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Architectural Characteristics and Determination Seismic Risk Priorities of Traditional Masonry Structures: A Case Study for Bitlis (Eastern Türkiye)

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Abstract: The loss of life due to large-scale structural damage has again demonstrated the importance of taking precautions before an earthquake. In this context, determining the risk priorities for the existing building stock and making the final decisions about the buildings is one of the basic measures to be taken before an earthquake. Within the scope of this study, the regional risk priorities have been determined for twenty different masonry buildings in Bitlis (Türkiye), located in the Lake Van Basin, which has a high earthquake risk. The Turkish Rapid Assessment Method was used for masonry structures in this study which was updated in 2019 using the necessary data obtained for each structure on site. In addition, information about the architectural characteristics and current structural conditions of traditional Bitlis houses is given in this study. Current seismic parameters are also obtained for the location of each building. All data in the article were obtained from field research, and this is one of the first studies in which the rapid assessment method was used. In this method, buildings with low scores have a higher risk priority, and building performance scores were obtained between 25 and 85. With this and similar studies, regional risk priorities can be determined, and the number of buildings subjected to detailed assessment can be reduced.

Keywords: Bitlis; traditional; masonry; seismic risk; architectural; rapid assessment

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1. Introduction

Lake Van Basin is a high seismic risk region in the Eastern Anatolia Region. In the basin, Bitlis City has been the cradle of many different civilizations and is located on a strategic transition corridor. Especially in recent years, the devastating earthquakes in this basin and the loss of life and large-scale economic damage resulting from these earthquakes have brought up the importance of studies, research, and measures to be taken regarding earthquakes.

An important part of modern predisaster management is that an assessment of the behavior of the existing structures under the influence of earthquakes is carried out before a possible earthquake. The main purpose of determining the earthquake safety of buildings is to make the right decisions about the existing building stock by making the necessary assessments and structural analysis before a possible earthquake [1–8]. It is not easy to make detailed structural analyses due to the large stock of existing buildings. It is also a problematic process regarding time, cost, and technical staff for detailed structural analysis. Therefore, using fast and accurate evaluation methods on the existing building stock is a practical solution [9–12]. These methods, developed using post-earthquake statistical data, are very practical in applicability [13,14]. These methods are generally based on the observational analysis of the building from the outside and partly from the inside [15]. There are many methods for rapid assessments of the existing structures. The Turkish Rapid

Assessment Method (PDRB-2019) [16] was used in this study, updated in 2019. Within this study's scope, the sample buildings' regional risk priorities were determined using this method. This method was first published and implemented in 2013 by the Ministry of Environment, Urbanization, and Climate Change. In light of earthquakes in Türkiye and scientific developments, both the earthquake hazard map and the seismic design code were updated in 2018. The Turkish Rapid Assessment Method was also updated in 2019 in accordance with the important changes made in the map and code [16–19]. In this regulation, simplified methods that can be used to determine the regional earthquake risk distribution of different types of buildings, such as reinforced concrete and masonry, are specified with detail. In this study, the proposed method for masonry structures was used.

The history of masonry buildings dates back to the settled life of people. A large part of the existing building stock consists of masonry structures that were built without any engineering services. Therefore, these types of structures are most affected by earthquakes [20]. Structural damages in masonry buildings reveal that the earthquake resistance of such structures is lower than other structures [21–27]. The masonry structures built with local materials and construction techniques are shaped by the effects of climate and topography. Architectural characteristics in masonry buildings also directly affect risk priorities [28,29]. In this respect, studies on such structures can be an important support tool for decision makers.

There are studies on seismic risk priorities related to urban-level scoring. Formisano et al. [30] made a seismic evaluation of two ancient masonry church sets in two different regions in Italy with three different simplified methods. Fabbrocino et al. [31] used a simplified method for regional-scale seismic assessments, and they obtained a global score for churches located on two different islands in Italy. Khemis et al. [32] determined the risk ratings for 226 unreinforced masonry buildings in Annaba, Algeria. The seismic fragility assessment of masonry buildings in two different settlements in Bosnia and Herzegovina was carried out using a macro seismic model by Ademović et al. [33]. Pirchio et al. [34] developed 13 different indices for risk grading with their fieldwork for 72 medieval masonry churches in Italy. Formisano and Marzo [35] compared the results by performing structural analysis and the simplified LV1 and advanced LV3 analysis levels given by the Italian Cultural Heritage Guidelines for a masonry building. Lourenço et al. [36] have presented a simplified method for the seismic assessment of large-span masonry structures, which provides lower bound formulas for different simplified geometric indices, applied to a database of 44 monuments in Italy, Portugal, and Spain. Özbay and Karapınar [37] tried to determine risk priorities for 213 masonry structures located in Istanbul Galata. This and similar studies can be considered case studies to determine risk priorities.

In this study, the authors carried out the architectural characteristics of the traditional Bitlis houses, which were built in masonry style, as a result of field investigations. As a result of this observation-based study, information was given about the damages that occurred in these structures, and solutions were presented. All pictures and figures used in the article were prepared by the authors from the site and in a computer environment. Within the scope of the study, 20 different traditional Bitlis houses were examined. In another part of this study, seismic parameters were determined using an updated Türkiye Earthquake Hazards Map Interactive Web Application for each building by considering the geographic coordinates measured on site. The necessary data for the Turkish Rapid Assessment Method was obtained with the help of this application. In addition, it was carried out using the Turkish Rapid Assessment Method, which was updated in 2019, to determine the regional earthquake risks of twenty different masonry structures in Bitlis. As a result of the measurements made in situ, the structural result scores were calculated for each masonry structure, and risk priority was determined among the selected structures. This study is one of the first investigations using the Turkish Rapid Assessment Method in masonry structures. The obtained results were evaluated and suggestions were made. The study is one of the most comprehensive studies of masonry structures in Bitlis, which is one of the settlements with the high earthquake risk. The study provides detailed information regarding Bitlis masonry stock in terms of different disciplines. The last earthquakes in Kahramanmaraş, which occurred in Türkiye on 6 February 2023, have made it necessary to determine the earthquake risks of the existing building stock. This study will be a definitive study for settlements when determining the risk priorities of masonry structures. The Turkish Rapid Assessment Method has been explained in detail in the study and can be used for different settlement units.

2. Architectural Characteristics of Traditional Bitlis Houses

The masonry structures in Bitlis are seen in the first settlement areas of the city (Figure 1). The settlement in this section is located in the valleys formed by the streams.

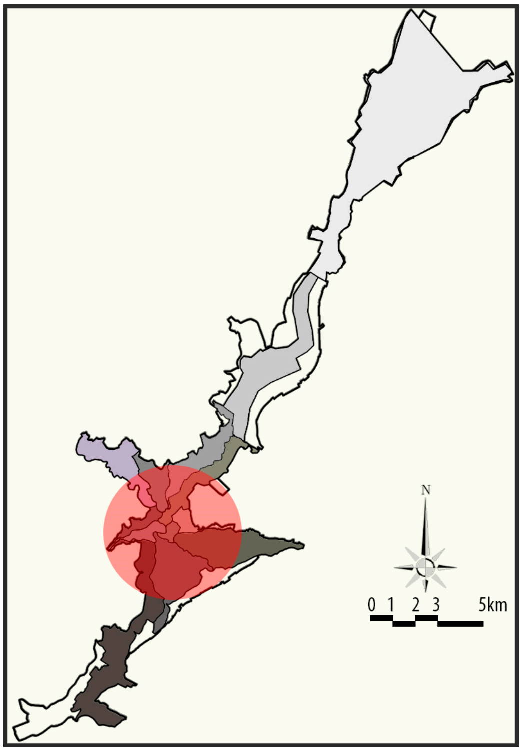

Figure 1. The location of the places where a traditional construction system is seen in the city of Bitlis.

The traditional masonry Bitlis houses have three floors at most. Due to the sloping topography, the floors in the buildings are built by gradual spreading from the ground floor to the top (Figure 2). In general, each floor can be accessed from the outside. However, there are also examples of vertical circulation from the bottom floor to the top. Due to the harsh climatic conditions, the building openings are small and few. The ornaments and decorations on the buildings consist of inscriptions.

The places where the structures shaped by the natural ground intersect with the rocky ground can be left without a wall. The lower floors are arranged as a barn or side sofa + room. In houses whose ground floor is used as a barn, the bottom of each room is mostly used as an independent unit. If there is more than one floor above, each floor is used as a separate independent unit. The upper floors are built with a middle sofa. The blind facades on the natural ground side are used as service spaces. It is connected to the outside with a small opening in the form of a culvert. Otherwise, lighting is made in the form of a chimney. The kitchen space is constructed together with the sofa; it creates a special area with its hearth and niches. The rooms are placed in sections with open walls so that they are not covered with the land. There are benches in front of the windows in the rooms with window openings that expand from the outside to the inside. Due to the crowded family structure in some houses, there are wet areas in the rooms. There are niches on the walls where beds and diary items are placed.

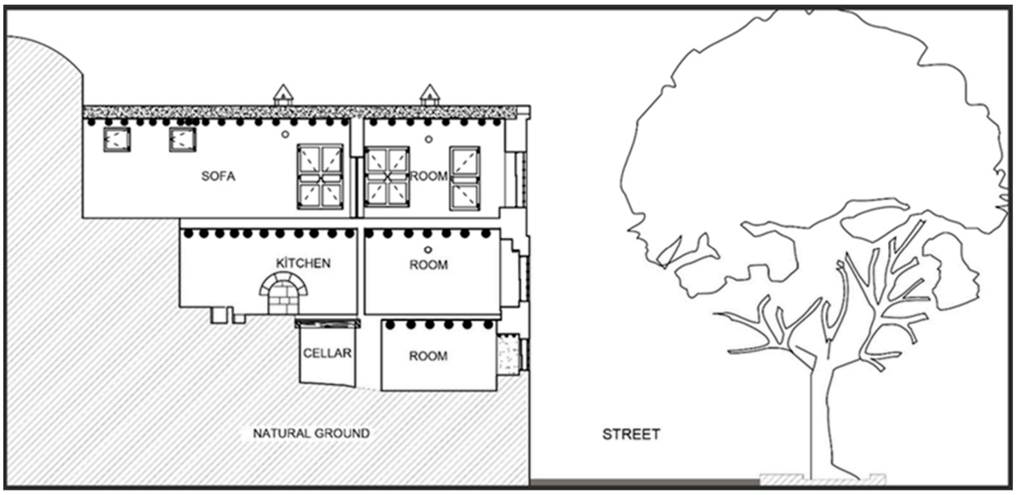

Figure 2. Section of the structure built with a masonry system.

The outer walls of the masonry Bitlis houses are in the form of multi-leaf stone masonry walls (Figure 3). There is cut stone on the outside, rough-cut stone on the inside, and rubble stone mixed with mortar in the middle. It is built in such a way that the wall thicknesses become thinner from the lower floor to the upper floor (100 cm to 75 cm). Although the separating walls in the interior of the space are mostly built with a similar method, the wooden Bağdadi construction (lath technique) is also seen [38,39].

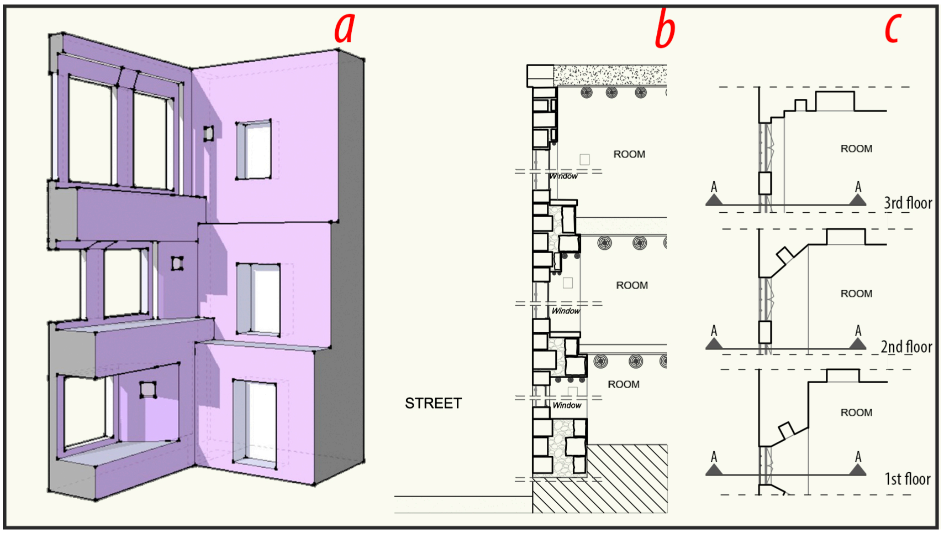

Figure 3. Wall detail: (**a**) Model of a 3-storey building, (**b**) Section, (**c**) Plans.

Although the mezzanine floors are vaulted in relatively qualified buildings, they are mostly built with wooden beams. Thin twigs, reeds, and wood veneer boards are added to the wooden beams. In some houses, it is also possible to make a stone coating on them. The top cover, which is built with a flat earth roof, is also built with wooden beams. On the top of the upper floor slab, which has a similar structure, soil fill called "Püsürük" and local soil called "Seg" filled with salt–straw–limestone are used.

3. Observational Structural Analysis in Traditional Bitlis Houses

Bitlis Stone, with its local name, was used in traditional Bitlis houses. Bitlis stone is considered to be a pyroclastic rock formed by the volcanic lavas from the explosion of the

Nemrut crater in the past, spreading and cooling in the region [40]. These ignimbrites are very sensitive to chemical and physical degradation. It is partially soft under the ground and hardens when in contact with air. The desired shapes can be readily given to the soft Bitlis stone by hand or machine. In addition, due to its porous structure, the Bitlis stone shows a certain degree of insulation if water absorption is prevented [41].

Bitlis City, in addition to being the province with the most snowfall in Türkiye, is located in a geography where temperature differences are high [42,43]. Snowfall generally starts in the first week of November and continues until the middle of the spring season. In the last week of April, the precipitation leaves its place to the melting process of the accumulated snow. The fact that the precipitation period is so long during the year increases the risk period in Bitlis [44]. Due to these reasons, various types of damage occur in Bitlis houses. In addition, various damages have occurred due to other environmental factors such as rupture and wear, depending on time. In these structures, which do not receive any engineering services, additional damages are observed due to precipitation, since no water isolation is applied to the ground. Water alone or together with other environmental factors negatively affects the mechanical properties of the building blocks and accelerates the degradation. It is known that due to temperature differences and frost events, some of the structures cause disintegration and rupture. Moisture-induced deterioration is observed in the sections of the stone texture that come into contact with water. The freeze–thaw cycle, which is effective in cold periods, is one of the most significant factors in the deterioration of structural materials, especially in Bitlis City, where the winter season is long. Depending on the seasons dominated by the dry climate, lichen formations attract attention. Lichen formations can have negative effects on the appearance and characteristics of the natural structure over time. There are calcifications in some of the structures examined due to excessive precipitation. It is observed that there are wear and mass losses in the wall joints. In addition, one of the common features of Bitlis stone is color change and discoloration with the impacts of natural conditions over time. Discoloration was observed in nearly all the examined structures. Since the soil properties are good in the examined structures, it has been observed that there is almost no ground consolidation over time.

In general, soil roofs are preferred in Bitlis masonry houses, which cause significant damage due to excessive snowfall. In some cases, depending on the degree of damage, structures become unusable over time. Damage to the structures due to roof leaks or collapses and the premature end of their useful life cause the homeowners to leave the buildings. Due to the official process for the repairs, it is not repaired and the house is in ruins over time. It is not possible to regain the houses that started to disappear over time because they are not used and maintained. Some images of the damage observed in the examined structures are shown in Figure 4.

Figure 4. Some of the observed damages to the structures: (**a**) Collapsed roof, (**b**) Moisture and lichen formation, (**c**) Surface loss, color change, vegetation.

4. Determination of Seismic Parameters for Selected Structures

Lake Van basin is one of the regions where current seismic activity is intense in Türkiye. The earthquakes and losses that occurred in this basin again revealed the seismicity risk of the basin. Earthquake hazard maps renewed in 1945, 1947, 1963, 1972, and 1996 in Türkiye, where the basin is located, were last updated in 2018 and entered into force in 2019 [45]. With the current earthquake map, the earthquake hazard has now started to be calculated specifically for the geographical location. The current map is shown in Figure 5.

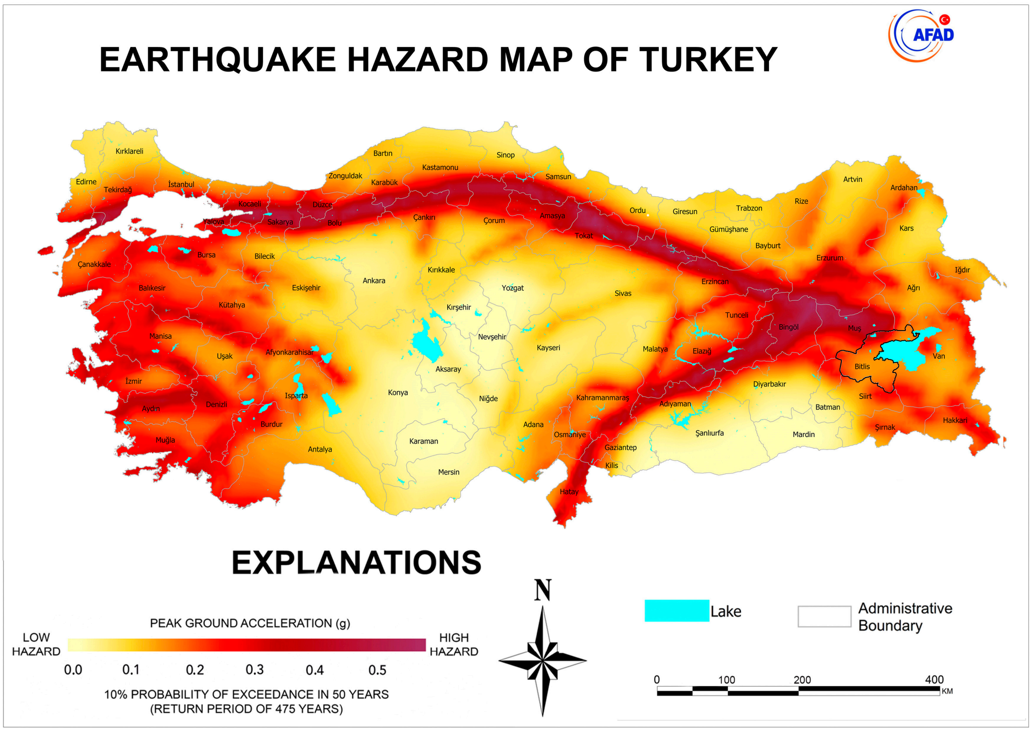

Figure 5. The current Earthquake Hazard Map of Türkiye [18].

A number of parameters are needed for the calculations of buildings under earthquake loads, and these values can be obtained with the help of the Türkiye Earthquake Hazard Maps Interactive Web Application, which was created together with the TBEC-2018 that came into force in 2019 [18]. The peak ground acceleration (PGA), peak ground velocity (PGV), map spectral acceleration coefficients (S_S and S_1), local ground effect coefficients (F_S and F_1), design acceleration spectral coefficients (S_{DS} and S_{D1}), and horizontal and vertical design spectrums can be obtained with the help of this application, for any geographical location, taking into account different earthquake ground motion levels and different local soil classes. This application cannot be used if the soil properties are very bad, that is, if the local soil class is ZF. In this study, seismic parameters were obtained by considering the geographical location of each masonry structure using the mentioned application. In the TBEC-2018, the earthquake ground motion level is expressed in four different ways, unlike the previous regulations. The earthquake ground motion levels used in the study are given in Table 1. The earthquake parameter values were calculated separately for four different earthquake ground motion levels.

A comparison of the PGA and the PGV values for different earthquake ground motion levels for each of the locations of twenty masonry buildings using the Türkiye Earthquake Hazard Maps Interactive Web Application is shown in Table 2.

A comparison of the short-period map spectral acceleration coefficient (S_S) for various earthquake ground motion levels and map spectral acceleration coefficient (S_1) for a 1.0 s period using the same application is shown in Table 3.

Table 1. Earthquake ground motion levels [17].

Ground Motion	Probability of Exceedance (in 50 Years)	Repetition Period	Definition
DD-1	0.02	2475	Largest earthquake ground motion
DD-2	0.1	475	Standard design earthquake ground motion
DD-3	0.5	72	Frequent earthquake ground motion
DD-4	0.68	43	Service earthquake ground motion

Table 2. PGA and PGV values obtained for the different probabilities of exceedance.

No	Peak Ground Acceleration (g) Probability of Exceedance in 50 Years				Peak Ground Velocity (cm/s)—PGV Probability of Exceedance in 50 Years			
	2%	10%	50%	68%	2%	10%	50%	68%
1	0.501	0.266	0.104	0.074	27.887	14.714	6.172	4.548
2	0.500	0.266	0.104	0.074	27.867	14.708	6.172	4.548
3	0.500	0.266	0.104	0.074	27.853	14.699	6.159	4.536
4	0.501	0.267	0.104	0.074	27.887	14.713	6.170	4.546
5	0.500	0.266	0.104	0.074	27.842	14.707	6.170	4.546
6	0.500	0.266	0.104	0.074	27.864	14.696	6.160	4.537
7	0.501	0.266	0.104	0.074	27.891	14.716	6.174	4.549
8	0.500	0.266	0.104	0.074	27.892	14.717	6.177	4.552
9	0.500	0.266	0.104	0.074	27.853	14.703	6.169	4.545
10	0.500	0.266	0.104	0.074	27.853	14.703	6.169	4.546
11	0.501	0.267	0.104	0.074	27.860	14.705	6.170	4.546
12	0.499	0.266	0.104	0.074	27.801	14.683	6.157	4.535
13	0.500	0.267	0.104	0.074	27.839	14.693	6.158	4.532
14	0.500	0.267	0.104	0.074	27.839	14.693	6.154	4.532
15	0.500	0.266	0.104	0.074	27.839	14.695	6.160	4.537
16	0.500	0.266	0.104	0.074	27.838	14.694	6.159	4.536
17	0.501	0.267	0.104	0.074	27.855	14.700	6.159	4.536
18	0.500	0.266	0.104	0.074	27.829	14.692	6.158	4.536
19	0.500	0.266	0.104	0.074	27.816	14.687	6.157	4.535
20	0.500	0.267	0.104	0.074	27.849	14.698	6.157	4.535

The same local soil conditions and the fact that the buildings are very close to each other in all examined structures caused the earthquake parameters calculated in Tables 2 and 3 to be quite close to each other. For the probability of exceedance of 10% in 50 years, the PGA value is calculated as 0.27 g. It should be noted that there will be significant differences between these values for different local soil conditions in different regions. The local soil classes for the masonry buildings examined were obtained from the soil surveys made by the relevant public institutions and organizations; the ZB local soil class properties are shown in Table 4.

Considering the ZB local soil class, the earthquake parameters obtained with the help of the earthquake application are shown in Table 5.

Table 3. S_S and S_1 values were obtained for the different probabilities of exceedance.

No	S_S Probability of Exceedance in 50 Years				S_1 Probability of Exceedance in 50 Years			
	2%	10%	50%	68%	2%	10%	50%	68%
1	1.222	0.625	0.237	0.169	0.306	0.167	0.072	0.053
2	1.220	0.624	0.237	0.169	0.306	0.167	0.072	0.053
3	1.222	0.625	0.237	0.169	0.306	0.167	0.072	0.053
4	1.222	0.625	0.237	0.169	0.306	0.167	0.072	0.053
5	1.221	0.624	0.237	0.169	0.306	0.167	0.072	0.053
6	1.221	0.625	0.237	0.169	0.306	0.167	0.072	0.053
7	1.222	0.625	0.237	0.169	0.306	0.167	0.072	0.053
8	1.221	0.624	0.237	0.169	0.306	0.167	0.072	0.053
9	1.220	0.624	0.237	0.169	0.306	0.167	0.072	0.053
10	1.220	0.624	0.237	0.169	0.306	0.167	0.072	0.053
11	1.222	0.625	0.237	0.169	0.306	0.167	0.072	0.053
12	1.219	0.624	0.237	0.169	0.306	0.167	0.072	0.053
13	1.222	0.625	0.237	0.169	0.306	0.167	0.072	0.053
14	1.222	0.624	0.237	0.169	0.306	0.167	0.072	0.053
15	1.221	0.625	0.237	0.169	0.306	0.167	0.072	0.053
16	1.221	0.625	0.237	0.169	0.306	0.167	0.072	0.053
17	1.222	0.625	0.237	0.169	0.306	0.167	0.072	0.053
18	1.221	0.624	0.237	0.169	0.306	0.167	0.072	0.053
19	1.220	0.625	0.237	0.169	0.306	0.167	0.072	0.053
20	1.221	0.625	0.237	0.169	0.306	0.167	0.072	0.053

Table 4. Local soil class type ZB [17].

Local Soil Class	Soil Type	Upper Average at 30 m $(V_S)_{30}$ [m/s]	$(N_{60})_{30}$ [Pulse/30 cm]	$(cu)_{30}$ [kPa]
ZB	Slightly weathered, medium-tough rocks	760–1500	—	—

Table 5. Seismic parameters for selected locations.

No	F_S	F_1	S_{DS}	S_{D1}	T_A	T_B	T_{AD}	T_{BD}
1	0.900	0.800	0.563	0.134	0.048	0.238	0.016	0.079
2	0.900	0.800	0.562	0.134	0.048	0.238	0.016	0.079
3	0.900	0.800	0.563	0.134	0.048	0.238	0.016	0.079
4	0.900	0.800	0.563	0.134	0.048	0.238	0.016	0.079
5	0.900	0.800	0.562	0.134	0.048	0.238	0.016	0.079
6	0.900	0.800	0.563	0.134	0.048	0.238	0.016	0.079
7	0.900	0.800	0.563	0.134	0.048	0.238	0.016	0.079
8	0.900	0.800	0.562	0.134	0.048	0.238	0.016	0.079
9	0.900	0.800	0.562	0.134	0.048	0.238	0.016	0.079
10	0.900	0.800	0.562	0.134	0.048	0.238	0.016	0.079
11	0.900	0.800	0.563	0.134	0.048	0.238	0.016	0.079
12	0.900	0.800	0.562	0.133	0.047	0.236	0.016	0.079
13	0.900	0.800	0.563	0.133	0.047	0.236	0.016	0.079
14	0.900	0.800	0.563	0.133	0.047	0.236	0.016	0.079
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16	0.900	0.800	0.563	0.133	0.047	0.236	0.016	0.079
17	0.900	0.800	0.563	0.134	0.048	0.238	0.016	0.079
18	0.900	0.800	0.562	0.133	0.047	0.236	0.016	0.079
19	0.900	0.800	0.562	0.133	0.047	0.236	0.016	0.079
20	0.900	0.800	0.563	0.134	0.048	0.238	0.016	0.079

5. Turkish Rapid Assessment Method for Masonry Buildings

The loads in the masonry buildings are carried to the load-bearing walls and are constructed to be transferred to the ground through the walls. The wall thicknesses are considerably higher than the wall thicknesses in reinforced concrete structures. The inner and outer walls of the structure are created as a result of stacking local materials on top of each other and assembling them with a binding material. Masonry materials such as brick, adobe, stone, etc., are utilized in the vertical structural members (columns and walls) of masonry systems, and the dominant stress type of the system is pressure. The tensile strength of the materials used in masonry structures is low and the compressive strength is high. Therefore, these members, which can withstand high compressive forces, are not resistant to the effects of shear and bending forces [46–54]. In this context, determining the risk priorities of masonry structures becomes more important.

Simplified methods that can be used in the rapid evaluation technique, which is used to define risk priorities, are specified with their details. The parameters to be considered with this technique and how the structural result scores should be calculated are specified discretely for various types of buildings. Within the scope of this study, risk priorities were determined among twenty building samples using the rapid assessment technique determined for masonry buildings in the Turkish Rapid Assessment Method. This method can be used for existing masonry structures between one to five floors. The parameters required to use the method are given below. In this method, firstly, the design spectral acceleration coefficient (S_{DS}) is determined using the Türkiye Earthquake Hazard Map depending on the earthquake ground motion level. Standard earthquake ground motion level (DD-2) is taken into account, where the probability of exceedance is 10% in 50 years and the corresponding recurrence period is 475 years. The geographical location of each building on the map and S_{DS} values for DD-2 are obtained. The S_{DS} values, earthquake hazard zones, and base score values according to the number of floors are shown in Table 6.

Table 6. Earthquake hazard zones and base score for masonry structures [16].

Number of Stories	Earthquake Hazard Zone		
	Region I $S_{DS} \geq 1.0$	Region II–III $0.5 \leq S_{DS} < 1.0$	Region IV $S_{DS} < 0.5$
1	110	120	130
2	100	110	120
3	90	100	110
4	80	90	100
5	70	80	90

With this method, a base score is obtained and each negativity parameter is reduced from this base score. Within the scope of this study, the negativity parameters taken into consideration for masonry structures in the Turkish Rapid Assessment Method are explained in detail below:

- Masonry building type: By determining the structural system of the building, one building type such as unreinforced masonry, reinforced masonry, contained masonry, and mixed (masonry wall and reinforced concrete frame) system is selected as the building system (Figure 6). All examined masonry structures were considered unreinforced masonry structures.

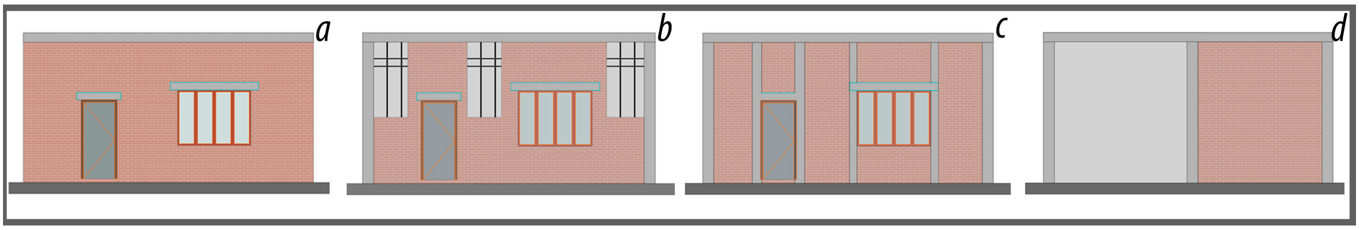

Figure 6. Type of masonry building: (**a**) Unreinforced masonry, (**b**) Reinforced masonry, (**c**) Contained masonry. (**d**) Mixed system (RC frame and masonry wall).

- Number of free stories: The facade with the highest number of floors starting from the ground is taken into account as the number of free floors. The determination of the number of free stories belonging to different situations is given in Figure 7.

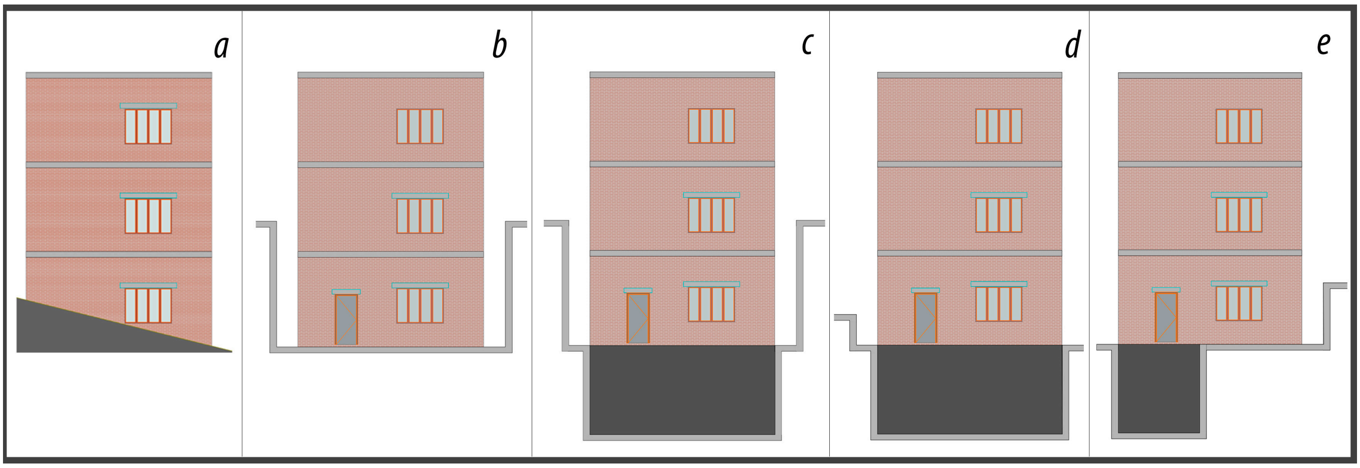

Figure 7. Specification of the number of stories (for the 3-stories buildings): (**a**) Hill slope effect, (**b**) Below ground level, (**c**) Below ground level and has a basement, (**d**) Having a basement in the building, (**e**) Having partial basement in the building.

- Building regulation/pounding: The location of adjacent structures can affect earthquake performance due to pounding. The structures located on the edge are most adversely affected by this condition, and if the floor levels of the adjacent structure are different, this negativity increases even more. The building order and floor level with adjacent buildings will be evaluated together. Five different situations are considered for this parameter (separate, adjacent middle–same, adjacent middle–different, adjacent edge–same, adjacent edge–different). The determination of the building order is shown in Figure 8.

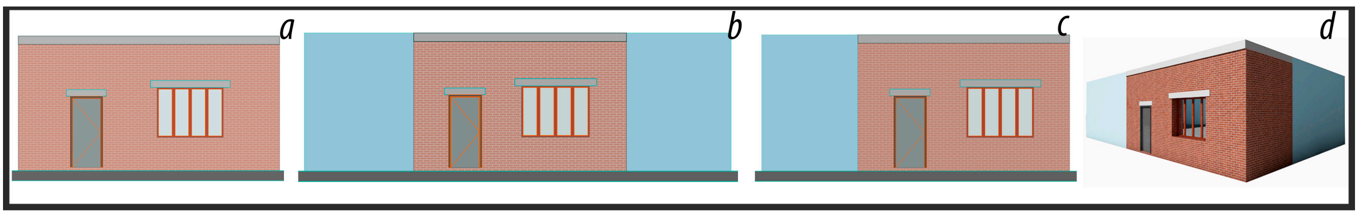

Figure 8. Structure order: (**a**) Separate, (**b**) Adjacent middle, (**c**) Adjacent edge, (**d**) Adjacent corner.

If the investigated building is adjacent, floor levels should also be taken into account in these buildings (Figure 9).

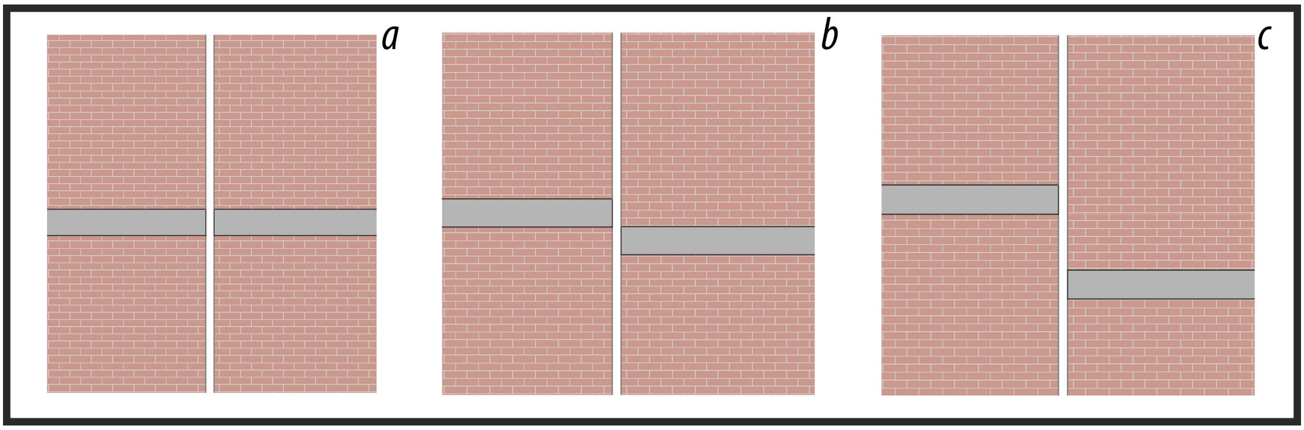

Figure 9. Floor levels in adjacent buildings: (**a**) Same, (**b**)Same (Limit condition), (**c**) Different.

- Current situation and visual quality: Material type, quality, and masonry construction work will be checked separately and classified as good, moderate, and bad. In addition, it will be determined whether there is damage to the existing structure.
- Irregularity in plan: Irregularity in the plan is determined in three different ways: regular, irregular, and extremely irregular according to the plan geometry. The different situations related to this are shown in Figure 10.

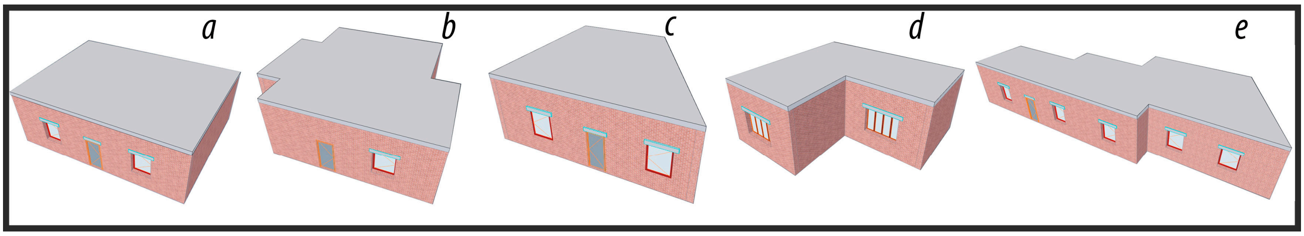

Figure 10. Examples of irregularity in plan: (**a**) Regular, (**b**) Irregular, (**c**) Regular, (**d**) Irregular, (**e**) Extremely irregular.

- Insufficient wall quantity: Facade wall length in both perpendicular directions will be determined on the critical floor (usually the ground floor) of the building, as shown in Figure 11. Accordingly, the number of walls (DM) in the building is high if the length of the door and window openings on the front or side facades on the ground floor is less than 1/3 of the facade length, and medium if the length of the gaps is between 1/3 and 2/3 of the facade length. If the length of the gaps is more than 2/3 of the facade length, it will be considered low. Calculations for the wall quantity are shown in Table 7.

Table 7. Parameters for calculating the wall quantity.

Plan Width (Front Facade) (m)	A	Plan Width (Side Facade) (m)	B
Distance of Gap (Front Facade) (m)	x + y	Distance of Gap (Side Facade) (m)	z + t
Gap-to-Length Ratio (BO) = (x + y + z + t)/(A + B)			
Amount of wall (DM) If BO $\leq$ 1/3 DM = High If 1/3 < BO $\leq$ 2/3 DM= Medium If 2/3 < BO DM = Low			

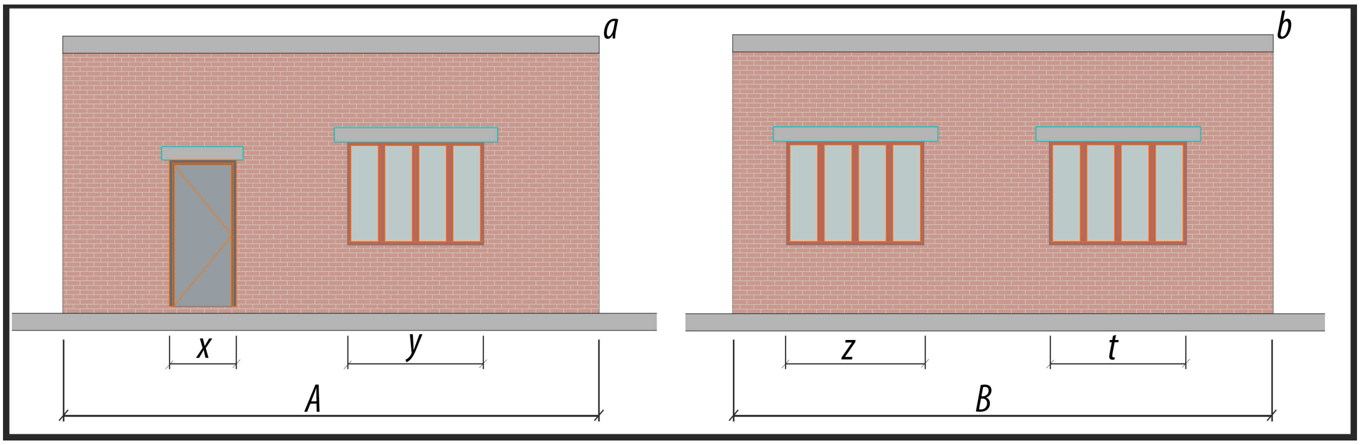

Figure 11. Necessary measurements to determine the insufficient amount of wall: (**a**) Front facade, (**b**) Side facade.

- Vertical spacing irregularity: the vertical spacing according to the vertical placement of the door and window spaces in the building: regular, less regular, and irregular (Figure 12).

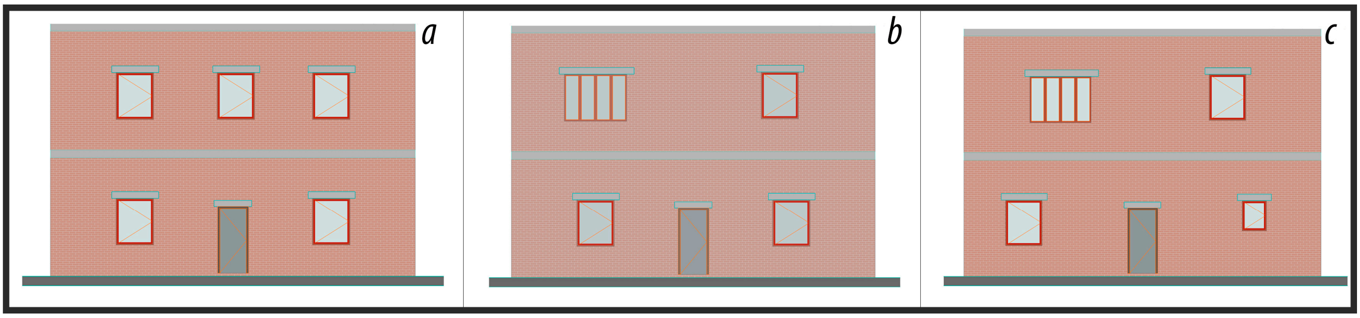

Figure 12. Vertical spacing irregularity: (**a**) Regular, (**b**) Less irregular, (**c**) Irregular.

- Changing the number of stories according to the facade: it will be determined whether different facades of the building have different floors, as shown in Figure 13.

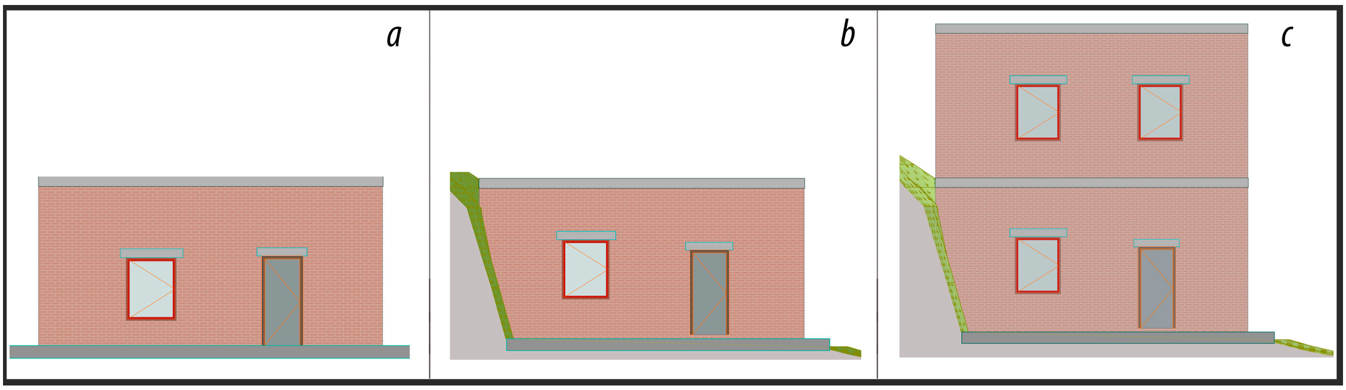

Figure 13. Differences between the floors according to the facade: (**a**) None, (**b**) Available, (**c**) Available.

- Soft/weak story: it will be determined observationally, taking into account the apparent stiffness difference between floors as well as story height difference as shown in Figure 14.

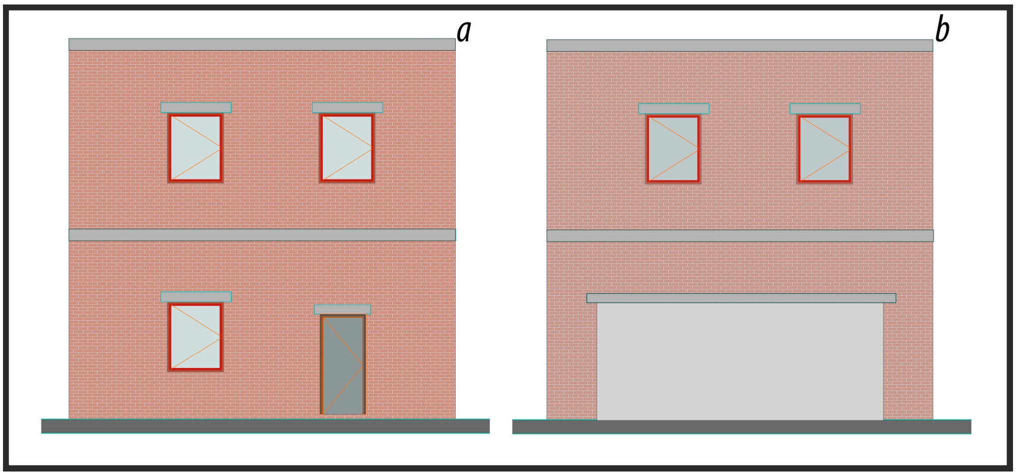

Figure 14. Soft/weak story: (**a**) None, (**b**) Available.

- Out-of-plane behavioral problems: It will be determined whether masonry building walls tend to exhibit out-of-plane behavior. The negativities that trigger out-of-plane behavior in masonry buildings and which can usually be detected from outside the building can be listed as follows:
  a. Weak wall-to-wall and wall-to-floor connections (cracks or damage where the connections are located, no bond beam in the joint).
  b. No slab exhibiting rigid diaphragm behavior (only masonry structures with reinforced concrete slabs will be deemed to exhibit this type of behavior).
  c. Very poor quality of mortar or no mortar (causing the wall to separate in an out-of-plane direction).
- Roof material: this parameter will only be set for earth roof masonry buildings.
- Earthquake region: it is determined in accordance with earthquake ground motion levels and local soil classes.
- Geographic coordinates: the latitude and longitude to be obtained for each structure are expressed.
- Lack of horizontal bond beam: a selection is made by looking at whether there are bond beams or not as shown in Figure 15.

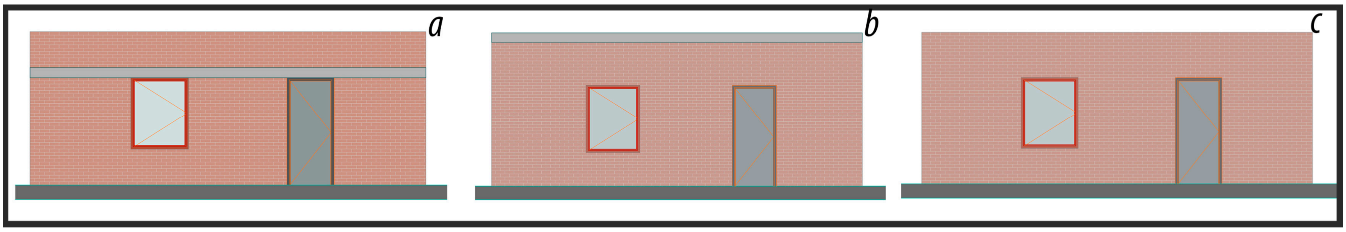

Figure 15. Lack of horizontal bond beam: (**a**) Above the window, (**b**) Above the wall, (**c**) No bond beam.

In order to determine the regional earthquake risks used in the study, the negativity parameter values taken into account in masonry structures are given in Table 8.

Table 8. Negative parameter values (O_i) [16].

Number	Negativity Parameter	Case 1		Case 2	
		Parameter Detection	Parameter Value	Parameter Detection	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	None	0	Irregular, (Extremely Irregular)	1, (2)
6	Lack of horizontal bond beam	Above the window, Above the wall	0	None	1
7	Insufficient wall quantity (DM)	High	0	Moderate, (Low)	1, (2)
8	Vertical spacing irregularity	None	0	Less Irregular, (Irregular)	1, (2)
9	Floor Difference by Facade	None	0	Available	1
10	Soft/Weak Story	None	0	Available	1
11	Floor Type	Reinforced concrete	0	Wood, Volto	1
12	Mortar Material	Cement	0	Lime, Mud, None	1
13	Wall-to-Wall Connection	Good	0	Bad	1
14	Wall-to-Floor Connection	Good	0	Bad	1
15	Roof Material	Tile, Sheet, Concrete	0	Soil	1

The current situation in the masonry structures, the wall labor, and the estimated negativity scores for the damages are shown in Table 9.

Table 9. Current status and quality negativity scores [16].

Material Quality (0/1/2)	Wall Labor (0/1/2)	Current Damage (0/1)
−10	−5	−5

With the method regarded in this paper, the negativity scores for geometry, wall quantity, and bond beam/lintel as irregularities in the plan are shown in Table 10.

Table 10. Negative scores in the plan [16].

Geometry (0/1/2)	Amount of Wall (0/1/2)	Bond Beam/Lintel (0/1)
−5	−5	−5
−10	−5	−5
−10	−10	−5
−15	−10	−5
−20	−15	−5

Vertical negativity scores are also shown in Table 11.

Table 11. Vertical negativity scores (PDRB-2019).

Number of Floors	Space Layout (0/1/2)	Floor Difference According to the Facade (0/1)	Soft/Weak Story (0/1)
1	0	−5	0
2	−5	−5	−5
3	−5	−5	−5
4	−10	−5	−10
5	−10	−5	−10

The relationship between the building and the negativity scores estimated for the floor level are demonstrated in Table 12.

Table 12. Negativity scores of building order and floor level (PDRB-2019).

Separate	Adjacent Middle–Same	Adjacent Edge–Same	Adjacent Middle–Different	Adjacent Edge–Different
0	0	−5	−5	−10

All results and building performance scores will be determined with the help of the following formula.

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

where PP denotes the performance score, TP denotes the base score, O_i denotes each negativity parameter, O_{Pi} denotes the negativity parameter score, and YSP stands for the positive parameter score as the structural system score. The effect of the structural system type will be considered as a positive score. The structural system score (YSP) shows the parameter that reflects the effect of the structural system type of the building on the earthquake performance. The YSP value is taken as zero for unreinforced and mixed masonry buildings. The YSP value was taken as zero since all the buildings considered were unreinforced masonry.

6. Determination of Seismic Risk Priorities for Investigated Masonry Structures

Within the scope of the study, twenty traditional houses built with a masonry system from different districts within Bitlis' city center were examined, as shown in Figure 16. Some examples of masonry structures considered in this context are shown in Figure 17. The ground floor plans of the masonry structures examined are shown in Figure 18.

The negativity parameters and values obtained for twenty masonry structures considered within the scope of the study are shown in Table 13.

While six of the examined buildings are three-storey, thirteen of them are two-storey, and only one of them is one-storey. In general, traditional Bitlis houses are built as two-storey buildings. With the growth of the nuclear family, storeys were added to the existing structure as much as the masonry construction technique allowed. In houses built in this way, the wall thickness on the lower storey can be two storeys, since it is not suitable for three storeys. Due to the topographical structure of the province of Bitlis and the limited land use, the buildings were built adjacently. A total of 75% of the examined structures were built in adjacent order. These reasons also caused irregularity in the plan of the buildings. Bitlis stone was used in traditional Bitlis houses. These stones, which lost their properties over time, did not encounter any significant problems in terms of material due to the interventions made by the relevant building owners. Since masonry stone workmanship is highly developed in the Bitlis province and there are sufficient personnel in this regard, no significant problems were observed in terms of masonry walls. Mud was used as a joint mortar in all of the buildings. The wall–wall and wall–floor connections are sufficient due to good masonry stone workmanship. Different levels of damage to the masonry structures have been observed over time due to the heavy and long winter season, the heavy snowfall, and the temperature differences between day and night in Bitlis. In addition, the weak strength properties of the stone used are among the main causes of damage. In many masonry structures, load-bearing walls, windows, and doors are not used symmetrically. Soft story risk was not observed in any examined structures. In general, the purpose of use in the building does not change much. Heavy earthen roofs are used in all masonry structures. Heavy earthen roofs cause additional forces in the structure under the effect of an earthquake and directly affect the level of damage that may occur in the structure. Generally, horizontal/vertical beams were not used in these structures, which were built without any engineering service.

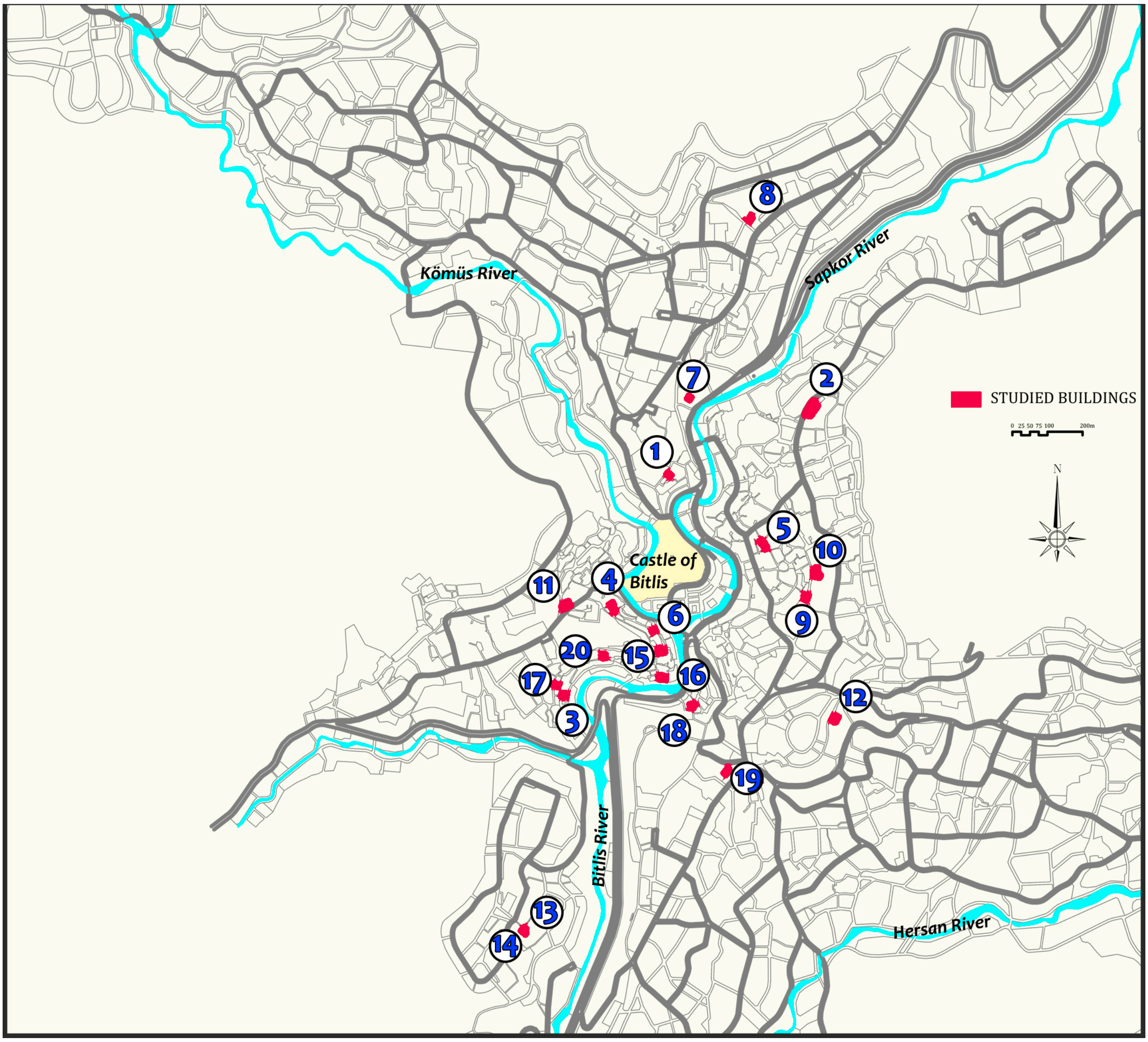

Figure 16. Locations of the twenty investigated structures in the city.

Figure 17. Some examined masonry structures.

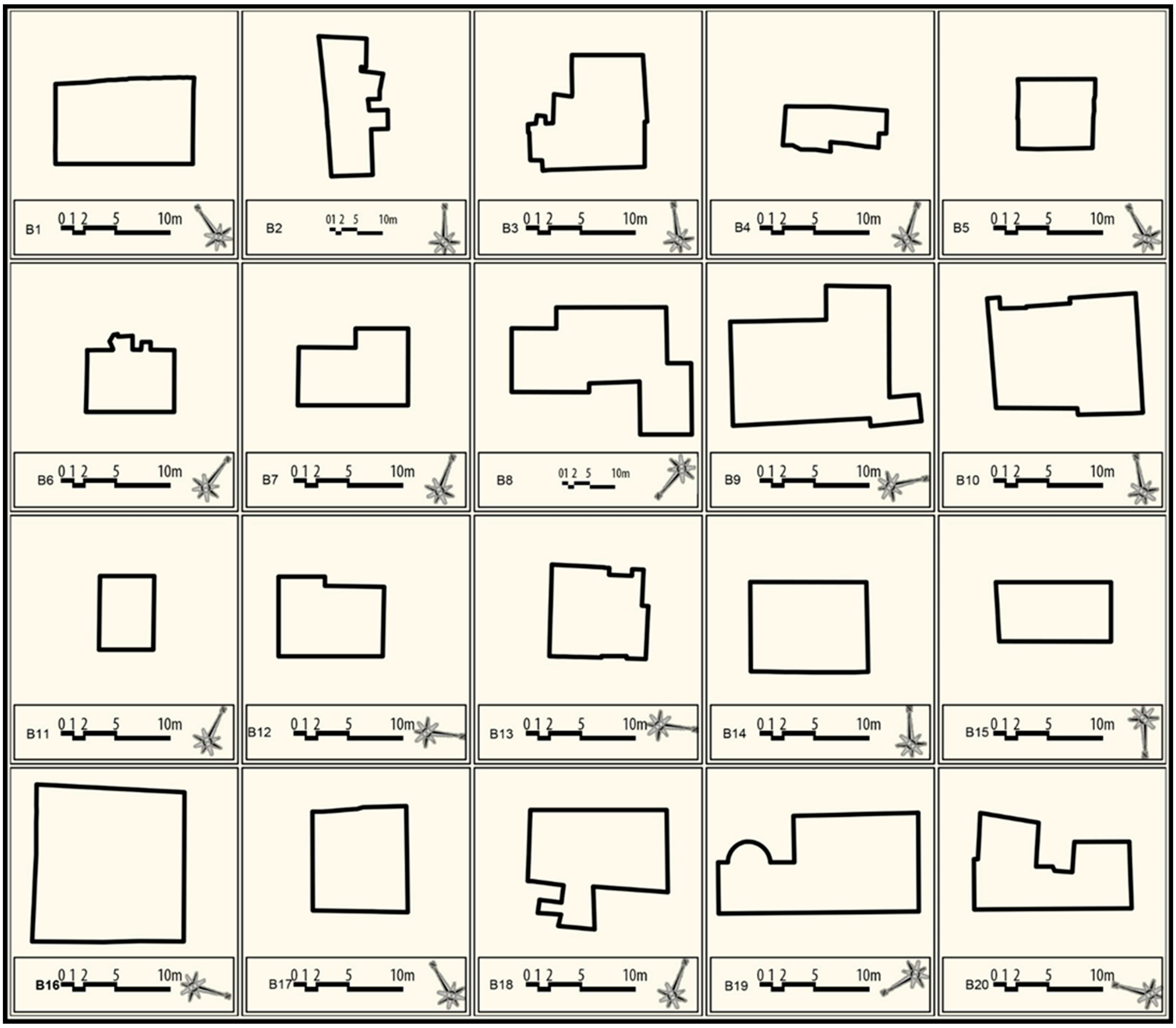

Figure 18. The ground floor plans of the examined masonry structures.

The parameter values and structural result scores obtained using the Turkish Rapid assessment method are shown in Table 14.

Table 13. Parameters of the investigated masonry structures.

Parameters	1	2	3	4	5	6	7	8	9	10
Number of floors	1	2	3	2	3	2	2	2	2	2
Building Order	Adjacent corner	Adjacent corner	Adjacent corner	Adjacent Medium	Adjacent corner	Separate	Separate	Separate	Separate	Adjacent corner
Material Quality	Bad	Good	Moderate	Bad	Good	Moderate	Moderate	Good	Good	Good
Wall Labor	Moderate	Good	Moderate	Bad	Good	Moderate	Moderate	Good	Good	Good
Current Damage	Available	Available	Available	Available	None	Available	None	Available	Available	Available
Irregularity in the Plan	Regular	Extremely Irregular	Extremely Irregular	Regular	Regular	Regular	Irregular	Irregular	Irregular	Irregular
Lack of horizontal bond beam	None	Available	Available	Available	Available	Available	Available	Available	Available	Available
Insufficient amount of wall (DM)	0.15	0.17	0.21	0.15	0.08	0.24	0.18	0.23	0.15	0.06
Vertical spacing irregularity	Regular	Less Irregular	Irregular	Irregular	Less Irregular	Less Irregular	Less Irregular	Less Irregular	Less Irregular	Less Irregular
Floor Difference by Facade	None	Available	Available	Available	Available	Available	Available	None	Available	Available
Soft /Weak Story	None	None	None	None	None	None	None	None	None	None
Mortar Material	Mud	Mud	Mud	Mud	Mud	Mud	Mud	Mud	Mud	Mud
Wall-to-Wall Connection	Moderate	Moderate	Good	Bad	Good	Moderate	Moderate	Bad	Good	Bad
Wall-to-Floor Connection	Moderate	Moderate	Good	Bad	Good	Moderate	Moderate	Bad	Good	Bad
Roof Material	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
Parameters	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Number of floors	3	2	3	2	3	2	2	2	2	3
Building Order	Adjacent corner	Adjacent corner	Adjacent Medium	Adjacent Medium	Adjacent corner	Separate	Adjacent corner	Adjacent corner	Adjacent corner	Adjacent corner
Material Quality	Bad	Moderate	Moderate	Moderate	Good	Good	Good	Good	Good	Moderate
Wall Labor	Bad	Moderate	Moderate	Bad	Good	Good	Good	Good	Good	Moderate
Current Damage	Available	None	None	Available	Available	Available	Available	Available	None	None
Irregularity in the Plan	Regular	Regular	Regular	Regular	Regular	Regular	Regular	Irregular	Irregular	Irregular
Lack of horizontal bond beam	Available	Available	Available	Available	Available	Available	Available	None	Available	Available
Insufficient amount of wall (DM)	0.1	0.09	0.14	0.14	0.03	0.06	0.17	0.31	0.19	0.06
Vertical spacing irregularity	Irregular	Less Irregular	Less Irregular	Less Irregular	Irregular	Irregular	Irregular	Regular	Less Irregular	Less Irregular
Floor Difference by Facade	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available
Soft /Weak Story	None	None	None	None	None	None	None	None	None	None
Mortar Material	Mud	Mud	Mud	Mud	Mud	Mud	Mud	Mud	Mud	Mud
Wall-to-Wall Connection	Good	Good	Good	Good	Bad	Good	Bad	Good	Good	Good
Wall-to-Floor Connection	Good	Good	Good	Good	Bad	Good	Bad	Good	Good	Good
Roof Material	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil

Table 14. Parameter values and structural result scores of the examined structures.

Parameters	Building No																			
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Base Score	120	110	100	110	100	110	110	110	110	110	100	110	100	110	100	110	110	110	110	100
Building Order	−5	−5	−5	−5	0	0	0	0	0	−5	−5	−5	0	0	−5	0	−5	−5	−5	−5
Material Quality	−20	0	−10	−20	0	−10	−10	0	0	0	−20	−10	−10	−10	0	0	0	0	0	−10
Wall Labor	−5	0	−5	−10	0	−5	−5	0	0	0	−10	−5	−5	−5	0	0	0	0	0	−5
Current Damage	−5	−5	−5	−5	0	−5	0	−5	−5	−5	−5	0	0	−5	−5	−5	−5	−5	0	0
Irregularity in the Plan	0	−20	−20	0	0	0	0	−10	−10	−10	0	0	0	0	0	0	0	−10	−10	−10
Lack of horizontal bond beam	0	−5	−5	−5	−5	−5	−5	−5	−5	−5	−5	−5	−5	−5	−5	−5	−5	0	−5	−5
Insufficient wall amount (DM)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vertical spacing irregularity	0	−5	−10	−10	−5	−5	−5	−5	−5	−5	0	0	0	0	0	0	0	−5	−5	−5
Floor Difference by Facade	0	−5	−5	−5	−5	−5	−5	0	−5	0	−5	−5	−5	−5	−5	−5	−5	−5	−5	−5
Soft/Weak Story	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Floor Type																				
Mortar Material	0	0	0	−10	0	0	0	−10	0	−10	0	0	0	0	−10	0	−10	0	0	0
Wall-to-Wall Connection																				
Wall-to-Floor Connection																				
Roof Material	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10
Building performance score	75	55	25	30	75	65	70	65	70	60	40	70	65	70	60	85	70	70	70	45

The result scores obtained for 20 traditional Bitlis houses, which are the subject of the study, vary between 25 and 85 points. While the lowest building performance score was 25 for building number 3, the highest score was 85 for building number 16. When all structures were taken into account, the average building performance score was 62. The resulting score of the six structures examined was below this score. Therefore, these six structures, which are below 62 points, must first be subjected to a detailed evaluation. In the Turkish Rapid Assessment Method, buildings with low structural performance are buildings with high-risk priority. This result is used to determine regional risk priorities. The risk priorities for the examined buildings were 3, 4, 11, 20, and 2 buildings in the first five buildings, respectively. The lowest risk priority was obtained for building 16.

7. Conclusions

In this study, 20 traditional masonry structures located in the city center of Bitlis were taken into account in order to determine regional risk priorities. These structures in the province of Bitlis, located in the Lake Van Basin with high seismic risk, were built without any engineering services. Traditional Bitlis houses have an important status in terms of historical and cultural heritage. The main causes of damage in these structures are severe climatic conditions, day–night temperature differences, and low-strength building materials. In addition, the result of people leaving the buildings, their use, and the impact of natural disasters, to a lesser extent, should not be ignored.

It is possible to determine the regional earthquake risk of the building stock with the studies to be carried out on the building stock in areas with earthquake risks. However, the large number of building stock reveals that using rapid assessment techniques is a practical and scientific solution for determining risk priorities. Within the scope of this study, a sample application was carried out for the province of Bitlis using the current Turkish Rapid Assessment Method recommended for masonry structures. The study is one of the first studies in which this method was used.

Necessary data were obtained due to the observational assessments and measurements made in the field related to the buildings. The seismic parameters for each building location were obtained according to the current earthquake hazard map using some of these data. The risk priorities of the sample buildings were determined with the help of the Turkish Rapid Assessment Method using some of the seismic parameters and other data. While the low structural performance scores obtained in the Turkish Rapid Assessment Method increase the risk priority, the risk priority ranking decreases in high-rise buildings. It cannot be said with certainty whether buildings with low structural result scores comply with the seismic design code. As stated in the regulation, this is only the first evaluation stage. Therefore, definitive results will only emerge from detailed analyses.

This study is limited to twenty different buildings in total. In future studies, all risky buildings can be determined by considering all masonry structures in the city center and its districts. To determine risk priority, this work should also be done in reinforced concrete structures. This study will be a guide for similar studies to be done in the future. Since there is no similar study in Bitlis, the results could not be analyzed comparatively. This study will provide a comparison opportunity for future studies to be carried out in the Bitlis province.

In order for the structural system to gain flexibility, it is necessary to support the structures with modern systems. Strengthening, such as increasing or renewing the number of wooden bond beams in the openings of the sections with insufficient wall quantity and adding steel ties, will provide flexibility; in cases where these methods are not suitable, the use of methods such as carbon fiber should be encouraged. In this context, recyclable applications should be made without damaging the cultural heritage.

In the traditional construction system, the floor heights of the adjacent buildings are compatible and their floors are at the same level. In restoration (especially reconstruction) applications, the floor slab height can be increased in a way that is contrary to the original structure, with the desire to obtain a more spacious space. These situations, which increase the risks of impact from collision with the adjacent order, should be avoided. Likewise, since the window openings whose dimensions have been changed will cause a change in the vertical space order, the continuation of the original building systems is recommended.

Traditional Bitlis houses are built in masonry style by local masters and workers with the wishes of the building owners without any engineering services. In this context, training local craftsmen about the relevant regulations and developing building materials, and the implementation of these trainings, will be important in terms of increasing building performance.

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