EFFECTS OF INFILLED MASONRY WALLS ON NONLINEAR STRUCTURAL BEHAVIOR OF PRECAST CONCRETE STRUCTURES IN TURKEY

K.A. Korkmaz[1] F. Demir[1] H. Tekeli[2], A.E. Karahan[3]

[1] *Asst. Prof. Dr., Dept. of Civil Engineering , Suleyman Demirel University, Isparta. Turkey*
[2] *Dr., Dept. of Civil Engineering , Suleyman Demirel University, Isparta. Turkey*
[3] *Civil Engineer,Ms, Dept. of Civil Engineering , Suleyman Demirel University, Isparta. Turkey*
email:armagan@mmf.sdu.edu.tr

ABSTRACT :

Turkey is one of earthquake prone country. 90% of its buildings is under earthquake risk. 1998 Adana and 1999 Marmara earthquakes caused high damages not only in high rise buildings but also in important industrial buildings too. In the recent earthquakes, large numbers of people have died or heavily injured in the complete collapse of buildings constructed with reinforced and precast concrete structures. In Turkey, most of the industrial buildings are prefabricated structures. In industial zones precast concrete structures are prefered because of their economic and rapid production. It is a fact that a large part of the industrial regions are located on high risk earthquake zones. In the design of precast concrete structures, frames are generally analyzed in two dimensions. The infill masonry walls increase the stiffness and lateral capacity of the frame structures. Although, infill masonry walls increase these parameters, infill walls are generally not taken into consideration in the lateral load capacity of precast concrete structures. In the present study, in order to determine the effects of infill walls in earthquake behavior of single story hinged prefabricated industrial buildings in Turkey, the capacities of these buildings which were related with different parameters as concrete strength, column dimension, reinforcement ratio, soil class, story height and truss span, were determined. In the analyses, diagonal strut model is adopted for modeling masonry infill walls. Structural behaviors and load deformation relationship of precast concrete structures both with and without infilled walls are evaluated and compared.

KEYWORDS: Prefabricated Industrial Buildings in Turkey, Infilled Masonry Wall Effects, Seismic Assessment, Hinge Connections.

1. INTRODUCTION

Hinge connected precast concrete structures are ideal solutions to build factories, which need open spaces without columns and many buildings in these industrial regions are constructed using this type of construction. Precast concrete structures are also prefered because of their economy and rapid production. In Turkey,, industrialization is developing regularly. In this manner, the requirements for industrial structures are increased gradually. However a large part of the industrial regions are located on high risk earthquake zones. In a number of recent earthquakes, large numbers of people have died and many of injured in the complete collapse of buildings constructed with reinforced and precast concrete structures. Infill walls increase global stiffness and strength of the structure. But, infill walls are generally not taken into account in the evaluation of the lateral load capacity of precast concrete structures. In the current study, the effect of infill walls on the overall structural behavior and on the lateral load capacity of hinge connected precast concrete structure is researched (Karahan, 2007). The point is which structural approach is more effective; wheatear considering the infill walls is more realistic than not considering.

2. PRECAST STRUCTURES

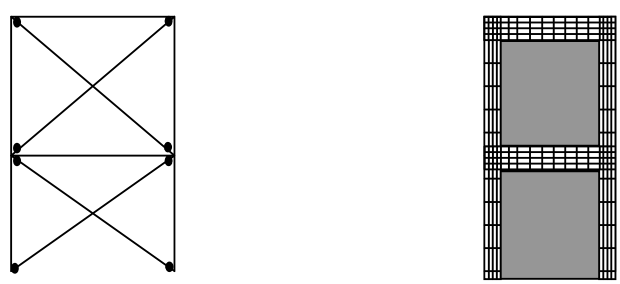
There is a great demand for industrial buildings in Turkey. In order to minimize the time span of the construction, prefabrication is generally preferred. Turkey is located at around one of the most active fault zones in the world and is exposed frequently to destructive earthquakes .In Turkey, 92 % of Turkish territory, 95

% of the overall population and 98 % of the entire industry rest on seismically active zones (Tankut, Korkmaz, 2005). Most of the factories, under seismic risk, are constructed with precast elements. In precast structures, lateral drifts are very large and the structure is not ductile. Many industrial facilities of precast concrete collapsed as a result of failures at the beam to column connections. Particularly in Marmara Earthquake, a considerable count of prefabricated structures was damaged as a consequence of poor nature of the connection details.

3. EFFECTS OF MASONRY INFILL WALLS

Masonry infill walls are found in concrete and precast frame building systems. These types of infills are common in Turkey where seismicity is main issue of the design. The masonry infill walls which constructed after completing of precast frames are included in numerical calculations of structural response. Since, masonry panels are normally considered as secondary structures. Although they are designed to perform architectural functions, masonry infill walls do resist lateral forces with substantial structural action. Infill walls have a considerable strength and stiffness and they have significant effect on the seismic response of the structural system. There is a general agreement among researchers that infilled frames have greater strength as compared to bare frames. On the other hand, the presence of the infill also increases the lateral stiffness considerably. Due to the change in stiffness and mass in the structural system, the dynamic characteristics change as well. Recent earthquakes Erzincan, Düzce and İzmit showed that infill walls have an important effect on the resistance and stiffness of buildings (Demir, Sivri, 2002).

Infill masonry effects not only the damage level, but also the damage pattern of frames (Hong, Guo, 2002). The precast buildings respond to seismic forces by swaying with them, rather than by attempting to resist them with rigid materials and connections. This is not an elastic response, but plastic. At the earthquakes, they do incremental low-level cracking which is distributed throughout the wall. Determination of effect of the infill walls on the building under seismic loading is very complex. Since the behavior of the structural systems is highly nonlinear it is very difficult to predict it by analytical methods unless the analytical models are supported using experimental data (Langenbach, 2004). These effects of the infills on the analysis must be considered together with high degree of uncertainty related to the behavior, namely (Penelis, Kappos, 2001).



(a) Diagonal strut model (b) continuum model
Figure 1 Models for masonry

In conventional analysis of infilled frame systems, the masonry infill is modelled using either equivalent strut model in Figure 1 (a) or a refined continuum model in Figure 1 (b) (Sivri, 2003). The former is simple and computationally attractive and generally preferred for simplicity but is theoretically weak. First, identifying the equivalent nonlinear stiffness of the infill masonry using diagonal struts is not straightforward, especially when there exist some openings, such as doors or windows, in the wall. Furthermore, it is also not possible to predicted the damaged area of masonry either. The latter method based on continuum model can provide an accurate computational representation of both material and geometry aspects, if the properties and the nonlinearity of the masonry carefully defined (Demir, Sivri, 2002).

The width is given by

$$W_{ef} = 0.175\left(\lambda_h H\right)^{-0.4} \sqrt{H^2 + L^2} \qquad (3.1)$$

where $$\lambda_h = \sqrt[4]{\frac{E_i\, t \sin 2\theta}{4 E_c I_c H_i}} \qquad (3.2)$$

H and L are the height and length of the frame, E_c, and E_i are the elastic modulus of the column and of the infill panel, respectively; t is the thickness of the infill panel, θ is the angle defining diagonal strut, I_c is the modulus of inertia of the column and H_i is the height of the infill panel.

4. APPLICATION

A precast sample real structure has been selected to investigate the effect of infill walls on the overall structural behavior and on the lateral load capacity of hinge connected precast concrete structure as the plan of its given in figure 3 (Karahan, 2007). In Figure 2 pictures of the sample model structure is given. In Table 1, structural properties of the structure is given.

Figure 2 Pictures of Model Prefabricated Building

Table 1 Structural Properties of the Model Building

C	(MPa)	Concrete	30
H	(m)	Story Height	7.5
L	(m)	Span	20
$\mathbf{B_k}$	number	Corner column	16
$\mathbf{B_o}$	number	Mid column	-
$\mathbf{n_a}$	number	Girder	98
$\mathbf{n_o}$	number	Gutter	14
$\boldsymbol{\phi_\ell}$	(mm)	Longitudinal Reinforcement	4Φ22
$\mathbf{ø_e}$	(mm)	Stirrup	ø8/10-20
Z	-	Soil Class	Z3-C
$\mathbf{n_x}$	number	X Span	1
$\mathbf{n_y}$	number	Y Span	7

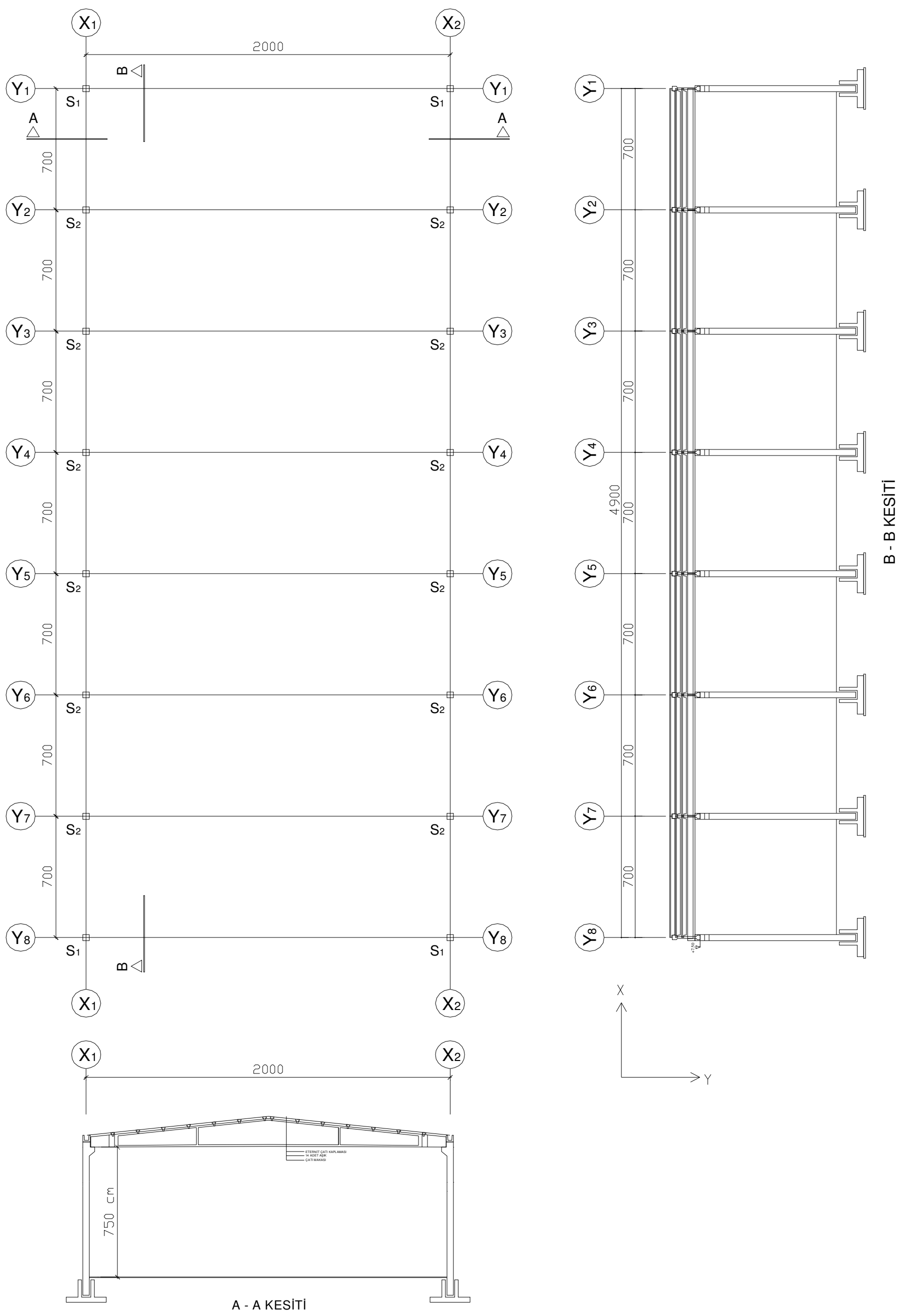


Figure 3 Plan and Sections of the Model Building

Nonlinear structural analyses are applied on the structure given in figure 3. First, structure is analyzed without infill walls as bare frame, then structure is analyzed with infill walls. After conducting pushover analyses, pushover curves are sketched and plastic hinges on the structure is determined. The computer model of the building is given in figure 4. The results of the pushover analyses are given as pushover curves and plastic hinge map in the study. The pushover curves are given in figure 5. Then, plastic hinges occurred on the structure are given in figure 6 for bare frame, and for structure with infill walls. As it is seen in figure 5, when V (Shear force) reached for 250 kN, for bare frame, V (Shear force) reached for 3000 kN for structure infill walls.

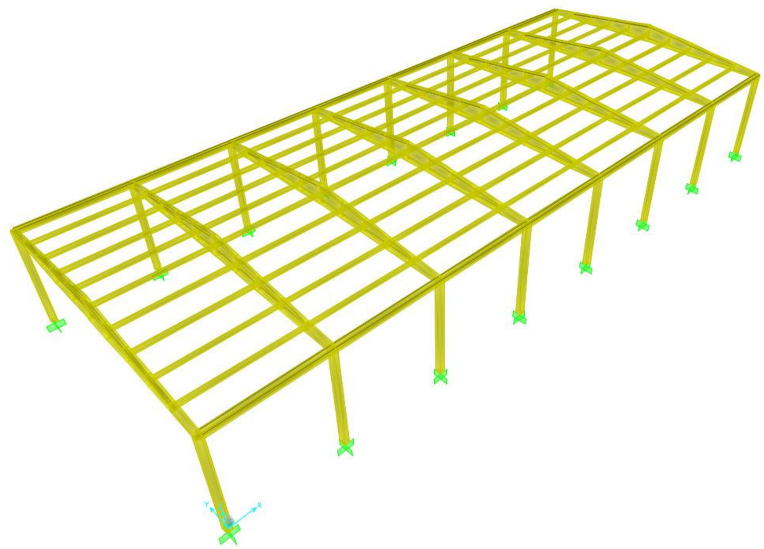
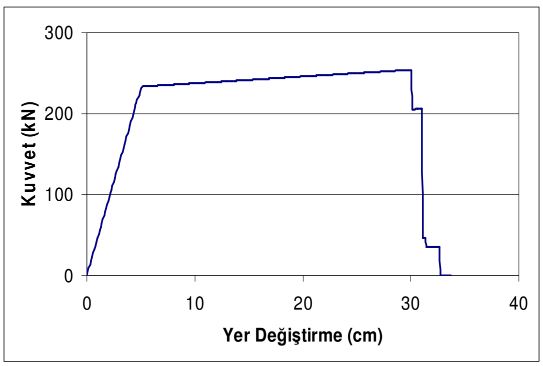
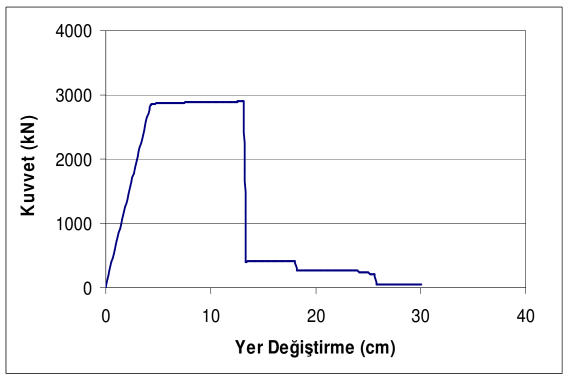


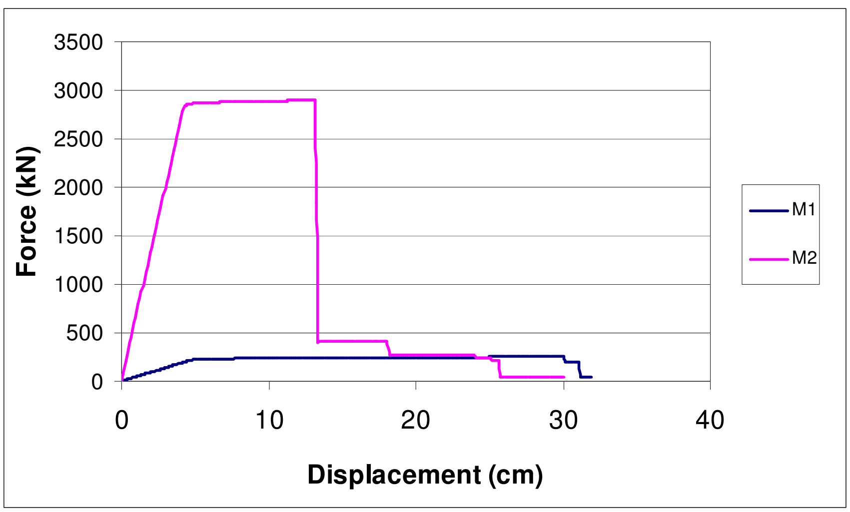
Figure 4 3-D Computer Model



a) Model 1. Bare Frame

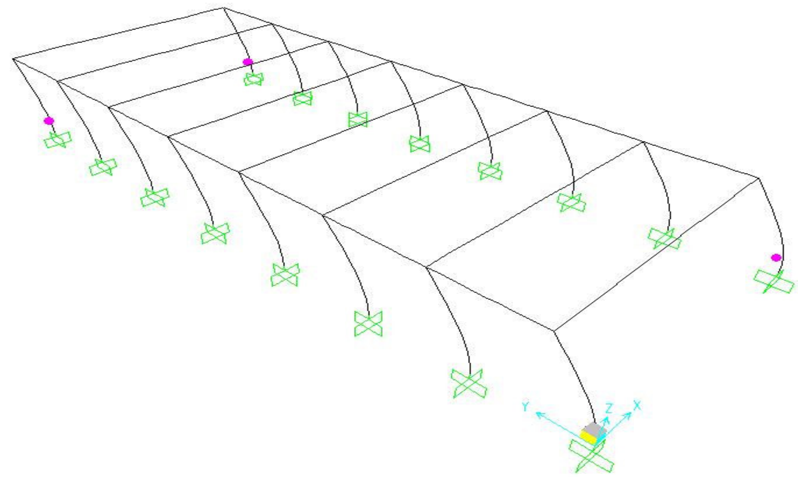


a) Model 2. Frame with Infill Wall

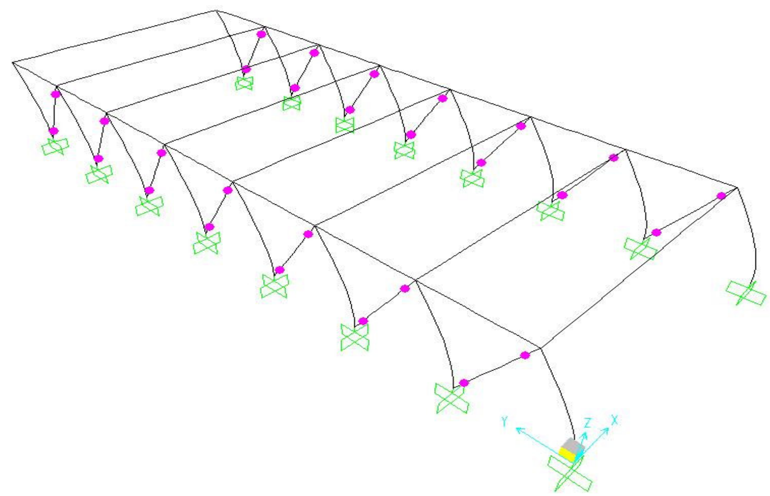


c) Comparison of the Models

Figure 5 Push Over Curves



a) Model 1. Bare Frame



b) Model 2. Frame with Infill Wall

Figure 6 Plastic Hinge Map

5. RESULTS

The results of nonlinear pushover analysis show that the presence of nonstructural masonry infills can modify the earthquake response of precast concrete frames to a large extend. The stability and integrity of precast concrete frames are enhanced with masonry infills. Presence of masonry infill also alters displacements and base shear of the precast concrete frame. As a result of this, nonlinear pushover analysis shows that masonry infills walls have important weight in the analyses.

Considering the infill walls as a structural member, increase the lateral load carrying capacity. Hence it is possible that infill walls increase the rigidity of the structure however this could cause increase the earthquake loads in some particular situations. In trade off, it would be counted as positive effect that considering the infill walls as a structural member.

REFERENCES

Demir, F., Sivri, M., Earthquake Response of Masonry Infilled Frames ECAS2002 International Symposium on Structural and Earthquake Engineering, METU, Ankara, 2002.

Dowrick, D.J., Earthquake Resistant Design for Engineers and Architects, John Wiley & Sons, New York, 1987.

Hong Hao, Guo-Wei M., Yong L., Damage Assessment of Masonry Infilled RC Frames Subjected to Blasting Induced Ground Excitations, Engineering Structure, Vol.24, No.6, pp.671-838., 2002.

Karahan, E., 2007, Investigation of Infill Wall Effects on Performance Based Evaluation of Prefabricated Industrial Structures in Turkey, Ms Thesis, SDU, Natural and Applied Sciences, Isparta, Turkey

Langenbach, R., Traditional Timber-laced Masonry Buildings that Survived the Great 1999 Earthquakes in Turkey and the 2001 Earthquake in India, While Modern Buildings Fell, senior Disaster Recovery analyst, federal Emergency Management Agency, USA, 2002.

NEHRP Guildelines for the Seismic Rehabilitation of Buildings, Developed by the Building Seismic Safety Council for the Federal Emergency Management Agency (Report No. FEMA 273), Washington, D.C, 1997.

Tankut, T., Korkmaz, H.H., Performance of a precast concrete beam-to-beam connection subject to reversed cyclic loading, Engineering Structures, Vol.27, pp.1392-1407, 2005.

Penelis, G.G., Kappos, A.J., Earthquake-Resistant Concrete Structure, & E FN Spon, An imprint of Chapman & Hall, London, 2001.

Seismic Evaluation and Retrofit of Concrete Buildings, Volume 1, ATC-40 Report, Applied Technology Council, Redwood City, California, 1996.

Sivri, M., 2003. Earthquake Behavior of Infill Walls. Ms Thesis, SDU, Natural and Applied Sciences, Isparta, Turkey

Tassios, T.P., Masonry Infill and R/C Walls Under Cyclic Actions, CIB Symposium on Wall Structure, Invited State–of-the Art Report, Warsaw, 1984.