Seismic Behaviour of Tall Buildings with and Without In-Fill Walls

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Abstract—The design of masonry in-fills is an issue that has attracted the attention of several researchers in the past, both from the experimental and analytical points of view. Nevertheless, the results are often questionable due to the large variability of masonry properties. Presence of in-fill walls in the frames alters the behaviour of the building under lateral loads. However, it is common industrial practice to ignore the stiffness of in-fill wall for analysis of framed buildings. In this paper, seismic analysis of multi-storeyed building for different plan configurations like rectangular, C, L and I-shapes is mainly emphasized. The building was analysed for seismic zone V of IS 1893-2002. The building was analyzed for four different cases a) without considering in-fill wall, b) considering brick masonry in-fill wall. Modelling of 15- storeys R.C. framed building is done on the ETABS software for analysis. In-fill stiffness was modelled using a diagonal strut approach. Response spectrum analysis is carried out for the models and the results were compared.

Index Terms— Equivalent Diagonal Strut , In-fill wall , Response Spectrum Analysis, Time Period, Displacement, ETABS 9.7.2

1 INTRODUCTION

REINFORCEDconcrete (RC) frames with Un-Reinforced Masonry In-fill panels (Masonry in-fills) are one of the most famous types of construction throughout the world. The major reason for this is ease of construction and economy and apart from this is, masonry in-fill provides excellent insulation and isolation from climatic forces such as heat, sun, wind, rains, extreme cold etc. The in-fill may be masonry brick in-fill or concrete blocks or finished stones or concrete hollow blocks. The in-fills are mostly used as interior partition walls and external wall which protect from outside environment.

The buildings are generally designed as framed structures without considering the structural action of in-fill walls. They are considered as non structural element. Thus under seismic action, the RC frames will purely act as moment resisting frames.

In the present work, dynamic analysis of buildings with and without in-fill walls in different plan configurations using the finite element software ETABS is done.

2 OBJECTIVES

- To find the seismic behavior of tall buildings with and without in-fill walls for different plan configurations,
  a) Rectangular plan
  b) L shape plan
  c) I shape plan
  d) C shape plan
- To model and analyze the structures using the software ETABS

To find the parameters such as storey displacement, and time period in seismic zone V and compare the results to find which one is most suitable for earthquake prone areas..

3 IN-FILL WALL

Unreinforced masonry in-fill walls are not considered in analysis and design of RC frame buildings in current design practice in many countries. They are assumed to not carry any vertical or lateral forces, and hence, declared as non-structural elements insofar as transfer of forces is concerned between structural elements (e.g., beams and columns) that are generated in the building during earthquake shaking. This assumption causes a large gap between the building that is considered in analysis and design, and that finally constructed.

This is attributed to the fact that URM in-fills interfere with lateral deformation of beams and columns of buildings during earthquake shaking (Fig 1), and significantly influence seismic behaviour of buildings by participating in lateral force transfer.

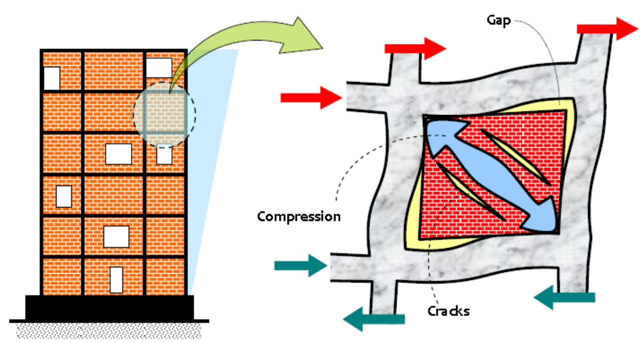

Fig. 1 Deformation of RC frame Building with URM In-fill Walls

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3.1 Concept of Equivalent Strut

Investigators have proposed various approximations for the width of equivalent diagonal strut. Originally proposed by Polyakov(1956)and subsequently developed by many investigators, the width of strut depends on the length of contact between wall and column αh and between the wall and beam αL shown in Fig 2. Stafford smith (1966) developed the formulation for αh and αL on the basis of beam on an elastic foundation. The following equations are proposed

$$\alpha h = \frac{\pi}{2}\sqrt[4]{\frac{E_f h I_c}{2t \sin 2\theta E_m}} \quad (1)$$

$$\alpha L = \pi\sqrt[4]{\frac{E_f L I_b}{2t\ sin\ 2\theta E_m}} \quad (2)$$

Where

E_f and E_m is elastic modulus of the masonry wall and frame material respectively

t, h, L are the thickness height and length of the in-fill wall

I_c and $I_b$are the momentof inertia of column and beam. The effective width is given by

$$\theta = tan^{-1}\left({}^{h}/_{L}\right) \quad (3)$$

The effective width is given by,

$$W_{ef} = \frac{1}{2}\sqrt{\alpha h^2 + \alpha L^2} \quad (4)$$

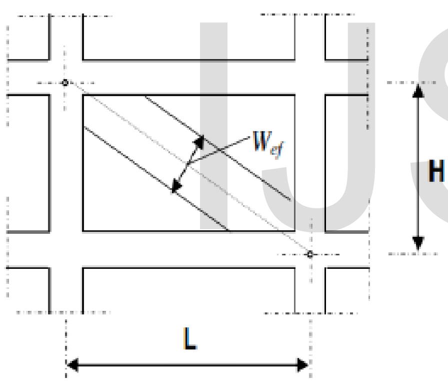

Fig. 2 Equivalent structure

4 MODELLING AND ANALTSIS

4.1 Analysis Software

For the present study the software ETABS 9.7.2 is used and the salient features of the same are presented.

ETABS is a sophisticated, yet easy to use, special purpose analysis and design program developed specifically for building systems. ETABS Version 9.7.2 features an intuitive and powerful graphical interface coupled with unmatched modeling, analytical, and design procedures, all integrated using a common database. Although quick and easy for simple structures, ETABS can also handle the largest and most complex build-in models, including a wide range of nonlinear behaviours, making it the tool of choice for structural engineers in the building industry.

4.2 Data Collection

A fifteen storied RC building with different plan configurations is being considered with a storey height of 3 m in each floor. The detail of the structure considered is shown below. The following are the plan configurations provided,

a. Rectangular shape
b. C shape
c. I shape
d. L shape

The building has eight bays in X direction and six bays in Y direction with the plan dimension 32 m × 24 m.

TABLE 1 Properties of the Structure

Length x width	32m x 24m
No. of storeys	15
Storey height	3m
Beam size	0.45m x 0.45m
Column 1-5 storeys dimensions	0.6m x 0.6m
Column 6-12 storeys dimensions	0.5mx0.5m
Slab thickness	0.125m
Thickness of brick wall	230 mm
Height of parapet wall	.90m
Thickness of parapet wall	115mm
Support conditions	Fixed

TABLE 2 Material Specifications

Grade of Concrete ,M30	f_{ck}=30N/mm^2
Grade of Steel	f_y=415N/mm^2
Density of Concrete	Υ_c=25kN/m^3
Slab thickness	0.120m
Unit weight of concrete	25 KN/m^3
Unit weight of masonry Brick walls considered	20kN/m^3
Modulus of elasticity of masonry Brick walls considered	14800N/mm^2

TABLE 3 Loads acting on the structure

1. Self weight	Weight of beams, columns and slab of the building.
2. Dead load a) Wall load	(unit weight of brick masonry X wall thickness X wall height)= 20 kN/m3 X 0.230m X 3m = 13.8 kN/m (acting on the beam)
b)Wall load (due to Parapet wall at top floor)	= (unit weight of brick masonry X parapet wall thickness X wall height) = 20 kN/m3 X 0.115m X 0.90m = 2.07 kN/m (acting on the beam)
3. Live load a) Floor load b) Roof load	4kN/m^2 2 kN/m^2 (IS 875 (Part 2) acting on beams

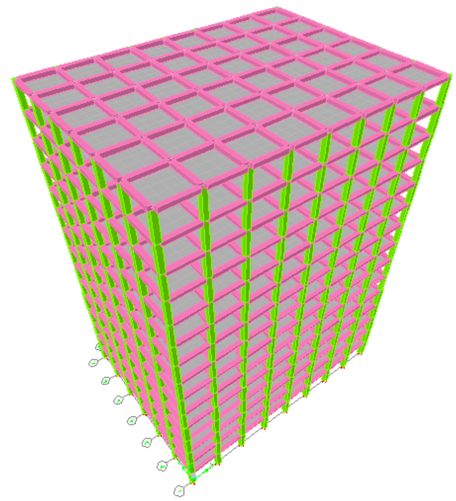

Fig. 4.3-D model of case study structure without in-fill

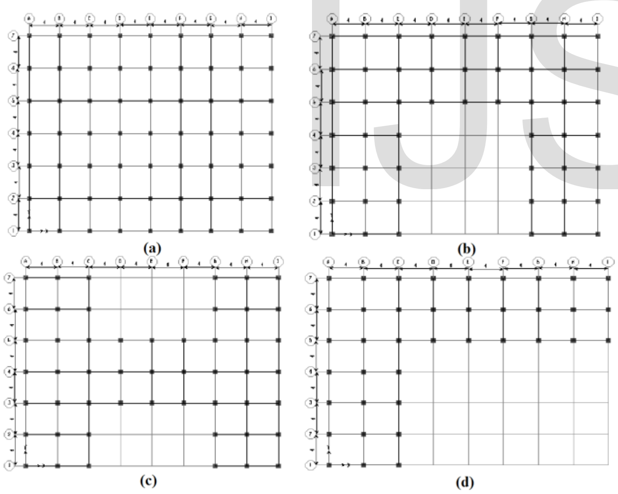

Fig. 3 Beam Column layout: (a) Rectangular shape, (b) C shape, (c) I shape (d) L shape

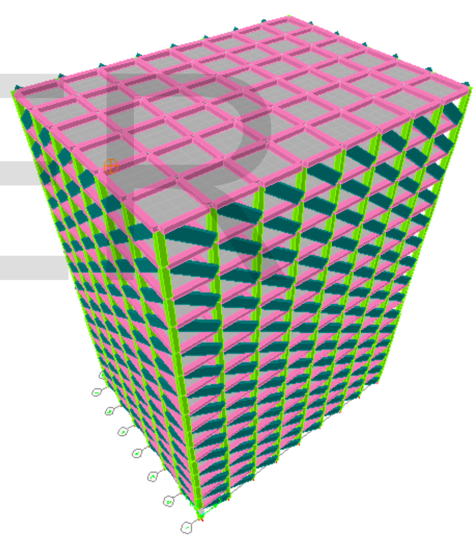

Fig. 5 3-D model of case study structure with in-fill

TABLE 4 Strut widths for the in-fill materials considered

Material	Strut width
Brick masonry in-fill wall a) 1-5 column b) 6-15 column	 .99m 1m

5 RESULTS AND DISCUSSIONS

Response spectrum analyses of the building models are carried out to evaluate the effect of in-fill on the seismic behaviour of building of different plan configuration. Following sections presents the results obtained from these analyses.

5.1 Modal Analysis

When the in-fill stiffness is considered in the building model the global stiffness is bound to increase, reducing the fundamental period of the building. This reduction may attract additional seismic force and this is one of the factors that make difference between buildings modeled with and without in-fill stiffness. Therefore shift in fundamental period can be considered as an important parameter to describe how much the in-

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fill stiffness contributes to the global stiffness of the building.

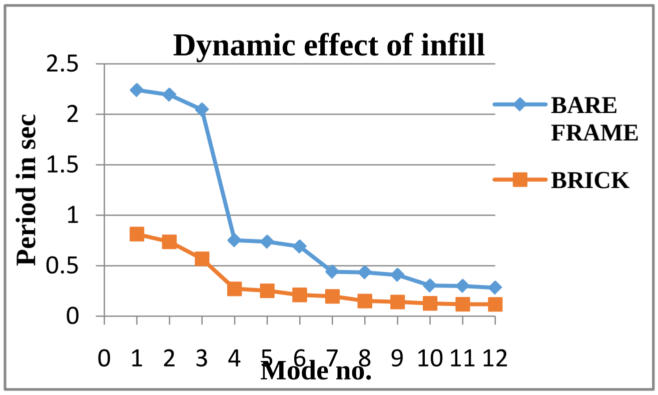

Fig. 6 Plots between Time period V/S Modes for rectangular plan shape

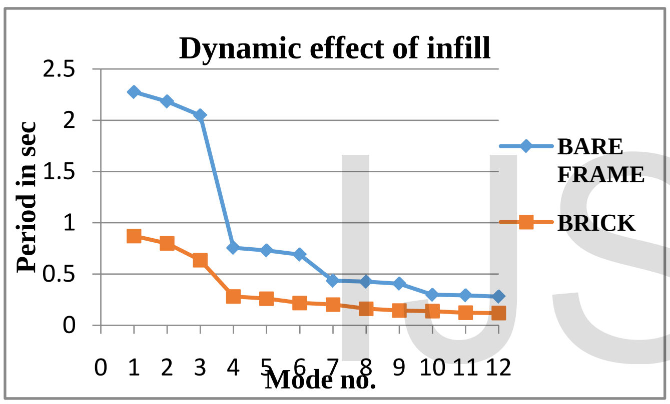

Fig. 7 Plots between Time period V/S Modes for C shape plan

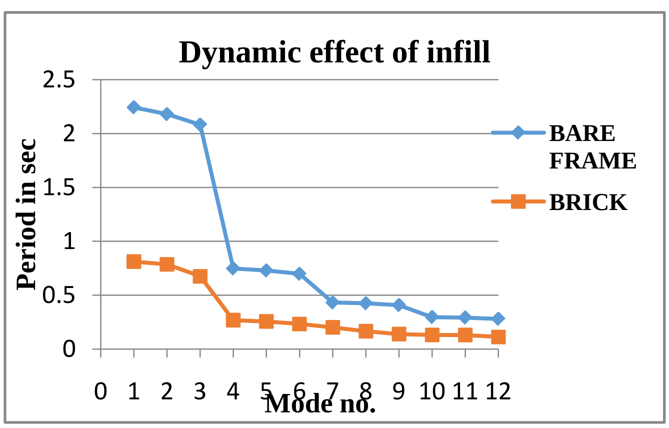

Fig. 8 Plots between Time period V/S Modes for I shape plan

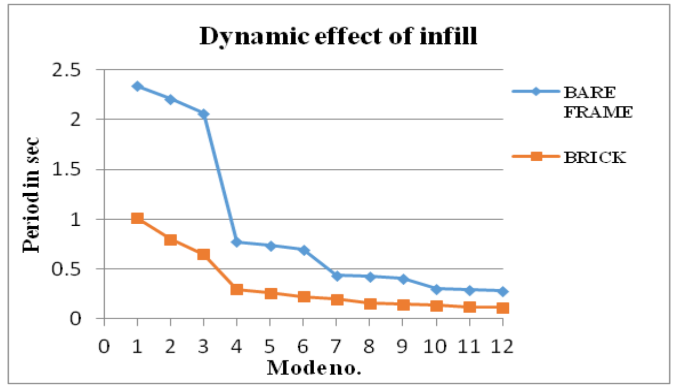

Fig 9 Plots between Time period V/S Modes for L shape plan

The figures 6, 7, 8, 9 shows the graph drawn between time period versus mode no

TABLE 5 Percentage reduction in time period

Plan	Brick in-fill
Rectangular shape	63.83%
C shape	61.84%
I shape	63.83%
L shape	56.83%

5.2 Response Spectrum Analysis

After analyzing the structure, the response of the structure is obtained for the response spectrum functions applied. The maximum displacements at each storey of the building due to external excitation were obtained is shown below

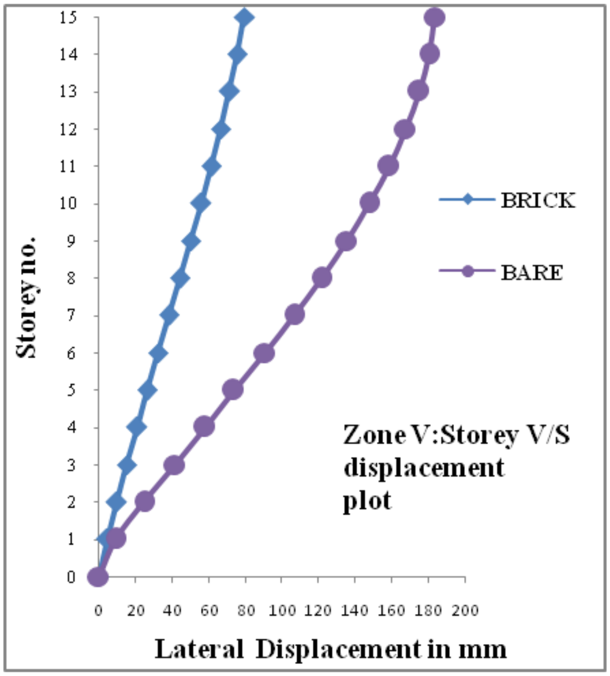

Fig 10 Storey no. V/S Lateral Displacement for Rectangular Shape

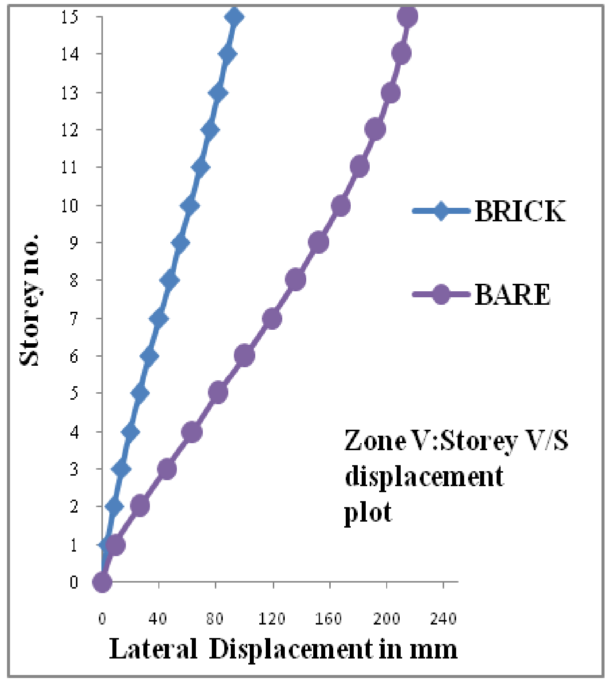

Fig 12 Storey no. V/S Lateral Displacement for I Shape

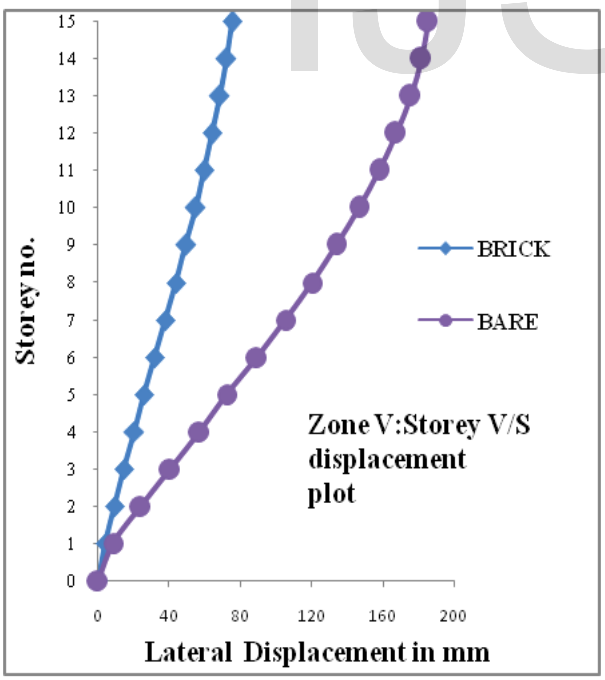

Fig 11 Storey no. V/S Lateral Displacement for C Shape

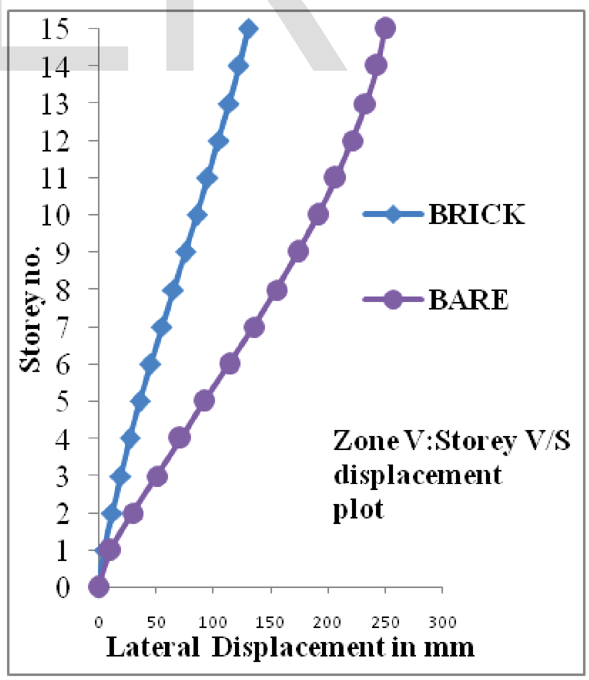

Fig 13 Storey no. V/S Lateral Displacement for L Shape

From the response spectrum analysis carried out for different shaped building, generally the displacement decreases when in-fill is provided

The percentage reduction in displacement when compared with bare frame is given below:

TABLE 6 Percentage reduction in displacement

Plan	Brick in-fill
Rectangular shape	56.79%
C shape	56.74%
I shape	59.45%
L shape	47.81%

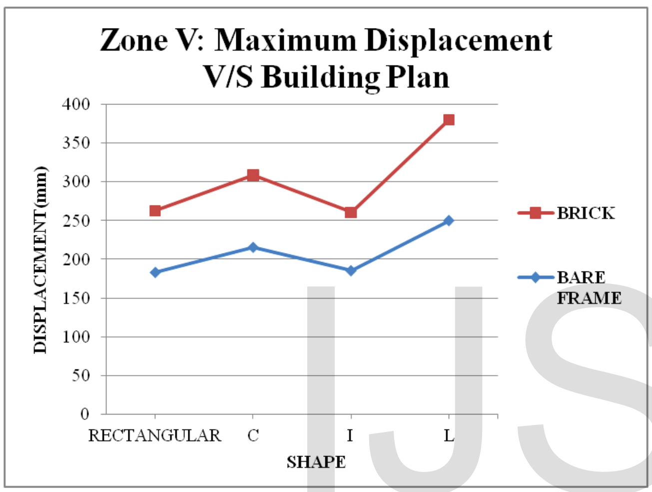

Fig 14 Maximum displacement V/S building plan

From the four building plans considered, it is clear that the building with complex shapes shows maximum response, ie, L shape shows maximum response and then C, L, rectangular shape in a decreasing order.

6 CONCLUSIONS

Time period of the bare frame and in-fill frame were compared. With the addition of in-fill wall the time period decreases. So with the provision of in-fill it is possible to attain a reduction in structural response by energy dissipation. The storey displacement is more in building without in-fill wall. Results show that storey displacement decreases with the provision of in-fill walls. Generally the buildings with complex shapes, particularly with re-entrant corners exhibits special modes of oscillations and the responses will be higher compared with regular plan shapes. So from the four building plans considered, it is clear that the building with complex shapes shows maximum response, ie, L shape shows maximum response and then C, L, rectangular shape in a decreasing order.

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