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# INFLUENCE OF THE DISTRIBUTION OF THE SHEAR WALLS ON THE SEISMIC RESPONSE OF THE BUILDINGS

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**Abstract:** In this paper, an evaluation was tried for the impact of structural design on structural response. Several situations are foreseen as the possibilities of changing the distribution of the structural elements (sails, columns, etc.), the width of the structure and the number of floors indicates the adapted type of bracing for a given structure by referring only to its Geometric dimensions.

This was done by studying the effect of the technical design of the building on the natural frequency of the structure with the study of the influence of the distribution of the structural elements on the seismic response of the building, taking into account of the requirements of the Moroccan earthquake regulations 2000/2011 and using the ANSYS APDL and Robot Structural Analysis software.

**Keywords:** Structural response, Type of bracing, Fundamental frequency, Shear walls, Columns

## 1. Introduction

The fundamental period of vibration of the structures constitutes a decisive parameter in the design and the dimensioning of structures in seismic zones, as well as the design of shear walls for the construction of structures is becoming a major factor in the seismic response of buildings [1], [2]. In addition to their bearing on vertical loads, they are particularly effective in ensuring resistance to horizontal forces, taking up most of the seismic effort due to their great rigidity with respect to horizontal forces [3]. An

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adequate disposition of the shear walls makes it possible to have an optimal use of their rigidity during the dynamic stresses. The shear walls reduce also considerably the seismic damage of non-structural elements, the value of which generally exceeds two-thirds of that of the entire building. They condition the behavior of the structures, and play a primordial role for safety compared to other typologies of structures [4].

However, the Moroccan seismic code (RPS 2011) [5], recommends some precisions for the locations to be avoided and others to be adapted during the design phase of structure. The plane symmetry and continuity in elevation must be mentioned. These parameters do not specify the impact on the different types of structure (in geometry, and height for example) and does not predict the seismic behavior in these cases [6], by using the ANSYS APDL [7] and Robot Structural Analysis software [8].

In this study, a simple guide is proposed to the structural designers to determine the optimal arrangement of the sails by evaluating the seismic performances of the structure [9], through the observation of the variation of the eigen-frequencies [10] with the various proposed configurations and according to several variants [11] to know the arrangement of the sails, the height, width, etc.

## 2. Material and methods

### *2.1. Material*

The material is concrete structure with the following characteristics: section of columns: $S_c$= 0.5 * 0.5 m²; section of the beam: $S_b$= 0.5 * 0.5 m²; the height of the column: $H_c$ = 4 m; the rigidity of the concrete $E_c$ = 32000 Mpa; Poison coefficient $\rho$= 0.2; density $d$= 24.5 kg/m$^3$.

### *2.2. Numerical model*

A numerical approach is considered, using the finite element method with ANSYS software and the Robot Structural Analysis software [8]. Using the element beam 188 [7] in ANSYS software. This element based on Timoshenko beam [7] with six or seven degrees of freedom at each node includes translations in the $x$, $y$, and $z$ directions and rotations about the $x$, $y$, and $z$ directions theory. A seventh degree of freedom (warping magnitude) is optional, which includes shear-deformation effects [7].

The modeled structure in ANSYS is represented in the *Fig. 1*, in the Robot Structural Analysis is represented in the *Fig. 2*. The structure is assumed to be embedded in the soil in both cases.


*Fig. 1.* Model on ANSYS

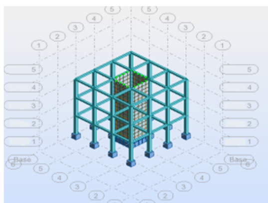

*Fig. 2.* Model on robot structural analysis

## 3. Results and discussion

*3.1. 2D analysis*

Buildings with a regular, symmetrical architecture behave better and are more resilient than buildings with complex geometric shapes [6]. Taking into account this information of the systematic response for a simple structure by changing the geometric parameters and the design of the bracing is analyzed.

At first a 2D analysis was performed by changing the elevation location of the bracing to get a clear idea of key locations not to be overlooked during the design phase of the structure, *Fig. 3* shows the distributions studied with sails on a 2-D model of three floors, and *Table I* gives the values of the natural period of fundamental mode for every type of bracing, *Fig. 4* and *Fig. 5* shows the variation of the natural period with all type of bracing.

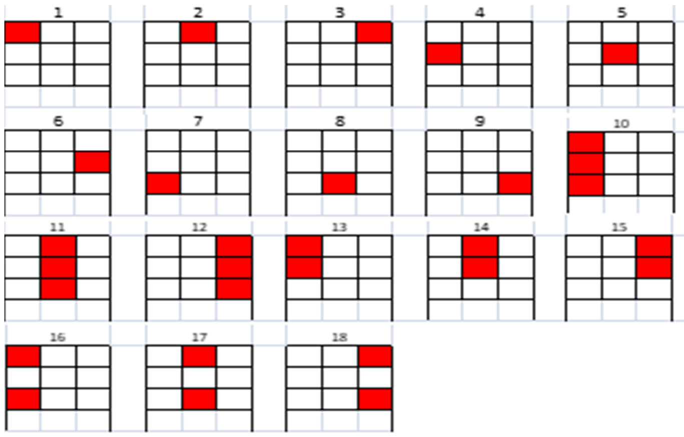


*Fig. 3*. Elevation location of the bracing with the sails

*Table I*

Results of the natural periods of the first 10 natural modes for the elevation bracing

| Number of bracing location | Natural period of fundamental mode | Number of bracing location | Natural period of fundamental mode | Number of bracing location | Natural period of fundamental mode |
|---|---|---|---|---|---|
| 1 | 3.04 | 7 | 1.00 | 13 | 2.46 |
| 2 | 2.70 | 8 | 0.97 | 14 | 2.02 |
| 3 | 3.04 | 9 | 1.00 | 15 | 2.46 |
| 4 | 2.35 | 10 | 0.95 | 16 | 1.27 |
| 5 | 2.16 | 11 | 0.95 | 17 | 1.27 |
| 6 | 2.35 | 12 | 0.95 | 18 | 1.27 |

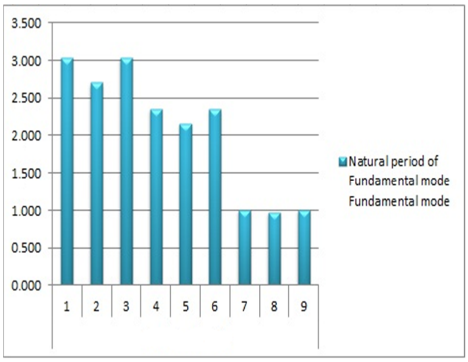


*Fig. 4*. Variation of the natural mode for models from 1 to 9

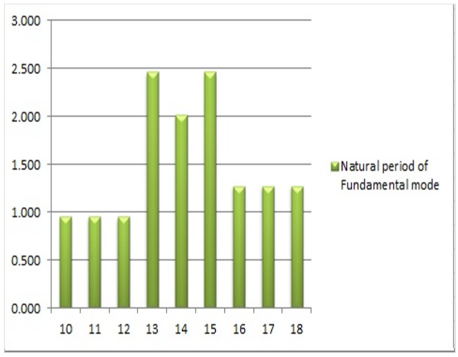


*Fig. 5*. Variation of the natural mode for models from 10 to 18

It can be seen that the natural period decreases by lowering the braces of the upper parts of the structure to the lower part, and the location at the middle column shows a high rigidity related to the end this is due to the rigidity of the nodes adjacent to the bracing.

Bracing 13, 14 and 15 shows the perfect agreement between the results found and the recommendations of RPS 2011 [5], which predicts to avoid flexible ground floors.

For bracing 16, 17 and 18 the analysis of the results mode/period checks a second time the validity of the recommendations of the RPS 2011 [5] concerning the flexible floors, however the results advance more on this last point see (the cases 16, 17, 18 flexible floor) and favors the flexible floors compared to the flexible ground floor.

Then the results found in the first part concerning the installation of the bracing between the most rigid nodes are confirmed, which increases the rigidity of the structure and consequently its resistance to the seismic load.

*3.2. 3D analysis*

In the second part a 3D analysis was proceeded to by changing the location and the design while maintaining the symmetry in both axes of the bracing in order to delimit the suitable design by changing the number of the floors of the 3, 5, and 10 floors.

The figures below represent the distributions studied on the 3D model for the case of a width of 15 m in *Fig. 6* and for a width of 25 m in *Fig. 7*.

The tables below give the values of the natural period of fundamental mode for every type of bracing in 3D model for a width of 15 m in *Table II*, and for a width of 25 m in *Table III*.

*Analysis for the case of the width 12 m*

The low natural period value was founded for the type of bracing M3. Also the type M4 has an acceptable value for the case of 3 floors, for the 2nd case of 5 floors the slope of the line between the model M3 and M4 decreases but always the M3 is the best in terms of value of the natural period, in the last case of 10 floors that the M4 has the low value of natural period.

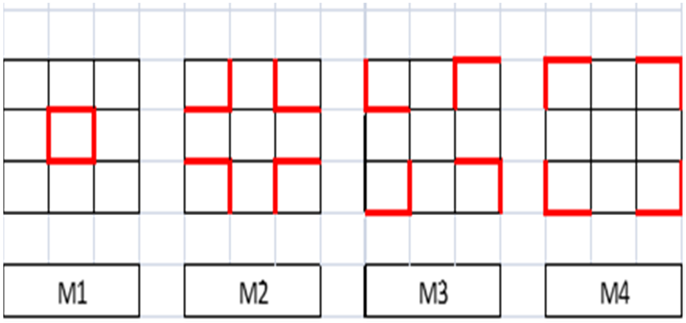


*Fig. 6*. Plane location of the bracing for the case of a width of 12 m

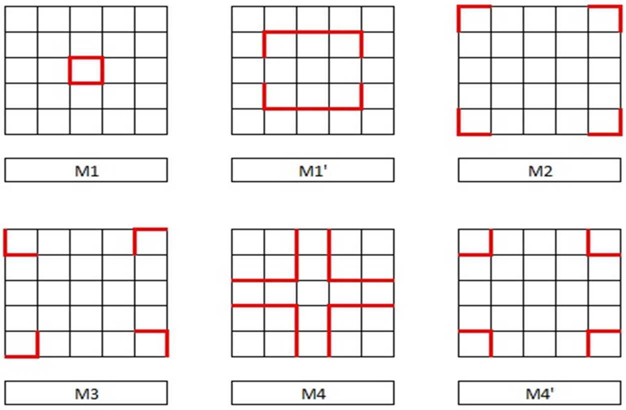


*Fig. 7*. Plane location of the bracing for the case of a width of 20 m with the spotting

*Table II*

Results of the natural's periods of the plane location of the bracing for 12 m

| Type of bracing | Number of floors | Natural period of fundamental mode | Type of bracing | Number of floors | Natural period of fundamental mode |
|---|---|---|---|---|---|
| 3*3 M1 | 3 floors<br>5 floors<br>10 floors | 0.21<br>0.27<br>0.59 | 3*3 M3 | 3 floors<br>5 floors<br>10 floors | 0.09<br>0.2<br>0.63 |
| 3*3 M2 | 3 floors<br>5 floors<br>10 floors | 0.21<br>0.32<br>0.75 | 3*3 M4 | 3 floors<br>5 floors<br>10 floors | 0.15<br>0.21<br>0.59 |

*Table III*

Results of the natural's periods of the plane location of the bracing for 20 m

| Type of bracing | Numbre of floors | Natural period of Fundamental mode | Type of bracing | Numbre of floors | Natural period of Fundamental mode |
|---|---|---|---|---|---|
| 5*5 M1 | 3 floors<br>5 floors<br>10 floors | 0.29<br>0.45<br>0.73 | 5*5 M3 | 3 floors<br>5 floors<br>10 floors | 0.19<br>0.28<br>0.86 |
| 5*5 M1' | 3 floors<br>5 floors<br>10 floors | 0.19<br>0.26<br>0.73 | 5*5 M4 | 3 floors<br>5 floors<br>10 floors | 0.32<br>0.48<br>0.84 |
| 5*5 M2 | 3 floors<br>5 floors<br>10 floors | 0.24<br>0.31<br>0.74 | 5*5 M4' | 3 floors<br>5 floors<br>10 floors | 0.21<br>0.28<br>0.74 |

*Analysis for the case of the width 20 m*

It was found that for 3 floors the bracing types M3 and M1' has the low values of the natural period, but for the second case of 5 floors kept the same performances for the two models, in our last case of 10 floors, the type M3 is no longer presents a favorable response but in type M1' the performance is kept, and only the model M1' has the lowest value of the natural period.

*Fig. 8, Fig. 10* and *Fig. 12* represent the variation of the natural period with type of bracing in 3D model for a width of 15 m respectively for 3, 5, and 10 5 floors.

*Fig. 9, Fig. 11* and *Fig. 13* represent the variation of the natural period with type of bracing in 3D model for a width of 25 m respectively for 3, 5, and 10 5 floors.

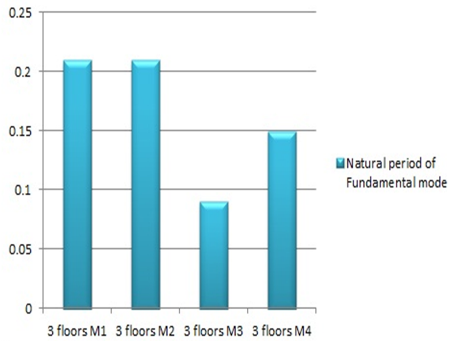


*Fig 8*. Variation of the natural mode for models *L*=12 m and 3 floors

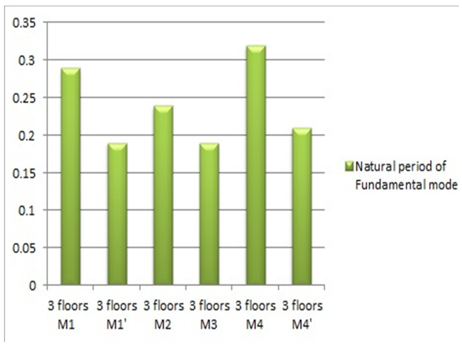


*Fig 9*. Variation of the natural mode for models L=20 m and 3 floors

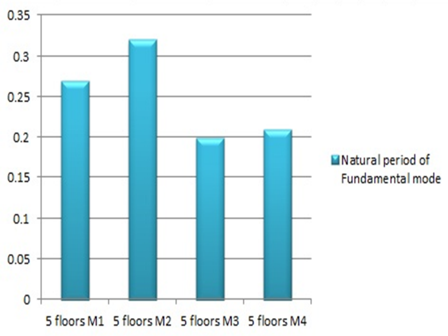


*Fig. 10.* Variation of the natural mode for models *L*=12 m and 5 floors

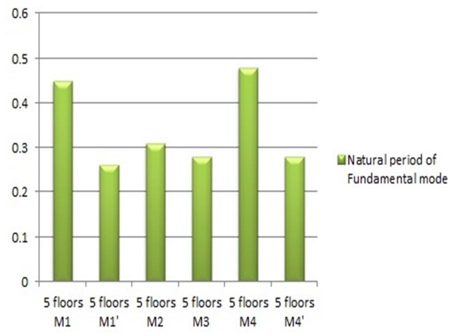


*Fig. 11.* Variation of the natural mode for models *L*=20 m and 5 floors

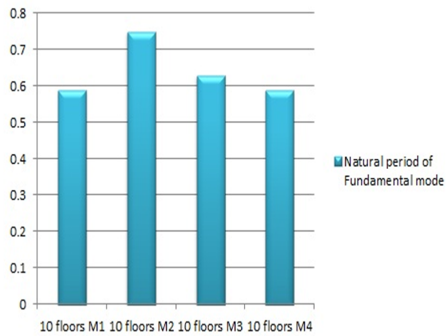


*Fig. 12.* Variation of the natural mode for models *L*=12 m and 10 floors

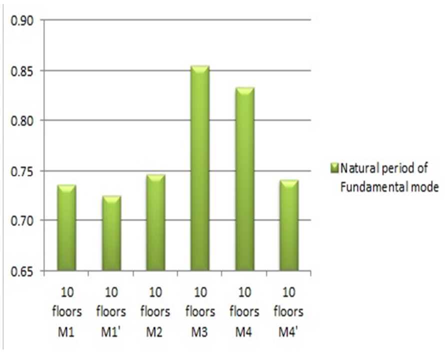


*Fig. 13.* Variation of the natural mode for models *L*=20 m and 10 floors

## 4. Conclusion

To conclude the arrangement of sails in structures is essential to have an adequate design and good structural behavior. A good disposition of the sails makes it possible to have an optimal use of the rigidity of the structure.

However, in order to improve the recommendations of the Moroccan seismic code (RPS2011) after analysis the following results were noticed:

- In elevation: the bracing must be placed in the most rigid nodes locations, respecting the continuity in elevation;
- On the plane: for the width 12 m, the type M3 is the one to adapt during the design for the small and medium height, but when the height is important, it is necessary to go to type M4, also the type M2 is to be avoided;

– On the plane: for the width 20 m, type M3 and the most stable for the majority of the naturals modes for the small and medium height, but for the high heights the types M1', also the type M4 is to be avoided.

Then generally for structures that have small widths, if the height is increasing it is necessary that the bracing locations must converge from the middle to the ends, however for structures that have large widths the bracing location need to converge from the ends to the middle when the height is increased.

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