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Seismic Response of Multistory Building with Floating and Setback Columns

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Abstract: **he purpose of this research is to show significant points which can be used in the architectural design process by investigating the basic principles of earthquake resistant design. 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.One of the vertical irregularities is due to floating column and setback column.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. In the present study, effects of floating and setback column in RC frames building 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. Different model of the frame are developed by using ETABS softwarefor G+9 multi-storey RC buildings to carry out comparative study of structural parameters such as time period, storey displacement andtorsionunder seismic excitation.Further from 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.**

Keywords: Floating column, Setback column, Seismic Response, Time history analysis, ETABS etc.

I. INTRODUCTION

Earthquake has been known as one of the critical natural disasters for thousands of years. Recentmajor earthquakes have caused severe social disruption in the vicinity of the epicenter, especially due to structural failures causing damage to the people and properties in urban area where the structures are concentrated. 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. Now a day's multi-storey buildings constructed for the purpose of residential, commercial, industrial etc., with an open ground storey is becoming a common feature. For the purpose of parking, usually the ground storey is kept free without any constructions, except the columns which transfer the building weight to the ground. For a hotel or commercial building, where the lower floors contain banquet halls, conference rooms, lobbies, show rooms or parking areas, large interrupted space required for the movement of people or vehicles. Closely spaced columns based on the layout of upper floors are not desirable in the lower floors. So to avoid that problem, floating column concept has come into existence.

1.1.Floating and Setback 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 isa vertical member starting from foundation level to height of structure and transferring the load to the ground. The term floating column is vertical elementwhich (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. 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.

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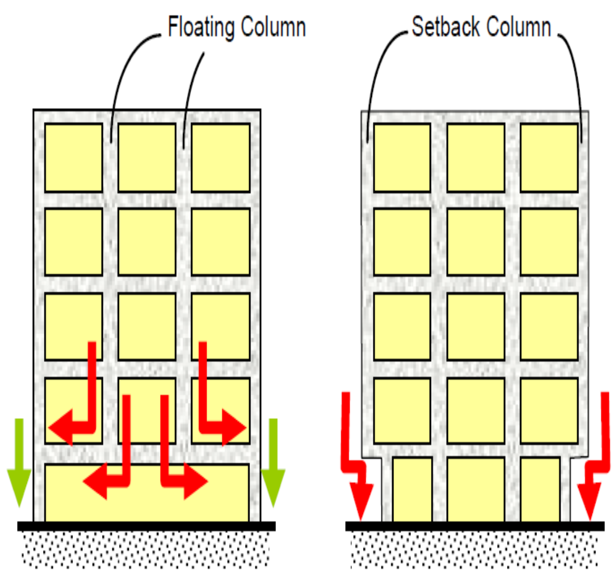

Figure 1: (a) floating column: the column is discontinued at a lower level, and (b) set-back column: the column is moved out of plumb

II. LITERATURE REVIEW

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.S.Varadharajan[13]Study summarizes the research works done in the past regarding different types of structural irregularities i.e. Plan and vertical irregularities. Criteria and limits specified for these irregularities as defined by different codes of practice (IS1893:2002, EC8:2004 etc.) have been discussed briefly.Sukumar Behera[12]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. Isha Rohilla[7]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.Amit Namdeo Chaudhari[1]There are numerous observations of damages caused by irregularity in buildings, such as vertical irregularity, is predominant to structure while earthquake excitation, the earthquake forces developed at different floor levels in building need to be brought down along the height to the ground by the shortest path, any deviation or discontinuity such as floating columns results in poor performance of building

III. OBJECTIVES OF WORK

The major objectives of the work are as follows.

1. To study the behavior of multi-storied buildings with floating and setback columnsunder earthquake excitations.
2. To carry out nonlinear time history analyses using ETABS software.
3. To study the structural response of the building models with respect to following aspects i.e Time period, storey displacement and torsion.
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.

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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	Length in X-direction	27 m
2	Length inY-direction	27 m
3	Floor to floor height	3.25 m
4	Total height of building	32.75 m
5	Number of Stories	G+9
6	Depth of slab	130 mm
7	Concrete	M 35
8	Rebar	Fe 500
9	Live load (roof)	$2KN/m^2$
10	Live load (floor)	$4 KN/m^2$

Table 2: Sesmic Data

1	Zone	IV
2	Type of structure	(SMRF)
3	Type of soil	Medium; Type-II
4	Damping in structure	5%
5	Importance factor	1
6	Response reduction factor (R)	5
7	Time period	Program calculated
8	Time History Data	Sikkim-Nepal

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.

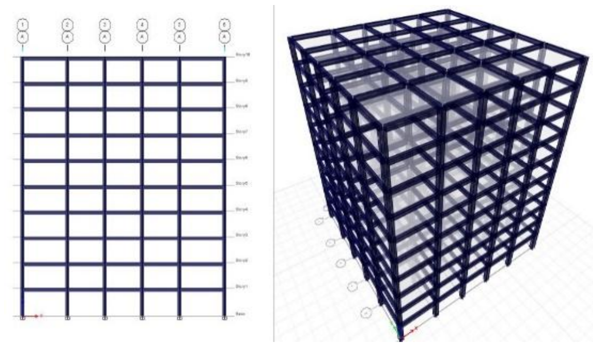

Figure 2: Shows elevation and 3D view of model -1

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.

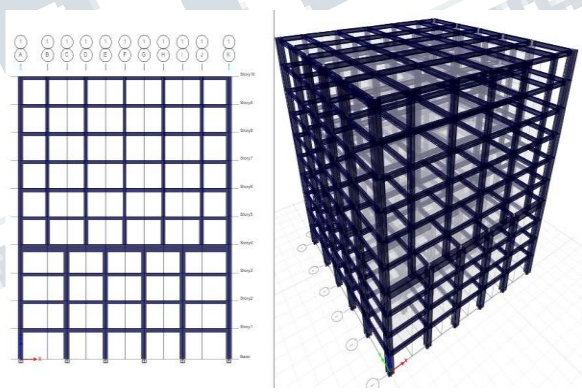

Figure 3:Shows elevation and3D view of model -2

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.

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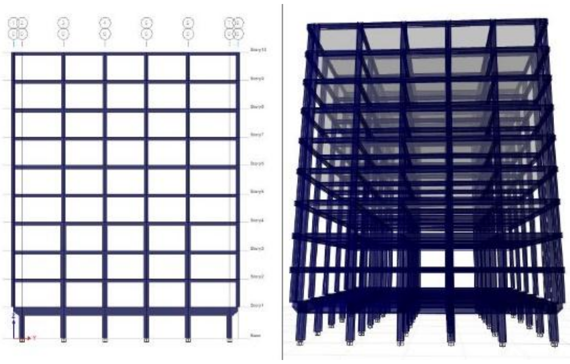

Figure 4:Shows elevation and 3D view of model-3

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.

1.Time Period

The fundamental natural period of the building is the time taken by it to undergo one complete cycle of oscillation. It is an inherent property of a building controlled by it mass (m) and stiffness (k).

$$T = 2\pi\sqrt{(m/k)}$$

Buildings that are heavy (with larger mass m) and flexible (with smaller stiffness k) have larger natural period than light and stiff buildings. Usually, natural periods (T) of 1 to 20 storey normal reinforced concrete and steel buildings are in the range of 0.05 - 2.00s.

Table 2: Time period

S.No.	Mode	Model 1	Model 2	Model 3
1	1	1.664	1.607	2.201
2	2	1.664	1.303	1.960
3	3	1.553	1.283	1.780
4	4	0.531	0.535	0.687
5	5	0.531	0.524	0.648
6	6	0.495	0.487	0.585
7	7	0.295	0.262	0.414
8	8	0.295	0.257	0.383
9	9	0.274	0.225	0.341
10	10	0.192	0.158	0.286
11	11	0.192	0.141	0.263
12	12	0.178	0.129	0.235

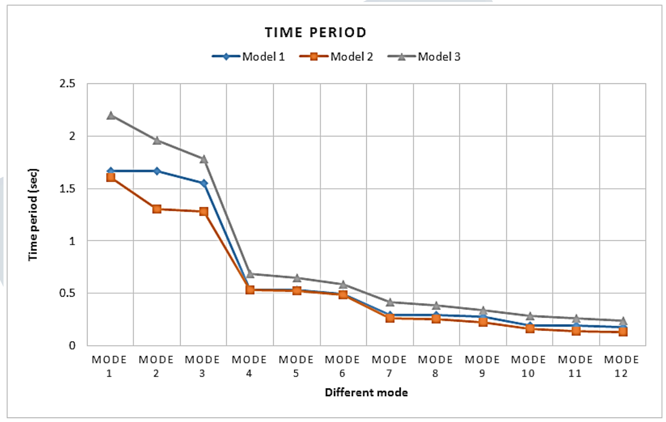

Figure 5: Graph show variation of time period with different mode

2.Storey Displacement

Storey displacement is the lateral movement of the structure caused by lateral force. The deflected shape of a structure is most important and most clearly visible point of comparison for any structure. The maximum displacements of building in different stories for all models have been compared.

Table 3: Storey Displacement

S.No	Storey	Model 1 Max Displacement (mm)	Model 2 Max Displacement (mm)	Model 3 Max Displacement (mm)
1	Storey 1	2.707	1.967	1.068
2	Storey 2	7.187	5.674	4.636
3	Storey 3	12.135	9.431	10.299
4	Storey 4	17.094	11.382	16.444
5	Storey	21.859	13.743	25.351

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6	Storey 6	26.271	18.541	33.878
7	Storey 7	30.172	24.132	41.496
8	Storey 8	33.394	29.264	47.883
9	Storey 9	35.788	33.4	52.671
10	Storey 10	37.323	36.511	55.554

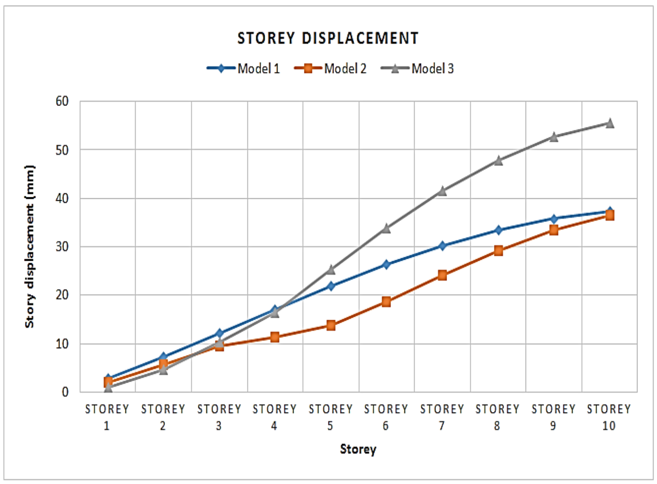

Figure 6: Graph show variation of storey displacement with storey height

3. Max / Avg. storey drift ratio (Torsion)

As per IS 1893:2016 Code describe that the torsional irregularity will be occur when max storey drift / average storey drift ratio is more than 1.2.

Table 4: Max / Avg. storey drift ratio

		Model 1	Model 2	Model 3
S. No.	**Storey**	**Max / Avg. storey drift**	**Max / Avg. storey drift**	**Max / Avg. storey drift**
1	Storey 1	1.006	1.007	1.083
2	Storey 2	1.004	1.008	1.03
3	Storey 3	1.001	1.036	1.018
4	Storey 4	1	1.058	1.017
5	Storey 5	1	1.057	1.011
6	Storey 6	1	1.031	1.004
7	Storey 7	1	1.004	1.003
8	Storey 8	1.001	1.001	1.003
9	Storey 9	1.004	1.003	1.005
10	Storey 10	1.033	1.019	1.017

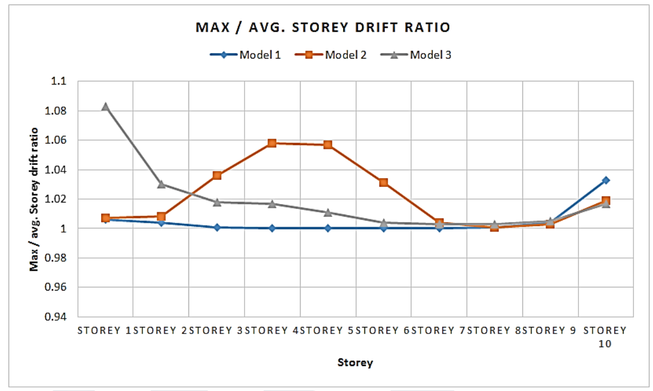

Figure 7: Variation of Max / Avg. storey drift ratiowith height of storey

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)The storey displacements increase as storey height. Storey displacement is maximum for setback column building for all model frames as the mass carried by it is maximum. Displacement is comparable for normal and floating column building but maximum for setback column building and is 48% more than normal building.

(II) Discontinuity in column shifts the fundamental period of the structure from the dominant period of the earthquake. It generally shifts the fundamental time period of the structure more than 2 seconds. Fig.5 depicts the variation of time period of various modes of frame. Time period value for building with setback column is 32 % more than that of normal building.

(III) Max. / Avg. storey drift ratio for setback column building is observe more when compare to normal building. From fig. 7 and table 4, the torsion value for setback column building is 7.65% more than normal building for storey 1.

(IV) The final conclusion is that building with discontinuity in columnperformed poorly under seismic excitation do 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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