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Research Article

A STUDY ON DETERMINATION OF REGIONAL EARTHQUAKE RISK DISTRIBUTION OF MASONRY STRUCTURES

Veda Seven Biçen[1,a], Ercan Işık[2,b], Enes Arkan[1,c], Ali Emre Ulu[2,d,*]

[1] Bitlis Eren University, Faculty of Engineering and Architecture, Dept. of Architecture, Bitlis
[2] Bitlis Eren University, Faculty of Engineering and Architecture, Dept. of Civil Eng., Bitlis

ORCID[a] : 0000-0002-8747-051X
ORCID[b] : 0000-0001-8057-065X
ORCID[c] : 0000-0002-6588-7234
ORCID[d] : 0000-0001-7499-3891

[*]Corresponding Author: aliemreulu@gmail.com
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Abstract

Masonry structures, built using local materials, with the help of local craftsmen and workers, without any engineering service, make up the majority of rural building stocks. Earthquake resistance of such structures is lower than other structures. Within the scope of this study, risk priorities have been determined for different geographical locations by using the simplified method proposed for determining the regional earthquake risk distributions of masonry structures included in the Principles Regarding the Determination of Risky Structures that entered into force in 2019. For this purpose, a province has been selected from each geographical region. Structural performance scores were calculated to determine the risk priorities of the masonry structure chosen as an example in these provinces. The results obtained were interpreted and suggestions were made.

Keywords: Masonry Structure; Rapid Assessment; Risk Distribution; Geographic Location.

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Araştırma makalesi

YIĞMA YAPILARIN BÖLGESEL DEPREM RİSK DAĞILIMLARININ BELİRLENMESİ ÜZERİNE BİR ÇALIŞMA

Özet

Yöresel malzemeler kullanılarak, yöresel usta ve işçiler yardımı ile herhangi bir mühendislik hizmeti almadan inşa edilen yığma yapılar kırsal yapı stoklarının büyük bir çoğunluğunu oluşturmaktadır. Bu tür yapıların deprem dayanımları diğer yapılara oranla daha düşük olmaktadır. Bu çalışma kapsamında, 2019 yılında yürürlüğe giren Riskli Yapıların Tespit Edilmesine İlişkin Esaslar içerisinde yer alan yığma yapıların bölgesel deprem risk dağılımlarının belirlenmesi için önerilen basitleştirilmiş yöntem kullanılarak farklı coğrafik konumlar için risk öncelikleri belirlenmiştir. Bu amaç doğrultusunda her bir coğrafi bölgeden bir il seçilmiştir. Örnek olarak seçilen yığma yapının bu illerde yer almasına göre risk önceliklerinin belirlenebilmesi için yapısal performans puanları hesaplanmıştır. Elde edilen sonuçlar yorumlanarak, öneriler yapılmıştır.

Anahtar Kelimeler: Yığma yapı; Hızlı değerlendirme; Risk dağılımı; Coğrafik konum.

1. INTRODUCTION

The history of masonry structures in most rural areas goes back to the settled life of people. The vast majority of such structures have not received engineering service and are designed without complying with the design principles contained in the relevant regulations. Damages in masonry structures after earthquakes reveal that the earthquake resistance of these types of structures is lower than other structures. It is important to know the seismic performances for masonry structures that make up a large part of the rural building stock. However, the high number of building stock does not make the detailed structural evaluation process of the buildings possible both in terms of time and cost. Therefore, risk priorities can be determined by using fast and accurate assessment methods on building stocks (Özlük et al., 2019; Karaşin et al., 2016; Yakut, 2004; Šipoš, Hadzima-Nyarko, 2017; Arslan, 2010; Harirchian & Lahmer, 2020; Işık et al., 2017; Işık, 2016). In this context, rapid assessment methods have been developed for building stocks. Using these methods, risk priorities can be determined for building stocks. This creates a great reduction in the number of structures to be examined in detail. (Işık, 2013; Işık, 2015).

With the regulation published by the Ministry of Environment and Urbanization in 2013, the first phase assessment method related to the identification of risky buildings was specified in detail. As a result of the important changes in the Turkey Earthquake Hazard Maps and Turkey Building Regulations updated in 2018, this regulation was updated and put into effect in 2019 (TBEC-2018; PDRB, 2019; https://tdth.afad.gov.tr/,2020). In this regulation, simplified methods that can be used to determine the regional earthquake risk distribution of different types of buildings are specified with details. The parameters to be taken into consideration in this method and how the structural result scores should be calculated are specified separately for different types of structures.

Within the scope of this study, using the rapid assessment method determined for masonry structures in this regulation, risk priorities were determined if a sample masonry structure is located in different geographical locations. For this purpose, a province was selected from each geographical region which are Bitlis, Ankara, Diyarbakır, Adana, Giresun, Denizli and Tekirdağ. Updated earthquake maps for these provinces and earthquake parameters were determined with the help of an interactive web application. Using the obtained earthquake parameters, risk priority was determined between regions for the masonry structure model selected as an example.

2. MATERIALS AND METHODS

2.1. Masonry Structure Properties Selected As An Example

Loads formed in masonry structures are carried to the bearing walls. The loads formed in the building are constructed to be transferred to the ground by means of walls with a carrier feature. Wall thicknesses take values well above the wall thicknesses of reinforced concrete structures. Since the wall elements will exhibit both partition and bearing properties, the thickness value takes great values. The inner and outer walls of the building are formed by stacking local materials and joining them with the help of binding material. Masonry materials such as stone, adobe, brick, etc. are used in the vertical bearing elements (walls and columns) of masonry systems and the stress type prevailing in this system is pressure. The compressive strengths of the materials used in masonry structures are high and the tensile strengths are low. In this case, these elements, which can be exposed to large pressure forces, are not resistant to bending and shear effect (Bayülke, 2011; Arun, 2005; Korkmaz et al., 2014; Koç, 2016; Çırak, 2011;

Karaşin & Öncü, 2009; Korkmaz et al., 2016; Hadzima-Nyarko, et al., 2018; Biçen & Işık, 2018; Özlük et al., 2019b). The floor plan of the masonry structure considered within the scope of this study is shown in Figure 1. This masonry structure chosen as an example has been evaluated as having the same structural features for all provinces subject to the study. Different geographic locations were chosen as variables.

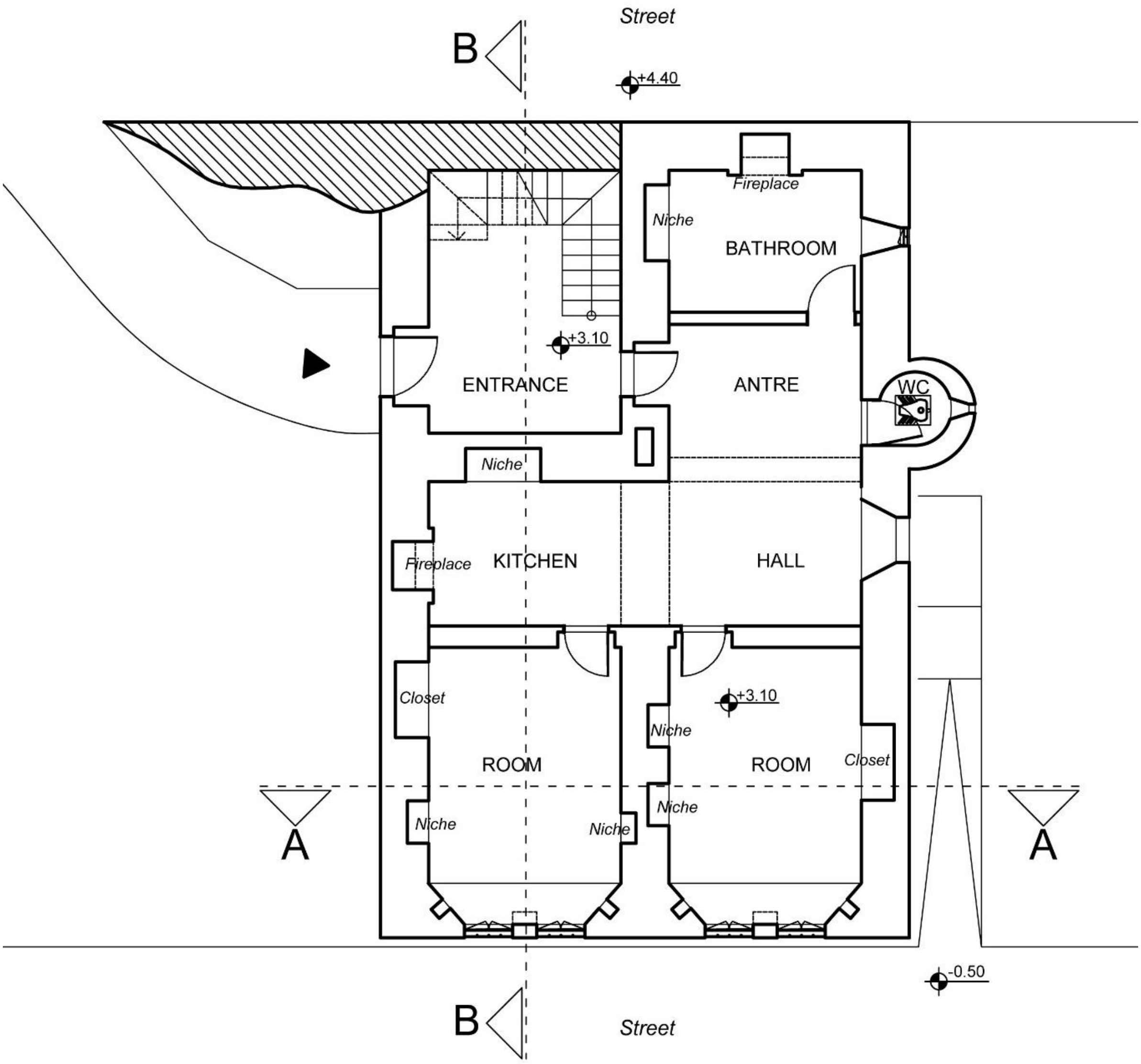

Figure 1. The considered masonry structure floor plan

The facade view of the masonry structure considered is shown in Figure 2.

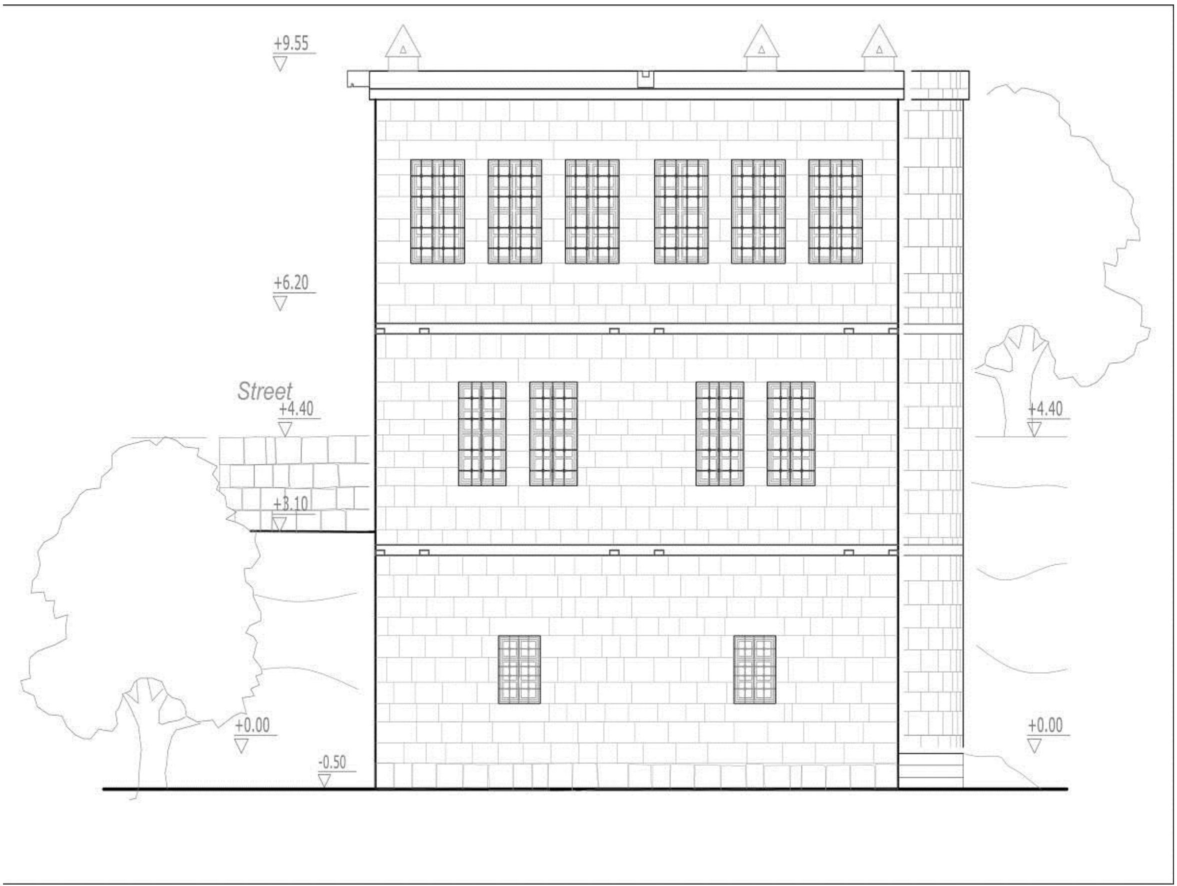

Figure 2. The front view of the masonry structure considered.

2.2. Determination of Earthquake Parameters

The study aims to reveal the effect of different geographical locations for a masonary structure with the same local ground conditions, the same earthquake ground motion level and the same structural features. In this context, one province from each region was selected to represent the seven geographical regions. For this purpose, any geographical location from Bitlis, Ankara, Diyarbakır, Adana, Giresun, Denizli and Tekirdağ provinces were chosen randomly. The provinces considered in the study are shown in Figure 3.

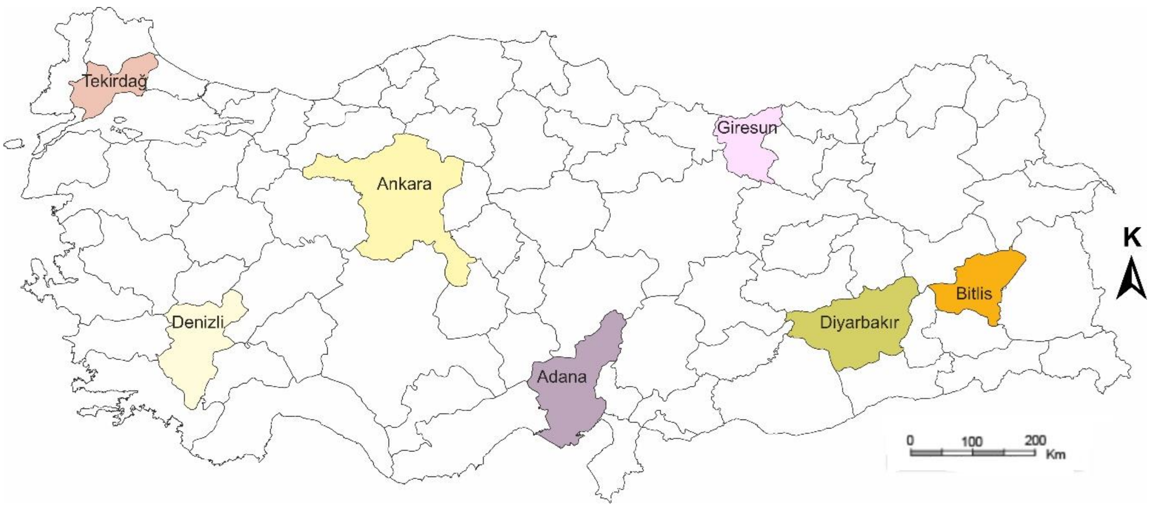

Figure 3. Different geometrical positions considered in the study

In the selections made for all provinces subject to the study, the earthquake ground motion level DD-2, which has a probability of exceeding 50 years as the ground class ZC and 10% (repetition period 475 years) as earthquake ground motion, was taken into consideration. Within the scope of the study, using Turkey Earthquake Hazard Maps Interactive Web Application, short period map spectral acceleration coefficient (SS) for each province in each geographic region, map spectral acceleration coefficient (S1) for a 1.0 second period, greatest ground acceleration (PGA), maximum ground velocity (PGV), local ground impact coefficients (FS and F1), design spectral acceleration coefficients (Short period design spectral acceleration coefficient (SDS) and design spectral acceleration coefficient (SD1) for 1.0 second period) and horizontal and vertical elastic spectrum values were calculated separately. Earthquake parameters for these provinces are shown in Table 1.

Table 1. A comparison of earthquake parameter values for DD-2 ground motion level

Parameter	Adana	Ankara	Bitlis	Denizli	Diyarbakır	Giresun	Tekirdağ
SS	0.537	0.446	0.612	1.148	0.315	0.391	0.985
S1	0.133	0.127	0.171	0.265	0.131	0.140	0.274
PGA	0.235	0.192	0.259	0.469	0.140	0.168	0.402
PGV	12.064	11.200	15.014	26.584	10.432	11.499	25.616
FS	1.285	1.300	1.255	1.200	1.300	1.300	1.200
F1	1.500	1.500	1.500	1.500	1.500	1.500	1.500
SDS	0.690	0.580	0.768	1.378	0.409	0.508	1.182
SD1	0.199	0.191	0.257	0.397	0.197	0.210	0.411

3. RESULTS

3.1. Evaluation Method for Masonry Structures

The risk priority has been determined for the masonry buildings that can be found in the geographical locations considered within the scope of this study. The Principles for Determining Risky Buildings, which came into force on 16/02/2019, has been taken into consideration in this study (PDRB, 2019). This method can be used for existing masonry buildings of 1 to 5 stories. Earthquake hazard zones have been calculated for masonry buildings given in Table 2.

Table 2. Earthquake hazard zones for masonry buildings (PDRB, 2019)

<table>
<tr><th rowspan="2">Number of Storey</th><th colspan="3">Earthquake Danger Zone</th></tr>
<tr><th>Region I
$S_{DS} \geq 1.0$</th><th>Region II-III
$0.5 \leq S_{DS} < 1.0$</th><th>Region IV
$S_{DS} < 0.5$</th></tr>
<tr><td>1</td><td>110</td><td>120</td><td>130</td></tr>
<tr><td>2</td><td>100</td><td>110</td><td>120</td></tr>
<tr><td>3</td><td>90</td><td>100</td><td>110</td></tr>
<tr><td>4</td><td>80</td><td>90</td><td>100</td></tr>
<tr><td>5</td><td>70</td><td>80</td><td>90</td></tr>
</table>

The earthquake hazard zones of sample masonry building taken as an example considering for all provinces are shown in Table 3.

Table 3. The hazard zone for sample masonry buildings

No	Province	S_{DS}	Hazard Zone Region
1	Adana	0.690	II-III
2	Ankara	0.580	II-III
3	Bitlis	0.768	II-III
4	Denizli	1.378	I
5	Diyarbakır	0.409	IV
6	Giresun	0.508	II-III
7	Tekirdağ	1.182	I

The parameters required for this method for existing masonry buildings to be used are as follows:

- Masonry building type
- Number of free stories
- Building regulation / pounding
- Current situation and visual quality
- Irregularity in plan
- Insufficient wall quantity
- Vertical spacing irregularity
- Changing number of stories according to the facade
- Soft /weak storey
- Out-of-plane behavioural problems
- Roof material
- Earthquake region
- Geographic coordinates

The negativity parameter values used in the study and considered in the masonry structures in order to determine the regional earthquake risks are given in Table 4.

Table 4. Negative parameter values (PDRB-2019)

Negative parameter no	Negative parameter	Case 1		Case 2	
		Parameter identification	Parameter value	Parameter identification	Parameter value
1	Building Order	Separate	0	Adjacent/Adjacent to Corner	1
2	Material Quality	Good	0	Moderate, (Bad)	1,(2)
3	Wall Labor	Good	0	Moderate, (Bad)	1,(2)
4	Current Damage	None	0	Available	1
5	Irregularity in the Plan	Regular	0	Irregular, (Extremely Irregular)	1,(2)
6	Lack of horizontal girder	Above the wall, above the window	0	None	1
7	Wall Quantity Insufficient (WQ)	High	0	Moderate, (Low)	1,(2)
8	Vertical Gap Irregularity	Regular	0	Less Irregular, (Irregular)	1,(2)
9	Floor Difference by Facade	None	0	Available	1
10	Soft Storey/Weak Storey	None	0	Available	1
11	Floor Type	Reinforced concrete	0	Wood,Volto	1
12	Mortar Material	Cement	0	Lime, Mud, None	1
13	Wall-Wall Connection	Good	0	Bad	1
14	Wall-Floor Connection	Good	0	Bad	1
15	Roof Material	Tile, Sheet, Concrete	0	Soil	1

Table 5 shows the predicted negativity scores for the current situation, masonry and damages in masonry structures.

Table 5. Current state and quality negativity scores (PDRB-2019)

Material quality (0/1/2)	Wall Labor (0/1/2)	Current Damage (0/1)
-10	-5	-5

In the method considered in the study, the negativity points specified for geometry, amount of wall and beam/lintel as irregularities in the plan are shown in Table 6.

Table 6. Scores of negation in plan (PDRB-2019)

Geometry (0/1/2)	Wall Amount (0/1/2)	Beam/Lintel (0/1)
-5	-5	-5
-10	-5	-5
-10	-10	-5
-15	-10	-5
-20	-15	-5

The negative points in the vertical are shown in Table 7

Table 7. Vertical negativity scores (PDRB-2019)

Number of floors	Space layout (0/1/2)	Floor difference according to facade (0/1)	Soft Storey/Weak Storey (0/1)
1	0	-5	0
2	-5	-5	-5
3	-5	-5	-5
4	-10	-5	-10
5	-10	-5	-10

The relationship of the building with other buildings and the predicted negativity scores for the floor level are shown in Table 8.

Table 8. Building order and floor level negativity scores (PDRB-2019)

s	Adjacent Medium-Same	Adjacent Edge-Same	Adjacent Medium-Different	Adjacent Edge-Different
0	0	-5	-5	-10

Building performance score with all results obtained will be determined with the help of the formula below.

$$PP = TP + \sum_{i=1}^{n} (O_i * OP_i) + YSP \quad (1)$$

Here, PP refers to performance score, TP base score, Oi, each negativity parameter, OPi negativity parameter score, and YSP refers to the positive parameter score as structural system score. The structural system score (YSP) of the masonry structure selected as an example (since it is unreinforced) is taken as zero. The parameters and parameter values determined for the examined sample masonry structure are shown in Table 9. Since the building is not adjacent to any building, it is considered as separate. The medium value was chosen as the material quality. It is accepted that there is no damage in the building with good masonry. The number of free floors of the sample masonry structure, which does not contain any irregularities in the plan, is considered as 3 floors. It is assumed that beams and lintels were used on the windows, doors and walls of the building. The ground floor is taken into account for the amount of walls. Front wall lengths in two perpendicular directions were obtained on this floor. The total lengths of the spaces such as windows and doors on the two facades were found and divided by the total length of the facade wall and the wall void ratio (VR) was calculated. Since the window and door openings in the vertical direction partially overlap, less regular selection has been made. There is no soft/weak storey in the structure with no difference in floors on the facades. The entire building is used for residential purposes, and the load-bearing walls are in the same position on all floors. Soil roof was adopted as roofing a material.

Table 9. Parameter values for sample masonry building

No	Negation parameter	Parameter detection	Par. value
1	Building Order	Separate	0
2	Material Quality	Medium	1
3	Wall Labor	Good	0
4	Current Damage	None	0
5	Irregularity in the Plan	Regular	0
6	Lack of horizontal girder	Above the Wall/Window	0
7	Wall Quantity Insufficient (WQ)	VR=0.126 <1/3; DM=High	0
8	Vertical Gap Irregularity	Less regular	1
9	Floor Difference by Facade	None	0
10	Soft Storey/Weak Storey	None	0
11	Floor Type	Wood etc.	1
12	Mortar Material	Lime etc.	1
13	Wall-Wall Connection	Good	0
14	Wall-Floor Connection	Good	0
15	Roof Material	Soil	1

Performance scores for each province are shown in Table 10 in the light of these features determined in the masonry structure selected as an example.

Table 10. Performance scores for masonry structure with the same characteristics in different provinces

No	Province	Hazard Zone Region	TP	Total negativity score	YSP	PP
1	Adana	II-III	100	-25	0	75
2	Ankara	II-III	100	-25	0	75
3	Bitlis	II-III	100	-25	0	75
4	Denizli	I	90	-25	0	65
5	Diyarbakır	IV	110	-25	0	85
6	Giresun	II-III	100	-25	0	75
7	Tekirdağ	I	90	-25	0	65

4. CONCLUSIONS

Along with the updated earthquake regulations and maps, regulations on risky buildings have been changed. One of the most important changes in the updated earthquake hazard maps is the calculation of geographic location-specific earthquake parameters. The seismicity elements of each settlement may differ. In the previous maps, earthquake parameters were calculated on a regional basis. With this study, one province from seven different geographical regions in Turkey was taken into consideration. Earthquake parameters are calculated separately for each province. In light of these parameters, Denizli was the province with the highest risk among the provinces considered in this study, while the lowest risk was calculated for Diyarbakır.

In addition, in the study, necessary updates were made in the "Principles Regarding the Determination of Risky Buildings", which is inevitable to be renewed in accordance with the updated map and regulation in 2018. Based on these updated principles, if a masonry structure is selected as an example is located in seven selected provinces, its scores were calculated based on risk priorities. The aim of the study is to determine the risk distributions when a masonry structure with the same structural features is located in different regions. A complete harmony has been achieved between the obtained earthquake parameters and the calculated performance scores. While the highest risk priority for masonry structures is calculated for Denizli, the lowest risk priority is calculated for Diyarbakır. The purpose of this method is only to determine risk priorities.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

REFERENCES

Arslan, M.H. (2010). An evaluation of effective design parameters on earthquake performance of RC buildings using neural networks. Engineering Structures, 32(7), 1888-1898.

Arun, G. (2005). Yığma Kagir Yapı Davranışı,- Yığma Yapıların Deprem Güvenliğinin Arttırılması Çalıştayı, Orta Doğu Teknik Üniversitesi, Ankara.

Bayülke, N. (2011). Yığma Yapıların Deprem Davranışı ve Güvenliği, Türkiye Deprem Mühendisliği Ve Sismoloji Konferansı, Orta Doğu Teknik Üniversitesi, Ankara.

Biçen, V.S., & Işık, E. (2018). Evaluation of building elements and material usage in traditional Bitlis houses on a sample structure. International Conference on Multidisciplinary, Science, Engineering and Technology (IMESET'18 Dubai). Dubai.

Çırak, İ.F. (2011). Damages observed in masonry structures, causes and recommendations. SDU International Technologic Science, 3(2), 55-60.

Hadzima-Nyarko, M., Ademović, N., Pavić, G. & Šipoš, T.K. (2018). Strengthening techniques for masonry structures of cultural heritage according to recent Croatian provisions. Earthquakes and Structures, 15(5), 473-485.

Harirchian, E. & Lahmer, T. (2020). Improved Rapid Visual Earthquake Hazard Safety Evaluation of Existing Buildings Using a Type-2 Fuzzy Logic Model. Applied Sciences, 10(7), 2375.

Işık, E. (2013). Bitlis ili yapı stoğunun birinci kademe (sokak tarama yöntemi ile) değerlendirilmesi. Journal of Natural and Applied Science, 17(1), 173-178.

Işık, E. (2015). Investigation of an existing RC building with different rapid assessment methods. Bitlis Eren University Journal of Science and Technology, 5(2), 71-74.

Işık, E. (2016). Consistency of the rapid assessment method for reinforced concrete buildings. Earthquakes and Structures, 11(5), 873-885.

Isik, E. Isik, M.F. & Bulbul, M.A. (2017). Web based evaluation of earthquake damages for reinforced concrete buildings. Earthquakes and Structures, 13(4), 387-396.

Karaşin, A., & Öncü, M.E. (2009). Evaluation of earthquake safety of multi-storey masonry buildings. Doğu Anadolu Araştırmaları Dergisi, 2009, 63-68.

Karaşin, İ.B., Eren, B. & Işık, E., (2016). Mevcut bir yığma yapının farklı hızlı değerlendirme yöntemleri ile değerlendirilmesi. Dicle Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 5(2), 70-76.

Koç, V. (2016). Depreme Maruz Kalmış Yığma ve Kırsal Yapı Davranışlarının İncelenerek Yığma Yapı Yapımında Dikkat Edilmesi Gereken Kuralların Derlenmesi,Çanakkale Onsekiz Mart Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 2, 1, 36-57 https://tdth.afad.gov.tr/ (Access date: 08.07.2020)

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

Korkmaz, A., Çarhoğlu, A.I., Orhon, A.V. & Nuhoğlu, A. (2014). Effects of different structural material properties on masonry building structural behaviour. Nevşehir Journal of Science and Technology, 3(1), 69-78.

Özlük, M.H., Işık, E., Günsel E., Büyüksaraç, A. & Aydın M.C. (2019). 20 Şubat 2019 Meydana Gelen Ayvacık Depreminde Yığma Yapı Hasarlarının İncelenmesi. 1. Uluslararası Uygulamalı Bilimler Kongresi, 26-28 Nisan 2019, Diyarbakır.

Özlük, M.H., Işık, E., Günsel E., Büyüksaraç, A., & Aydın M.C. (2019b). Yığma Yapılar İçin Hasar Derecelendirilmesi Üzerine Örnek Bir Çalışma 1. Uluslararası Uygulamalı Bilimler Kongresi, 26-28 Nisan 2019, Diyarbakır.

PDRB (2019). Principles for Determining Risky Buildings, RG-16/2/2019-30688, Ankara, Turkey.

Šipoš, T.K. & Hadzima-Nyarko, M. (2017). Rapid seismic risk assessment. International Journal of Disaster Risk Reduction, 24, 348-360.

TBEC (2007). Turkish Building Earthquake Code, Ankara, Turkey

Yakut, A. (2004). Preliminary seismic performance assessment procedure for existing RC buildings. Engineering Structures, 26(10), 1447-1461.