Non-Linear Seismic Analysis of Floating Column Supported on Transfer Beam

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***Abstract* — The revised Indian code for earthquake resistant design of structure IS 1893(Part 1):2016 not considered non-linear analysis methods hence we have to consider codes ATC 40 and FEMA. Also IS code suggest that the floating column should be avoided as a lateral load resisting member. Considering above cases, the authors intend to do inelastic analysis of typical 10 -storey building with different conditions such as without floating column, with floating column and with provision of shear walls at different locations and compare the results. The paper validates the IS provisions and pinpoints further investigation areas.**

Keywords: Floating Column, Shear Wall, Push Over Analysis, ETABS 20.

I. INTRODUCTION

During severe earthquakes, structural design for seismic loading is primarily concerned with structural safety, serviceability, and the potential for economic losses. Therefore, it is necessary to study the structural behavior under large inelastic cyclic deformations. In principle, the behavior of a structure under earthquake loading is different from other lateral or gravity loads. Ensuring acceptable seismic performance outside the elastic range requires more detailed analysis. Inelastic energy dissipation in structural systems is allowed in almost all codes, due to which when the structure experiences an earthquake, most of the structural damage is done.

The main focus of seismic analysis and design of buildings is reducing the risk of the loss of life in the most significant expected earthquake. The provisions in the codes take into account the historical performance of structures and their deficiencies for the development of structures concerning life safety by preventing a collapse in the most intense earthquake expected at the site during the life of the structure.

A column is a vertical compressive member. It transfers superstructure load to the foundation and then to the ground. The floating column is also a vertical member, but its lower end is not connected to the foundation. Instead, the end of the floating column rests on the transfer beam, which is a horizontal structural member, transferring a load of a floating column to other columns below it. The floating column is used for architectural views and more parking space.

Seismic analysis of high-rise buildings must be done to determine the seismic responses of the building to understand the actual behavior of the structure, so it can be done either by dynamic or simple equivalent static analysis. This linear static method can be used for stable structures with limited height.

It was found that, apart from detailed nonlinear analysis, the available methods have limited application areas and cannot be used for all types of buildings. One of the most challenging duties in structural engineering is determining the seismic demands on the structure. Most studies in this field provide more straightforward techniques to anticipate results with a fair degree of accuracy. The seismic analysis approaches have been utilized to estimate the demand.

II. PUSH OVER ANALYSIS

The capacity of construction materials or structural components to get energy by deformation to an inelastic range is called ductility. The ability of a structure to absorb energy with limited deformations and without failure is a desirable characteristic of any

earthquake-resistant design. Push over analysis is used to obtain the performance of building i.e., capacity of a building to sustain the base shear. It is a non-linear static analysis method but very effective in obtaining the maximum limit of displacement that structure can sustain in non-linear behavior of elements. This method also gives us the response of hinges during the targeted displacement analysis.
During non-linear analysis, acceptance criteria is provided for performance levels such as Immediate Occupancy (IO), Life Safety (LS), and Collapse Prevention (CP). The approximate limits are shown in below diagrams in idealized force vs deformation curve graph. As per primary and secondary component, component materials etc. values vary distinctly. The limits for various components are mentioned in FEMA 273 and ATC 40.

III.MODEL PROPERTIES:

A 10-storey building situated in the Shillong region is considered. The building falls in seismic zone V as per IS 1893(Part1):2016 and medium-type soil is considered with importance factor 1, response reduction factor 5 and 5% damping. The plan area for the building is 400 sq.m. The plan for the rectangular building is 20m X 20m. Models classified as
Model 1. Building without floating column.
Model 2. Building with the floating column.
Model 3. Building with floating column and corner shear walls
Model 4. Building with floating column and intermediate shear walls

The buildings are considered to be fixed at the base. The floor-to-floor height is kept constant and is taken as 3m.
Properties of Building:

Height of building (m)	=	30
Plan area (sq.m)	=	400
Plan dimension (m)	=	20 X 20
Column size (mm) –		
Base to 4th Storey	=	800 X 800
5th to 7th Storey	=	600X600
8th to 10th Storey	=	400X400
Beam size (mm)	=	300X300
Transfer Beam (mm)	=	900X900
Thickness of slab (mm)	=	125
External wall width (mm)	=	250
Internal wall width (mm)	=	150
Parapet wall width (mm)	=	250
Parapet wall height (m)	=	1
Shear wall width (mm)	=	250
Unit weight of concrete (kN/m3)	=	25
Grade of Concrete	=	M25
Grade of Steel	=	Fe500

Loads Applied on Building:

Live Load Floor (kN/m)	=	2
Live Load Roof (kN/m)	=	1.5
Floor Finish (kN/m)	=	1.5
Roof Treatment (kN/m)	=	1.5
External Wall (kN/m)	=	13.5
Internal Wall (kN/m)	=	8.1
Parapet Wall (kN/m)	=	5

Model 1:

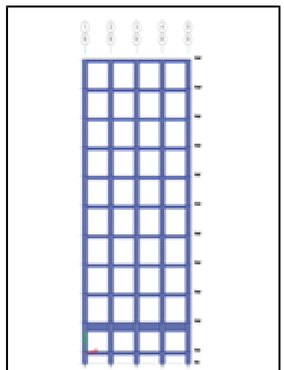


Fig. 1 Elevation

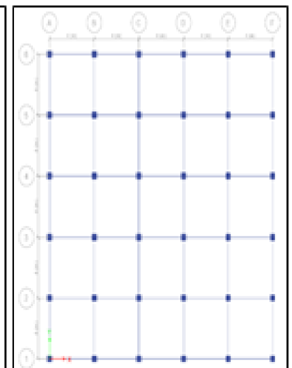


Fig. 2 Plan

Model 2:

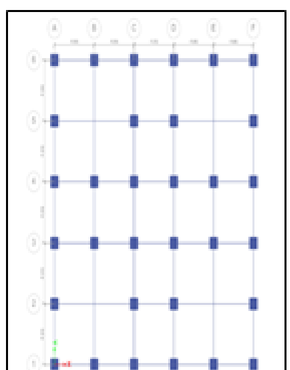


Fig. 3 Plan

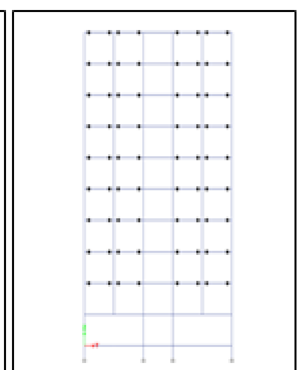


Fig. 4 Elevation

Model 3:

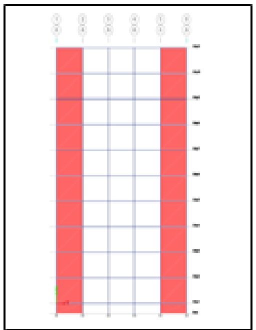


Fig. 5 Elevation

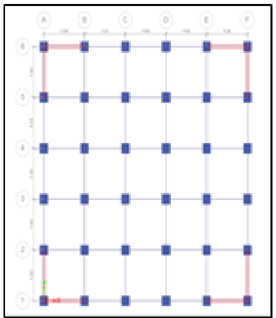


Fig. 6 Plan

Model 4:

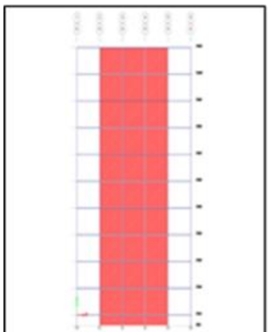


Fig. 7 Elevation

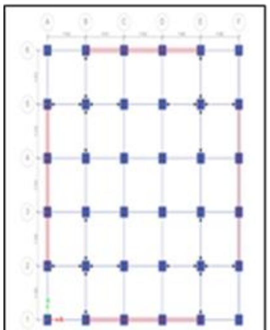
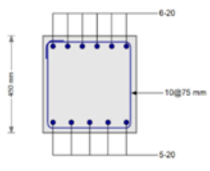


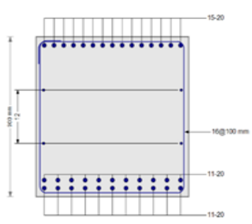
Fig. 8 Plan

Reinforcements

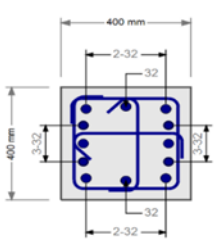
BEAM 450 X 450



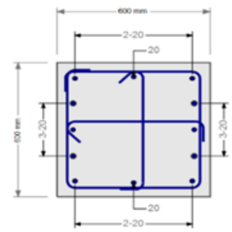
BEAM 900 X 900



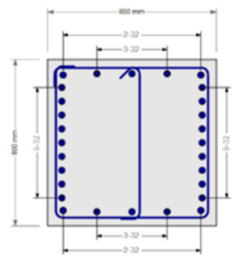
COLUMN 400 X 400



COLUMN 600 X 600



COLUMN 800 X 800



IV. RESULTS

For inelastic analysis, the results for models in below table suggests that as displacement increased the base shear also increased which resulted in deformation of non-linear hinges provided at ends of beams and columns. For push over analysis target displacement method is used. The target displacement given is 350 mm which is in limit. As FEMA suggested that maximum target displacement should be 4% of height of building which is in our case 1280 mm. As per the ATC 40, the states given for non-linear behavior of members that are IO, LS and CP.

Push Over Curve X – Direction: -

- In model 1, even after monitored displacement of 207 mm, 144 hinges passed the IO state limit and base shear is 30101.39 KN.
- In model 2, after monitored displacement of 207 mm, 66 hinges passed the IO state limit and base shear is 22635.54 KN.

Table 1. Base Shear vs Monitored Displacement

Monitored Displacement mm	Model 1	Monitored Displacement mm	Model 2
0	0	0	0
35	7320.631	35	5442.6076
70	14641.27	70	10885.2153
86.126	18013.9	86.499	13450.7346
121.131	22895.94	122.468	17296.3291
157.598	25852.89	157.702	19478.5868
193.988	28268.06	193.037	21083.5743
228.988	30101.39	229.53	22635.5486
244.834	30922.25	264.53	23966.566

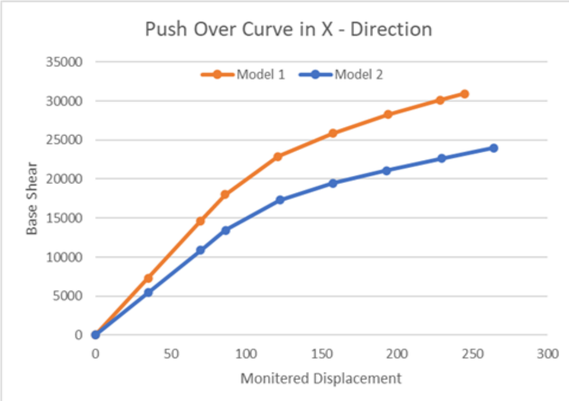


Fig. 9 Push Over Curve for Model 1 & Model 2

Table 2. Base Shear vs Monitored Displacement

Monitored Displacement mm	Model 3	Monitored Displacement mm	Model 4
0	0	0	0
0.949	399.0481	14	16212.4505
24.227	10231.5772	19.401	22231.1778
38.227	16120.1109	33.592	36977.9693
56.863	23803.6899	49.727	52365.3236
71.141	29007.9936	63.842	64159.2405
85.036	33396.3314	78.123	74394.9796
95.17	36538.2639	84.741	78658.6422
95.174	36732.2836	84.744	78654.691
109.174	41528.5078	109.029	94988.242
123.174	44872.1002	123.029	102648.1991
137.174	47925.2224	137.029	110158.9855
151.174	50901.1533	151.029	116444.0843
165.174	53623.2218	165.029	123653.3849
179.174	55988.385	179.029	130034.5127
193.174	58355.7476	193.029	136523.2007
207.174	60228.6499	207.029	141654.0698

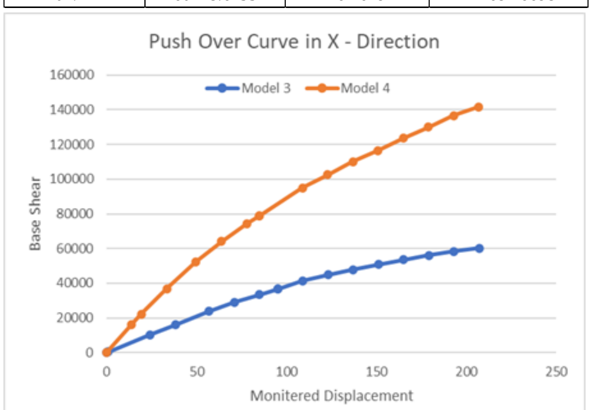


Fig. 10 Push Over Curve for Model 3 & Model 4

Push Over Curve Y - Direction:

- In model 3, after monitored displacement of 207 mm, 18 hinges passed CP state limit, 6 hinges passed LS state limit, 50 hinges passed IO state limit and the base shear is 60228.65 KN.
- For model 4, the monitored displacement and base shear are 207 mm, 26 hinges passed the CP state, 8 hinges passed LS state, 98 hinges passed IO state and base shear is 141654.06 KN.

Table 3. Base shear Vs Monitored Displacement

Monitored Displ	Model 1	Monitored Displ	Model 2
mm	kN	mm	kN
0	0	0	0
35	7338.2897	35	5442.6076
70	14676.5855	70	10885.215
85.92	18014.316	86.499	13450.735
120.23	22830.1863	122.468	17296.329
157.321	25848.0661	157.702	19493.418
193.898	28276.132	192.837	21100.746
255.809	31509.6991	227.837	22594.675
290.809	33326.6255	271.587	24452.063
327.176	35141.8987	307.68	25832.463
350	36177.6117	332.367	26644.672

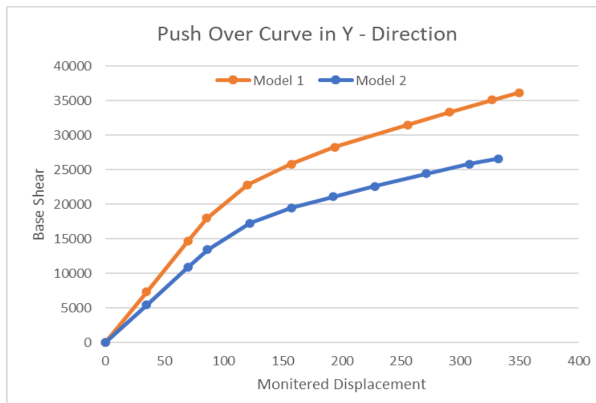


Fig. 11 Push Over Curve for Model 1 & Model 2

Table 3. Base shear Vs Monitored Displacement

Monitored Displacement mm	Model 3	Monitored Displacement mm	Model 4
0	0	0	0
0.949	399.0481	14	16212.4505
24.227	10231.5773	19.401	22231.1777
38.227	16120.111	33.442	36829.5744
56.863	23803.6899	47.568	50366.5533
71.107	28982.6566	61.898	62500.0326
82.434	32586.323	76.987	73477.7158
82.438	32581.0927	84.875	78604.9766
82.781	32947.0501	84.879	78804.4355
98.288	37935.7518	106.698	92919.6753
112.288	41825.6816	120.698	101048.5678
126.288	45048.5473	134.698	108669.2041
140.288	47980.4907	148.698	116470.2579
154.288	50827.3041	162.698	122085.9337
168.288	52914.3284	176.698	128435.6975
182.288	54832.3433	190.698	135232.8625
196.288	57267.6675	204.698	141162.2549
210.288	59065.5244	218.698	146509.1738
224.288	60630.5816	232.698	151052.4872
239.792	63020.3161	239.792	152979.2786

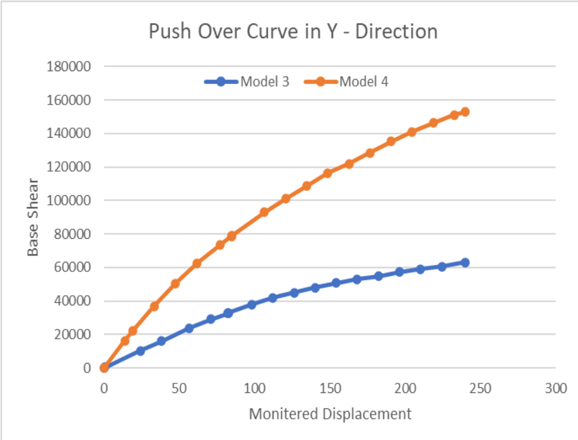


Fig. 12 Push Over Curve for Model 3 & Model 4

V. CONCLUSION

1. In regular building, the base shear for 207 mm monitored displacement is 32.98% higher than building with floating column.
2. Corner shear wall building provide 166.08% higher base shear for monitored displacement of 207 mm than building with floating column.
3. While intermediate shear walls building provide 525.80% higher base shear for monitored displacement of 207 mm than building with floating column.
4. The higher base shear suggests that the capacity of building to resist seismic load is higher while displacement is same.
5. Shear wall hinges near floating column storey also goes in LS state while floating column stays in IO state which shows that the shear wall is very effective in case of floating column. and first failure will happen in shear wall rather in floating column and transfer beam.

REFFERENCE

[1] P. C. Wang and A. J. Philippacopoulos. Seismic Inputs for Nonlinear Structures. Journal of Engineering Mechanics, Vol. 110, No. 5, May, 1984. ©ASCE, ISSN 0733-9399/ 84/0005-0828 (1984).

[2] Jack P. Moehle and Luis F. Alarcon. Seismic Analysis Methods for Irregular Buildings. Journal of Structural Engineering, Vol. 112, No. 1, January, 1986. ©ASCE, ISSN 0733-9445 (1986).

[3] Carlos E. Ventura and Bruce F. Maison. Dynamic Analysis of Thirteen-Story Building Journal of Structural Engineering, Vol. 117, No. 12, December,1991. ©ASCE, ISSN 0733-9445/91/0012-3783 (1991).

[4] Sudhir K. Jain. A Proposed Draft for IS:1893 provisions on seismic design of buildings – Part – II: Commentary and Examples. Journal of Structural Engineering Vol. 22 No. 2 July 1995 pp 73-90. (1995)

[5] Jaswant N. Arlekar, Sudhir K. Jain, and C.V.R. Murty. Seismic Response of RC Frame Buildings with Soft First Storeys. Proceedings of the CBRI Golden Jubilee Conference on Natural Hazards in Urban Habitat, New Delhi. (1997).

[6] Abbas Moustafa. Critical earthquake load inputs for multi-degree-of-freedom inelastic structures, Journal of Sound and Vibration (2009)

[7] N. R. Chandak. Response Spectrum Analysis of Reinforced Concrete Buildings. Journal Institution of Engineers India Ser. A (May–July 2012) 93(2):121–128 (2012)

[8] Keerthi Gowda B. S. and Syed Tajuddin. Seismic Analysis of Multistorey Building with Floating Columns. Proceedings of the First Annual Conference on Innovations and Developments in Civil Engineering, ACIDIC 2014, NITK, India. (2014)

[9] Sabari S and Praveen J. V. Seismic Analysis of Multistorey Building with Floating Column. International Journal of Civil and Structural Engineering Research ISSN 2348-7607 (Online) Vol. 2, Issue 2, pp: (12-23), Month: October 2014 - March 2015 (2015)

[10] Sarika Yadav, Raksha Parolkar. Seismic Behavior of Multistorey Buildings Having Floating Columns. International Journal of Civil and Structural Engineering Research ISSN 2348-7607 (Online) Vol. 4, Issue 1, pp: (87-94), Month: September 2016 (2016)

[11] Israa H. Nayel, Zahraa M. Kadhum, and Shereen Q. Abdulridha. The Effect of Shear Wall Locations in RC Multistorey Building with Floating Column Subjected to Seismic Load. International Journal of Civil Engineering and Technology (IJCIET), Volume 9, Issue 7, July 2018, ISSN Print: 0976-6308 and ISSN Online: 0976-6316 (2018).

[12] N. H. M. Kamrujjaman Serker and Kishalay Maitra. Evaluation of Seismic Performance of

Floating Column Building. American Journal of Civil Engineering. Vol. 6, No. 2, 2018, pp. 55-59. doi: 10.11648/j.ajce.20180602.11 (2018).

[13] Rashi Chaurasia and Ankit Pal. Comparative Analysis of Multi-Storey RC Frame Building with and without Floating Column using Base-Isolation in Seismic Zone V. International Journal of Advanced Engineering Research and Science (IJAERS) [Vol -6, Issue-6, June- 2019], ISSN: 2349-6495(P) | 2456-1908(O) (2019).

[14] Ahmed Ibrahim and Hamed Askar. Dynamic Analysis of a Multi-storey Frame RC Building with and Without Floating Columns. American Journal of Civil Engineering. Vol. 9, No. 6, 2021, pp. 177-185. doi: 10.11648/j.ajce.20210906.11 (2021).