SEISMIC PERFORMANCE OF REINFORCED CONCRETE FRAME BUILDING WITH AND WITHOUT URM INFILL WALLS

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ABSTRACT

In the conventional practice masonry walls are considered as non-structural element and its load is considered on the corresponding elements. Effect of infill is mostly ignored during analysis of the structure. To obtain the perfect model of a building the behaviour of all the primary components is needed and their load carrying capacities are required. This study attempts to simulate the nonlinear behaviour of URM infill frames using SeismoStruct v7.0 where diagonal strut model is used to idealize the effect of infill wall. A six storied ordinary moment resisting frame is considered with and without infill walls and capacity of the structure is evaluated and compared using capacity spectrum method. Prior to that pushover analysis was carried out for both configuration of the structure. It is observed from pushover analysis that the bare frame comprises lesser stiffness when compared to the frame with infill within a range of displacement. Ductility of bare of frame also reduces with inclusion of infill masonry walls as is observed from capacity demand curve of the structure. However inclusion infill walls increases the capacity of the structure to withstand stronger ground motion compared to bare frame structure.

Keywords: Diagonal strut model; stiffness; ductility; un-reinforced masonry; capacity spectrum method

INTRODUCTION

The Reinforced Concrete frame building with URM infill walls are very common in Bangladesh and many other countries. Easy and low-cost constructing is known as a main reason for uses of the brick masonry in the developing countries. The purpose of masonry is mostly to protect inside of the structure from the environment and to separate internal spaces. In most of the cases of seismic resistant design, particularly in Bangladesh, the brick masonry infill walls in RC frame building is typically considered as non-structural elements. Therefore, this consideration may result inaccurate prediction of the lateral stiffness, strength, and ductility of the structure. Reluctance of numerous engineers to take into account the contribution of brick masonry infill is due to the inadequate knowledge in structural modelling and uncertainty involved in interaction between infill and RC frame.

In recent times several researchers (Decanni et al., 2004; Baran and Sevil, 2010 etc.) have compared experimental and analytical results of interaction between RC frame and URM infill walls. Such experimental results revealed that performance of URM infill walls inside RC frame varied with lateral loads applied on the structure (Decanni et al., 2004; Baran and Sevil, 2010). URM infill remains in contact with RC frame under very low lateral loads and hence there is composite action between RC frame and URM infill walls. Initial lateral stiffness increased for the URM infill model in compare to bare frame model. A number of research works have been done in past decades to generate acceptable model for structural analysis in order to account interaction between URM infill and RC frames. Among several models, equivalent diagonal strut model for infill panels is preferred due to its simplification in URM behaviours. In this study, the structural model was developed in a software package Seismostruct v7.0 to perform structural analyses for the index building. The objective of this work is to compare the seismic performance of RC frame building with and without inclusion of unreinforced masonry walls.

METHODOLOGY

Modelling of Infill Wall

The most critical part of modelling of a RC frame with URM infill wall is to model the URM infill properly. There have been several research conducted in past studies to develop micro model for the numerical simulation of infill panels using two dimensional finite element (Ellul and D'Ayala, 2012), however, the diagonal strut model (see Fig.1) is still the most widely used and accepted by the researchers as its simplified approach for bulk analysis, and has been advocated in many documents and guidelines (CSA, 2004 and NZSEE, 2006).

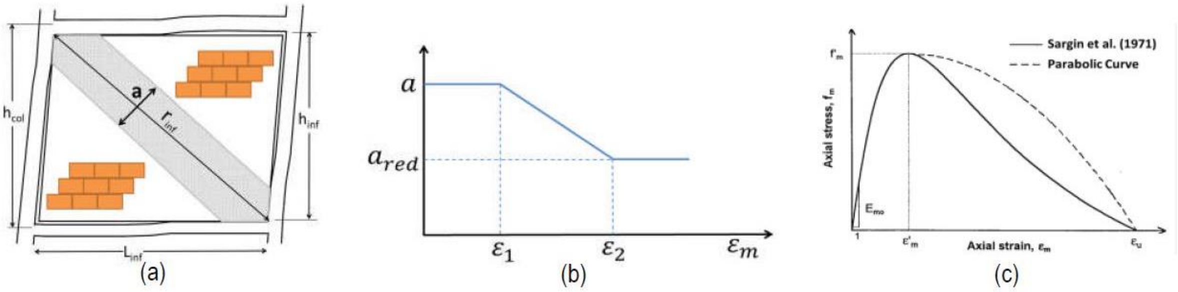


Fig.1: Diagonal strut for masonry infill panel modelling; (a) Equivalent diagonal strut representation of an infill panel, (b) Variation of the equivalent strut width as function of the axial strain, (c) Envelope curve in compression

Diagonal strut model utilizes a four-node masonry panel element for the modeling of infill panel. Six strut members are used to illustrate each panel. Every diagonal direction characterizes two parallel struts to carry axial loads across two opposite diagonal corners and a third one to carry the shear from the top to the bottom of the panel. The operation of fifth and sixth strut members activate on deformation of the panel as they only act across the diagonal that is on compression. Stiffness and strength of an infill panel is calculated from width of equivalent strut using formula proposed by Mainstone and Weeks (1970) and Mainstone (1971).

$$a = 0.175(\lambda_I h_{col})^{-0.4} r_{inf} \quad (1)$$

Where,

$$\lambda_I = \left[\frac{E_m t_{inf} \sin 2\theta}{4E_c I_{col} h_{inf}}\right]^{\frac{1}{4}} \quad (2)$$

Where λ is the coefficient used to determine equivalent width of infill strut; h_{col} is column height between centerlines of beam; h_{inf} is height of infill panel; E_c is expected modulus of elasticity of frame material; E_m is expected modulus of elasticity of frame material; I_{col} is moment of inertia of column; r_{inf} is diagonal length of infill panel; t_{inf} is thickness of infill panel and equivalent strut; and θ is angle whose tangent is the infill height-to-length aspect ratio.

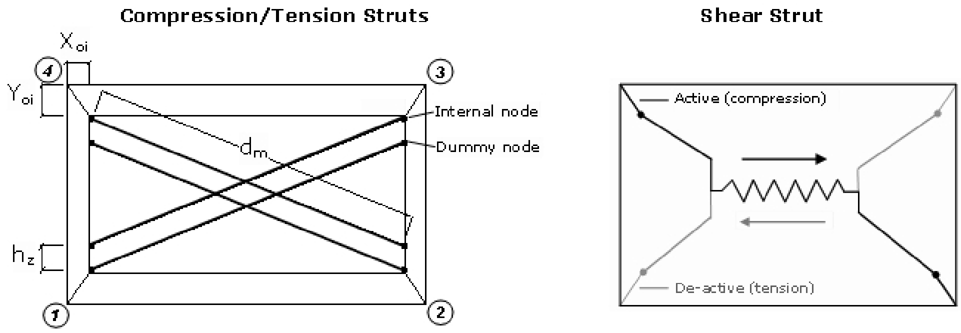
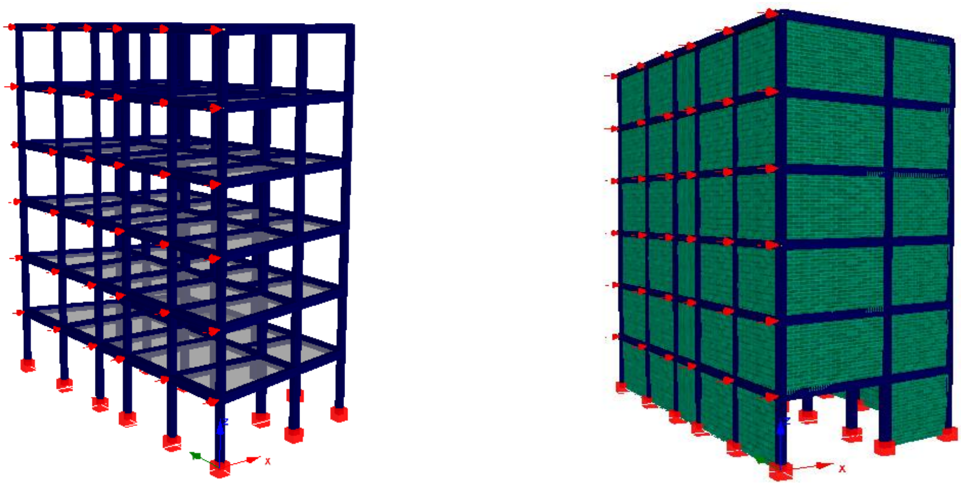


Fig.2: Equivalent strut model for infill panel (Crisafulli, 1997)

The selected building is modelled using finite element package software named SeismoStruct. SeismoStruct is able to predict large displacement behavior of space frames under static or dynamic loading, taking in to account both geometric nonlinearities and material inelasticity. Bare frame and infill frame model of the building is shown in Fig.3(a) and Fig.3(b) respectively.



(a) (b)

Fig.3: (a) Bare frame model; (b) URM Infill frame model

Design Spectrum and Seismic Design

The design spectra in proposed BNBC is developed based on following relationship,

$$C_s(T) = \left[1 + (\eta.2.5 - 1)\frac{T}{T_B}\right], 0 \leq T \leq T_B \tag{3}$$

$$C_S(T) = S.\eta.2.5, T_B \leq T \leq T_C \tag{4}$$

$$C_S(S) = S.\eta.2.5\left(\frac{T_C}{T}\right), T_C \leq T \leq T_D \tag{5}$$

$$C_S(T) = S.\eta.2.5\left(\frac{T_C T_D}{T}\right), T_D \leq T \leq 4S \tag{6}$$

Cs depends on S and values of T_B, T_C and, T_D which are all functions of the site class (in Fig.4) is the damping correction factors. Z represents seismic zoning coefficient, I is the structural importance factor and R is the response reduction factor.

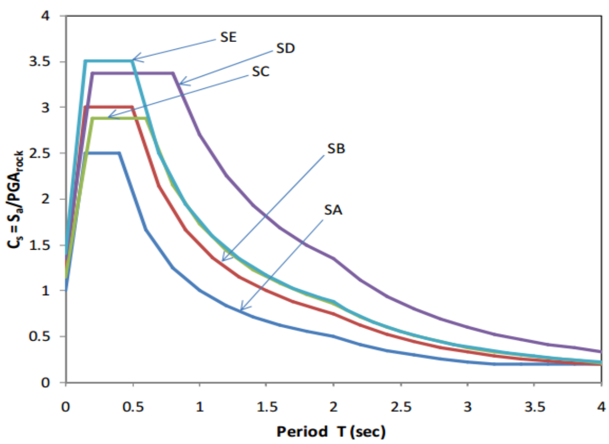


Fig.4: Normalized acceleration response spectrum for different site classes for proposed BNBC 2010.

RESULTS AND DISCUSSION

Pushover analysis is performed by applying a controlled displacement (Response control) at the top of a particular frame. Capacity curve is determined for both configuration of the building. Pushover analysis provides non-linear force-displacement relationship of the Multi Degree of Freedom (MDOF) system. Relation between Normalized lateral forces and normalized displacements are assumed as Eq. (7) where, m_i is the mass of the i-th story. Displacements are normalized in such a way that n = 1, where n is the control node whereas n denotes roof level. Fig.5 to Fig.11 describes the step by step procedure for the determination of performance point for bare frame and URM masonry infill frame structure.

$$F_i = m_i \Phi_i \qquad (7)$$

Step-1: Pushover Curve for Bare and URM Frame Model

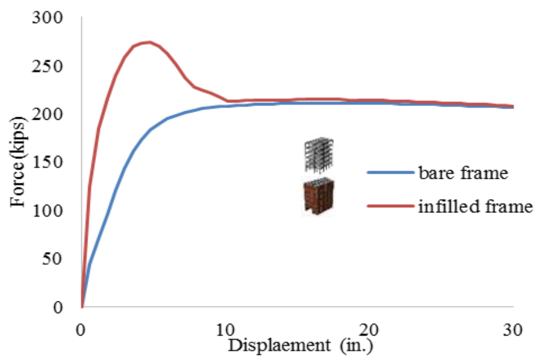


Fig.5: Pushover curve for bare frame and infill frame model

Step-2: Demand Spectra in AD Format

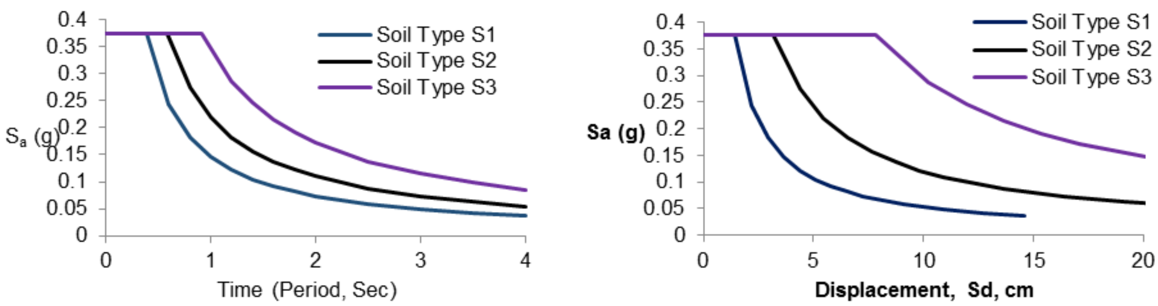


Fig.6: conversion of elastic acceleration spectra to demand spectra

Step-3: Equivalent SDOF Model

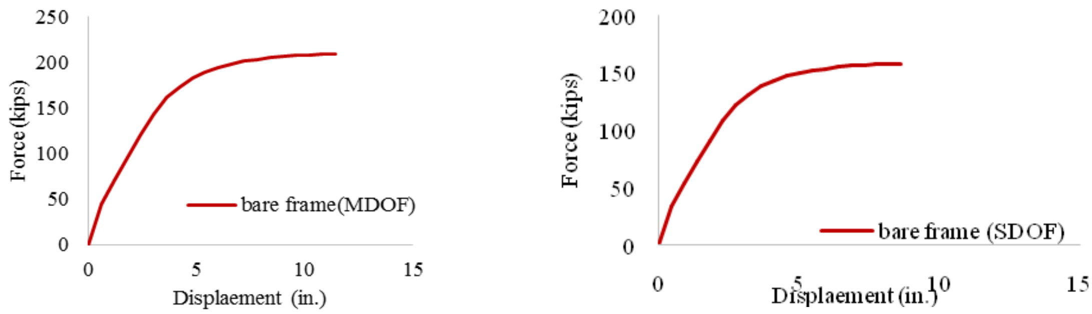


Fig.7: Pushover curve for MDOF bare frame model (left) and for equivalent SDOF model (right)

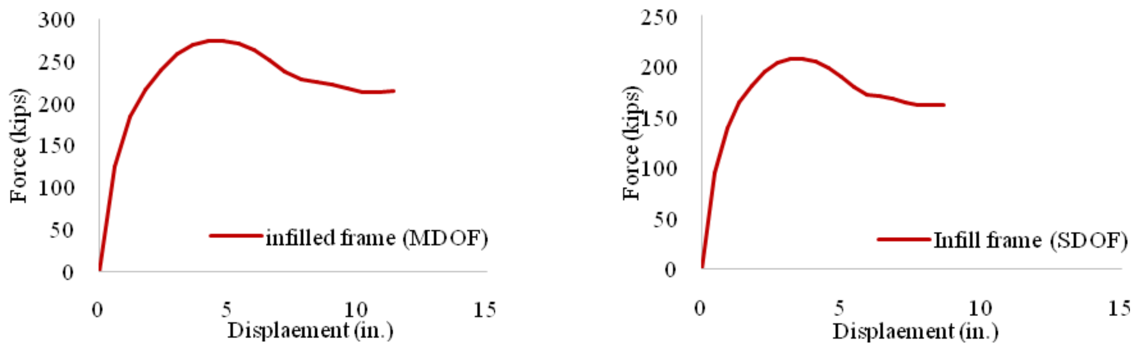


Fig.8: Pushover curve for MDOF infill frame model (left) and for equivalent SDOF model (right)

Step-4: Equivalent Conversion of Pushover Curve to Capacity Curve

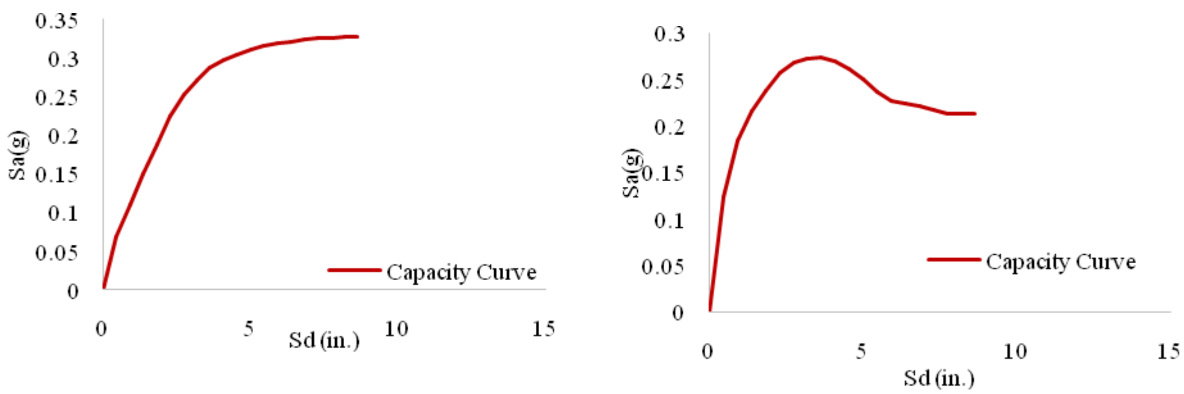


Fig.9: Capacity curve for bare frame model (left) and for infill frame model (right)

Step-5: Superposition of Capacity Curve and Demand Curve

Intersection point of the capacity curve and the demand curve gives the displacement demand. Performance point of the selected building is obtained for both infill and bare frame model by superposition of capacity curve and demand spectra for soil type 1.

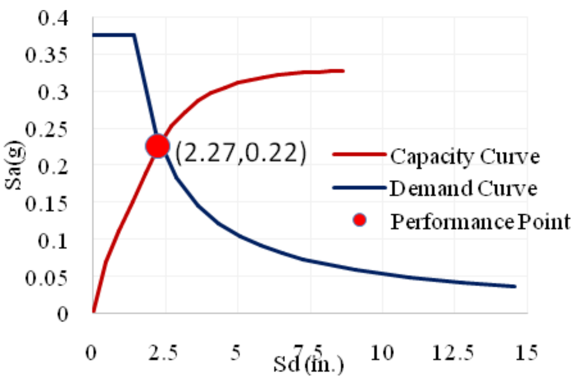


Fig.10: Capacity curve versus demand curve for bare frame model

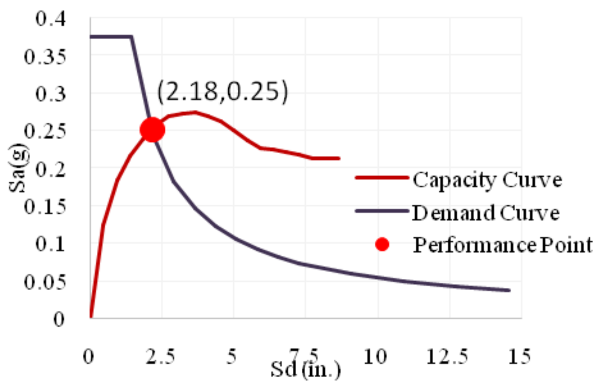


Fig.11: Capacity curve versus demand curve for infill frame model

CONCLUSIONS

By closely observing, Fig.5 reveals that the pushover curve for infill frame structure has larger gradient than of structure without infill walls up to a certain displacement which indicates higher stiffness of the structure. However, this stiffness drops sharply at a particular value of displacement and the same trend is observed for further displacement value. Such behaviour figures out the fact that Inclusion of masonry wall in bare frame structures increases the lateral stiffness and resistance of RC frame building significantly. Although, Seismic performance of bare frame is found to be inferior to infill frame, ductility of the structure decreases with the inclusion of URM infill. Comparative response of bare frame and infill frame is summarized in Table 1.

Table 1: Comparative response of bare frame and infill frame model

Analysis types	Parameters	Bare Frame Structure	Infill Frame Structure
Nonlinear Static (Pushover)	Approximate Peak Loading Capacity (Kips)	200	280
	Yield Displacement (inch)	4.8	4.2
	Ultimate Displacement (inch)	11.4	11.4
Capacity Spectrum	S_a (g)	0.22	0.25
	S_d (inch)	2.27	2.18

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