BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iași
Volumul 66 (70), Numărul 4, 2020
Secţia
CONSTRUCŢII. ARHITECTURĂ

CASE STUDY ON THE INTERACTION BETWEEN THE MASONRY PANEL AND THE REINFORCED CONCRETE FRAME STRUCTURE

BY

VLĂDUȚ-IONEL IFTODE*, IOANA OLTEANU-DONȚOV, PETRU MIHAI and ION SOCOCOL

“Gheorghe Asachi” Technical University of Iași,
Faculty of Civil Engineering and Building Services, Iași, Romania

Received: October 22, 2020
Accepted for publication: November 5, 2020

Abstract. A frame structure is relatively flexible and has high ductility, while unreinforced masonry is stiff and brittle and can "explode" even under the effect of low deformation. The article studies the influence of the infill masonry on the overall behavior of a frame structure. 4 cases are considered in a finite element software and compared in terms of internal efforts, deformations and failure mechanism. It was concluded that the masonry panels stiffens the reinforced concrete frame structures, but by using flexible joints on the perimeter and in the assizes, it diminishing the surface of the masonry panel and its stiffness decreases.

Keywords: RC frames; masonry panel; joint; stiffness.

1. Introduction

Structural vulnerability represents the building predisposition to suffer damage in case of natural hazard. The seismic hazard was always on interest for Romania, but after the 1977 earthquake which produced the most damage along

---

*Corresponding author; *e-mail*: vladut-ionel.iftode@student.tuiasi.ro

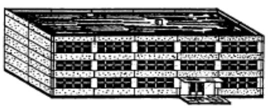
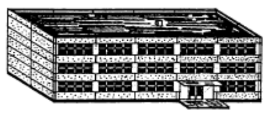
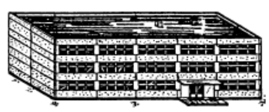
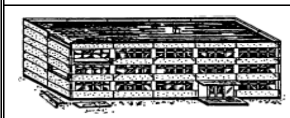
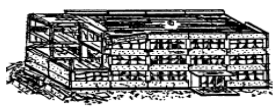
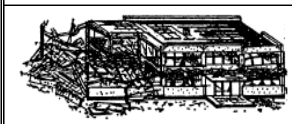
the years, it became a priority. Choosing a method to assess building vulnerability depends and influences all the parameters used to analyze the seismic risk: description of the seismic risk, characterization of the exposed elements and damage assessment.

By seismic vulnerability of a structure is meant the intrinsic predisposition of items exposed to dangerous events to be affected or susceptible to damage following an event with known characteristics (Bărbat *et al*., 2011).

Vulnerability is an attribute of structures that may be affected by violent or progressive earthquakes. This characteristic is expressed in physical, biophysical and social structures on a scale from 0 (no damaged) to 1 (extremely susceptible to damage), imposing limits or classes of vulnerability when classifying structures (Bărbat *et al*., 2011).

In case of a seismic event, the behavior of structures depends on the number of factors that influence the increase of their vulnerability, either by affecting the strength of the structure or by affecting the non-structural elements. The vulnerability factors which may lead to supplementary damage are prone to appear in all stages of the building: during the design stage, the execution process and / or during the life cycle of the buildings.

Table 1
Damaged Level on a Reinforced Concrete Frame Structure

Structural damage	EMS 98
	No damage
	Slight damage: no structural damage, no significant non-structural damage, with insignificant non-structural damage
	Moderate damage: slight structural damage, moderate non-structural damage
	Significant or major damage: moderate structural damage, major non-structural damage
	Severe damage (major structural damage, severe non structural damage): serious damage of walls, partial failure of roofs and floors
	Collapse: very serious structural damage

A qualitative descriptor classifies structures according to the vulnerability class, such are: low, medium, high or A, B, C, etc., macroseismic scales. The European Macroseismic Scale (EMS 98) is the basis for assessing seismic intensity in the European countries and is divided the effect produced by earthquakes into 12 rankings from barely noticeable earthquakes to severe ones that lead to local or global collapse.

Damages produced by earthquake according to the EMS scale are assessed on the basis of three factors: people, objects and structure. Based on the effects that an earthquake may have on a reinforced concrete constructions, Grünthal defines 5 stages of degradation, plus a no damage one which are summarized in Table 1 (Grünthal, 1998).

The use of reinforced concrete frame structures has been developed at the same time with population growth in both developed and industrialized countries. In order to ensure an efficient functionality according to their purpose, most of the reinforced concrete frame structures are partitioned and enclosed with masonry panels.

Filling the frames with masonry panels can lead to improved structural behavior to horizontal actions, but only for low loads, and as long as the masonry remains intact. The frame structure is relatively flexible and has high ductility, meanwhile unreinforced masonry is stiff and brittle and may explode under the effect of low deformation. At the beginning of an earthquake, the masonry takes up much of the seismic action, but as the intensity increases, masonry creeps due to the shear force which acts perpendicular to the wall plane and due to landslides.

Fig. 1 – Masonry panel cracked due to horizontal seismic action (Javed *et al*., 2006).

The appearance of diagonal cracks in the masonry panels is characteristic for the seismic failure, Fig. 1. Two failure mechanisms can be identified in case of reinforced concrete frame structures infilled with masonry:

either the columns are stronger than the masonry or vice versa. In Fig. 2 is shown a case when the columns are stronger, meanwhile the masonry is less rigid in comparison with the structural system and the masonry was expelled from the frame.

Fig. 2 – Masonry panel expelled from the structural system (Javed *et al*., 2006).

When the columns are less stiff than the masonry, they suffer deterioration, and sometimes fail due to increased shear forces produced by the infilling masonry, reaching often to collapse.

A particular case, probably more dangerous than the one previously presented, is when the frame structure is partially infilled. This can lead to supplementary nodes development which create a short column failure mechanism. The consequences of such supplementary construction elements are represented by different failure mechanisms mainly due the increased shear force in the middle of the column or the development of rotation mechanisms which produce the collapse of the structure, Fig. 3.

Fig. 3 – Failure mechanism due to short column development (Pradhan *et al*., 2012).

In order to reduce this type of failure mechanism for reinforced concrete frame structures, a perimeter joint and/or along the masonry rows can be introduced when placing the masonry into place. For this joint, materials with elastic characteristics are recommended such are: rubber, polystyrene, polyurethane, so on. An example of how this could applied in practice is presented in Fig. 4.

Fig. 4 – Masonry panel with rubber joint placed on perimeter and along the masonry rows.

2. Case Study

For the case study a 2D reinforced concrete frame structure with 3 stories is considered, with an opening of 6 m and a level high of 3 m. C20/25 concrete grade is used and sections of 50x50 cmxcm for the columns and 30x50 cmxcm for the beams are adopted. Several cases are analyzed: the bare frame, the frame infilled with bricks of 25 cm width without joint and with a 5 cm rubber joint on the perimeter of the frame and at every 100 cm masonry row. The objective of the study is to establish the internal efforts distribution, to compute the roof displacement for all the cases and to establish the failure mechanism in order to compare them and decide on the influence of the infill panel regarding the overall behavior of reinforce concrete frame structures.

The analysis was performed in computer software SAP2000. A static analysis, a modal analysis and a pushover analysis were considered.

Fig. 5 presents a comparison for all the considered cases for the bending moment measured at the bottom of the ground floor columns. The shape of the bending moment is different for the cases when the structures are infilled with masonry panels with flexibile joins.

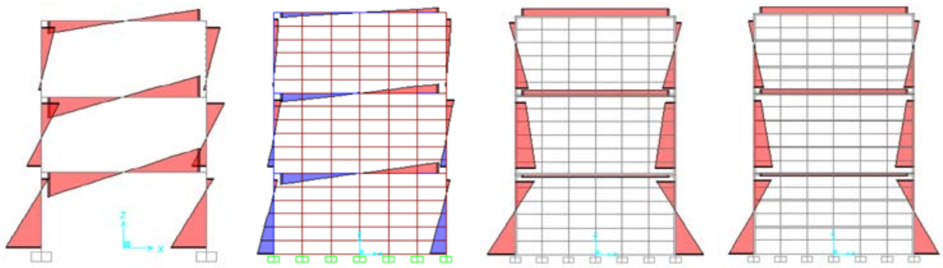


Fig. 5 – Bending moment diagrams for: *a*) bare frame, *b*) frame with masonry infill, *c*) frame with masonry infill and a joint on the perimeter, *d*) frame with masonry infill and rubber on the perimeter and at every 100 cm.

The comparison between the periods of vibrations in the fundamental mode of vibration is represented in Fig. 6. As expected, it is observed that the frame with masonry infill in classic execution is the stiffer one, meanwhile the bare frame is the most flexible one. A flexible structure behaves better in case on horizontal action. The cases with rubber joints are in between the extreme ones identified earlier. They show that by introducing the rubber the stiff effect of the masonry panel is diminished and the structure has a more flexible tendency, which means a better behavior in case of seismic action.

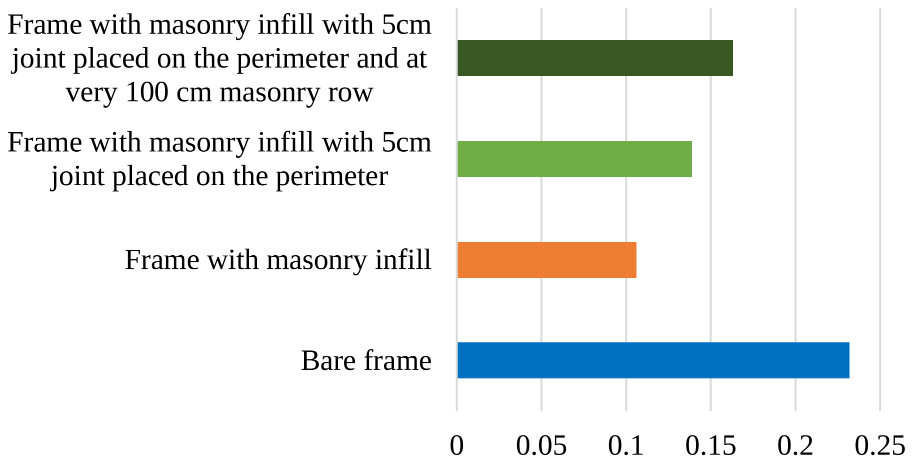


Fig. 6 – Value for fundamental mode of vibration [s].

Fig. 7 presents a comparison of the maximum displacement measured in the first mode of vibration at the top of the structure. The obtained displacements are in total accordance with the results obtained in Fig. 6. The more flexible a structure is, the bigger the target displacement.

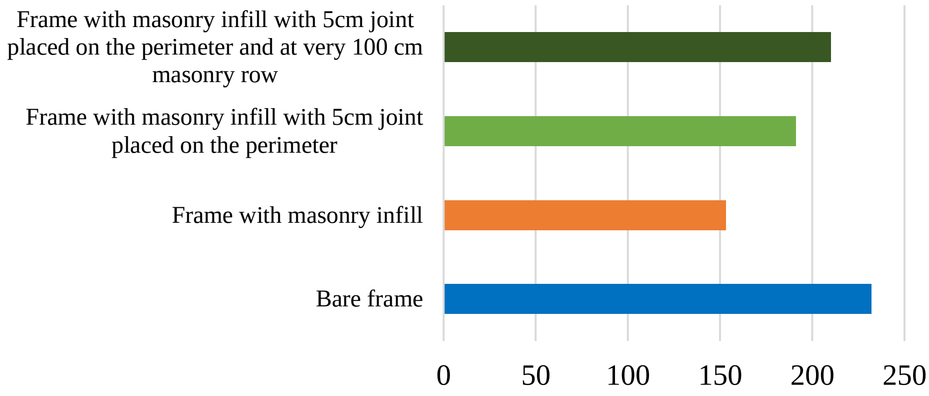


Fig. 7 – Displacements at the top of the structure [mm].

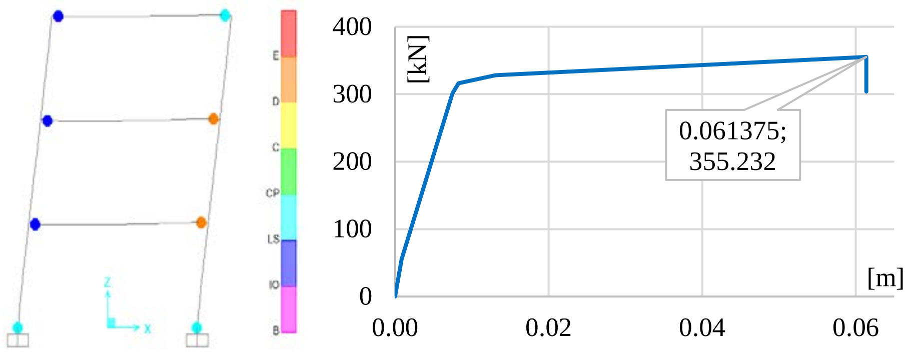


Fig. 8 – Capacity curve for the bare frame and plastic hinge development.

The pushover analysis is a static nonlinear analysis which subjects the structure with incremental load and measures the corresponding displacement. Beside the capacity curve which is obtained in such an analysis, the development of the failure mechanism is generated. In Fig. 8÷11 are presented both the failure mechanism and the capacity curve. The colored bullets represent the damage level the element suffers or the damage level of the plastic hinge which develops in the edge areas of the elements. Hence, pink is for superficial cracks, dark blue for immediate occupancy, light blue for life safety, green for capacity prevention, yellow represents the collapse and orange is for damage.

In all cases the failure mechanism is represented by the failure of the beams and then the columns. The differences between the four cases refers to the yielding point and the ultimate displacements. Even though the differences are not significantly, it is noticed an increase in the structure capacity when the frame is infilled.

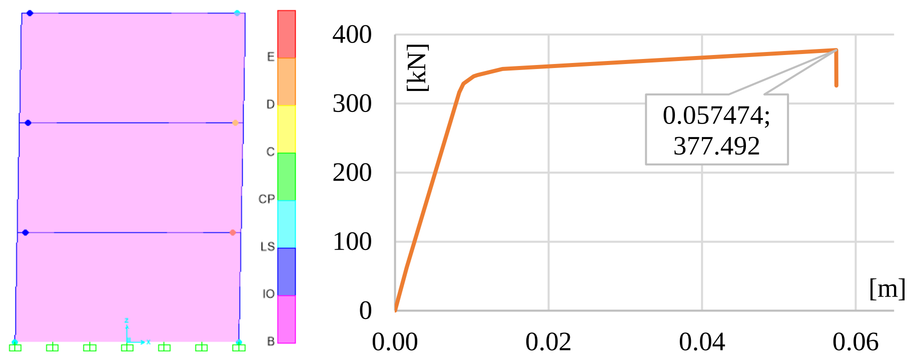


Fig. 9 – Capacity curve for the frame with masonry infill and plastic hinge development.

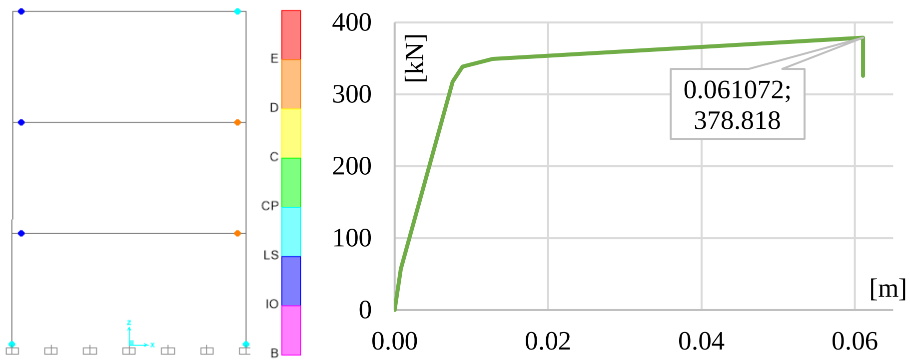


Fig. 10 – Capacity curve for the frame with masonry infill with 5cm joint placed on the perimeter and plastic hinge development.

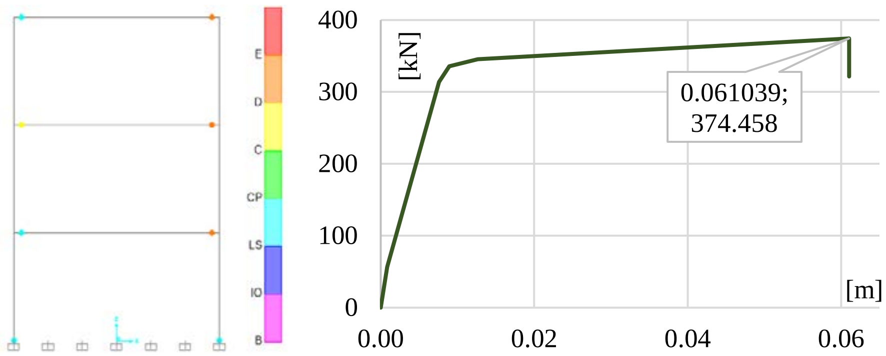


Fig. 11 – Capacity curve for the frame with masonry infill with 5 cm joint placed on the perimeter and at very 100 cm masonry row and plastic hinge development.

3. Conclusions

Due to the uncertainties surrounding the actual collaboration between the frames and the panels and the lack of conclusive experimental results, the calculation model for seismic design of new buildings will not take into account the possible favourable effects of the framed masonry panels. The favourable effect of these masonry will only be taken into account for assessing the safety of existing buildings according to P 100-3 / 2013 Code, depending on the actual seismic response of the respective buildings.

For the case study in Chapter 2, according to the synthesis in Fig. 12, it can be mentioned that in case of structures in brick reinforced concrete frames, the best option for the masonry panel is to choose the perimeter groove and / or the length of the 5 cm rubber asise.

From the synthesis, it can be seen that the perimeter groove enables the reinforced concrete frame with the masonry panel to record a movement roughly equal to that of the bare frame, but at the same time it increases the height of the assembly.

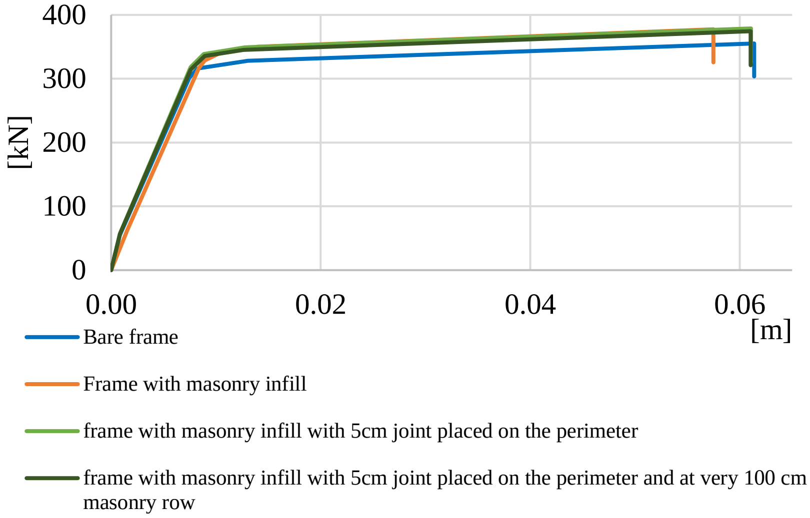


Fig. 12 – Capacity curve synthesis.

REFERENCES

Barbat A.H., Olteanu I., Budescu M., *Seismic Vulnerability Factors*, Conferința Internațională DEDUCON 70, 2011, Romania, Iași, Paper A13.

Grünthal G., *European Macroseismic Scale*, Vol **15**, Luxemburg: Centre Européen de Géodynamique et Séismologie, Cahiers du Centre Européen de Géodynamique et de Séismologie, 1998.

Javed M., Naeem Khan A., Penna A., Magenes G., *Behaviour of Masonry Structures During the Kashmir 2005 Earthquake*, First European Conference on Earthquake Engineering and Seismology, 2006, Geneva, Switzerland, Paper 1077.
Pradhan P.M., Pradhan P.L., Maskey R.K., *A Review on Partial Infilled Frames Under Lateral Loads*, Kathmandu University Journal of Science, Engineering and Technology, **8**, *1*, 142-152 (2012).
*** Seismic Design Code Indicative P100-1 2013 *Design Provisions for Buildings*.
*** Seismic Design Code Indicative P100-3 2018 *Provisions for Seismic Assessment of Existing Buildings.*

STUDIU DE CAZ PRIVIND INTERACŢIUNEA ÎNTRE PANOURILE DE ZIDĂRIE ŞI STRUCTURILE ÎN CADRE DIN BETON ARMAT

(Rezumat)

Structura în cadre este relativ flexibilă şi are ductilitate ridicată, pe câtă vreme zidăria nearmată este rigidă şi casantă putând „exploda” chiar și sub efectul unor deformaţii reduse. Articolul studiază influenţa zidăriei de umplutură asupra comportamentului general al unei structuri în cadre din beton armat. 4 cazuri sunt luate în considerare într-un program de calcul cu element finit şi comparate în ceea ce privesc eforturile, deformaţiile şi mecanismul de cedare. S-a ajuns la concluzia că panourile de zidărie rigidizează cadrele din beton armat, dar, în urma adoptării unor rosturi flexibile perimetrale şi în lungul asizelor, diminuând suprafaţa panoului de zidărie, rigiditatea acestuia scade.