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# Seismic Response of Multistory Building for Discontinuity in Columns

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***Abstract:***-- **In present scenario, multi-storey buildings in urban cities are designed with various levels of irregularities in accordance with shortage of space, population and also for aesthetic and functional requirements. Irregular structures come into existence due to Plan and vertical irregularities. Criteria and limits specified for these irregularities as defined by codes of practice (IS1893 (Part-1):2016) have been discussed briefly. One of the vertical irregularities is due to discontinuity of columns. In the present study, effects of the structural irregularity which is produced by the discontinuity of a columns such as floating column, setback column e.t.c in RC frames subjected to seismic loads was investigated. The effect of earthquake forces on various building models for various parameters is proposed to be carried out with the help of Nonlinear Time History analysis methods. Models of the frame are developed by using ETABS softwarefor G+9 multi-storey RC buildings with and without discontinuity in columnsto carry out comparative study of structural parameters such as storey drift, storey shear andlateral stiffnessunder seismic excitation.Furtherfrom the study, it was concluded that building with discontinuity in column performed poorly under seismic excitation as various structural parameter exceed limit value describe by code at some specific point of time.**

**Index Terms: Discontinuity in columns, Seismic Response, Time history analysis, ETABS etc.**

## I. INTRODUCTION

Earthquakes in different parts of the world demonstrated the hazardous consequences and vulnerability of inadequate structures. A large portion of India is susceptible to earthquake. Hence, it is necessary to take into account the seismic load for the design of structures. In buildings the lateral loads due to earthquake are matter of concern. These lateral forces can produce critical stresses in the structure, induce undesirable stresses in the structure, induce undesirable vibrations or cause excessive lateral sway of the structure. Most of the structural systems are designed having various level irregularities in accordance with shortage of space, population and also for aesthetic and functional requirements. Irregular structures come into existence due to irregularity in mass, vertical geometric irregularity and due to asymmetric geometrical configuration on plane. The damage caused due to vertical irregularity is predominant in structure while earthquake excitation, these forces developed at different floor levels in building need to be brought down along the vertical member to foundation level by the shortest path, any deviation or discontinuity such as floating columns results in poor performance of building.However, seismic codes suggest to avoid all type of discontinues produce by structural system because of unusual seismic behavior and additional seismic demands require for the irregular structure. In some cases seismic codes provide empirical rules for dealing with additional seismic demands required due to structural irregularity. In most of the cases empirical rules require an increase in the structural capacity of the elements which produces the irregularity and those of the structural elements in its neighborhood.

### A. Sesmic code criteria for vertical irregularities in building

In the Indian Standard Criteria for Earthquake Resistant Design of Structures IS 1893 (Part 1)-2016, irregular configuration of buildings due to vertical irregularity have been listed into seven types. They

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are: stiffness irregularity, mass irregularity, vertical geometric irregularity, in-plane discontinuity in vertical elements resisting lateral force, strength irregularity, floating or stub column and irregular modes of oscillation in two principal plan direction.As per IS 1893 (Part 1)-2016), a structure is defined to be vertical irregular ifany one of the condition for mass, stiffness, strength, geometry e.t.c between adjacent stories exceeds a minimum prescribed value describe in the code. These values (such as storey lateral stiffness less than storey above for soft story, 150% for mass irregularity, 125% for vertical geometric irregularity). Further, various building codes suggest that irregular structureshould be analyze by dynamicanalysis (such as nonlinear time history analysis or Response-spectrum analysis) to come up with design lateral force distribution.

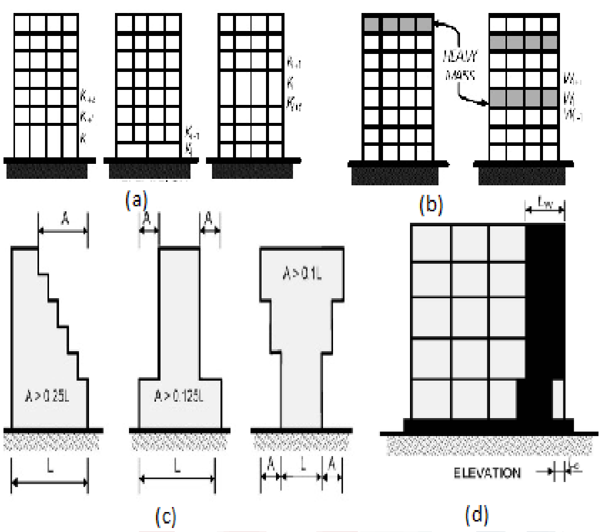


*Figure 1: (a)Stiffness/strength irregularity; (b) Mass irregularity; (c) Vertical geometric irregularity; (d) in-plane discontinuity invertical elements resisting lateral force*

**B.Discontinuities in columns**

Irregularity in structural are defined in plan and in elevation. One of the vertical irregularities is discontinuity in columns and shear walls.A column is a vertical member starting from foundation level to height of structure and transferring the load to the ground. The term floating column is vertical element which (due to architectural design/ site situation) at its lower level (termination Level) rests on a beam. The beam in turn transfers load to the column below it, thus load transfer path in the discontinuous frame changes from vertical to horizontal.Such columns are called *floating columns*. There are many projects in which floating columns are adopted, especially above the ground floor, so that more open space is available in the ground floor. These open spaces may be required for assembly hall or parking purpose.When a column is pushed out of the vertical line in a lower storey, the forces carried by the upper portion of the column have to bend at the setback location to continue towards the foundation such columns are called *setback columns*. Presence of a setback column also leads to poor building performance in an earthquake; brittle damage is expected in beam-column joints and beams adjoining the setback location.Floating or setback columns are adopted to increase the built up area on the floor.

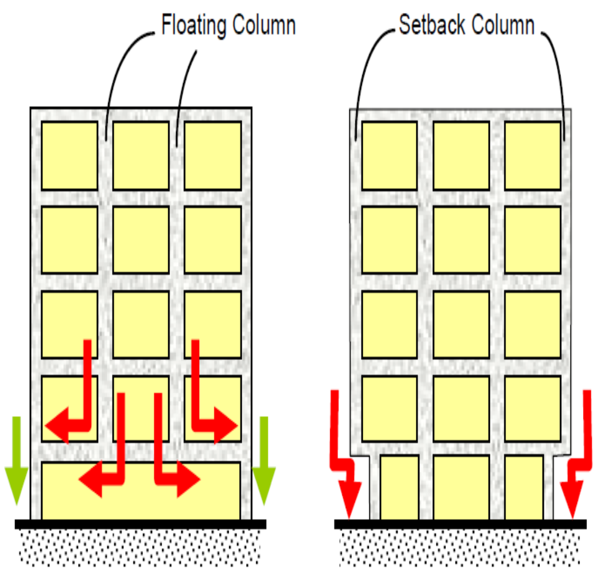


***Figure 2: (a) floating column: the column is discontinued at a lower level, and (b) set-back column: the column is moved out of plumb***

## II.LITERATURE REVIEW

The various literatures have been referred from journals, preceding, books etc to understand present status of project undertaken. Vertical irregularities are characterized by vertical discontinuities in the distribution of mass, stiffness and strength. Very few research studies have been carried out to evaluate the effects of discontinuities in each one of these quantities independently, and majority of the studies have focused on the elastic response. **Devesh P. Soni**[12] summarizes state-of-the-art knowledge in the seismic response of vertically irregular building frames. A review of studies on the seismic behavior of vertically irregular structures along with their findings has been presented. **N. Kara**[10]study effects of the structural irregularity which is produced by the discontinuity of a column in a plane frame subjected to seismic loads including the gravity loads is investigated. Investigation is carried out by adopting the linear and the nonlinear static and dynamic analyses of the structural system such as, the pushover analysis and the analysis in the time domain by considering various seismic records compatible with the spectrum provided in the Turkish seismic code.**Sukumar Behera**[13]represented stiffness balance of first storey and the storey above are studied to reduce irregularity occurs due to presence floating column. To study response of structures under different earthquake excitation having different frequency content keeping the PGA and time duration factor constant they develop FEM codes for 2D frames with and without floating column. The behavior of building frame with and without floating column is studied under static load, free vibration and forced vibration condition. The finite element code has been developed in MATLAB platform. **Isha Rohilla**[6]made assessments for the critical position of floating column in vertically irregular buildings for G+5 and G+7 RC buildings for zone II and zone V. Also the effect of size of beams and columns carrying the load of floating column has been assessed.**M. Pavan Kumar**[11]determined the effects of the structural irregularity which is produced by the discontinuity of a columns in RC space frames subjected to different wind loads was investigated. Investigation was carried out for R.C space frames, with and without vertical discontinuity of columns for G+5, G+10 & G+15 storeys, assumed to be located in different wind zones in India. Both regular and irregular structures were analyzed using STAADPro.

## III.OBJECTIVES OF WORK

The major objectives of the work are as follows.

1. To study the behavior of multi-storied buildings with vertical discontinuity of columns under earthquake excitations.
2. To carry out nonlinear time history analyses using ETABSsoftware.
3. To study the structural response of the building models with respect to following aspects i.e storey drift, storey shear and lateralstiffness.
4. To find whether the structure is safe or unsafe with vertical discontinuity in column when built in seismically active areas.

## IV.METHODOLOGY

Some buildings may be too complex to rely on the nonlinear static procedure. Those cases may require time history analysis of the nonlinear behaviour of the structure during analysis for a particular example of earthquake. The kinds of the buildings that may require this specialized analysis are highly irregular or complicated.

### A.Time history analysis

This method calculates response of structure subjected to earthquake excitation at every instant of time. Various seismic data are to carry out the seismic analysis i.e. acceleration, velocity, displacement data etc. which can be easily procured from seismograph data's analysis for any particular earthquake. This method is performed using time histories prepared according to the actual ground motions recorded. The requirements for the mathematical model for time history analysis are identical to those developed for response spectrum analysis. The damping matrix associated with the mathematical model shall reflect the damping inherent in the structure deformation levels less than the yield deformation.Nonlinear dynamic time-history analysis is often used if a high degree of accuracy is required.

## V.MODELLING OF BUILDING

For this study, 10-story building with a 3.25-meters height for each story, regular in plan is modeled. These buildings were designed in compliance to the Indian Code of Practice for Seismic Resistant Design of Buildings. The buildings are assumed to be fixed at the base. The sections of structural elements are square and rectangular. Storey heights of buildings are assumed to be constant including the ground storey. The buildings are modeled using software ETABS. Three different models were studied with different positioning discontinuity of column in building.

**Table 1: Building description**

| | | |
|---|---|---|
| 1 | Zone | IV |
| 2 | Type of structure | (SMRF) |
| 3 | Number of Stories | G+9 |
| 4 | Floor-to-floor height | 3.25 m |
| 5 | Depth of slab | 130 mm |
| 6 | Type of soil | Medium; Type-II |
| 7 | Damping in structure | 5% |
| 8 | Importance factor | 1 |
| 9 | Live load (roof) | 2KN/m$^2$ |
| 10 | Live load (floor) | 4 KN/m$^2$ |
| 11 | Materials | M35, & Fe500 |

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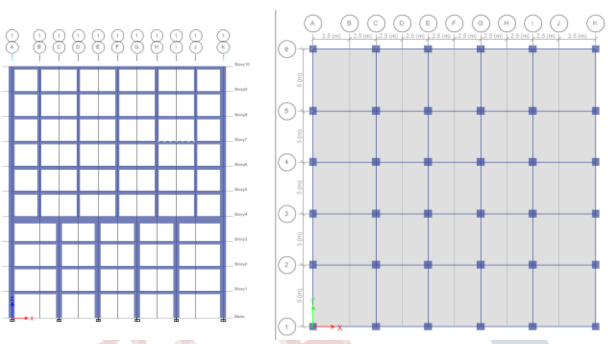
**A.*Model 1:Normal Building***

Here a G+9 building with all edge columns which is nothing but a normal building is considered as mode 1 with dimensions of beams as 350mm X 500mm and column as 550mm X 550mm.

**B.*Model – 2: Floating column Building***

Here a G+9 building with floating columns is considered as model 2 with dimensions of beams as 300 mm X 450 mm and column as 750mm X 750mm up to fourth storey and 350mm X 500mm from there floating columns are introduced. The structure is not safe with same beam dimensions. To make the structure safe beams and columns are to be increased due to this transfer beams are considered.

*Figure 3:Shows elevation and plan of model -2*



**C.*Model – 3: Setback column Building***

Here a G+9 building with setback columns is considered as model 3 with all edge columns removed. Dimensions of beams as 500mm X 900mm for first storey and then after 300mm X 450mm and column as 650mm X 560mm up to fourth storey and 350mm X 500mm from there.

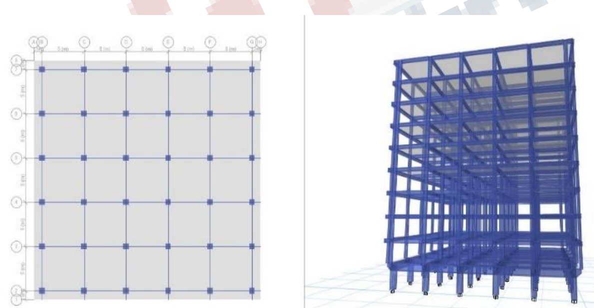


*Figure 4:Shows plan and 3D view of model-3*

**VI.RESULTS AND DISCUSSIONS**

The seismic analysis of a structure involves evaluation of the earthquake forces acting at various level of the structure during an earthquake and the effect of such forces on the behaviour of the overall structure where earthquakes are prevalent.

**A.Storey Drift**

Story drift is the displacement of one floor level relative to the other floor level above or below. Damage to non-structural components of buildings depends on drift. **According to IS 1893 (part I) 2016** storey drift in any storey due to the minimum specified design lateral force shall not exceed 0.004 times the storey height. In setback column building story drift is maximum i.e. 84% more than normal building as compare to 14% increase in floating column building.

**Table 2: Storey drift**

| | | Model 1 | Model 2 | Model 3 |
|---|---|---|---|---|
| **S.No.** | **Storey** | **Max Drift (mm)** | **Max Drift (mm)** | **Max Drift (mm)** |
| **1** | Storey 1 | 2.707 | 1.967 | 1.078 |
| **2** | Storey 2 | 4.502 | 3.724 | 3.659 |
| **3** | Storey 3 | 4.95 | 3.779 | 5.71 |
| **4** | Storey 4 | 4.961 | 2.111 | 6.154 |
| **5** | Storey 5 | 4.765 | 2.367 | 9.031 |
| **6** | Storey 6 | 4.412 | 4.977 | 8.548 |
| **7** | Storey 7 | 3.901 | 5.619 | 7.64 |
| **8** | Storey 8 | 3.223 | 5.135 | 6.415 |
| **9** | Storey 9 | 2.397 | 4.137 | 4.819 |
| **10** | Storey 10 | 1.552 | 3.134 | 2.932 |

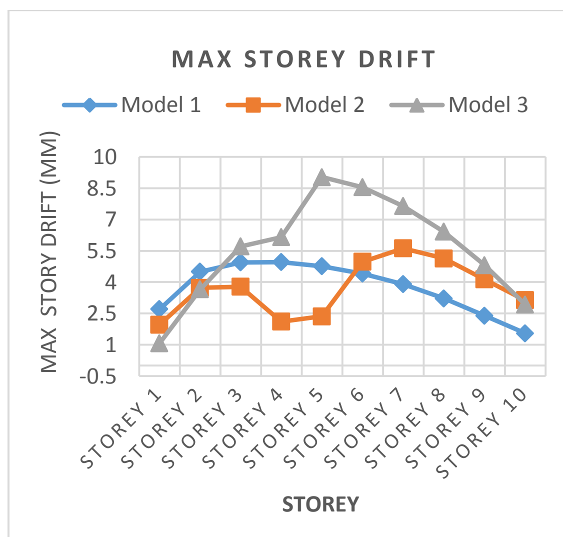



***Figure 5: Variation of storey drift with height of storey***

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**B.Storey Shear**

Storey shear is the distribution of design base shear along height of thestructure. Shear induced at the base of building during earthquake is called base shearwhich depends on the seismic mass and stiffness of buildingfrom the analysis it is found that value of storey shear is higher forsetback column building than floating column building and it is less for normal building. There is increase of 210% in storey shear for setback column building from normal building. As it is less for normal building it give more stability to structure and consume less reinforcement as compare to other type of structure.

**Table 3: Storey shear**

| | | Model 1 | Model 2 | Model 3 |
|---|---|---|---|---|
| S.No. | Storey | Storey shear (kN) | Storey shear (kN) | Storey shear (kN) |
| 1 | Storey 1 | 879.46 | 1180.72 | 1748.66 |
| 2 | Storey 2 | 876.79 | 1176.71 | 1739.53 |
| 3 | Storey 3 | 866.90 | 1161.99 | 1719.09 |
| 4 | Storey 4 | 845.19 | 1129.68 | 1674.24 |
| 5 | Storey 5 | 807.08 | 1057.04 | 1597.85 |
| 6 | Storey 6 | 747.98 | 976.15 | 1482.53 |
| 7 | Storey 7 | 663.32 | 865.41 | 1317.26 |
| 8 | Storey 8 | 548.49 | 715.23 | 1093.12 |
| 9 | Storey 9 | 398.91 | 519.63 | 801.16 |
| 10 | Storey 10 | 210.08 | 272.54 | 432.43 |

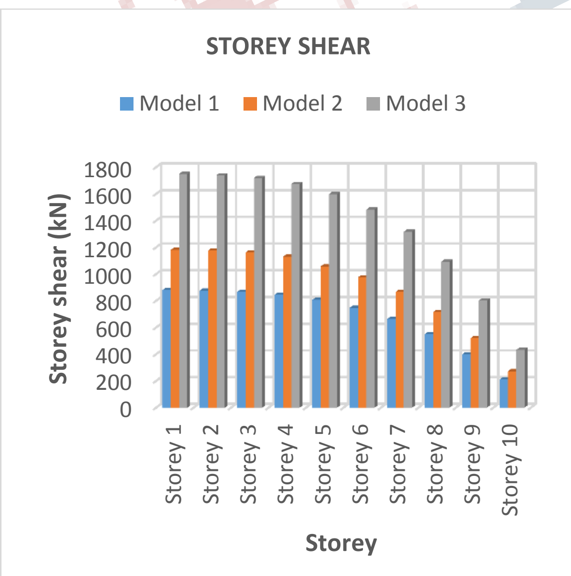


*Figure 6:Variation of storey shear with height of storey*

**C.Story Stiffness**

The storey stiffness is defined as the magnitude of the force couple required atthe floor levels adjoining the storey to produce a unit lateral translation within thestorey, letting all the other floors to move freely. **As per Clause 7.1 from table 6 of IS 1893-2016:** It states that if the lateral stiffness is less than storey above, then it will be said to have soft storey effect.It can be seen that in floating column building stiffness of forth floor is 78% more than storey below so it have soft storey effect.

**Table 4: Story Stiffness**

| | | Model 1 | Model 2 | Model 3 |
|---|---|---|---|---|
| S.No. | Storey | Stiffness (kN/m) | Stiffness (kN/m) | Stiffness (kN/m) |
| 1 | Storey 1 | 489150.8 | 904044.2 | 2609991 |
| 2 | Storey 2 | 293047.9 | 476749.5 | 733433.3 |
| 3 | Storey 3 | 262849.8 | 470893.4 | 455822.1 |
| 4 | Storey 4 | 255631.8 | 842227.9 | 415654.2 |
| 5 | Storey 5 | 254130.6 | 704216.6 | 267855.3 |
| 6 | Storey 6 | 254350.3 | 298973.8 | 261312.2 |
| 7 | Storey 7 | 255137.5 | 231789.9 | 259550.6 |
| 8 | Storey 8 | 255475.6 | 209029.6 | 256631.5 |
| 9 | Storey 9 | 250717.5 | 188767.6 | 250851.5 |
| 10 | Storey 10 | 208018.2 | 132443.9 | 225977.9 |

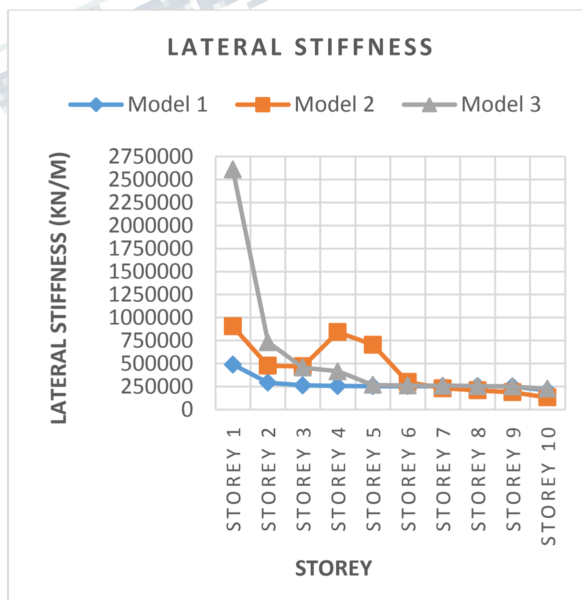


*Figure 7:Variation of lateral stiffness with height of storey*

## VII.CONCLUSION

The study presented in the paper compares the difference between normal building and a building with discontinuity in column. The following conclusions were drawn based on the investigation.

(I) Thestorey drift at each floor for the buildings with discontinuity in column will suffer extreme storey drift than normal building. The storey drift is maximum for setback column building at 5th storey levelsi.e. 84% more than normal building.

(II) The building with discontinuity in column experienced more storey shear than that of the normal building. As it is less for normal building it give more stability to structure than floating and setback column building.

(III) Result of lateral stiffness at each floor for the buildings show thatfloating column building stiffness of forth floor is 78% more than storey below so it will suffer soft storey effect where normal building is free from soft storey effect. So the floating column building is unsafe.

(IV) The final conclusion is thatbuilding with discontinuity in columnperformed poorly under seismic excitationdo not prefer to construct floating column or setback column in buildings unless there is a proper purpose and functional requirement for those. With increase in dimensions of all members also it is getting more displacements than a normal buildings and also the cost for construction also increased if they are to be provided then proper care should be taken while designing the structure.

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