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Original scientific paper

# THE ACTION OF SEISMIC LOADS ON RESIDENTIAL BUILDINGS IN ROWS

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**Abstract**

Earthquakes have been and will be one of the most horrific natural disasters and catastrophes for humanity. When earthquakes happen, man-made buildings collapse causing great economic damage, and a great number of victims. “Rowbuildings” has become a daily occurrence of urbanism in the Northern Republic of Macedonia. Today our cities are long boulevards with buildings near each other. The largest category of constructed buildings has neighboring buildings on both sides, there are cases of even more than two sides. Therefore, this analysis of the action of seismic loads and the displacement of the object under the action of seismic loads is a concept for consideration and modeling of structures, especially when the buildings have longitudinal front facades and are bordered by neighboring buildings on both sides. This paper analyzes the action and the way of adapting the seismic forces in the structure and the displacement of the structure in both possible directions, especially from the neighboring buildings.

*Keywords:* analysis, earthquakes, seismic, structures, buildings

## 1 Introduction

The structures are under the action of dynamic loads that change vibrations. Among them, we can mention wind loads, seismic loads caused by earthquakes, loads of various vibrating mechanisms, etc. Earthquakes are one of the biggest natural hazards for life on earth, seismic loads caused by major earthquakes cause big damage to structures.

Therefore, the seismic design of the structure was done at this time. The purpose of the project is to study and analyze the seismic design of structures in the range. The actions of seismic loads on residential buildings in rows in recent years, all over the world, have been studied and applied practice techniques to analyze and study several types of structural typology. The study, in addition to identifying this problem in our country, aims to analyze these structures based on the contemporary literature of developed countries. The paper will focus on seismic response analysis of structures. Once the theoretical foundations of the analysis are addressed, they will be applied to reinforced concrete structures for the selected building with a height of Bo + P + 4 floors. Some cases have been analyzed for the structure but only the 3 most important cases are presented below.

## 2 General knowledge about earthquakes

Earthquakes are the leading cause of damage or collapse of the structure, anywhere in the world, because they cause great human and economic losses. Many earthquakes, unfortunately, give very little or no warning before they occur, and this is the main reason why the damage from it is great.

### 2.1 *General characteristics of earthquakes-*

The rapid development of Earthquake Engineering has accumulated a lot of experience with errors and failures in the design of structures to improve the seismic response of structures and reduce or avoid damage and disasters from earthquakes. Worldwide experience has shown that structural damage caused by earthquakes depends on the position of origin and the distance from the epicenter. Reducing the seismic response of structures after a strong earthquake is a key issue for constructors to prevent damage and collapse of the structure. The traditional way consists in designing ductile structures and distributing the total seismic energy coming to the structure, through the large stresses that arise in its constituent elements, but this causes damage and can lead to impractical designs.

### 2.2 *Causes of the occurrence and spread of earthquakes –*

Earthquakes are caused by a series of phenomena that can be natural or the result of different activities of people. In recent years, underground nuclear explosions, the erection of large water reservoirs, etc. are included. But the vast majority of strong and damaging earthquakes are natural. Their origin is usually at the boundaries of tectonic plates or microplates, into which the Earth's upper solid layer (lithosphere) is divided. These are tectonic earthquakes. Their cause lies in the constant movements of the plates against each other. These movements are performed according to tectonic fault plans. Inland, the movements of its masses cause continuous accumulations of relative deformations in the rocky materials that fill the spaces of the fracture planes ("seismic joints"), accompanied by very large corresponding cracks. At a given moment, the deformations and cracks in the rock reach the resistance or resistance limit capacity. This is the moment of earthquake occurrence, which appears as a fracture and strong, sudden, slippery motion in contact between two neighboring blocks and microplates.

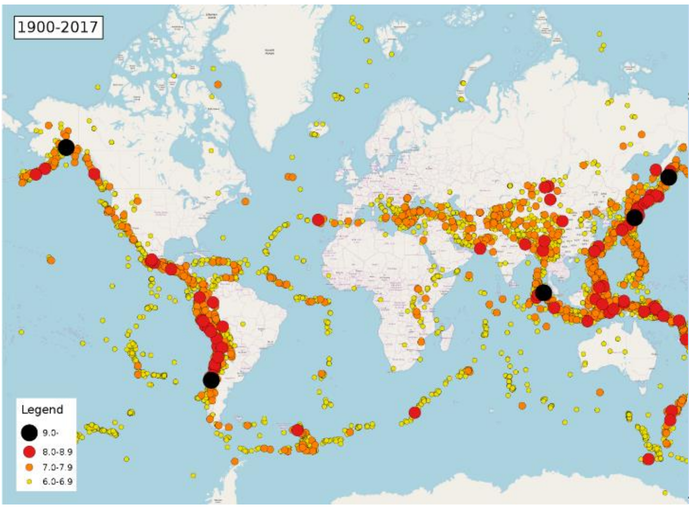



**Figure 1.** Map of earthquakes occurred on earth's surface from 1900-2017 (https://commons.wikimedia.org/wiki/File:Map of earthquakes_1900-.svg, Search Earthquake Archives, USGS)

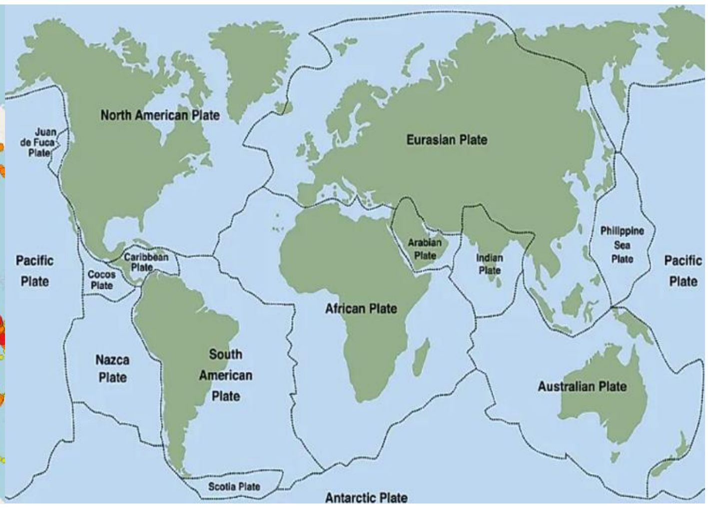



**Figure 2.** Map of tectonic plates on the earth's surface (earth-s-tectonic-plates.webp )

## 3 Aseismic design of structures

The design philosophy is a great term we use for the basics of design. It includes loads, analytical techniques, design procedures, preferences for structural configuration, and materials that aim at economic optimization. The importance of design philosophy becomes high when seismic consideration dominates the design. This is because we usually accept higher risks of damage under the action of seismic forces than under the action of other comparable extreme loads, such as temporary loads or wind forces. For example, in modern building codes, structures in seismic regions according to Eurocode 8 must be constructed such as to meet the following criteria:

a) Damage limitation requirement

b) No-collapse requirement

c) Structural resistance (near collapse limit state)

## 4 The action of seismic loads on residential buildings in rows

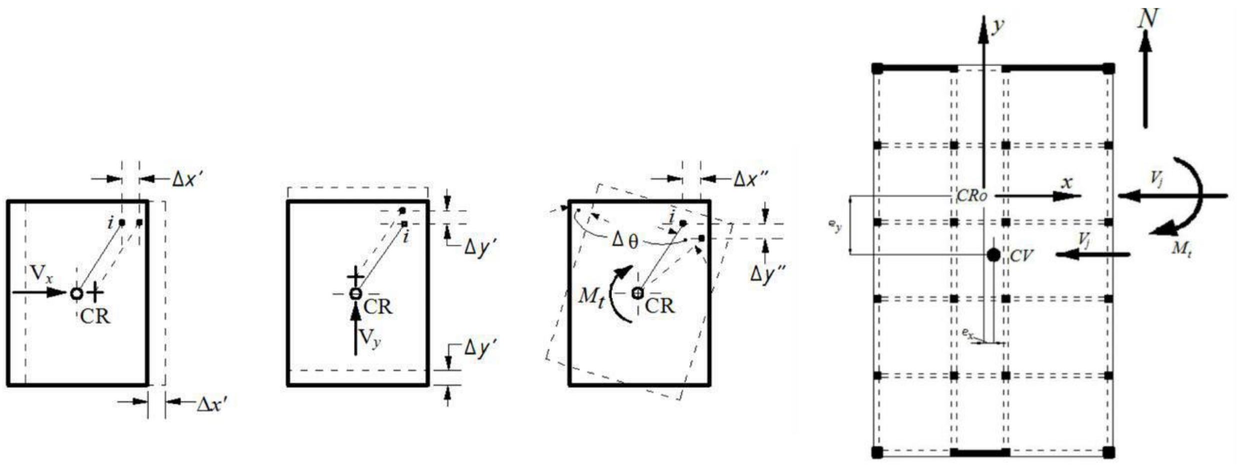
In order to design residential buildings in rows and structures to be able to adapt to the action of seismic loads, it is necessary to consider several key features, which are:

*a) Stiffness*

*b) Resistance*

*c) Ductility*

*d) Resistance and torsional stiffness*




**a)Displacemen** **b)Displacemen** **c) Torrosions** **d) Extrencity**

**Figure 3. Relative displacements in the plan**

(Figure form EN 1998-1 (2004) (English): Eurocode 8: Design of structures for earthquake resistance-Examples)

## 4.1 *Resistance and torsional stiffness*

In addition to resistance to lateral forces, the structure must also provide strength and rigidity to withstand the effect of torsion. The latter tends to load the structural elements in an irregular shape. This is achieved by reducing the distance between the center of mass (CM), where the horizontal seismic forces are applied, and the center of rigidity (CR).

**Not preferable** **Preferred**

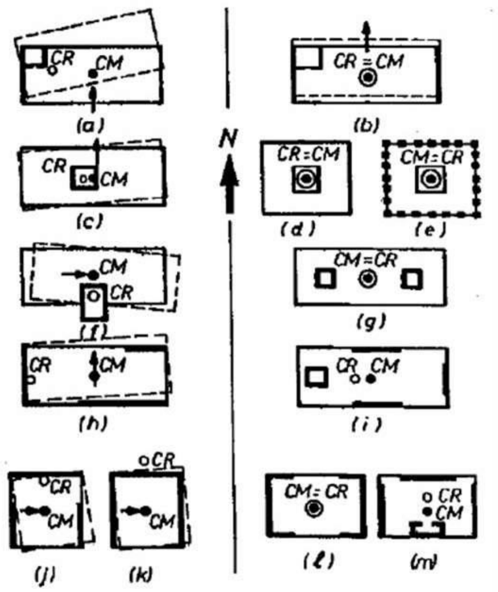



**Figure 4.** The relationship between the center of gravity and the center of mass

(Figure from EN 1998-1 (2004) (English): Eurocode 8: Design of structures for earthquake resistance-Examples)

## 5 Technical description of the construction

The object that has been analyzed is a classic reinforced concrete structure, in terms of height divided into seven platforms, the floors in terms of height are 2.88 m, while the ground floor with a height of 3.24 m, In the plan divided 6 axes in the X direction, and in 4 axes in the Y direction, which can be seen in the plane of the formwork.

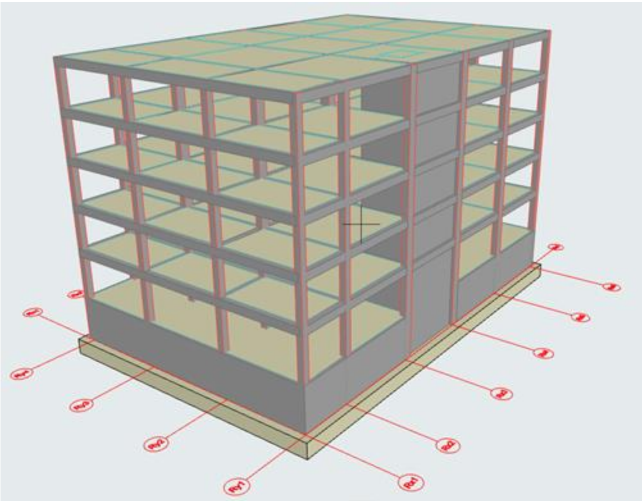


**Figure 5.** 3D MODEL (by author)

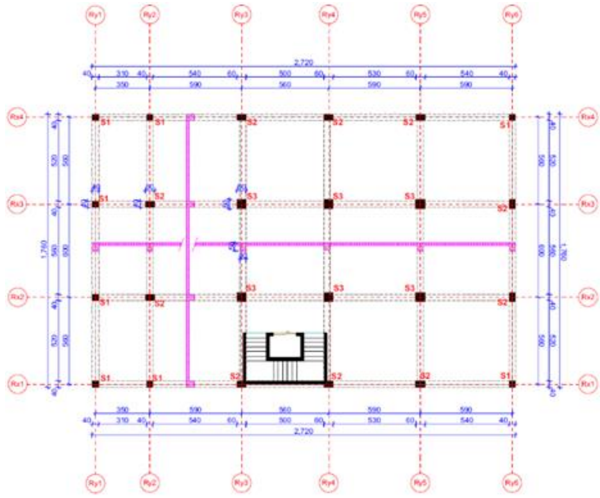


**Figure 6.** Structure plan (by author)

### 5.1 *Seismic analysis –*

The static and dynamic calculation is performed based on the standards "JUS, PBAB 87 for Concrete and Reinforced" loads are taken according to the load analysis, the analysis of tones for the determination of periods and the frequency for seismic determination is done.

*Modal analysis*

n = 3 * nk => n- number of tones , nk –number of floors =>n =3 * 6 = 18

*Calculation of seismic forces*

**S =K *G**

Where:
**G** -Mass converted loads
$K = K_0 * Ks * Kd * Kp$
$K_0$ – Coefficientof the objectcategory, Category II=> $K_0 = 1.00$
Ks– Seismic intensity coefficient, Grade IX=>Ks =0.100
Kd– Dynamic coefficient Land category II => $K_d = \frac{0.70}{T}$
Kp– Ductility and damping coefficient Category I =>Kp =1.00

### 5.2 *The first case of dynamic analysis-*

The ram construction system is analyzed from the results obtained from the analysis of tones we notice that the structure is in torsion because the first (main) tone is in torsion, where the center of gravity does not coincide with the center of mass (from the cases in torsion presented in above), therefore this case is not preferred to calculate seismic forces, for residential buildings built in a row.

**Table 1.** Modal analysis, period of tones and frequency (by softwarradimpex Tower 6

Periudhat e oscilimit të konstruksionit

| No | T [s] | f [Hz] |
|---|---|---|
| 1 | 0.5833 | 1.7145 |
| 2 | 0.5071 | 1.9718 |
| 3 | 0.3106 | 3.2195 |
| 4 | 0.1854 | 5.3946 |
| 5 | 0.1383 | 7.2284 |
| 6 | 0.1071 | 9.3347 |
| 7 | 0.0942 | 10.6117 |
| 8 | 0.0934 | 10.7026 |
| 9 | 0.0894 | 11.1862 |
| 10 | 0.0873 | 11.4578 |
| 11 | 0.0848 | 11.7973 |
| 12 | 0.0836 | 11.9613 |
| 13 | 0.0791 | 12.6415 |
| 14 | 0.0785 | 12.7311 |
| 15 | 0.0783 | 12.7676 |
| 16 | 0.0776 | 12.8784 |
| 17 | 0.0774 | 12.9142 |
| 18 | 0.0772 | 12.9478 |

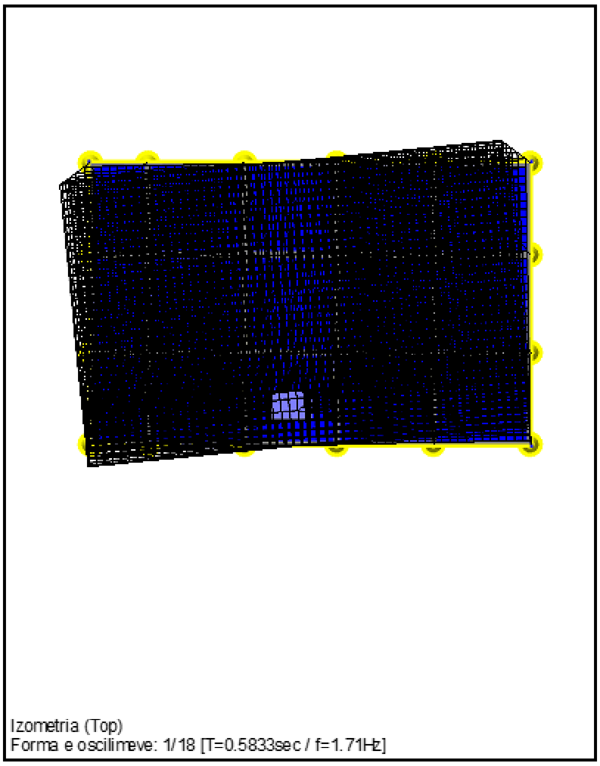



**Figure 7.** The form of oscillations (by softwarradimpex Tower 6)

## 5.3 *The second case of dynamic analysis-*

Because our structure in the constructive global system is twisted, we are forced to place the center of mass and stiffness in a line, so we set the concrete diaphragm in the longitudinal direction on the axis Ry1 and Ry6 (which we will see below). The obtained results show that the first tone works in torsion, even in this case it is not preferable to calculate the seismic forces, for residential buildings built in a row.

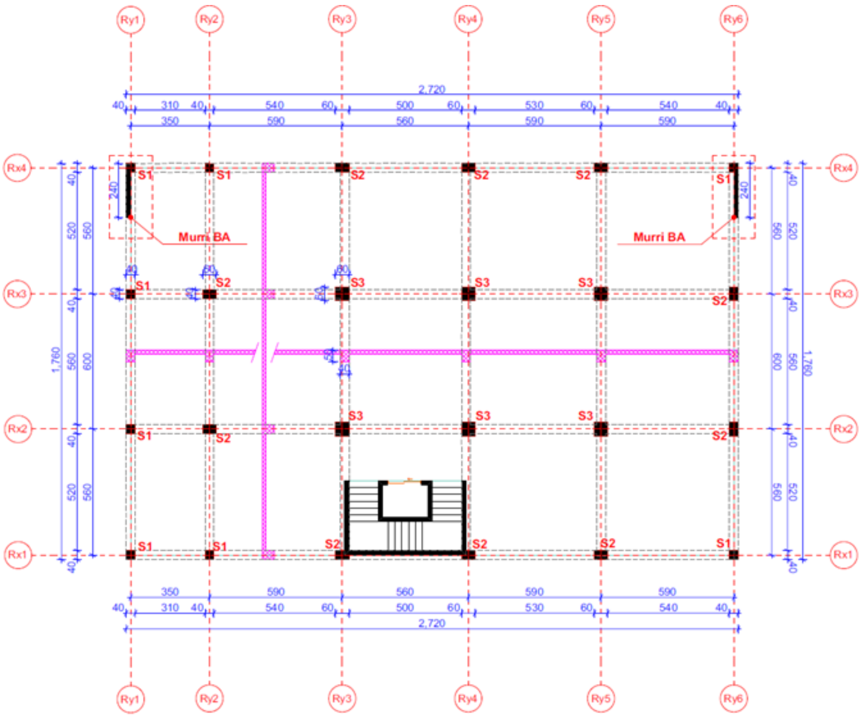



**Figure 8.** Structure plan with seismic walls (by author)

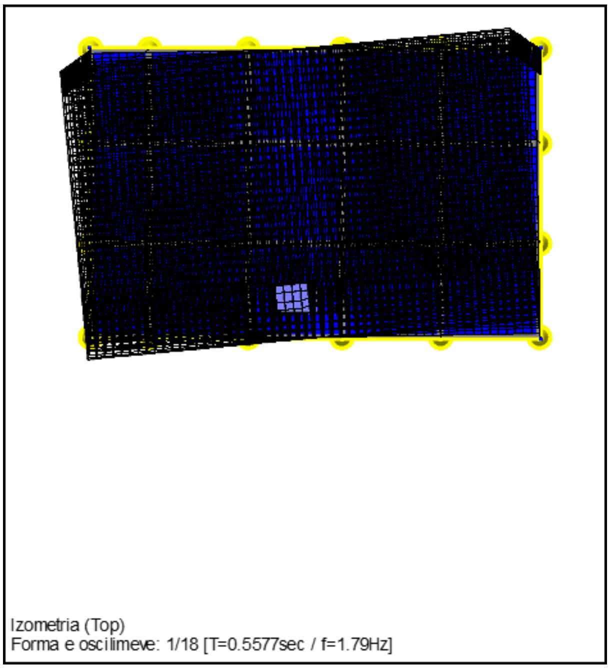



**Figure 9.** The form of oscillations for case 2 (by softwarradimpexTower 6)

**Table 2.** Modal analysis, period of tones and frequency for case 2 (by softwarradimpex Tower 6)

| Periudhat e oscilimit të konstruksionit | | |
|---|---|---|
| No | T [s] | f [Hz] |
| 1 | 0.5577 | 1.7932 |
| 2 | 0.4899 | 2.0410 |
| 3 | 0.3066 | 3.2615 |
| 4 | 0.1729 | 5.7831 |
| 5 | 0.1338 | 7.4734 |
| 6 | 0.0966 | 10.3537 |
| 7 | 0.0935 | 10.6948 |
| 8 | 0.0927 | 10.7843 |
| 9 | 0.0884 | 11.3130 |
| 10 | 0.0867 | 11.5282 |
| 11 | 0.0841 | 11.8928 |
| 12 | 0.0823 | 12.1475 |
| 13 | 0.0786 | 12.7199 |
| 14 | 0.0782 | 12.7822 |
| 15 | 0.0774 | 12.9120 |
| 16 | 0.0773 | 12.9441 |
| 17 | 0.0769 | 13.0018 |
| 18 | 0.0768 | 13.0145 |

## 5.4 *The third case of dynamic analysis*

In the latter case the placement of the concrete diaphragms in the longitudinal direction on the Rx1 axis is analyzed, the results obtained (which we will see below) show that the first tone made pure translational movements, and unlike the previous cases we have consistency almost complete of the center of mass and center of gravity.

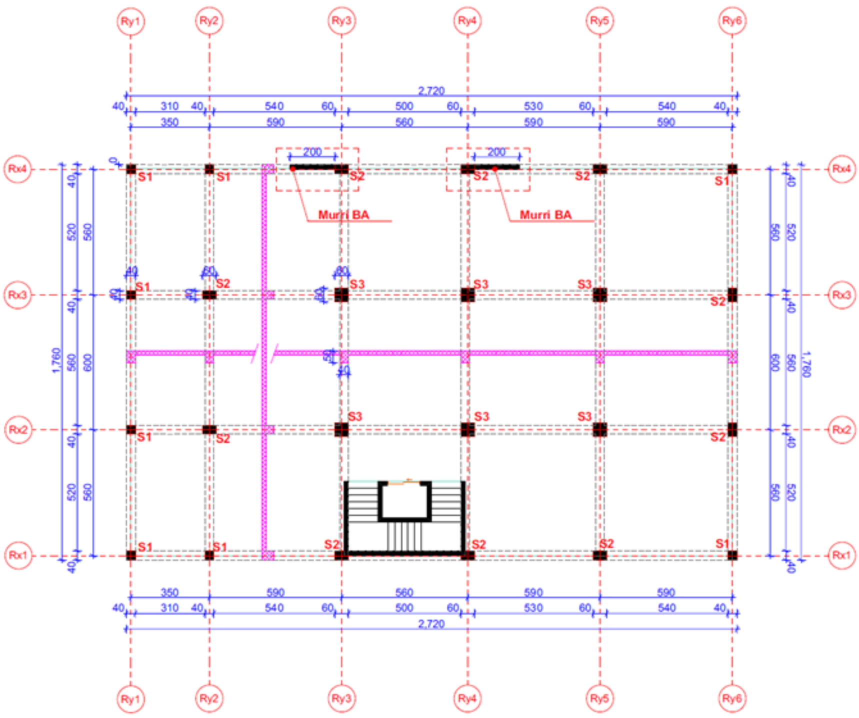



**Figure 10.** Structure plan with seismic walls for case 3 (by author)

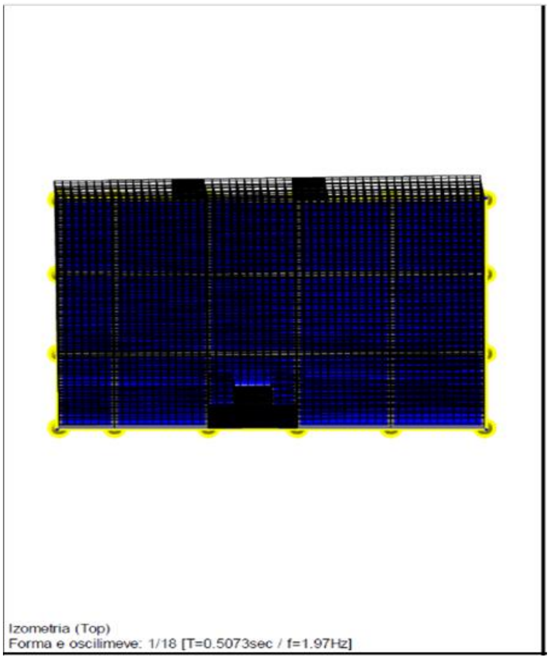



**Figure 11.** The formofoscillationsforcase 2 (by softwarradimpexTower 6)

**Table 3.** Modale analysis, period of tones and frequency for case 3 (by softwarradimpex Tower 6)

| Periudhat e oscilimit të konstruksionit | | |
|---|---|---|
| No | T [s] | f [Hz] |
| 1 | 0.5073 | 1.9714 |
| 2 | 0.5065 | 1.9743 |
| 3 | 0.3098 | 3.2274 |
| 4 | 0.1486 | 6.7304 |
| 5 | 0.1383 | 7.2317 |
| 6 | 0.0938 | 10.6650 |
| 7 | 0.0922 | 10.8441 |
| 8 | 0.0891 | 11.2248 |
| 9 | 0.0862 | 11.6024 |
| 10 | 0.0835 | 11.9795 |
| 11 | 0.0813 | 12.3016 |
| 12 | 0.0787 | 12.7029 |
| 13 | 0.0783 | 12.7691 |
| 14 | 0.0781 | 12.8103 |
| 15 | 0.0775 | 12.9055 |
| 16 | 0.0769 | 13.0119 |
| 17 | 0.0766 | 13.0478 |
| 18 | 0.0763 | 13.1055 |

## 6 Comparison:

From the comparison of the obtained results, we notice that the third case is the case which is preferred for dynamic and static accounts as we have pure translational motion, The geometry of the structure in the third case, has an adequate geometry to be able to accept seismic loads. The periods of tones in the third case are almost approximate, as is the frequency, we can conclude that the center of mass almost coincides with the center of gravity. The first major tone is in the Y direction, with a form of pure oscillations.

**Table 4.** Comparison for the three cases (by author)

| Comparison of the dynamic analysis for the three cases examined | | | |
|---|---|---|---|
| The case of dynamic analysis | The number of tones | Period [T] | Frequency f[Hz] |
| The first case | 1 | 0.5833 | 1.7145 |
| | 2 | 0.5071 | 1.9718 |
| | 3 | 0.3106 | 3.2195 |
| The second case | 1 | 0.5577 | 1.7932 |
| | 2 | 0.4899 | 2.0410 |
| | 3 | 0.3066 | 3.2615 |
| The third case | 1 | 0.5073 | 1.9714 |
| | 2 | 0.5065 | 1.9743 |
| | 3 | 0.3098 | 3.2274 |

## Conclusion

From the analyzed cases we can conclude that adequate structure modeling has a key role against seismic impacts. The geometry of the structure is very important for the seismic design of buildings built in rows.

The design of residential buildings in rows is the adequate solution for the use of space, but special attention should be paid to horizontal displacements by seismic loads, to determine the expansion joint.

Placing diaphragms from reinforced concrete in special places to achieve consistency of the center of mass and stiffness to have pure translational movements, sometimes presents architectural problems in terms of aesthetics, so it is reasonable to do a more detailed analysis detailed to find a suitable solution both structurally and architecturally (aesthetically).

## References

[1]. EN 1998-1 (2004) (English): Eurocode 8: Design of structures for earthquake resistance – Part 1: General rules, seismic actions and rules for buildings [Authority: The European Union Per Regulation 305/2011, Directive 98/34/EC, Directive 2004/18/EC]

[2]. Chopra, A. K., “Dynamics of Structures: Theory and Application to Earthquake Engineering”, Prentice-Hall, NewJersey, 1995.

[3]. Chopra, A. K., “Dynamics ofStructures: TheoryandApplication to Earthquake Engineering", 2nd Ed, Pearson Prentice Hall, Upper Saddle River, New Jersey, 2007

[4]. Enis JAKUPI, Liljana DENKOVSKA, Elena DUMOVA-JOVANOSKA, Seismic Vulnerability Of Rc Buildings In Polog Valley, International scientific journal “Micro, Macro & Mezzo Geo Information, Volume 5, Pages 004-0.615, Publication date 2015/12, ISSN: 1857-9000 (printed version), 1857-9019 (electronic version).

[5]. EnisJakupi, Definition of seismic vulnerability of existing residential buildings and buildings for family housing in Polog Valley, International Journal of Scientific & Engineering Research, Volume 6, Issue 11, November-2015, PAGES 415, ISSN 2229-5518.

[6]. Enis JAKUPI, Erda BESIMI, Contemporary Architecture In Seismic Zones, Concepts And Realizations, International Scientific Journal “Micro, Macro & Mezzo Geo Information, No.14, Year 2020, Pages 31, Publication date 2015/12,ISSN: 1857-9000, EISSN: 1857-9019

[7]. Jakupi, Enis (2021) Existing Residential Buildings And Family Housing Facilities in the Polog Valley of the Republic of Northern Macedonia With Mandatory Seismic Resistance. Journal of Applied Sciences-SUT, 7 (13-14). pp. 25-33. ISSN 2671-3047

[8]. Enis Jakupi, Festim Ademi, New concepts in the field of seismic-pushover engineering analysis, Journal of Applied Sciences-SUT, Publication date 2015/12, Volume 1, Issue 1, Pages 96-101, ISSN 2671-3047