SCIENNOVATION
A Journal of Structural Science and Innovation

RESEARCH ARTICLE

Date Received: 02. March.2020
Date Accepted: 12. March.2020

Investigation of Earthquake Behaviour of Different Building Materials Used in Masonry Structures

Ceren Aydın

Freelance Construction Engineer, İstanbul, Turkey. Corresponding Author Email: ccerenaydin@gmail.com

Keywords:
Masonry structure, Structural materials, Effect of different materials on masonry structure. Earthquake behaviour of masonry structure.

Abstract

The use of masonry structures dates back many years. It is important to determine the behaviour of masonry structures, which are widely used today. The most important factor determining the behaviour of the masonry structure is the structural material used in the structure. In this study, a masonry wall built with aerated concrete, pumice, brick and stone building materials used in masonry structures was modelled in 3D in ANSYS program and its behaviour against 3 different earthquakes was investigated. As a result of the investigation, the reliability of construction materials according to earthquake records was listed.

Yığma Yapılarda Kullanılan Farklı Yapı Malzemelerinin Deprem Davranışlarının İncelenmesi

Anahtar Kelimeler;

Yığma yapılar, Yapısal malzeme, Farklı malzemelerin yığma yapıya etkisi, Yığma yapının deprem davranışı.

Özet

Yığma yapıların kullanımı uzun yıllara dayanmaktadır. Günümüzde de kullanımı oldukça yaygın olan yığma yapıların davranışlarının belirlenmesi önemlidir. Yığma yapının davranışını belirleyen en önemli etken, yapıda kullanılan yapısal malzemedir. Bu çalışmada yığma yapılarda kullanılan gazbeton, ponza, tuğla ve taş yapı malzemeleri ile inşa edilen bir yığma duvar, ANSYS programında 3 boyutlu olarak modellenmiş ve 3 farklı deprem karşısındaki davranışı incelenmiştir. İnceleme sonucunda yapı malzemelerinin deprem kayıtlarına göre güvenilirlikleri sıralanmıştır.

1 INTRODUCTION

When the structures used in our country are examined, the use of masonry structures as well as reinforced concrete structures draws attention. (Korkmaz et al., 2014). Seismic behaviour of these structures will be examined and their safety will contribute to the prevention of possible damages (Korkmaz et al., 2014). Masonry structures are generally constructed from different materials such as stone, brick, adobe, briquette and have been used from past to present (Çırak, 2011). In a masonry structure, the walls serve as carriers (Çırak, 2011).

When determining the damage level of a masonry structure after an earthquake, the repair and strengthening status of the structure is examined (İnangu, A., Kırbaş, H.,1999). Earthquake behavior of each material used in masonry structure is different (Çırak, 2011). The best method for determining earthquake behavior is nonlinear time history analysis (Badry and Satyam, 2014). For this reason, Time history analysis method was preferred in this study.

The earthquake behaviour of the masonry structure can be shown as in figure1. Damages occurring or expected in the structure can be classified according to the severity of the earthquake. Damages at level A and B are the expected damage levels for earthquakes of magnitude 6-7, damages at level C and D are for earthquakes of magnitude 8-9, and earthquakes at level E are the expected damage levels for earthquakes greater than 9. (İnangu, A., Kırbaş, H.,1999).

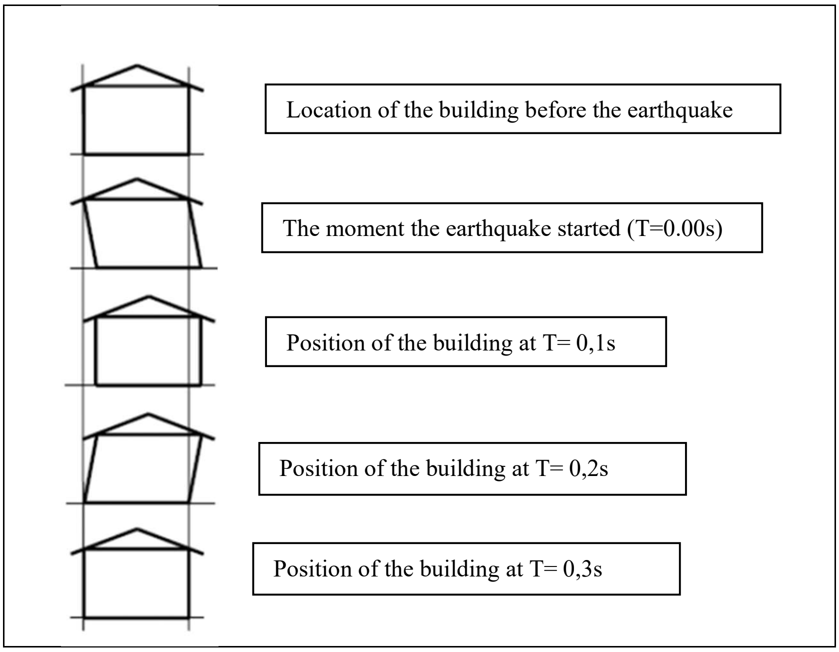

Figure 1. “Earthquake Behaviour of Structures” (İnangu, A., Kırbaş, H.,1999).

A. “Undamaged or slightly damaged structure: No cracks or plaster cracks in the structure.” (İnangu, A., Kırbaş, H.,1999).

B. “Slightly damaged structure: 45 degrees of cutting cracks on structure.” (İnangu, A., Kırbaş, H.,1999).

C. “Moderately damaged wall structures: The walls have 45 degree cut cracks. However, shear stress on the wall decreased. (%30-%40)” (İnangu, A., Kırbaş, H.,1999).

D. “Heavy damaged masonry structure: Crack gap exceeds 25 mm in structures and walls are separated at the corners, the effect of shear forces is weakened, and the fragmented walls become incapable of carrying vertical loads, causing swelling and collapse of the walls due to vertical loads.” (İnangu, A., Kırbaş, H.,1999).

E. “Demolished masonry structure: A large part of the carrier wall is demolished, and the floors are stacked on top of each other, this damaged structure is no longer repairable.” (İnangu, A., Kırbaş, H.,1999).

2 MATERIAL AND METHOD

Materials used in masonry structure may vary depending on the region built (Bayülke, 2011). Wooden structures are used in the Black Sea Region, mudbrick structures are used in Southeast Anatolia and stone walls are used in Eastern Anatolia (Bayülke, 2011).

Robustness, strength, economy, sound and heat insulation, workmanship is important in the choice of construction material (Bayülke, 1998; Köktürk, 1997). The lightness of the material used in the structure reduces the building load (Korkmaz et al., 2014). Porous and lightweight construction materials have sound and heat insulation (Bayülke, 1998; Köktürk, 1997). It is also cheaper and does not require much labour, so it is more preferred (Bayülke, 1998; Köktürk, 1997).

The brick is used both as a carrier and as a partition wall (Bayülke et al., 1989). Ductile behaviour of brick masonry structures is poor (Bayülke et al., 1989). That is why brick masonry structures exhibit brittle behaviour (Bayülke et al., 1989).

“Stones are natural, crystalline internal and inorganic building materials.” (Köktürk, 1997). Used in the construction of the carrier wall since the past (Köktürk, 1997). But because it is heavy and the conditions of use are difficult, its use is limited (Köktürk, 1997). Granite, basalt, andesite, sandstone, tuff slate, limestone and sandstone are natural Stones (Köktürk, 1997).

Pumice of volcanic origin, glassy and porous structure is a lightweight construction element (Bayülke et al., 1989). It has low permeability and high heat and sound insulation due to interpore spaces (Bayülke et al., 1989). Due to these physical properties, pumice is used in the construction of concrete briquettes and blocks, and in heat and sound insulation in constructions (Benedetti et al., 1998).

Aerated concrete, porous, lightweight, has heat and sound insulation and is a fireproof material (Benedetti et al., 1998). It is economical because of its easy workability and low workmanship (Benedetti et al., 1998). It is a light material and reduces the load (Benedetti et al., 1998). "In the masonry constructions constructed with aerated concrete, it is observed that the rigidity and strength are maintained against horizontal forces in the earthquakes." (Benedetti et al., 1998). Nowadays it is more preferred than other materials (Benedetti et al., 1998).

3 CASE STUDY

In the study a masonry structure made of brick, stone, pumice and aerated concrete material was modelled in three dimensions in ANSYS program and its behaviour against earthquake was investigated. Three earthquake acceleration recordings were applied by using the analysis method for four different material states in the time domain and the displacement and stress values obtained were compared and the reliability of the structure under earthquake effect was determined. The 3D of 4m/4m/0,25m masonry wall is shown in figure 2.

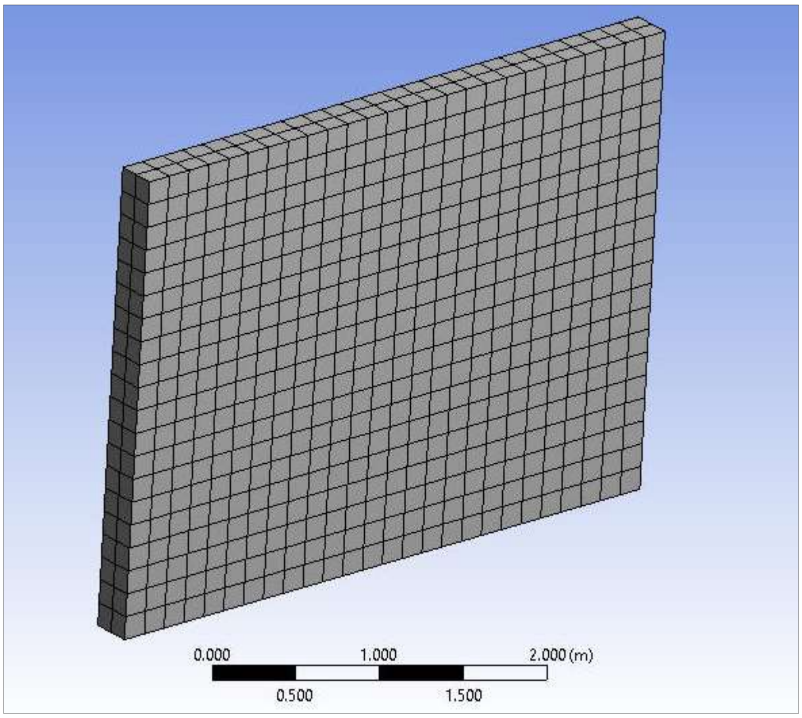

Figure 2. 3D Model Of Masonry Wall Example (4,00x4,00x0,25m).

Table 1. Material properties used in the analyses (Korkmaz et al. , 2014).

Material Type	Modulus of Elasticity (MPa)	Poisson Ratio	Unit Weight (kN/m3)
Brick	3000	0,2	20
Stone	26000	0,2	25
Pumice	22000	0,2	16
Aerated Concrete	25000	0,2	6

Table 2. Earthquake characteristics used in analysis (Korkmaz et al. , 2014)

No	Earthquake	Year	Moment Size	Scale Factor	Arias Intensity	Tp	Distance
			(Mg)		(m/s)	(s)	(km)
1	El Centro	1940	6,95	1.0	1,6	-	6,09
2	Shandon	1966	6,19	1.0	0,4		12,90
3	Gilroy	1979	5,74	1.0	0,8	1,232	3,11

Figure 3-11 show X, Y and Z component of ground motion records

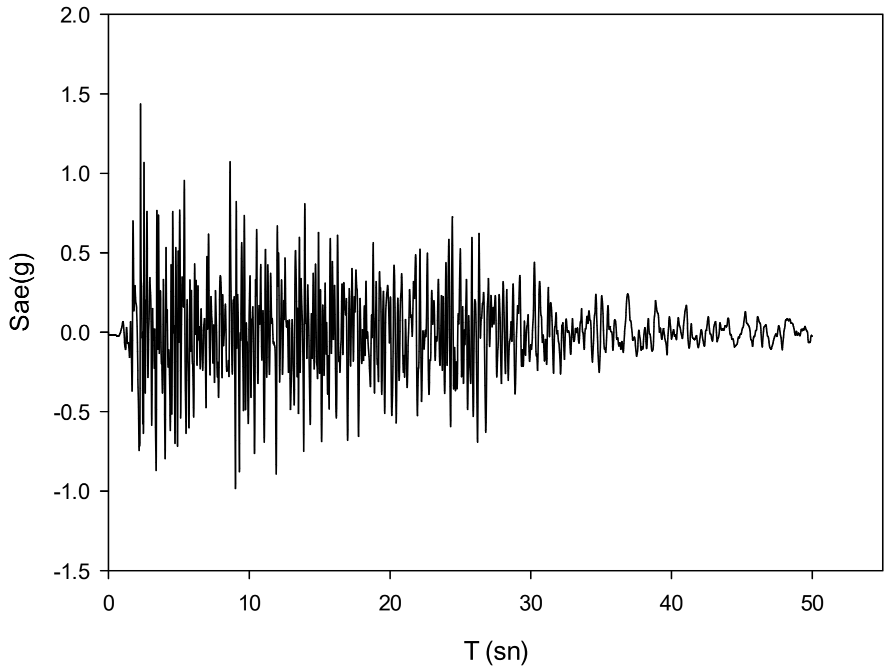

Figure 3. X Component of 1940 El Centro earthquake

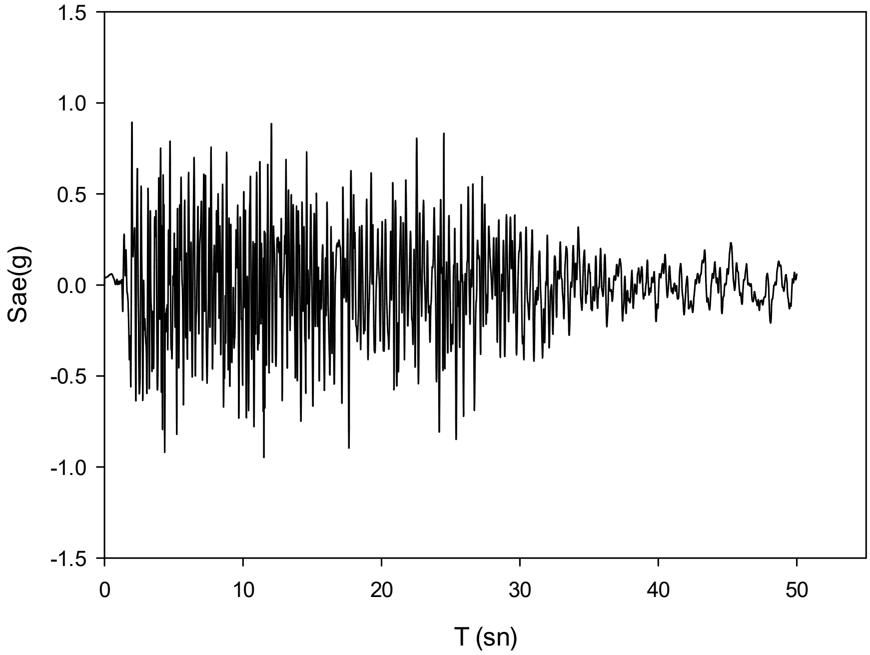

Figure 4. Y Component of 1940 El Centro earthquake

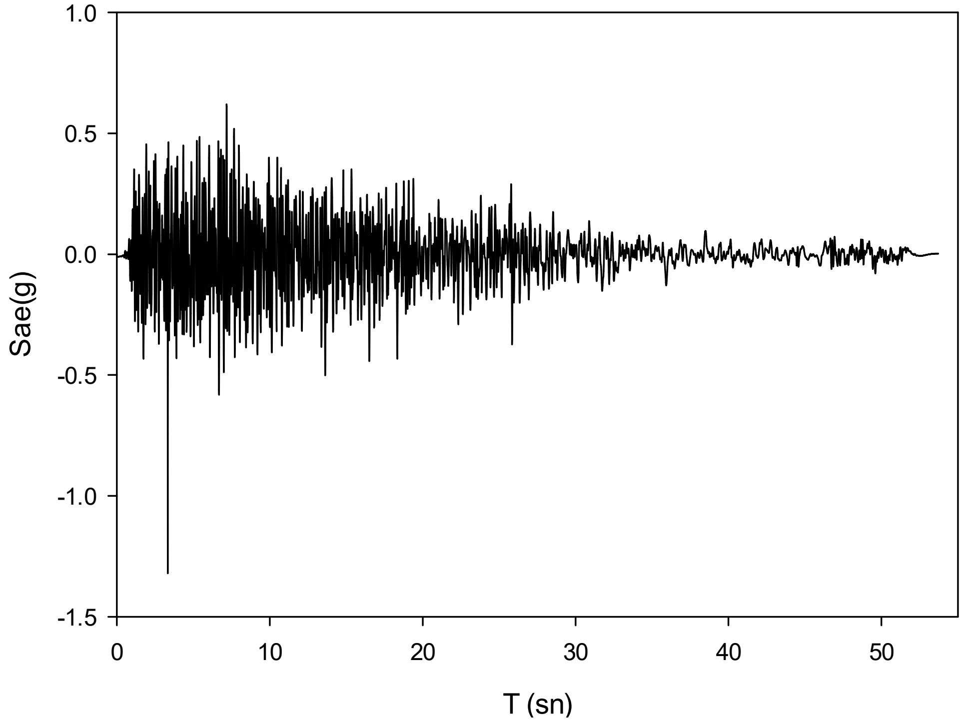

Figure 5. Z Component of 1940 El Centro earthquake

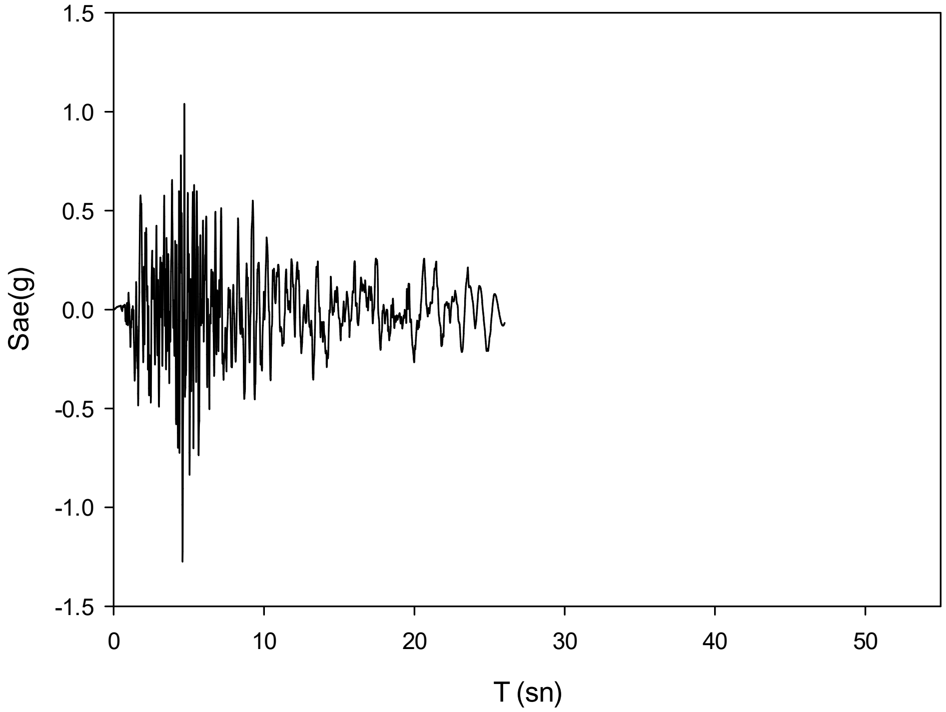

Figure 6. X Component of 1966 Shandon earthquake

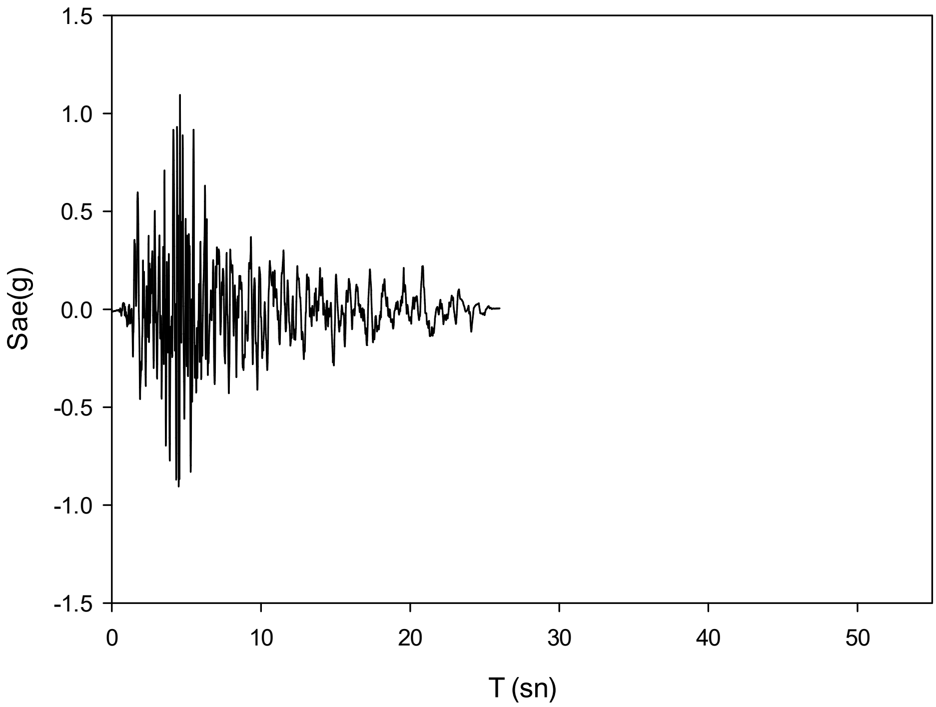

Figure 7. Y Component of 1966 Shandon earthquake

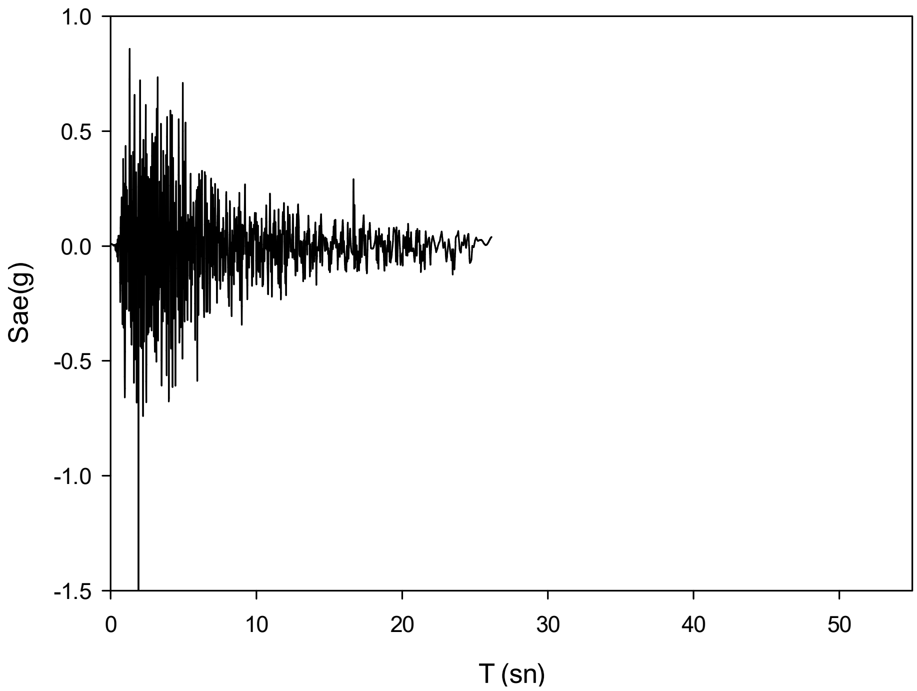

Figure 8. Z Component of 1966 Shandon earthquake

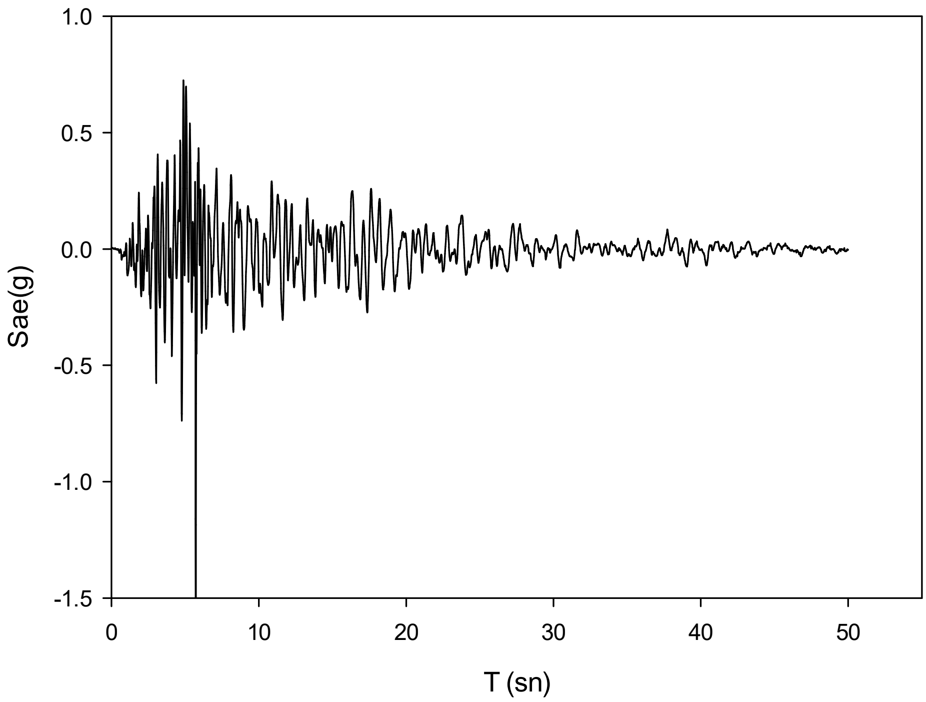

Figure 9. X Component of 1979 Gilroy earthquake

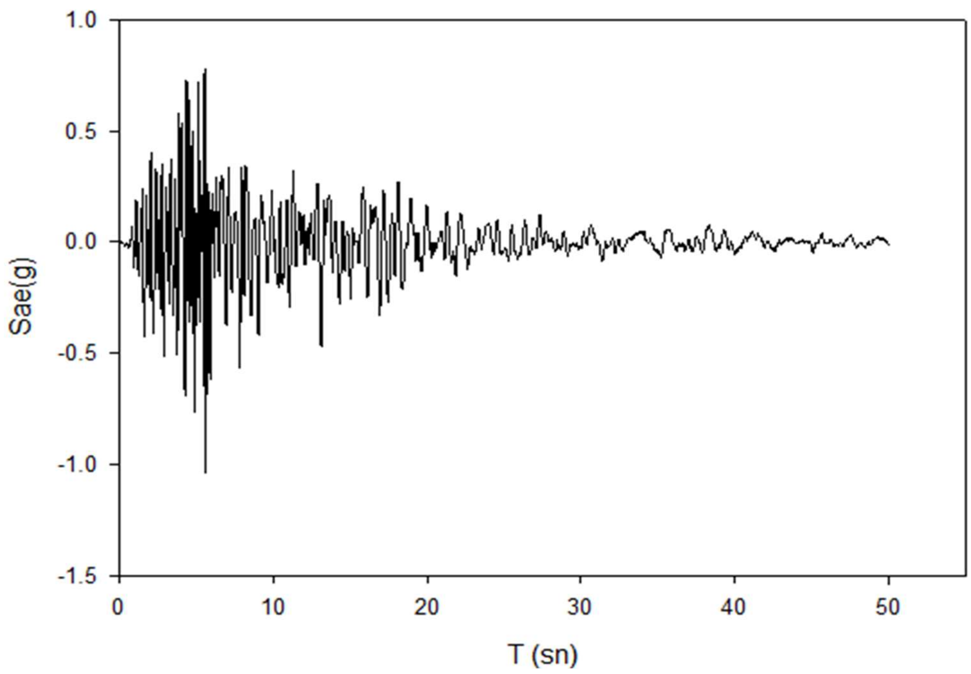

Figure 10. Y Component of 1979 Gilroy earthquake

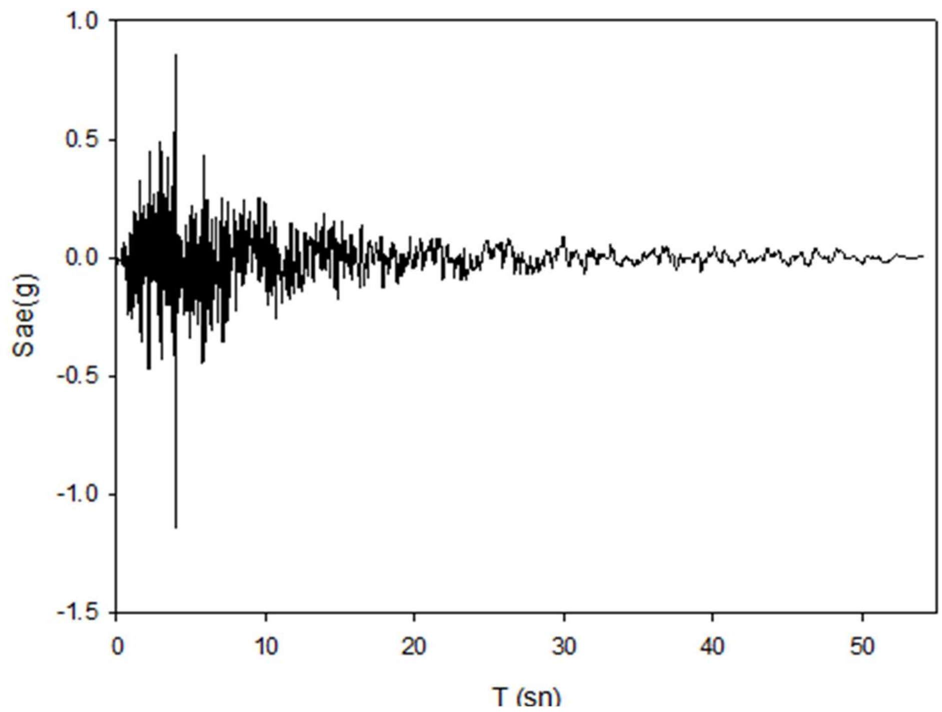

Figure 11. Z Component of 1979 Gilroy earthquake

Figure 12 shows that maximum values of lateral displacements for different materials according to earthquake records.

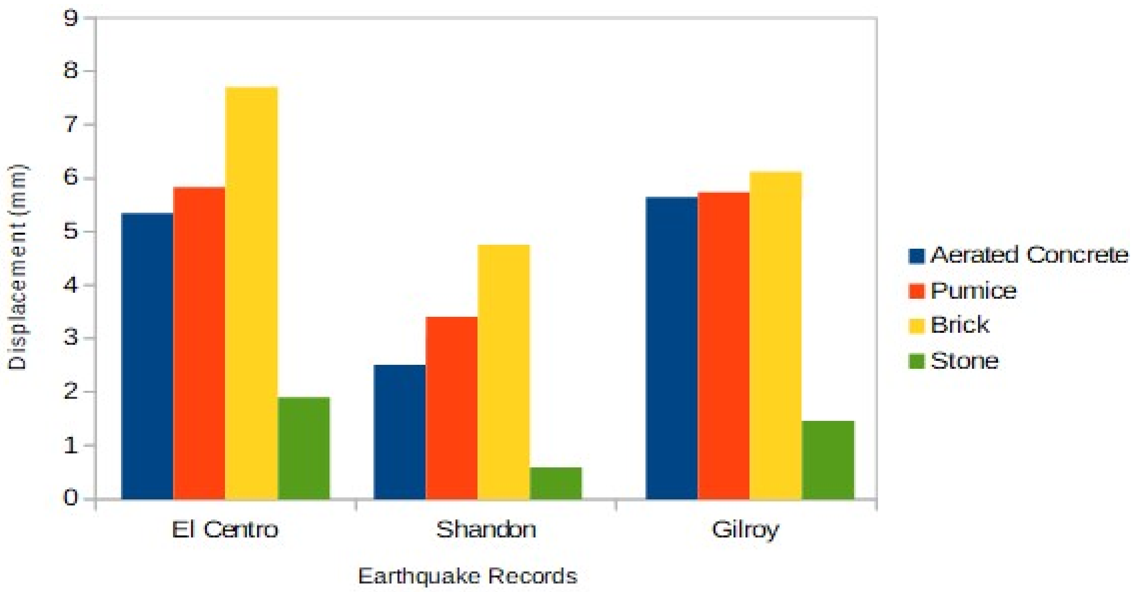

Figure 12. Lateral displacement values

3. CONCLUSION

In this article, the working principle of the masonry structures used from past to present, the materials used in the structure and how these materials affect the structure are examined. A masonry wall is modelled in ANSYS program. the dimensions of the wall are 4m x 4m x 0.25m. Aerated concrete, pumice, brick and stone materials were introduced separately as wall materials. Analyses were made for each earthquake applied to the wall. When the analysis results were examined, it was found that the brick with the lowest flexibility module had higher displacement and the stone with the highest flexibility module had the lowest displacement. When we sort the displacement order from big to small, it becomes brick, pumice, aerated concrete and stone. The reason why earthquakes with different dimensions have the same displacement is seen when focal depths are examined. The amount of displacement is related to the depth of focus of the earthquake. When we look at the El Centro and Gilroy earthquakes, the earthquake dimensions are 6.95 Mg for El Centro and 5.74 Mg for Gilroy. However, the displacement amount is the same in both earthquakes. The reason for this is that the depth of focus is 6.09 km in the El Centro earthquake and 3.11 km for the Gilroy earthquake. As a result, in the earthquake of the same size, the amount of displacement in the earthquake region with a close focus depth will increase and will decrease reliability.

REFERENCES

Badry, P., Satyam, N. (2014). Dynamic Analysis to Study Soil-Pile Interaction Effects, *Internatinal conference in Emerging trends in Civil Engineering (ICETCE 2014)*

Başyiğit C., Gençer Ö.,Terzi S. (2001). 'Bimsblok ile yapılan yığma yapının deprem davranışının araştırılması', *İMO Antalya bülteni*.

Bayülke, N., Hürata, A., Doğan, A. (1976). Düşey Delikli Taşıyıcı Tuğladan Yapılmış Yığma Yapıların Sarsma Tablası Deneyleri' Raporu. *Bayındırlık ve İskan Bakanlığı Afet İşleri Genel Müdürlüğü Deprem Araştırma Dairesi Başkanlığı*, s76. Ankara.

Bayülke, N., (1998). Depreme Dayanıklı Betonarme ve Yığma Yapı Tasarımı. *İnşaat Mühendisleri Odası İzmir Şubesi* Yayın No:27, 245s.

Bayülke, N. (2011). Yığma Yapıların Deprem DavranıÇı ve Güvenliği, *1. Türkiye Deprem Mühendisliği ve Sismoloji Konferansı*, 11-14 Ekim ODTÜ, Ankara.

Benedetti, D., Carydis, P., Pezzoli, P. (1998). *Shaking Table Tests on 24 Simple Masonry Buildings*. Earthquake Engineering and Structural Dynamics, (27), 67-90.

Çırak, İ.F. (2011). Yığma Yapılarda Oluşan Hasarlar, Nedenleri ve Öneriler, *SDU International Journal of Technologic Sciences, No. 2,* pp. 55-60.

Korkmaz K.A., Çarhooğlu A.I., Orhon A.V., Nuhoğlu A. (2014). Farklı Yapısal Malzeme Özelliklerinin Yığma Yapı Davranışına Etkisi, *Nevşehir Bilim ve Teknoloji Dergisi,* Cilt 3(1), ss.69-78.

Köktürk, U. (1997). Endüstriyel Hammaddeler, *Dokuz Eylül Üniversitesi Yayını*,Yayın No:205

Sesigür H., Büyüktaşkın H.,A., Çılı F. (2005). Gazbeton duvar ve döşeme elemanları ile inşa edilen az katlı konut binalarının deprem güvenliği. *Kocaeli deprem sempozyumu*.