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Effect of Floating Columns on Seismic Response of Multi-Storeyed RC Framed Buildings

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***Abstract*—Floating columns are a typical feature in the modern multi-storeyed construction in urban India and are highly undesirable in buildings built in seismically active areas. The present study investigates the effects of the structural irregularity which is produced by the discontinuity of a column in a building subjected to seismic loads.**

In this paper static analysis and dynamic analysis using response spectrum method is done for a multi-storeyed building with and without floating columns. Different cases of the building are studied by varying the location of floating columns floor wise and within the floor. The structural response of the building models with respect to Fundamental time period, Spectral acceleration, Base shear, Storey drift and Storey displacements is investigated. The analysis is carried out using software STAAD Pro V8i software.

Keywords*—*Floating columns, static analysis, dynamic analysis, response spectrum analysis.

I. INTRODUCTION

Today many multi-storeyed buildings in India have floating columns as an unavoidable feature. This is being adopted- a) to provide more space in ground floor for accomodation of parking or ground lobbies b) for architectural beauty c) to increase floor space index.

Floating columns in a building may result in a concentration of forces or deflection or in an undesirable load path in the vertical lateral-force-resisting system. In extreme cases, this can result in serious damage or collapse of the building, since the lateral load resisting system is often integral with the gravity load resisting system. Vertical irregularities typically occur in a storey that is significantly more flexible or weaker than adjacent stories. Many buildings with vertical discontinuities collapsed or were severely damaged during the 2001 Bhuj earthquake in Gujarat.

Thus, buildings with columns that hang or float on beams, at an intermediate storey and, do not go all the way to the foundation, have discontinuities in the load transfer path. This paper presents the results of investigation of structural response quantities of a multi-storeyed building with floating columns.

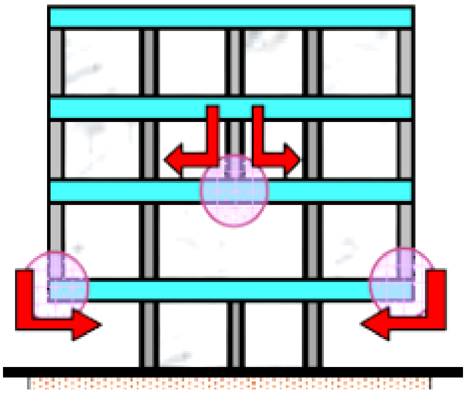


Fig. 1. Building with floating columns.

II. OBJECTIVES

The primary objectives of the study are as under –

1. To model the building using software STAAD PRO V8i for analysis and design purpose.
2. To carry out Static and Dynamic analyses for different cases by varying the location of floating columns floor wise and within the floor.
3. To study the structural response of the building models with respect to following aspects –

- Fundamental time period of the building.
- Spectral acceleration of the building.
- Base shear.
- Storey displacement.

III. MODEL STUDIES

A 12.5m x 24m multi-storeyed building (G+6), with special moment resisting frame was selected for study. The building had a one brick thick exterior wall along the periphery and all the interior walls are half brick thick. It was considered to be located in Zone IV on Type II soil. The loads and member sizes are summarized in Table I. In this study first a normal building (NB) without any floating columns is modeled whose floor plan and elevation are shown in figure 2. Then, two types of models, namely 1 and 2 are modeled. In model 1, the floating columns are located at ground floor and in model 2 they are located at first floor. For each model three different cases are studied by varying the location of floating columns. In all six cases have been studied namely-NB, 1A, 1B, 1C, 2A, 2B and 2C.

TABLE I. BUILDING DATA

<table>
<tr><td colspan="3">Member dimensions</td></tr>
<tr><td colspan="2">Slab</td><td>125 mm thick</td></tr>
<tr><td colspan="2">Beams</td><td>450 mm x 300 mm</td></tr>
<tr><td colspan="2">Columns</td><td>450 mm x 450 mm</td></tr>
<tr><td colspan="2">Outer walls</td><td>230 mm thick</td></tr>
<tr><td colspan="2">Inner walls</td><td>115 mm thick</td></tr>
<tr><td colspan="3">Loads</td></tr>
<tr><td colspan="2">Unit weight of concrete</td><td>25 kN/m^3</td></tr>
<tr><td colspan="2">Unit weight of brick infill</td><td>20 kN/m^3</td></tr>
<tr><td rowspan="2">Floors</td><td>Live load</td><td>3 kN/m^2</td></tr>
<tr><td>Finish</td><td>6.5 kN/m^2</td></tr>
<tr><td rowspan="2">Walls</td><td>Outer</td><td>15 kN/m^2</td></tr>
<tr><td>Inner</td><td>7.5 kN/m^2</td></tr>
<tr><td colspan="3">Grade of concrete</td></tr>
<tr><td colspan="2">Beams</td><td>M35</td></tr>
<tr><td colspan="2">Columns</td><td>M35</td></tr>
</table>

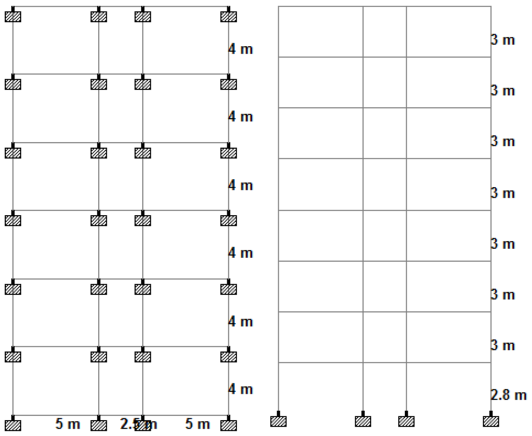


Fig. 2. Plan and elevation of normal building.

For the analysis purpose two models have been considered namely as:

MODEL 1 – Building in which floating columns are located at ground floor.

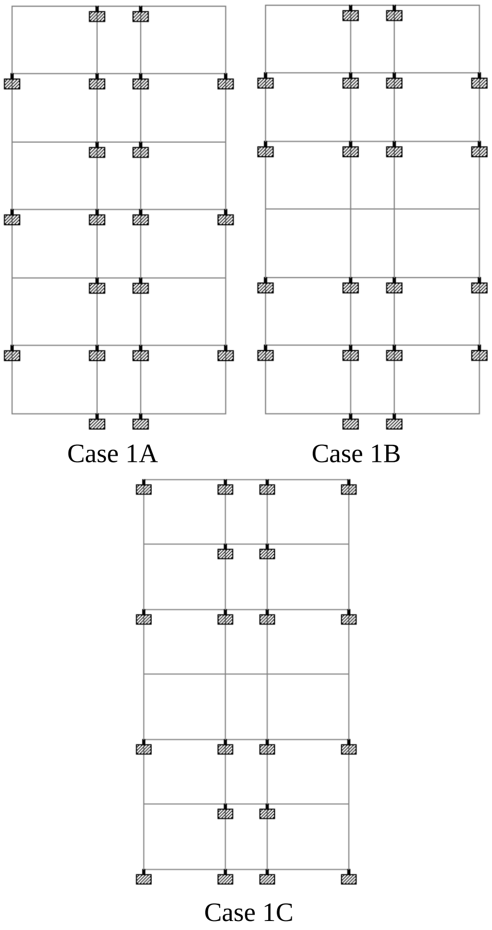
MODEL 2 – Building in which floating columns are located at first floor.

MODEL 1 – Following cases have been considered under this model based on the location of floating columns –

CASE 1A – Corner columns and alternate columns in exterior frame along the two long edges are floating columns.

CASE 1B – Corner columns and all the columns in the centre most frame along the short edge are floating columns.

CASE 1C – Alternate columns in exterior frame along the two long edges except the corner ones and those in the centre most frame along the short edge are floating columns.



Case 1A

Case 1B

Case 1C

Fig. 3. Plan of cases of model 1.

MODEL 2 – Following cases have been considered under this model based on the location of floating columns –

CASE 2A – Corner columns and alternate columns in exterior frame along the two long edges are floating columns.

CASE 2B – Corner columns and all the columns in the centre most frame along the short edge are floating columns.

CASE 2C – Alternate columns in exterior frame along the two long edges except the corner ones and those in the centremost frame along the short edge are floating columns.

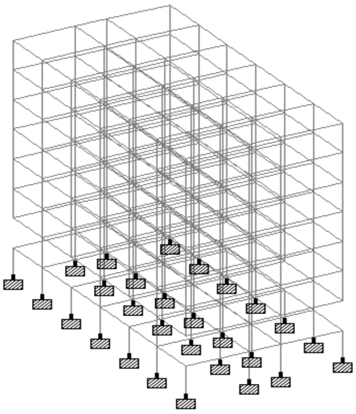


Fig. 4. Isometric view of case 2A of model 2.

IV. METHODS OF ANALYSIS

Seismic analysis is an important tool in earthquake engineering which is used to investigate the response of buildings in a simpler manner due to seismic forces. It is a part of structural analysis and a part of structural design where earthquake is prevalent.

The earthquake analysis methods used in the study are-

I. Equivalent Static Analysis
II. Response Spectrum Analysis

I. Equivalent Static Analysis - This approach defines a series of forces acting on a building to represent the effect of earthquake ground motion, typically defined by a seismic design response spectrum. It assumes that the building responds in its fundamental mode. The response is read from a design response spectrum, given the natural frequency of the building

II. Response Spectrum Analysis- This method permits the multiple modes of response of a building to be taken into account. Computer analysis can be used to determine these modes for a structure. For each mode, a response is obtained from the design spectrum, corresponding to the modal frequency and the modal mass, and then they are combined to estimate the total response of the structure. In this the magnitude of forces in all directions is calculated and then effects on the building are observed.

V. RESULTS AND DISCUSSIONS

In the present study, the effect of varying the location of floating columns floor wise and within the floor of multi storeyed RC building on various structural response quantities of the building using static analysis and dynamic analysis is studied. The results are compared in tabular form and graphically for the analysis of the building without floating columns and with floating columns.

A. *Fundamental time period*

Fundamental time period is the time taken by the building to undergo a cycle of to and fro movement. The fundamental time period determined for building with and without floating columns of different cases is presented in Table II. The variation of time period due to the effect of floating columns is also shown in Fig. 5 and Fig. 6 for X and Z directions respectively.

It has been found that by incorporating floating columns there is about 5-8% increase in fundamental time period in X-direction as compared to building without floating columns (NB). The increase in fundamental time period is 3-7% when seismic excitation is taken in Z-direction.

The introduction of floating columns in the RC building increases the time period due to decrease in the stiffness of structure. The columns act as springs in the building with having some stiffness value. The storey having floating columns in it has lesser columns and therefore lesser stiffness resulting in the decrease of overall stiffness of the building.

TABLE II. COMPARISON OF FUNDAMENTAL TIME PERIOD IN sec

Cases	Time period in sec (X-direction)	Time period in sec (Z-direction)
NB	1.44083	1.34285
1A	1.53495	1.43937
1B	1.55198	1.43221
1C	1.53600	1.37773
2A	1.52013	1.43824
2B	1.55961	1.42614
2C	1.54603	1.40163

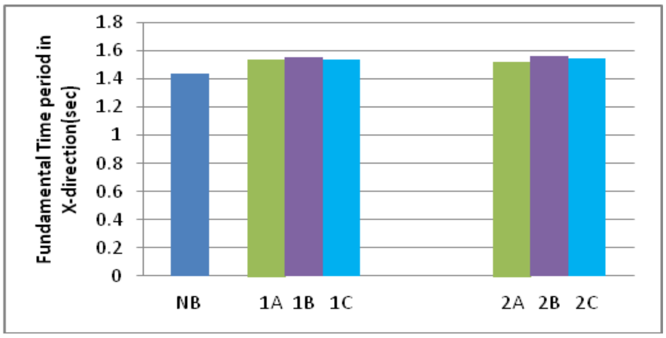


Fig. 5. Comparison of Fundamental Time Period in X-direction

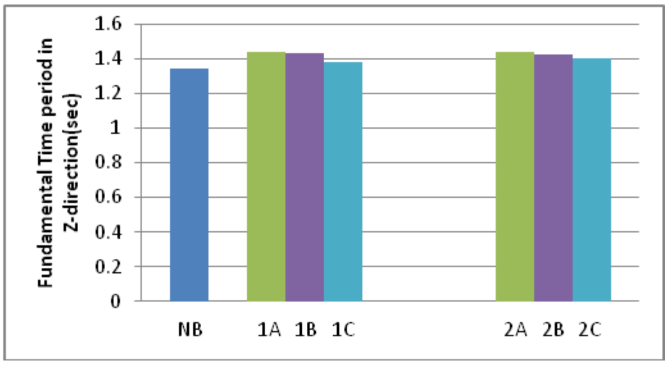


Fig. 6. Comparison of Fundamental Time Period in Z-direction

B. Spectral acceleration

Spectral acceleration describes the maximum acceleration in an earthquake on an object. Spectral acceleration, with a value related to the natural frequency of vibration of the building gives a very close approximation to the motion of a building or other structure in an earthquake.

The spectral acceleration observed from the study on building with and without floating columns of different cases is presented in Table III. The variation of Spectral acceleration due to the effect of floating columns is also shown in Fig. 7 and Fig. 8 for X and Z directions respectively.

It has been found that by incorporating floating columns there is about 5-8% decrease in Spectral acceleration in X-direction as compared to building without floating column (NB). The decrease in Spectral acceleration is 3-7% when seismic excitation is taken in Z-direction.

The introduction of floating column in the RC building decreases the spectral acceleration due to increase of natural period of vibration of structure.

TABLE III. COMPARISON OF SPECTRAL ACCELERATION

Cases	Spectral acceleration (X-direction)	Spectral acceleration (Z-direction)
NB	0.944	1.013
1A	0.886	0.945
1B	0.876	0.950
1C	0.885	0.987
2A	0.895	0.946
2B	0.872	0.954
2C	0.880	0.970

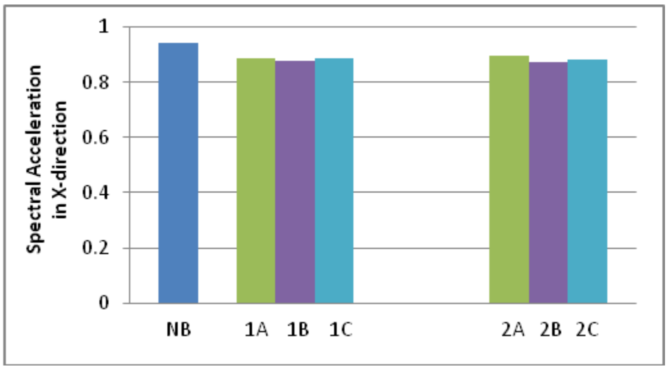


Fig. 7. Comparison of Spectral Acceleration in X-direction

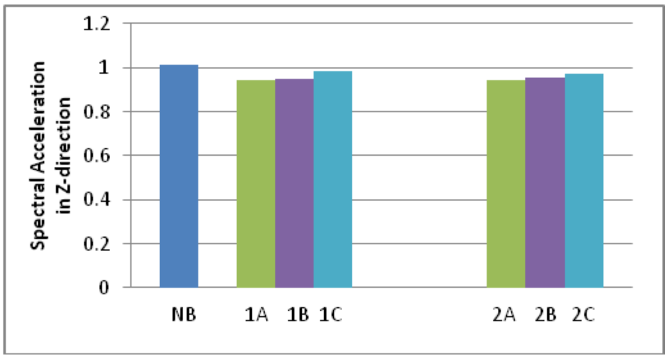


Fig. 8. Comparison of Spectral Acceleration in Z-direction

C. Base shear

Shear induced at the base of building during earthquake is called base shear which depends on the seismic mass and stiffness of building. The results of variation in Base Shear due to the effect of floating columns for different cases are tabulated in Table IV. The variation of base shear is also shown through graphs in Fig. 9 and Fig. 10 for X and Z directions respectively.

The Base Shear decreases by about 5-8% when seismic force acts in X-direction and 3-7% % when seismic force acts in Z-direction.

It is observed that due to the introduction of floating columns in the building the value of base shear decreases due to increase of natural period of vibration of structure. Also, the mass of concrete in column is less for floating column building as compared to normal building (NB), so this further decreases the base shear.

TABLE IV. COMPARISON OF BASE SHEAR IN sec

Cases	Base Shear in kN (X-direction)	Base Shear in kN (Z-direction)
NB	1290.4	1383.97
1A	1209.1	1290.76
1B	1197.4	1294.64
1C	1209.1	1345.19
2A	1220.5	1290.50
2B	1188.0	1300.66
2C	1199.7	1323.95

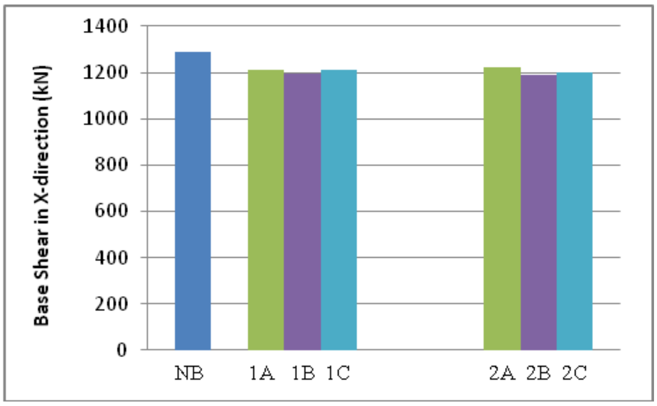


Fig. 9. Comparison of Base Shear in X-direction

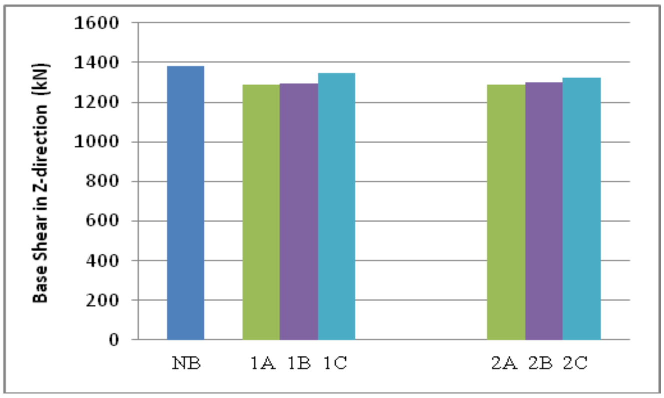


Fig. 10. Comparison of Base Shear in Z-direction

D. *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. No other parameter of comparison can give a better idea of behaviour of the structure than comparison of storey displacement.

The comparisons of storey displacements for X-direction and Z-direction are shown in Table V and Table VI respectively. It can seen from tables that in case of Model 1 deflection is more for building with floating columns by an amount 6-40% as compared to building without floating column (NB) when seismic force acts in X-direction, while this value is -9-18% in case of Model 2. When seismic force acts in Z-direction, in case of Model 1 deflection is more for building with floating columns by an amount 0.5-32% as compared to building without floating column (NB), while this value is -8-17% in case of Model 2.

The difference in percentage of deflection for with and without floating column buildings is more when seismic force is considered in X-direction as compared to when seismic force considered in Z-direction. Also the deflections are more in Model 1 as compared to Model 2. The deflections at different storeys for different cases are shown in Fig. 11, 12, 13 and 14.

It is also noted that in Model 1 for both X and Z directions there is a marginal increase in deflection of first storey level as floating columns are located at this level. Similarly in Model 2 for both X and Z directions there is a marginal increase in deflection of second storey level as floating columns are located at this level but there is a decrease in value of deflection of first storey level.

The reason for high storey displacements in buildings with floating columns is that the overall stiffness of the building decreases due to the presence of floating columns. Due to discontinuity of stiffness, the flexibility increases and strength decreases resulting in high displacements.

TABLE V. VARIATIONS IN STOREY DISPLACEMENTS IN X-DIRECTION

Storey level	Storey displacement (in cm)						
	NB	1A	1B	1C	2A	2B	2C
0	0	0	0	0	0	0	0
1	0.416	0.502	0.585	0.585	0.382	0.377	0.38
2	1.193	1.311	1.384	1.374	1.265	1.407	1.407
3	2.022	2.169	2.235	2.214	2.120	2.244	2.232
4	2.829	3.007	3.066	3.033	2.967	3.069	3.044
5	3.570	3.784	3.836	3.790	3.753	3.834	3.795
6	4.197	4.454	4.502	4.441	4.434	4.496	4.441
7	4.663	4.980	5.018	4.942	4.963	5.009	4.938
8	4.939	5.326	5.359	5.264	5.314	5.348	5.258

TABLE VI. VARIATIONS IN STOREY DISPLACEMENTS IN Z-DIRECTION

Storey level	Storey displacement (in cm)						
	NB	1A	1B	1C	2A	2B	2C
0	0	0	0	0	0	0	0
1	0.410	0.544	0.511	0.538	0.377	0.381	0.3979
2	1.149	1.305	1.278	1.268	1.312	1.263	1.3471
3	1.922	2.093	2.071	2.020	2.095	2.055	2.0947
4	2.664	2.850	2.832	2.741	2.852	2.817	2.8027
5	3.334	3.540	3.527	3.393	3.541	3.513	3.4432
6	3.892	4.125	4.115	3.935	4.125	4.102	3.9758
7	4.291	4.562	4.554	4.323	4.561	4.542	4.3567
8	4.504	4.827	4.821	4.531	4.825	4.809	4.5607

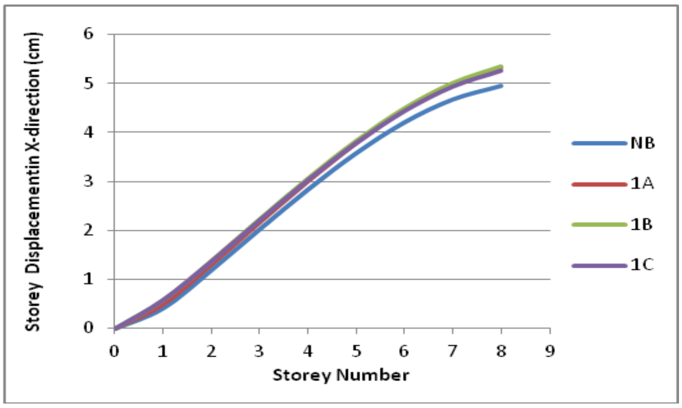


Fig. 11 Variation of Storey Displacement in X-direction for Model 1.

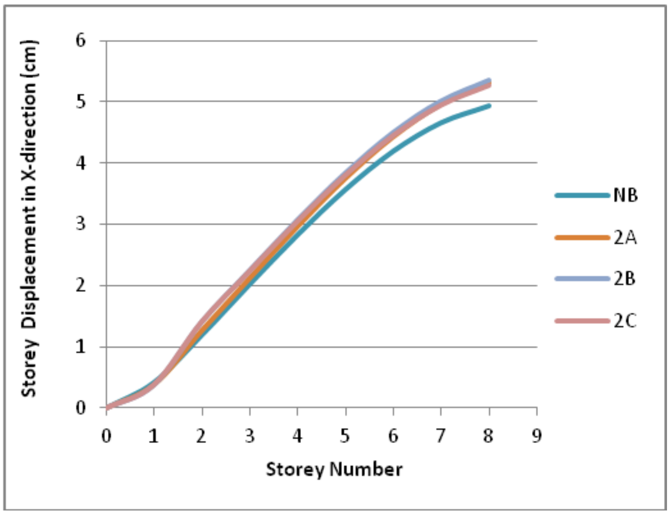


Fig. 12 Variation of Storey Displacement in X-direction for Model 2.

Fig. 13 Variation of Storey Displacement in Z-direction for Model 1.

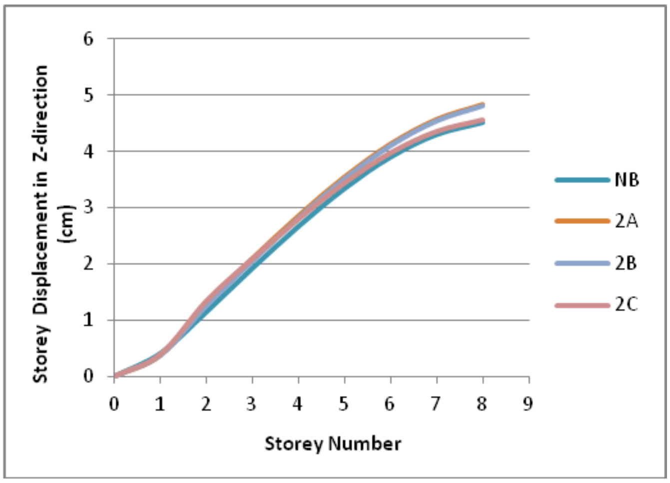


Fig. 14. Variation of Storey Displacement in Z-direction for Model 2.

VI. CONCLUSIONS

The present study investigated the effect on structural response quantities of the building due to the presence of floating columns. Analytical study was carried out on a building by comparing seven cases. Following are some of the conclusions which are drawn on the basis of this study.

1. It was observed that in building with floating columns there is an increase in fundamental time period in both X-direction as well as Z-direction as compared to building without floating columns (NB).
2. By introduction of floating columns in a building base shear and spectral acceleration decreases. Thus, it has this technical and functional advantage over conventional construction.
3. The storey displacements increase when floating columns are introduced in the building. The deflections were more in Model 1 as compared to Model 2, which proves that buildings with floating columns in ground floor are more vulnerable during earthquake. It was also observed that deflections increase marginally in that storey where floating columns are located.

The effect on various parameters reflects the deficiencies, if floating columns are incorporated in a building without considering any measure for safer construction. The failure of storeys having floating columns can have a serious effect on progressive collapse of the building. Hence, floating columns should be avoided as far as possible in seismic regions and if they are unavoidable, then the structure should be strengthened by adopting some remedial features.

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