Scientific Journal of Impact Factor (SJIF): 5.71

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 7, Issue 06, June -2020

NUMERICAL MODELING OF PERFORATED INFILL WALLS IN RC FRAME STRUCTURES

Imad Said[1], Muhammad Rashid[1] & Fasih Ahmad Khan[2]

[1]*Undergraduate Student, University of Engineering & Technology, Peshawar Pakistan.*

[2]*Lecturer, University of Engineering & Technology, Peshawar Pakistan.*

Abstract: *Usually the masonry Infill walls are not considered in the design of the structures, but during lateral loads it affect the structural performance significantly. Experiences from the past earthquakes studies have shown the undesired damage in structures, like soft story mechanism, torsional failure and short column phenomena. Due to these complexities, and seismic evaluation performance, numerical modeling becomes necessary. However for numerical simulation of these infill walls, different modeling techniques can be used. The infill walls are modeled as a diagonal strut element and as a link element. Both of the models were analyzed in SAP2000, and obtained the Pushover/ backbone curve. The strut element results are compared with the compression link element modeling approach, and this was observed that these results were very closely coinciding in terms of base shear- roof displacement curve at each story level.*

Keywords: *Numerical modeling, Brick masonry, Link, Diagonal strut, Pushover*

1. Introduction

In Pakistan, frame construction is the trending practice both in residential and commercial types of structure [3]. Most of the time, the partition walls are provided at the locations depending upon the structure usage, which is economical as well as easy to fabricate for thermal insulation and sound barrier purposes [3].

Usually at the design stage, the effect of the infill wall is ignored and the frame elements are considered responsible for resisting the loads [1]. The infill are considered as non-structural elements, this consideration may lead to severe stress concentration in some elements or the infill panel during lateral loading, which increase the life safety risks [3].

The most dominant effects of the partition walls are, increase in stiffness, in-plane or vertical irregularity in stiffness distribution and an increase stress in masonry panel. In case of openings in the wall, there is severe stress concentration at the corners of opening [1].

The frequency of the structure closely depend upon the stiffness, so by introducing the infill the frequency of the structure will get increased [10].

In case of irregularities in stiffness the center of rigidity doesn’t coincide with the center of mass actions, which causes the twisting of the structure [10].

The 2005 earthquake and onward investigation shows that the interaction between the infill and frame should be taken into consideration during the design stage [2].

During lateral loading the infill detached from the frame at the opposite diagonal corners, and the columns are severely stressed in shear at the ends where the infill is in contact [1].

Due to the negative consequences of the infill- frame interaction, the design code recommend to take into account the effect of the infill panels in structure design. Several modeling techniques are available ranging from equivalent pinned macro-model to the finite element based micro-modeling [8].

This paper present the modeling of the brick masonry panel with perforated infills in RC frame and the performance of the RC frame subjected to lateral loading, using the pushover analysis.

2. Description of the Tested Model

This study aims to investigate the seismic response of RC Frame structure with openings in the infill walls. The structure examined was half scale two bay and two story structure. The story height was 5.5 feet and was constant. The bay width was 5 feet c/c (Figure 1).

The infill panel were 4 inch thick, following the conventional double leaf wall with English bond, with masonry infill strength equal to 438 psi, and Young Modulus equal to 78 ksi, which is good clay masonry [2].

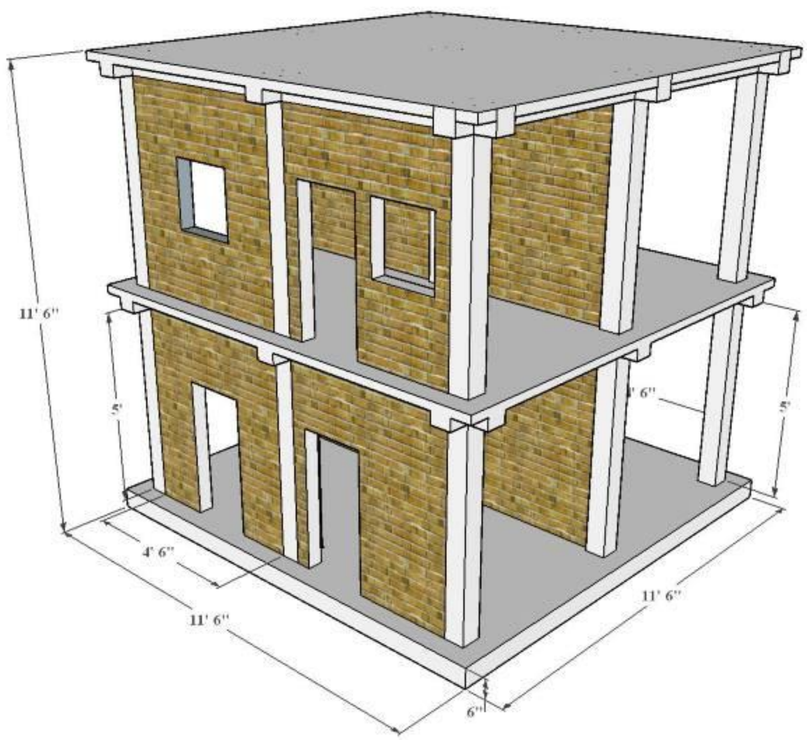

Figure 1: Schematic view of the Tested Half Scale Model

2.1 Frame Structural Design

The frame was designed according to BCP-SP 2007 for seismic zone 4 with importance factor equal to 1. The specified concrete strength (28 days) was 3 ksi for all RC members, and Grade 40 steel were used throughout the members. Beams were 6 x 6 (in), with six #3 bar as main reinforcing bars. The columns also have same dimensions with eight #3 bars as main reinforcing steel. The slab was 2.5 inch thick for both cases.

Figure 2: Half Scale Tested Model

2.2 Infill Wall Modeling

For analysis purpose the infill wall behavior and their interaction with the frame can be modeled using the equivalent diagonal compression strut method. The geometrical and mechanical characteristic of the strut are calculated based on the infill material properties and interacting frame dimensions. The diagonal strut can adequately model the infill inelastic behavior, that’s why it is most commonly adopted [1].

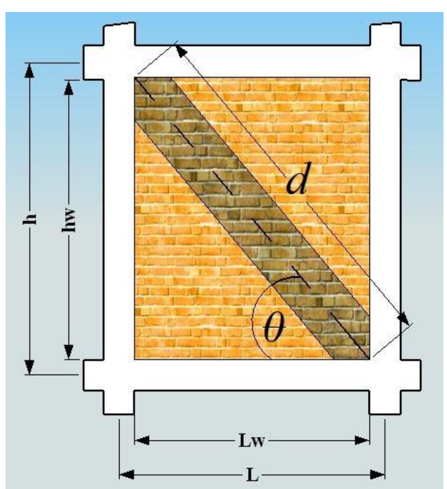

Figure 3: Infill Wall Modeling Parameters

Several researchers worked out the strut geometrical formulations. Based on experimental and analytical data, Mainstone [6] proposed the simplest empirical equations (Eq-1-3) for the calculation of equivalent diagonal strut width *w* [1]. Later on these equations were published in FEMA-274, for retrofitting and rehabilitation purposes [7].

For completely infilled frame structure:

$$w' = d * 0.175\, \lambda'^{-0.4} \tag{1}$$

Where

d = Diagonal length of the infill panel

And $$\lambda' = h \sqrt[4]{\frac{Ew * tw * \sin 2\theta}{4EIc * hw}} \tag{2}$$

And $$\tan\theta = \frac{h}{L} \tag{3}$$

Where

Ew = Modulus of elasticity of the brick panel

EI = Columns Flexural rigidity

t_w = Thickness of the brick infill wall = Equivalent strut thickness

h = Column height c/c of beams

hw = Height of infill wall

Θ = Slope of the infill diagonal to the horizontal

Asteris proposed stiffness reduction factor, in case of perforation in the infill walls. The stiffness reduction is proportional to the effective resisting panel dimensions [9]. The perforated infill wall effective stiffness is calculated using the reduction factor λr, given by (Eq-4);

$$\lambda r = 1 - 2\alpha^{0.54} + \alpha^{1.14} \tag{4}$$

Where

$$\alpha = Opening\ Area/Infill\ wall\ Area$$

Table 1: Equivalent Strut Calculations

Wall Opening Case	Completely Filled	One Window 20" x 20"	One Door 20" x 40"	Window + Door
$w(in)=w'*\lambda r$	4.24	1.89	1.12	0.65
$w' = d * 0.175\ \lambda'^{-0.4}$	4.24	4.236	4.236	4.24
$\lambda' = h \sqrt[4]{\frac{Ew * tw * \sin 2\theta}{4EIc * hw}}$	20.31	20.308	20.308	20.31
$\lambda r = 1 - 2\alpha^{0.54} + \alpha^{1.14}$	0.00	0.446	0.263	0.15
α	1.00	0.123	0.247	0.37

2.3 Modeling RC Structure in SAP2000

The structure was modelled as 3D frame using SAP2000. The Auto plastic hinges were assigned to the beams and columns at the ends. The auto hinge type and properties were based on FEMA 356, Table 6-7 for beams and Table 6-8 for columns.

In the first case, the masonry infill was modelled as strut element with brick properties, whose dimensions were calculated on the basis of the above formulations. Considering the simplest case, each panel was represented by two equivalent braced diagonal compression strut elements, having properties based on the effective stiffness of the corresponding panels, as shown in Fig (3).

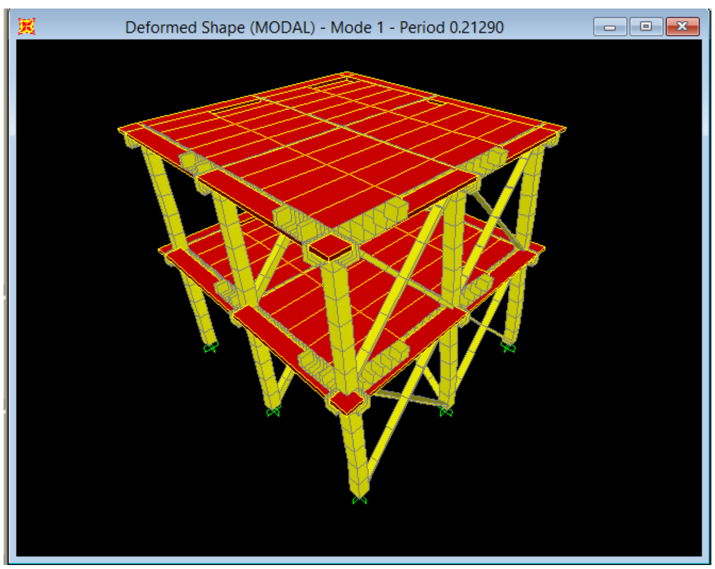

Figure 4: RC Frame with Strut Elements in SAP2000

3. Infill Wall as Link Element

In order to define and analyze the special behavior of a particular structural or non- structural element, Link elements are used. The structural behavior can be analyzed at single or multiple joints, for each case different link properties are calculated and assigned [4].

The infill wall behavior was modelled and analyzed as a two joint link element, because the dominant behavior was axial stressing of the infill panel provided in-between the two consecutive columns.

For defining the link element, different properties were assigned, on the basis of which the true behavior of the infill was modelled and analyzed. To replace the strut elements by the link elements, the axial stiffness were calculated for each panel,

$$K = EA / L \quad (5)$$

Where,

K = Stiffness of the element

E = Elastic Modulus of the material

L = length of the element

Eq-5 shows that the stiffness is directly proportional to the effective resisting infill panel area. For different infill wall cases, the stiffness were calculated as shown;

Table 2: Stiffness of the Infill Walls with different Opening Case

Infill wall Case	K (kip/in)
Window +Door	4.697
Window	13.75
Door	8.109
Solid Wall	30.83

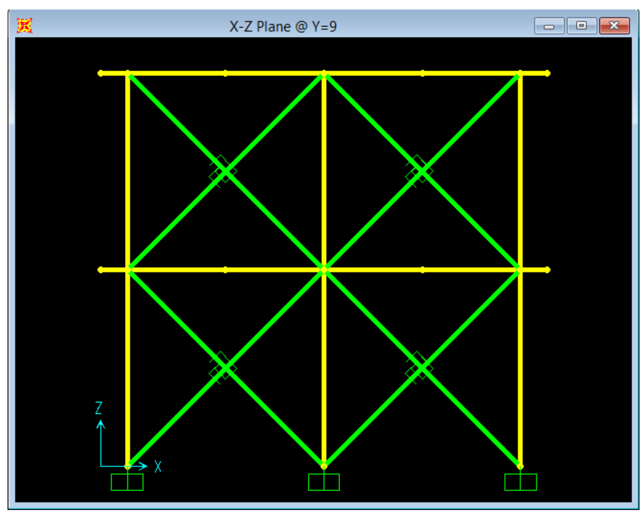

Figure 5: RC Frame with Link Elements in SAP2000

4. Pushover Analysis

The actual applied lateral cyclic loads (Sine-sweep Loading) were applied and the corresponding Base Shear- roof displacement curves were obtained at the point of interest. For each frame two curves are obtained, one at each story mid-point.

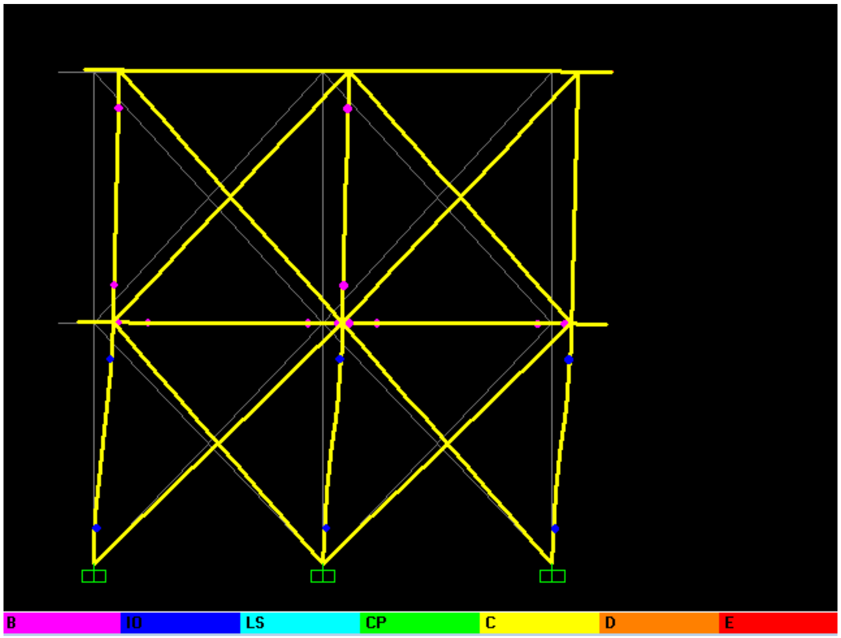

Figure 6: Deformed Shape of the Structure

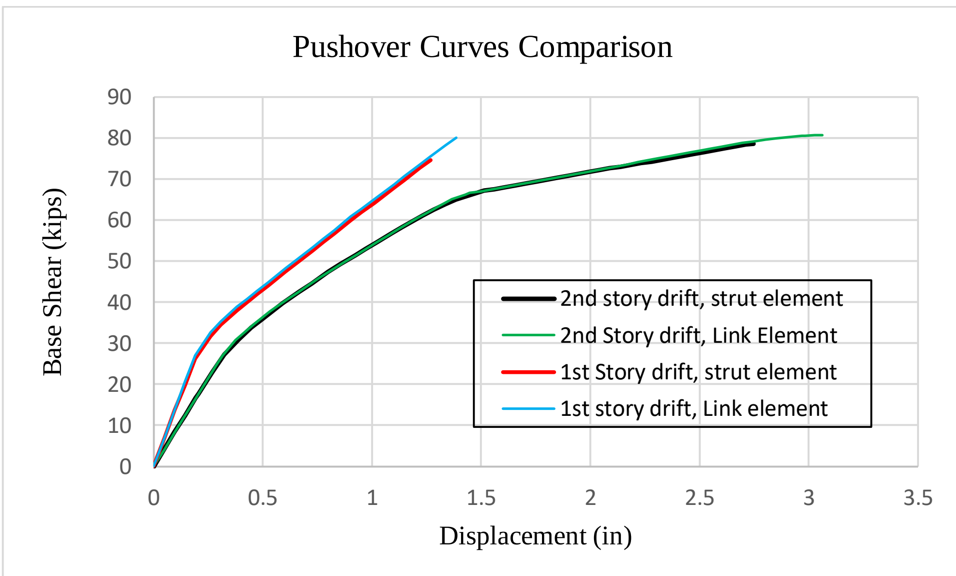

Figure 7: Pushover Curve Comparison of Frame with Link & Strut Elements

5. Findings

Based on the above study, the result from the Numerical Modelling in SAP 2000 and the actual shake-table test results were appreciably comparable. The small discrepancy in the results may be due to poor workman-ship during model construction.

- Actual Frequency of the Model Tested = 4.21 Hz
- Numerical (SAP2000) Model Frequency = 4.60 Hz

6. Conclusions

In the preceding discussion, the modelling techniques of the infill wall is discussed. Static pushover analysis are subsequently performed for both the frame, with infill wall as equivalent diagonal compression strut and infill wall as compression link elements. Based on these results the following main points are concluded:

- During the initial design stages, the infill wall effect should be taken into consideration
- The equivalent diagonal compression strut is the good representative of the infill panel
- The link elements gives accurate results, both linear and non-linear, provided that the actual stress- strain curve for the infill material is defined
- The non-uniform distribution of the infill create torsional mechanism, which significantly reduces the capacity of the frame structure and therefore should be included in model

References

[1] Alkis Fotos, F. F. (2017). INELASTIC RESPONSE OF MASONRY INFILLED REINFORCED CONCRETE STRUCTURES. *Computational Methods in Structural Dynamics and Earthquake Engineering.*

[2] Shahzada, K., Khan, A., Elnashai, A., Ashraf, M., Javed, M., Naseer, A., & Alam, B. (2012). Experimental Seismic Performance Evaluation of Unreinforced Brick Masonry Buildings. *Earthquake Spectra, 28*(3), 1269-1290. doi: 10.1193/1.4000073

[3] MIRCEA BARNAURE, D. N. (2015). ANALYSIS OF MASONRY INFILLED RC FRAME STRUCTURES UNDER LATERAL LOADING. *Mathematical Modelling in Civil Engineering*.

[4] (2016). *Multi Linear Elastic & Plastic Link in SAP 2000.* Cambridge: Newtecnic Building Engineering.

[5] P.G. Asteris, L. C. (2016). Numerical modelling of out-of-plane response of infilled frames: State of the art and future challenges for the equivalent strut macromodels. *Engineering Structures*, 111-122.

[6] R.J. Mainstone, Supplementary note on the stiffness and strengths of infilled frames. Current Paper CP 13/74, Building Research Station, Garston, Watford, U.K., 1974.

[7] FEMA-274. NEHRP Commentary on the Guidelines for the Seismic Rehabilitation of Buildings, Washington (DC), Federal Emergency Management Agency, 1997.

[8] H.A. Moghaddam, P.J. Dowling, *The State of the Art in Infilled Frames*. ESEE Re-search Report No. 87-2, Imperial College of Science and Technology, Civil Engineering Department, London, U.K, 1987.

[9] P.G. Asteris, Lateral stiffness of brick masonry infilled plane frames. *ASCE Journal of Structural Engineering*, **129** (8), 1071-1079, 2003.

[10] Chopra, A. K. (1981). *Dynamics of Structures.* Harlow, UK: Pearson Education Limited.

