

Masonry Infill Panels with Openings, Modeling, Effect on Seismic Response of Concrete Frame and Example Study According the Provisions in Morocco «Rps 2011»

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Abstract

Masonry remains today an essential, even indispensable at buildings in Morocco, however, the lack of experimentation led to the neglect thereof in digital computing models especially the panels with openings. On the other hand, damage in seismic zones showed a significant participation of the latter on failure modes of a structure. It is noteworthy that the Moroccan earthquake regulations RPS 2000 Version 2011 advocates modeling masonry infill panels with two equivalent rods [cf. Art No. 7.3.3].

Keywords: Equivalent strut; Frame; Infill; Masonry; Opening

Introduction

The infill elements whatsoever clay brick or concrete blocks, with or without openings are neglected in all research departments in conventional buildings. Indeed, engineers design numerical models via columns and beams systems mixed with bracing sails without an interest in infill masonry elements (as by their dead weight) that of the nature, or the parameters of openings therein. Although the infill is responsible for breaking by shear and/or torsion-flexure many frames and hence collapse under earthquakes in some cases. In addition, openings, such as windows and doors change already behavior of the panels; depending on several criteria (size, position...). The commonly made and extremely reductive simplification consisting in the consideration of the masonry as non-structural element may in some cases lead to dangerous structures during earthquakes [1-3]. The simplification done is extremely reductive, masonry that considers as non-structural element may in some cases lead to dangerous structures during earthquakes. In an attempt to understand this issue, a study was conducted through the modeling of the filling elements with apertures of a real project in R + 10 while treating the effect on the seismic behavior and the intrinsic characteristics of structures (own period - rigidity, supports efforts to, alteration of internal forces).

The exhaustive literature review addressing the different analytical and experimental research on masonry interacting with the framework, the model of the strut was deemed suitable for modeling fills [4].

Parametric Analysis

At this stage, the analyses were performed in the linear domain. First, it should present the demonstration procedure for the validation of the finite element model and the choice of the equivalent rod model based on an experimental study by researchers "Afefy Taher and" to move to the introduce opening of the effect by introducing a reduction coefficient.

Frame studied by Afefy and Taher (Reference frame)

The gantry is shown in Figure 1 below; the infill panel is composed of thick red bricks 120 mm. the concrete used is B25, and the mortar compressive stress is 10 MPa. A horizontal force at the top of the left post loads the frame [5,6]. Based on the method described in paragraph 3.4 of Eurocode 6 P1-1, results of calculation of the masonry are:

- Resistance characteristic of the brick: $R_c = 6$ MPa.
- Resistance declared characteristic of brick: $f_b = R_c \cdot \beta \cdot \delta \cdot \chi = 7.08$ MPa.

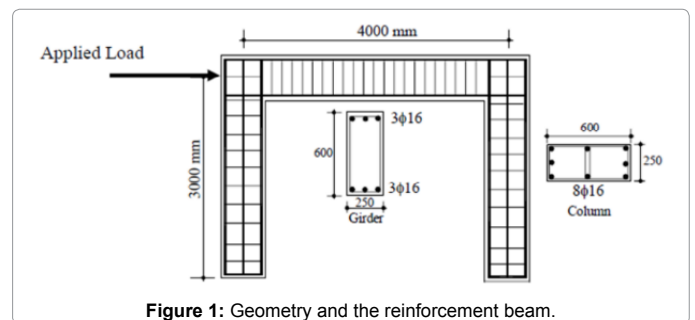


Figure 1: Geometry and the reinforcement beam.

Table 1: Width of the connecting rod for each model.

	Smith Carter	Mainstone	Paulay et Priestley	Liau et Kwan	Holmes
w_{ds}	1.79	0.65	1.25	1.57	1.67

- Compression strength of masonry: $f_k = K \cdot f_b^{0.7} \cdot f_m^{0.3} = 1.57$ MPa.
- Modulus of masonry: $E_m = f_k \cdot K_e$ with $K_e = 1000$ is $E_m = 1570.56$ MPa.

Note: The characteristics of masonry and mortars are from laboratory testing in Moroccan projects during the 2014-2015 year (Table 1).

Models rods used

Smith and Carter 1969.

$$\text{Mainstone 1971: } w_{ds} = 0,175 \cdot \lambda_h^{0,4} \cdot d \quad (1)$$

$$\text{Paulay and Priestley 1992: } w_{ds} = \frac{d}{4} \quad (2)$$

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Received June 20, 2016; Accepted July 19, 2016; Published July 20, 2016

Citation: Benamar A, Elouali T, Cherradi T (2016) Masonry Infill Panels with Openings, Modeling, Effect on Seismic Response of Concrete Frame and Example Study According the Provisions in Morocco «Rps 2011». J Civil Environ Eng 6: 244. doi:10.4172/2165-784X.1000244

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$$\text{Liauw and Kwan 1984: } w_{ds} = \frac{0,95 \cdot H \cdot \cos \theta}{\sqrt{\ddot{e}_h}} \quad (3)$$

$$\text{Holmes 1961: } w_{ds} = \frac{d}{3} \quad (4)$$

Main stone with eccentricity, below are shown the different widths equivalent rods according to the above models:

Modeling of finite element calculation software (SAP2000)

In the actual behavior of the completed framework, for some value of the load separation between the frame and panel takes place in the tension zone (Figures 2 and 3). Therefore, to address this important parameter impact on the results, it is necessary to model the interface as follows:

In the compression zones, define a connecting element (“Gap” for SAP2000) to take account of the presence of the mortar between the BA frame and the masonry panel [7-9], by introducing the following parameters:

- Between nodes link direction according to the local coordinate system of the element i.e., U1.

(5) The effective stiffness calculated using the formula: $\frac{A_{mor} * E_{mor}}{t_{mor}}$

where: A_{mor} : mortar contact surface.

E_{mor} : Young’s modulus of the mortar.

t_{mor} : thickness of the mortar.

In traction areas, two scenarios are possible: first place, generalizing type links “Gap” across the contact interface. In addition, in a second case, unlink nodes in the tension zone.

Finite element model validation

The exercise done in numerical modeling shows that the FE model

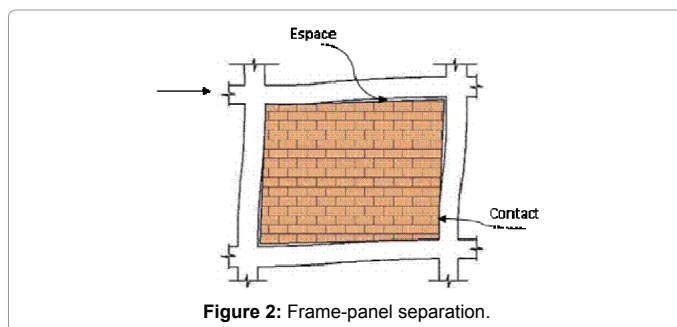


Figure 2: Frame-panel separation.

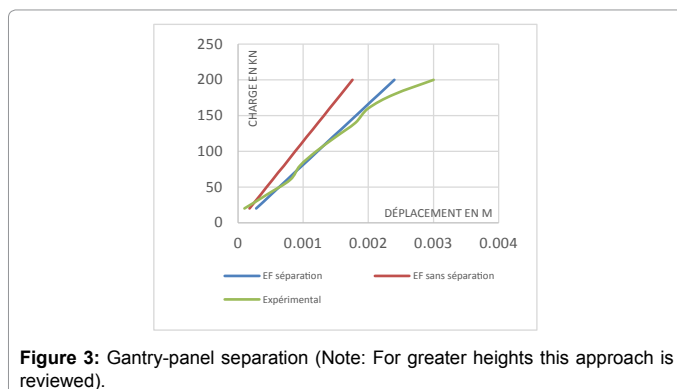


Figure 3: Gantry-panel separation (Note: For greater heights this approach is reviewed).

S cm	Lateral stiffness KN/m	S cm	Lateral stiffness KN/m	Error
50 × 100 cm	45392.646	100 × 50 cm	45351.473	0.00090703
50 × 150 cm	43591.979	150 × 50 cm	43140.638	0.01035375
50 × 200 cm	41806.020	200 × 50 cm	40436.716	0.03275374
100 × 150 cm	41067.761	150 × 100 cm	39666.798	0.03411345
100 × 200 cm	38910.505	200 × 100 cm	36231.884	0.06884058
150 × 200 cm	35087.719	200 × 150 cm	32711.808	0.06771344

Table 2: Lateral stiffness in function of the dimensions of the openings.

created with separation (gantry and panel) loading gives relatively close results of those from experience and Afefy Taher.

Choice of rod model

The results obtained for the different models are shown in a diagram with the finite element model (reference model).

According to the diagrams, the model rod closest to the finite element model is the one proposed by Paulay and Priestley. The average error between the latter two is of the order of 3%. Paulay and Priestley the model is then adopted for the future [10].

Study of the Effect of Openings

Note: the opening explored in this chapter is a rectangular window type.

The effect of the apertures is discussed in some detail the way through finite element model with separation validated previously and by studying several parameters related to openings and influencing the linear elastic behavior of the portico filled masonry.

The parameters in this analysis are:

- The percentage of occupation of the opening surface,
- The geometric shape of the opening (direction of orientation),
- The position of the aperture in the panel.

The literature search asserted that the openings have a reducing effect of the lateral stiffness of the completed frame. Therefore, researchers have considered appropriate to introduce the equivalent effect on the rods through reduction coefficients applied to the width thereof (Table 2).

Effect of the form

To study this parameter, the following openings were chosen: $S = 0.5 \times 1 \text{ m}^2$; $0.5 \times 1.5 \text{ m}^2$; $0.5 \times 2 \text{ m}^2$; $1 \times 1.5 \text{ m}^2$; $1 \times 2 \text{ m}^2$; $1.5 \times 2 \text{ m}^2$. Then reversing of these dimensions was done.

Based on these results, the error average outcome of this comparison is 3.6%. To this end, the shape of the opening can be neglected.

Effect of the size of the opening

All constructions in Morocco last use-these-years as masonry separating elements, following the recommendations of the DTU 20.1 20.13 and 21 relating to masonry, openings are still confined via stiffeners reinforced concrete around.

This configuration gives the infill panel rigidity and replaces the derived portion thereof (Figure 4).

However, tests carried out in the literature do not allow to properly assessing the behavior of the panel with opening stiffened, particularly in Morocco. The exercise will be done for panels with openings without stiffening reinforced concrete.

The size of the aperture has a big influence on the behavior of BA frame filled with masonry. And given that the geometric shape of the opening does not have a great influence on the overall behavior of the filled part was considered studying square central openings in different sizes (ranging from 10% to 60% of the surface of panel).

- K: lateral stiffness of the frame filled with opening.
- K0: lateral stiffness of the frame with filling without opening.
- a: the strut width reduced relative to the crank Paulay and Priestley.
- ap: width of the Paulay and Priestley strut.

The coefficient size is defined by:

$$\rho_{size} = \frac{\text{strut width with opening}}{\text{strut width without opening}} \quad (6)$$

$$F_n = (F - F_t) \frac{W_n h_n}{\sum W_i h_i}$$

The relationship between the normalized lateral stiffness and the ratio of rods widths follows a linear trend, using the following equation:

$$y = 0.6061x + 0.3806$$

While the relationship between the normalized lateral stiffness and the size of the aperture can be approximated by a polynomial of order 2 trends:

$$y = 1.6556x^2 - 1.8506x + 0.9771 \quad (7)$$

with a correlation coefficient : $R^2 = 0.9952$.

α is the percentage of area occupied by the opening with respect to the panel surface.

The end result:

$$\rho_{size} = 2,7316. \alpha^2 - 3,0533 .\alpha + 0,9842 \quad (8)$$

Effect of the position of the aperture

The proposed locations are: high right, center high, high on the left, middle left, center middle, middle left, Lower right, and low central lower left (Figure 5 and Table 3).

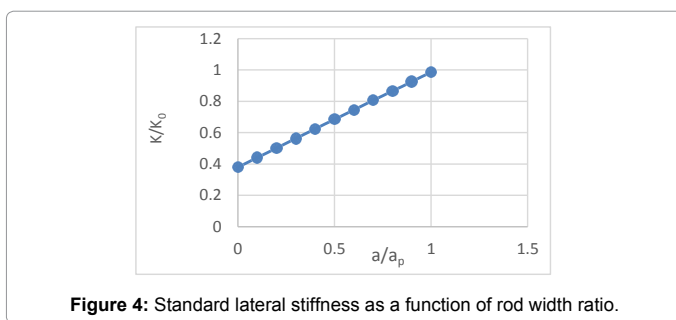


Figure 4: Standard lateral stiffness as a function of rod width ratio.

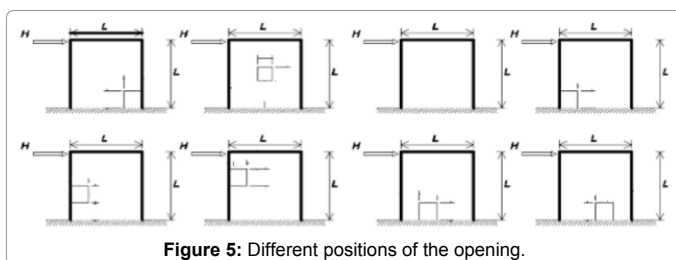


Figure 5: Different positions of the opening.

Position	Correct Co-efficient
Top Left	0.85
top center	1.00
top right	1.14
Middle left	1.07
Middle center	1.00
Middle right	0.96
Bottom left	1.13
Bottom center	1.09
Bottom right	0.74

Table 3: Correction coefficients.

To study the effect of the position, it is based on a central opening of 5% of the panel surface. Therefore, the obtained coefficients have been calibrated in such a way to have a coefficient of 1 for the case of the central middle position.

Note that both high and low left-right positions are the most unfavorable relative to the center because in both cases the key opening the diagonal where the connecting rod is formed. (Charging is in this case applied to the left side of the porch).

Application for a Case Study

This building is reinforced concrete spread over area of 425 m² composed in a single block. It is located in an average seismicity zone (zone II in speed and acceleration) and comprises: a ground floor and 10 floors mainly dedicated to offices.

Masonry used is characterized by a compressive strength:

$$f_k = k * f_b^{0.7} * f_m^{0.3} = 4,6 \text{ MPa}$$

– The Poisson factor : $\nu = 0.3$

The modulus of elasticity of $E = K_E * f_k$ with $K_E = 1000$ therefore $E = 4594 \text{ MPa}$.

The effect of the openings is made by reducing the width of the equivalent rod of the results of the linear elastic study. The filling was neglected for executives whose percentage occupancy of the opening is greater than 60%.

Effect on the natural period

In addressing the effect of the masonry on the natural period of the structure considered in this case, modeling fillings gave an average reduction of the natural period of up to 64% compared to that of without consideration structure fillings. In addition, the introduction of openings reduced the effect of the masonry.

Effect on the displacement

In terms of the overall movement of the vessel, the presence of the masonry induced a remarkable decrease. On average, the maximum displacement in the X direction is reduced by 82% for fills without openings, and 70% for the case with central opening. The presence of the openings increases the displacement of 45% compared to the full panel for the model adopted in this project. The masonry filler solid panels give an average reduction of inter-story displacement of up to 71%, against 63% for fills with openings.

Effect on rollover stability

Masonry stabilizes vis-à-vis building overthrow.

Indeed, it gives an average reduction of θ index (reversal index in the RPS 2000 V2011) 68% for solid panels and 64% for fills with

openings. As previously reported, diagrams drawn above were drawn in the linear elastic range for several reasons, not the mastery of the dynamic behavior of masonry without experimentation is the main. Thus this study was limited in that area. But during a violent earthquake materials do not remain in their elastic state, therefore, the linear approach can provide only limited understanding of this behavior and the consideration nonlinearities is essential for a proper assessment of the behavior seismic structures. This leads to lead a non-linear structure analysis with the Pushover method (progressive spurts).

Analysis of Pushover

The pushover analysis is basically an approximate nonlinear static analysis, performed under increasing horizontal loads, a monotonically distributed throughout the height of the structure according to a predefined pattern, until the ruins patterns begin to appear. During this analysis, gravity loads remain constant. The result of the push over analysis is a curve, which gives the stress at the base of the structure according to the movement in the latter head; this curve is called capacity curve or curve push over (Figure 6, Tables 4 and 5).

Consideration was given to a representative study of a structure braced frame by frame limited to 6 levels based on the architectural plans of a practical case, sizing and reinforcement of the portico was done according RPS2011 BAEL99 and regulations. The distribution of the lateral force is a subject which differs from its principles in computer codes (FEMA 273, EC08, RPS2011) for nonlinear static analysis which is based on the relationship-demand capacity, distribution of force depends on the mass inertia and the transition to a system with one degree of freedom. In RPS2011, the lateral force is described as follows:

Equivalent lateral force (STF)

According RPS2011, lateral seismic force is expressed as follows:

$$F = \frac{vSDIW}{K} \tag{9}$$

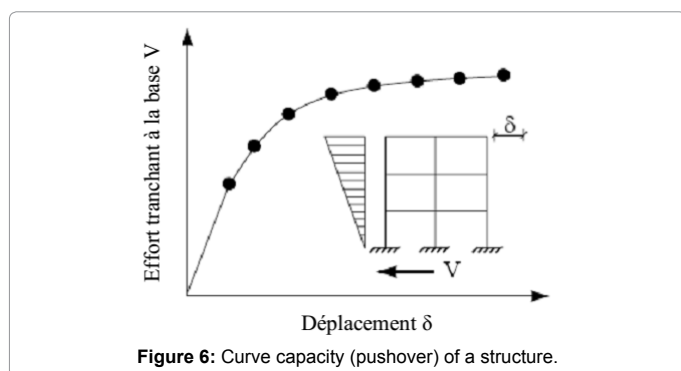


Figure 6: Curve capacity (pushover) of a structure.

Section Beam (cm ²)	
25 × 50 cm ²	Étages
25 × 50 cm ²	Terrasse

Table 4: Sections of the posts.

Floor	Section (cm ²)
Ground	40 × 50 cm ²
1	40 × 50 cm ²
2	35 × 50 cm ²
3	35 × 50 cm ²
4	30 × 50 cm ²
Top floor	30 × 50 cm ²

Table 5: Sections des poteaux.

Where:

- v : speed zones coefficient.
- S : Site Coefficient.
- D : dynamic amplification factor.
- I : Priority Coefficient.
- W : behavior factor.
- K : The load taking into account the structure.

Distribution of efforts on the floors

The seismic lateral force will be spread over the floors of the building. We write (RPS2011):

$$F_n = (F - F_t) \frac{W_n h_n}{\sum W_i h_i} \tag{10}$$

with:

$$- F_t = 0 \text{ Si } T \leq 0.7 \text{ s} \tag{11}$$

$$- F_t = 0.07TF \text{ Si } T > 0.7 \text{ s}$$

- T = the fundamental period of the structure

It is particularly interested in the effect of the presence of the filler on the seismic behavior of the portico. During the Pushover analysis, we begin by modeling the filling model Paulay and Priestley and then passes Mainstone model, and finally the model shifted Mainstone Based on the capacity curves are compared mainly, results for the elastic limit state (V_y dy, K_0) and those relating to the strength limit state (V_u , du).

State Elastic limit

We note an increase in the elastic shear (V_y) to the porticos with fill from the bare frame. The increase is 311% for the case of model Paulay and 358% for the case of model Mainstone and 267% for the case of model shifted Maidstone.

Regarding the initial stiffness K_0 , the largest increase is that of Morel Paulay which equal to 870% of the initial stiffness of the bare frame, and the model of Mainstone, it is 463% and the growth of the initial stiffness of the frame if the offset Morel Mainstone is equal to 236%. For the ultimate limit state of resistance, we note the increase of the ultimate shear force V_u and decreased movement of the ultimate limit for all models compared to the bare frame. For the model of Paulay, increasing Seen is 259% and the decrease in the displacement of the boundary is 90%, on the model of Mainstone increasing V_u and 463% and decreasing the limit of movement is 87%, and for the Mainstone model with increasing offset V_u is 176% and the decrease in the displacement of the was 79% (Figures 7-10).

Conclusion

Certainly, masonry provides a gain in terms of resistance and rigidity to the structure. However, it causes a considerable lack in terms of ductility of the structure when it is subjected to a strong earthquake. Also by acting on the internal forces in nodes, something that changes the way of destruction of the brittle ductile structure is noted. In the example studied, the openings were chosen -by lack of locally experimenting central rectangular window types, while other types of opening will be the subject of future research. From this retrospective, filling masonry is pointed out that only a low resistance in comparison to that of the structural elements and allowing a contribution in rigidity and strength in the plastic range, but giving place to the structural elements in post-elastic range to dissipate seismic energy ductility. This

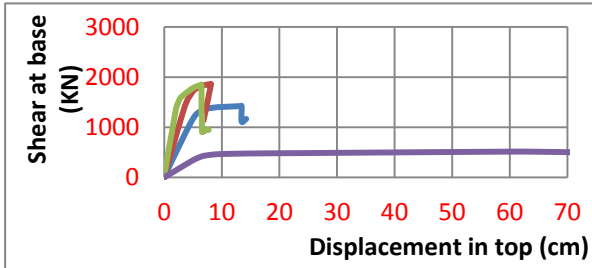


Figure 7: Capacity curves of the bare frame and filled with different patterns.

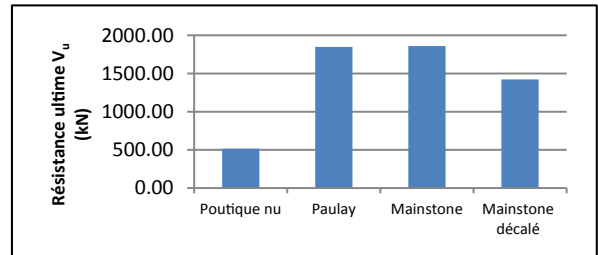


Figure 10: Comparison of ultimate resistance V_u .

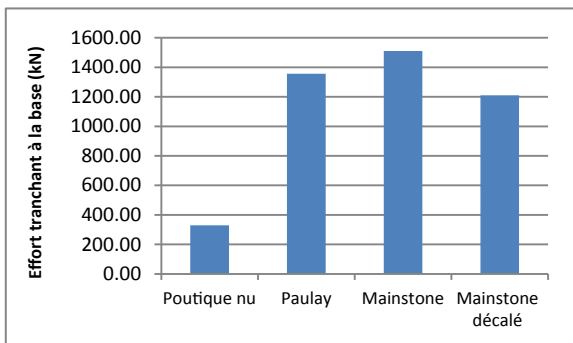


Figure 8: Comparison of elastic shear forces gantries.

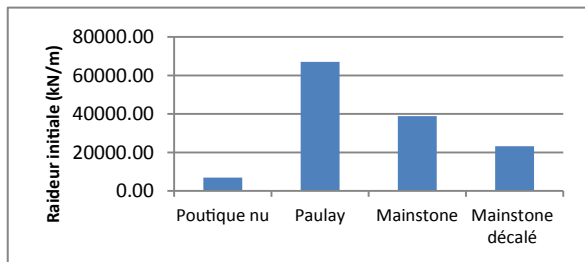


Figure 9: Comparison of initial stiffness K_0 different models.

compromise between gain in strength and stiffness and ductility loss induced by filling masonry remains a potential research subject.

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