Earthquake Safety of Masonry and Reinforced Concrete Buildings

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ABSTRACT
In this study firstly residential building typologies of some small-scale cities in earthquake prone areas of Turkey are investigated and 4-storey masonry residential buildings is proposed instead of multi-story reinforced concrete apartment blocks for these cities. Here, it is aimed to enliven the use of masonry again in these regions. To achieve this aim it is necessary to verify the fact that it is possible to construct a four-story residential building with masonry bearing walls instead of reinforced concrete beam and column skeleton system keeping the existing plan scheme in other words without changing its architectural characteristics. In order to do this, 3D models are created to compare the behaviours of the masonry building and reinforced concrete building. The behavioural investigation of the two models is performed in the finite element platform with the help of SAP 2000. Finally it is certified that this proposal is successfully efficient.
Keywords*:* Finite Element Method, Earthquake Safety, Masonry, Reinforced Concrete, Residential Buildings, Structural Analysis.

1. INTRODUCTION

In most countries of the world residential construction is at a turning point. The issues of providing housing for large numbers of people are being replaced increasingly by the concerns improving the quality of housing. In many developed countries of the world, especially in Europe masonry structures are widely used for the construction of residential buildings. Brick and concrete masonry blocks are much popular in these countries, due to the many advantages of masonry. Masonry is therefore still an important construction system due to its architectural and structural properties. From an architectural point of view, masonry offers freedom of layout in spatial design, rich colors and textures, and a striking appearance for façade design. From a structural point of view, the wall system reduces the cost of framing as the enclosing wall is also load-bearing wall. Masonry walls also serve as interior finishing surfaces providing fire resistance, stability and sound insulation. Construction speed, material availability, thermal and sound insulation are other important advantages of masonry as a construction system. Nevertheless, the literature on the use of masonry in earthquake-prone areas is relatively weak and the current studies are mostly on existing structures. The load-bearing capacity of various masonry structures has been investigated by researchers in many previous studies (Er Akan, 2008; Bayraktar et all, 2007; Wipplinger, 2004; Aras et all, 2011; Özmen et all, 2011; Çakır et all. 2016; Çakır et all. 2015). This research is generally concerned with the evaluation of seismic vulnerability of masonry buildings and strengthening techniques for these structures. It goes without saying that stone structures must be preserved in order to preserve the cultural heritage of a country with a long history of civilization. However, while research focuses on this issue, the use of masonry materials in new constructions has been neglected. Despite the advantages of masonry, the majority of Turkey's urban population today lives in multi-storey reinforced concrete block apartment buildings. Masonry has been a traditional building material in many parts of the country, but until recently it was not considered a suitable material for modern housing. Not only in Turkey, but also in many other countries reinforced concrete is considered as a common material for residential buildings. Hence, many researchers have studied RC structures and their seismic performance (Yön et all. 2015;Bayraktar et all, 2011;Sezen et all,2003; Doğangün, 2004; Timurağaoğlu et all.2019; O'Brien et all. 2011; Ait Belkacem et all. 2019).

Due to the development of technology, new building materials are used instead of traditional constructions. Generally, reinforced concrete was used in the era of modernization and people abandoned traditional stone and wooden buildings. The importance of brick and wood was therefore diminished and utilized less than its potential. In fact, in the 1920s, the urbanization problem, which was evident in the capital Ankara, began. In this period, the main strategy after the establishment of the republic was to choose Ankara as the capital. The creation of a new capital for Anatolian regional development was a unique example in world planning experience. Thus, the positive and negative effects of urbanization in Ankara were revealed. In the 1950s and 1960s, the impact of this urbanization process spread from Ankara to neighboring cities. Similar arguments have been made by many researchers on this subject (Keskinok, 2010; Rivkin, 1964; Tekeli, 1980; Altaban, 1998). As a result of this unhealthy phase of urbanization, most of the built environment in the country became reinforced concrete buildings of five or more.

During this period, a vast amount of reinforced concrete apartments were built and all cities looked alike. Many cities in Anatolia began to lose their vernacular architectural characteristics. It did not prevent unhealthy urbanization in the big cities of the country. With the dominance of reinforced concrete buildings, all cities began to resemble each other and lose their originality. During the 1950s, the common attitude could pursue the path of strengthening and modernizing the traditional masonry building instead of investing in reinforced concrete apartments. But the small towns still have hope. This study aims to evaluate the use of masonry structures instead of reinforced concrete buildings in the construction of mid-rise apartment blocs in small towns in a seismic region of Turkey. The hypothesis of this study is that it is possible to construct a four-storey residential building with load-bearing masonry walls instead of a reinforced concrete frame system while keeping the existing floor plan. Thus, this hypothesis was confirmed by the numerical simulation method. The purpose of these analyzes is to show that four or five-storey reinforced concrete apartments can be built as masonry without any modification, instead of showing masonry buildings have superior seismic resistance. Therefore, the research should also contribute to the comparative general understanding and perception of the architectural features of masonry and reinforced concrete structures.

1.1. Residential Building Environment of the Small-Scale Cities in Turkey

Currently, most of Turkey's urban population lives in multi-storey reinforced concrete blocks. Statistics from the National Institute of Statistics (DIE) on the construction of urban housing indicate that more than 50% of existing buildings in the three largest cities (Istanbul, Ankara and Izmir) are reinforced concrete frame structures and among them, 75% are more than three storeys. Therefore, 80% of urban households live in these medium-sized apartments. In recent years, medium- and high-rise reinforced concrete houses have become more dominant (Erdik and Aydinoglu, 2002). Changing living conditions and technological developments aim to move people towards increasing housing construction with ideas that are signs of modernity. For this reason, cities and towns do not reflect their own characteristics. As shown in Figure 1, in urban areas the ground floor of most of the framed buildings was occupied by commercial establishments or offices.

In multi-functional contemporary buildings residential, commercial and office functions exist in the same building. The ground floor reached a height of 4-5 meters, significantly exceeding the height of the upper floors. The frame filling on the inside of the ground floor was either not provided or had a much lower stiffness than the one on the floor above. These apartments are often irregular with lots of projections and indentations with a lack of proper engineering. To illustrate the effects of these restrictions and the results of unconscious experimentation, this study examined the building typologies of several small towns in earthquake-prone areas such as Bolu, Cankırı, Corum, Duzce, Kastamonu and Kırkkale (Figure 2).

Figure 1 Trade Occupancy or Offices on the Ground Floor (Kırıkkale and Düzce)

These cities are closely associated with their proximity to the capital, Ankara, and have suffered the highest levels of urbanization impacts. Thus, for Ankara, the negative and positive effects of the urbanization process can be seen in the features of the built environment. Field surveys show that although these cities are located in seismic areas, their residential building stock consists mainly of multi-story reinforced concrete houses. The safety of reinforced 0concrete apartment buildings is still in question as recent earthquakes have degraded their performance. The weight of these buildings killed about 80,000 people in Turkey's earthquakes in the last century. In fact, low-rise buildings made of lightweight materials are more effective at keeping people away from the devastating effects of earthquakes. However, reinforced concrete high-rise buildings are still being built as the focus is on financial gain rather than building safety. The limits of the City Planning Code (Turkey Land Development Planning and Management Act, 1985) and the Turkish Earthquake Code (TDY 2007) also contribute to this standardization.

As a result, the built environment exhibits the same characteristics in almost all settlement areas across the country. The buildings do not reflect the vernacular architectural characteristics that once prevailed.

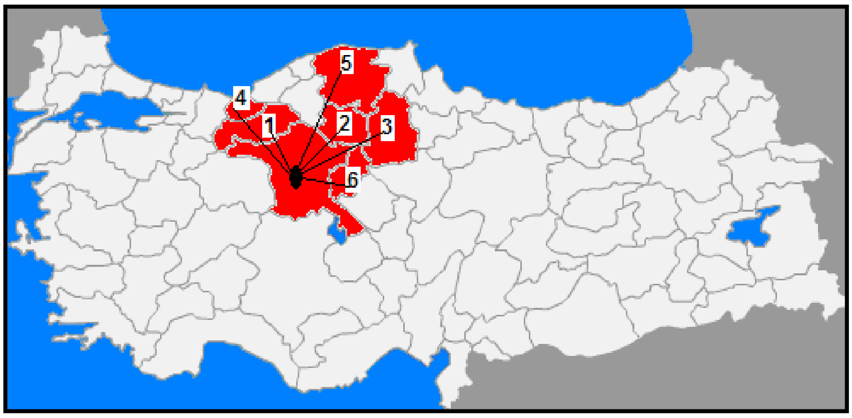


Figure 2 1-Bolu, 2- Çankırı, 3- Çorum, 4- Düzce, 5- Kastamonu, 6- Kırıkkale

1.2. Seismic Performance of Residential Buildings in Turkey

Turkey which is in the Alp Himalayan seismic zone has a long history of big-scale earthquakes. Also, most of the country lies on the Anatolian plate, which lies between the Eurasian, African, and Arabian plates. The Erzincan earthquake of 1939, the Kocaeli earthquake of August 17, 1999, and the Duzce earthquake of November 12, 1999, are the greatest natural disasters of the 20th century in Turkey. Especially the last one in 1999, caused significant damage to the region which's housing stock, most of which are reinforced concrete houses, and to the economic life whole country since it was the industrial center of Turkey.

Although, well-designed buildings suffered less damage; the structural framework of the damaged buildings was generally irregular and poorly detailed, and even buildings over five stories did not use shear walls. There is also an important relationship between the number of floors and the degree of damage to the building. The most critical buildings against earthquake disasters are the five-storey to his eight-storey reinforced concrete buildings (Sucuoğlu and Erberik, 1997). All other considerations aside, the real tragedy of the 1999 earthquake was that the poorly engineered buildings killed 17,000 people when their homes collapsed.

M. Erdik et al. conveyed that unlike other earthquakes in developing countries, most people affected by earthquakes in turkey were upper-middle class living in multi-story apartment buildings with compromised building quality. (Erdik and Aydinoglu, 2002). Consider examples found in the literature, high vulnerability can be criticized, especially when:

- Unfortunately, the building construction system in Turkey leads to poor construction quality.
- Chronically high inflation, accompanied by high real interest rates, is the biggest problem of the industrialization of the mortgage market, large housing projects, and residential construction.
- Affordable housing is in demand in every city due to high levels of industrialization and urbanization.
- Even the total number of existing housing units exceeds the capacity of local governments to regulate and monitor them.
- Much of the demand was met by the construction of five to six storey reinforced concrete buildings by local contractors with imprecise engineering and poor construction often run without a municipal controlling system.
- The constructive sectors and institutions suffer from lack of integration and planning.

Furthermore, Özmen and Ünay explain the problems behind the seismic performance of buildings in the following general classification (Özmen and Ünay, 2007).

- A universal lack of knowledge of the sciences related to earthquake engineering.
- The indifference of the public and some members of the engineering and architectural community to earthquake risk.
- Ignoring geological and geotechnical conditions when selecting urban settlements under rapid and undisciplined urban growth.
- Structural deficiencies in masonry buildings due to a general lack of understanding of this construction system and poor quality of construction.
- Structural deficiencies in reinforced concrete buildings are being constructed everywhere and of all sizes, from remote villages to large urban settlements.

Therefore, the lessons learned from previous catastrophic earthquakes, revealed several architectural design defects, such as problematic geometric configurations, insufficient lateral stiffness, and problems in architectural detailing. In particular, the regularity in plans is one of the most vital considerations in earthquake-resistant architecture. Regular plans always have better seismic performance than irregular plans. For example, if the columns are organized according to an axial system and evenly distributed in each direction of the earthquake, the lateral stiffness of the building will be high and displacements will be limited (Tuna, 2000).

In brief, residential blocks located in earthquake-prone areas present several structural and architectural problems and, there is a lot to do in all respects of earthquake-resistant architecture in Turkey. As an earthquake-prone country, Turkey first needs to have a clear understanding of earthquake risks and the need for precautions against an earthquake, hence, to revise its building codes and regulations. After all, the construction process is made up of multiple people: architects and engineers, owners, builders, inspectors, material suppliers, and even local schoolteachers. Therefore, good teamwork among these people is required to make an earthquake-resistant built environment.

The second important issue is the lessons to be learned from the earthquake safety of traditional Turkish houses. Until the 1999 earthquake, society believed that modern materials were superior to traditional seismic materials. Therefore, the adaptation of reinforced concrete has been rapid. In 1999, the superior earthquake resistance of traditional buildings changed this idea and increased the public's interest in traditional construction systems. Thus, innovative construction systems using traditional materials as an alternative solution to reinforced concrete blocks began to be considered. As recent earthquakes have shown, traditional Turkish architecture has taken different approaches to earthquake risk. Therefore, while a few reinforced concrete buildings remained standing after the earthquake, most of the traditional buildings survived successfully. Therefore, understanding both the positive and negative aspects of traditional building practices can assist in designing earthquake-resistant buildings. Architects should try to learn from the past for today's buildings by studying vernacular construction techniques.

Despite its inherent properties and advantages as a building material such as seismic resistance, economy, and new job opportunities, the use of masonry materials in contemporary constructions seems to be neglected. In the design process, the geological features of the site, soil characteristics, height of the building, configuration of the structure, lateral and vertical loads, etc. are considered. Among these, the choice of structural system is one of the most important parameters, which strongly depends on the geographical location of the building, the local characteristics of the site, and the local conditions.

This study shows that a four-storey RC residential building can be constructed with masonry load-bearing walls instead of a reinforced concrete frame system by preserving the existing floor plan, and without changing its architectural characteristics. This is not a proposal for residential blocks with commercial units on the ground floor on the main avenues, but only for classical residential units of four floors or five floors on side streets. As a result, an attempt was made to demonstrate the use of masonry materials for the main structural system of a housing block unit without compromising either the safety or the design of the building. For this purpose, a typical RC apartment block in Bolu is chosen. Two distinctive models (using brick masonry and reinforced concrete frame system) are produced in the same floor plan of this four-story residential building. All the architectural design features of the houses chosen in Bolu are preserved in the creation of the structural model. The commercial structural analysis software Sap 2000VRS10 is used to generate finite element models of the buildings. The purpose of these analyzes is to test the proposal by using digital simulations. Next, we compare the analysis results for the modal displacements and internal forces due to gravity and seismic forces. A comparison of the results showed that the hypothesis of this study is confirmed.

2 GEOMETRIC AND MATERIAL CHARACTERISTICS OF THE SELECTED BUILDING

A four-story apartment building with a regular geometric shape is chosen as a case study because it is the typical plan scheme used for reinforced concrete apartment buildings in the cities visited. Two different digital structural models are generated from the original dimensions of the same architectural drawing which will be abbreviated in the following manuscript as: Reinforced concrete (RCA) apartment model or brick (BMA) apartment model.

Both models have a 12m x 22m rectangular floor plan configuration as shown in Figures 3 and 4. Both structures have a height of 14.5m from the foundation level to the top, and both RCA and BMA use 150mm thick reinforced concrete slabs.

First, a 3D model of the RCA is created based on the actual cross-sections of all elements of the frame system to obtain accurate load-bearing behavior. The RCA has four different column sections: 25 x 100 cm, 250 mm x 2000 mm, 500 mm x 500 mm and 400 mm x 600 mm (Figure 4). These columns are modeled with frame elements and the structural floors are modeled with shell elements. The second model of NMA was created with the same geometry and architectural features. But this time, instead of a reinforced concrete framing system, there are 300 mm thick brick walls (Fig. 4).

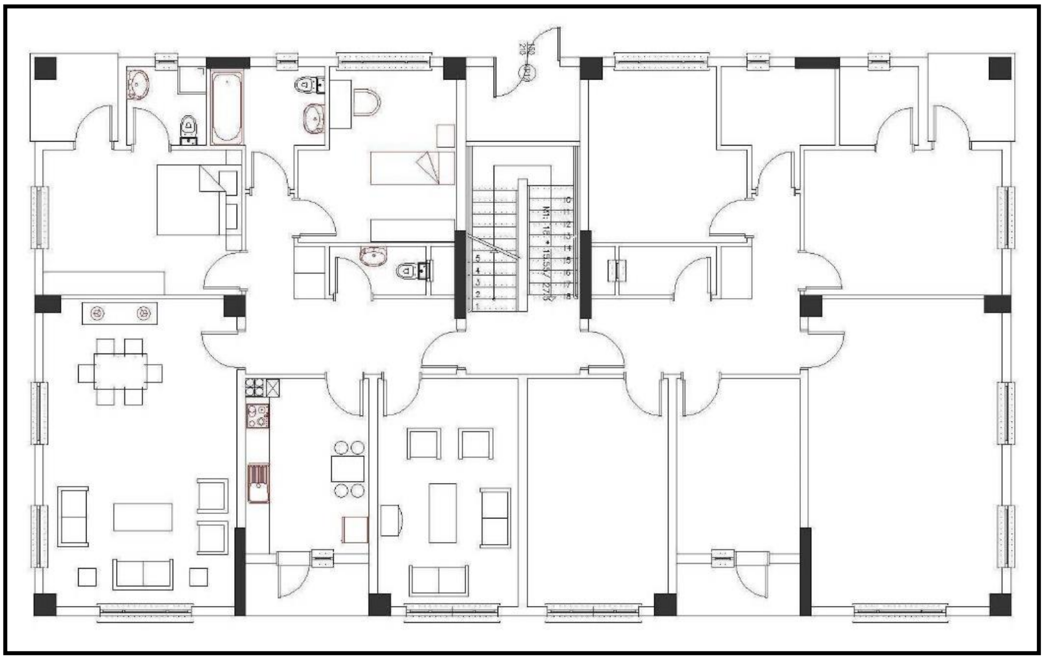


Figure 3 Reinforced Concrete Apartment Model (RCA)

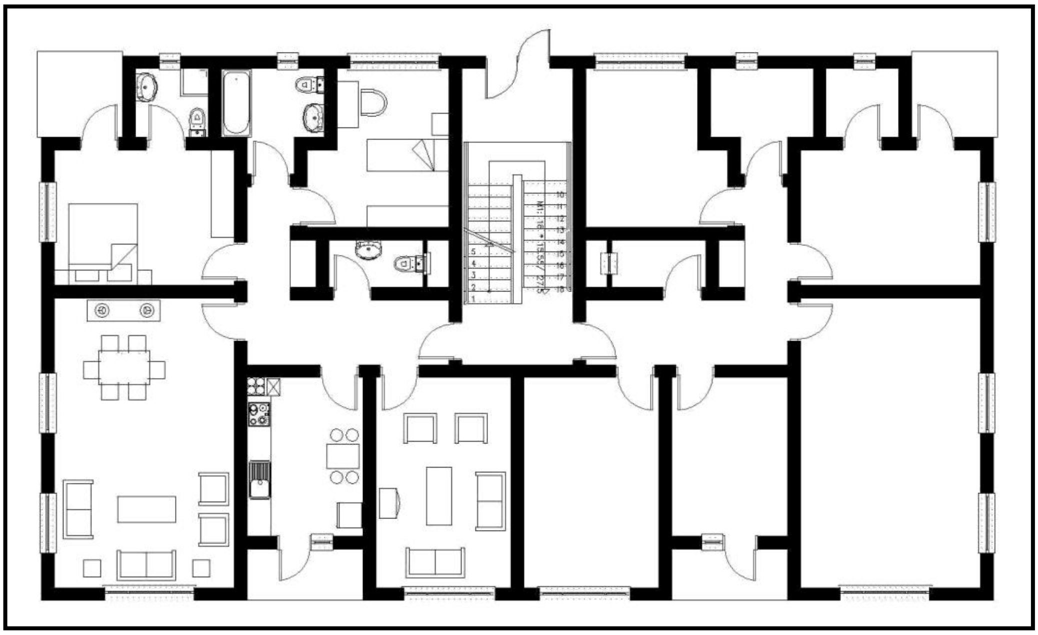


Figure 4 Brick Masonry Apartment Model (BMA)

3 FINITE ELEMENT ANALYSIS OF THE SELECTED HOUSING UNITS

3.1 Description of the Finite Element Method

The structural analysis became easier after the development of computers and new numerical methods. Finite element analysis (FEA)which is used to evaluate systems and structures, is an analytical engineering tool developed in the 1950s. In theory, the finite element method (FEA) can find approximate solutions to all kinds of engineering problems involving many complex variables. The FEA method which is continuously evolving is used in these days to analyze complex structures with different geometries, materials, and loading conditions by many engineers. This method, with the help of developing computer technology, uses integral calculations, very large matrix arrays, and mesh diagrams for the calculation of stress points, deflections, and movements of loads and forces; and compares the results with the given loading limits.

The finite element method (FEM) is based on the demonstration of structures in two or three dimensions with a finite number of lines called finite elements. The joining points of the lines are called nodes. By this way, the problem with an infinite number of degrees of freedom is converted to one finite number. Stresses and displacements are calculated for each finite element and these results are applied to the entire structural model (Toker, 2000 and Ünay, 1997). That is, the analysis is done by modeling the structure by decomposing it into thousands of smaller parts or elements (finite elements) which is called "discretization". In this method, the precision of the analysis depends on the number of elements used in the model, therefore, it is limited to computer applications since even simple elements require computational effort. Nevertheless, for a large and complex structure, idealized to many small finite elements, the computation time can be excessive. Therefore, the analysis of complex structures usually forces more computational power in FEM (Tüken, 2004).

3.2 Description of the Finite Element Model of the Selected Building

To confirm the validity of the proposed method, the models are tested with finite element analysis by using the structural analysis software Sap 2000 (Sap 2000, 2000). Digital models are created based on the actual geometry and cross-sectional dimensions of the structural elements. The first model is a reinforced concrete housing model (RCA) consisting of 360 shells, 408 frames, and 477 joints. Figure 5 shows a 3D view of the RCA model.

Meanwhile, the other digital model is created using load-bearing brick walls instead of reinforced concrete frames (Figure 6). This BMA model consists of 12400 shells and 11913 joints. Table 1 shows the identical load patterns applied to both models of RCA and BMA and the values used during structural analysis. In both cases, three different loadings are used. The first (L1) is the total load, which consists of dead and live loads. The second load (L2) and the third loads (L3) are seismic loads effects respectively in the x and y directions. Two different load combinations are defined to evaluate the analysis results: first, G+EQx (self-weight + dead load + seismic load in x direction) and second, G+EQy (self-weight + dead load + seismic load in y direction).

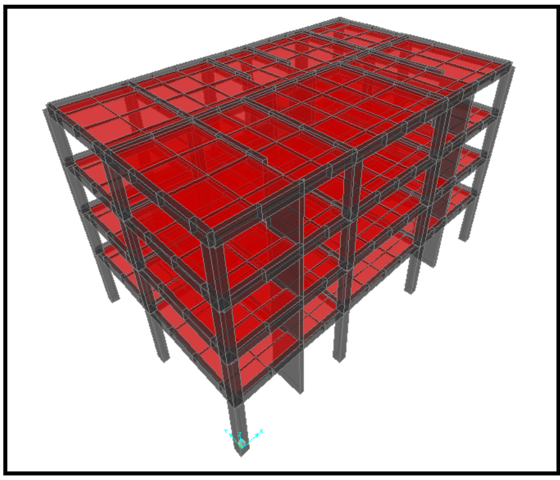


Figure 5 Finite Element Model of RCA

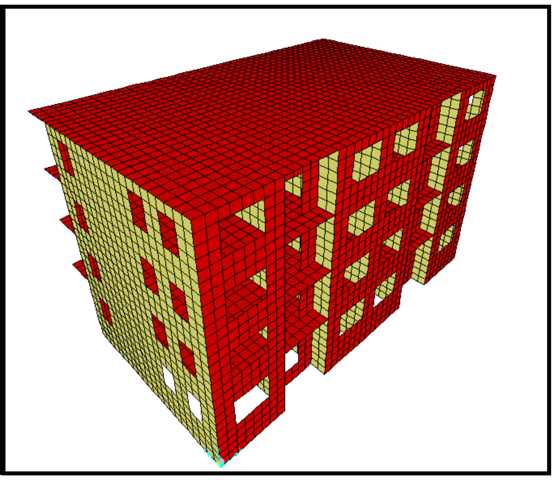


Figure 6 Finite Element Model of BMA

Table 1 Values Used in the Computer Analyses

Property of walls	For BMA Model	For RCA Model
Material	Brick	Reinforced concrete
Thickness (cm)	30	20
Modulus of Elasticity, E (KN/m2)	3500000	28500000
Shear Modulus (KN/m2)	1458333.3 brick walls 11875000 RC slabs	11875000
Weight per unit volume (kN/m3)	15 (for brick walls)	25 (for columns)
Weight per unit volume (kN/m3)	100 (for slabs)	70 (for slabs)
Mass per unit Volume	1.5291 (15/9.81) (brick walls)	7.1356 (70/9.81) (slabs)
Mass per unit Volume	10.1937 (100/9.81) (RC slabs)	2.5484 (25/9.81) (columns & beams)
Poisson's Ratio	0.2	0.2
Column Sections (mm)	-	250/2000 250/1000 500/500 400/600
Beam Sections (mm)	-	250/600
Property of slabs	Masonry	Concrete
Material	Reinforced concrete	Reinforced concrete
Thickness (mm)	150	150
General Characteristics	Masonry	Concrete
Number of Storey	4	4
Total Height (m)	14.5	14.5
Building Type	residential	residential
Project Parameters of the Buildings	Masonry	Concrete
Project of the building	Not Exist	Exist
Earthquake Zone	1	1
Soil Class	2	2

3.3 Methodology for the Comparison of the Analysis Results

As a methodology for the analyses, the results of RC and masonry are compared with each other in order to find out if the case housing unit can be built with a masonry construction system. The parameters chosen for this comparison are modal periods, displacements, and internal forces (moments, axial forces, and stresses).

Modal Periods: The first parameter is the mode period, which also affects the displacements within the structure. In fact, real-world builds have an almost infinite number of mods. But in practice, calculations are not concerned with all of the modes. As Atımtay conveyed, the natural period is related to mass, lateral stiffness, and energy absorption of the structure. These properties are determined by the geometric form of the structural elements ad the structure itself. In other words, it is mainly related to architectural preferences (Atımtay, 2001).

As the number of modes increases, the modally deformed shape becomes more complex. This is because of different combinations of node transformations. For normal buildings, the number of modes considered is usually three or four. Therefore, three modes of the model are obtained in this research. This modal validation compares the modal deformation geometry of SAP2000. Examination of Table 2 reveals that the first three modes are strong and weak deformations, as well as torsional effects. One of the expected behaviors of this type of masonry structure (BMA) is the low modal period. The results confirm this expectation. Also, the calculated modal period of BMA is lower than that of RCA.

Displacements: Displacement is an important variable for evaluating structural behavior. Because it helps show how the geometry of the element and the original position of the connections change under this particular load. There is a certain limit to the amount of displacement, not only from a static point of view, but also from the usage conditions. If the value obtained for the displacement exceeds the limit; the failure is not always due to structural defects, but also due to functional defects. Displacement is a parameter for understanding physical problems occurring in structures. Therefore, you can compare the displacements of the BMA and RCA models under seismic forces to get an idea of the structural differences between the two models.

Moments, Axial Forces and Stresses: The final parameter used in this study is internal force. Moments and axial forces and stresses. Like displacement, internal forces also have limits. At the end of the verification, it should be checked if the internal forces are within limits or if there are any possible failures due to the structure. Therefore, this study analyzes and validates the load-bearing elements under seismic force. By this way it is aimed to observe the relationship of current behavior to the expected capacitance of that element in the structure and understand how much the structure's capacitance is used in its shape and dimensions. Thus, moments and axial forces appeared on the supports of the RCA model compared to the M–N graphs drawn by Response 2000 (Response-2000, 2001) defining the limits of these supports. For the BMA model, the maximum stresses (compression and tension values) are compared with the allowable stresses defined in the Turkish Seismic Code.

4 Analysis Performed with Finite Element Model

As mentioned above, the analysis of the two models is performed according to the load combinations. The results of the analysis are annotated with mode shapes, stresses and internal forces according to the graphical output from Sap 2000 as shown in Tables 2 through 7. According to the modal analysis, the times are T1=0.220 s, T2=0.200 s, T3=0.173 s for the BMA model, but these values are T1=0.702 s, T2=0.466 s, T3=0.443 s for RCA model. The displacement of the BMA model is measured as Δx= 12.4 mm for EQx loads and Δy= 11.9 mm for EQy loads, as shown in Table 3.

For the RCA model, the displacement is measured as Δx=142.2 mm for EQx loads and Δx=639 mm for EQy loads. The results show that the observed displacement in the RCA model is larger than that in the BMA model. The stresses determined for the BMA model are then compared with the allowable stress values given in the Turkish seismic code. The allowable stress value for bricks in the code is 0.8 Mpa (800 KN). This value is increased by a factor of 3 for comparison. Assume fem= 0.8 × 3 = 2.4 Mpa.(2400 KN). The BMA model is shown in the table below.

Tables 3 and 4 show the compression and stress distributions for the BMA model. The locations of the regions of maximum tension and compression are shown in the diagram (Table 5). The maximum tension and compression values of the BMA model are on the conservative side according to seismic code limits. Moment (M) and axial force (N) diagrams are generated by Response 2000 software by defining the column volume that controls the safety of the RCA model (Response 2000, 2001). The RCA model has four different column sections as shown in Table 1. M-N interaction diagrams were formed for each compared to the actual M and N values obtained from the analysis in SAP 2000. Comparison results showed that all the actual moments and axial forces in the supports were not on the safe side (Table 6-7)

Table 2 Mode Shapes of BMA Model and RCA Model

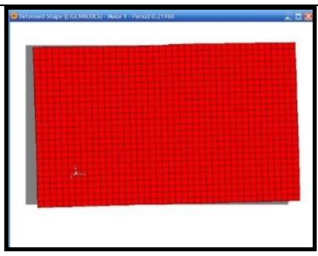
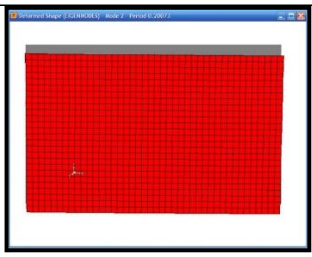
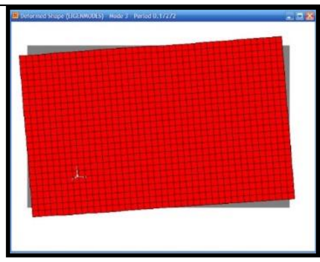
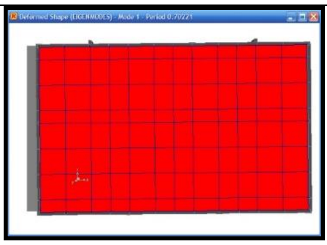
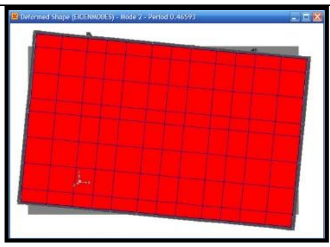
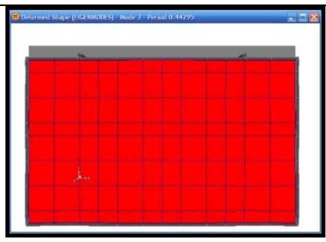
	Mode 1	Mode 2	Mode 3
BMA Model	 T= 0.21966 sec	 T= 0.20073 sec	 T= 0.17272 sec
RCA Model	 T= 0.70221 sec	 T= 0.46593 sec	 T= 0.44295 sec

Table 3 Displacements under EQx and S12-S22 Diagrams under G+EQx in BMA Model

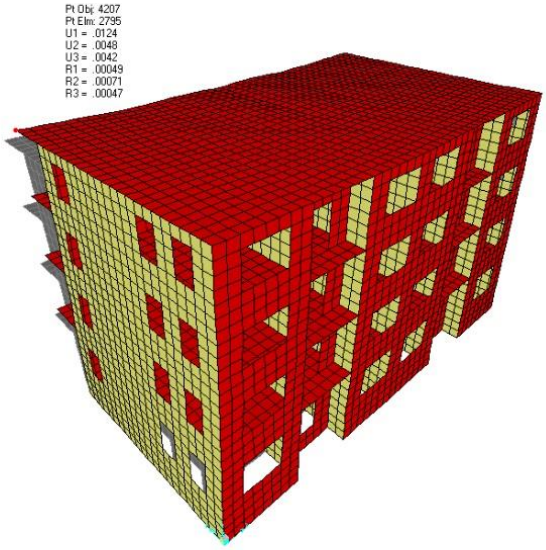
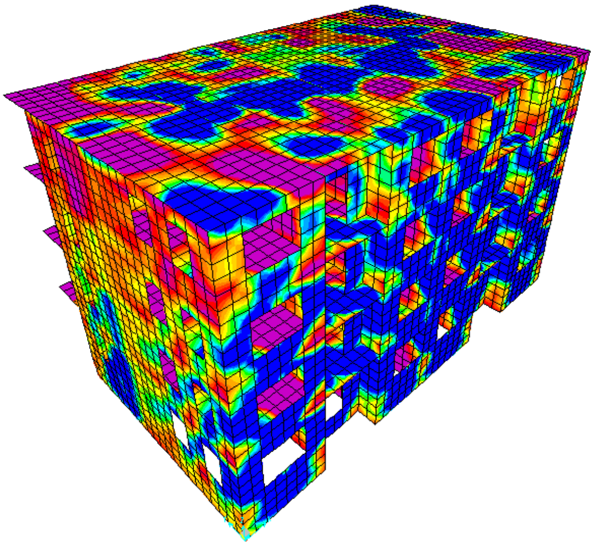
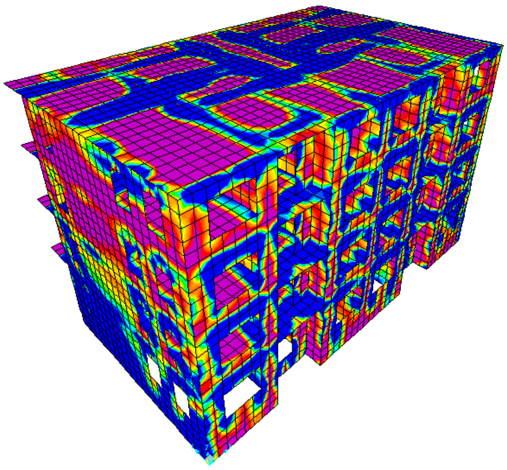
<table>
<tr><td>Deformed Shape
under EQx
U1= 12.4 mm
U2= 4.8 mm
U3= 4.2 mm
R1=0.00049 rad
R2=0.00071 rad
R3=0.00047 rad</td><td>
</td></tr>
<tr><td>S12 (In- plane shear stress) Diagram under G+ EQx</td><td></td></tr>
<tr><td>S22 (In- plane direct stress) Diagram under G+ EQx</td><td></td></tr>
</table>

Table 4 Displacements under EQy and S12-S22 Diagrams under G+EQy in BMA Model

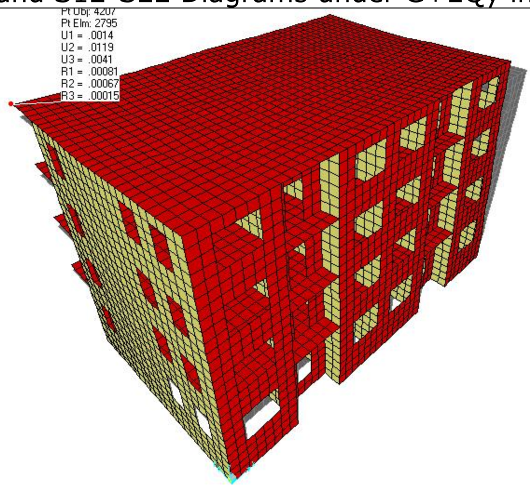
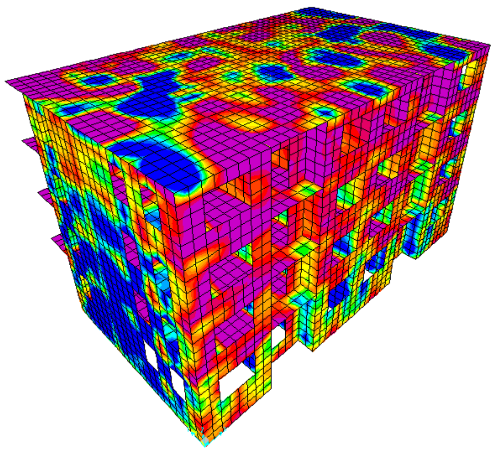
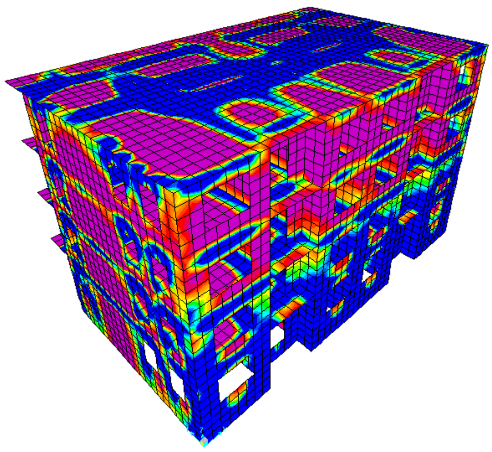
Deformed Shape under EQy U1= 1.4 mm U2= 11.9 mm U3= 4.1 mm R1=0.00081 rad R2=0.00067 rad R3=0.00015 rad	
S12 (In- plane shear stress) diagram under G+ EQy	
S22 (In- plane direct stress) diagram under G+ EQy	

Table 5 Max. Compression and Tension Areas under G+EQy

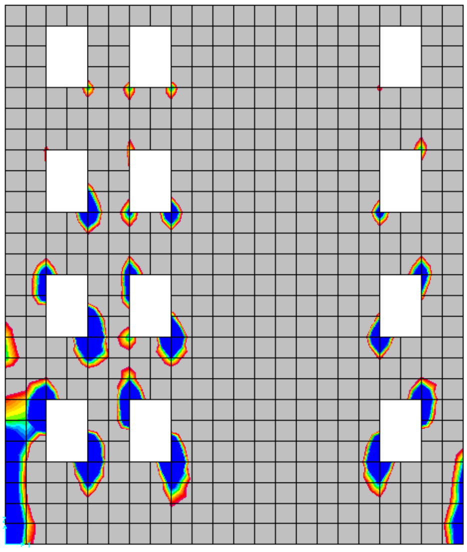
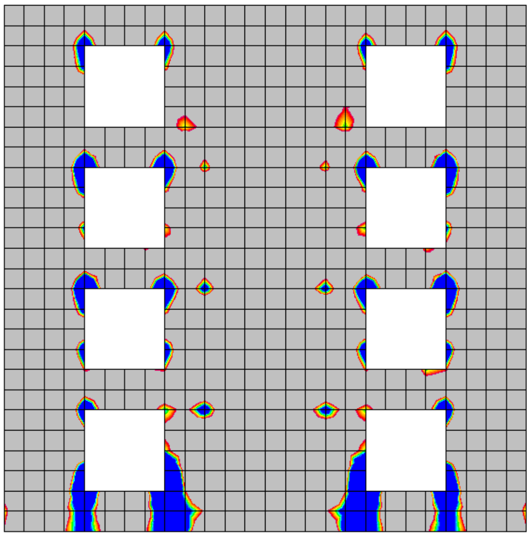
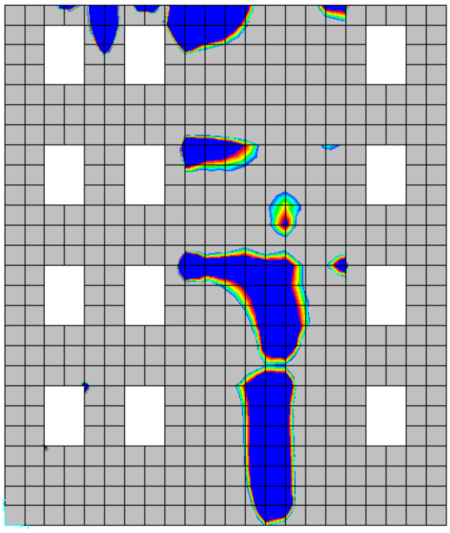
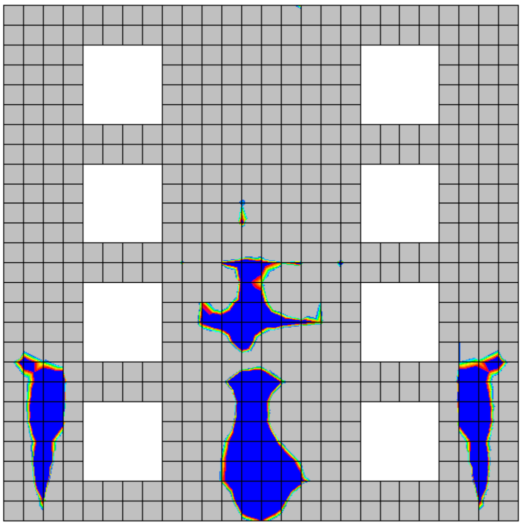
Max. Compression and Tension Areas under G+EQy	Max. Compression and Tension Areas under G+EQx
	
Tension areas in Wall 1 under G+EQy according to S22 Diagram	Tension areas in the Wall 6 under G+EQx According to S22 Diagram
	
Compression areas in Wall 1 under G+EQy according to S22 Diagram	Compression areas in the Wall 6 under G+EQx According to S22 Diagram

Table 6 Displacements under EQx and S12-S22 Diagrams under G+EQx in RCA Model

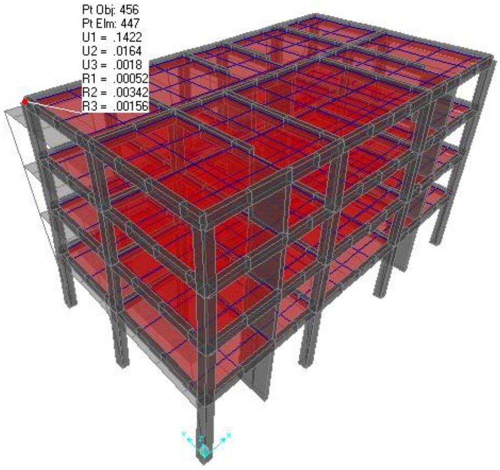
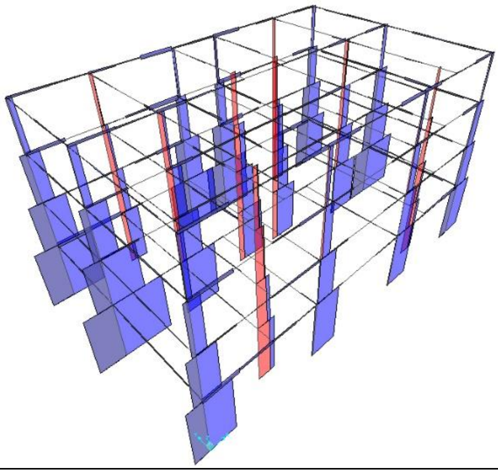
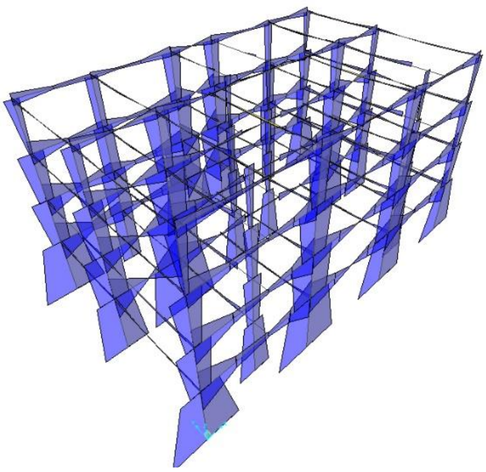
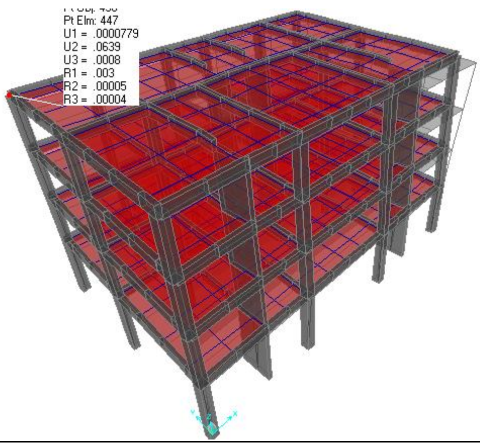
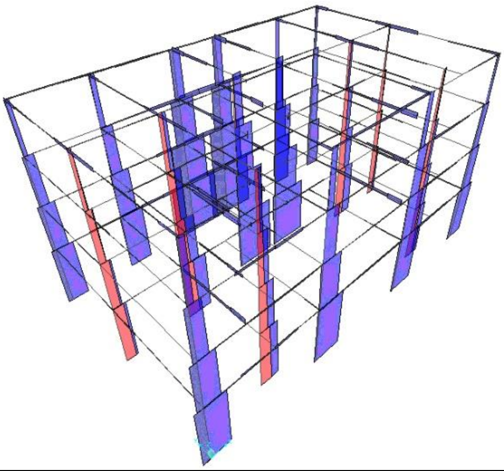
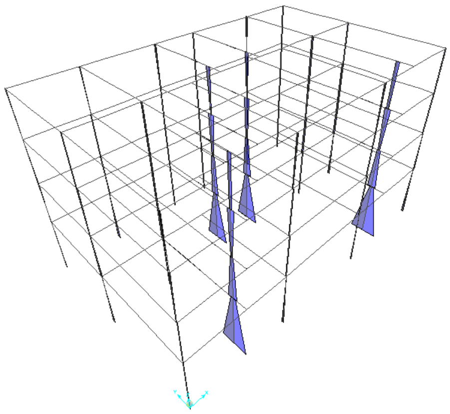
Deformed Shape under EQX U1= 142.2 mm U2= 164 mm U3= 1.8 mm R1=0.00052 rad R2=0.00342 rad R3=0.00156 rad	
Max Axial Force in the columns -1755.477 KN In the Column 500mm × 500 mm	
Max Moment in the Columns 10358.5526 KN.m In the Column 250 mm × 2000 mm	

Table 7 Displacements under EQy and S12-S22 Diagrams under G+EQy in BMA Model

Deformed Shape under EQY U1= 0.0779 mm U2= 639 mm U3= 0.8 mm R1=0.003 rad R2=0.00005 rad R3=0.00004 rad	
Max Axial Force in the columns -2776.500 KN In the Column 250 × 2000	
Max Moment in the Column 10358.5280 KN.m In the Column 250 × 2000	

4.1 DISCUSSION OF THE RESULTS

To evaluate the effectiveness of the proposal, the two models are compared in terms of load-bearing behavior under two different load combinations (G+EQx and G+EQy). The following parameters are considered in the comparison:

- modal periods and deformation shapes
- displacement values
- internal forces (moments and axial forces) in the RCA model

- total stress distribution in the BMA model

observations and corresponding conclusions from the analysis. Here are the final comments:

First test the finite element model considering the mode shapes. Modal deformation shapes are obtained in the first three modes using SAP 2000 software. As can be seen from the attached table (Table 2), the observed duration for the BMA model is shorter than that for the RCA model. You can also compare them in Table 8. Thus, verification of the proposal with modal periods is performed.

After validating the model with modal cycles, examine the displacements under lateral loads (under EQx and EQy). Again, the shift of the BMA mode is lower than that of the BMA mode, as seen from the difference in mode period between the BMA and RCA models (Table 8). This is because as the modal period decreases, the directly contributing shift also decreases. Therefore another verification is performed using the result of the displacement.

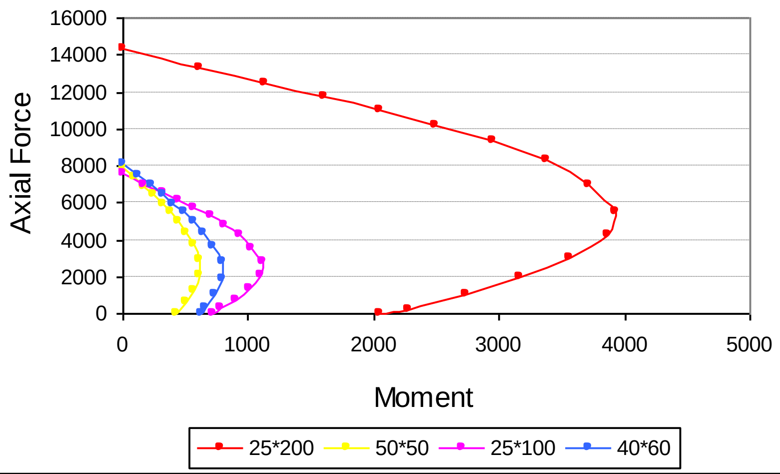
Table 8 Comparison of the Modal Periods and Displacements

Parameters	Masonry	Reinforced Concrete
Mode 1	T= 0.21966 sec	T= 0.70221 sec
Mode 2	T= 0.2007 sec	T= 0.46593 sec
Mode 3	T= 0.17272 sec	T= 0.44295 sec
Displacements Under G	U1= 0.01184 mm U2= 0.2 mm U3= 2.5 mm	U1=0.00001265 U2=0.0004 U3=0.0024
Displacements Under G+EQX	U1= 12.4 mm U2= 4.8 mm U3= 4.2 mm	U1= 142.2 mm U2= 168 mm U3= 2.2 mm
Displacements Under G+EQY	U1= 0.8 mm U2= 14 mm U3= 3.6 mm	U1= 0.09056 mm U2= 643 mm U3= 1.2 mm

Third, the strengths of columns for RCA models are determined using the Response 2000 computer program. This program obtains an M-N interaction diagram that defines the volume of the column. Then, according to the results of the analysis performed in Sap 2000, the moment and axial force of the column under lateral load are determined and compared with the M-N interaction diagram. Comparative results show that the maximum moment and axial force observed for all columns are higher than the maximum moment and axial force that the column can withstand (Figure 7). The values of M and N exceed the capacity of the column (Table 9).

Finally, the brick wall load-bearing capacity (Fig. 8) is determined modally with the BMA. As mentioned above, the allowable stress value in the Turkish seismic code is 0.8 MPa (800 KN). Since fem=0.8×3=2.4MPa, this value is tripled. (2400 KN) compared to the stress induced in the wall. As seen from Table 10, the observed compression values for all walls are below the limits defined by the seismic code. Therefore, this result is used to perform the third check of the proposal.

Table 9 M-N Diagram and Internal Forces in the Columns of the RCA Model



Column Sections (mm)	500 × 500	400 × 600	250 × 1000	250 × 2000
M3 (kN.m)	2450.776 - 2450.772	1499.5049 -1499.5014	858.9034 -858.9072	1160.426 -1160.4284
M2 (kN.m)	849.204 - 824.2121	702.9384 -718.4709	1538.8406 -1597.1862	10358.5526 -10390.1912
P (kN)	1514.854 - 2583.583	1729.077 -3151.389	60.614 -1578.675	192.185 -2776.572
T (kN)	17.1872 -17.1872	13.6177 -13.6176	8.7229 -8.7229	18.2151 -18.215

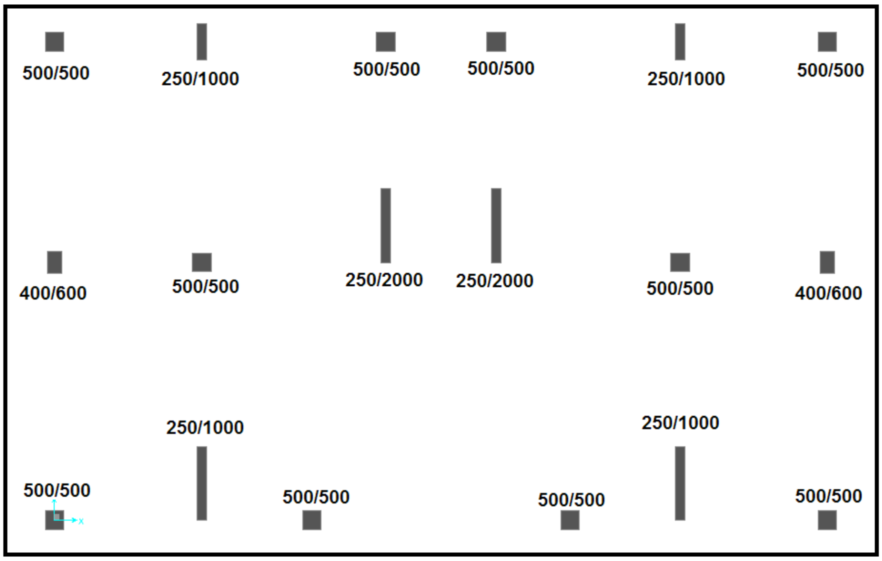


Figure 7 Column Sections in the RCA Model

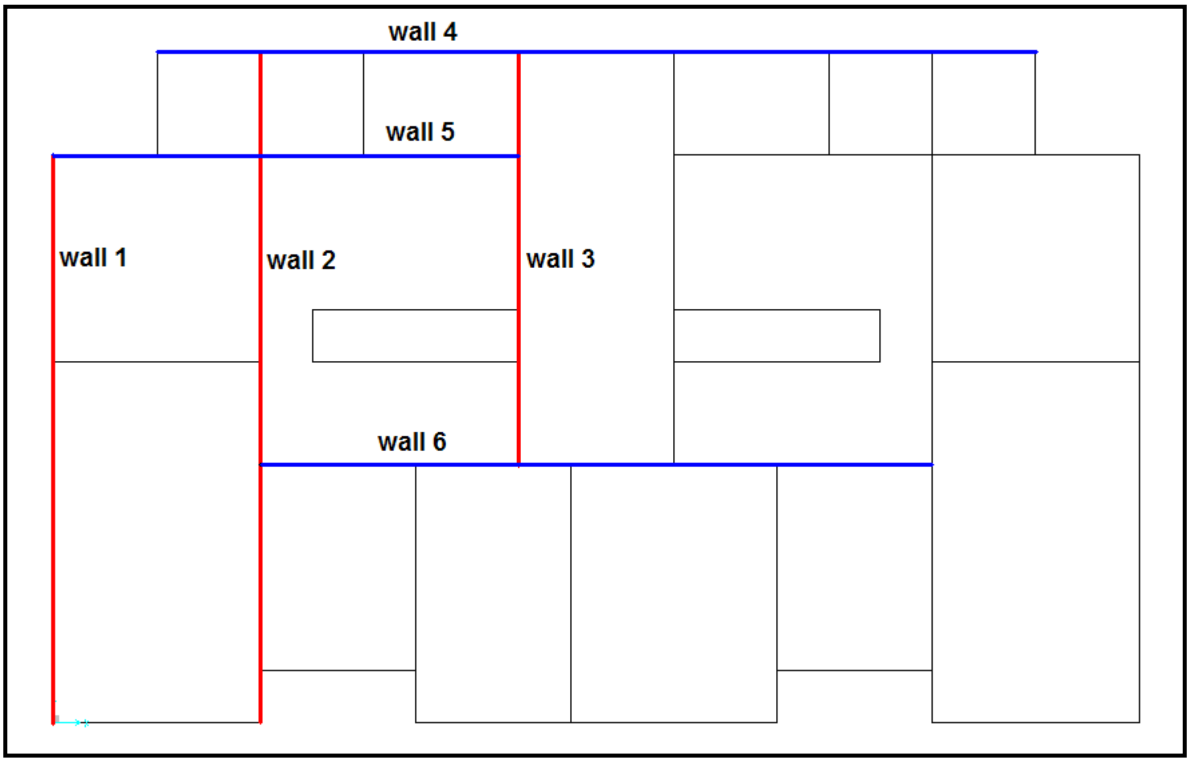


Figure 8 Critical Walls in the BMA Model

Table 10 Compression and Tension Values in the Critical Walls of the BMA Model According to S22 Diagrams

Brick Walls		Under G + EQX kN/m2	Under G + EQY kN/m2
Wall 1	Compression	-616.8702	-453.5958
	Tension	1924.1564	2137.8877
Wall 2	Compression	-571.7892	-617.4399
	Tension	2088.8588	1887.1563
Wall 3	Compression	-334.6284	-466.8790
	Tension	1817.3668	1768.2821
Wall 4	Compression	-212.7229	-71.8243
	Tension	2243.6638	1939.4317
Wall 5	Compression	-370.5247	-409.3414
	Tension	1604.6404	1297.4747
Wall 6	Compression	-558.7612	-530.1447
	Tension	1646.1648	1785.1366

The analysis results highlighted that the used method applied to a 4-storey residential building in Bolu proved to be more effective in reflecting the structure than the reinforced concrete apartment model. In other words, all the parameters used in the comparison have confirmed the proposition. So it can be said that a classic 4-storey apartment can be built using masonry system instead of reinforced concrete without any change in the architectural configuration of the building.

5 CONCLUSION

This study also aims to show the potential of masonry construction systems in Turkey. For this purpose, comparative studies between reinforced concrete frame systems and brick masonry systems were carried out during the research. These comparisons include building materials and reinforced concrete and masonry construction. The results of the study indicate that Turkey has a significant potential for brick production.

In this context, the difference in masonry construction systems for the Turkish state is emphasized. Contribution to the country's economy, creation new job opportunities, acceleration of construction completion time and revival of traditional construction technologies are evaluated as advantages of masonry. To show the difference between masonry and reinforced concrete construction a cost analysis is performed using the typical plan of a three-story building. The cost analysis results highlighted that the construction cost of brick construction is almost half of the cost of reinforced concrete construction. This economic advantage makes masonry an important system for the construction industry in Turkey. In summary, bricks have many advantages as a building material which can be listed as follows:

- The raw materials of bricks can be easily found in Turkey and can only be produced with domestic capital.
- It is a durable material that is not easily affected by environmental influences.
- It has no additives; It is a natural and healthy material.
- Brick is also an eco-friendly material as the waste materials are reused for production. Brick production is labor-intensive, providing job opportunities for many people.

This study also aims to show that bricks can be used instead of reinforced concrete in the construction of 4-5 storey residential buildings in small towns in Turkey. To verify this proposal, a typical 4-storey reinforced concrete residential building is selected in Bolu. Then, two separate digital models (using reinforced concrete and masonry) were created using the original dimensions of the architectural drawings.

The finite element method, which is the most powerful and suitable tool for structural analysis, was used to analyze these two models, and the SAP 2000 computer program was used to perform the analyses.

To evaluate the validity of the proposal, the two models were compared under two different load combinations (G + EQx and G + EQy) in terms of structural behavior. During the comparison, the following parameters are considered:

- Modal periods and deformed shapes
- Displacement values
- Internal Forces (Moment and Axial Forces) of the RCA model
- Overall stress distribution of BMA model

According to these parameters, the main observations and corresponding conclusions drawn from the analysis results are summarized as follows:
deformed shapes and modal periods: The results of the modality analyzes demonstrate that the periods observed in the BMA model are lower than those of the RCA model. The difference is on the order of 0.48255 s. The modal interval is an important parameter because it is one of the dynamic properties of the structure and the response of the structure to dynamic loads can be controlled with modal time. As a result, the BMA model has better underload response than the RCA model. This is the first step taken to verify the proposal. Therefore, the modal intervals and distortions of the analyzes confirmed this proposition.

Displacement values: In the second step, displacements in the x, y and z directions at the position of maximum deformation of the models are measured. In gravity analysis, the displacement of the BMA and RCA models is U1 = 0.01184 mm, U2 = 0.2 mm, U3 = 2.5 mm, U1 = 0.00001265, U2 = 0.0004 , U3 = 0.0024. In the case of load combination analysis (G + EQx and G + EQy), there is a larger difference between the displacements of the BMA and RCA models. The displacements in G + EQx are (for BMA) U1 = 12.4 mm, U2 = 4.8 mm, U3 = 4.2 mm and (for RCA) U1 = 142.2 mm, U2 = 168 mm , U3 = 2.2 mm. According to G + EQy, the displacements are (for BMA) U1 = 0.8 mm, U2 = 14 mm, U3 = 3.6 mm and (for RCA) U1 = 0.09056 mm, U2 = 643 mm, U3 = 1.2 mm. Therefore, as can be seen from the values, the results show that the displacements (in terms of G + EQx and G + EQy) in the BMA model are smaller than the displacements in the RCA model.

Internal forces (axial and moment forces) of the RCA model: In the third step, the capacity of the columns of the RCA model is studied using the computer programs Response 2000 and SAP 2000. Values of moment and axial force are generated in columns obtained from analyzes in SAP 2000. The values are then checked using an M-N interactive graph plotted with Response 2000. Comparison results shows that moments and axial forces appear in columns greater than their capacity.

Global stress distribution of the BMA model: In the fourth step, the stress distributions, S12 (in-plane shear stress) and S22 (in-plane direct stress), in the BMA model are obtained. research. Maximum stress values occur around openings without surprise. However, the numerical values of these stresses show that the maximum stress values are less than the allowable stress values (fem = 0.8 × 3 = 2.4 Mpa) given in the seismic code of Turkey. The analysis results show that the method applied to the construction of a 4-storey residential building in Bolu proved to be more effective in reflecting the structure than the reinforced concrete apartment model. In other words, all the parameters used in the comparison have confirmed the proposal. This paper has presented and discussed selected issues related to structural characteristics and seismic assessment of residential buildings made of brick and reinforced concrete. During the study, the need to introduce the potential of masonry in Turkish conditions was emphasized. Much of the discussion is devoted to the applicability and effectiveness of using brick masonry in the construction of 4-storey residential buildings in Bolu. Its contribution to the country's economy, new employment areas, local architectural features of small towns, construction completion time and training of specialized workers are also mentioned in the article. research.

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