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Evaluation of earthquake load resistance of masonry infilled RC frames using linear and non-linear dynamic analysis

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Abstract: The understanding of the dynamic behavior of structures is essential to design them to resist the lateral loads due to earthquakes. Recent past earthquakes have demonstrated the importance of proper designing of structural members to avoid damages in the buildings and loss of life. Generally the lateral load resistance of masonry infilled moment resisting frames is achieved by frame action and truss action. In this paper the seismic performance of a G+9 storeyed masonry infilled RC framed building is evaluated by linear and non-linear dynamic analysis. The analysis is carried out using the finite element software- ETABS. The response spectrum and time history pertaining to the specifications as given in the Indian Seismic Code IS 1893:2016 is considered for the analysis. Three different frame models are studied namely, bare frame, fully infilled frame and soft storey frame to understand the lateral load resistance of the frames. The dynamic characteristics of the frames such as time period, frequency, mode shapes, storey displacements, inter-storey drift, over-turning moments and energy dissipation capacity are evaluated and compared. The fully infilled frame shows better seismic behavior than that of other two frames though it attracts more forces.

1. Introduction

Multi-storey buildings are inevitable in Indian cities due to the demand of space for residential and commercial purposes. Most of these buildings are RC un-reinforced masonry infilled ordinary moment resisting framed structures with open ground storey for car parking, venue for family parties, etc. Many of them are designed and constructed only for gravity loading and their behavior during earthquake loading is uncertain. There are different methods to understand the buildings' behavior during earthquake using experimental and analytical methods. Dynamic test on multi-storey buildings is a very good preference to know the actual behavior of structures under earthquake loading, but it is very costly and needs very high expertise. Analytical methods are equally as good as tests to predict the behavior of structures using highly sophisticated finite element tools. Static analysis is of less importance because the earthquake loads are dynamic in nature; therefore the structures' response can be obtained by dynamic analysis [1, 2]. Dynamic analysis is mandatory for buildings with irregularities and buildings situated in high seismic zones.

The specifications given in IS 1893:2016 are very useful for regular buildings. The irregular and tall buildings are need to be analysed and checked for safety using response spectrum (RS) method or time history (TH) analysis method based on the actual or synthetic acceleration records [3,4,5].

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It is a usual practice of neglecting the role of masonry infills in the design of RCC framed buildings against earthquake loading. The masonry infills improve the strength and stiffness of the building and can be effectively utilized for the better design in the view of safety of the bounding frame to some extent and economy [6, 7, 8, 9, and 10]. In this paper, the seismic behavior of the multi-storey bare frame, fully infilled frame and soft-storey frame are analyzed using the linear (response spectrum) and non-linear (time history) dynamic analysis with the help of ETABS software.

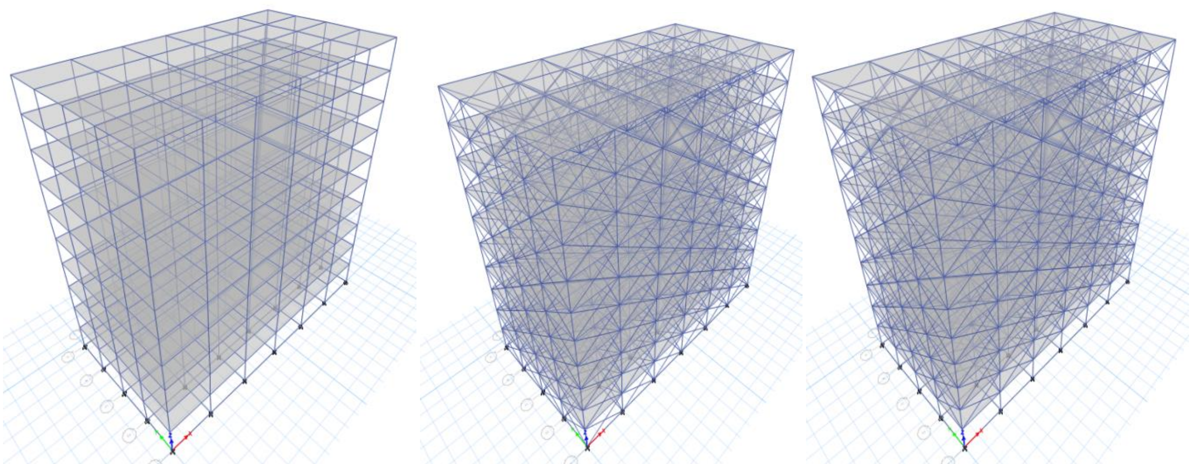
2. Analytical investigation

2.1 Details of the building

The details of the building in this study are given below.
6 bay by 4 bay G+9 storeyed residential building
Column Size- 350 mm x 350 mm
Beam Size- 250 mm x 400 mm
Slab Thickness- 120 mm
Burnt Clay Brick Masonry Thickness – 230 mm
Height of each storey – 3.0 m
Grade of Concrete – M 20
Grade of Steel – Fe 415
Zone III, Soil type-Medium
LL on floors – 3 kN/m^2

2.2 Modeling and analysis of the building frames

The modeling of the G + 9 storeyed building with and without masonry infill is done in ETABS and the material and section properties are assigned. The masonry infill is modeled as equivalent diagonal compression strut [11, 12]. Figure 1 shows the building models. The base is assumed to be fully fixed and the connectivity between the structural elements is considered as rigid. The dynamic responses of the frames are obtained by RS and TH methods. The response spectrum and time history data that are used in the analysis are given in figure 2(a) and (b), respectively. The modal characteristics such as mode shapes, frequencies and time periods are obtained for all the building models.



(a) Bare frame (b) Fully infilled frame (c) Soft-storey frame

Figure 1. 3-D Modeling of the frames.

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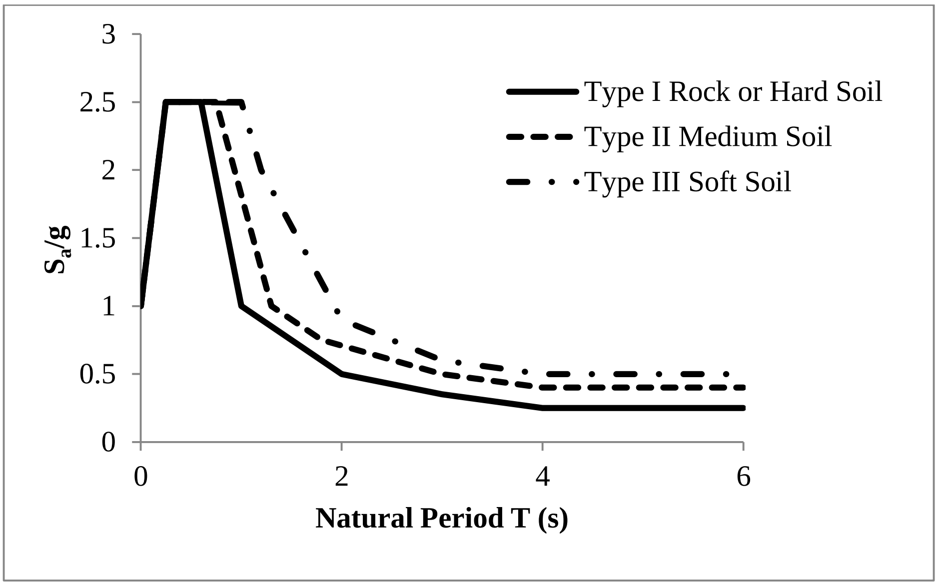
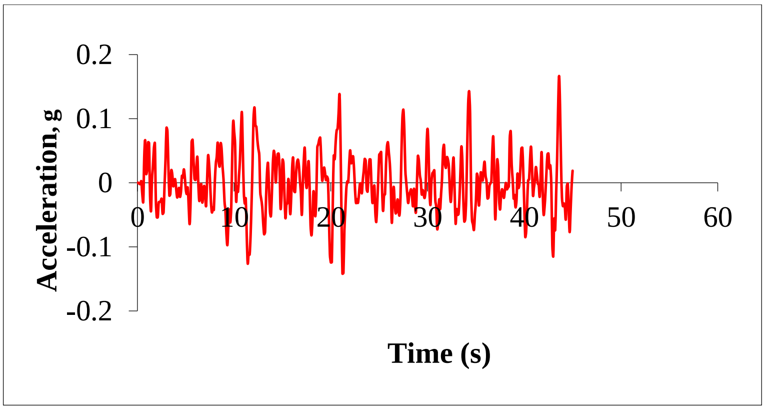


(a) Spectra for response spectrum analysis



(b) Data for time history analysis

Figure 2. Input for the analysis.

3. Results and Discussion

The fundamental frequency and mode shape of the building frames are shown in figure 3 and 4, respectively. The frequency of fully infilled frame is 2.28 times more than bare frame and soft-storey frame is 1.47 times more than bare frame. The mode shape explains the deflection pattern of the frames; the bare frame and fully infilled frame show the flexure mode whereas the soft-storey frame shows the shear mode.

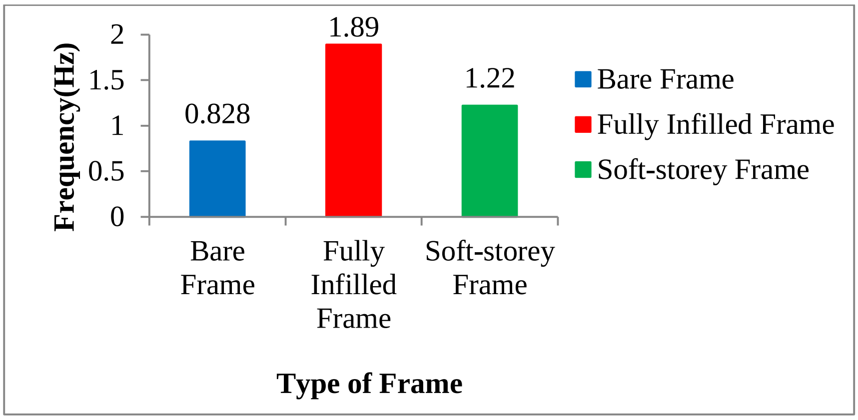


Figure 3. Fundamental **f**requency of the building frames.

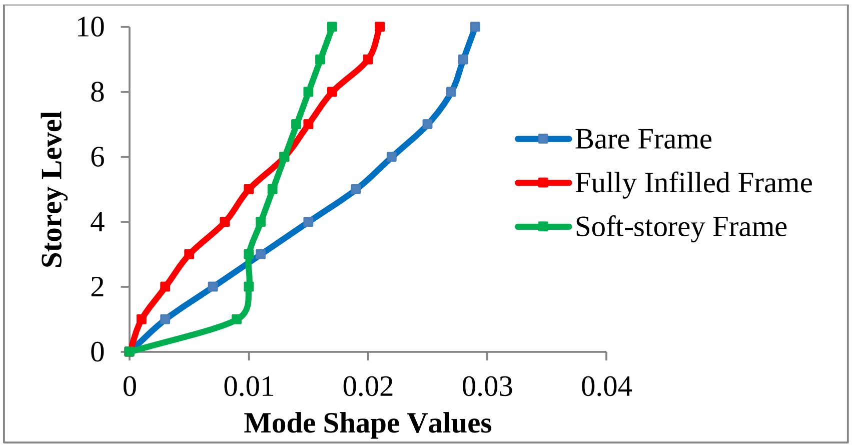


Figure 4. Fundamental mode shape of the building frames.

Storey stiffness is very significant in infilled frames than the bare frame; however the stiffness in the soft-storey frame between first and second floor is about 88.6 % (figure 5). This kind of behavior should be avoided in order to make the buildings safe against earthquake loads.

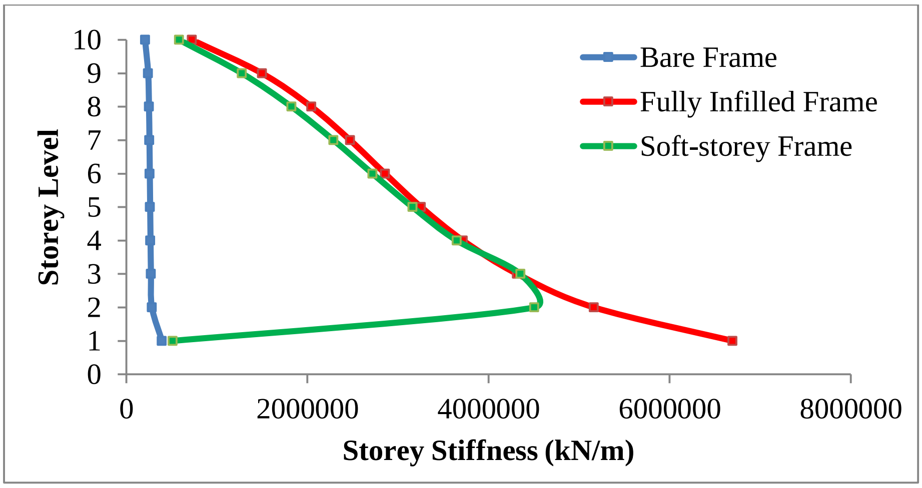


Figure 5. Storey stiffness of the building frames.

Tables 1, 2 and 3 represents the dynamic response of bare frame, fully infilled frame and soft-storey frame, respectively obtained from response spectrum analysis and time history analysis. The base shear of bare frame and fully infilled frame from RS and TH analyses is almost same but for the case of soft-storey frame the TH value is 35 % lower than that of RS approach.

The storey displacement for the bare frame is found to be more when compared to other two frames and observed that both RS and TH analyses produced nearly equal magnitude of displacement. The fully infilled and soft-storey frames have lower deflection from TH analysis than RS analysis.

The storey drift of all the three frames is within the limit as per the IS 1893 codal provisions. However, inter-storey drift between first and second floor in the case of soft-storey frame is found to be 89%.

Overturning moments are very high in frames with masonry infills when compared to bare frame. It is found that the values of overturning moments of frames with masonry infills from TH analysis are much lower than that of RS analysis.

The weight of the bare frame, fully infilled frame and soft-storey frame is 24142.24 kN, 62544.37 kN and 58704.15 kN, respectively. Due to more inertia the infilled frames attract more forces and becomes stiffer thereby reduction in the lateral displacement than the bare frame.

The dynamic responses of the bare frame are well simulated by RS and TH analyses whereas RS analysis resulted high values for frames with masonry infills. This may be due to the material non-linearity of masonry infill due to cracking and crushing.

Table 1. Response of bare frame.

Storey Level	Storey Shear (kN)		Storey Displacement (mm)		Storey Drift		Overturning Moment (kN-m)	
	RS	TH	RS	TH	RS	TH	RS	TH
Story10	187.18	144.62	23.12	22.17	0.000301	0.000233	0	0
Story9	349.43	241.16	22.34	21.47	0.000483	0.000387	545.88	368.92
Story8	479.55	361.93	21.08	20.32	0.000639	0.000528	1553.95	1170.31
Story7	584.78	487.83	19.37	18.74	0.000764	0.00067	2923.39	2304.26
Story6	672.85	561.86	17.27	16.79	0.000866	0.000796	4575.58	3764.02
Story5	750.52	622.46	14.81	14.41	0.000952	0.000924	6452.90	5598.15
Story4	821.81	698.08	12.06	11.68	0.001027	0.001002	8518.11	7786.06
Story3	886.29	800.45	9.03	8.78	0.001088	0.001052	10749.93	10187.58
Story2	938.43	853.49	5.79	5.69	0.00111	0.001079	13134.41	12751.29
Story1	967.97	842.78	2.46	2.45	0.000822	0.000818	15653.50	15429.31
Base	0	0	0	0	0	0	18272.62	18136.90

Table 2. Response of fully infilled frame.

Storey Level	Storey Shear (kN)		Storey Displacement (mm)		Storey Drift		Overturning Moment (kN-m)	
	RS	TH	RS	TH	RS	TH	RS	TH
Story10	790.59	1134.19	12.10	4.80	0.00033	0.000216	0	0
Story9	1820.70	2136.47	11.02	4.29	0.000405	0.000261	2215.91	3495.68
Story8	2684.76	2245.35	9.82	3.71	0.000438	0.000266	7460.77	10329.16
Story7	3403.92	1767.12	8.52	3.22	0.000459	0.000235	15354.93	18058.58
Story6	4001.60	1858.18	7.15	2.85	0.000467	0.000189	25524.59	24632.37
Story5	4497.05	1807.11	5.77	2.48	0.00046	0.000178	37625.08	28971.64
Story4	4902.19	2410.21	4.40	2.11	0.000439	0.000161	51338.13	30964.87
Story3	5218.77	3304.52	3.08	1.70	0.000403	0.000166	66366.28	31056.78
Story2	5441.54	4614.79	1.88	1.20	0.000351	0.000199	82419.78	31689.25
Story1	5556.26	5556.12	0.83	0.60	0.000277	0.000202	99203.96	36379.74
Base	0	0	0	0	0	0	116406.60	46623.87

Table 3. Response of soft-storey frame.

Storey Level	Storey Shear (kN)		Storey Displacement (mm)		Storey Drift		Overturning Moment (kN-m)	
	RS	TH	RS	TH	RS	TH	RS	TH
Story10	349.3441	195.397	13.382	9.24	0.000199	0.000127	0	0
Story9	841.2211	480.106	12.791	8.86	0.000219	0.000138	988.239	586.191
Story8	1297.29	761.509	12.14	8.445	0.000237	0.000149	3423.904	2021.712
Story7	1717.795	1042.02	11.438	7.997	0.00025	0.000158	7257.965	4306.24
Story6	2104.763	1325.627	10.698	7.521	0.000258	0.000165	12435.03	7432.315
Story5	2461.31	1611.612	9.933	7.025	0.00026	0.000169	18896.08	11409.20
Story4	2791.047	1893.324	9.163	6.516	0.000255	0.00017	26580.39	16244.03
Story3	3097.425	2161.511	8.405	6.006	0.000237	0.000162	35426.87	21924.00
Story2	3383.981	2410.397	7.697	5.521	0.00025	0.000175	45374.44	28408.54
Story1	3566.333	2566.406	6.947	4.995	0.002316	0.001665	56364.92	35639.73
Base	0	0	0	0	0	0	68029.31	43338.95

The base shear versus top displacement of the different frames describes the global behavior of the frames as shown in figure 6. The strength and initial stiffness of the fully infilled frame is higher than that of other two frames. The energy dissipation capacity of the fully infilled frame is nearly 2.84 times and 2.2 times higher than that of bare and soft-storey frames, respectively. Though the strength and initial stiffness of the soft-storey frame is better than the bare frame, the energy dissipation capacity is reduced by 20 % because of the absence of masonry infill in the ground storey.

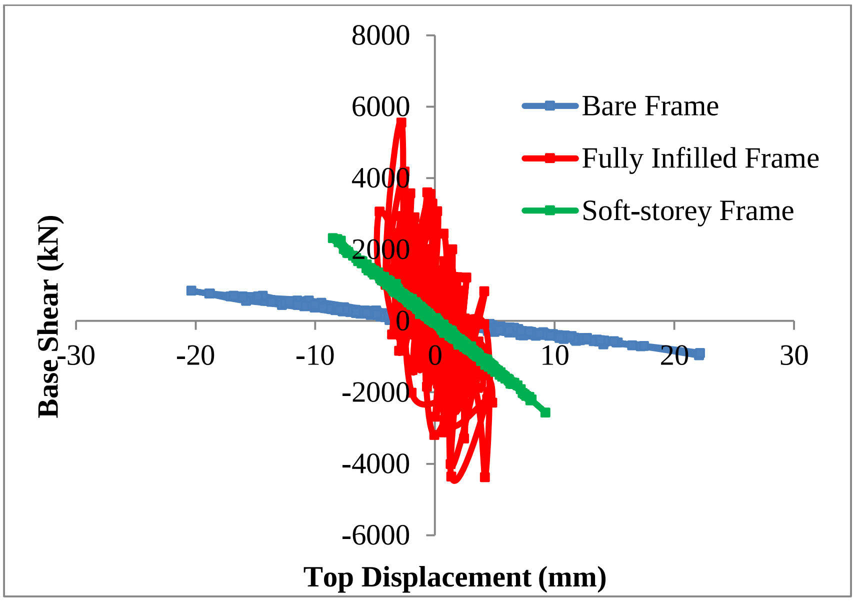


Figure 6. Base shear vs top displacement behavior of frames.

4. Conclusion

The RS and TH analyses of bare frame, fully infilled frame and soft-storey frame are compared for their seismic resistance. Considerable increase in base shear is obtained for frames with masonry infills and the infills reduced the lateral displacement significantly. Storey drifts of all the frames are lesser than the limit as given in the IS code; however the inter-storey drift in soft-storey frame in the bottom storey is relatively higher and this will lead to a concentration of heavy damage in the columns in that particular storey. The energy dissipation capacity of fully infilled frame is superior to that of other two frames. The dynamic responses of fully infilled and soft-storey frames from RS analysis are highly magnified when compared to TH analysis.

References

[1] Pradeep K R 2015 Importance of Dynamic Analysis in Earthquake Safety of Tall Buildings Int. Symp. Reducing Earthquake Losses and Advances in Earthquake Science.
[2] Abd-Elhamed A and Mahmoud S 2017 Linear and Nonlinear Dynamic Analysis of Masonry Infill RC Framed Buildings *Civil. Engg. J.* **3** 881
[3] Pradip S, Biju K P and Devdas M 2004 Survey And Assessment of Seismic Safety of Multistoreyed Buildings In Guwahati, India *13th World. Conf. Earthquake Engg*. (Vancouver, B.C., Canada)
[4] Hassaballa A E and Fathelrahman M. A and Ismaeil M A 2013 Seismic Analysis of a Reinforced Concrete Building by Response Spectrum Method, *J. Engg*. 3 01
[5] Patil S S, Ghadge S A , Konapure C G and Ghadge C A 2013 Seismic Analysis of High-Rise Building by Response Spectrum Method *Int. J. Com. Engg. Res*.3 272
[6] Haroon R T and Umesh.N K 2012 Seismic Analysis of RC Frame Structure with and without Masonry Infill Walls *Ind. J. Nat. Sci*..**3** 1137
[7] Panagiotis G A, Constantinos C R, Emmanouela V R and Liborio C 2017 Fundamental period of infilled reinforced concrete frame structures, *Str.Infra.Engg* **13** 929

[8] Murthy CVR and Jain S K 2000 Beneficial influence of masonry infill on Seismic performance of RC frames buildings *Proc.12th World Conf. Earthquake Engg.* (New Zealand)
[9] Gong X Y and Dai J W 2012 Nonlinear Seismic Analysis of Masonry Infilled RC Frame Structures *App. Mech. Mat*.**117** 288
[10] Santhi MH, Knight GMS and Muthumani K 2005 Evaluation of seismic response of soft-storey infilled frames *Comp. Con*. **2** 423
[11] Furtado A, Rodrigues H and Arede A 2015 Modelling of masonry infill walls participation in the seismic behaviour of RC buildings using OpenSees *Int J. Adv. Struct. Engg.* **7** 117
[12] Rodrigues H, Varum H and Costa A 2010 Simplified Macro-Model for Infill Masonry Panels *J. Earthquake Engg.* **14** 390
[13] IS 1893:2016 (Part 1): Criteria for Earthquake Resistant Design of Structures