eccentricities.

3) In this study, mass eccentricity is taken only in one direction or eccentricity is provided only in the horizontal directions of the asymmetric buildings. Therefore, there is a chance of evaluating building models by considering bi-directional eccentricity.

4) The reciprocity of soil-structure can be considered for such asymmetric buildings.

**REFERENCES**

[1] H. M. Irvine and G. E. Kountouris, Peak Ductility Demands in Simple Torsionally Unbalanced Building Models Subjected to Earthquake Excitation, Proceedings of 7th World Conference on Earthquake Engineering, Istanbul, 4(0), 117- 120 (1980).

[2] C. L. Kan and A. K. Chopra, Simple Model for Earthquake Response Studies of Torsionally Coupled Buildings, Journal of Engineering Mechanics Division, ASCE, 107(EM5), 935-951 (1981).

[3] C. L. Kan and A. K. Chopra, Torsional Coupling and Earthquake Responses of Simple Elastic and Inelastic Systems, Journal of Structural Division, ASCE, 107(ST8), 1569-1588 (1981).

[4] M. Bahrain Shahrooz and P. Jack Moehle, Seismic Response And Design of Setback Buildings, Journal of Structural Engineering, Vol. 116, No. 5, May, 1990 1423-1439.

[5] Sadek, A. W. Sobaih and H. S. Esmail, Approximate Seismic Analysis of Inelastic Asymmetric Structures, Engineering Structures, 14(1), 49-62 (1992).

[6] IS:13920, Indian Standard Code of Practice for Ductile Detailing of Reinforced Concrete Structure Subjected to Seismic Forces, Bureau of Indian Standards, New Delhi (1993).

[7] Valmundsson and Nau, Seismic Response of Building Frames with Vertical Structural Irregularities, Journal of structural engineering, 123:30-41 (1997).

[8] E.V. Valmundsson and J.M. Nau, Seismic Response of Building Frames with Vertical Structural Irregularities, Journal of Structural Engineering - ASCE 123(1): 30–41 (1997).

[9] IS:456 (Fourth Revision), Indian standard code for practice for plain reinforced concrete for general building construction, Bureau of Indian Standards, New Delhi (2000).

[10] A.M. Mwafy and S.A. Elnashai, Static Pushover verse dynamic-to-collapse analysis of RC buildings, Engineering Seismology and Earthquake Engineering Section, Imperial College of Science, Technology and Medicine. Report No. 00/1 (2000).

[11] FEMA 356, Prestandard and Commentary for the seismic Rehabitation of buildings, American Society of Civil Engineers, USA (2000).

[12] IS:1893 Part 1, Indian Standard Criteria for Earthquake Resistant Design of Structures, Bureau of Indian Standards, New Delhi (2002).

[13] M. De Stefano and B.L. Pintucchi, Effects of asymmetric distribution of axial forces in vertical resisting elements, Pacific conference on Earthquake Engineering (2003).

[14] FEMA 450, NEHRP recommended provisions for seismic regulations for new buildings and other structures (part 1: provisions), Building Seismic Safety Council(BSSC), Washington D.C., USA (2003).

[15] Poncet and Tremblay, Influence of mass irregularity on the seismic design and performance of multi-story braced steel frames, 13th World Conference on Earthquake Engineering, Vancouver, B.C., Canada, Paper No. 2896 (2004).

[16] Pradeep Kumar and D. K. Paul, Force Deformation Behavior of Isolation Bearings, Journal of Bridge Engineering, ASCE, 12(4), pp 527529 (2007).

[17] A. D Ambrisi, M. De Stefano and S. Viti, Seismic Performance of Irregular 3D RC Frames, The 14th World Conference on Earthquake Engineering (2008).

[18] M. Hashemi Yekani, A.S.Moghadam, M. Ziyaeifar and M.Hosseini, The method for control and reduction of torsion with base isolation, The 14th World Conference on Earthquake Engineering, 2008, Beijing, China.

[19] S.N Khante and Lavkesh R.Wankhade, Study of seismic response of symmetric and asymmetric base isolated building with mass asymmetry in plan, International Journal of Civil and Structural Engineering, ISSN 0976 – 4399, Volume X, No X, 2010.

[20] P. Sarkar, A. Prasad Meher and Devdas Menon, Vertical geometric irregularity in stepped building frames, Engineering Structures 32 (2010) 2175–2182.

[21] Bijily B and P. Sarkar, Seismic evaluation of asymmetric RC buildings designed in accordance with IS-1893: 2002, Proceedings of International Conference on Advances in Materials and Techniques for Infrastructure Development, September 28-30, 2011, NIT Calicut, India.

[22] S. Varadharajan, V. K. Sehgal and Babita Saini, Seismic response of multistory reinforced concrete frame with vertical mass and stiffness irregularities, Available : (wileyonlinelibrary.com/journal/tal) (2012).

[23] S. Varadharajan, V. K. Sehgal and Babita Saini, Seismic response of multistory reinforced concrete frame with vertical mass and stiffness irregularities by codal provision, Available : (wileyonlinelibrary.com/journal/tal) (2012).

[24] MH. Tsai, A performance-based design approach for retrofitting regular building frames with steel braces against sudden column loss, Journal of Constructional Steel Research - Elsevier 77: 1–11 (2012).

[25] Rebecca L. Johnson, Theory of Response Spectrum Analysis, Available : (wileyonlinelibrary.com/journal/tal) (2012).

[26] Bijily B and P. Sarkar, Critical evaluation of torsional provisions in design codes, Fourth International conference on structural stability and dynamics, Jan 4-6, 2012, MNIT Jaipur, India.

[27] A. E. Hassaballa, Fathelrahman M. Adam. and M. A. Ismaeil, Seismic analysis of a reinforced concrete building by response spectrum method, IOSR Journal of Engineering (IOSRJEN), e-ISSN: 2250-3021, p-ISSN: 2278-8719, Vol. 3, Issue 9 (2013).

[28] Yousuf Dinar, Md. Imam Hossain and Rajib Kumar Biswas, Descriptive study of pushover analysis in RCC structures of rigid joint, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), e-ISSN: 2278-1684, p-ISSN: 2320-334X, Volume 11, Issue 1 (2014).

[29] N. Anvesh, Dr. Shaik Yajdani and K. Pavan kumar, Effect of mass irregularity on reinforced concrete structure using Etabs, International Journal of Innovative Research in Science, Engineering and Technology, ISSN 2319-8753, Volume 4, Issue 10 (2015).

[30] Ajay Singh Gulshan and Poonam Dhiman, Response spectrum analysis of response of building with setbacks, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), e-ISSN: 2278-1684, p-ISSN: 2320–334X (2016).

[31] Jaya Rajkumar Ramchandani and Madhuri Nilesh Mangulkar, Comparison between different shapes of structure by response spectrum method of dynamic analysis, Open Journal of Civil Engineering, 2016, 6, 131-138.

[32] Aarti Baburao Rampure and Madhuri Nilesh Mangulkar, Comparison between response spectrum and time history method of dynamic analysis of concrete gravity dam, Open Journal of Civil Engineering, 2016, 6, 329-334.