Effect of Bracing on Seismic Performance of Multi-storeyed Building Frames with Floating Columns

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***Abstract*—To accommodate parking or reception lobbies, open ground floor is an inevitable feature of multi-storied RC structures in many urban habitats. Floating columns are usually adopted above the ground floor level so that maximum space is made available in the ground floor which is essentially required in apartments, mall or other commercial buildings where parking is a major concern. The earthquake forces developed at different storey levels in a building need to be brought down along the height to the ground by the shortest path, and any deviation or discontinuity in this load path results in poor performance of the building. Therefore the most critical regions of damage are the connecting beam and lower level columns. In this study, the effectiveness of various configurations of bracings to strengthen or to eliminate the floating columns is investigated and it is found that seismic performance of building model is improved considerably by providing bracings.**

Keywords—Floating columns, Open ground storey, Seismic analysis, Story displacement

I. INTRODUCTION

Nowadays multi-storey buildings constructed for the purpose of residential, commercial, industrial etc., with an open ground storey has become a common feature. The columns which are closely spaced in the upper floors are not advisable in the lower floors. So to avoid this problem, floating column concept has come into existence. The floating column is a vertical member which rest on a beam but doesn't transfer the load directly to the foundation.

The floating column act as a point load on the beam and this beam transfers the load to the columns below it. Hence the load transferring beams must be detailed and designed suitably, specifically in earthquake regions. Also provision of floating columns resting at the tip of overhanging beams increases the vulnerability of the lateral load resisting system due to vertical discontinuity. This type of construction may not create any problem under vertical loading conditions. But during an earthquake, a clear load path is not available for transferring the lateral forces to the foundation. Lateral forces accumulated at the upper floor during the earthquake have to be transmitted by the projected cantilever beams. Overturning forces thus developed overload the columns of the ground floor. Under this situation the columns begin to deform and buckle, resulting in total collapse. This is because of primary deficiency in the strength of ground floor columns, projecting cantilever beams and ductile detailing of beam column joint. In case of floating column, shear is induced to overturning the forces to another resting element of the low level. This imposition of overturning forces overloads the columns of lower level through connecting elements. Therefore the most critical region of damage is the connecting element (link between discontinuous columns to lower level column) and lower level columns.

Floating columns to get large uninterrupted space for the movement of people or vehicles etc., in the lower floor and those provided from overhanging beams to get more space in upper floor levels are shown in Fig. 1.

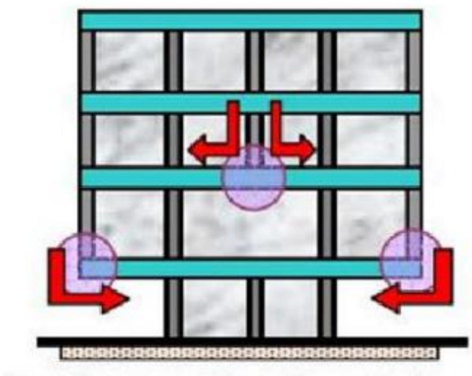

Fig 1. Floating columns resting on transfer girder and cantilever projection

These floating columns are supported on beams called transfer girders. The cantilever spans and transfer girders supporting the floating columns develop very high shear force and bending moment under gravity loads in combination with earthquake load (Mundadal et.al. 2014). The bays in the lower storey are usually not enclosed with infill masonry unlike higher storey and their absence worsens the effect of floating columns under earthquake load.

II. LITERATURE REVIEW

R. Harugoppa and S. M. Muranal (2019) carried out the dynamic linear and non-linear static analysis to analyse ordinary moment resisting frame models with conventional and floating columns. The requirement of appropriate value of response reduction factor which effect ductility factor and stiffness irregularity is studied. The study proposed the response reduction factor and reinforcement detailing in members supporting floating columns to reduce the effect of discontinuity in column in ordinary moment resisting frames [1].

Kishalay Maitra and N. H. M. Kamrujjaman Serker (2018) studied the performance of floating column building and compared with normal building under seismic load. In this study, static and dynamic analyses using response spectrum method have been carried out for multi-story building with and without floating columns. Different cases of the building have been studied by varying the location of floating column and increasing the column size. The results showed that story displacement increased by 56.96% in floating column building compared to normal building. Torsional irregularity was found when floating column was introduced unsymmetrically. It was also found that fundamental time period was increasing and lateral stiffness was decreasing in floating column building. When the lost cross sectional area due to floating columns were distributed among ground floor columns then it was found that story displacement as well as fundamental time period decreased and lateral stiffness increased [2].

Gulchaman Khan and Mayur Singi (2019) studied behaviour of multi-storey buildings having hanging columns beneath seismic forces and the effect of shear wall within the specified building. Three types of multi-storeyed buildings are taken into consideration having eight storeys, twelve storeys and sixteen storeys. All are taken into consideration having hanging columns furnished with and without shear partition, and moreover analyzed for zone V using software ETABS 2016. Observations show that hanging columns increase the vulnerability of the building and cause lateral displacement and storey drift [3].

Vinay Agrawal et al (2016) proposed a feasible solution to mitigate the effects caused due to non-uniformity of stiffness and discontinuity in load path and to simultaneously hold the functional use of the open storey particularly under the floating column, through a combination of various lateral strengthening systems. Two separate analyses on various models of the buildings namely, the equivalent static analysis and the response spectrum analysis as per IS: 1893-2002 were performed. Various measures such as incorporation of Chevron bracings and shear walls, strengthening the columns in the open ground storey and their different combinations were examined. A feasible combination of lateral strengthening is proposed by introducing shear walls at proper positions and lateral bracings under the floating columns [5].

A. Wahidi and D. Rama Seshu (2016) studied the nonlinear analysis for G+5 story normal and floating column buildings using the response spectrum specified in the IS code in SAP2000. Behaviour of buildings with floating column identified and based on these findings some new system of floating column buildings with different patterns of bracings and shear walls were proposed to make the buildings with floating column safe in seismically active areas. With the introduction of bracings and shear walls to the frames with floating columns, the lateral deflections are reduced. Hence the strengthened models used effectively resisted the lateral loads coming on the buildings during the earthquake ground motion [6].

III. Objectives of The Study

- To study the effect of provision of Chevron bracings as a substitution for floating columns resting on inside beams, on sway of multistoried buildings under seismic loading.
- To study the effect of provision of different types of bracings to strengthen floating column system on overhanging beams.

IV. Model and Parameters

Fig. 1 shows the frame modelled in STAAD representing a 5-storeyed, 4x2 bay RCC framed structure with floating columns in upper floors. Fig. 2 shows the frame representing the same building but the lower most floating column replaced by braces so as to ensure continuity in load path. The node (No. 173) marked in the figure is observed to have maximum displacement, hence considered for comparison.

Fig. 3 shows another model representing a building in which the floating column comes at the end point of an overhanging portion of the building. The node (No. 188) marked in the figure is observed to have maximum displacement, hence considered for comparison. Fig. 4 shows the frame representing the same building with the overhanging portion stiffened with single diagonal bracing on all floors and Fig. 5 shows the frame representing the same building with cross diagonal bracing in the lower most storey and single diagonal bracing on all above floors. Fig. 6 shows the frame representing the same building with a diagonal bracket below the floating column so as to ensure continuity in load path. Fig. 7 shows the arrangement similar to that of Fig. 4, but double diagonal bracing is provided in alternate floors of the bay adjacent to the overhanging bay.

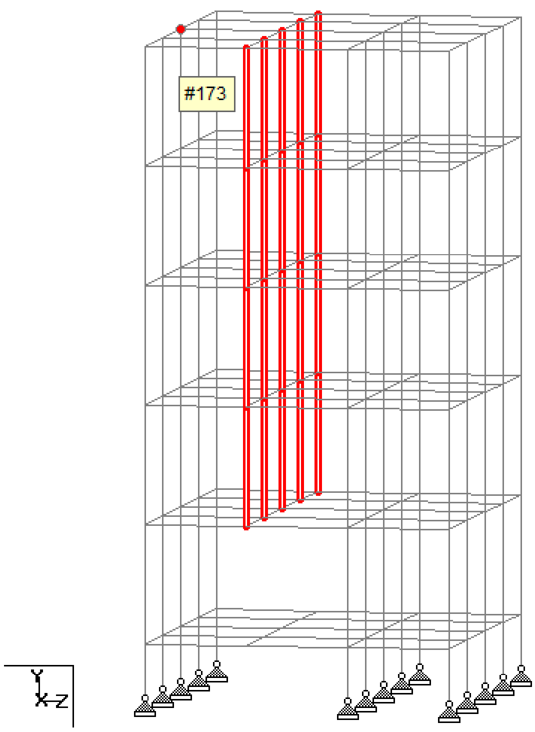

Fig. 1. Building Model with interior beams with

floating columns in first storey

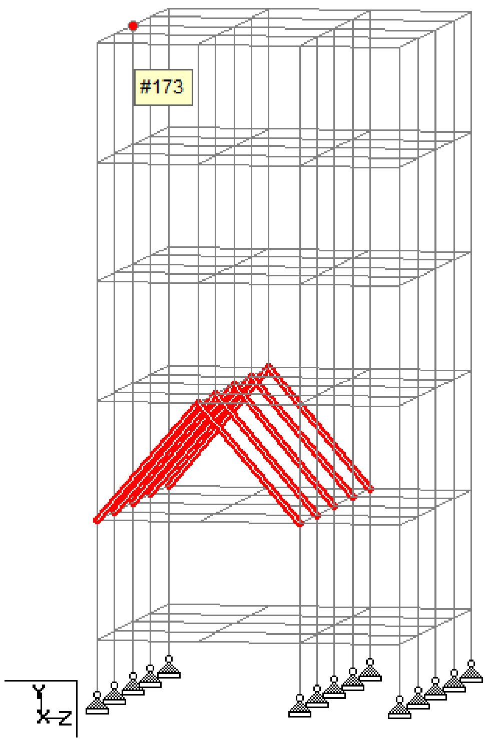

Fig. 2. Building Model with interior beams with Bracings in first storey

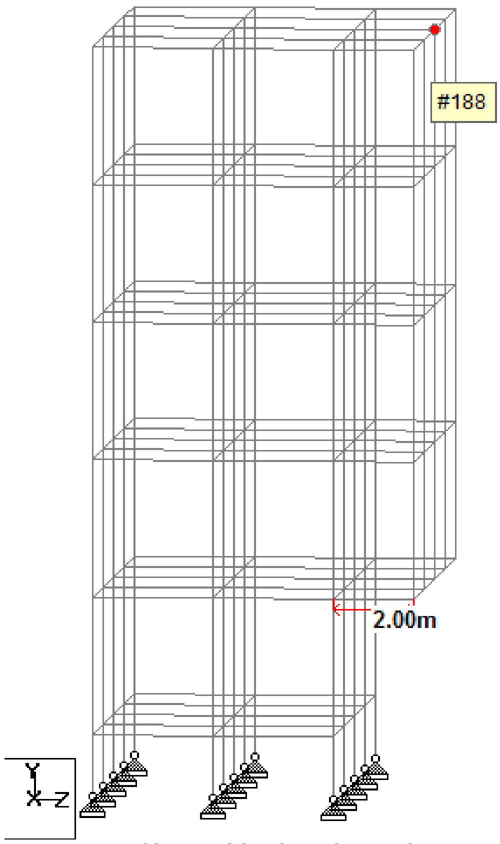

Fig. 3. Building Model with overhanging beams with floating columns

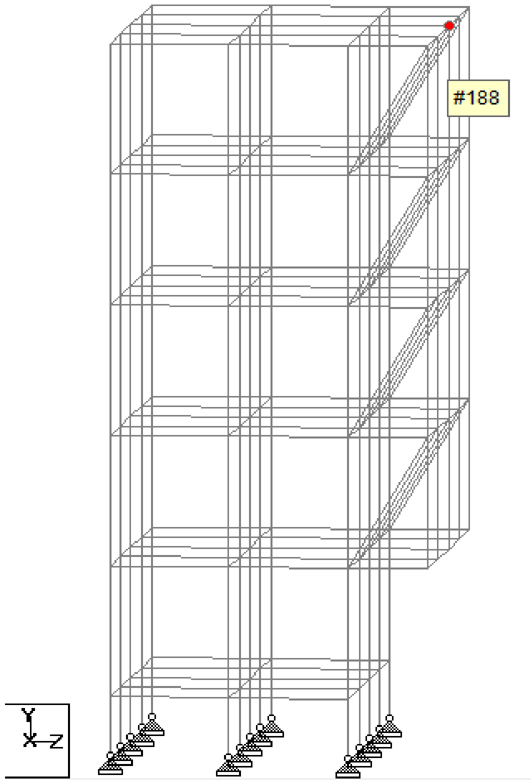

Fig. 4. Building Model with overhanging beams with floating columns and single bracing

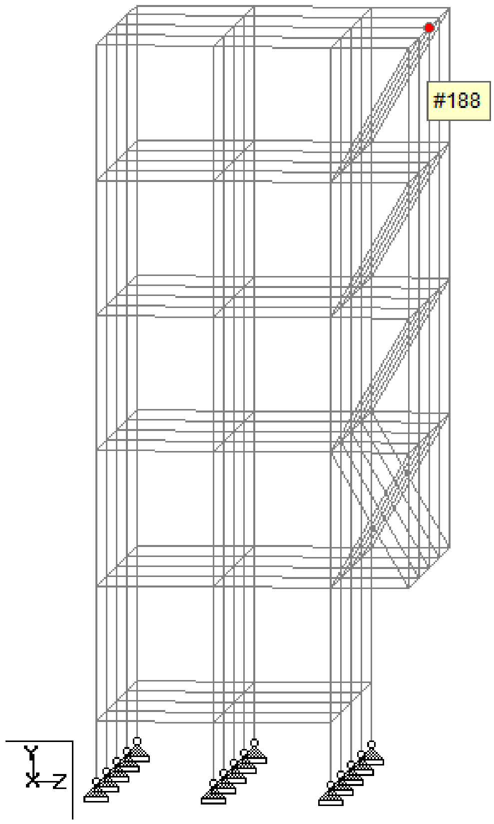

Fig. 5. Building Model with overhanging beams with floating columns and X bracing

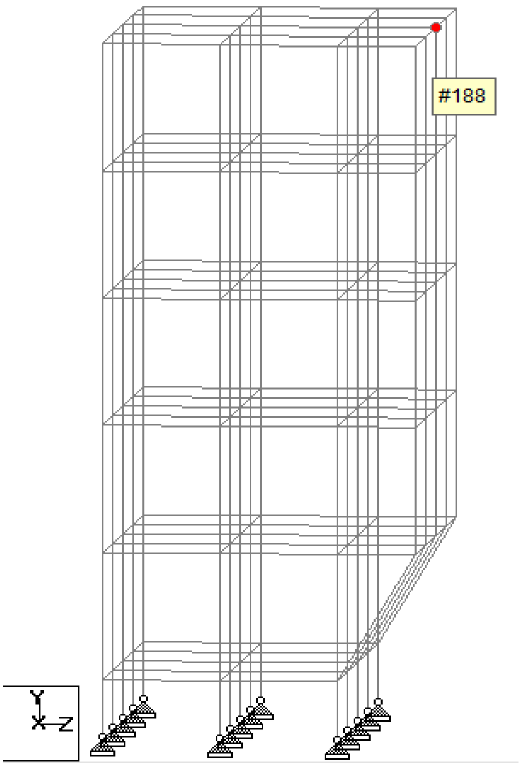

Fig. 6. Building Model with overhanging beams with floating columns with Bracket below

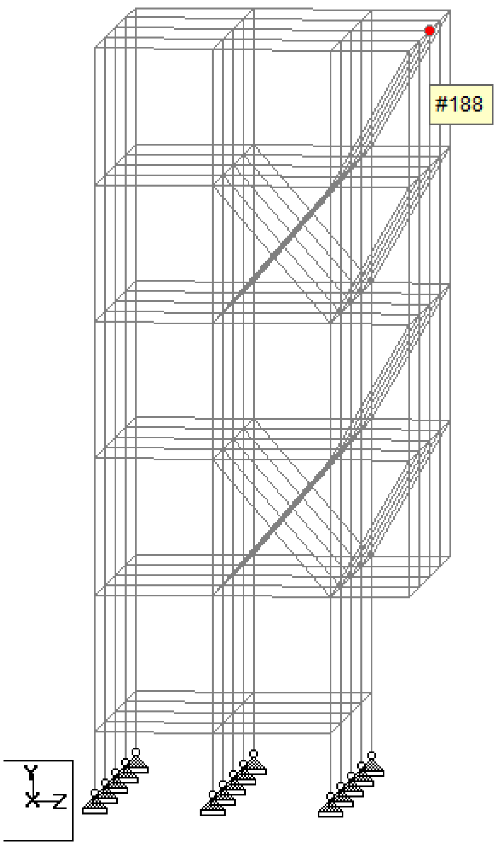

Fig. 7. Building Model with overhanging beams with floating columns with single bracing in end bay and cross bracing in adjacent bay

V. RESULT ANALYSIS

A. *Effectiveness of Bracings in place of Floating columns in inside beams*

Table I shows the displacements of node no. 173 in 3 directions under load combination for serviceability condition including earthquake forces in both directions. From the analysis of results it can be seen that by the provision of bracing replacing floating column in the lower most storey the continuity in the load path is ensured and the lateral stiffness of the frame as a whole is enhanced which resulted in reduced nodal displacement. The considerable reduction in the horizontal displacement proves the enhancement in lateral stiffness of the frame as a whole and stability attained through proper and continuous load path.

TABLE I. EFFECT OF BRACINGS FOR SUBSTITUTION OF FLOATING COLUMNS IN INSIDE BEAMS AT POINT OF MAXIUMU DEFLECTION

Load case considered	Horizontal	Vertical	Horizontal
	X mm	*Y mm*	*Z mm*
3D Frame with Floating Column			
9 Seismic Service - X	17.659	-6.61	11.403
10 Seismic Service - Z	0	-6.382	45.756
3D Frame with Bracing			
9 Seismic Service - X	17.981	-5.429	3.907
10 Seismic Service - Z	0	-5.178	30.33
% variation			
9 Seismic Service - X	-1.82343	17.86687	65.73709
10 Seismic Service - Z	0	18.86556	33.71361

B. *Effectiveness of Bracings for floating columns on overhanging beams*

Table II shows the displacements of node no. 188 in 3 directions under load combinations for serviceability condition including earthquake forces in both directions. From the analysis of results in Table II, it can be seen that by the provision of bracing, the stiffness of the overhanging portion is enhanced and thus the vertical nodal displacement is reduced. But it can be observed that by providing double diagonal bracing, which is supposed to impart greater lateral stiffness to the frame, no significant reduction in displacement occurs as compared to single diagonal bracing. This can be due to the fact that the 2nd diagonal bracing has much less contribution to impart continuity of load path. Provision of bracket below the floating column also has almost same effect in the seismic behaviour of the frame as that with single diagonal bracings. Apart from these, provision of double diagonal bracing in alternate floors of the bay adjacent to the overhanging bay shows significant reduction in the lateral displacement of the node. This is attributed to the increased stiffness of the frame with bracing. Thus such a combination of single diagonal bracing in the overhanging bay and double diagonal bracing in alternate floors of the adjacent bay can be resorted to for better seismic behaviour of the frame where space requirement demands such an arrangement.

TABLE II. EFFECT OF BRACINGS FOR SUBSTITUTION OF FLOATING COLUMNS ON OVERHANGING BEAMS AT POINT OF MAXIUMUM DEFLECTION

Load case considered	Horizontal	Vertical	Horizontal
	X mm	*Y mm*	*Z mm*
Floating Column on Cantilever			
8 EQX SERVICE	62.009	-16.191	34.821
10 EQZ SERVICE	0	-20.263	75.099
Floating Column on Cantilever with Diagonal Braces			
8 EQX SERVICE	59.433	-11.388	38.734
10 EQZ SERVICE	0	-15.921	78.891
Floating Column on Cantilever with Cross Braces at FF			
8 EQX SERVICE	58.885	-11.406	38.696
10 EQZ SERVICE	0	-15.936	78.77
Floating Column on Cantilever with Bracket at GF			
8 EQX SERVICE	54.539	-10.478	34.423
10 EQZ SERVICE	0	-14.922	74.746
Floating Column on Cantilever with Cross bracing in adjacent bay			
8 EQX SERVICE	59.004	-8.205	14.115
10 EQZ SERVICE	0	-10.246	33.352

VI. CONCLUSION

From the analysis and interpretation of the results it is concluded that provision of bracings is much effective in imparting lateral stiffness as well as ensuring continuity of load path in frames with floating columns. Hence, provision of bracings is an effective tool in frames with floating columns for enhanced and better performance under seismic loads and economy.

REFERENCES

[1] R. Harugoppa and S. M. Muranal, "Design requirement for Floating column under seismic forces", 2019 Pacific Conference on Earthquake Engineering by New Zealand society for Earthquake Engineering, 4 – 6 April, 2019.

[2] Kishalay Maitra, N. H. M. Kamrujjaman Serker, "Evaluation of Seismic Performance of Floating Column Building", American Journal of Civil Engineering. Vol. 6, No. 2, 2018, pp. 55-59. April 2018.

[3] Gulchaman Khan and Mayur singi, "Seismic Analysis of Multistorey Building having Floating column", International Journal of Engineering Sciences & Research Technology, JESRT: 8(1), January, 2019, ISSN: 2277-9655.

[4] Vyom Goel and Ajit Kumar Jain, "Seismic Analysis of Multi-storey Building with and without Floating Column and Shear Wall using STADD Pro Software", International Journal of Advanced Science and Technology Vol. 29, No. 8s, 2020, pp. 4306-4318 4306 ISSN: 2005-4238.

[5] Vinay Agrawal, Suyash Garg, Ravindra Nagar and Vinay Chandwani, "Seismic Retrofitting of RC Buildings with Soft Storey and Floating Columns", World Academy of Science, Engineering and Technology - International Journal of Structural and Construction Engineering Vol.10, No.12, pp. 1457-1495, 2016.

[6] A. Wahidi and D. Rama Seshu, "Seismic Analysis of Multistorey building with Floating Columns", Asian Journal of Civil Engineering (BHRC) Vol. 17, No. 8, 2016, pp. 1077-1085.

[7] A.P.Mundada and S.G.Sawdatkar, "Comparative Seismic Analysis of Multistorey Building with and without Floating column", International Journal of Current Engineering and Technology, Oct 2014, Vol. 4, No. 5, pp. 3395-3400.

[8] Priya Prasannan and Ancy Mathew, "Seismic Performance of RC Floating Column Considering Different Configurations", International Journal of Engineering Research & Technology, ISSN: 2278-0181, Vol. 6, Issue. 5, May 2017.

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