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EFFECT OF MASONRY INFILL WALLS ON THE SEISMIC RESPONSE OF A THREE STOREY INDUSTRIAL BUILDING IN BANGLADESH

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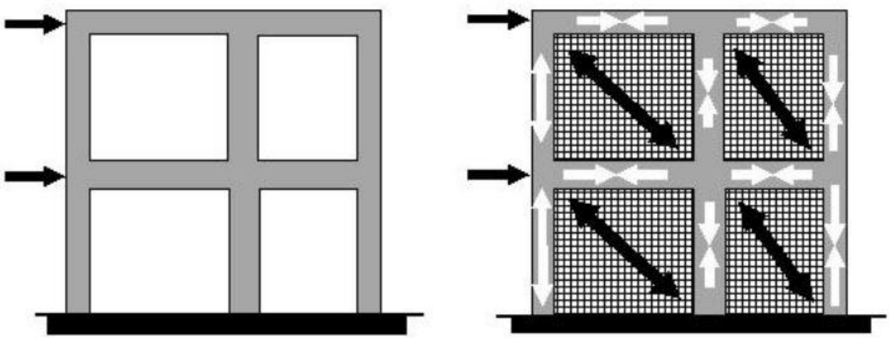
Abstract. *Masonry infill panels are often used as interior partitions and exterior walls in buildings. They are usually treated as non-structural elements, and their interaction with the bounding frame is often ignored in design. A three storey reinforced concrete frame structure consists of RC frames, RC floor slabs and URM infill walls are analyzed for strong ground motions to evaluate the influence of masonry infill panels on the dynamic response. Equivalent Strut method has applied on the simulation of infill walls. A detailed finite element model is constructed to carry out three-dimensional nonlinear time history analysis on the structure. The response simulations were performed for of bare frame and in filled frame.*

Keywords: Infill wall, Seismic response, Equivalent strut method, Time history analysis

1 INTRODUCTION

Reinforced concrete framed building with masonry infill walls have been widely constructed for commercial, industrial and residential buildings in seismic-prone regions worldwide. It is a structural composite system which consists of a reinforced concrete frame with masonry or concrete panels filling the planar rectangular voids between lower and upper beams and side columns. Structural engineers, during the design process of a building, typically, ignore the effects of infill masonry walls in the structural analysis. The Masonry panels which are required to build the partition and enclose the structure are generally considered as non-structural elements. Observations made after earthquake that these non-structural elements had beneficial effect on buildings seismic lateral capacity. The main objective of this paper is to bring a contribution to the knowledge of the effect of infill wall on seismic response of RC frame buildings. Fig. 1 shows lateral load transfer mechanism in bare frame and infill wall frame.



Frame action in bare frame Compression action in infill frame

Figure 1: Change in the lateral load transfer mechanism due to infill wall panels

2 EQUIVALENT STRUT METHOD

From several research paper studies it shows that Equivalent diagonal strut method is used for modeling the infill wall to easy represent the effect of inplane during lateral load and its equations for equivalent diagonal strut width for full infill wall given by various researchers are,

In 1961, Holmes [1] states that the width of equivalent strut to be one third of the diagonal length of infill.

$$w = \frac{dz}{3} \quad (1)$$

Where d_z = diagonal length of infill panel

In 1969 Stafford smith and cater [2] proposed a theoretical relation for the width of the diagonal strut based on the relative stiffness of infill and frame.

$$w = 0.58\left(\frac{1}{H}\right)^{-0.445} \cdot \left(\lambda_h . H_{inf}\right)^{0.335 d_{inf}\left(\frac{1}{H}\right)^{0.064}} \quad (2)$$

$$\lambda_h = \sqrt[4]{\frac{E_{inf} t \sin 2\theta}{4 E_c I_c H_{inf}}} \quad (3)$$

Where, t, H in f and E in f are the thickness, the height and the modulus of the infill respectively, θis the angle between diagonal of the infill and the horizontal, Ec is the modulus of elasticity of the column, $I_c$is the moment of inertia of the columns, His the total frame height, and $\lambda_h$is a dimensionless parameter.

In 1971 Mainstone [3] gave equivalent diagonal strut concept by performing tests on model frames with brick in fill's

$$w = 0.175 d_z (\lambda_h H)^{-0.4} \quad (4)$$

In 1984 Liauw and Kwan [4] proposed another relationship

$$w = \frac{0.95\, H \cos \theta}{\sqrt{\lambda_h H}} \quad (5)$$

In 1992 Paulay and Preistley [5] proposed,

$$w = \frac{dz}{4} \quad (6)$$

3 RESEARCH OBJECTIVES

The main objective of this study is to investigate the contribution of hollow masonry infill panels to lateral strength and stiffness of RC frame buildings. The simulation has done by creating a 3-D analysis model by ETABS 2015 a product of Computer and Structure Inc. [7]

4 THE CASE STUDIED

4.1 General Description Of The Structure

The three story concrete structure shown in the Fig. 2 is designed according to the BNBC 1993 (Bangladesh National Building Code) [6]. From soil report it has found the structure is built on soft soil (SD Type, SPT < 15) in zone 2 (moderate seismic intensity zone) of Bangladesh Seismic map.

This building is 64.5mx45m in plan and 4m x 3 floors in elevation. The bays are 8m center to center in X direction and 5 m center to center in Y direction with 8 bays in X direction and 9 bays in Y direction. There is an expansion joint in the middle of X direction. It has exterior infill wall panel in the all four sides of structure. To assess the influences of infill wall two structural models has been developed, one with infill wall panel (IF) another one is bare frame (BF). Infill panels with openings are not considered here, for simplification purposes.

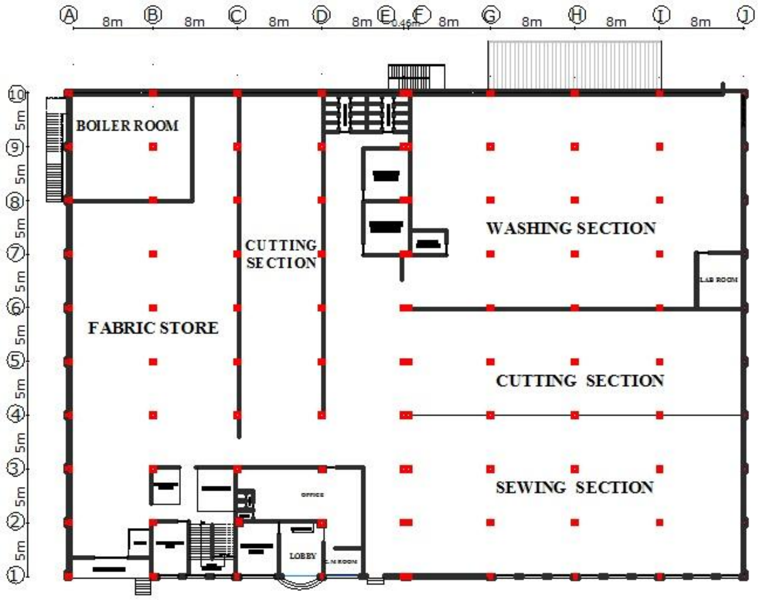


Figure 2: Typical layout plan of 3 storied industrial building

4.2 Mechanical Properties Of Materials

The compressive strength of concrete found from core test results is, f'c = 18 MPA for all the element, yield strength of the longitudinal and transverse reinforcement is $f_{y\,=}$ 415 MPA and the average compressive strength of masonry infill wall was 10 MPA. The modulus of elasticity of brick masonry is 8275MPA.

The geometrical parameters of the frame members are presented in the Table 1, and the properties of the materials are in the Table 2.

Table 1: Geometrical parameters of the frame members

Frame Element	Transverse Dimension (m)	Transverse Section Area (m^2)	Moment of Inertia (m^4)
Longitudinal Beams	0.38x0.76	0.29	0.0139
Transverse Beams	0.38x0.76	0.29	0.0139
Columns	0.38x0.38	0.14	0.00174

Table 2: Properties of material

Frame Element	Modulus of Elasticity (KN/m^2)	Poison Coefficient	Tension Steel , A_s (cm^2)	Compression Steel , A_s (cm^2)
Longitudinal Beams	$2.9x10^6$	0.3	17.03	8.51
Transverse Beams	$2.9x10^6$	0.3	14.19	8.51
Columns	$2.9x10^6$	0.3	34.064	34.064
Masonry	$1.2x10^6$	0.17	-	-

5 NUMERICAL METHODS

All computer models are generated and analyzed by ETABS 2015 finite element software developed by a product of Computer and Structure Inc.

Preliminary assessment, modal analysis and time history analysis has done to investigate changes in different parameter in infill wall frame with respect to bare frame.

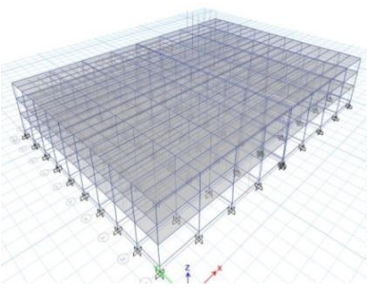


Figure 3: Bare frame 3D model

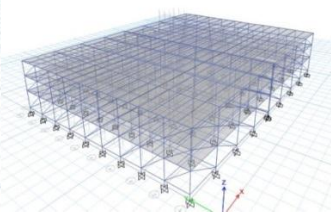


Figure 4: Infill Wall frame 3D model

6 FINDINGS AND DISCUSSION

6.1 Dynamic Responses

The response of a structure subjected to dynamic loading mostly dependent on such basic properties as the damping and fundamental period of structure. These properties are dependent on the mass, stiffness and strength of the structure affected by bay size, steel ratio, section dimension, number of storey, infill panel, concrete cracking and axial load level.

After performing a modal analysis it can be seen that the fundamental period for the bare frame is 0.476s and for infill wall frame 0.366s.

From the decreasing of fundamental period in infill wall frame it can be pointed out that infill wall contribute to increase the stiffness of the structure. In case of bare frame the time period calculated by Raleigh's method $T = 0.075H^{0.75}$= 0.484s is close the estimated value. With regard instead of infill structure, the formula reported by BNBC 1993, $T = 0.046H^{0.9}$ = 0.431s can be assumed as a reference point.

Finally a comparison has been carried out also with respect to displacements. It is possible to observe that the presence of infill is crucial. Moreover, it is observed a reduction of about 175% of the maximum displacement in the X direction between the bare and infilled frame and 110% in the Y direction.

6.2 Time History Analysis

In this study an earthquake record obtained at Natore (Ansary, 2009) is taken as a reference which has been used to develop earthquake time history for Dhaka after appropriate scaling. The acceleration data for recent earthquake at Station ID:ALTUS S/N 2928, 06th Jan 2009 16:04:03 (GMT), Magnitude 4.0, location: Natore, Bangladesh is shown in Fig. 5.

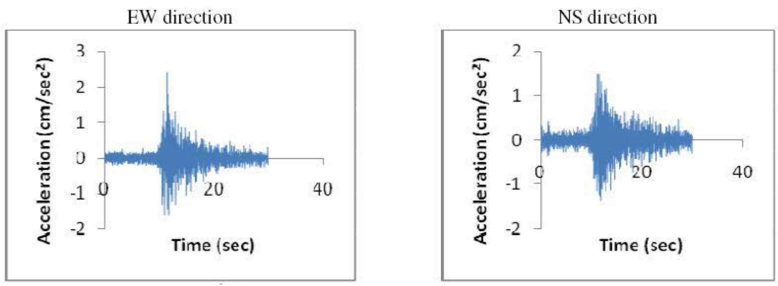


Figure 5: Earthquake Time History of Natore

Here in the Natore earthquake record the peak ground acceleration is 2.43 cm/sec^2 at 11.425 sec. but the maximum ground acceleration as per BNBC (1993) for Dhaka is 0.15g = 147.15 cm/sec^2 resulted 61.58 times greater. So, the values have been multiplied by 61.58 and the modified Time history curves for Dhaka is shown in Fig. 6

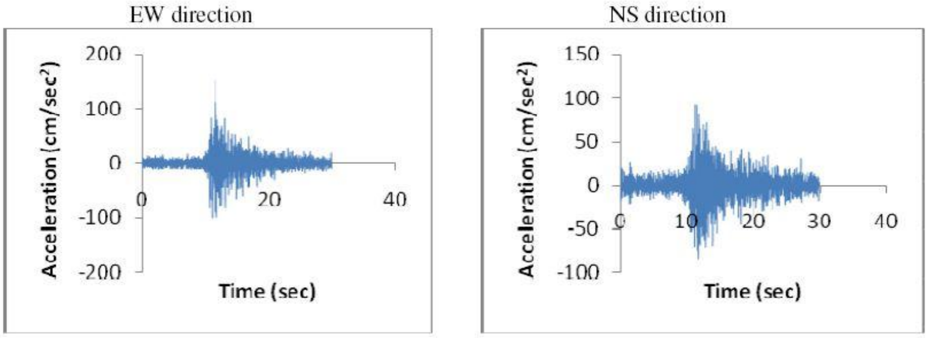


Figure 6: Modified Earthquake Time History of Dhaka

The story drift value for time history analysis is shown in Table 3.

Table 3: Storey Drift value for bare frame and infill frame

Story Level	Direction	Story Drift in mm	
		Bare Frame	Infill Frame
0	X	0	0
3		1.13	0.09
0	Y	0	0
3		1.75	0.15

7 CONCLUSIONS

Under the light of the results of the present numerical study, the following conclusions may be stated:

- The distribution of masonry infill panel throughout the story has insignificant effect on seismic response of reinforced concrete buildings.
- As compared to the bare frame the maximum roof displacement is reduced in a large extent in infill wall frame.
- The storey drift values decreases in infill frame and therefore infills increase the stiffness of RC frame
- It can be concluded that brick infill wall is to be included and carrying out seismic analysis of multistoried frame.
- This three storied RC frame arranged with symmetric pattern of infill wall panel further study can be worked out for unsymmetrical arrangement of infill wall.

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