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Non-Linear Dynamic Analysis of 3D Infilled Frames

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***Abstract*:-In this Paper an attempt is made to study on the effect of mass on 3d infilled frame during earthquake for single bay, four storey reinforced concrete frames with brick masonry infill in the form of equivalent diagonal strut. For this purpose, a four storey RCC frame constructed and tested at the tower testing facility at Central Power Research Institute (CPRI), Bangalore that provided a base shear v/s displacement plot was considered and SAP 2000 v14 for dynamic analysis of masonry infilled frames. The reinforced concrete frame structure with infill's as diagonal strut is analyzed for strong ground motions to evaluate the influence of masonry infill panels on the dynamic response. The observations and results reveal that masonry infill walls play an important role in resisting the lateral load effectively. The fully infilled frame has the lowest collapse risk compared to that of bare frame and infilled frame with 20% opening. It has been observed that infill's contribute to a large increase in the stiffness and strength of the structure while the deformation capacity of the structure gets reduced.**

Keywords: Infill, Seismic weight, time period, natural frequency, displacement.

INTRODUCTION

The infill panels were invariably considered to be 'non-structural'. A historical review of the state-of-the-art in infilled frames under static loads and dynamic loads, with linear approach and non linear approach and by elastic theory and plastic theory has been studied. Infills have a wide variety of geometric configurations. Aspect ratios (length/height) for infilled panels usually vary from approximately 1:1 to 3:1 with most ranging from 1.5:1 to 2.5:1. Most of the work has focused on steel frame infilled with R.C. panels for high rise construction, or R.C. frames infilled with plain masonry for medium high rises. ELENA VASEVA (2009) conducted "Seismic Analysis of Infilled RC Frames with Implementation of a Masonry Panel Models". The results from nonlinear analysis of the bare and infilled frames are compared. With the application of the strut model it is possible to give good solution for infill frame evaluation. The presence of masonry infill walls can affect the seismic behavior of framed building to large extent. These effects are generally positive: masonry infill walls can increase global stiffness and strength of the structure. The energy dissipation capacity of the frames with infill walls is higher than that of the bare frame.

MODELING AND ANALYSIS

1 Earthquake Records

The earthquake records (ground motion) considered in this study are; the Imperial Valley earthquake (El Centro) and Bhuj earthquake. The acceleration time history of each earthquake which was used as the input load during the time history Analysis. The maximum peak ground acceleration for El Centro and Bhuj are 0.31g and 0.10g respectively.

2. Experimental Building description:

Type of structure: Ordinary moment resisting RC frame
Grade of concrete: M 20
Grade of reinforcing steel: Fe415
Plane size: 5mX5m
Number of stories: G+ 3 storeys
Building height 16m above ground level
Type of foundation: Raft foundation which is supported on rock bed using rock grouting.

3. Geometry:

The structure is a G+3 storied RCC bare framed structure. Fig 1 shows the basic overall geometry of the structure.

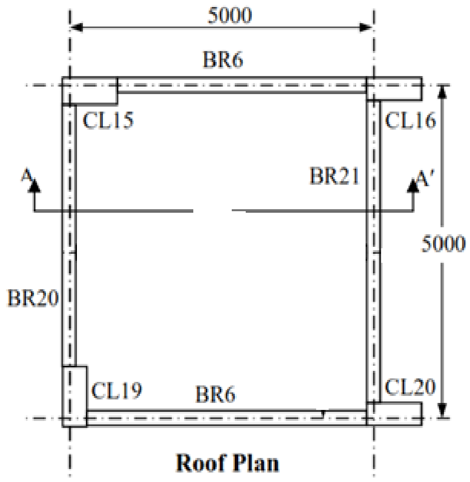
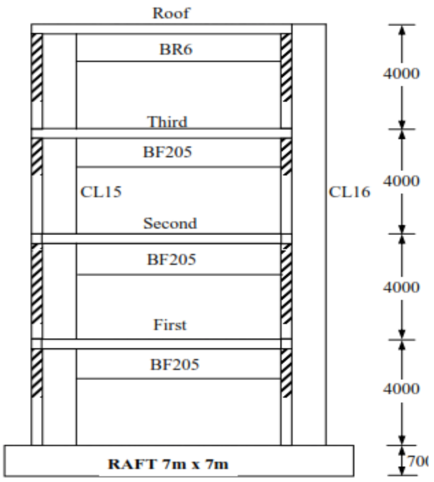


Fig. 1 Roof plan and section at A-A'



Section A-A′

The material properties considered for the analysis are given above Material Characteristic strength (MPa) of Concrete (M20), *fck* = 20, Ec = 22360 Modulus of Elasticity (MPa) of Reinforcing steel fy = 415, Es = 2 E+5

4. Design of Reinforced frames

The reinforced concrete structures were designed as per IS456-2000 and IS1893-2002 according to limit state concept to proportion the structural members. The concrete material with young's modulus of elasticity of 22360Mpa and Poisson's ratio of 0.2 has been considered in this design. The density of concrete and brick masonry was considered as $25kN/m^3$ and $19.2kN/m^3$ which will be used for seismic weight calculations.

The sources of structural mass are from structural members, infill walls, floor slabs, finishes, and the imposed load from movable objects.

5. Structures designed as per IS1893-2002

The above loads were used to find the total seismic weight which in turn was used to obtain the total base shear of the system under static conditions. Table 5.1 shows the seismic weight calculations of the four storey bare frame system.

The fundamental natural period of the structural system was found to be 0.6 seconds by using the empirical expression given in the code for, without infill walls.

$T=0.075h^{0.75}$ ….. (5.1)

Where

T=Fundamental period of the reinforced concrete building structures without infill walls

h=height of the building in meters.

And, the fundamental natural period of the structural system was found to be 0.64 seconds by using the empirical expression given in the code for infill walls.

$Ta=0.09h/\sqrt{d}$ ………… (5.2)

Where

Ta=Fundamental periods of the reinforced concrete building structures with infill walls

h =height of the building in meters

d= base dimension of the building at the plinth level in m, along the considered direction of the lateral force

Table 1 Seismic weight calculations of four storey structure

Storey level	Storey Height(m)	Slab, kN	Beam,kN	Column,kN	Infill,kN	TotalDL,kN
1	4	75	88.02	135	227.33	525.35
2	4	75	88.02	135	227.33	525.35
3	4	75	90.04	119	232.63	516.67
4	4	75	91.06	105	235.26	506.32
					Total	2073.69

The total seismic weight of the structure is given below:

Bare Frame: 1151.14kN

Infilled Frame: 2073.69kN

The design horizontal seismic coefficient is given by the following expression (IS 1893-2002)

$A_h= (ZISa/g)/2R$ ……….. (5.3)

Where,

Z=zone factor for the maximum considered earthquake (MCE)

I=Importance factor, depending upon the importance of the structure

R=Response reduction factor

Sa/g=average response acceleration coefficient corresponding to the period

½= the factor used to convert MCE to Design based Earthquake (DBE)

A zone factor Z=0.24,I=1,R=3,Sa/g=2.5,for medium soil condition corresponding to the fundamental period of 0.6 seconds (IS1893-2002).

It was assumed that the structure is located in seismic zone IV. Based on the above assumption, the lateral seismic coefficient was found as $A_h= (0.24x1x2.5)/(2x3)=0.1$. The total base shear is given by the following equation from the code;

$V_b= A_hW$ ………… (5.4)

Where

W is the total seismic weight of the building. Thus, the total base shear is=207.36KN.

This total base shear was distributed to storey levels using the formula in the code and the corresponding lateral forces shown in table.2, was applied at the storey levels.

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Table 2: Distribution of lateral force

Storey	W_i,KN	h_i,m	$W_ih_i^2$	$W_ih_i^2/\sum W_ih_i^2$	$Q=(W_ih_i^2/\sum W_ih_i^2)V_b$	Vi,kN
4	525.35	16	134489.6	0.5351	110.95	110.95
3	525.35	12	75650.4	0.3010	62.41	173.36
2	516.67	8	33066.88	0.1315	27.26	200.62
1	506.32	4	8101.12	0.0322	6.676	207.29
		$\sum W_ih_i^2$	251308			

RESULTS AND DISCUSSION

Table 3: Showing maximum displacement details at various storey level for BHUJ Earthquake

NO OF STOREYS	Displacement ,mm			
	Bare frame	Infilled frame	Infilled frame 20% opening	Soft storey with 20% opening
4	14.47	4.43	6.66	12.45
3	12.11	3.89	5.94	11.28
2	8.08	3.56	4.36	8.672
1	3.45	1.81	2.12	5.07
0	0	0	0	0

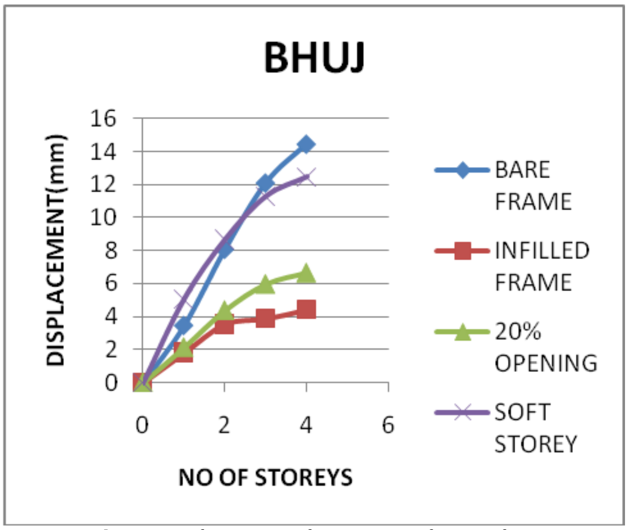

Fig. 2 Displacement of 4 storey rc frame vs No of Storey for BHUJ Earthquake

Table 4: Maximum Acceleration details at different storey levels for Bhuj Earthquake

No of Storeys	Maximum acceleration, m/sec^2			
	Bare Frame	Infilled Frame	Infilled Frame with 20% Opening	Soft Storey with 20% Opening
4	6.44	3.94	4.51	6.34
3	5.57	3.60	3.99	5.695
2	4.12	3.03	3.03	4.44
1	1.99	1.45	1.54	2.67
0	0	0	0	0

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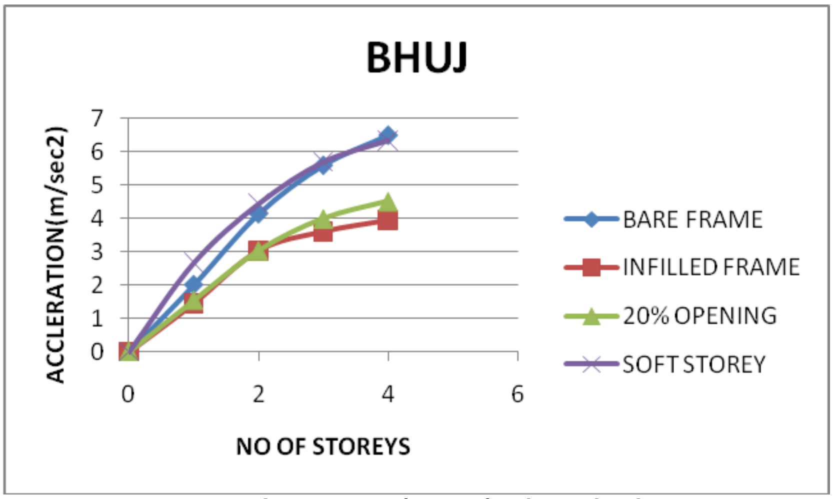

Fig. 3: Accleration vs No of Storeys for Bhuj Earthquake

Table 5: Time period details at different modes for Bhuj Earthquake

Mode No.	Bare Frame	Infilled Frame	Infilled Frame with 20% Opening	Soft Storey with 20% Opening
1	0.2849	0.197	0.2288	0.2591
2	0.0974	0.063	0.079	0.086
3	0.0569	0.048	0.05	0.052

Table6: Frequency details at different Modes for BHUJ Earthquake

Mode No	Bare Frame	Infilled Frame	Infilled Frame with 20% Opening	Soft Storey with 20% Opening
1	3.509	5.063	4.37	3.85
2	10.263	15.701	12.55	11.62
3	17.55	20.805	19.83	18.91

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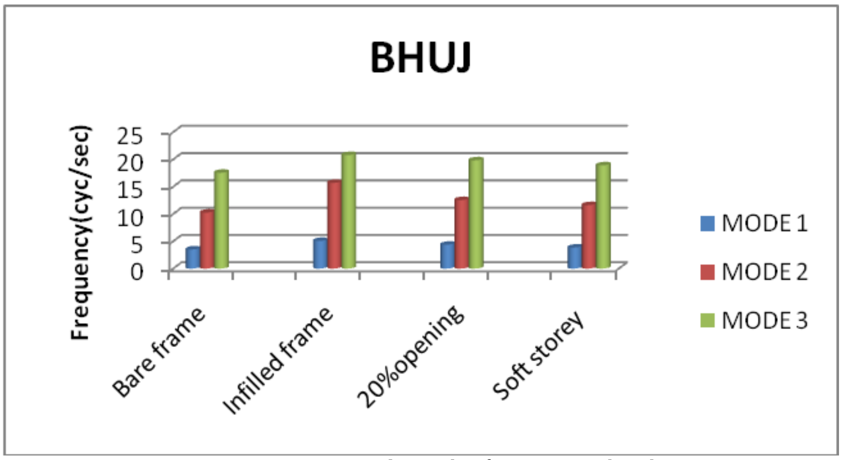

Fig. 4: Frequency vs Mode Number for BHUJ Earthquake

Table7: Maximum displacement details at various storey level for EL CENTRO Earthquake

NO OF STOREYS	Displacement ,mm			
	Bare frame	Infilled frame	Infilled Frame with 20% opening	Soft storey with 20% opening
4	45.28	24.40	29.02	26.48
3	38.47	21.88	25.80	24.18
2	26.35	16.34	18.94	18.91
1	11.65	8.26	9.23	11.04
0	0	0	0	0

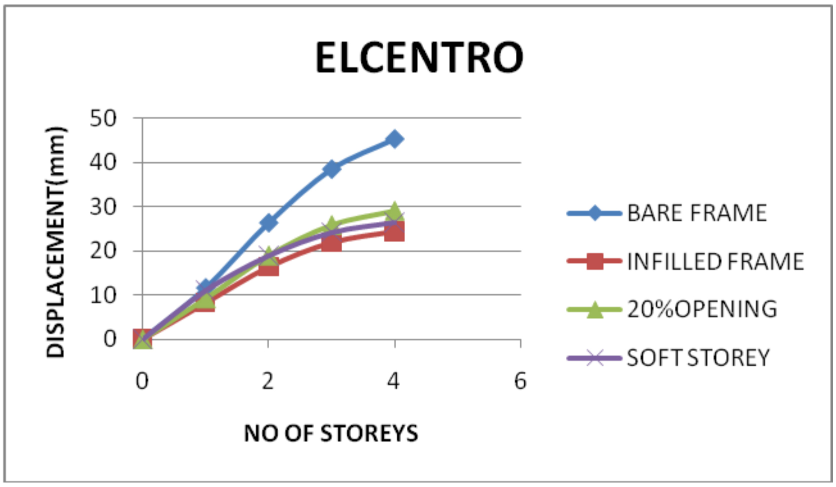

Fig. 5: Maximum displacement vs storey level for EL CENTRO Earthquake

Table 8: Summary of maximum top Bhuj and EL Centro earthquake

Structure	BHUJ	EL- CENTRO
	Maximum top Displacement(mm)	Maximum top Displacement(mm)
Bare frame	14.47	45.28
Infilled frame	4.43	24.40
Infilled frame 20%Opening	6.66	29.02
Soft Storey with 20% Opening	12.45	26.48

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Table9: Maximum acceleration details at different storey levels for EL Centro Earthquake

No of Storeys	Maximum acceleration, m/sec^2			
	Bare Frame	Infilled Frame	Infilled Frame with 20%Opening	Soft Storey with 20% Opening
4	15.19	11.72	13.67	11.83
3	13.08	10.43	11.90	10.56
2	8.99	7.77	8.45	7.90
1	3.93	3.86	4.05	4.43
0	0	0	0	0

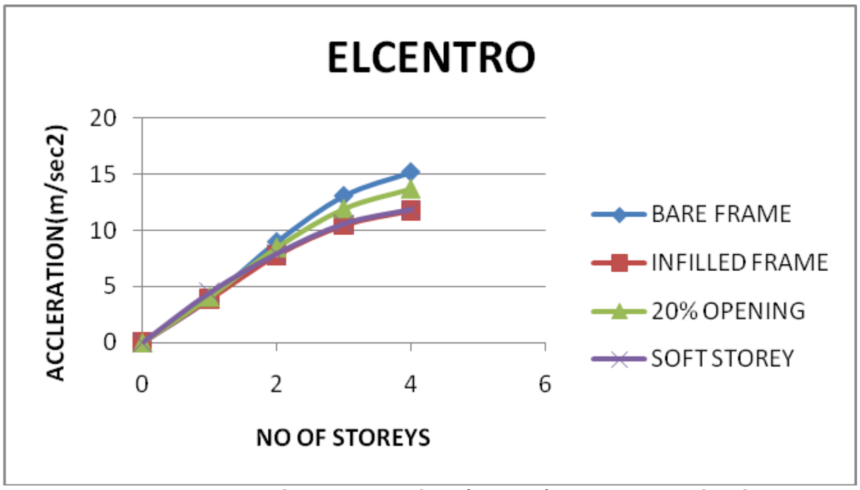

Fig.6: Maximum acceleration vs Number of storeys for EL Centro Earthquake

Table10: Frequency details at different Modes for EL Centro Earthquake

Mode No	Bare Frame	Infilled Frame	Infilled Frame with 20% Opening	Soft Storey with 20% Opening
1	3.509	4.731	4.352	3.858
2	10.263	13.56	12.484	11.62
3	17.55	20.739	19.67	18.91

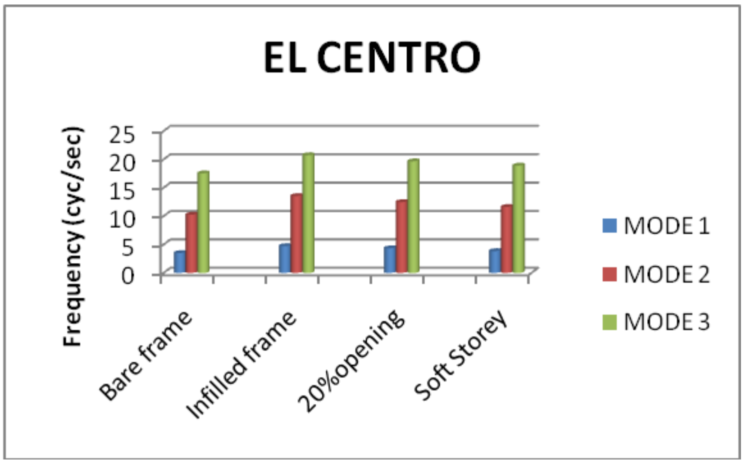

Fig.7: Frequency vs Mode Number for EL Centro Earthquake

Table 11: Time period details at different modes for EL Centro Earthquake

Mode No	Bare Frame	Infilled Frame	Infilled frame with 20% Opening	Soft Storey with 20% Opening
1	0.284	0.211	0.229	0.259
2	0.097	0.0737	0.08	0.086
3	0.056	0.0482	0.05	0.052

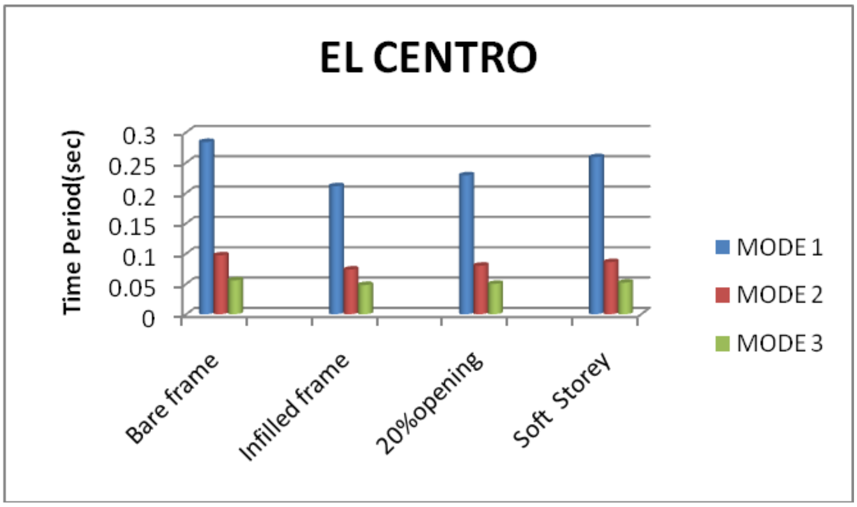

Fig.8: Time period vs Mode No for El Centro Earthquake

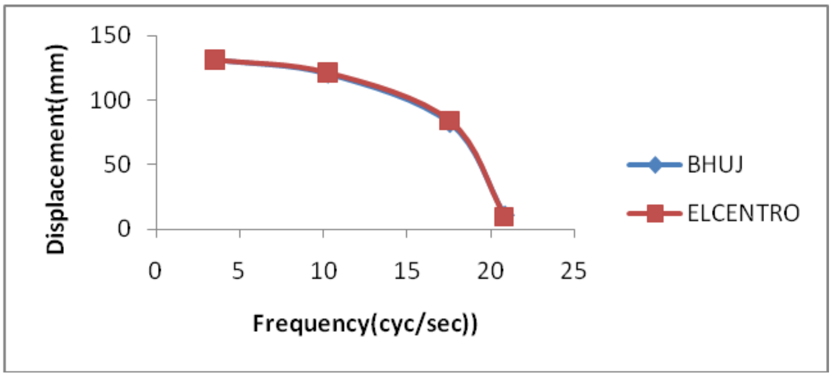

Fig.12: Displacement vs Frequency for Bhuj and EL Centro Earthquakes

CONCLUSIONS

Based on the results of the present study the following conclusions can be drawn:

1. For the four storey model, a load combination of 1.5(DL+EQ) governs the member design.
2. Irregularity of mass distribution in vertical and horizontal planes can result in irregularity responses.
3. On the basis of time period, the four storey model may be classified as rigid since T<0.3 sec.
4. Building with higher natural frequency and short natural period tend to smaller displacement.
5. The building without opening has less displacement and acceleration than compared to infill wall with opening.
6. The building without opening has less Time period and higher natural frequency compared to infill wall with opening and building with soft storey.
7. In case of infilled frame with soft storey the displacement decreases with percentage increase in opening.
8. As the peak ground acceleration (PGA) i.e. when the ground motions increases the response (displacement, acceleration, amplification ratio) of the building increases.

9. The displacement of the building depends on frequency of earthquake and natural frequency of the structure.
10. Infilled frame with soft storey showed maximum response when compared to infilled frame without soft storey from this it is clear that with fixed base the infilled frame with soft storey are Vulnerability to the damage during earthquake.

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