Artvin Çoruh Üniversitesi
Doğal Afetler Uygulama ve Araştırma Merkezi
Doğal Afetler ve Çevre Dergisi

Artvin Çoruh University
Natural Hazards Application and Research Center
Journal of Natural Hazards and Environment

Araştırma Makalesi / Research Article, Doğ Afet Çev Derg, 2019; 5(1): 65-79, DOI: 10.21324/dacd.420168

Situation of the Yukarıköy's Traditional Stone Masonry Houses Affected by 2017 Ayvacık Earthquakes

Ali Rıza Parsa[1], Ali Osman Kuruşcu[2,*]

[1]*Department of Engineering and Architecture, Istanbul Esenyurt University, Istanbul, Turkey. ORCİD: 0000-0001-6642-818X*
[2]*Department of Architecture, Yildiz Technical University, Istanbul, Turkey. ORCİD: 0000-0002-4402-0711*

Abstract

Turkey is considered one of the most earthquake-prone countries in the world. Turkey has hosted many important civilizations in history. Some of the important structures and settlements symbolizing the socio-economic and cultural life of these civilizations have survived to the present day. Located in the rural areas of Turkey, many of the new masonry structures that continue to be constructed under the influence of the structural culture formed by the civilizations are also under the influence of earthquake loads. February-March 2017 Çanakkale/Ayvacık-based earth-quakes caused significant damage to the traditional masonry structures. The region in which Gülpınar based earthquakes took place has a significant historical background. The geography of the region where the earthquake took place hosts different civilizations from the chalcolithic period to the present. The examination of this region is important in that it is an earthquake region as well as having a noteworthy historical background. This study examines the behavior of the masonry structures damaged by the mentioned earthquakes, and the causes of damage. The study also reveals the importance of the architectural design of structures under the effect of the earthquake to its users. In the period of new settlement that will take place after the earthquake, in the light of the analyzes, suggestions have been made in order to bring out the structures that are comfortable, safe, and sustainable, considering the structural culture of the region.

Keywords
Traditional Architecture, Masonry, Earthquake, Damage, Stone

2017 Ayvacık Depremlerinden Etkilenen Yukarıköy Geleneksel Taş Evlerinin Durumu

Özet

Türkiye bir deprem ülkesidir. Türkiye'nin bulunduğu topraklar aynı zamanda önemli medeniyetlere ev sahipliği yapmıştır. Bu medeniyetlerin sosyo-ekonomik ve kültürel yaşamlarını simgeleyen önemli yapı ve yerleşmelerin bir bölümü günümüze kadar ayakta kalmayı başarmıştır. Medeniyetlerin oluşturduğu yapısal kültürün etkisinde yapılmaya devam eden yeni yığma yapıların büyük bir bölümü Türkiye'nin kırsal bölgelerinde yer alırken aynı zamanda deprem yüklerinin etkisi altındadır. Şubat-Mart 2017 Çanakkale/Ayvacık merkezli depremler bu bölgedeki geleneksel yığma taş yapılarda önemli hasarlar oluşturmuştur. Gülpınar merkezli depremlerin gerçekleştiği bölge önemli tarihi geçmişe sahiptir. Depremin gerçekleştiği Bölgenin Coğrafyası elverişli olduğundan, kalkolitik döneminden günümüze kadar farklı medeniyetlere ev sahipliği yapmıştır. Bir taraftan deprem bölgesi olması, diğer taraftan önemli tarihi geçmişe sahip olan bölgenin incelenmesi önemlidir. Bu Çalışma, adı geçen depremlerin etkisinde hasar görmüş yığma taş yapıların depreme karşı davranışı ve hasar nedenleri incelenmiştir. Çalışmada ayrıca, depremin etkisindeki yapıların mimari kurgusunun kullanıcıları için ne derece önemli olduğunu ortaya çıkarılmıştır. Depremden sonra bölgede gerçekleşecek yeni yapılaşma döneminde, bölgenin yapısal kültürü dikkate alınarak konforlu, güvenli ve sürdürülebilir özellikte yapıların ortaya çıkması için analizler ışığında öneriler geliştirilmiştir.

Anahtar Sözcükler
Geleneksel Yapı, Yığma Yapı, Deprem, Hasar, Taş

1. Introduction

Turkey is a country that has various geographical, socio-economic and cultural characteristics. These factors have helped emerge a number of construction systems by also creating an influence on the structures. The economic developments taking place in Turkey and the world have resulted in "the expansion of the concrete frame building systems and the decline of traditional construction systems in Turkey as of 1950s. Thus, the diversity of construction systems among regions has ceased to exist, and buildings with the same type of reinforced concrete skeletal system have been constructed throughout the country"(Yüksek 2015). The disappearance of traditional construction systems has caused construction cultures acquired over centuries to become gradually forgotten. For this reason, the craftsmen who will apply the traditional construction techniques have vanished.

* Sorumlu Yazar: Tel: +90 (212) 3832615 Faks: +90 (212) 3832650
E-posta: aripars@yahoo.com (Parsa A.R), aliosmankuruscu@yahoo.com (Kuruşcu A.O)
Gönderim Tarihi / Received : 01/05/2018
Kabul Tarihi / Accepted : 07/08/2018

However, the problem is not just that of abandoning or forgetting these techniques. A large part of Turkey's lands is under the risk of earthquakes. Since this risk is not taken into consideration, the traditional structures constructed in recent times have been found to get damaged from earthquakes of magnitude 5 and above. The earthquakes occurring in February-March 2017 caused significant damage to the traditional masonry stone structures of Çanakkale/Ayvacık and its surroundings.

This study aims to examine the traditional masonry stone structures damaged by Ayvacık earthquake. For this purpose, the in-place identification of the structural damage that occurred in the area was made. Yukarıköy, the area where the damage was more intensely observed and the life was still going on, was selected as the study area so that the outcomes of the study could be linked to more concrete values.

As the study method, the following procedures were employed to identify the damage on 36 structures, which were the most damaged buildings of Yukarıköy:

• The damage assessment forms prepared by the Ministry of Public Works for traditional masonry stone structures were used (AFAD 2000).

• The damages were examined and documented considering the village development plan.

Based on the causes of the current damage, a solution proposal was developed for the earthquake- resistant traditional masonry stone structures in Yukarıköy.

2. The Features of the Earthquake Impact in Yukarıköy

The earthquake that took place in February 2017 particularly hit the rural areas of the Ayvacık district of Çanakkale. A moderate earthquake, measuring 5.3 on the Richter scale, hit the township Ayvacık of the southern province of Çanakkale, Turkey at 06:51 a.m. local time on Monday, February 6, 2017. The same day at 01:58 p.m. local time, a second moderate earthquake of 5.3 on the Richter scale struck the same province. Only one day later, at 05:24 a.m. local time on Tuesday, February 7, 2017 a third moderate earthquake of 5.2 on the Richter scale crashed into the same province as seen in the figure 1. And then, at 11:55 a.m. local time on Friday February 10, 2017 and at 04:48 p.m. local time on Sunday February 12, 2017; a fourth moderate earthquake of 5.0 on the Richter scale and a fifth moderate earthquake of 5.3 on the Richter scale bump into the Ayvacık (Adanur et. al. 2018). The hypocenter of the earthquakes identified in the framework of earthquake storm was about 6 km, which were a shallow, moderate earthquake. When the seismicity of the region was examined, it was determined to be one of the most important active seismic and deformation areas located between North West Anatolia and North Aegean Sea, the Eurasian and African tectonic plates.

"Two major earthquakes occurred in recent years in the region, one was Ayvalık-Çanakkale centered earthquake with a magnitude of 7.0 in 1919, and the other was Edremit Gulf centered earth-quake with a magnitude of 6.8 in 1944. Records indicate that devastating earthquakes had also hit the region in ancient times" (URL-1 2017).

Researches show that effective earthquakes happened in the district before. Earthquakes of "1672 Bozcaada, 1707,1737 Biga, 1707,1739 Foça,1762 and1773-1774 Çanakkale are effective earthquakes on the district" (Ambraseys and Finkel 1995).

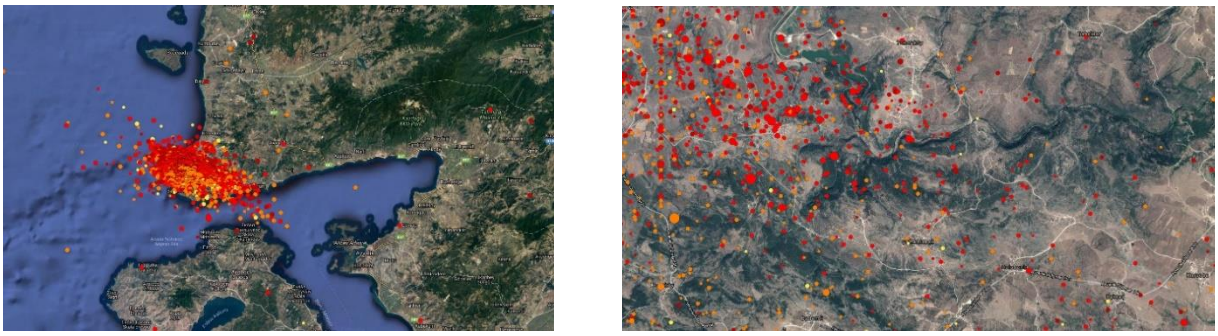


Figure 1: Earthquakes Occurring in Çanakkale Province, Ayvacık County and Villages (URL-1 2017)

2.1. The Features of Yukarıköy

The population of Yukarıköy, located in the south of Çanakkale, is 644 and it has 240 families"(URL-2 2017). The people of the region, which have historical characteristics, make their living from agriculture, animal husbandry, and making carpet. On the other hand, animal owners who have to move according to weather conditions continue to live a nomadic lifestyle keeping up with this situation (Figure 2). Archaeological investigations show that the region, one of the most important parts of the history of civilization, has been developing under the socio-economic and socio-cultural impacts of various civilizations since Troy and still following their traces. "Smintheion rural area is located in Gülpinar town of Ayvacık county of Çanakkale province on the south-west corner of Biga peninsula, to the north-west of Anatolia.

Gülpınar and its environs are situated on a volcanic plateau. Smintheion, located on the slopes of Gülpınar, is made up of sedimentary rocks which starts from the area where Gülpınar settlement ends and reaches up to the sea. The formation of Gülpınar geography is also the foundation for the existence of the Smintheion sanctuary because the Apollon sanctuaries are usually close to water resources or they are established at the source, like the Smintheion sanctuary. This source provided uninterrupted long-term settlement of the region where it was located. Due to the geographical suitability, the settlements in the region have hosted different periods since the Chalco-lithic era to the present day" (Özgünel 2008).

Figure 2: Life in Yukarıköy

2.2. Characteristic Architectural and Structural Features of the Houses in the District

2.2.1. Characteristic Architectural Features of the Houses in the District

Geographical and geological features of the region are the main reason for the frequent use of stone materials in constructions. The kind of stone is Ignimbrite. It is a type of pyroclastic rocks, and it's occurrence is still debated (MTA 2007). It is known that stone material is also used in the structures that make up the historical texture in the environment (Behramkale, Apellon and its environs). The re-search revealed that the structural details of the masonry stone structures under investigation were not made in accordance with the criteria to be considered in the structures to be constructed in the earthquake zones. The masonry stone structures in the region were generally built as single-story buildings and a partial basement was built under the entrance taking the advantage of the slope in sloping areas. While waste water released to the environment pollutes the environment, it can also cause diseases. The hallways built at the entrance to the houses heated by solid fuel are also considered as the passage with doors leading to other rooms while also providing access to the building from the garden.

Another function of the hallways is that they are used as the kitchen. The rooms opening to the hall-way were built as multipurpose rooms (Figure 3). Inherent in all of the varied house plans developed in Turkey's different ecological environments as one of the distinctive characteristics of the plan type of Turkish house, sofa is an environmental adaptation product created in the transition process from nomadic to settlement and fed from the base of traditional Turkish nomadic culture (Köse 2005).

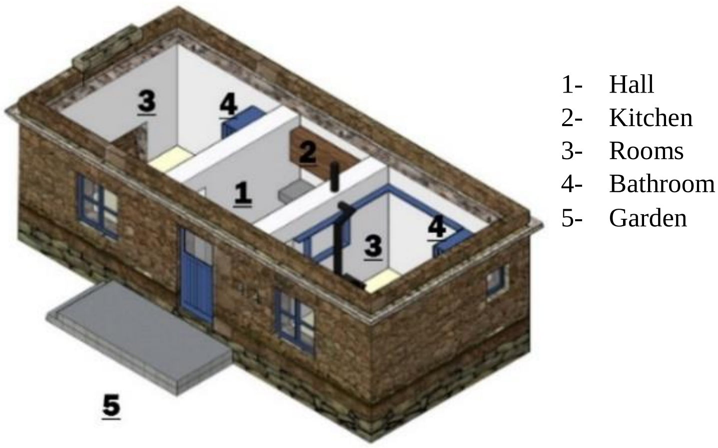


Figure 3: General Condition of Ayvacık Rural Masonry Stone Structures

2.2.2. The Structural Features of the Houses in the District

The main material of the majority of the buildings under investigation in the region is stone. The bearing systems used in masonry stone constructions include the following:

- Stone foundation,
- Stone wall, and
- Earth roof on wood beamed ceiling.

In the masonry structures, the bearing walls, an important element of the bearing system, were constructed as double-layer walled with soil and rubble-stone filling inside and plastered with soil mortar (Figure 4).

Figure 4: A Section from Bearing Stone Walls Constructed in the Region

3. The determination of earthquake damage

Earthquakes that occurred in February 2017 caused significant damage to structures in Yukarıköy. "Most of the structures in the rural area of Ayvacık were masonry building. According to the post-earthquake building damage survey of the Republic of Turkey Prime Ministry, Disaster and Emergency Management Presidency, about 1000 masonry buildings collapsed or damaged in the rural area of Ayvacık. About 600 of them were completely collapsed or heavily damaged and the others were medium or minor damages" (Adanur et al. 2018). The examinations carried out during the study focused on 36 damaged structures of Yukarıköy. But, the 36 mentioned structures represent a large part of the structures in the region affected by the 2017 Ayvacık earthquakes in terms of material used, construction techniques and damage types. While a considerable part of these buildings used as dwellings is masonry stone structures, a few hybrids and BA were also encountered. 94 % of the structures investigated are masonry stone structures. This ratio indicates that stone is an important building material in the region.

A significant part of the Yukarıköy buildings, where the severest impacts of the Ayvacık-based earthquake can be seen, is damaged. The damage assessment form prepared by the Ministry of Public Works and Settlement, General Directorate of Disaster Affairs were used to determine the extent of the damage in Yukarıköy buildings under investigation. The damage scores obtained as a result of the damage assessment based on the information in this form were used to classify the buildings as follows:

- Scores between 0 - 5 UNDAMAGED,
- Scores between 5 - 14 SLIGHTLY damaged,
- Scores between 14 - 43 MODERATELY damaged, and
- Scores above 43 SEVERELY damaged structures (AFAD 2000).

The details of the damage assessment table in the same form used for bearing masonry structures are shown in Table 1.

Table 1: Damage Assessment Table (AFAD 2000)

Member	Total Member Number	Without Damage (H) 0	Low Damage (A) 1	Moderate Damage (O) 2	Heavy Damage (AH) 4
Wall					

The damage and the system damage score presented in Table 1 was calculated using the equation 1.

$$SDS = (A*1+O*1+AH+4) * 100/(4*TS) \quad (1)$$

SDS: System Damage Score
H: Without Damage
A: Low Damage
O: Moderate Damage
AH: Heavy Damage

To calculate the total damage score, other criteria that could lead to a further increase in the level of damage, such as irregularity in the plan, irregularity in the cross-section, building location, the relationship of adjacent structure, dilatation grouting, the quality of workmanship, material quality, vertical deviation rate of the building, and roof and stairs should be taken into account. The total damage score is the sum of the scores obtained from the mentioned titles and the 80% of the system damage score (SDS). The results revealed by the damage scores obtained by using this method for the structures of Yukarıköy are shown in figure 5.

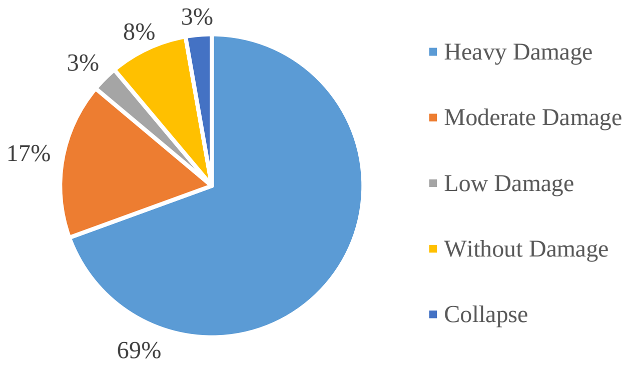


Figure 5: Damage Status of Structures under Investigation in Yukarıköy

The statistical values in Graph 1 show that most of the structures examined in Yukarıköy are severely and moderately damaged.

3.1. The Causes of the Earthquake Damage in the Structures of Yukarıköy

Studies conducted to determine the damage during the investigation revealed that the causes of the damage were clustered under certain headings. The following are the causes of the damage mentioned.

3.1.1. Inadequate Corner Point Details

In a structure, it is the corner points that are mostly forced under horizontal loads. In masonry stone structures, using larger and better-quality stones at corner points is a necessary detail to be applied. “If structural elements are used with different dimensions, care should be taken to use large elements and masonry techniques in the joining areas during the construction” (Koç 2016). The stones placed on top of each other in an interlocking manner with the effect of friction ensure that the structure remains standing without disturbing the integrity of the structure during the earthquake. The size of the stones and the connection details should prevent the deformations occurring in the structure during the earthquake and the possible destruction due to vertical deviations. If this condition is not fulfilled, the first and most damage and destruction are expected to take place in corner joints during the earthquake.

"The forces that push the structures in earthquakes are not one way. Constructions are forced with horizontal forces at the same time in both prime directions. This condition causes stress accumulations especially at the corners of the structures where the walls coming from two sides intersect." (Bayülke 1980). Figure 6 shows the damaged corner details determined after the earthquake in the study area.

Figure 6: A Damaged Corner Detail

3.1.2. Unfavorable Ground-Structure Relationship

Relationship of the structure with the ground where it is built is one of the important factors affecting the behavior of the structure either positively or negatively during an earthquake. It is recommended that on hard grounds flexible structures should be built and rigid structures should be constructed on soft grounds. "If the oscillation period of a building is close to the oscillation period of the ground on which the structure is sitting, the damage to that structure is quite severe. Due to this impact, which is defined as resonance, the force affecting the structure increases the amount and number of deformation of the structure each time (Bayülke 1978).

The majority of the structures built on rocky grounds at high levels in Yukarıköy were damaged severely. It is thought that rigid masonry stone structures built on hard grounds is one of the main reasons for the largescale damage to the building upon resonance during an earthquake. The structure-ground relationship in the region is shown in figure 7.

Figure 7: Ground-Structure Relationship

3.1.3. Independent load-bearing walls with double wall

The inner and outer double walls, which are not connected to each other, move independently of each other under the influence of the vertical loads in the amount exceeding the capacity of the wall. In this case, the bearing capacity of the wall weakens and causes damage to the structure during the earthquake (Figure 8).

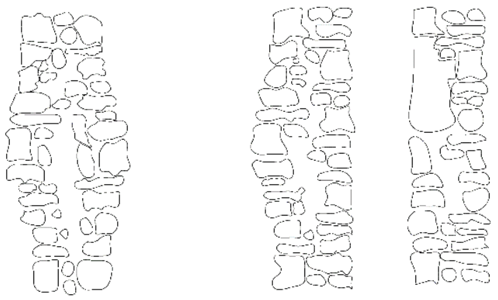


Figure 8a: Bent or unbent double wall (Arun 2010)

Figure 8b: Example of a Damaged Wall with Double Wall in a Structure in Yukarıköy

Figure 8: Double-Walled Wall

3.1.4. Low Strength Mortar Used in Walls

The quality of the mortar that connects the blocks used in walls is an important factor affecting the behavior of the wall during an earthquake. It was determined that additive-free soil mortar was used in all of the severely damaged structures in the study area. Figure 9 shows a damaged soil mortared wall in the area. When the structure is made of a low strength mortar, the strength of the wall, which plays an important role in the masonry structure, is very low and can totally collapse under horizontal loads.

Figure 9: Damage to a Structure with Low Strength Soil Mortar

In buildings with little or no damage at all, cement mortar was found to be used. As seen in the figure 10, it was determined that clay-based soil mortar was used in 89 % of the analyzed structures.

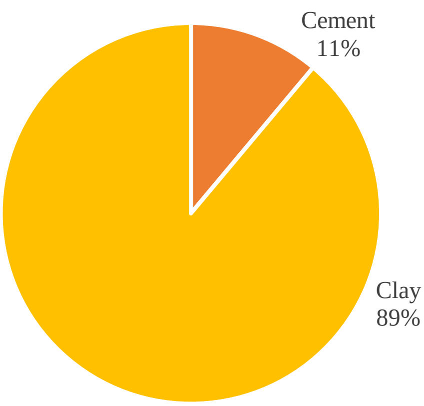


Figure 10: Distribution of mortar type used in region

3.1.5. Beamless Walls

It was determined that none of the damaged structures in Yukarıköy had horizontal beams. This caused the extent of the damage in the buildings to grow. Masonry building walls, unless flooring and beam connections done in sufficient rigidity at the upper part, cannot withstand the loads to their planes perpendicular as well. It is necessary to make horizontal beam connections at units such as subbasements, doors, window loungers, and floor loungers in walls according to the technics (Çırak 2011). Figure 11 shows examples of the structures with beams or with no beams at all in the region.

Figure 11a: Example of undamaged re-inforced concrete structure with beams

Figure 11b: Example of damaged beam-less structure

Figure 11: Examples of Walls with Beams or with no beams

3.1.6. Wall-ceiling Connection Details

In most of the structures built in rural areas, floor beams are placed on the wall with no connection to the wall. The circular cross-section of these beams also reduces the friction effect and weakens the diaphragm function of the floor by facilitating the movement of the beam. In this case, the wall does not support the floor and structure can collapse due to this deformation. Figure 12a shows the typical wall-beam relationship applied in the region and a damaged structure is displayed in figure 12b due to this application. Furthermore, the friction forces between the stone surfaces are marginal, since the stones are of irregular shapes, not prismatic, and the contact surfaces are not sufficient to cause adequate amount of friction. Additionally, wooden beams of roofs are aligned in one direction and the beams are supported by two walls opposite to each other. Therefore, the weight of the heavy roof and corresponding horizontal earthquake loads are transferred to these walls (Celep et. al 2011).

Figure 12a: Draft of the well-designed structure

Figure 12b: Collapsed Structure in Yukarıköy

Figure 12: Wall-floor relationship

3.1.7. Heavy Earth Ceiling

"A roof protects a building against external factors as well as shielding the interior against the effects of cold and hot weather" (Koç 2016) For this purpose, the choice of bearing and insulation details of the roof is critical. Due to economic concerns and lack of information on the structures built in rural areas, a very thick and heavy earth ceiling is used to provide thermal insulation.

The beams bearing this roof are not connected to the supporting walls, so they move independently of the wall during an earthquake. "Cross cracks in the walls of masonry structures with heavy-weight roofs usually arise from the effect of shear force. Conically shaped breaks on the upper sides of the common corners of the walls are actually the intersection of two crossed cracks cutting the wall. It has been observed that such structures rise up from the ground due to the overturning effects of the wall ends" (Budak 2004). The additional weight of the soil cover naturally caused the structures to be affected by the earthquake more. "The ceilings of rural structures with mud-brick and stone walls are generally covered with mud. One-meter square weight of the wooden bearer and earth covering of the ceiling is about 750-1000 kg. Therefore, a huge ceiling load presses on the walls. The walls are already forced hard, during an earthquake due to their construction, so it is inevitable that they will be damaged during earthquake because of heavy ceiling" (Ergünay 1978). Same types of damages are seemed at the 2010 Kovancılar and Palu (Elazığ) Earthquakes and 2011 Van Earthquakes in Turkey. The features of the roof cover in the structures examined are shown in figure 13. In addition, figure 14 shows the examples of heavily damaged earth roof structures.

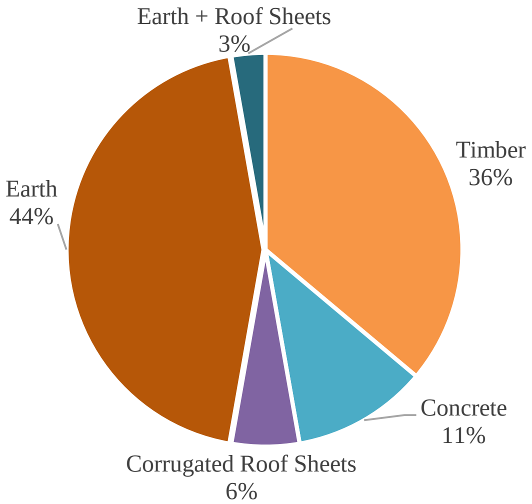


Figure 13: The state of the ceiling cover in the structures studied

Figure 14: Damaged structures with soil roof

3.1.8. Gradual Foundation Application in Sloping Areas

The architecture which developed due to topographic features caused some buildings to be built together with a partial basement (Figure 15). This situation, which is considered to be an irregularity in the section, affects the behavior of the building negatively in terms of earthquake loads. It has been determined that part of the damages arose from this reason. "It should be avoided to construct partial basement which is a cause of significant damage" (Önal 2005).

Figure 15: A damaged structure built on sloping land

3.1.9. Chimney Details

The opening to the wall for the chimney weakens the wall section and increases the risk of dam-age to the double-walled wall under horizontal loads (Figure 16 and 17). 89% of the damaged structures that studied were damaged due to the chimney opening in the bearing wall.

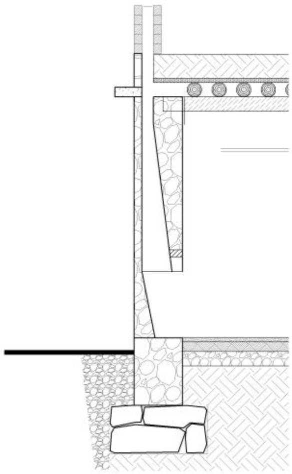


Figure 16: Chimney section

Figure 17: The damage caused on the wall by the chimney

3.1.10. The Proportion and Locations of the Spaces on The Wall

The greatest deformation and stress intensity emerge at the connection points of the walls, which are under horizontal loads. For this reason, the section area of the wall, material quality and workmanship are more important than other components of the structure. The deformations that occur in these areas cause the structure to suffer significant damage.

It has been determined that a large part of the damaged structures in Yukarıköy area were built with no regard to the location and size of the spaces. Figures 18a and 18b illustrate this situation. "The design process of masonry buildings needs more regularity compared to other supporting systems, because resisting system must have continuity and regularity in order to take the stress of the shear from an earthquake. In rural areas, however, traditional fireplaces have been used in buildings, and they are built within the wall by decreasing the wall thickness or curving the wall outward. In such cases, irreversible damage is inflicted on the wall because of decreasing shear resistance" (Livaoglu et al. 2018).

Figure 18a: Damaged building in Yukarıköy

Figure 18b: Collapsed building in Yukarıköy

Figure 18: Effect of the design with wrong location and size of the spaces

4. Recommendations for reducing earthquake damages

To prevent structures from suffering heavy damage, different proposals in line with the reasons of the damage determined during the study have been developed.

4.1. Corner and Beam Details of the Recommendations

Corner points are the parts of a structure that are pressured most during an earthquake. Horizontal beam recommendations are presented in figure 19 within the framework of the terms envisaged by Earthquake Code (Earthquake Regulation 2007) in effect in Turkey. With the recommended horizontal reinforced concrete beams, the provision of the following areas is intended:

- Decreased wall vulnerability,
- Connection of the inner and outer surfaces of the wall,
- Preventing the crack on the wall from progressing.

Moreover, "reinforced concrete beams are more ductile and higher-strength elements than masonry walls. They prevent the progress of the cracks caused by the horizontal earthquake loads on the wall, the scatter of the wall, and the loss of horizontal and vertical load-carrying strength of the wall." (Bayülke 2011).

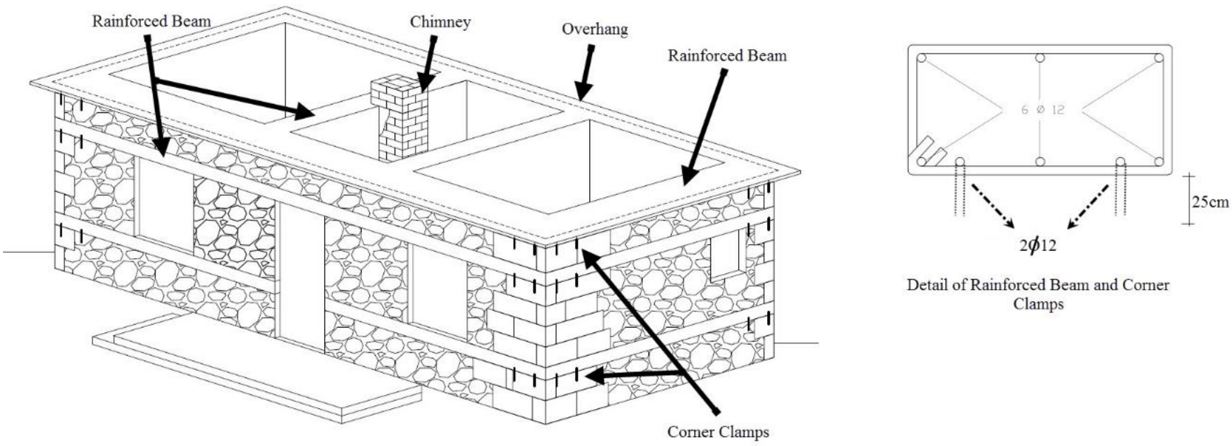


Figure 19: Recommended corner and chimney detail

The clamps placed in the reinforced concrete beam are placed in two directions and two levels to prevent the walls from moving out of the plane. Figure 19 shows suggestions to prevent the damage caused by the corner deformation of the structure.

4.2. Arrangement of the Chimney Location

When the chimney is located inside the supporting wall, the cross-section and strength of the wall reduce. Chimneys located on the outer wall also cause heat loss and condensation. For this reason, the chimney is suggested to be located outside the chimney wall section and on the inner wall as proposed in figure 19.

4.3. Arrangement of Overhang

No eaves application was found in existing constructions. Eaves protect the building against external factors in the long run. For this reason, it is suggested to make the overhang as shown in figure 19.

4.4. Mortar Quality

Cement-lime mortars or at least lime mortar should be used as binder mortar. Various mortar mixture ratios are suggested for the structures in the region in the table below.

Table 2: The recommended mortar material ratios (Bayülke 1980)

Cement	Lime	Sand
1	1	6
1	2	9
1	3	12
1	0	3
0	1	3

4.5. Suggestions for The Proportion and Location of the Space in The Wall

"In masonry structures, one of the most important structural details that provide earthquake resistance is the existence of adequately filled wall between windows and door openings. While these walls provide the area required for the transport of both vertical and horizontal loads, a wide wall will help control the vertical and shear stresses" (Bayülke 2011). In this case, the location and total length of the spaces to be opened on the wall must be taken into consideration. Figure 20 shows the location and length of the spaces to be considered in 1st, 2nd, 3rd, and 4th degree earthquake zones as defined in Earthquake Code (Earthquake Regulation 2007).

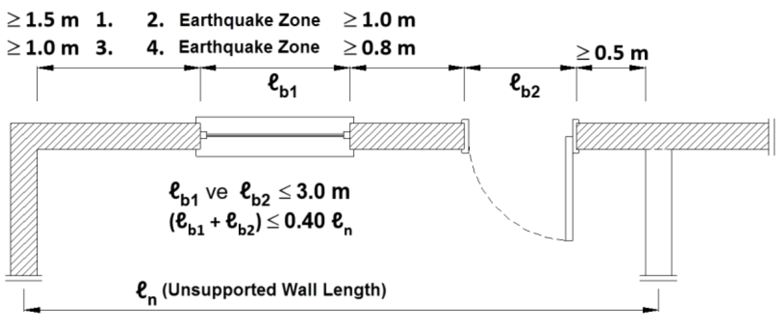


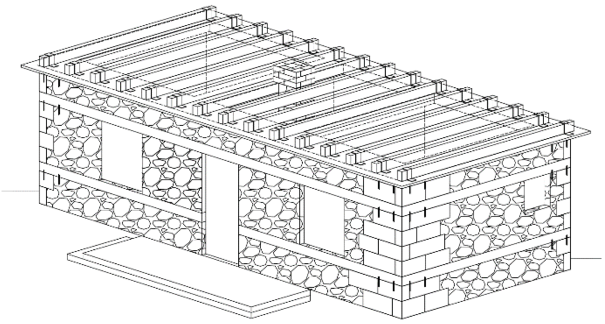
Figure 20: Proportion and Location of Spaces (Earthquake Regulation 2007)

At the same time, the window and door openings should be symmetrical in the plane of the plan, so as not to create torsional irregularity in the structure.

4.6. Wall-ceiling Connection Details

The wooden beams which form the floors of the masonry structures should prevent the wall un-der the effect of vertical loads from moving out of its plane by connecting to the wall. For this purpose, the beam-wall connection details are important. In order to ensure proper distribution of the loads, the diaphragms must be more rigid in their planes than the bearing walls (Zacek 1999). A considerable part of the damage seen in the rural structures after every earthquake arises from this cause.

The proposal developed in this study recommends the ceiling-wall connection detail as shown in figure 21. In the detail presented in the figure, "TÜBİTAK approved insulation material" (Kanca 1977). is recommended instead of earth roof which is used as thermal insulation in rural buildings.



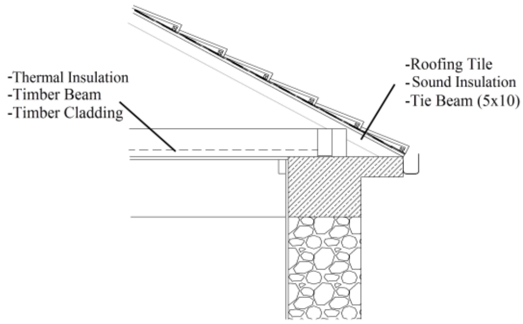


Figure 21: Beam-wall connection and roof details

4.7. Foundation Proposal for Structures to Be Built in Sloping Grounds

The foundations of the buildings built on sloping grounds need to have a gradual structure. Figure 22 shows the foundation details to be built on sloping lands in earthquake areas.

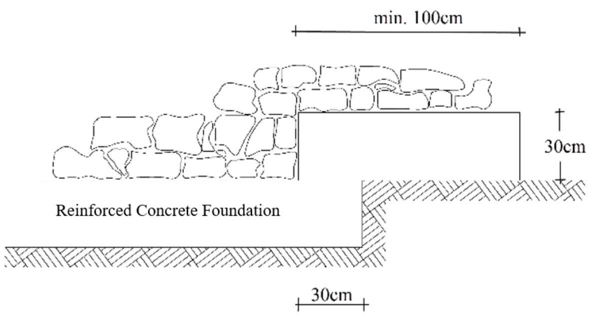


Figure 22a: Foundation Detail for (G1), (G2)

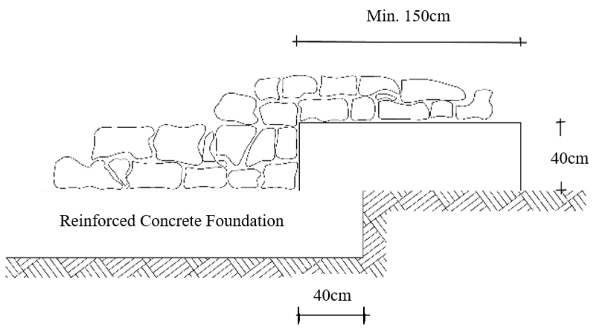


Figure 22b: Foundation Detail for (G3), (G4)

Figure 22: Gradual Foundation Detail for (G1), (G2), (G3) and(G4) (Parsa 2015)

4.8. Detail Proposal for Double Walled Walls

It is necessary to prevent double-walled walls from moving independently of each other. In figure 23, a block stone connecting the two sides of the wall at regular intervals is proposed. In this way, the two layers work together.

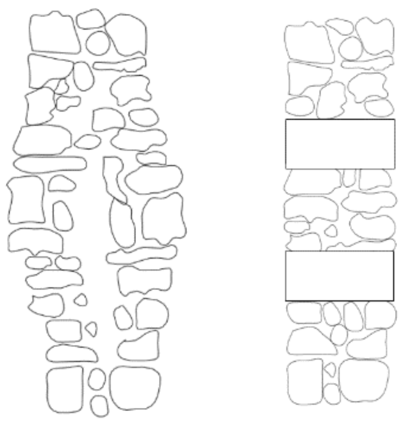


Figure 23: The connection of inner and outer wall layer (Earthquake Regulation 2007)

4.9. Inner-Outer Wall Connection Detail

It was observed during the study that the connections between the inner and outer walls were inadequate in all of the damaged structures in the region. These walls suffered significant damage after the earthquake. Figure 24a shows the damaged structure in this respect. In figure 24b, the alignment of the stone blocks is shown as a proposal for connecting the inner and outer walls against horizontal loads.

Figure 24a: Inner-outer wall with poor connection

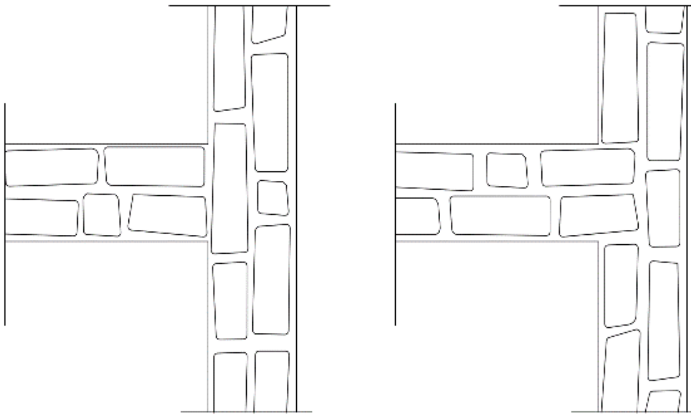


Figure 24b: Connection details of outer wall with inner wall

Figure 24: Connection between the inner and outer walls

5. Conclusion

There are many traditional buildings built in Anatolia geography with various materials and construction techniques. However, the rapid expansion of the reinforced concrete building system throughout the country has led to a gradual decline in structures built using traditional construction techniques. The diminution of traditional structures also led to the reduction of the craftsmen who built these structures, and oblivion of construction techniques. Indeed, measures to be taken against earthquake loads in traditional structures will ensure the safety of these structures.

Construction of buildings using natural material such as soil and stone in Turkey is seen in rural areas. These buildings are built by low-income dwellers with minimum cost with no engineering service at all. In this case, poor quality and unstable constructions emerge. As a result, great damage occurs during an earthquake especially in rural houses made from stone and mud brick and causes loss of life and property.

The study was conducted in the rural area of Çanakkale city, which is one of the most important historical districts of the world and Turkey. No traces of structural culture emerging as a result of thousands of years of the trial-and-error process in the region can be seen in new buildings. Except for the architectural elements developing from the stone decor, texture and rural life, many important details have not been carried from the past to the present.

When the structural details presented as a solution in the study are considered, they will positively affect the continuity of the masonry stone housing construction belonging to the region that has been going on for centuries as well as improving the behavior of the buildings against the devastating impacts of the earthquake.

References

Adanur S., Altunışık A.C., Günaydın M., Mosallam A., (2018), *Performance of Masonry Buildings during the February, 2017 Ayvacık (Çanakkale) Earthquakes*, 2nd International Symposium on Natural Hazards and Disaster Management (ISHAD2018), 04-06 May, Sakarya, Turkey.

AFAD (2000), *Ministry of Public Works and Settlement, General Directorate of Disaster Affairs*, Damage Assessment Form, p. 1-5 Ankara, Turkey.

Ambraseys N.N., Finkel C.F., (1995), *The Seismicity of Turkey and Adjacent Areas a Historical Review 1500-1800*, Eren Publishing, p. 85-205, İstanbul, Turkey.

Arun G., (2010), *Unpressed Lecture notes of Structural System Design*, Yildiz Technical University, İstanbul, Turkey.

Bayülke N., (1978), *Earthquake Resistant Constructions,* Turkish Ministry of Reconstruction and Resettlement. Earthquake Research Institute, Ankara, Turkey.

Bayülke N., (2011), *Earthquake Behavior and Security of Masonry Structures*, Turkey Earthquake Engineering and Seismology Conference I, 11-14 October 2011, Middle East Technical University, Ankara, Turkey.

Bayülke N., (1980), *Masonry Constructions, Ministry of Reconstruction and Public Works*, Earthquake Research Institute, Ankara, Turkey.

Budak A., Uysal H., Aydın A.C., (2004), *Earthquake Behavior of Rural Buildings,* Atatürk University the Journal of Agriculture, 35 (3-4), 209-219.

Celep Z., Erken A., Taskin B., Ilki A., (2011), *Failures of masonry and concrete buildings during the March 8, 2010 Kovancılar and Palu (Elazıg) Earthquakes in Turkey*, Engineering Failure Analysis, 18(3), 819-1142.

Çırak İ.F., (2011), *Yığma Yapılarda Oluşan Hasarlar, Nedenleri ve Öneriler,* SDU International Technologic Science, 3(2), 55-60.

Earthquake Regulation of Turkey 2007, *Regulation for the Buildings to be Built in Earthquake Regions,* p.93-103 Ankara, Turkey.

Ergünay O., (1978), *Earthquakes and Earthquake-Resistant Structures: Flat-roofed Ceilings*, Journal of Ministry of Public Works, Institute of Earthquake Research Department, 102-114.

Kanca A.C., (1977), *Using Economical and Practical Material of Termal Insulation for Village Houses*, Knowledge profile of TÜBITAK, vol. 60, Ankara, Turkey.

Koç V., (2016), *Depreme Maruz Kalmış Yığma ve Kırsal Yapı Davranışlarının İncelenerek Yığma Yapı Yapımında Dikkat Edilmesi Gereken Kuralların Derlenmesi*, Çanakkale Onsekiz Mart University, Journal of Graduate School of Natural and Applied Sciences, 2016:2, 1, 36-51.

Köse A., (2005), *Traces of Nomadic Turkish Culture on the Plans of Traditional Rural Houses in Turkey*, Afyon Kocatepe Üniversitesi, Sosyal Bilimler Dergisi, 7(2), 158-191.

Livaoglu R., Timuragaoglu M.O., Serhatoglu C., Doven M.S., (2018), Damage during the 6-24 February 2017 Ayvacik (Canakkale) earthquake swarm, Natural Hazards and Earth System Scıences, 18(3), 921-934.

MTA, (2007), 1/100.000 ölçekli Çanakkale -İ17 paftası jeoloji haritası, MTA Jeoloji Etütleri Dairesi, Ankara, Turkey.

Önal M.M., Koçak A, (2005), *Yığma Yapı Hasarları Onarım ve Güçlendirme Yöntemlerinin Ayrıntıları*, Antalya Yöresinin İnşaat Mühendisliği Sorunları Kongresi, Cilt 1, s.88-102, Antalya, Turkey.

Özgünel, C., (2008), *Reaching the 30th year of Gülpınar / Smintheion excavations*. Ayvacık Values Symposium, ÇOMÜ Publications, No. 80, p. 39- 46, Çanakkale, Turkey.

Parsa A.R., (2015), *Earthquake Resisting Country Houses of East Anatolian*, Arkeoloji Publishing, p.49, İstanbul, Turkey.

URL-1, (2017), http://udim.koeri.boun.edu.tr/zeqmap/gmapt.asp, [Access 10 March 2017].

URL-2, (2017), http://www.yerelnet.org.tr/koyler/koy.php?koyid=241049, [Access 10 March 2017].

Yüksek İ., (2015), *A Study on the Earthquake Resistance of Traditional Turkish Houses*, IBEES2015, Burdur, Türkiye.

Zacek M., (1999), *Earthquake Resistant Building Design: Preliminary Project Phase*, s:94, France.