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SEISMIC ANALYSIS OF G+ 7 STOREY BUILDING WITH AND WITHOUT INFILL

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Abstract: Contribution of infill walls in building is yet to sink into mind set of the urban people. Hyderabad city and Many other urban cities in India with multi storey buildings are seen with open ground story as an unavoidable aspect, basically to generate parking or reception lobbies. The upper storey has brick infilled wall panel with various openings and aspect ratios in them. These types of buildings are not desirable in seismically active areas because various vertical irregularities are induced in such buildings which have performed consistently poor during past earthquakes. It has been known since long time that masonry infill walls affect the strength and stiffness of infilled -framed structures. Infill wall are generally seen as a non structural element and their effect is neglected by ignoring the stiffness of the infill wall during the modelling phase of the structure (analysed as a 'linear bare frame') leading to substantial inaccuracy in obtaining the actual seismic response of framed structures.

In this study, building is analysed using numerical simulation and the results are compared with the performance of open ground storey buildings. As the more realistic performance of this building the modelling of the stiffness and strength criteria are considered. Two cases are considered; with and without infill walls for a frame are studied by time history method.

Key Words: Open ground storey, masonry infill walls, non-structural element, bare frame, infill stiffness, Time History method, SAP 2000.

I. Introduction

A **soft story building** is a multi-story building in which one or more floors have windows, wide doors, large unobstructed commercial spaces, or other openings in places where a shear wall would normally be required for stability as a matter of earthquake engineering design. A typical soft storey building is an apartment building of three or more stories located over a ground level with large openings, such as a parking garage or series of retail businesses with large windows.

II. Geometry And Analysis of Building

To perform any sort of analysis i.e. linear/non-linear, static/dynamic it's necessary to develop a computational model. A detailed description on the nonlinear modelling of RC building frames is discussed in this chapter.

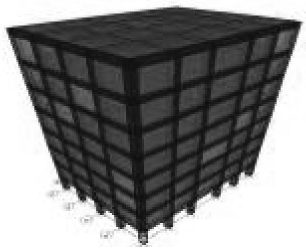

Figure 2.1 Soft Storeyed Building Model Developed by using SAP2000

A. Loading

The structural design is carried out as per the latest versions of Indian Standard codes published by Bureau of Indian Standards. Various design codes and standards referred are:

− IS 456 for Plain and Reinforced Concrete

− IS 875 Part 1, 2, 3 & 5 for dead load, live load, wind load and combinations

− SP 34 for detailing of reinforcement

Loads considered

(i) Self-Weight of members

(ii) Wall Load

(iii) Slab Live Load (as per IS 875 Part II)

a) Residential: 3 KN/m2

b) Commercial/public buildings: 5 KN/m2

(iv) Stair/Lift/Ramp load

Following densities and load values are considered for design:

(i) Density of Reinforced concrete: 24 KN/m^3

(ii) Density of brick masonry : 18.85 KN/m^3

(iii) Density of earth : 18 KN/m^3

(iv) Superimposed Live Load : 5 KN/m^2

(v) Floor Finishes : 1.5 KN/m^2

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Criteria for Earthquake Resistant Design of Structures. (IS 1893-2002) Clause 6.3.1.2 Partial safety factors for limit state design of reinforced concrete and pre-stressed concrete structures. In the limit state design of reinforced concrete structures, the following load combinations are to be accounted for:

(i) 1.5(DL+IL)

(ii) 1.2(DL+IL±EL)

(iii) 1.5(DL±EL)

(iv) 0.9DL±1.5EL

B. Mode shapes for framed Building

As a characterstic behavior of any structure depends on its mode shapes, which actually depends on the gemometrys, material and boundry condition, the same has been done for structures considered only Framed G+7 Storey.

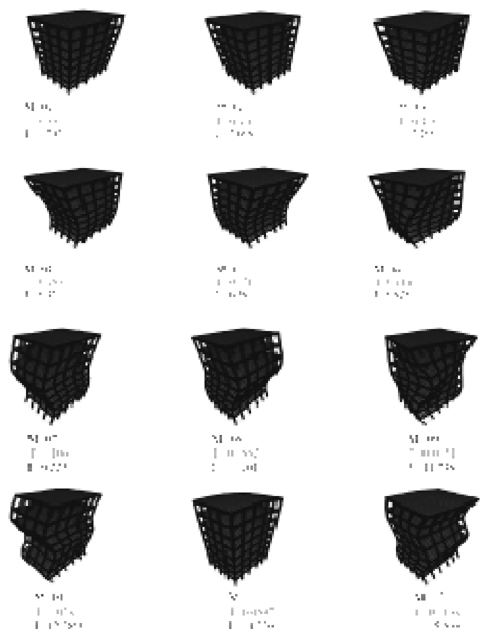


Figure: 2.2 First 12 mode shapes of Framed building (M = mode numbers, T = time period,

F = frequency of the concerned mode)

As seen in the figure as the mode number increasing, the frequency is also increasing till the tenth mode.

Table: 2.1 Time Period And Frequency of Twelve Mode Shapes for Framed Building

Mode Shape	Time Period	Frequency
M1	0.556	1.795
M2	0.476	2.096
M3	0.435	2.296
M4	0.184	5.410
M5	0.156	6.391
M6	0.144	6.925
M7	0.106	9.225
M8	0.089	11.201
M9	0.085	11.738
M10	0.078	12.789
M11	0.097	14.336
M12	0.063	15.638

C. Mode shapes for Soft Storey Building

As a characterstic behavior of any structure depends on its mode shapes, which actually depends on the gemometrys, material and boundry condition, the same has been done for structural considered Soft Stoey at Ground Floor for a G+7 Storey.

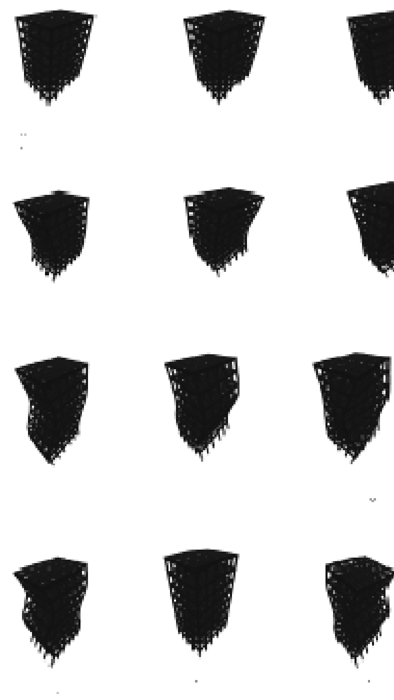


Figure: 2.3 First 12 mode shapes of Soft Storeyed building (M = mode numbers, T = time period,

F = frequency of the concerned mode)

Table: 2.2 Time Period And Frequency of Twelve Mode Shapes for Soft Storey Building

Mode Shape	Time Period	Frequency
M1	0.526	1.898
M2	0.477	2.094
M3	0.432	2.310
M4	0.174	5.723
M5	0.156	6.383
M6	0.143	6.991
M7	0.101	9.880

M8	0.088	11.292
M9	0.084	11.887
M10	0.072	13.752
M11	0.067	14.858
M12	0.063	15.638

The model analysis is carried for the selected building and has been observed that as the mode number is increasing, the frequency is also increasing till the twelvth mode. The variations in time periods of obtained for this 12 mode shapes is gradnally decreased except the time period of secound and third mode shape which is differed by almost 51% .

III. Time History Analysis

Time History is a record of the ground acceleration at defined time segments for a specific earthquake in a certain direction. The record is usually normalized and therefore needs to be multiplied by the acceleration due to gravity. The displacement time history plotted are considered for 4 joints 2,4,7 and 9 are shown in the fig.4.2

El-centro and Uttarkashi Ground motions in both X and Y directions are considered for the above mentioned joints.

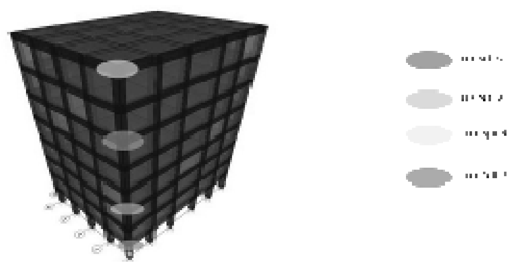


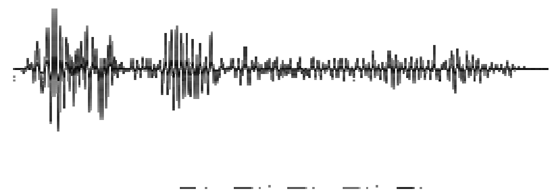
Figure 3.1. Shows Various Joints in Numerical Modal

A. Response of the Framed structure – El Centro Ground Motion

The minimum displacement of the parking structure in X-direction at joint 2, 4, 7 and 9 are -0.00108m, -0.00369m, -0.006854m, and -0.00789m respectively. Where as in Y-direction -0.000643m, -0.00234m, -0.00452m and -0.00531m respectively.

The maximum displacement of the parking structure in X-direction at joint 2, 4, 7 and 9 are 0.000978 m, 0.00324m, 0.00582m, and 0.00663m respectively. Where as in Y-direction 0.000523m, 0.00191m, 0.00377m and 0.00443m respectively.

Framed Structure Response for El Centro Ground motion in X – direction



A Graph Shows Response for El Centro Ground Motion in X-direction for framed structure

Framed Structure Response for El Centro Ground motion in Y – direction

A Graph Shows Response for El Centro Ground Motion in Y-direction for framed structure

Table 3.1 Shows Maximum and Minimum Response of Structure in X and Y direction for El Centro Ground Motion

Joint	El Centro Ground Motion			
	X max	X min	Y max	Y min
2	0.000978	-0.00108	0.000523	-0.000643
4	0.00324	-0.00369	0.00191	-0.00234
7	0.00582	-0.00685	0.00377	-0.00452
9	0.00663	-0.00789	0.00443	-0.00531

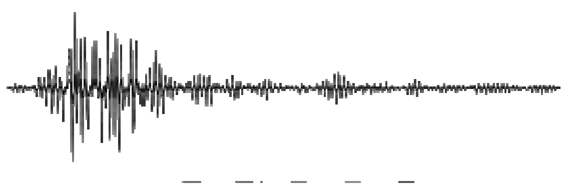
The variation in response of the building at various joints is increasing gradually.

B. Response of a Framed Structure – Uttarkashi Ground Motion

The minimum displacement of the Super Structure in X-direction at joint 2, 4, 7 and 9 are -0.00636m, -0.0208m, -0.0367m and -0.0416m respectively. Where as in Y-direction -0.00372m, -0.0132m, -0.0248m, and -0.0293m respectively.

The maximum displacement of the parking structure in X-direction at joint 2,4, 7, and 9 are 0.00691, 0.0225, 0.0408 and 0.0469 respectively. Where as in Y-direction 0.00359m, 0.0132m, 0.0257m and 0.0323 respectively.

Framed Structure Response for Uttarkashi Ground motion in X – direction



A Graph Shows Response for Uttarkashi Ground Motion in X-direction for framed structure

Framed Structure Response for Uttarkashi Ground motion in Y- direction

A Graph Shows Response for Uttarkashi Ground Motion in Y-direction for framed structure

Table 3.2. Shows Maximum and Minimum Response of Structure in X and Y direction for Uttarkashi Ground Motion

Joint	Uttarkashi Ground Motion			
	X max	X min	Y max	Y min
2	0.00690	-0.00636	0.00359	-0.00372
4	0.0225	-0.02038	0.0132	-0.0132
7	0.0408	-0.03677	0.0257	-0.0248
9	0.0469	-0.04162	0.0323	-0.0293

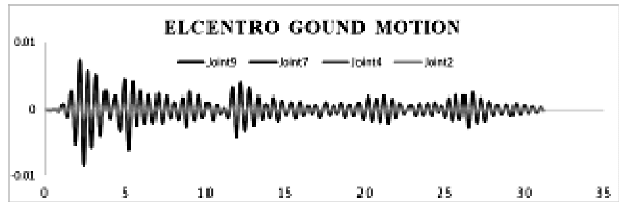
The variation in response of the building at various joints is increasing gradually.

C Response of the Soft Storied structure – El Centro Ground Motion

The minimum displacement of the parking structure in X-direction at joint 2, 4, 7 and 9 are -0.00140m, -0.0041m, -0.00733 and -0.00838 respectively. Where as in Y-direction -0.000932m, -0.0031m, -0.00558 and -0.00681 respectively.

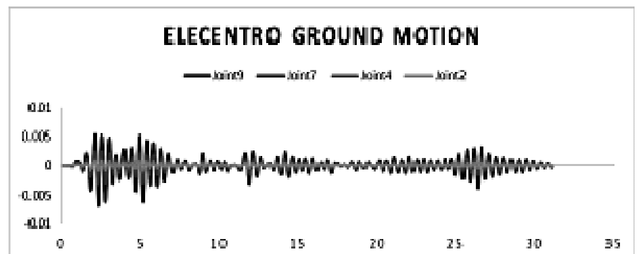
The maximum displacement of the parking structure in X-direction at joint 2, 4, 7 and 9 are 0.00134m, 0.00378m, 0.00656m and 0.00746m respectively. Where as in Y-direction 0.0008042m, 0.00259m, 0.00464m and 0.00534m respectively.

Soft Storey Structure Response for El Centro Ground motion in X – direction



A Graph Shows Response for El Centro Ground Motion in X-direction for Soft Storyed structure

Soft Storey Structure Response for El Centro Ground motion in Y – direction



A Graph Shows Response for El Centro Ground Motion in Y-direction for Soft Storeyed Structure

Table 3.3. Shows Maximum and Minimum Response of Structure in X and Y direction for El Centro Ground Motion

Joint	El Centro Ground Motion			
	X max	X min	Y max	Y min
2	0.00134	-0.00141	0.000804	-0.0009324
4	0.00378	-0.0041	0.00259	-0.0031
7	0.00656	-0.00733	0.00464	-0.00582
9	0.00746	-0.00838	0.00534	-0.00681

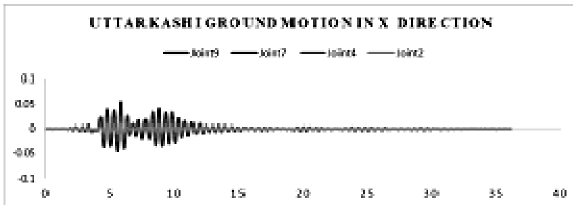
The variation in response of the building at various joints is increasing gradually.

D. Response of the Soft Storey structure - Uttarkashi Ground Motion

The minimum displacement of the Super Structure in X-direction at joint 2, 4, 7 and 9 are -0.00854m, -0.0237m, -0.0400m and -0.0450m respectively. Where as in Y-direction -0.00529m, -0.0168m, -0.0302m and -0.0352m respectively.

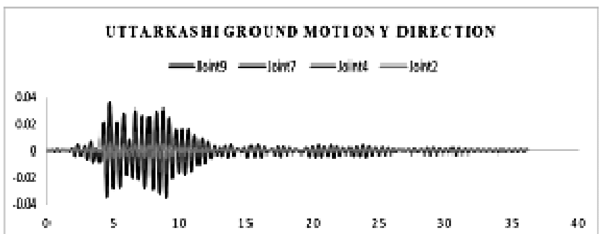
The maximum displacement of the parking structure in X-direction at joint 2,4, 7, and 9 are 0.00935m, 0.0268m 0.0474m and 0.0542m respectively. Where as in Y-direction 0.0055m, 0.0173m, 0.0308m and 0.0358m respectively.

Soft Storey Structure Response for Uttarkashi Ground motion in X – direction



A Graph Shows Response for Uttarkashi Ground Motion in X-direction Soft Storey Structure Response

Soft Storey Structure Response for Uttarkashi Ground motion in Y- direction



A Graph Shows Response for Uttarkashi Ground Motion in Y-direction Soft Storey Structure Response

Table 3.4. Shows Maximum and Minimum Response of Structure in X and Y direction for Uttarkashi Ground Motion

Joint	Uttarkashi Ground Motion			
	X max	X min	Y max	Y min
2	0.00935	-0.00854	0.00555	-0.00529
4	0.02681	-0.02376	0.01734	-0.03026
7	0.04748	-0.04006	0.03084	-0.03026
9	0.05423	-0.04508	0.03583	-0.03524

The variation in response of the building at various joints is increasing gradually.

IV. Results

Time history analysis is required for tall storied structures, especially when structures are located in high seismic zones. In this study the structure's displacement by time history analysis is carried for three earthquakes (El Centro and Uttarkashi) to understand its behavior in both directions. Top joint 9 and Bottom Joint 2 is compared between Framed Structure and Soft storey Structure.

Table 4.1 Showing the response for Soft Storey in X & Y direction

Elcentro Earth Quake Response For Soft Storeyed Building				
Joint	X Direction		Y Direction	
	Minimun Response (M)	Maximum Response (M)	Minimun Response (M)	Maximum Response (M)
Joint 2	-0.00141	0.00134	-0.000932	0.000804
Joint9	-0.00838	0.00746	-0.00681	0.00534

For Soft storey building at joint 2 maximum displacement is found to be 0.00141m in X direction and at joint 9 is 0.00838m in X direction.

Table 4.2 Showing the response for Bare Framed Building in X & Y direction

Elcentro Earth Quake Response For Bare Framed Building				
Joint	X Direction		Y Direction	
	Minimun Response (M)	Maximum Response (M)	Minimun Response (M)	Maximum Response (M)
Joint 2	-0.00108	0.000978	-0.000643	0.000523
Joint9	-0.00789	0.00663	-0.00531	0.00443

For Framed building at joint 2 maximum displacement is found to be 0.001081m in X direction and at joint 9 is 0.00789m in X direction.

Table 4.3 Showing the response for Soft Storey in X & Y direction

Uttarkashi Response For Soft Storeyed Building				
Joint	X Direction		Y Direction	
	Minimun Response (M)	Maximum Response (M)	Minimun Response (M)	Maximum Response (M)
Joint 2	-0.00854	0.00935	-0.00529	0.00555
Joint9	-0.04508	0.05423	-0.03524	0.03583

For Soft storey building at joint 2 maximum displacement is found to be 0.00935m in X direction and at joint 9 is 0.05423m in X direction.

Table 4.4 Showing the response for Bare framed in X & Y direction

Uttarkashi Response For Bare Framed Building		
Joint	X Direction	Y Direction

	Minimun Response (M)	Maximum Response (M)	Minimun Response (M)	Maximum Response (M)
Joint 2	-0.00636	0.0069	-0.00372	0.00359
Joint9	-0.0416	0.0469	-0.0293	0.0302

For Framed building at joint 2 maximum displacement is found to be 0.0069m in X direction and at joint 9 is 0.0469m in X direction.

From the cases considered for Uttarkashi and El Centro earthquakes. From above result it can be seen that displacement of soft storey building is more than that of framed building. Soft storey effect contributes to reduction of stiffness in building due to which overall response is increasing.

V. Conclusion

1. Study of soft storey building is essential in current scenario. Most of the buildings in Indian metro city are found soft Storeyed.
2. SOFT STORED buildings are considered vulnerable in earthquake prone areas.
3. It is important to safeguard building, avoiding soft storey and following building bye laws and using design codes.
4. From above result, it can be seen that displacement of soft storey buildings is more than that of RC framed in-filled building. Soft storey effect contributes to reduction of stiffness in building due to which overall response of the building at particular joint is increasing.
5. Corner walls can be provided to the building for the better performance and increase the lifetime of the building.
6. Since the behaviour of the soft storey is very different during earthquake. For this reason, in regions where the risk of earthquakes is high, soft storeys should be avoided, if necessary, earthquake resistant design should be done starting from the design stage through the stage of occupancy.
7. Present soft storeys should be examined and if necessary, should be strengthen with brick infill walls.
8. In constructions where it is necessary to build a soft storey, lateral rigidity of this particular storey should be brought to the rigidity level of the other storeys. To be able to do this, the number of columns and shear walls should be increased. Because of this increase, longitudinal and lateral reinforcement should also be increased. These raise the cost of the construction. Soft storey is an irregularity, which affects the behaviour of a construction during a quake and also increases the construction costs. For this reason, soft storeys should be avoided as much as possible. In case it is necessary, by the controls to be performed as a result of calculation made, irregularities can be eliminated as follows:

a) Building additional walls
b) Increasing the rigidity of the columns and the Shear walls on the soft storey.

Future Scope

The present work can also be analysed by using Non-linear Static and Dynamic approaches, which will be able to find the exact deformation of the Soft Storey. The work can be extended from Residence building to Commercial building. The study can be done with the help of Push over Analysis to get exact deflection, deformation and also stiffness of the building. The present work can be further studied by comparing high-rise buildings and also for different Earthquake Response.

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