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STUDY OF BEHAVIOUR OF SOFT STOREY AT DIFFERENT LOCATIONS IN THE MULTISTORY BUILDINGS

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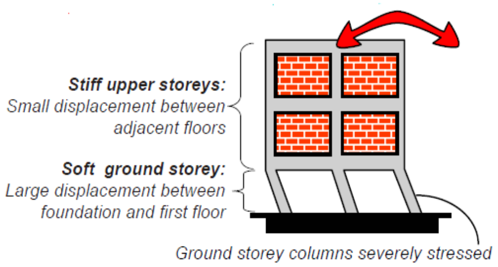
Abstract: In high rise building or multi storey building, soft storey construction is a typical and unavoidable feature because of urbanization and the space occupancy considerations. These provisions reduce the stiffness of the lateral load resisting system and a progressive collapse becomes unavoidable in a severe earthquake for such buildings due to soft storey. This storey level is unable to provide adequate resistance, hence damage and collapse.
In the current study the focus is to investigate the effect of a soft storey for multi-storeyed high rise building with different models having identical building plan. Soft storey level is altered at different floors in different models & equivalent static analysis is carried out using ETABs software. This study has been undertaken to study of different location on the seismic behavior of multi-story building, linear dynamic analysis (Response spectrum analysis) in ETABs software is carried out. Different seismic parameters like time period, story shear, and story displacement are checked out.

Index Terms- Soft Storey, ETABs, High Rise Building**.**

I. INTRODUCTION

Many buildings in India are arising with open ground storey for architectural and functional purposes. Parking is one of the most important purposes to build open ground storey as shown in figure1.1. This may be due to land limitations. Parking is not only the purpose to build soft storey but also restaurants, hotels, retail shopping, and multipurpose halls. To fulfill these requirements, the term is introduced and it is called “Soft storey/Open ground storey”. Soft storey is the one in which the lateral stiffness is less than 70 percent of that in the storey above or less than 80 percent of the average lateral stiffness of the three storey’s above. Weak storey is the one in which the storey lateral strength is less than 80 percent of that in the storey above. Weak storey is related to lateral strength.
Soft storey effect, It is reported that many buildings with vertical stiffness irregularities such as buildings with first storey, not in filled with masonry walls, as done in the upper storey’s, suffered extensive damage during Bhuj (India) earthquake (26 January 2001). The first storey is made wall-free to accommodate the parking in the building owing to high cost of land as shown in Figure1.2. Such considerable decrease in lateral stiffness of masonry infill compared to the lateral. Stiffness of adjoining storey, leads to “Soft storey effect”. The consequence of the presence of a soft storey may lead to a dangerous sway mechanism due to formation of plastic hinges at the top and bottom end of columns. These columns are subjected to large lateral forces, hence relatively large cyclic deformations and apparently severe stresses are induced in it.



As shown in Figure , greater displacement occurs in between ground storey column and foundation and small displacement occur in upper storey. Hence, ground storey columns are severely stressed. To overcome these soft storey effect IS1893 (Part-I):2002 clause no.7.10.

Recommended various analytical approaches and solutions for it. So, by using these clauses soft storey behavior can be improved and it will show better performance under lateral loading.

II. AIMS OF PRESENT WORK

1. To know the structural response of soft storey under lateral loading and to overcome the setbacks of soft storey by introducing Masonry infill walls, Tie-beam and Bracings in Soft-Storey.
2. To know which approach of soft storey analysis and design as specified in IS 1893(Part- I):2002 is most convenient optimum and easily applicable.

III. THESIS OUTLINE

General introduction focuses on the background of this dissertation. It shows that detailed investigation and study has to be done for soft storey behavior and soft storey design.

Literature review deals with the summary of the technical papers published till date and the data regarding the dissertation in the same. It also focuses on the extensive research significances carried out up till now regarding the dissertation as well as the scope for further studies.

Theoretical formulation with different loads and their combinations has been defined along with some different seismic parameters using software ETABS 9.7 for Structural analysis of Frame without effect of masonry infill (Bare frame), Masonry Infill frame, Frame with Tie-beam and Frame with Bracings including strength and stiffness effect.

Parametric investigation shows the models with and without infill effect, Frame with Tie-beam and Frame with Bracings that are studied for soft storey behavior. It includes detailed tables and Figures showing the variation of ratios of axial forces and bending moment in X and Y direction that is acting in-plane or out-of-plane for different soft storey heights. The detailed observations and findings based on the results obtained during the analysis of frames are carried out and various solutions are obtained for soft storey effect.
Conclusion and scope for future work deals with summarized observations. It also deals with one of the approach of soft storey analysis which is more beneficial.

IV. DESCRIPTION OF STRUCTURAL MODEL

In this work G+5 three dimensional models are selected for which the soft storey behavior is modelled. For this a typical rectangular building is taken having 5 bays in X-direction each is of 4.5 m span, and the 3 bays in Y-direction each of 4 m span each. Height of each story is taken as 3.2 m. Models are generated to get displacement, storey drift, base shear and story shear are discussed here in this work. The common practice of building design considers infill as nonstructural elements and building is designed as framed structures without regard to structural action of masonry infill walls. The soft storey effect and presence of infill in any building changes the behavior of frame action due to the relative changes of stiffness of the frame by a factor of three to four times and lateral load distribution. Such buildings are required to be analyzed by the dynamic analysis and designed carefully. As the dynamic ductility demand during probable earthquake gets concentrated in the soft storey and the upper storey tends to remain elastic. Hence the building is totally collapsed due to soft storey effect shown as below in figure 1.

Figure 4.1. Failure due to large lateral displacement in soft storey

V. DETAILS OF STRUCTURAL ELEMENTS AND MATERIAL USED

Table 5.1: Analysis Data of (G+5) RCC Building for Program Calculated

Sr. No.	Data summary for Models	
1	Grade of Concrete	M25
2	Main Steel Reinforcement	Fe 500
3	Yield stress of Stirrups and Links	Fe 415
4	Number of Storey	(G+5)
5	Plan Size	5x3 bay
6	Spacing In X-direction In Y-direction	4.5m 4.0m
7	Floor to Floor Height	3.2m
8	Bottom Storey Height	1.2-2.2 (interval 0.2m)
9	Density of Concrete	25 KN/m^3
10	Modulus of Elasticity of Concrete	25000N/mm^2
11	Poisson Ratio for Concrete	0.2
12	Damping	5%
14	Importance Factor	1
15	Response Reduction Factor	5
16	Foundation	Hard soil
17	Beam Size (mm) for Tie-Beam and Bracing	230 x 450
18	Column Size (mm) Bottom Middle Top	350 x750 300 x680 300 x600
19	Slab Thickness	150mm
20	Density of Brick Masonry	20KN/m^3
21	Modulus of Elasticity of Brick Masonry	1255 N/mm^2
22	Thickness of wall	150 mm
23	Poisson Ratio for Brick Masonry	0.15

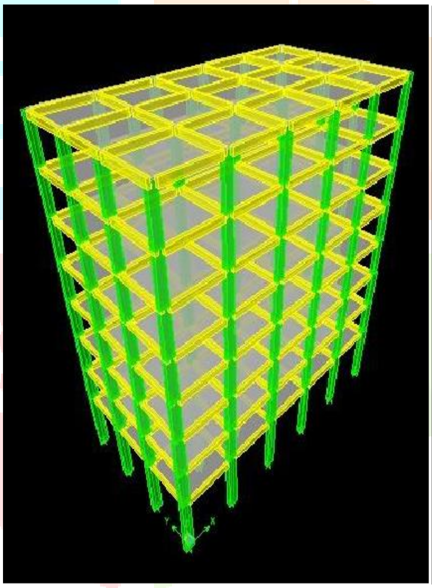
VI. MODELLING

ANALYTICAL MODELS CONSIDERED

Following models were considered for analysis purpose and remained same through-out the analysis irrespective of soil conditions and time period considered for seismic analysis as per Program Calculated and as per Codal Provision. The models analyzed are shown as below from fig 4.7- 4.10. The masonry infill, tie-beam and bracings are provided only in bottom storey through-out the periphery of the frames. It is shown in table no4.4

Table 6.1: Types of Models used for Analysis

Model No.	Name of Model
Model I	Frame without masonry infill effect (Bare Frame)
Model II	Frame with Masonry Infill effect
Model III	Frame with Tie-beam
Model IV	Frame with Bracings



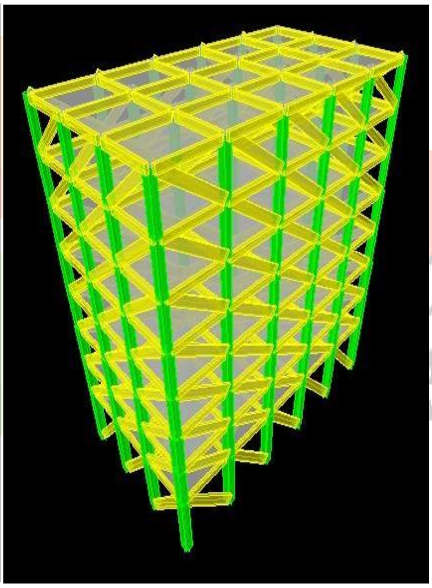
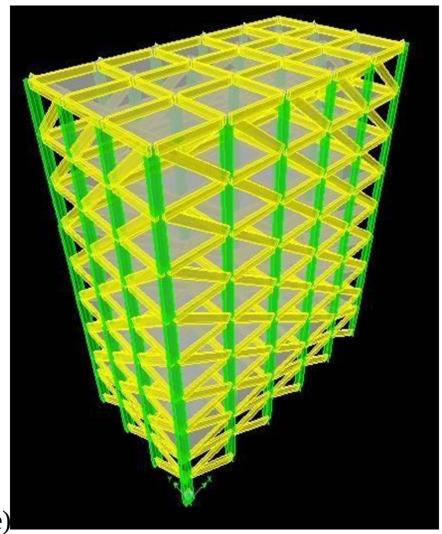


Figure 6.1: Model 1-Frame without

Figure 6.2: Model 2- Frame with Infill effect (Bare frame) effect masonry of masonryinfill

(Infill frame)



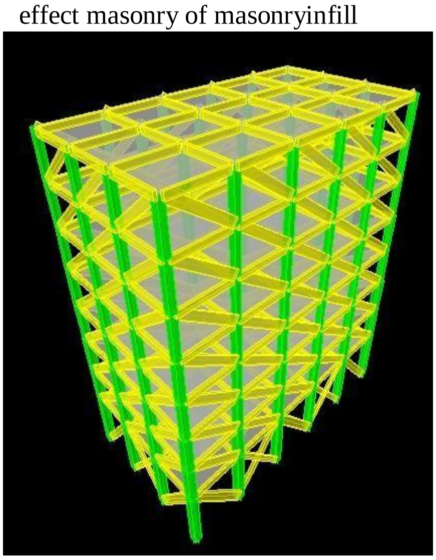


Figure 6.3: Model 3–Frame with

Figure 6.4: Model 4-Frame with Tie-beams Bracings

VII. ASSIGNING LOADS

After having modeled the structural components, load cases are assigned as follows:

Gravity loads

Gravity loads on the structure include the self-weight of beams, columns, slabs, walls and other permanent members. The self weight of beams and columns (frame members) and slabs (area sections) is automatically considered by the program itself

Dead Loads (D.L)

(a) Slab load(D.L)

Intensity of slab load = 0.15x1x25=3.75KN/m Load transfer = Wlx/3 = 3.75x4/3 =5KN/m

(b) Wall load on beams = (3-0.45)x0.15x20=7.65KN/m

(c) Floor finish(F.F)

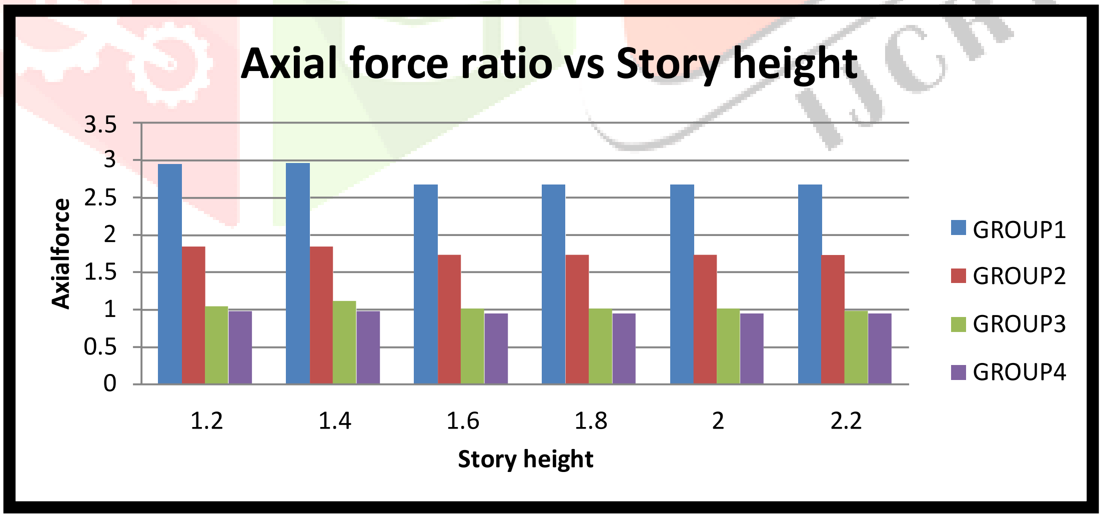
Intensity of Floor finish load = 1.0x1 = 1.0KN/m Load transfer = $Wl_x/3$ = 1.0x4/3 = 1.33 KN/m Live Load (L.L)
Live load on floor=4KN/m^2
As per IS 875 Part-II (Public Building)
Intensity of live load = 4x1 = 4KN/m Load transfer = $Wl_x/3$ = 4x4/3=5.33KN/m

The seismic weight

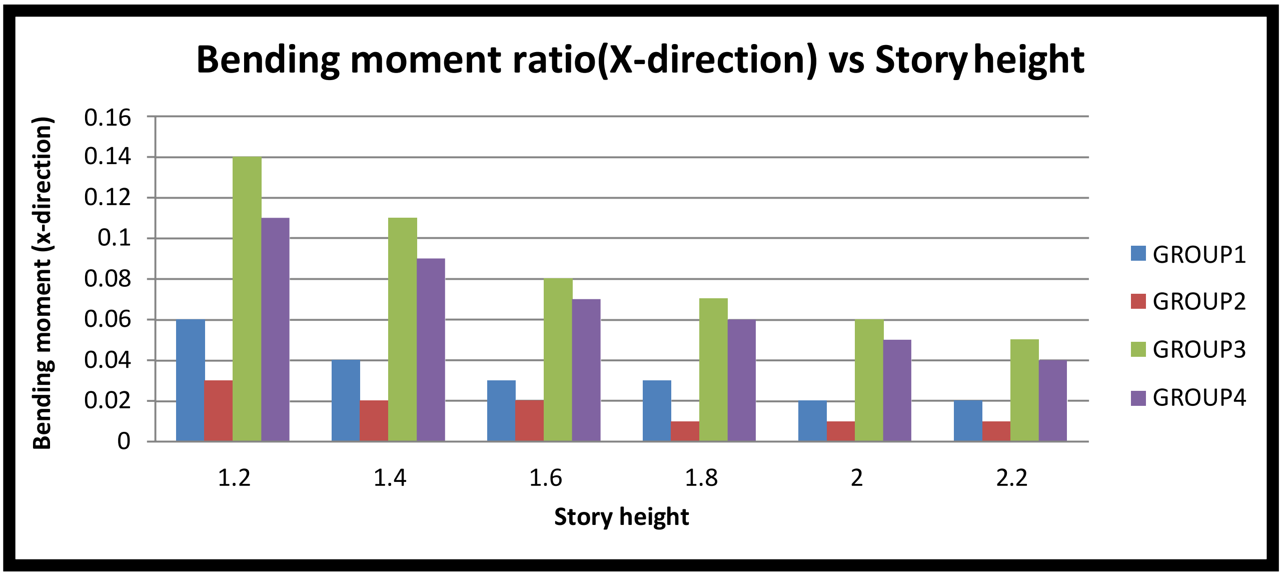
The seismic weight of each floor is its full dead load plus appropriate amount of imposed load. The defined load patterns are as shown below in figure 4.9 having Dead load, live load and horizontal earthquake load in both i.e X direction and Y direction as per IS 1893(Part 1):2002.
RESULTS AND DISCUSSION

'ORY HT	GROUP 1			GROUP 2			GROUP3			GROUP4		
	Rpu	Rmu	RMU	Rpu	Rmu	RMU	Rpu	Rmu	RMU	Rpu	Rmu	RMU
1.2	2.94	0.06	1.21	1.84	0.03	1.17	1.04	0.14	1.12	0.97	0.11	1.19
1.4	2.95	0.04	1.36	1.84	0.02	1.36	1.11	0.11	1.3	0.97	0.09	1.38
1.6	2.67	0.03	0.77	1.73	0.02	0.79	1.01	0.08	0.73	0.94	0.07	0.78
1.8	2.67	0.03	0.85	1.73	0.01	0.88	1.01	0.07	0.79	0.94	0.06	0.87
2	2.67	0.02	0.93	1.73	0.01	0.96	1.01	0.06	0.85	0.94	0.05	0.95
2.2	2.67	0.02	1	1.73	0.01	1.05	0.98	0.05	0.91	0.94	0.04	1.03

Table 8.1: Ratios obtained for different Groups and Soft Storey heights are summarized for Frame with Masonry Infill.

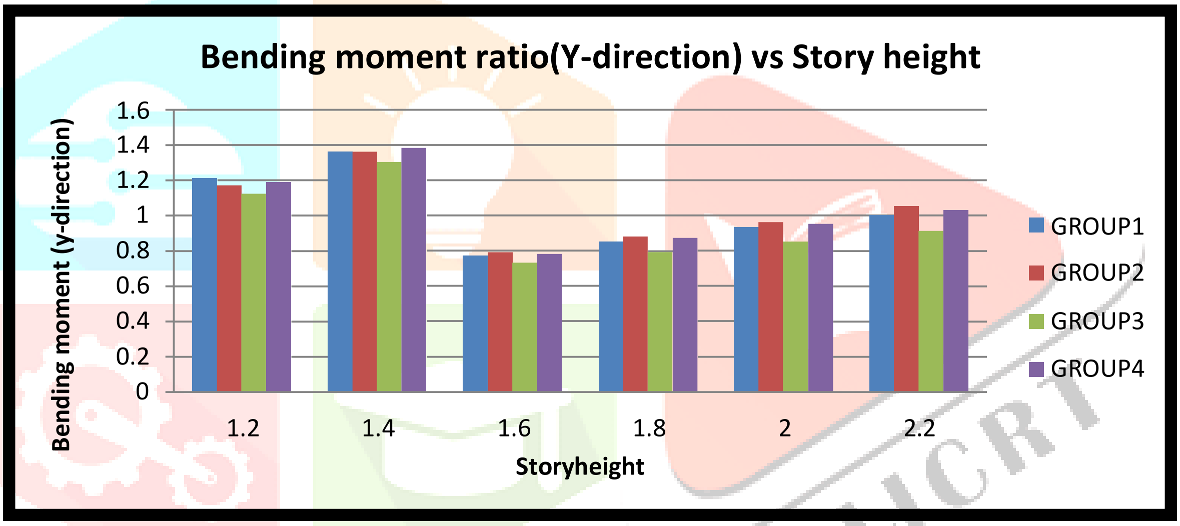


Graph 8.1: Variations of Axial Force for different soft story heights and column groups Observations and Discussions
Axial compressive force ratio at bottom story is decreasing in group 2 & 4 as bottom storey height increases. Axial compressive force ratio is constant for group 1up to 2.2m storey height i.e. 2.67 which is observed to be maximum



Graph 8.2: Variations of bending moment(X-direct.) for different soft storey heights and column groups Observations and Discussions ending moment ratio in X-direction is in decreasing trend forgroup1, 3 and 4. For group 1 it decreases up to 1.6m and increases for 1.8m.

In group 1, the ratio of bending moment in X-direction is observed to be maximum for soft story height 1.2m.



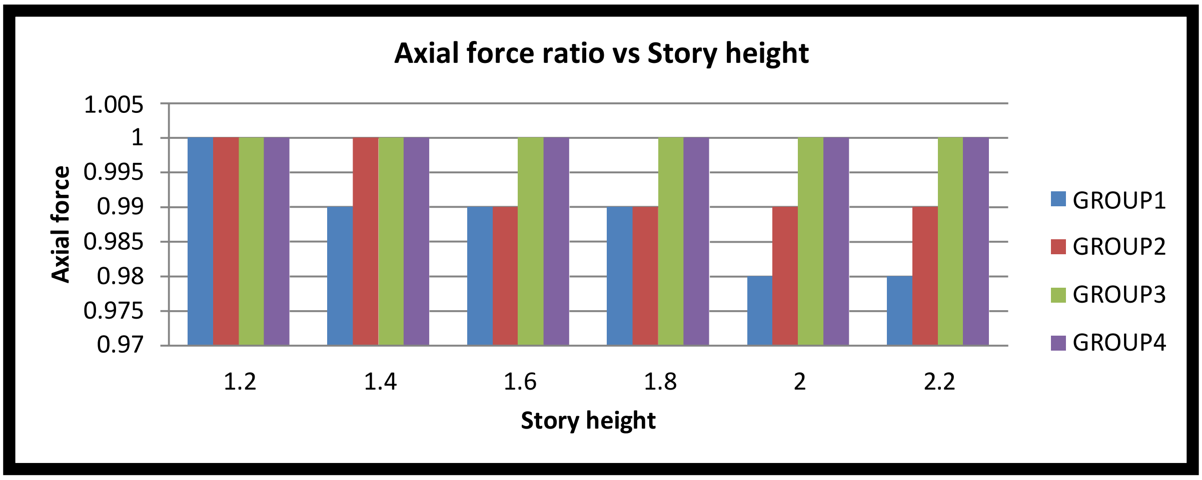
Graph 8.3: Variations of bending moment (Y-direct.) for different soft storey heights and column groups

Observations and Discussions

Bending moment ratio in Y-direction for all groups is observed to be in increasing for soft story height 1.4m.It is maximum for soft story height (1.4m) in group 2 i.e. 1.29.

STORY HT	GROUP 1			GROUP 2			GROUP 3			GROUP 4		
	Rpu	Rmu	RMU	Rpu	Rmu	RMU	Rpu	Rmu	RMU	Rpu	Rmu	RMU
1.2	1	0.82	1.09	1	0.79	1.04	1	1.19	1.11	1	1.2	1.03
1.4	0.99	0.74	1.06	1	0.72	1.04	1	1.21	1.12	1	1.24	1.02
1.6	0.99	0.7	1.04	0.99	0.68	1.03	1	1.16	1.08	1	1.19	1.01
1.8	0.99	0.67	1.02	0.99	0.66	1.03	1	1.13	1.05	1	1.03	1.01
2	0.98	0.66	1.01	0.99	0.65	1.03	1	1.13	1.03	1	1.03	1
2.2	0.98	0.65	1	0.99	0.64	1.02	1	1.15	1.01	1	1.17	0.99

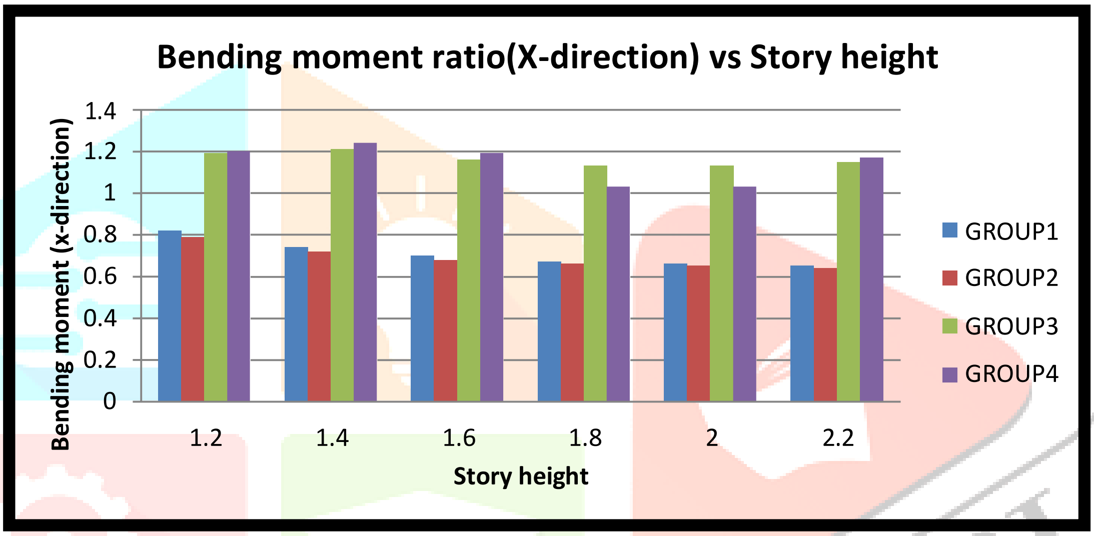
Table 8.2: Ratios obtained for different Groups and Soft Storey heights are summarized for Frame with Tie-Beam.



Graph.8.4: Variations of Axial Force for different soft storey heights and column groups Observations and Discussions

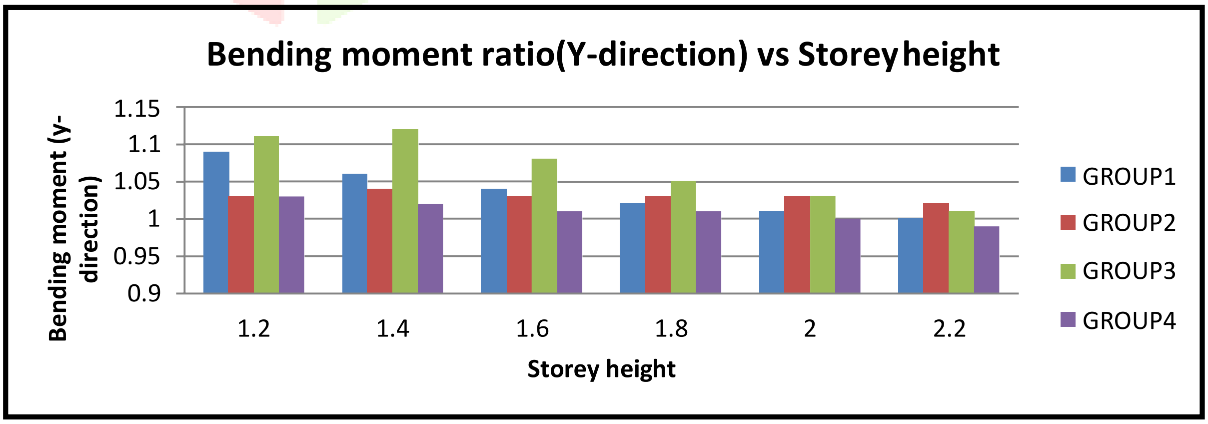
Axial Compressive Force ratio in group 1and 2 decreases as bottom storey height increases, whereas it is observed to be constant for group 3 and 4.

Axial Compressive Force ratio is maximum in group 1 at 1.4m height i.e. 1.



Graph 8.5: Variations of Bending moment(X-direct.) for different soft storey heights and column groups Observations and Discussions

Bending Moment ratio in X-direction for group 1and 2 is observed to be decreasing and it is maximum for group 4 at 1.4m storey height i.e 1.24



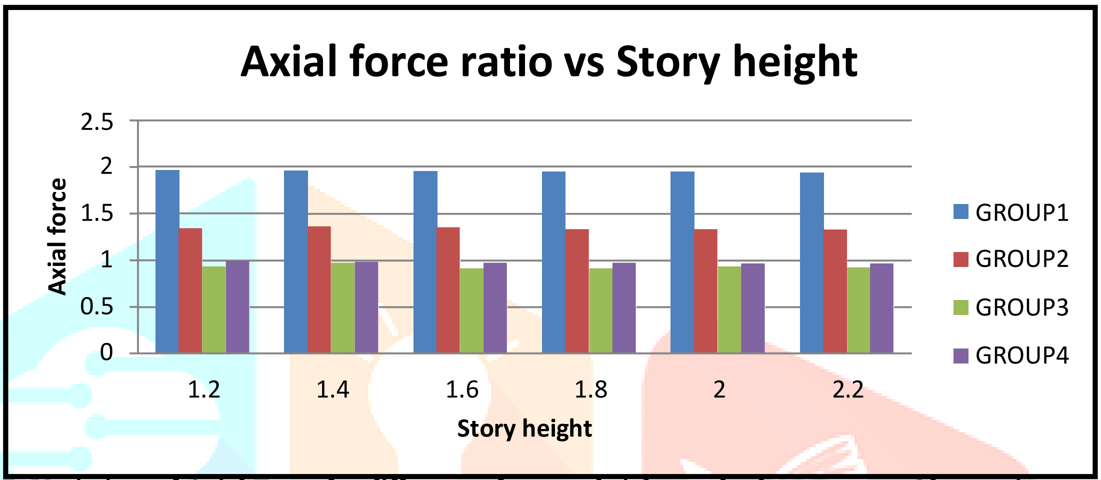
Graph 8.6: Variations of Bending moment(Y-direct.) for different soft storey heights and column groups

Observations and Discussions

Bending Moment ratio in Y-direction, intensively reduces for group 1 as compared to all other groups. And it is observed to be maximum in group 4 at 1.4m soft storey height i.e 1.12

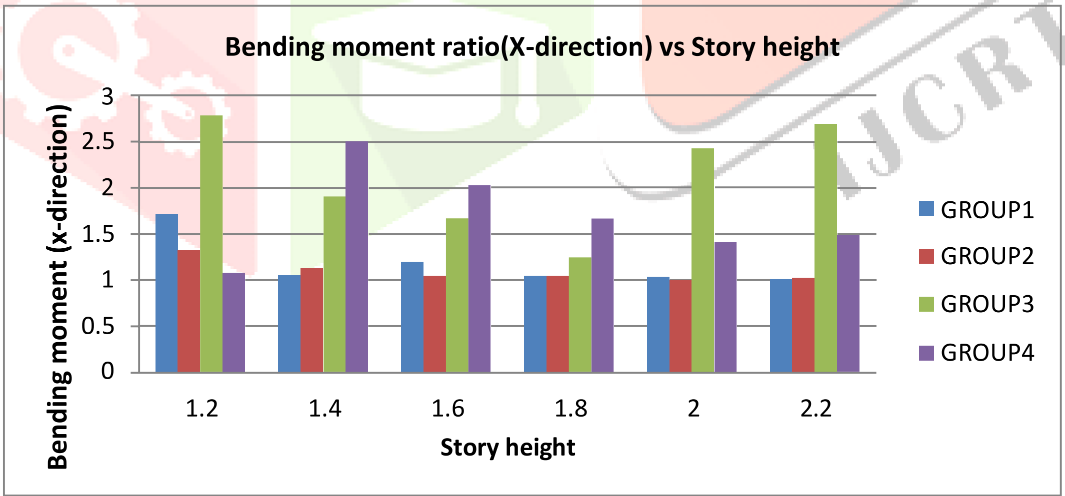
:ory ht	GROUP 1			GROUP2			GROUP3			GROUP 4		
	RPu	Rmu	RMU	Rpu	Rmu	RMU	Rpu	Rmu	RMU	Rpu	Rmu	RMU
1.2	1.96	1.71	1.25	1.34	1.32	0.84	0.93	2.78	1.04	0.99	1.08	0.68
1.4	1.96	1.05	1.17	1.36	1.12	0.78	0.97	1.9	1.02	0.98	2.5	0.62
1.6	1.95	1.19	1.07	1.35	1.04	0.81	0.91	1.66	0.94	0.97	2.02	0.57
1.8	1.94	1.04	0.99	1.33	1.04	0.66	0.91	1.24	0.86	0.97	1.66	0.51
2	1.94	1.03	0.91	1.33	1	0.6	0.93	2.42	0.8	0.96	1.41	0.47
2.2	1.93	1.01	0.84	1.32	1.02	0.55	0.92	2.69	0.75	0.96	1.48	0.43

Table 8.3: Ratios obtained for different Groups and Soft Storey heights are summarized for Frame with Bracings.



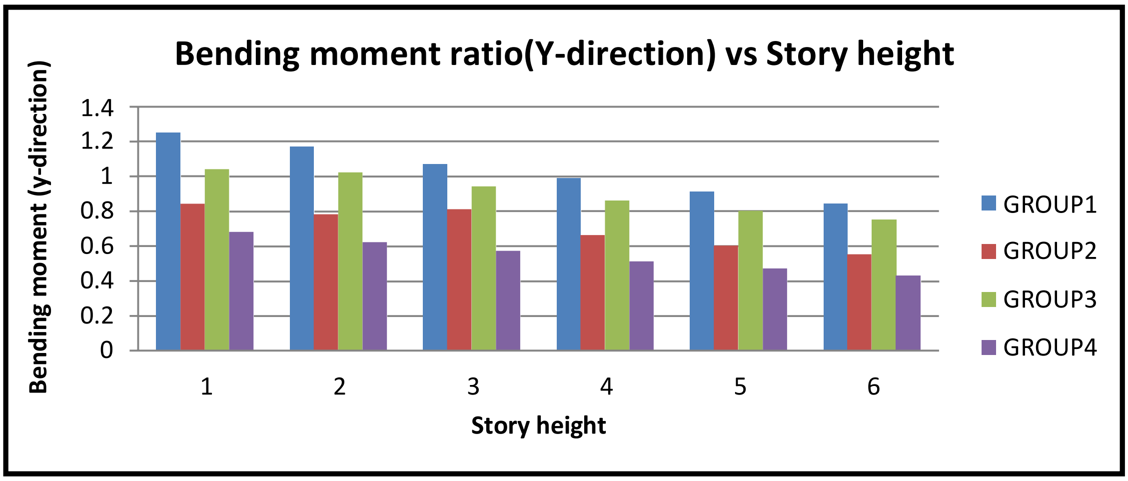
Graph 8.7: Variations of Axial Force for different soft storey heights and column groups Observations and Discussions

Axial Compressive Force ratio in group 1 and 2 remains constant for bottom storey height 1.6 to 2.2 m i.e. 2.67 and 1.73.
Axial compressive force ratio is increases for group 3 at 2.2m height and then decreases upto soft story height 2.2m.



Graph 8.8: Variations of Bending moment(X-direct.) for different soft storey heights and column Groups Observations and Discussions

Bending Moment ratios in X-direction for group 3 is maximum for soft storey height of 1.2m and it is observed to be 2.78 and for rest soft storey height (1.2-2.2m) the trend is increasing in the range (1.9-2.69).



Graph 8.9: Variations of Bending moment(Y-direct.) for different soft storey heights and column groups

Observations and Discussions

In group1, Bending Moment ratios in Y-directions maximum for group 1i.e.1.25 for soft story height 1.2m. For group 3 bending moment in Y-direction decreases in range (1.04-0.75).

VIII. CONCLUSION

The seismic analysis of RC frames is done by considering strength and stiffness effect of infill walls. The equivalent diagonal strut method is used for this purpose. Following prominent conclusions are drawn from parametric investigations.

- Few masonry infill walls are provided along periphery in the ground storey to reduce the soft storey effects shows and it shows better performance as compared to full open ground storey.
- Seismic coefficient method using fundamental natural period as specified in IS 1893(Part-I):2002 gives insufficient guidelines for infill effect. As the same empirical relationship is used for infilled frame, frame with Tie-beam and frame with Bracings.
- It can be concluded that fundamental natural period of bare frame not only depends on building height but also on span length and the stiffness of building which are not quantified in the Codal expressions.
- Based on extensive parametric investigation of space frame, square column is more effective than rectangular column as far as soft storey effect is considered.
- The Ratio of maximum bending moments and Shear force of the columns for the case of Infilled frame, considered to that of bare frame model varies from column to column. As the multiplication factor 2.5 as suggested by IS1893 (Part-I) : 2002 is not constant for all soft storey columns. Therefore it is recommended to use the dynamic analysis approach as specified in IS1893 (Part-I): 2002.
- Also this 2.5 multiplication factor is approximate, as it is not distributed in proper manner to the soft storey columns.
- Out of all models that is Frame with Infill, Frame with Tie-beam and Frame with Bracings the most economical is Braced frame. Bracings are more efficient in carrying moments because the ratio observed is minimum for bracings.
- To synchronize in order providing Tie-beam is more effective than only infill whereas providing Bracings is most effective than providing Masonry infill and Tie-beam.
- The multiplication factor observed in the study is represented in below

Soil Type	or Observed for Time Period considered for Seismic Analysis as per	
	PROGRAM CALCULATED	CODAL PROVISIONS
I	1.5	1.64

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