CHARACTERISTICS OF UNREINFORCED MASONRY BUILDINGS IN ANTAKYA THROUGH FIELD SURVEY

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ABSTRACT:

In the context of TUBITAK-BMBF Joint Project regarding the seismic vulnerability of masonry buildings in Antakya, a field survey was conducted in October 2012 by technical teams from different universities and research institutions. First, a survey form, which includes the major structural parameters of masonry buildings to be inspected, was prepared. Then nearly 250 masonry buildings were identified in different districts of Antakya with the intention of considering different masonry building typologies within a specific stock of buildings. The selected buildings were inspected from the street and the properties of the inspected buildings were recorded in the survey forms. In the second phase of the study, a database was formed by the field data obtained after the survey. This statistical information enables the quantification of local characteristics of the unreinforced masonry buildings in Antakya and their corresponding vulnerabilities. Furthermore, the quantification of the seismic performance of surveyed unreinforced masonry buildings in Antakya was achieved by the method developed for the Prime Ministry Disaster and Emergency Management Presidency (DEMP). According to this method, a performance score is calculated for each building. The performance score is composed of a base score, which is a function of seismic zone and number of stories, and penalty scores, that reflect the structural deficiencies of the inspected building. Based on the results, it is concluded that the majority of the surveyed masonry buildings in Antakya seem to possess moderate seismic risk. The reason of this seems to be the similar construction practice due to socio-economical and cultural characteristics in the region in addition to the local and traditional techniques.

KEYWORDS: Unreinforced masonry, field survey, performance score, seismic risk.

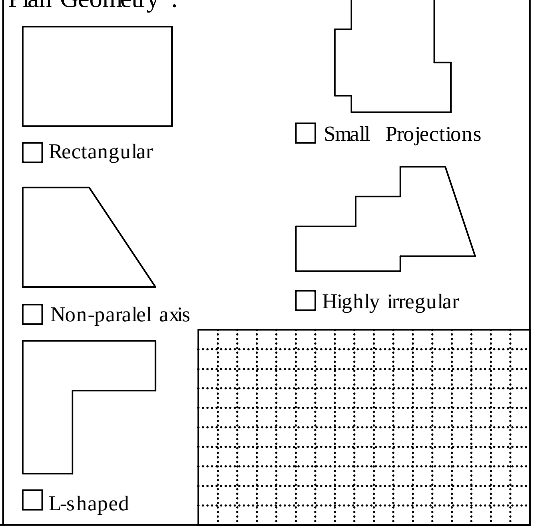
1. INTRODUCTION

In the context of TUBITAK-BMBF Joint Project regarding the seismic vulnerability of masonry buildings in Antakya, a field survey was conducted in October 2012 by technical teams from different universities and research institutions. Among a total of 6,494 masonry buildings, 265 buildings were pre-selected in such a way that this small-sized population represents the general characteristics of the whole inventory. The selected buildings were examined by technical teams that are composed of researchers from Middle East Technical University, Mustafa Kemal University, Zirve University and Bauhaus-Universität Weimar (Germany) within three days. The data collection form shown in Figure 1 was used in order to collect the structural data from each selected building during the field survey. It is composed of two parts: general information about the surveyed building and structural information including some major parameters.

EVALUATION FORM FOR MASONRY BUILDINGS

General Information:

Name of the Surveyor / Date	
Building ID	
Address	
Construction Year	
Coordinates	

Photo of the Building	Plan Geometry :
	

Structural Information:

Occupancy Type	☐Residential	☐Commercial	☐Industrial	☐ Public
Occupancy Distribution	☐ All stories same	☐ Above ground floor residential		
Number of Stories	( ) Normal + ( ) Mezzanin + ( ) Penthouse = ( ) Total			
Load-bearing Wall Material	☐Adobe	☐ CMU	☐ Perforated Brick	
	☐Solid Brick	☐ Stone	☐ Hybrid	☐Unidentified
Total Length (Front Façade)	(meters)			
Total Opening Length (Front F.)	(meters)			
Total Length (Lateral Façade)	(meters)			
Total Opening Length (Lateral F.)	(meters)			
Horizontal Bond Beam ?	☐Floor level	☐Over window	☐None	
Vertical Alignment of Openings	☐Regular	☐In Between	☐Not Regular	
Floor Type	☐RC	☐Wooden	☐Unidentified	
Adjacency	☐Separate	☐Adjacent	☐Adjacent at corner	
Building height difference in the case of adjacency	☐No	☐Yes		
Floor height difference in the case of adjacency	☐No	☐Yes		
Roof Geometry	☐Flat	☐Shed	☐Gable	☐ Hipped
Roof Material	☐Tile	☐ RC Slab	☐ Metal Sheet	☐ Earthen
Basement	☐Yes	☐No	☐Unidentified	
Apparent Condition	☐Good	☐In Between	☐Poor	

Figure 1. Data collection form

2. OBSERVED CHARACTERISTICS OF UNREINFORCED MASONRY BUILDINGS IN ANTAKYA

Antakya is an Anatolian town possessing several physical and social traces from different periods and civilizations as a result of continuous settlement since ancient times (Naycı *et al*., 2003). As suggested by Topçu and Kubay (2012), the city can be divided into two districts as "new city" and "old city". The new city refers to the newly developing and planned district on the west side of Asi river whereas the old city denotes the historical district that has an organic urban fabric on the east side of the river. Most of the surveyed masonry buildings are within the old city. According to the statistical data, majority of the surveyed buildings are either one or two stories (Figure 2.a). It is also observed that the most commonly used load-bearing wall materials are cellular concrete block (CCB) and stone (Figure 2.b). According to the current Turkish earthquake code (2007), such concrete blocks with holes should not be used as load-bearing wall material since they have very low strength, but unfortunately this is not the case in practice. Hence concrete masonry buildings (Figure 3) are generally vulnerable to seismic action. On the other hand, most of the stone masonry buildings in the region are rather old. They can be classified as "simple stone masonry" in which irregularly sized and rounded stones had been used with either lime or mud mortar in the load-bearing wall construction. In some of these buildings, large connecting stones had been used in the corners to maintain the integrity of the perpendicular walls (Figure 4.a). There are also buildings that can be classified as "massive stone masonry" (Figure 4.b).

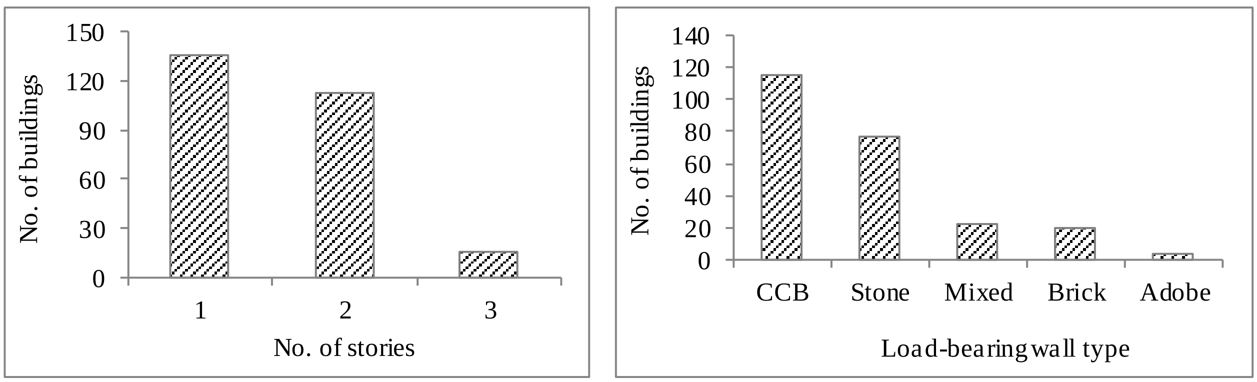


Figure 2. Statistical distribution of a) number of stories, b) load-bearing wall type

Figure 3. Surveyed masonry buildings constructed with cellular concrete blocks

Figure 4. Surveyed stone masonry buildings; a) simple stone, b) massive stone

Within the rich and mixed socio-cultural fabric of the city, it is also worth mentioning the traditional buildings, which were considered in the context of “mixed” systems during the field survey. These buildings, generally constructed during the Ottoman Empire, have a rigid stone masonry ground floor and timber-laced brick (or adobe) masonry walls in the upper stories (Figure 5). This type of mixed traditional construction is called “hımış”. In order to assess the seismic performance of these buildings, one should consider the coupling of different materials and structural systems present within the same building.

Figure 5. Traditional timber-laced masonry buildings called as “hımış”

The statistical distributions of surveyed masonry buildings in terms of geometry in plan and elevation are provided in Figure 6. In this study, regular buildings in plan are considered as the ones that have rectangular floor plans or nearly rectangular floor plans with small projections whereas irregular buildings in plan are defined as the ones that possess irregular (L-shaped, U-shaped, or of any other type) floor plans, plans with non-parallel axes or both. The results indicate that a significant percent of the surveyed buildings seems to be regular in plan (Figure 6.a). However it should be noted that most of the regular buildings are small-sized single story buildings.

In terms of elevation geometry, the surveyed buildings are again classified as regular and irregular. Irregularity in elevation refers to misalignment of openings with height, heavy overhangs, set-backs and penthouses (Figure 7). The statistical data in Figure 6.b is limited to buildings with two or more stories for which the elevation geometry becomes relevant and it reveals that irregularity in elevation is an important issue for masonry buildings in Antakya.

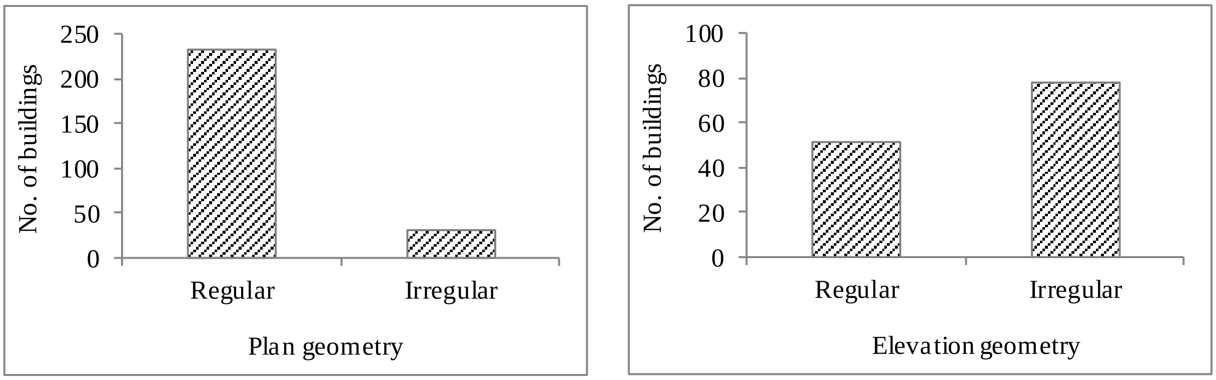


Figure 6. Statistical distribution of a) plan geometry, b) elevation geometry (for masonry buildings with two or more stories)

Figure 7. Surveyed masonry buildings with irregularities in elevation

According to Figure 8.a, most of the surveyed buildings seem to be located in clusters adjacent to each other (see Figure 9). It can be misleading to consider the seismic performance of these buildings individually due to pounding effects and aggregate (block) behavior due to coupling as also stated by Abrahamczyk *et al*. (2012). Especially the buildings at the corner of the block can suffer more from the coupled block motion.

Figure 8.b reveals that most of the surveyed buildings are in residential use only. There are few buildings for which the ground story is used for commercial purposes but the upper stories are residential, which is denoted as “Commercial G.F.” in the figure.

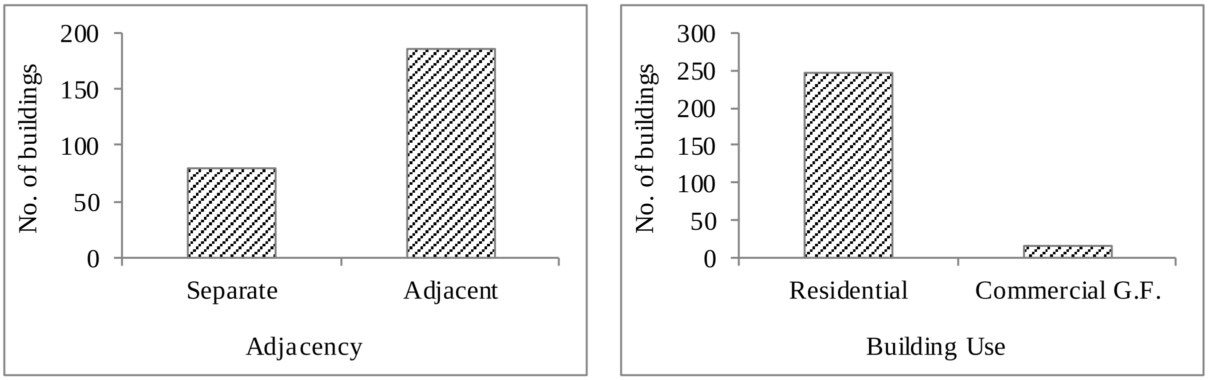


Figure 8. Statistical distribution of a) adjacency, b) building use (occupancy)

Figure 9. Clusters of surveyed masonry buildings

Another important parameter to assess the seismic behavior of masonry structures is the floor type. From Figure 10.a it can be clearly observed that most of the surveyed masonry buildings have rigid RC floors. The buildings with flexible wooden floors are generally the older constructions. There are few buildings for which the floor type had not been identified.

The last parameter to consider is the apparent condition of the surveyed building. As it can also be seen in the bottom line of the data collection form in Figure 1, the apparent condition of the surveyed buildings can be regarded as good, in-between (moderate) and poor, which is a subjective decision given by the surveyor. The material and construction quality, workmanship and existence of any type of damage (due to any reason) in the building guides the surveyor to make this classification regarding the apparent condition of the building. The statistics in Figure 10.b show that most of the buildings were considered as being in poor condition and there are only few to be considered as good. This is an important conclusion which is also linked to the socio-economic status of people living in these dwellings.

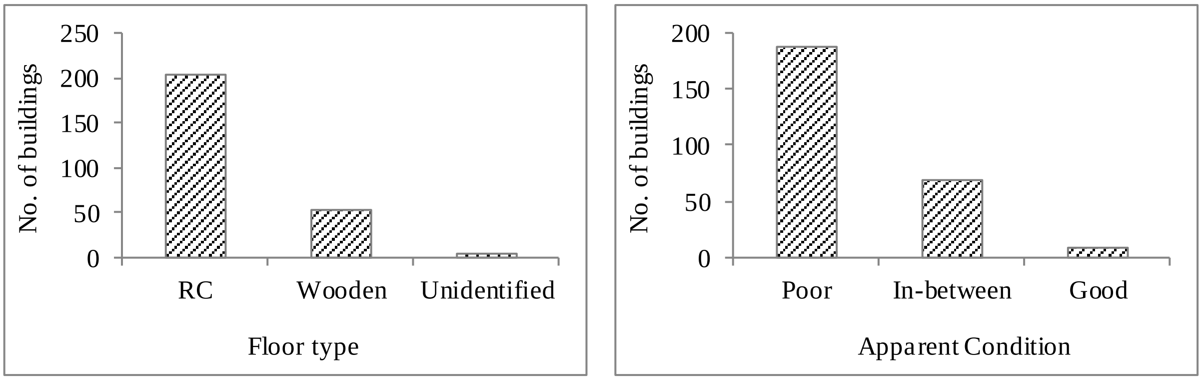


Figure 10. Statistical distribution of a) floor type, b) apparent condition

3. PRELIMINARY RISK ASSESSMENT OF MASONRY BUILDINGS BY USING THE FIELD DATA

For the preliminary risk assessment of surveyed masonry buildings in Antakya, the method developed for the Prime Ministry Disaster and Emergency Management Presidency (DEMP) has been employed. The method is based on calculating a performance score (PS) for each building by using the structural parameters that had been obtained from field survey. In order to achieve this, first a base score (TP) is determined in accordance with seismic zonation and number of stories of the inspected building. Then the base score is reduced by the penalty scores (OP_i) that reflect the structural deficiencies of the inspected building.

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

In Equation 1, O_i stands for the weighing factor multiplied by the negative penalty score (OP_i) in order to reflect the effect of the corresponding structural deficiency on the inspected building and can take values of 0, 1, or 2. Parameter YSP represents the type of masonry construction and takes positive values in the case of confined (30 points) and reinforced masonry (60 points) buildings.

The base score is a function of seismic zone and number of stories. Masonry buildings are evaluated in three seismic zones in accordance to the requirements of the current Turkish earthquake code (2007). The base scores are calculated by considering the maximum number of stories permitted by the code for masonry buildings (other than adobe) according to the seismic zone that the buildings reside. The base score for the minimum requirement of the code in terms of number of stories for a specific seismic zone is considered as 100. Each additional story means violation of the code requirement and hence punished by a penalty score of 10 per story. On the other hand, if the number of stories of the inspected building is less than the code requirement, then the base score is increased by 10 per story. For adobe structures, since the earthquake code allows the construction of this type as a single story regardless of the seismic zone, the base score for adobe construction is adjusted such that it is reduced by 30 compared to the base scores of masonry buildings other than adobe.

Penalty scores, which represent the structural deficiencies of masonry buildings, can be grouped as follows:

- Existing condition and apparent quality of the building
- Irregularities in plan
- Irregularities in elevation
- Location of the building (adjacency)
- Out-of-plane vulnerability of the masonry walls

The penalty scores are calculated by using the building information in the data collection form. If the parameter under consideration is deemed to affect the seismic performance of the building severely, then the weighing factor is increased to yield a higher penalty score. Some of the structural deficiencies mentioned above are dependent on number of stories (e.g. irregularity in elevation) and some are not (e.g. material quality). The details of the performance score assignment procedure can be found elsewhere (Yakut *et al*. 2013).

The aforementioned assessment method is applied to 265 masonry buildings surveyed in Antakya and the final performance scores (PS) are obtained. The distribution of the buildings according to their performance scores are shown in Figure 11. Theoretically, a masonry building with PS=100 can be regarded as an earthquake-resistant structure without any structural deficiency. On the other hand, a masonry building with PS=0 or having a very low PS value can be regarded as a highly vulnerable building against seismic action with many structural deficiencies. The PS values in between these two bounds give information about the relative seismic performance of a masonry building. Accordingly, Figure 11 reveals that most of the masonry buildings in Antakya have PS values between 45 to 80. In other words, these can be considered as buildings which possess some typical structural deficiencies.

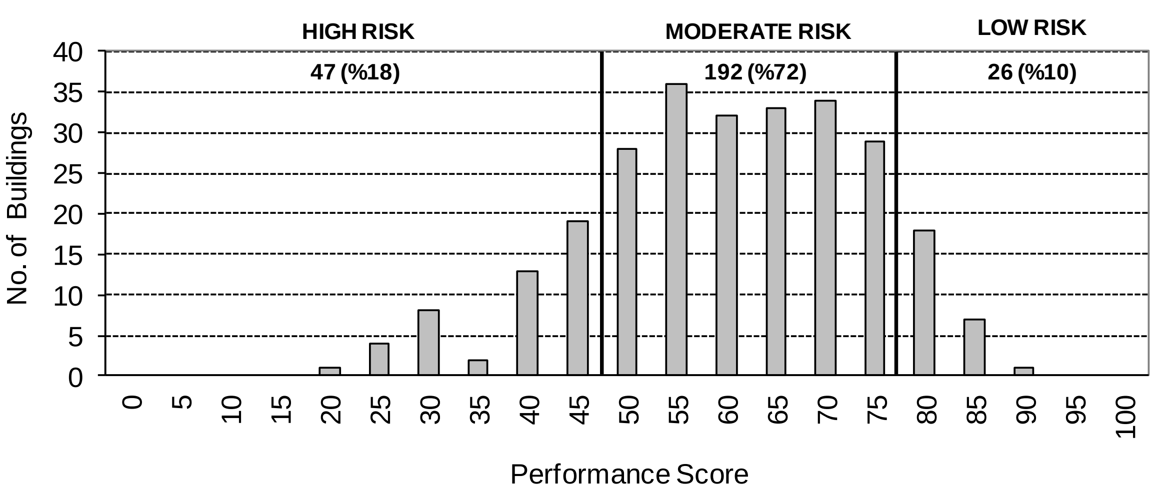


Figure 11. Distribution of the masonry buildings in Antakya according to PS values

In order to make a quantitative classification for the masonry buildings in Antakya, the method has been applied to the damaged buildings surveyed after the 1995 Dinar Afyon earthquake and PS values obtained are compared with the observed damage states of the buildings.

The Dinar database includes 102 masonry buildings, for which the damage levels were determined by using the damage assessment form of the Ministry of Public Works and Settlement (METU-EERC, 1996). According to this form, damage scores (DS) are awarded for the walls of the most damaged story of the masonry structure as well as for the stairs and roof. Damage is classified as undamaged (0–1), minor (1–3), moderate (4–6), severe (7–9) or collapse (>9). The numbers in parenthesis represent the score range for each damage state. The comparison of the inverse of the damage score (1/DS) with the performance score (PS) obtained by using the proposed methodology is presented in Figure 12. There seems to be an increasing trend line for the scattered data. In other words, buildings with serious damage after the earthquake receive low PS values as it should be the case. R^2 value is not too high since the damage score obtained after the earthquake does not contain many of the parameters used in calculating the performance score by the proposed methodology, so it is not possible to make a one-to-one comparison between these two measures.

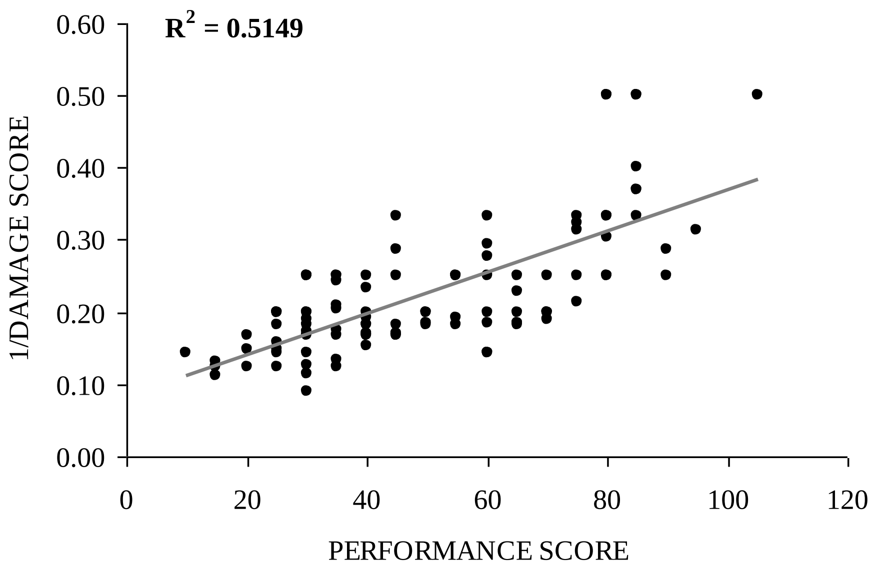


Figure 12. Comparison of performance score (PS) with the inverse of the damage score (1/DS) obtained after the 1995 Dinar earthquake

In accordance with the above evaluation, two limit states have been proposed for the performance score. This means there exist three performance states: low risk, moderate risk and high risk (see Figure 11). The average performance score and the related standard deviation for each performance state are also provided in Table 1. Using these values, it is assumed that buildings with PS≤45 are in "high risk" region, the ones with 45<PS≤75 are in "moderate risk" region and the ones with PS>75 are in "low risk" region. Hence among 265 surveyed buildings in Antakya, 47 of them (18%) possess high seismic risk, 192 of them (72%) possess moderate seismic risk and 26 of them (10%) possess low seismic risk. The reason of having the majority of the buildings with moderate seismic risk is the similar construction practice due to socio-economical and cultural characteristics in the region in addition to the local and traditional techniques. It is common to encounter typical buildings with 1-2 stories, made of stone or concrete masonry units, poor material and construction quality, irregularities in plan and elevation. Although exceptional, it is also possible to encounter buildings with much more and less seismic performance in the region. Such buildings already reside at either end of the distribution shown in Figure 11.

Table 1. The relationship between the calculated PS values and the observed DS values after the 1995 Dinar Afyon earthquake

Damage score intervals	Level of seismic risk	Performance Score (PS)	
		Average	St. Deviation
DS < 3	Low	79.4	18.3
3 ≤ DS ≤ 7	Moderate	55.8	17.6
DS > 7	High	43.1	10.9

4. CLOSURE

The study presents the local characteristics of masonry buildings in Antakya based on field survey results. Then the seismic risk of the surveyed masonry buildings in Antakya are assessed by using a recently proposed score assignment procedure. The results indicate that the existing masonry building stock in Antakya seems to possess considerable seismic risk. It should be noted that the method discussed in this report is to rank the buildings relatively in terms of seismic risk and it is developed for population of buildings, hence it may be misleading to apply it to a single building and compare the results with the ones obtained from detailed analytical methods.

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REFERENCES

Abrahamczyk, L., Schwarz, J., Langhammer, T., Genes, M.C., Bikce, M., Kacin, S., Yakut, A., Erberik, M.A. and Gülkan, P. (2012). Empirical and Analytical Vulnerability Assessment of the Masonry Building Stock in Antakya (Hatay/ Turkey). Proceedings of the 15th World Conference on Earthquake Engineering, Lisbon, Portugal.

METU-EERC, (1996). Repair and Rehabilitation Project for Moderately Damaged Masonry Structures after 1995 Dinar Earthquake, Earthquake Engineering Research Center, Civil Engineering Department, Middle East Technical University, Ankara.

Naycı, N., Bilgin Altınöz, A.G. and Şahin Güçhan, N. (2003). An appraisal of an conservation project in Antakya. Proceedings of the CIPA International Symposium on New Perspectives to Save Cultural Heritage, Antalya, Turkey.

Topçu, M. and Kubat, A.S. (2012). Old and new city: morphological analysis of Antakya. Proceedings of the Eighth International Space Syntax Symposium, Santiago, PUC.

Turkish Earthquake Code (2007). Specification for Buildings to be Built in Seismic Areas. Ministry of Public Works and Settlement, Ankara, Turkey.

Yakut, A., Erberik, M.A., İlki, A., Sucuoğlu, H. and Akkar, S. (2013). Rapid Seismic Assessment Procedures for the Turkish Building Stock. SERIES Proceedings on "Seismic Evaluation and Rehabilitation of Structures", Springer (to be published).