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Dynamic Analysis Of Masonry Infill Rc Frames For Soft Storey Criteria

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***Abstract*— This dissertation work is carried out on the 2D RC frames to study the dynamic behaviour of MI and soft storey criteria. 2D RC frames with MI are carried out for bare frame, infill frame and soft storey having one, two, three bays with one to five storeys using SAP 2000 software. MI is modelled as equivalent diagonal strut. The modal analysis is carried out on the models, the results are compared with the available experimental results obtained from shake table tests conducted at CPRI, Bangalore and the models are validated. The Dynamic analysis involving, modal analysis to obtain natural frequencies, equivalent static analysis and response spectrum analysis to obtain base shear and displacement for all the zones (II-V) as per IS 1893(Part1):2002, time history analysis to obtain displacement are carried out. Based on the analysis results such as natural frequency, base shear, displacement are tabulated and compared and hence conclusions are drawn based on the above results.**

***Index Terms*— Masonry infill (MI), Reinforced concrete (RC)**

I. INTRODUCTION

A large number of reinforced concrete (RC) buildings are constructed with masonry infill MI). MI are often used to fill the void between the vertical and horizontal elements of the building frames with the assumption that these MI will not take part in resisting any kind of load either axial or lateral; hence its significance in the analysis of RC frame is generally neglected. In fact, an MI wall enhances considerably the strength and rigidity of the structure. It has been recognized that RC frames with MI have more strength and rigidity in comparison to the bare frames and the ignorance of MI has become the cause of failure of many of the multi-storied buildings. The main reason of failure is the stiffening effect of MI frame that changes the basic behaviour of buildings during earthquake and creates new failure mechanism. The primary function of MI is either to protect the inside of the structure from the environment (rain, snow, wind, etc.) or to divide inside spaces. In either case, common practice has always been to ignore MI during the design and analysis of steel/RC frame structures. However, MI tends to interact with the surrounding RC frame when the structure is subjected to lateral loads. In MI structures the ordinarily occurring dead or live loads do not pose much of a problem in the analysis and design. But the lateral loads due to wind and earthquake, tremors or blast loads are a matter of great concern and need special consideration in the design of buildings.

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II. SCOPE OF THE PRESENT STUDY

MI is commonly used in buildings for functional and architectural reasons. However, structural contribution of MI walls cannot simply be neglected particularly in regions of moderate and high seismicity and its ignorance has become the cause of failure of many of the multi-storied buildings. So dynamic analysis of 2D RC frames with MI is carried out for 3 different cases namely bare frame, infill frame and soft storey.
FE analysis involving modal Analysis, equivalent static analysis, response spectrum analysis, time history analysis are performed using SAP 2000 software and the analysis results so obtained are tabulated and compared.

III. METHODOLOGY

Detailed literature survey is carried out on the dynamic effect of MI RC frames, effects of soft storey on RC frames, shake table tests and the analytical work carried out on MI RC frames.
2D RC frames with one, two, three bays having one to five storeys are considered with different configuration of MI for the dynamic analysis using SAP 2000 software. The model specifications are kept same as that for CPRI models.
Equivalent strut method is used for modelling the MI assuming the thickness of strut to be equal to the thickness of MI and the width of diagonal strut is carried out based on the literature.
Modal analysis is carried out to obtain natural frequencies and mode shapes and the results are compared with available experimental results obtained from shake table tests results conducted at CPRI, Bangalore and the models are validated. By increasing bays and storeys, dynamic analysis is continued with modal analysis to obtain natural frequencies followed by equivalent static and response spectrum analysis are carried out to obtain base shear and displacement for all the zones (II-V) as per IS 1893 (Part 1):2002, time history analysis are carried out using Bhuj earthquake data to obtain displacement.
Results obtained for these analyses are tabulated, discussed and conclusions are drawn.
Calculation of width of diagonal strut
Chethan K (2009) [4]
A new method is proposed for calculating width of the equivalent diagonal strut based on the work of Smith and Carter.
w = 1.414αh
The column contact length, „*αh*‟, is related with the relative stiffness of the infill to frame by the approximate equation

$$\alpha_h = \frac{\pi}{2\lambda}$$

Beam contact length „αL‟ is taken approximately half of its span. The width „w‟ of the strut is given by

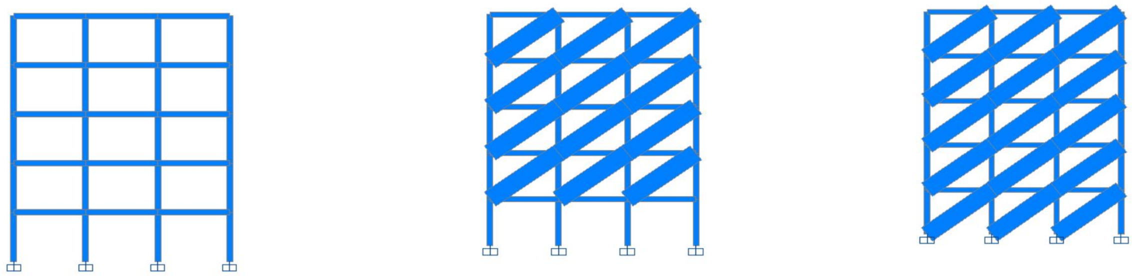
$$w = \sqrt{\alpha_L^2 + \alpha_h^2}$$

„*λ*‟ is an empirical parameter expressing the relative stiffness of the column to the infill

$$\lambda = \sqrt[4]{\frac{E_m t \sin 2\theta}{4 E_c I_c h}}$$

Where;
t = Thickness of MI.
h = Height of MI.
l = Length of the infill.
d = diagonal length of the MI.
Em = Modulus of elasticity of MI.
Ec = Modulus of elasticity of column.
EL = Modulus of elasticity of beam.
Ic = Moment of inertia of the column.
IL = Moment of inertia of beam.
λh =coefficient used to determine equivalent width of infill strut.
λL = empirical parameter expressing the relative stiffness of the beam to the infill.
θ = Slope of the infill diagonal to the horizontal
αh = the relative stiffness of the infill to frame

The width of equivalent diagonal strut is 0.332m Chethan K (2009) [4] is considered for analysis of 2D RC frames with various configurations of MI. The RC frame models are of one, two bay and three bays with one to five storeys for bare frame, Infill frame, Soft storey crit



3B5S 3B5SF 3B5SF

Figure. 1 Typical RC frames with MI modelled as diagonal strut

Figure.1 shows typical 2D RC frames modelled as one, two, three bays with one to five storeys with different configurations of MI.
Where,
3B5S = three bay five storey bare frame
3B5SF =three bay five storey infill frame
3B5SS = three bay five storey soft condition

IV. RESULTS AND DISCUSSIONS

This dissertation work is carried out to find the effects of soft storey on the dynamic characteristics of RC frames with masonry infill (MI). 2D RC frames with MI having one, two, three bays with one to five storeys are considered. MI is modelled as equivalent diagonal strut. The modal analysis is carried out and results are compared with the available experimental results from the shake table tests conducted at CPRI, Bangalore and the models are validated. The analysis is continued with modal analysis for all the models to obtain natural frequencies followed by equivalent static and response spectrum analyses to obtain base shear and displacement for all the zones (II-V) as per IS 1893 (Part 1):2002. Time history analysis is carried out for Bhuj earthquake data to obtain displacement. Analysis results such as natural frequencies, base shears and displacements are tabulated and compared.

A.Comparison of natural frequencies (Hz) of 2D RC frames

In Table I , shows the natural frequencies obtained for 2D RC frames from modal analysis and compared with the shake table tests.
It is observed that the natural frequency obtained from FE analysis matches well with the shake table test results and the models are validated. Hence the models so developed are used for further analysis.

TABLE I. COMPARISON OF NATURAL FREQUENCIES (HZ) OF 2D RC FRAMES

SL. No	Model	Shake Table Test	Modal Analysis
1	1BIS	41.25	45.11
2	1B1SF	**	114.04
3	1B2S	20.00	22.414
4	1B2SF	42.75	45.54
5	1B2SS	16.5	16.61
6	1B3S	14.00	14.30
7	1B3SF	29	29.25
8	1B3SS	12.75	13.11
9	2B1S	39.75	42.38
10	2B1SF	**	115.00
11	2B1SS	**	107.92
12	2B2S	19.25	21.75
13	2B2SF	42	46.93
14	2B2SS	15	17.16
15	2B3S	14	14.31
16	2B3SF	29.50	30.55

B. Modal Analysis Results Bv

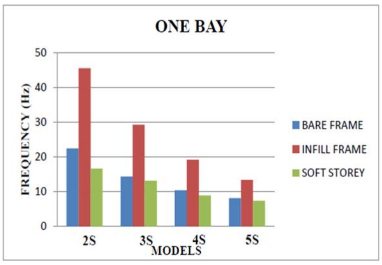


Figure. 2 (a) Comparison of natural frequency (Hz) for one bay

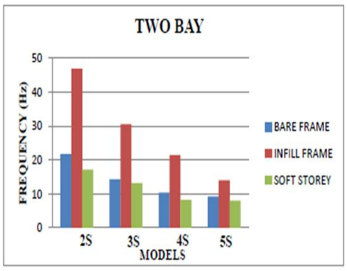


Figure. 2 (b) Comparison of natural frequency (Hz) for two bay

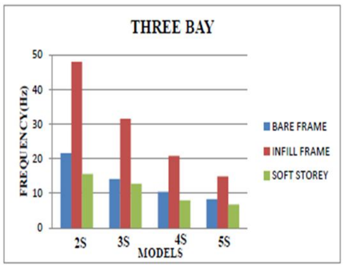


Figure. 2 (c) Comparison of natural frequency (Hz) for three bay

Modal analysis is carried out for one, two and three bays with one to five storeys. Figure 2 (a), (b), (c) shows the comparison of natural frequencies (Hz) for bare frame, MI and soft storey conditions. It is observed that the natural frequency of soft storey decreases compare to bare frame and infill frame, whereas the natural frequency of infill frame are also double the frequency of the bare frames. The natural frequency of soft storey decreases by 60% compare to MI.

C. Equivalent static and response spectrum analyses results

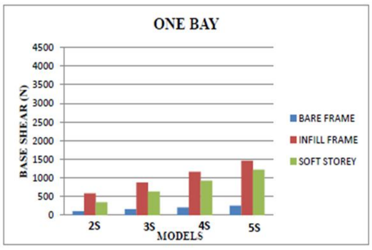


Figure. 3 (a) Comparison of Base shear (N) For one bay

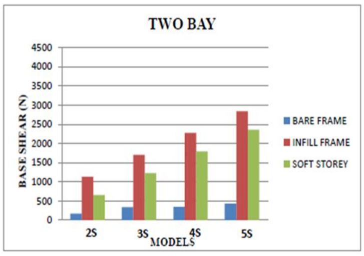


Figure. 3 (b) Comparison of Base shear (N) for two bay

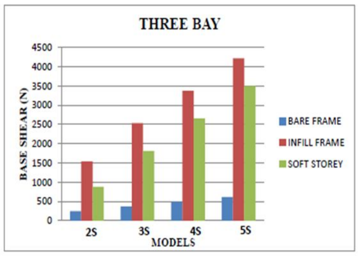


Figure. 3 (c) Comparison of Base shear (N) for three bay

Figure 3 (a), (b), (c) shows the comparison of base shear (N) for bare frame, infill frame, and soft storey for one, two, three bays. It is observed that base shear is least for bare frames and highest for MI frames. Base shear of soft storey decreases by about 20% when compare to MI frame.

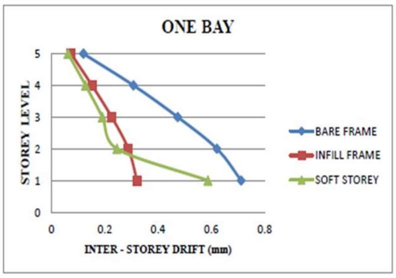


Figure. 4 (a) Comparison of Displacement (mm) for one bay

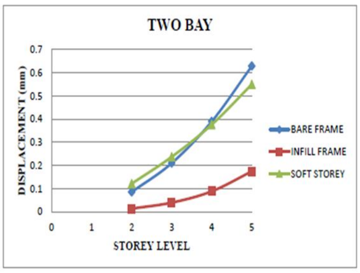


Figure. 4 (b) Comparison of Displacement (mm) for one bay

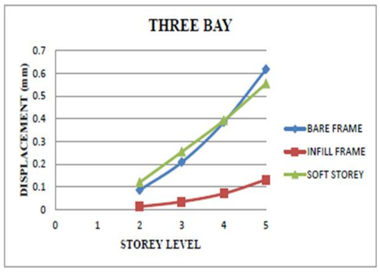


Figure. 4 (a) Comparison of Displacement (mm) for two bay

Figure 4 (a), (b), (c) shows the comparison of displacement (mm) for bare frame, MI, and soft storey conditions with one, two, three bays. It is observed that the displacement in the soft storey is maximum in the lower storeys as compared to the other two conditions which show its criticality in the earthquake resistant design. Whereas in the upper floors, the displacement is higher in bare frame as compared to soft storey condition. Displacements in the MI frames are least due to the presence of infill.

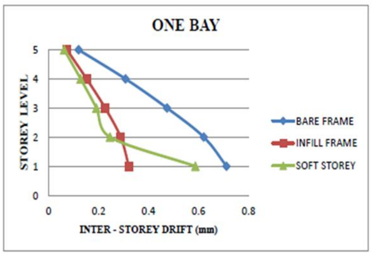


Figure. 5 (a) Comparison of Inter-storey drift (mm) for one bay

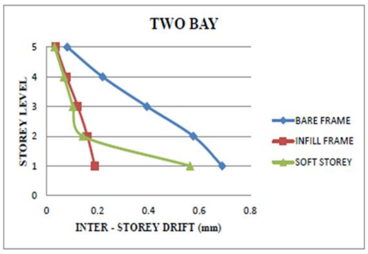


Figure. 5 (b) Comparison of Inter-storey drift (mm) for two bay

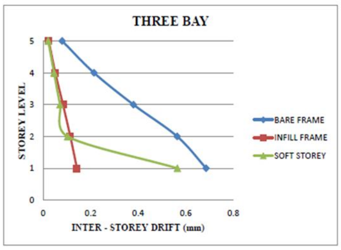


Figure. 5 (a) Comparison of Inter-storey drift (mm) for three bay

Figure 5 (a), (b), (c) shows the comparison of Inter-storey drift (mm) for bare frame, MI, and soft storey conditions with one, two, three bays. The inter-storey drift in the first storey are large for soft storey compared to bare frame and infill frame which shows the sudden change in slope of drift, this is due to the abrupt change in storey stiffness, whereas the bare frame and infill frame shows a smooth profile. For soft storey, the inter-storey drift in the first storey increases by 53% of the second storey compared to bare frame and infill frame.

D. Time history analysis results

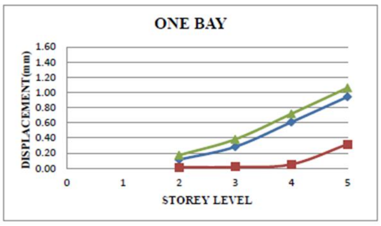


Figure. 6 (a) Comparison of Displacement (mm) for one bay

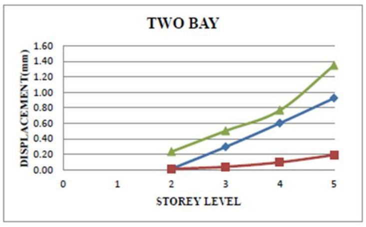


Figure. 6 (a) Comparison of Displacement (mm) for one bay

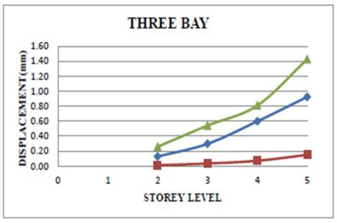


Figure. 6.5 (a) Comparison of Displacement (mm) for one bay

Figure 6(a), (b), (c) shows the comparison of displacement (mm) for bare frame, infill frame, and soft storey with one, two, three bays with respect to the time history analysis using Bhuj earthquake data. It is observed that the large displacement occurs in soft storey compare to bare frame and infill frame. Displacements of soft storey increased by 75% compare to infill frame.

V. Conclusion

The present study is carried out to find the effects of soft storey on the dynamic characteristics of RC frames with masonry infill (MI). 2D frames with one, two, three bays with one to five storeys are considered with different configuration of MI. Dynamic analysis involves modal analysis, equivalent static analysis, response spectrum analysis, time history analysis are performed using SAP 2000 software and the following are the major conclusions.

The masonry infills, although do not interfere in the vertical load resisting system for the RC frame structures, they significantly affect the lateral load-resisting system of the same due to its stiffness and mass.

FE analysis matches well with the shake table test results. Hence, the prediction of natural frequencies for 2D frames with MI can be done using equivalent diagonal strut method in the FE analysis to a reasonable accuracy.

From the modal analysis, it is found that the natural frequencies of the infill frame are around twice when compared to bare frames. The frequencies for frames with soft storey are the least which is due to the sudden reduction in stiffness in the lower floor and presence of mass in the upper floors.

By comparing results of modal analysis, it is observed that the natural frequency does not depend on the number of bays, whether it is a bare frame, infill frame or soft storey. Hence the natural frequency of the structure is independent of the number of bays.

Base shear in bare frame is least compared to soft storey and infill frames, this is due to the increase in mass in the other two conditions. From response spectrum analysis, it is found that the displacement of soft storey is maximum in the lower floors due to the sudden change in lateral stiffness, whereas the displacement of bare frame are higher in the upper floors due to less rigidity.

The inter - storey drifts of soft storey are very large in the lower floor because of the abrupt change in stiffness which leads to stiffness irregularity. Thus they are more vulnerable to collapse and also exhibit poor performance during a earthquake. Therefore alternative measures need to be adopted for these specific circumstances.

From time history analysis, it is found that the large displacement occurs in the soft storey compared to bare and infill frames due to the abrupt change in storey stiffness.

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