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Analysis Of The Influence Of Masonry Infill Walls On The Response Of An R+4 Structure To Seismic Forces

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ABSTRACT
In Morocco, in the calculation of reinforced concrete structures, the behavior of the infill walls is not taken into account. The masonry infill walls are considered until now as non-bearing elements, therefore the role of resumption and transmission of vertical loads (permanent and operating) and horizontal loads (seismic) is ensured only by the reinforced concrete structure (frame structures). Several researchers insist on the positive role of the infill walls in the rigidity of reinforced concrete structures under the action of horizontal forces. the experience of past earthquakes around the world has shown that not taking into account the infill effect in the modeling of the structure is a simplifying and approximate approach, the analysis of the damage caused by earthquakes, shows that neglecting masonry walls in calculations can decisively influence, and even disrupt, the response of structures to seismic forces, and many multi-storey reinforced concrete portal frame buildings with infill have suffered damage that has been attributed, according to other researchers, to the adverse effect of infill on the frame. In this paper, we have modeled the behavior of portico-fill wall, through equivalent diagonal braces, to study the influence of fill walls in the seismic performance of structures.
The case study concerns a 4-storey structure with and without taking into account the effect of the infill walls, by modeling the presence of masonry infill walls by equivalent diagonal braces and by applying the recommendations of the Moroccan seismic regulations (RPS2000/ amended 2011), This study has shown the shortcomings in the design and modeling standards used by structural engineers in Morocco, including the underestimation of overturning moments and shear forces, and the overestimation of natural periods and displacements of floors. All this shows the need for revision of the current Antiseismic standards.
KEYWORDS: *frame structures, structures, masonry, concrete, loads, diagonal, Seismic characteristics.*

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I. INTRODUCTION

The column-frame structures present the largest part of the buildings in Morocco, the walls of these structures are not load-bearing and they are made of hollow bricks in the form of panels linked together by mortar joints.

These structures are considered very vulnerable to seismic forces. Most of the structures built with this type of construction have suffered significant damage in areas affected by earthquakes, taking into account the presence of these walls proves to be of economic interest, however in practice the structural engineers wanted this contribution is ignored in the calculations because of the lack of a regulatory tool.

Studies by researchers have revealed that these infills are not always safe, but they can promote structural failure.

During our research, we noted the absence of analytical studies and applications on real buildings using Moroccan standards. The only work published by ZAIN.R (author of this article) concerns an experimental study on the determination of the width of the equivalent diagonal representing the behavior of these walls, and the work published by KETTAR,J,BABA,K , NOUNAH,A, BAHI,L.

In this article, analytical and comparative studies were carried out on a 4-storey building, in order to better understand the risks related to the lack of knowledge of the behavior of these walls in the real and global behavior of the structures, and to propose improvements to be made for eventual updates of the Antiseismic standards.

II. RESEARCH METHOD

The objective of the paper is to complete and contribute to existing research and knowledge on the behavior of masonry walls with respect to the shearing force

Description of the studied structures
It is about the construction of a building in Rez of roadway and four floors, of square form and of 14 meters of dimensions, this building and use hotel (building receiving of the public)

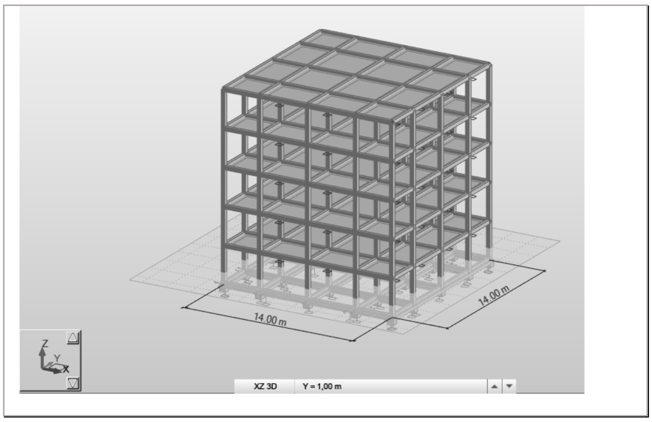

Figure 1 The studied structure in 3 dimensions

The structure is symmetrical in both directions, the dimensions of all floors are identical. the design is in accordance with PS 92 rules.
The height of each floor is 3 metres

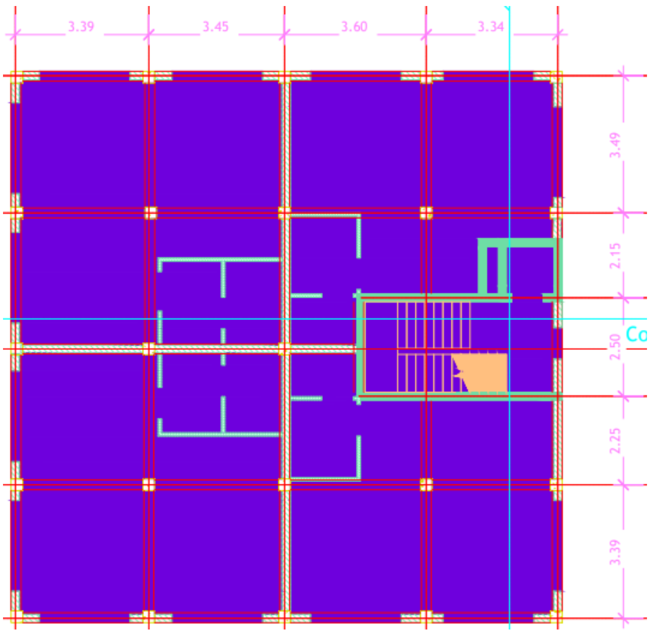

Figure 2 The studied structure in 2 dimensions

all column have 25-centimetre square cross-sections, in accordance with Moroccan anti-seismic regulations.
slabs are 15 cm thick beams have dimensions of 25cm*30cm columns, beams, foundations and slabs are made of reinforced concrete, walls of masonry

Macro-modeling of masonry infill walls

The masonry is modeled by an equivalent diagonal element, the dimensions of this diagonal bar are determined by Durani's method confirmed by experiment and by the finite element method (A.J. Durrani, Y.H. Luo, Seismic Retrofit of Flat-slab Buildings with Masonry Infills,NCEER workshop on seismic response in Masonry Infills, 1994,), (Zain Rachid, Mostafa Serroukh, Behavior of Masonry Walls with Respect to Seismic Stress, Analysis and Recommendation), the diagonal rod will have the same mechanical characteristics as the concrete material.

$$w = \gamma \times \sin(2\theta) \times D$$

$$\gamma = 0.32\sqrt{Sin(2\theta)} \times (\frac{h^4 E_m t_i}{m E_c I_c h_i})^{-0.1}$$

$$m = 6(1 + \frac{6 E_b I_b h}{\pi E_c I_c L}) \quad (1)$$

Figure 3 : Formula for calculating the thickness of the equivalent bar according to Durani's method

With :
w : the thickness of the bar.
D: length of the diagonal.
γ: Coefficient to be determined experimentally.
Em: Young's modulus of the masonry.
ti : thickness of the bar, it is taken equal to that of the masonry.
θ : the angle between the horizontal plane and the diagonal.
Ec : Young's modulus of the column.
Eb: Young's modulus of the beam.
Ic : modulus of inertia of the column.
Ib : modulus of inertia of the beam.
L: length of infill.
h: height of the column (hcol)

Modeling Software

Robot Structural Analysis Professional is a structural analysis program using the finite element method. It allows non-linear static and dynamic analysis of plane or three-dimensional structures subjected to vertical and horizontal static actions as well as to seismic actions. Seismic actions can be taken into account by equivalent horizontal forces or by ground level accelerograms.

Models considered for the analysis

The models developed are:
Structure without taking into account the effect of masonry infill on the overall behavior of the structure;
Structure with the effect of masonry infill on the global behavior of the structure.

Comparative technical study

In this section, comparative studies between the response of structures with and without the consideration of masonry walls will be discussed and analysed.

Modelling and analysis hypotheses

Adopted regulations

- BAEL 91 modified 99: for the reinforced concrete calculations
- RPS2000 modified 2011: for the seismic calculation.
- Fascicule N62: for the calculation of foundations.

The characteristics of materials

Concrete:

A concrete dosed at 350 Kg / m3 with the following characteristics will be used:
- Characteristic compressive strength of concrete: fc28=25 MPa
- Characteristic tensile strength of concrete: ft28=0,06 fc28 +0,6=2,1 MPa.
- Volumetric weight: ρ=2500 Kg / m3.
- Modulus of elasticity E=11000*(fc28)(1/3) =34 180 MPa
- Design stress of the concrete at ULS: σbc=15 Mpa
- Not very detrimental cracking (ELS)

Steel:

For the reinforcement, steel with the following characteristics is used:

- Elastic limit of the steel: fe=500 MPa
- Design stress of the steel at ULS: σsu=434.78MPa
- Longitudinal modulus of elasticity: E=210 000 MPa.
- Meshing method used: Delaunay with a regular mesh.

Seismic characteristics of the project according to RPS2000 modified 2011

Acceleration factor (A)

According to the seismic zoning map, our project is located in Casablanca, so we are in zone 2 where: A= 0.08 g (Probability 10% in 50 years)

Site coefficient (S)

According to the geotechnical report the project site is classified as S1 type, hence S=1

Priority Coefficient (I)

Our project is a standard building for residential, office and commercial use and is therefore classified as Class 2, hence I= 1

Damping coefficient (ξ)

The structure being reinforced concrete therefore, ξ = 5%.

Behavior factor (k)

Our structure will be taken as not very ductile (ND1) and the main bracing will be provided by walls, hence k =1.4

Seismic priority classes

It is a building for hotel use, so it belongs to class III, a priority coefficient equal to 1.

Loading conditions

Concrete Permanent loads

In addition to the structure's own weight, the permanent loads that will be applied are:

Terrace :

- Form of slope 250kg/m².
- Thermal insulation 15kg/m²

Current floor :

- Floor covering: 140kg/m².
- Coating/false ceiling including hangers: 30kg/m².
- Double partitions:240kg/m2
- Various networks : 20kg/m2

Operating loads

The operating loads in the buildings are in accordance with the values fixed by the standard NFP 06-001 of June 1986.

The operating loads, not weighted, retained are :

- Accessible terrace: 150kg/m².
- Stairs: 250kg/m².
- Rooms and sanitary facilities: 150kg/m².
- Circulations DRC : 400kg/m2
- Circulation floor : 250kg/m2
- Restaurant/main hall :400kg/m2

Modeling of the structure

The structure was modeled on design and modeling software as shown in the figure below:

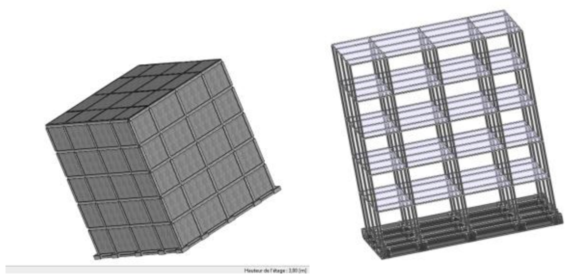

Figure 4 Structure without masonry infill.

In the figure above, the structure is modeled under Autodesk Robot Structural Analysis without taking into account the effect of the infill walls in the overall behavior of the structure, it is with this method that all structures in Morocco are modeled

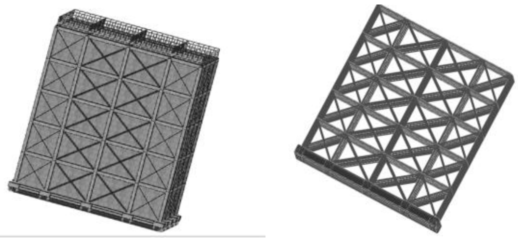

Figure 5 Structure with masonry infill.

In the figure above, the structure is modeled with Autodesk

Robot Structural Analysis software but taking into account the effect of the infill walls in the overall behavior of the structure, the infill walls have been modeled as equivalent diagonal bars following the method of Durani.

for the modeling, the method used is that of the finite elements with a regular mesh used is the delaunay method.

III. RESULTS AND DISCUSSIONS

Modal Analysis Results

Considering the vibration modes, the results of the spectral modal analyses performed, in the longitudinal X direction and in the longitudinal Y direction, on the two models presented previously, treated both with and without diagonal bars, are presented and discussed in this section

Table 1
Modal analysis of the structure without infill

Mode	Frequency[Hz]	Period [sec]	Cumulative Weights UX [%]	Cumulative Weights UY [%]
1	0,73	1,36	38,47	37,15
2	0,74	1,36	76,20	76,23
3	0,89	1,12	76,82	76,82
4	2,28	0,44	81,62	81,46
5	2,29	0,44	86,30	86,30
6	2,77	0,36	86,36	86,36
7	4,02	0,25	88,24	88,19
8	4,03	0,25	90,10	90,10
9	4,36	0,23	90,10	90,10
…	…	…	…	…
29	11,24	0,09	92,77	92,77
30	11,36	0,09	92,77	92,77

We note that the variation of the mass participation is very slow for the last modes and that the first 30 modes are sufficient to have a mass participation greater than or equal to 90%, the value of the frequency of the last mode of 11.36 Hz, indicates that the stiffness of the load-bearing elements (poles), is normal compared to the weight of the building, so we have a good mass-rigidity ratio.

According to the animations made on software, modes 1 and 2 are modes of translations, and mode 3 of torsion.

Table 2
Modal analysis of the structure with infill

Mode	Frequency[Hz]	Period [sec]	Cumulative Weights UX [%]	Cumulative Weights UY [%]
1	6.55	0,10	2,29	77.26
2	6.82	0,10	73,74	79,88
3	7.62	0,09	74,05	79,88
4	13.51	0.07	74,05	79,88
5	14.38	0.05	74,05	80,34
6	14.62	0,05	74,17	80,36
7	14.76	0,04	74,6	80,36
8	15.52	0,03	74,73	81,33
9	15.68	0,03	74,73	81,35
…	…	…	…	…
29	20.12	0,02	94,04	97,25
30	20.40	0,02	94,80	97,25

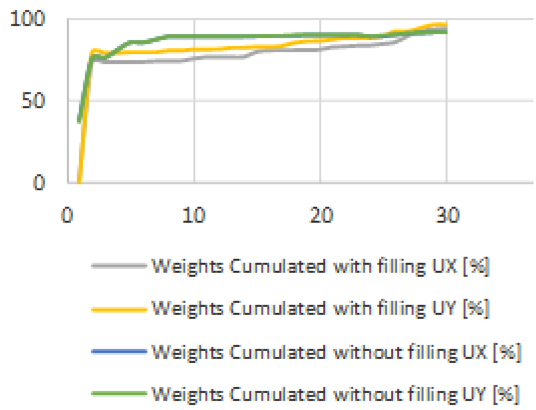

Figure 6 The comparative evolution of the cumulative masses in the three directions for the two structures

We note that the mass participation is greater than 90% and the value of the frequency of the last mode is 20.40 Hz, these two results meet the values required by the RPS 2000 modified 2011, they also indicate that the stiffness of the load-bearing elements (columns), is normal compared to the weight of the building, so we have a good mass-stiffness ratio.

According to the Moroccan seismic regulations, the natural period depends only on the dimensions of the structure (length and height), while the dynamic modeling has shown that this is not the case.

Comparing the two models on the figure above, the structures with the effect of the infill walls have a lower natural period than the structures with walls without infill. This is due to the stiffness brought by the diagonals equivalents to the structure.

Response in terms of fundamental natural period

We observe that the model without infill (without connecting rod) gives a longer period compared to the models with infill. The results indicate that the introduction of the fill drastically reduces the period of vibration in the construction models by about 13.6 factor on average compared to the model without fill. This

is due to the addition of the lateral stiffness provided by the connecting rod to that provided by the columns and walls, which expresses that the natural period depends mainly on the stiffness and mass of the structure.

By analyzing the current Moroccan seismic regulations (RPS2000/version2011), we deduce that the presence of the infill walls has no effect on the value of the main period of the structures. This is explained by the fact that the value of the behavior factor has no influence on the estimation of the natural period which depends mainly on the stiffness and mass of the structure when the percentage of the damping coefficient is low, Similarly, the empirical formula used for the calculation of the fundamental period of vibration is a function of the total height of the building and the length of the wall that constitutes the main bracing system in the direction of the seismic action (Article 6. 3 of RPS 2000 amended 2011).

Basic shear force of the structure
According to Section 6.4.1.b of the 2011 amended RPS2000, the value of the seismic lateral force V used in the calculation shall not be less than 0.90 times the value obtained by the equivalent static approach.

Structure without masonry infill:
Basic shear forces (spectral modal analysis) for the structure without infill: from Autodesk Robot structural analysis:

- Tx=659.40 KN
- Ty=659.81 KN

Structure with masonry infill:
Basic shear forces (spectral modal analysis) for the structure with infill: from Autodesk Robot structural analysis:

- Tx=895.90 KN
- Ty=946.60 KN

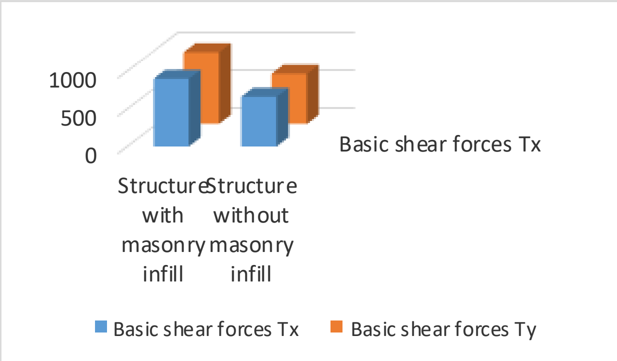

Figure 7 The comparative evolution of the Basic shear forces for the two structures

the shear force due to the presence of the infill is quite important, which will further increase the dimensioning of the load-bearing elements and consequently the resistance of the structure to shear, hence the obligation to take into account the effect of infill in the calculations of structures to avoid under sizing the structures and load-bearing elements of buildings.

Floor Shear Response:
As shown in the table, the storey shear force response for the model without rigid infill shows a smaller transmission of shear forces, approximately 40% on average, at the base and superstructure than those transmitted to the building models with rigid masonry infill. From a seismic design point of view, ignoring the masonry infill wall action significantly underestimates the base shear force, which is considered one of the main parameters during the design stages, and can therefore lead to an excessively safe but very costly design.

Interstage Lateral Displacements:
The inter-story lateral displacements Del evaluated from the design actions are schematized in the following table:

Structure without masonry infill:

Table 3
Inter-storey lateral displacements for the structure without masonry infill

Floor	Earthquake following the X direction		Earthquake following the Y direction		Displacement inter-floor limit (cm)
	Ux (cm)	Uy(cm)	Ux(cm)	Uy(cm)	
1	0.00	0.00	0.00	0.00	2,14
2	0.00	0.00	0.00	0.00	2,14
3	0.00	0.00	0.00	0.00	2,14
4	0.00	0.00	0.00	0.00	2,14
5	0.00	0.00	0.00	0.00	2,14

we notice that all the displacements are lower than the limit displacements required by the Moroccan Antiseismic norm, the maximum displacement is in the head of the building.

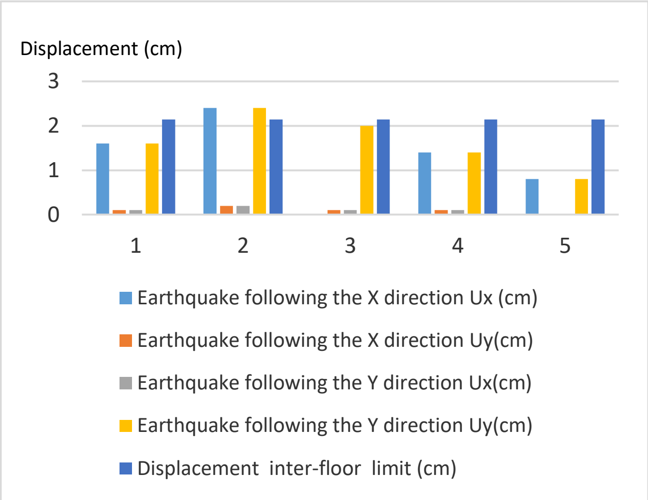

Figure 8 inter-storey movements of the structure without infill walls

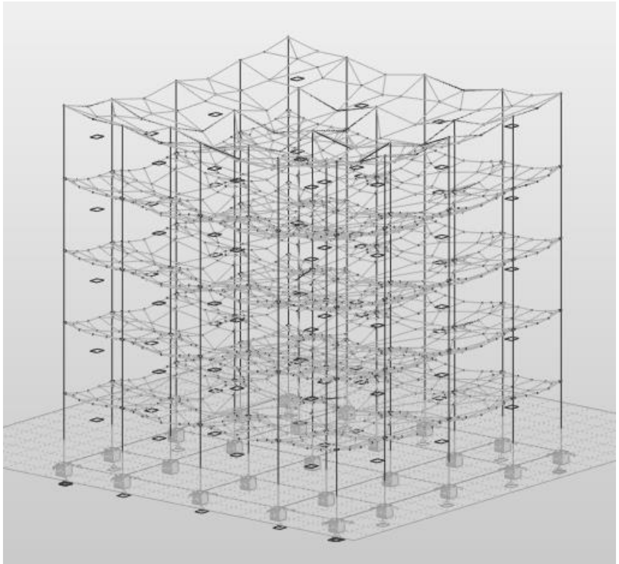

Figure 9 deformation curve

The figures above show that the displacements reach their maximum in the direction of the seismic forces, however their values remain always lower than the limit value authorized by the Moroccan standard.

Structure with masonry infill:

Table 4
Inter-storey lateral displacements for the structure with masonry infill

Floor	Earthquake following the X direction		Earthquake following the Y direction		Displacement inter-floor limit (cm)
	Ux (cm)	Uy(cm)	Ux(cm)	Uy(cm)	
1	1,60	0,10	0,10	1,60	2,14
2	2,13	0,20	0,20	2,13	2,14
3	2.00	0,10	0,10	2.00	2,14
4	1,40	0,10	0,10	1,40	2,14
5	0,80	0.00	0.00	0,80	2,14

We can see that not taking into account the effect of the infill resulted in higher global displacements compared to the structure with infill.

It can also be observed from the table, that the displacements obtained at each floor level are significantly higher for the model without infill compared to the model with rigid masonry infill, especially at the upper floors of the building.

It is also noted that the inter-storey displacements obtained at each floor level for the model without infill are significant but do not exceed the limit allowed suggested by the seismic regulations of Morocco. We also notice that the inter-storey displacements obtained at each floor level for the model without rigid infill, are considerably high, compared to the model with infill. This is probably due to the increase in the stiffness of the building with the consideration of the action of the masonry infill wall.

By considering the action of the masonry infill wall in the building modeling, it decreases the values of the induced inter-story displacements.

Stability of the structure at overturning
Structure without masonry infill (X direction)
this section is devoted to the verification of the structure's stability against overturning

Table 5
Tipping stability of the masonry structure without infill in the X direction

Floor	W(KN)	depmax(inter-floor dep) (cm)	V(seismic force) (KN)	MZ(KN.m)	θ
1	4598,84	1,60	658,70	796,57	0,074
2	3442,48	2,13	602,77	731,83	0,091
3	3442,48	2.00	499,66	606,43	0,092
4	3442,48	1,40	359,36	432,83	0,089
5	2286,13	0,80	171,77	199,09	0,071

According to Article 8.2.3 of Moroccan seismic regulations 2000 amended 2011, the stability of the structure to overturn is ensured according to the stability index which is less than 0.1.

Structure without masonry infill (Y direction)

Table 6
Tipping stability of the masonry structure without infill in the Y direction

Floor	W(KN)	depmax(inter-floor dep) (cm)	V(seismic force) (KN)	MZ (kN.m)	θ
1	4598,84	1,60	658,70	785,67	0,074
2	3442,48	2,13	602,77	721,7	0,091
3	3442,48	2.00	499,60	598,1	0,092
4	3442,48	1,40	359,36	427,1	0,089
5	2286,13	0,80	171,77	196,77	0,071

According to Article 8.2.3 of Moroccan seismic regulations 2000 amended 2011, the stability of the structure to overturn is ensured according to the stability index which is less than 0.1.

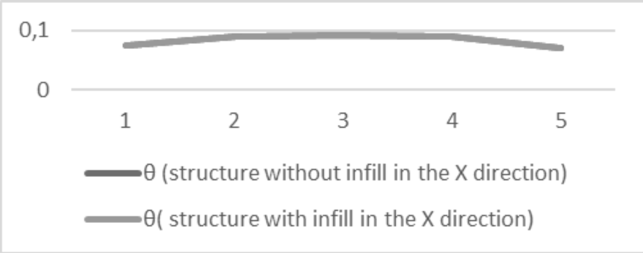

Figure 10 Comparison of the stability index between the different structures and directions

The risk of overturning the structure if the earthquake strikes in the Y direction is the same as in the X direction, this is due to the symmetry of the structure.

Structure with masonry infill (direction X)

Table 7
Overturning stability of the masonry structure with infill in the X direction

Floor	W(KN)	depmax(inter-floor dep) (cm)	V(seismic force) (KN)	MZ (kN.m)	θ
1	5000,60	0.00	789,35	664.72	0,000
2	3044,91	0.00	672,49	655.95	0,000
3	1925,67	0.00	514,78	588.62	0,000
4	1925,67	0.00	371,73	418.43	0,000
5	1925,67	0.00	179,94	190.05	0,000

Structure with masonry infill (direction Y)

According to Article 8.2.3 of Moroccan seismic regulations 2000 amended 2011, the stability of the structure to overturn is ensured according to the stability index which is less than 0.1.
since the displacements of the structure are zero for this model, no risk of overturning the structure

Table 8
Overturning stability of the masonry structure with infill in the Y direction.

Floor	W(KN)	depmax(inter-floor dep) (cm)	V(seismic force) (KN)	MZ (kN.m)	θ
1	5000,60	0.00	845,28	1008.21	0,000
2	3044,91	0.00	711,64	852.05	0,000
3	1925,67	0.00	535,87	641.52	0,000
4	1925,67	0.00	380,57	452.31	0,000
5	1925,67	0.00	179,85	206.02	0,000

According to Article 8.2.3 of Moroccan seismic regulations 2000 amended 2011, the stability of the structure to overturn is ensured according to the stability index which is less than 0.1.

From the figure above, it is clear that the stability index of structures with the infill effect taken into account is lower than the same index for structures where the infill effect is ignored and this in both directions, this is mainly due to the contribution of stiffness of these walls in the overall response of the structure to horizontal forces

According to Article 8.2.3 of Moroccan seismic regulations 2000 amended 2011, the stability of the structure to overturn is ensured according to the stability index which is less than 0.1.

It can be observed from the tables that the p-Δ effects obtained at each floor level for the model without infill are significant but do not exceed the allowable limit suggested by the RPS of 0.1. It is also noticed, that the p-Δ effects obtained at each floor level for the model without infill, are considerably high, compared to the model with masonry infill, This is due to the increase in the stiffness of the building with the consideration of the masonry infill wall action.

By considering the action of the masonry infill wall in the building modeling, it decreases the values of the induced p-Δ effects.

It can be seen also, that the response in terms of P-Δ effect of floors for the model without infill displays higher values at the base and superstructure than those obtained for the building models with rigid masonry infill.

It is also concluded that the model that ignores the masonry infill wall action significantly underestimates the overturning moments compared to the model that takes the infill action into consideration. The induced overturning moments for the portico building model with fully filled masonry walls and those without fill show significant changes in the values obtained at the upper floors. However, the change in moments is slightly pronounced at the lower floors.

IV. GENERAL CONCLUSION

The modes of ruin of buildings under the effect of past earthquakes have shown that a perfect control of the structure is possible only by a correct modeling of the masonry walls, in our project we studied the influence of the horizontal effort on the behavior of the structures

A comparative study is carried out on the impact of masonry infill walls on the seismic behavior of a 4-storey reinforced concrete frame structures, by modeling, on the one hand, the presence of masonry infill walls by a single equivalent diagonal rod and by applying the recommendations of the Moroccan seismic regulations (RPS2000/version 2011), on the other hand to this end, a dynamic modal spectral analysis of different models of three-dimensional buildings of 4 floors such as bare frame and frame with infill panels on the entire height.

The analysis results obtained in this work indicate that the seismic response of reinforced concrete building models analyzed with the modeling of the action of masonry infill walls with an equivalent diagonal connecting rod is significantly more realistic and representative of the portal-fill interaction than that of buildings modeled according to the seismic regulation RPS2000 modified 2011.

with regard to the Moroccan seismic regulations, it can be said:

Surestimate considerably the value of the fundamental period for all constructions with integral rigid infill or having transparency. It provides an identical value of the period for all models, which does not reflect the mechanical action of the presence or absence of the infill.;

Relatively underestimates the floor shear forces for infilled construction, which affects the design and cost of the structure;

Significantly overestimates the values of all storey displacements for constructions with infill. It provides identical storey displacements for both models indicating its insensitivity to the presence of infill;
Significantly overestimates the inter floor displacements;

Significantly overestimates the P-Δ effects of floors for structures with fill, this regulation provides larger values of the P-Δ effects of floors for structures with fill than those provided for structures without; infill, something that contradictorily reflects the expected action of the integral presence of infill walls;

Underestimates the overturning moment for structures with infill, this regulation gives values of overturning moments of floors for structures with rigid infill significantly less important than those provided for structures without infill, something that goes against the expected action of the integral presence of infill walls. The current Moroccan seismic regulation RPS2000/2011 gives results that do not correctly reflect the influence of the infill on the overall behavior of the structure when subjected to lateral forces. These findings confirm the usefulness and necessity of incorporating the modeling of the action of the presence of the infill walls by an equivalent diagonal rod in the current Moroccan seismic regulations.

Following the last seismic events in the world (Turkie) and having exceeded 12 years of application, the Moroccan seismic regulation must be revised urgently to allow a good dimensioning of structures, this regulation must be the subject of a thorough study and taking into account all the data related to non-bearing elements (masonry wall, equipment, flexible floor ...) because it is the latter that can upset any ordinary calculation made

REFERENCES

[1]. Reglement De Construction Parasismique (R.P.S 2000 Version 2011, Kingdom Of Morocco, Ministère De l'Aménagement Du Territoire, De l'Urbanisme, De l'Habitat Et De l'Environnement Secrétariat d'État A l'Habitat, May 2013, Rabat

[2]. ZAIN,R, SERROUKH,M, Behavior Of Masonry Walls With Respect To Seismic Stress, Analysis And Recommendation, International Journal Of Science And Research (Ijsr), Volume 10 Issue 9, September 2021.

[3]. KETTAR,J,BABA,K , NOUNAH,A, BAHI,L. Mechanical Behavior Of The Reinforced Concrete Frame With Masonry Filling, MATEC Web Of Conferences 149, 02062 ,2018.

[4]. Conception Parasismique Des Bâtiments Règles De Construction Parasismique: Règles PS Applicables Aux Bâtiments, Dites Règles PS 92 –. MILAN ZACEK, (Edition AFNOR) 1995

[5]. A.J. Durrani, Y.H. Luo, Seismic Retrofit Of Flat-Slab Buildings With Masonry Infills,NCEER Workshop On Seismic Response In Masonry Infills, 1994.

[6]. Technical Rules For The Design And Calculation Of Reinforced Concrete Structures Using The Limit States Method 90 Modified 99 , Commission Générale De Normalisation Du Bâtiment-DTU ,February 2000,Paris.

[7]. Technical Rules For The Design And Calculation

[8]. For Reinforced Concrete Structures And Constructions Using The Limit States Method, Commission Générale De Normalisation Du Bâtiment-DTU ,February 1999,Paris.

[9]. Bases For Design Of Structures. Working Loads For Buildings. TC 98 Technical Committee, June 1986,Paris