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Study of Floating Column Considered as Gravity Column for various Plan and Story Configuration

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Abstract: Now a day's the multi-storey buildings are constructed for the purpose of residential, commercial, industrial etc., with an open ground storey is becoming a common feature. The most important application of floating column is for the construction of soft storey in the ground floor to facilitate free space for parking or entrance corridors. This free space will provide parking option for residential, industrial and commercial buildings. In banquet halls, lobbies, conference room, large interrupted column free space is required for free movement of people and vehicles. For the purpose of parking all, 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. With the advancement in construction materials and design technologies and the context of substantial urban growth, tall structures are increasing day by day, the cost of land also increases. Hence, it was the best idea to expand vertically. The design of the tall structure is highly conservative because tall structures are susceptible to seismic forces.
In this study, it is checking the behavior of floating column considering as gravity column type. Objective of paper was to avoid seismic effect on floating column by provide shear wall at core and at corner of the building, by provide very less stiffness modifiers for floating column, by providing pin joint at each end of floating column, and as per IS13920:2016, clause 11 additional moment applying on floating column by R times displacement for factored seismic load. The study reveals that the by providing pin joint on each end of floating column are the efficient and good result to avoid moment due to seismic load.

Key words: Shear Wall, Floating Columns, Seismic Load, Pin joint, Stiffness modifier ETABS-2018.

INTRODUCTION

Floating Column

Now a day's the multi-storey buildings are constructed for the purpose of residential, commercial, industrial etc., with an open ground storey is becoming a common feature. The most important application of floating column is for the construction of soft storey in the ground floor to facilitate free space for parking or entrance corridors. This free space will provide parking option for residential, industrial and commercial buildings. In banquet halls, lobbies, conference room, large interrupted column free space is required for free movement of people and vehicles. For the purpose of parking all, usually the ground storey is kept free without any constructions, except the columns which transfer the building weight to the ground. 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.

The floating column may be positioned on the first floor or top floors or any of the intermediate floors based on the requirements in the architectural design of the respective structure. The arrangement of a hanging column is in such a way that it simply floats or is being hung over a base (beam or slab) with no fixed support below with the foundation. Floating column is constructed over the beam and hence it won't be having any form of continuity with the structural elements below. Floating columns can make every floor different, with different grid system. This will affect vertical symmetry of the building. This will affect the building performance during earthquake forces. These floating column buildings are designed for gravity loads and safe under gravity loads but these buildings are not designed

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for earthquake loads. So, these buildings are unsafe in seismic prone areas. The using of floating column is for the aims of architectural view and site situations.

Gravity Column

Gravity columns are the vertical load bearing systems which do not resist any lateral loads on the structure but are capable of taking displacements produced due to lateral loads. As per the IS: 13920-2016, all the members of the building must be designed ductile when the building is located in zones III, IV, V except. As per the IS: 13920-2016, clause 11 says that, the gravity columns shall be designed for bending & shear when subject to 'R' times the design lateral displacement under the factored equivalent static design seismic loads, but there are many practical difficulties being experienced for design of the gravity columns based on the above clause.

The IS:13920-2016 code allows to considering that the certain columns may not be designed as an earthquake resistant element, but such columns shall be considered as gravity columns. Actual earthquake force on the structure may be significantly higher than what we consider in the design. Due to this fact, the structure may experience substantially higher displacements than it is derived in the analytical model. The code reckons that the actual displacement in the structure would be R*Displacement obtained in the analytical model with factored earthquake forces (R is response reduction factor). Gravity columns is a choice that as structural engineer we have to make in our system. To reflect this correctly in analysis, ideally these columns should not participate in lateral load resistance in carrying shear and bending moments. These should be defined as 'pinned' ends in lateral load analysis.

Priya Prasannan, Ancy Mathew [2017], have been studied the Seismic Performance of RC Floating Column Considering Different Configurations. The primary purpose is to study the effect of varying the location of floating columns floor wise and within the floor of multi storied RC building on various structural response quantities of the building using response spectrum analysis and compare total base shear force, storey drift, displacement and of floating column under different configurations. To find best configuration which causes minimum damage or collapse after the removal of the columns. From this they observe that the Shear wall provided at diagonal corners can be used as the best effective method to resist the lateral forces. Story drift and story displacement is more when floating columns are provided in fifth floor.

Vasant S. Kelkar, Ashish Bhangle, Prabhat Pandey [2018], did the study on Gravity Columns and Floating Columns. The main objective of this paper is to check Gravity columns could be used without designing them for bending moments/shears due to 'R' times the lateral displacements under the factored static design seismic loads required by Cl. 11 of IS 13920- 16. But then they should be detailed for ductility as per code, The Floating columns should be avoided. But where they are unavoidable with small plots and parking requirements in cities like Mumbai, floating columns even if they are a part of lateral load resisting system, could be permitted. But then the transfer girders and columns supporting them should be designed for Omega times (about 2.5 times) the moments/shears under design EQ loads as per ASCE.

P. Adebar, R. De Vall, and J.G. Mutrie [2010], have been studied on the Design of Gravity-Load Resisting Frames for Seismic Displacement Demands. The main objective of this paper was to determine the forces and deformations induced in the gravity-load resisting frame members due to the seismic deformation demands on the SFRS, in concept, this involves displacing the complete structure – SFRS and gravity-load resisting frame – to the design displacement. The yielding that occurs in the SFRS before it reaches the design displacement causes a concentration of deformation demands at plastic hinge locations. The influence of the resulting inelastic displacement profile of the SFRS must be accounted for when determining demands on the gravity-load frame.

A.M. Elsouri, M.H. Harajli [2015], have been studied on the Interior RC wide beam-narrow column joints: Potential for improving seismic resistance. The primary purpose of this work was to evaluating the seismic behavior of reinforced concrete as-built interior wide beam-narrow column joints, i.e., joints designed for gravity load, and for exploring the potential of improving their seismic performance without imposing significant changes in their design and construction practices. In this study, two ''as-built'' and two companion ''earthquake-resistant'' interior beam-column joints were tested under quasi-static cyclic loading. The as-built joints were designed for gravity load and the reinforcement was detailed accordingly. The two earthquake-resistant joints were also designed for gravity load, but their reinforcement detailing was improved to satisfy part of ACI 318-08 provisions and ACI 352-02 recommendations for earthquake-resistant structures in regions of moderate and high seismic hazard.

Amin Zaherdannak, Amirhosein Shabani, and Saeed Erfani [2020], study on the Seismic Performance Evaluation of Special RC Frames with Gravity Steel Columns under the Base Level. In this study, typical RC columns in middle frames at basement levels are substituted with simply connected steel columns to make these levels more ideal parking spaces by decreasing the space occupied by structural elements, i.e., columns. Seismic performance of structures with RC columns (RCT) and those with the substituted steel columns at basement levels (RCN) was evaluated based on the FEMA P695 method. RCN structures exhibit a similar or improved seismic performance compared to RCT building, therefore

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substituting RC columns by simply connected steel columns does not seem to negatively impact the overall behavior seismic of the structure.

Nakul A. Patil, Prof. Riyaz Sameer Shah [2015], have been completed the study on Comparative Study of Floating and Non-Floating Columns with and Without Seismic Behavior. The primary aim of this work is the comparative study of floating columns and non-floating columns with and without seismic behavior. To study the effect of internal and external floating columns on the building under earthquake loading for different seismic zones.

Description of building model

In this study, I have analyzed the building with G+15 story building for each plan configuration in ETABS for checking the behavior of structure. For analysis the following types of building modeled in ETABS.

a. MODEL-1: Column with Shear wall located at corners and center.

b. MODEL-2: Column with Shear wall located at center.

c. MODEL-3: Only Column supported.

Types of conditions for Floating column

For each building model, I have taken four conditions for comparison the effect floating column.

i. Without floating column

ii. With floating column with very less stiffness modifier.

iii. With floating column having stiffness modifier and pin joint at both end of column.

iv. Floating column considered as gravity column, also following IS 13920, cl.11.

The value of stiffness modifier for floating column taken 0.01.

Gravity column which is designed only for gravity loads and so in the lateral load analysis it may be considered as hinged at its top and bottom floor levels by giving moment releases to it at such joints (or by giving it a very low value of moment of inertia).

As a Gravity column the column will be designed for the resulting vertical loads plus moments/shears from gravity load analysis plus those due requirements of minimum eccentricity and slenderness as per code.

Model -01: Column with Shear wall located at corners and center

Table 1 General details of Building for Model-1

Specifications	G+15 storey
Building Dimension	23.18m x 21.45m
Floor height	3.0m
Building height	51.0m
Foundation depth	3.0m
Parking floor Slab thickness	200mm
Typical floor Slab thickness	125mm
Shear wall thickness	250mm
Primary size of Floating Column	300 x 750mm
Supporting Beam size for Floating Column	450 x 750mm
Other Column dimension	300x900mm
Beam dimension	300x450mm
Concrete Grade	M30
Steel Grade	Fe500
Light weight block masonry weight	10 kN/m^3
Live load	2 kN/m^2
Floor finish load	2 kN/m^2
IS:1893-2016	
Seismic zone	III
Importance Factor	1.0
Response reduction factor	5.0
Time period In X-Direction	1.61
Time period in Y-Direction	1.91

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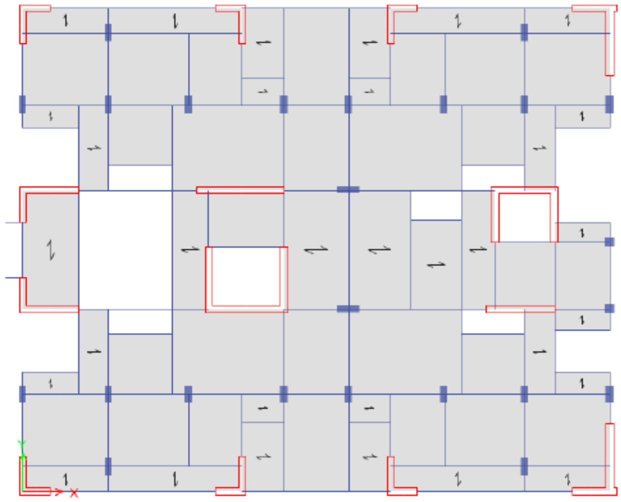

Figure 1 Parking Floor level (Ground floor slab) of Model-1

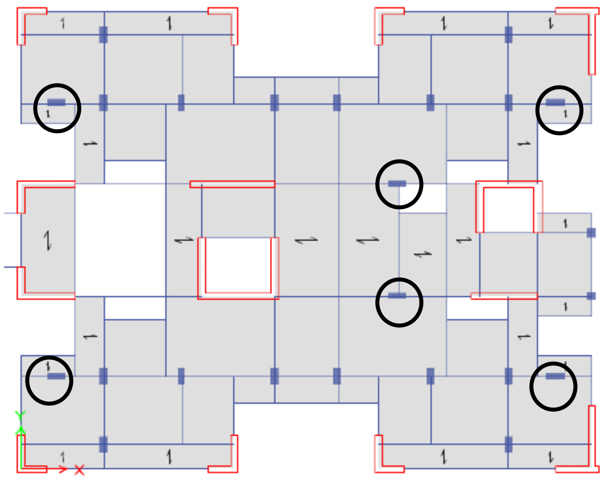

Figure 2 Storey 1 slab level of Model-1

Model -02: Column with Shear wall at center
Table 2 General details of Building for Model-2

Specifications	G+15 Storey
Building Dimension	22.93m x 16.38m
Floor height	3.0m
Building height	51.0m
Foundation depth	3.0m
Parking floor Slab thickness	200mm
Typical floor Slab thickness	125mm
Shear wall thickness	250mm
Primary size of Floating Column	300 x 750mm
Supporting Beam size for Floating Column	450 x 750mm
Other Column dimension	300x900mm
Beam dimension	300x450mm
Concrete Grade	M30
Steel Grade	Fe500
Light weight block masonry	10 kN/m^3

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weight	
Live load	2 kN/m^2
Floor finish load	2 kN/m^2
IS:1893-2016	
Seismic zone	III
Importance Factor	1.0
Response reduction factor	5.0
Time period In X-Direction	0.95
Time period in Y-Direction	1.12

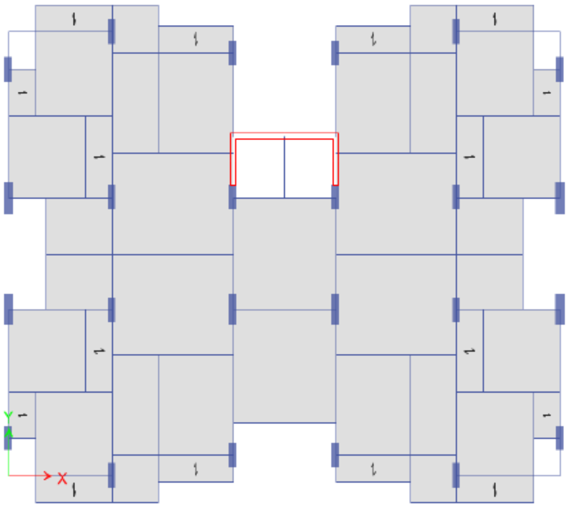

Figure-1 Parking Floor (Ground floor slab) level of Model-2

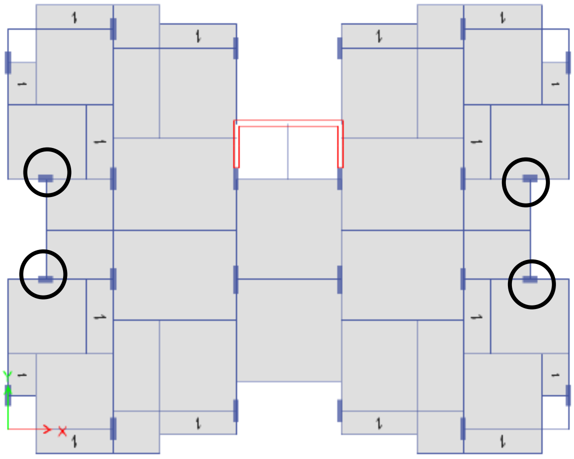

Figure-2 Storey 1 slab level of Model-2

Model -03: Column with Shear wall at center
Table 3 General detail of Building for Model-3

Specifications	G+15 Storey
Building Dimension	18.97m x 56.925m
Floor height	3.0m
Building height	51.0m
Foundation depth	3.0m
Parking floor Slab thickness	200mm

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Typical floor Slab thickness	125mm
Shear wall thickness	250mm
Primary size of Floating Column	300 x 750mm
Supporting Beam size for Floating Column	450 x 750mm
Other Column dimension	300x900mm
Beam dimension	300x450mm
Concrete Grade	M30
Steel Grade	Fe500
Light weight block masonry weight	10 kN/m^3
Live load	2 kN/m^2
Floor finish load	2 kN/m^2
IS:1893-2016	
Seismic zone	III
Importance Factor	1.0
Response reduction factor	5.0
Time period In X-Direction	1.04
Time period in Y-Direction	0.6

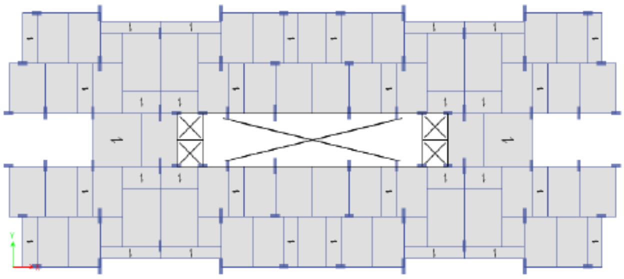

Figure-5 Parking Floor (Ground floor slab) level of Model-3

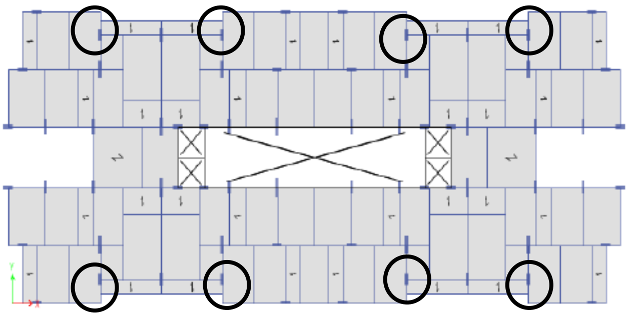

Figure-3 Storey 1 slab level of Model-3

DOI: 10.17148/IARJSET.2022.9642

RESULTS AND DISCUSSION:

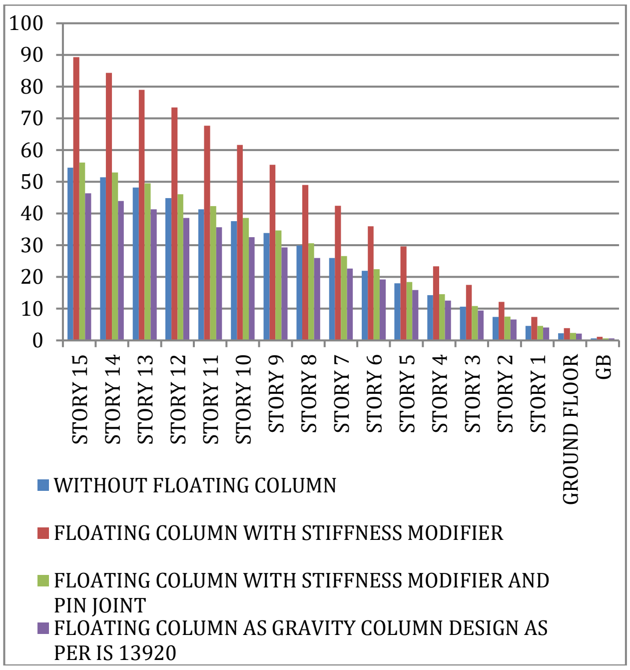

Figure-7 Maximum displacement in Model-1

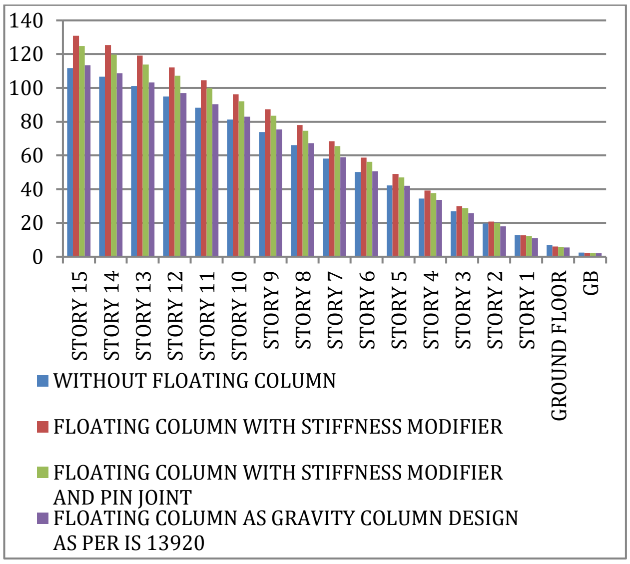

Figure-8 Maximum displacement in Model-2

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

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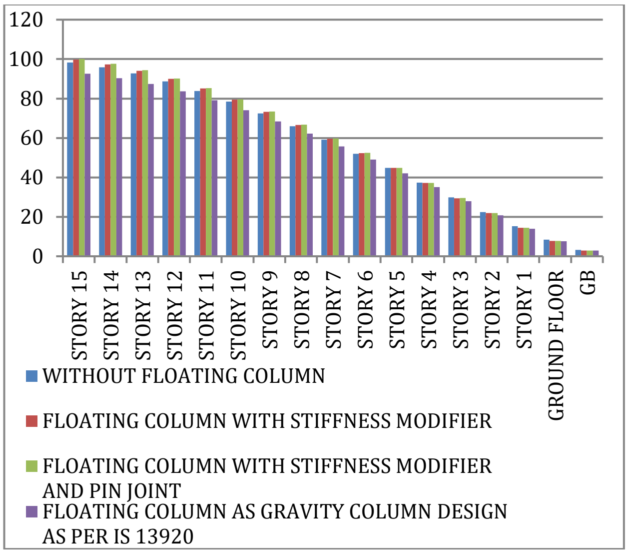

Figure-9 Maximum displacement in Model-3

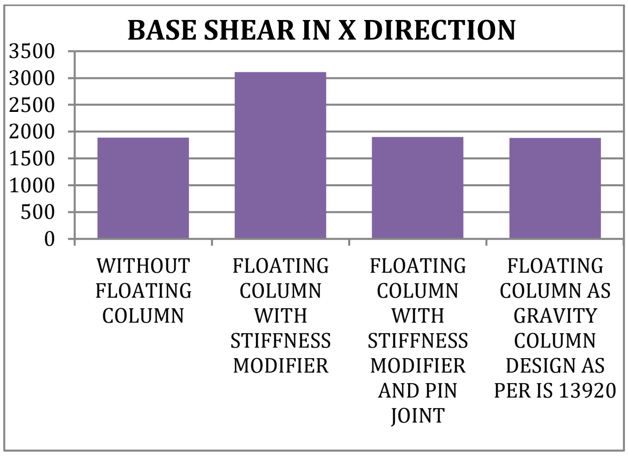

Figure-10 Base shear for Model-1

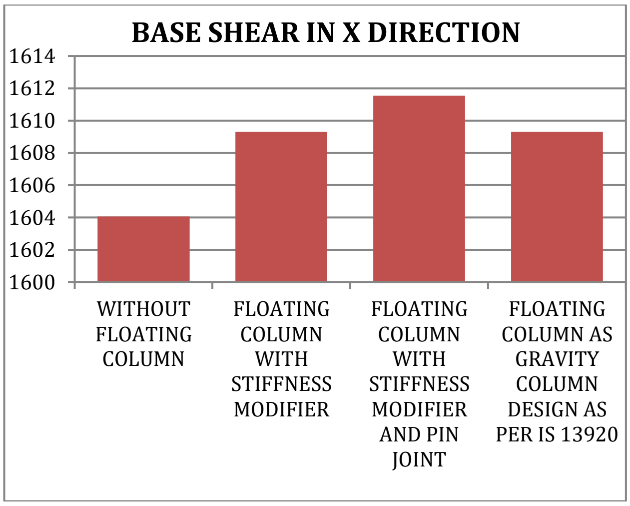

Figure-11 Base shear for Model-2

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

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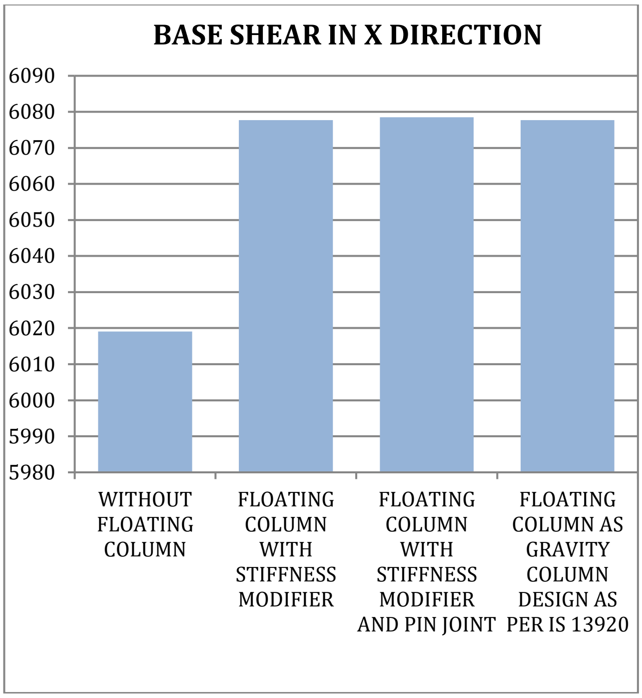

Figure-12 Base shear for Model-3

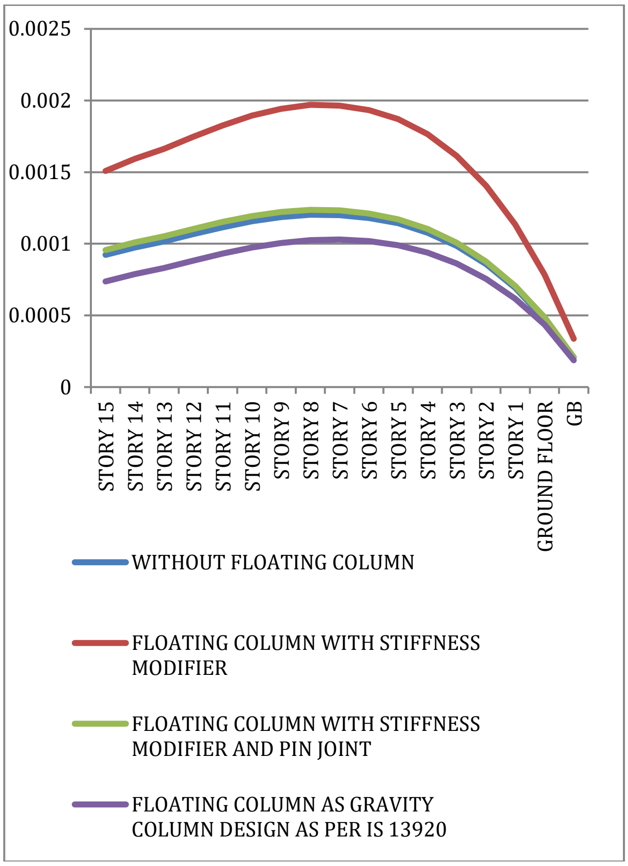

Figure-13 Story drift for Model-1

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

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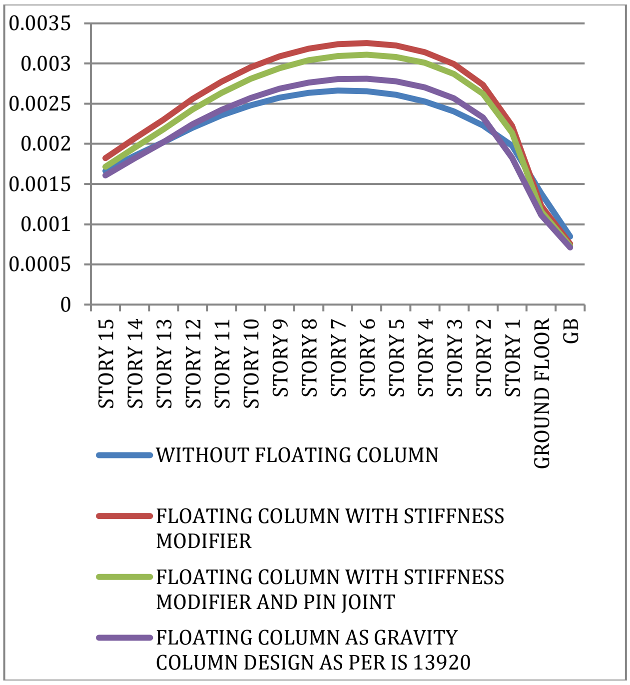

Figure-14 Story drift for Model-2

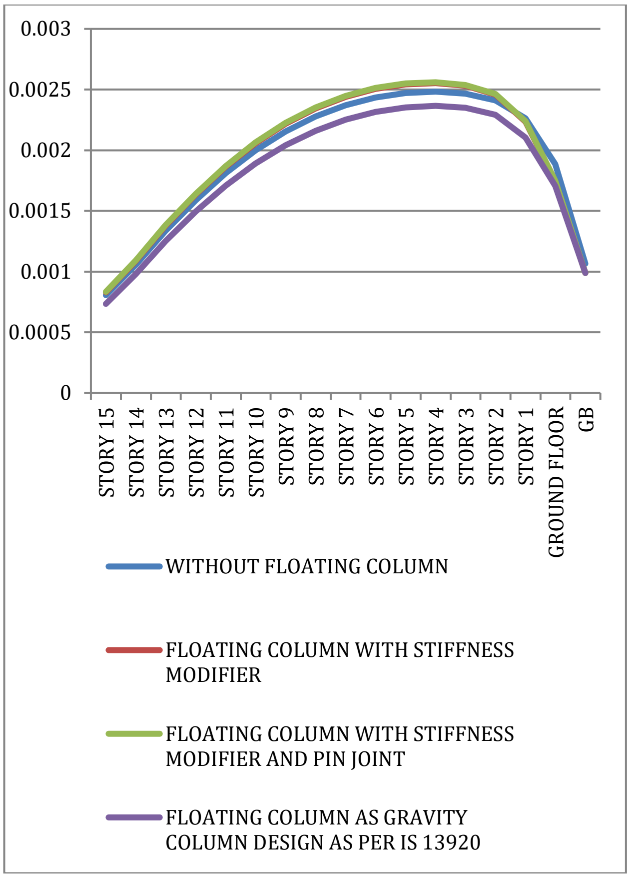

Figure-15 Story drift for Model-3

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

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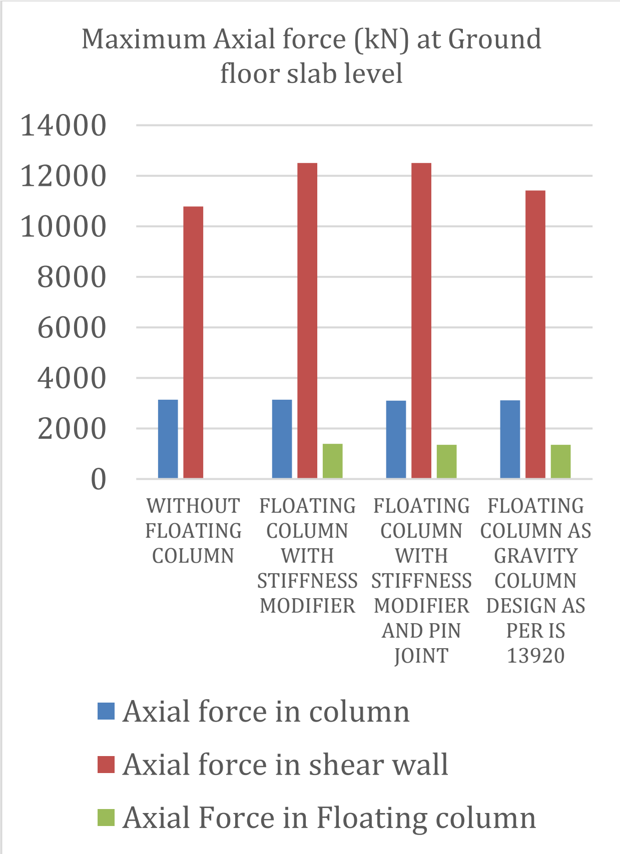

Figure-16 Maximum Axial force

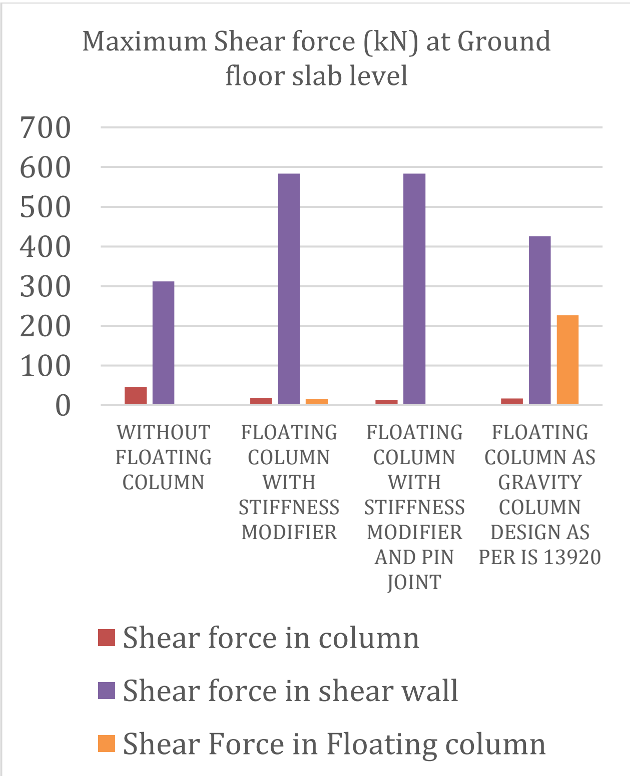

Figure-17 Maximum shear force

IARJSET
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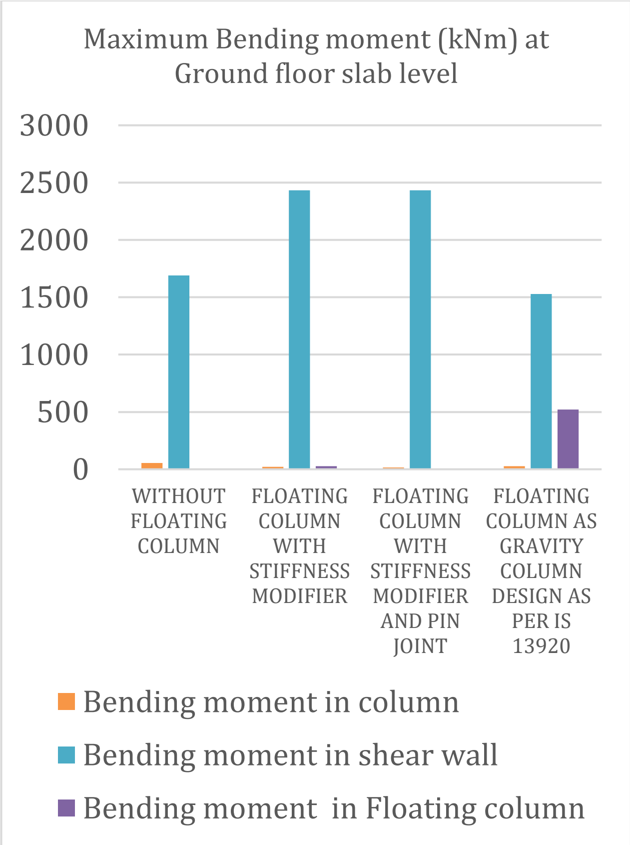

Figure-18 Maximum bending moment

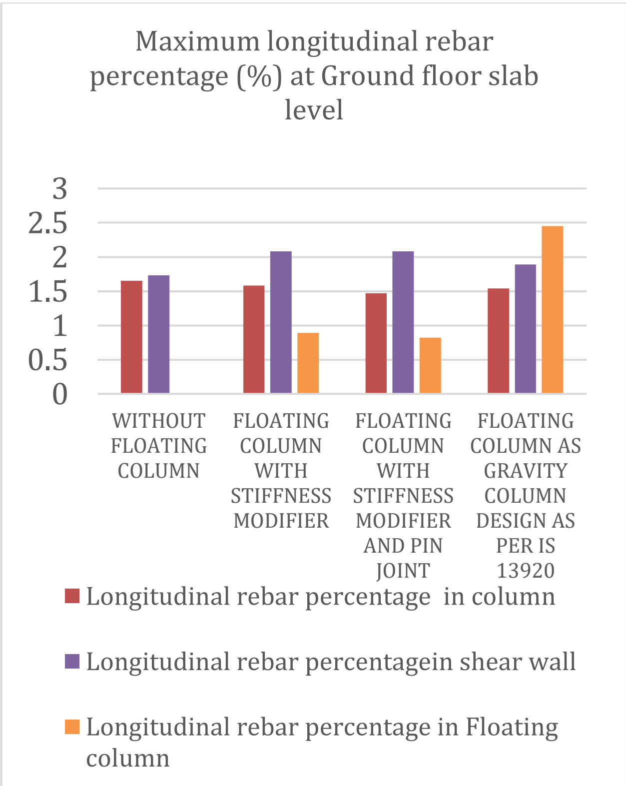

Figure-19 Maximum longitudinal rebar percentage

DOI: 10.17148/IARJSET.2022.9642

- As per the results the Model-1type building with pin joint at each end of floating column, the seismic effect is taken by shear wall located at corner and center, so the column will be taking less seismic effect as compare to other model.
- Also, the displacement and drift are less in Model-1 as compare to other.

Table-4 Comparison of cost

	WITHOUT FLOATING COLUMN	FLOATING COLUMN WITH STIFFNESS MODIFIER	FLOATING COLUMN WITH PIN JOINT	FLOATING COL DESIGN AS GRAVITY COL AS PER IS 13920-2016
TOTAL CONCRETE (CU.M)	3035.61	3059.085	3059.085	3059.085
TOTAL STEEL (KG)	355262.6	363371.9	358806.3	364264.3
CONCRETE COST (3800 INR/kg)	11535318	11624523	11624523	11624523
STEEL COST (73 INR/ kg)	25934170	26526148.7	26192859.9	26591293.9
TOTAL COST	37469489	38150671.7	37817382.9	38215816.9

POSSIBLE REINFORCEMENT DETAILING:

- Gravity columns must be designed for axial, shear, and flexural forces due to gravity loads. Although lateral force resistance is not the function of gravity framing, these elements must still be able to withstand earthquake displacements during a seismic event.
- The proposed possible reinforcement detailing is developed based on flexural stresses and deflection criteria with reference to obtained results.
- For floating column as the pin support are consider for its end, The column shall be designed as ordinary column design given in IS 456-2000, cl. 40 and cl.41.
- Longitudinal reinforcement satisfies cl.26.5.3.1, IS 456-2000.
- Transverse reinforcement is spirals, circular hoops, or rectilinear hoops and crossties, designed to resist shear corresponding to Pu. Transverse reinforcement satisfies cl.26.5.3.2, IS 456-2000.
- Transverse reinforcement to be designed such that shear strength of concrete is considered zero.
- As a pin joint consider to both ends of floating column, the confinement of transverse reinforcement are avoid to satisfy only axial compression and shear forces.
- Critical sections are the locations surrounding the beam-column joint.

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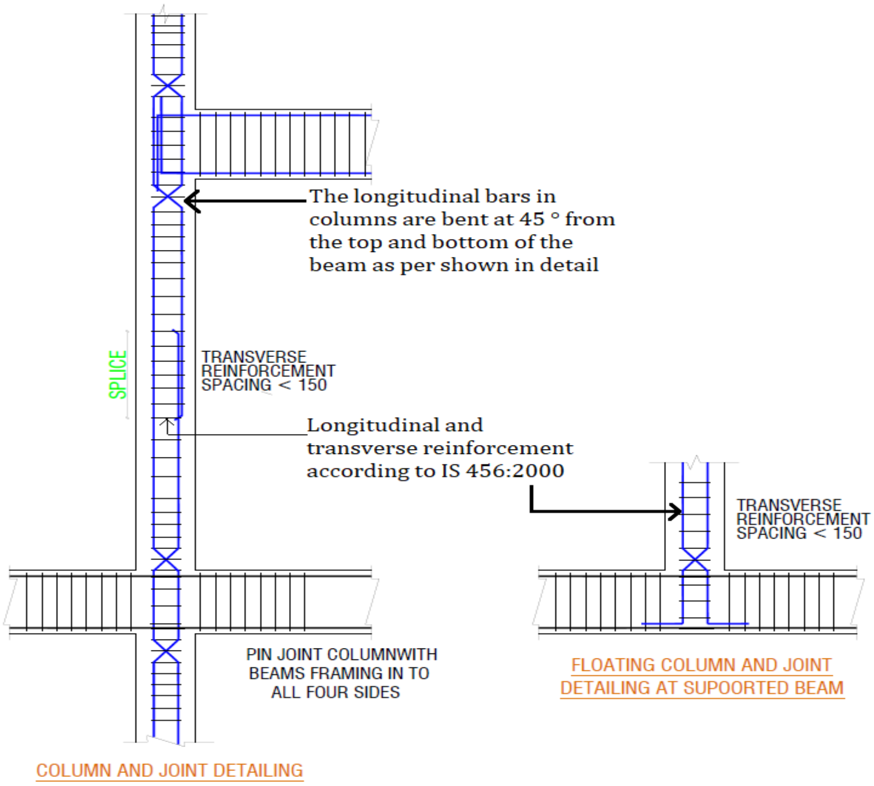

Figure-20 Reinforcement detailing for Floating Column

CONCLUSION

Floating column design as gravity column which is designed only for gravity loads and so in the lateral load analysis it will be considered as hinged at its top and bottom floor levels by giving moment releases to it at such joints (or by giving it a very low value of moment of inertia).

1. The maximum displacement of Floating column with pin joint at each end is less as compare to floating column with stiffness modifiers for Model-1 type of building.
2. Provision of pin joint at each end of floating column controls the story drift of the structure in model-1 type building.
3. Provision of pin joint at each end of floating column the base shear are similar compare to without floating column building. (refer Model-1)
4. By providing of floating column with pin joint at each end are less percentage reinforcement as compare to floating column design as gravity column criteria as per IS:13920-2016, clause 11.
5. The floating column considering as a Gravity column the column will be designed for the resulting vertical loads.
6. It is not subjected to any moments due to lateral loads, but it will be subjected to moment due to requirement of minimum eccentricity as per code.
7. It will be able to sustain the gravity load as per equilibrium of forces.
8. It can be used without designing them for bending moments due to 'R' times the lateral displacements under the factored static design seismic loads required by Cl. 11 of IS 13920- 16. But it can be detailed for ductility as per code.
9. The displacement of Building in Model-1 (with pin joint) are less as compare to other building.
10. The cost of material for floating column considered as gravity column is economical for case -3 (pin joint at each end of floating column).

If we consider the floating column in building it is compulsory to use lateral load resisting system or shear wall. Without this system floating column can fail in flexure.

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FUTURE SCOPE OF WORK

This thesis has been mainly focused on how to reduce the effect of moments due to seismic loads on floating column by considering gravity column criteria. By provision of pin joint at each end of floating column results the economic design of floating column.

The future scope of the present study is as follow:

- Study of nonlinear analysis for checking the behavior of building with floating column.
- Checking the behavior of the building with floating column at higher seismic zones (zone: IV, V).
- Checking the behavior of the building with floating column on effect of wind load.
- Study the floating column behavior on building by providing diagrid, outriggers, and bracing system.

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