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Seismic risk priorities of site and mid-rise RC buildings in Turkey

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ABSTRACT

Especially, the large-scale loss of life and property caused by the significant earthquakes in recent years has brought the importance of research and measures to be taken on this issue. Determining and analysing the ever-increasing building stock of the cities and detecting and managing all information related to buildings are important in terms of spatial planning and urban transformation. This study aims to determine tectonic characteristics calculating a and b values of Gutenberg- Richter magnitude-frequency relation which forms the basis of earthquake statistics for all cities in Turkey and the reinforced-concrete buildings which are primarily risky in terms of urban transformation. For this purpose, a total of 1620, 5-storey buildings from all provinces of Turkey were assessed. Twenty reinforced concrete buildings from each province were taken into consideration which has 5-stories. The first stage evaluation method specified in the principles regarding the identification of risky buildings issued in 2013 by the Republic of Turkey, Ministry of Environment and Urbanization was used in this study. The performance scores for 1620 buildings were calculated by using this method. A risk priority map was created for the provinces, taking into account for these buildings. The study aims to determine risk priorities of site and mid-rise reinforced-concrete buildings among the cities. The results obtained were interpreted and recommendations were made.

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1. Introduction

The first step in protecting a settlement from an earthquake disaster is to have theoretical predictions of the consequences such as socio-economic losses and structural damage that may occur after an earthquake. This is very important in terms of preparation for disaster management (Hadzima-Nyarko et al., 2016; Harirchian et al., 2020). Earthquakes occur frequently in Turkey due to the active seismic zones, and many reinforced-concrete (RC) buildings are damaged as a result of these earthquakes.

It is almost impossible to determine the seismic safety of existing RC buildings before a possible earthquake. The main purpose of the determination of seismic safety of buildings is to ensure making right decisions about the existing building stock by making necessary examinations and calculations before a possible earthquake. A large amount of existing building stock makes it difficult to evaluate buildings in a reasonable time due to the lack of adequate qualified personnel and economic perspectives. Even the detailed examination of seismic safety verification of an ordinary building continues for days. Therefore, it is not possible to examine every existing building in detail. In this context, accurate results can be achieved by using methods that will give faster and more accurate results (Işık, 2016). These methods are generally called the first stage evaluation methods. The buildings with risk priority can be determined using these methods. This will greatly reduce the number of buildings to be subjected to detailed analysis (Işık, 2015).

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There are various methods in the literature regarding the rapid evaluation of structures. Detailed information and analysis are not required in such rapid evaluation methods. There are many case studies on the use of these methods (FEMA-154, 2002; Japan Seismic Index–Ohkubo, 1991; NRCC, 1993; Šipoš et al., 2017; Kepekci and Ozcep, 2011; Hadzima-Nyarko et al., 2018; Villacis et al., 2000; Yakut, 2004; Benavent-Climent, 2011; Foo and Davenport, 2003; Jain et al., 2010; Sucuoğlu, 2007; Sinha and Goyal, 2004; İlki et al., 2014; Bal et al., 2008; Albayrak et al., 2015; Yakut et al., 2014; Arslan et al., 2010). The first stage evaluation method specified in the principles regarding the identification of risky buildings issued in 2013 by the Republic of Turkey, Ministry of Environment and Urbanization was used in this study (DRBB, 2013). A total of 1620 buildings including twenty RC buildings which are 5-storey from each of 81 provinces in Turkey were assessed in this study. Each performance score of these buildings was calculated using this method, and thus their risk priorities were determined.

The Gutenberg-Richter (1944) relation is currently used as a measure of earthquake efficiency based on the magnitude-frequency distribution. Obtaining this relationship for the whole of Turkey, it led to the production of basic information about the earthquake hazard. The "a" parameter in the magnitude-frequency relation changes depending on the observation period, the size of the study area and the level of earthquake activity. It is also defined as the average annual seismic activity index. The parameter "b" is an important parameter in the statistical analysis of earthquakes and gives the slope of the linear relationship. It is related to the deformation of rocks and thus the physics of earthquake occurrence. The "b" value is an indicator of seismic activity and varies from region to region. Normally, a small b value is associated with a high stress drop and a large b value is associated with a low stress drop. It was observed that the "b" value decreased before the earthquake (Anadolu and Kalyoncuoglu, 2010).

The study firstly presented the information about the rapid evaluation methods, mentioned about the reasons for the emergence of these methods and then provided information about Turkey's tectonic settings and seismicity. The seismicity parameters a and b were obtained for each province. The return periods for each province have been calculated for the probability of exceeding 10% in the earthquake regulation. This study also presented information about the rapid evaluation method used in this study and explained how this method is applied step by step. The method recommended by the Ministry of Environment and Urbanization in 2013 was used as the first stage assessment method in this study. Since this method includes calculations according to the 2007 earthquake regulation, this regulation was also taken into account within the scope of the study. A mapping procedure was applied for the site and RC buildings examined in this study considering their geometrical locations. The images of some of the examined buildings were included in the study. The distribution of the negativity parameters in the mid-rise RC buildings examined in the study was determined and the performance score for each building was calculated. It was tried to determine the risk priority among provinces by using the obtained results for site and mid-rise buildings. The results obtained were interpreted and suggestions were made in line with the results. This work from both seismicity as well as structural covers all provinces in Turkey. Considering the whole country rather than the regional basis adds a special importance to this study.

2. Tectonic Settings and Seismicity in Turkey

Turkey, as a part of Alpine-Himalayan orogenic belt, has tectonic progresses under the complex geodynamic effects of the relative motions of the Arabian, African and Eurasian plates. The majortectonic units, shaping the earthquake distribution in Turkey, are the North Anatolian Fault Zone (NAFZ), the East Anatolian and North-East Anatolian Fault Zones (EAFZ-NEAFZ), West Anatolian Extensional Province (WAEP) including a considerable amount of horst and graben structures bounded by normal faults, the subduction zones (Hellenic and Cyprus) (Reilinger et al., 2006) and the East Anatolian Collision Zone (EACZ) (Fig. 1). The North Anatolian Fault Zone (NAFZ) with an approximately 1600 km long is a right-lateral fault caused hazardous earthquakes and runs from Karlıova (Bingöl) triple junction through North Anatolia to the Marmara Sea. It produced a sequence of earthquakes having magnitudes greater than 7.0 (Mw) (Ateş et al., 2003, 2008, 2009, 2012; Bayrak et al., 2011). The East Anatolian Fault Zone (EAFZ) is also another major tectonic unit as a plate boundary with 500 km length between the Arabian and Anatolian plates. It starts from Gulf of Iskenderun and converges with NAFZ on the Karlıova triple junction. Although not as large as on the NAFZ, many major earthquakes are known to have occurred in or near EAFZ within the historical and instrumental period (Taymaz et al., 1991). WAEP, having the highest geothermal potential in Turkey, is one of the most seismically active and rapidly extending regions of the world (>30 mm/y) (Bozkurt, 2001). As a result of this extension, considerable number of large earthquakes occurs on the boundaries of horst and graben structures. As a result, Turkey can be considered as one of the most important tectonic laboratories in the world. There have been significant losses of life and property, due to earthquake damages in Turkey (Arslan et al., 2013; İnel et al., 2008; Bilgin, 2016; Bilgin and Uruçi, 2018; Utkucu et al., 2013).

After the significant contribution of the earthquake magnitude concept made by C. Richter in 1935, it was revealed that the earthquakes were not evenly distributed in time, space and size. The distribution of the earthquakes by size shows the scale invariance. This emphasizes that there is no characteristic size of the event (the theoretical limits in the maximum earthquake size). An experimental correlation defines the distribution of the earthquakes according to Ishimoto and Lida (1939) in the east and Gutenberg-Richter (1944) in the west (Eq. 1).

$$\log N = a - bM \quad (1)$$

where a and b are positive real constants for a given region and time interval, N number of earthquakes with magnitude M is given. a-value explains the seismic activity. It is determined by the event rate and depends on the selected region and time window. Typically, the b-value, which is close to 1, is a tectonic parameter that defines the relative multiplicity from large to small shocks. It is seen that the seismic environment represents the properties of the seismic environment in such a way as to the tension and/or material conditions. Eq. (1) is often referred to as the Gutenberg-Richter (G-R) magnitude-frequency relationship.

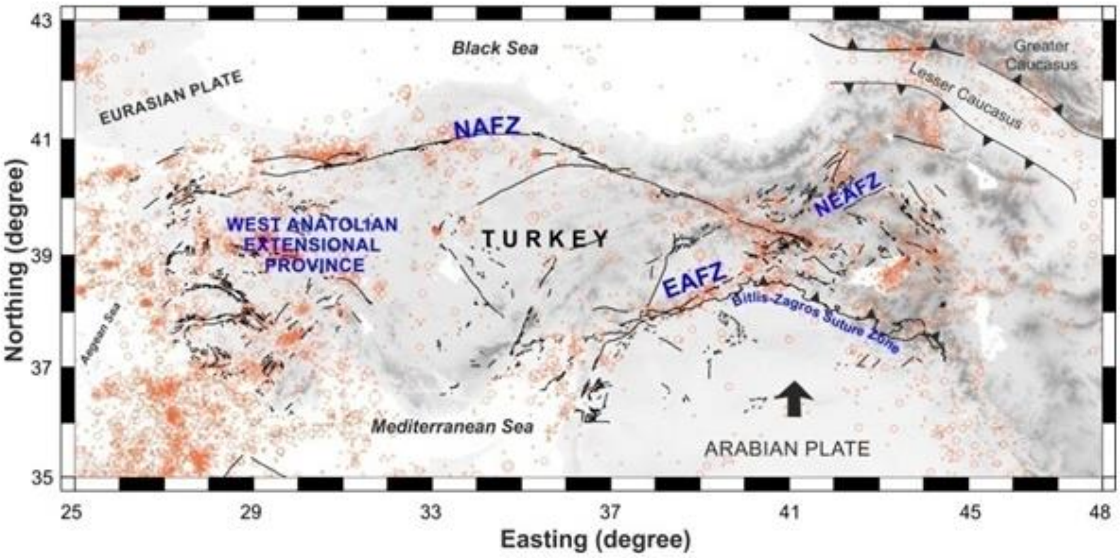

Fig. 1. Significant tectonic structures and earthquake activity (M>4) in Turkey during the instrumental period (Kalafat et al., 2011).

The space and temporal changes of the b-value have been previously used in a number of several seismicity studies. After the pioneering work of Mogi (1962), Scholz (1968) and Wyss (1973), the volumes of the active magmatic chambers (Wiemer and Benoit, 1996; Wiemer et al., 1998) by many investigators, and the origins of regional volcanism (Monterroso and Kulhanek, 2003) was widely used for identifying and estimating major tectonic earthquakes (Monterroso, 2003; Nuannin et al., 2005). The b-value studies on seismicity were carried out with the results published in many scientific articles in the last 25 years (Aki, 1965; Bender, 1983; Cao and Gao, 2002; Murru et al., 2007; Kalyoncuoglu, 2007; Farrell et al., 2009; Anadolu and Kalyoncuoglu, 2010; Kalyoncuoglu et al., 2013; Roberts et al., 2015). For small and M≥7.3 earthquakes, the frequency decreases faster than linearity, and in some cases, there may be a better approximation of the observed data. There are two explanations for deviations from linearity.

In minor earthquakes; there is a lack of data for years, especially in catalogues. However, recent studies have shown that the reduction of b-value below the threshold size is not only due to a lack of catalogues, but those small earthquakes are not counted as much as a fixed b-value predicted from major events and that the decrease in frequency may therefore be a certain extent real. In major earthquakes; saturation of the size scales; in other words, the problem with the method in which the magnitudes were measured. Another reason is the length of existing catalogues (usually very short) with large earthquakes missing. In general, repetition times beyond the time interval (catalogue) of data should be considered carefully. There are several acceptable explanations for the observed changes in b-values. High and low voltages lead to low and high b-value earthquake series (Scholz, 1968; Wyss, 1973). This observation is used to determine the structural anomalies and voltage levels in the crust and/or upper mantle in determining the prediction of earthquakes and determination of the volume of active chambers (Wiemer and Benoit, 1996; Wiemer et al., 1998).

Large heterogeneities correspond to higher b-values. Laboratory experiments have shown that heat changes result in an increase in b-value from 1.2 to 2.7 (Warren and Latham, 1970). The b-value of aftershocks is high, whereas the b-value of the leading earthquakes is low (Suyehiro et al., 1964). For example, in 1975, the b-value of Haicheng pioneering earthquake series was found to be 0.6. The b-value of the aftershocks was 0.9.

Earthquake storms come to the conditions where the b-value is greater than 1. Sometimes the b-value is greater than 2.5, meaning that large earthquakes occur later. Storms are often associated with volcanic activity. In volcanic regions, faults do not only create large earthquakes, but continuous stresses are largely heterogeneous. Swarms are caused by processes such as the lack of a clear mainstream shock and the migration of magmatic fluids or caldera development.

In summary, there is an inverse relationship between the size of the calculated b-value and the level of tension accumulation. Thus, it can serve as an approximation parameter to predict large earthquakes. In this study, a and b values are calculated using Gutenberg-Richter's (1944) equation for all cities in Turkey. Calculated values were presented city by city in the map of Turkey (Figs. 2 and 3).

When these maps are examined, regional similarities are observed in the a-value distribution map in Fig. 2 and continuity can be defined in areas with near tectonic features. In contrast, the b-value distribution map in Fig. 3 shows no tectonic identification that can be associated with each other in the nearby settlements. This may be due to province limitations in the database being used. However, if the selected cities are divided into geographic or tectonic regions, a different picture is encountered.

In this study, the risk map of provinces is shown in Fig. 4 if the probability of exceeding within a period of 50 years is 10%.

While all these calculations were performed, a 100 km wide zone was considered for each province and the earthquakes of $M \geq 3$ in this region were taken into consideration. Calculations were made by using the Seismic Hazard and Risk Analysis Program (Alan, 2016).

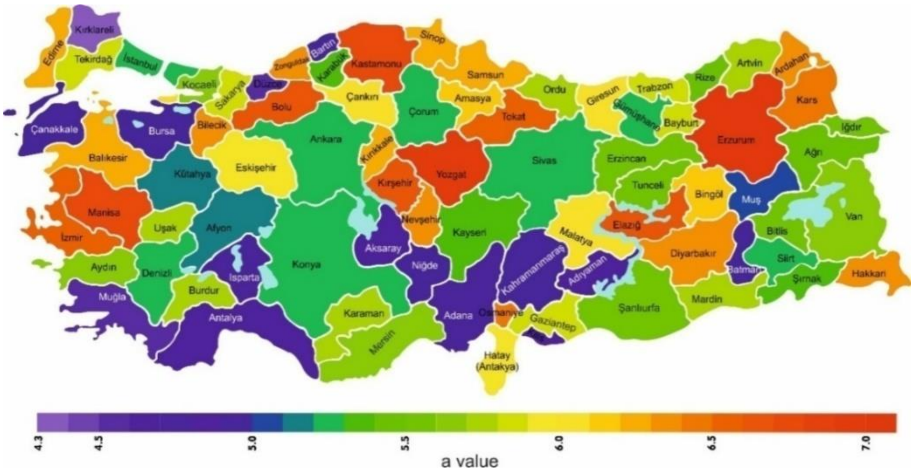

Fig. 2. Distribution map of a-value.

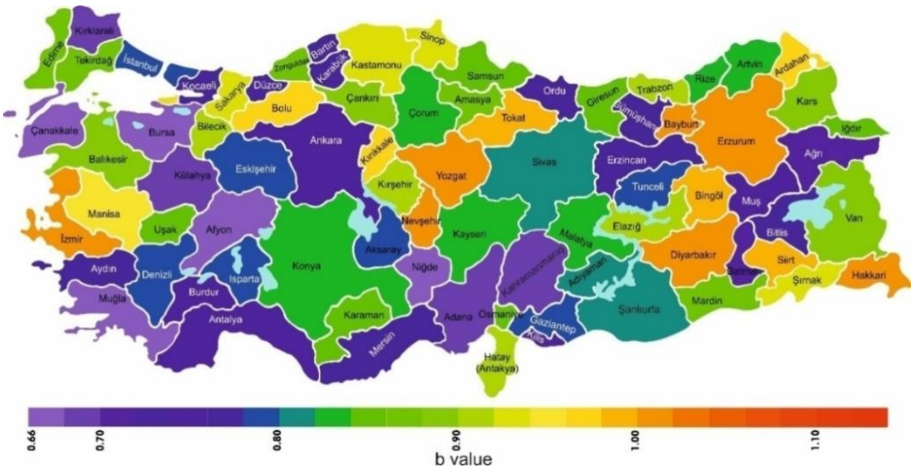

Fig. 3. Distribution map of b-value.

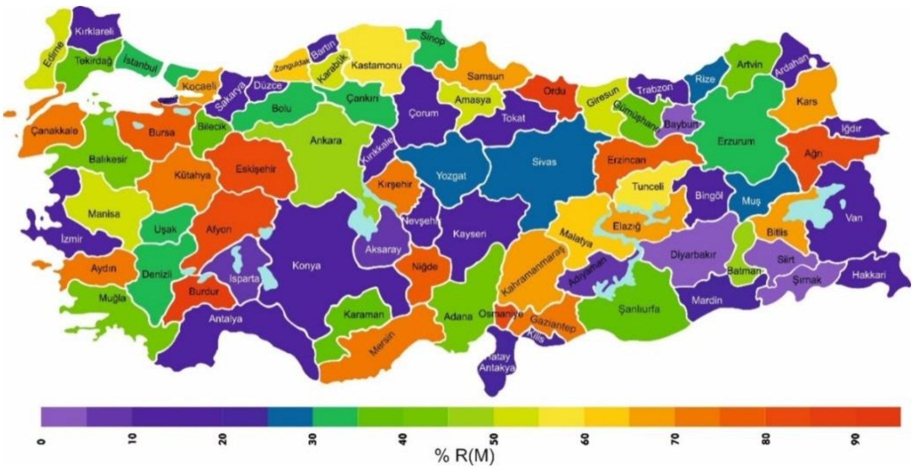

Fig. 4. Risk map for earthquakes with a probability of exceedance over 50 years.

3. Earthquake Risk Priorities of Existing Mid-rise RC Buildings in Turkey

It is a well-known fact that structural damage varies according to structural properties. The nature and amount of structural damage depend on the nature of the loads acting on the structures and the quality of the materials that compose the structural and non-structural elements, on the type and configuration of structural systems (Aksoylu et al., 2016; Hadzima-Nyarko et al., 2011). However, identifying these properties can be achieved pursuant to the evaluation of the data obtained as a result of classifying them. In this context, it is important to identify risky buildings. It cannot be said that buildings with low risk are in compliance with seismic design code. As mentioned above, this is only the first stage evaluation. Therefore, definite results will only be produced as a result of using definite detailed analysis methods. This method is only aimed at determining the priority of the buildings to be examined in the second stage evaluation method (Işık, 2013).

Reducing the weaknesses of the building stock is an important step towards reducing seismic risk. Large scale evaluation methods are popular for the evaluation of building stock, although they are expensive and not easy to use (Chever, 2012). Another effective way to assess the seismic vulnerability of existing buildings is to make an urban and regional emergency response and earthquake protection and remediation plans to protect human life and the economy (Ahmed et al., 2014; Bilgin and Frangu, 2017). During the seismic risk assessment of RC buildings, seismic hazard and building sensitivity should be considered (Tesfamariam and Liu, 2010; Jain et al., 2010; Özcebe, 2004). Seismic scanning methods are designed as rough scan procedures using fewer resources per building (Tischer et al., 2011; Tischer et al., 2012).

A period of high residential building demand during the 1980's due to high population growth and migration from rural areas to the urban areas has caused non-engineered or low construction quality structures. As a result, major portion of Turkey's existing building stock is susceptible to earthquake-induced damage despite its high earthquake threat (Inel and Meral, 2016).

Taking into account the amount of building stock in Turkey, it is important to correctly know buildings' parametric data and to be able to access these data easily and quickly. The purpose of rapid screening methods is to determine the building's risk priorities and to make the right decisions for them. The building performance scores are calculated using these methods which enable to collect values for the parameters provided by methods without entering the building or partially entering the building, and then the building's risk priority can be decided as a result of comparing these values. The first-stage evaluation methods taking into account of building properties and earthquake hazard can be used to determine the risk priorities and regional distribution of the buildings which may be at risk in certain areas under the law issued by Republic of Turkey Ministry of Environment and Urbanization (DRBB, 2013). This method was revised in 2019, according to the earthquake regulation updated in 2018. This method was carried out by a commission created by experts in the field. In general, the factors weakening the building defence mechanism are considered in these methods. Short column, soft/weak story, vertical discontinuity, lateral discontinuity, year of construction, visible building quality and hill-slope effect are some of these negative parameters (DRBB, 2013; NRCC, 1993; Kaminosono, 1992; Okada, 1999; Gülay et al., 2010; Işık, 2016; Bayraktar et al., 2013; Inel, 2016; Işık and Kutanis, 2015; Srikanth et al., 2014; Alam et al., 2012; Sucuoğlu, 2007;Eleftheriadou and Karabinis, 2012; Mirshaiei et al., 2017; Zülfikar et al., 2017; Özmen and Inel, 2017; Işık et al., 2017; Scawthorn, 1986; Işık et al., 2018; Shehu et al., 2019).

This method can be used for RC buildings which vary between 1 to 7 storeys. The parameters which are required for the use of this method are given below:

- Structural system type
- Number of story
- Current situation and visual quality
- Soft /weak story
- Vertical irregularity
- Heavy overhangs
- Irregularity in plan / torsion
- Short column
- Building regulation / pounding
- Hillside effect
- Seismicity and soil type

A data collection report is created for each RC building to evaluate the reinforced concrete buildings under earthquake risk. This form is shown in Table 1. The data was collected for each building according to Table 1 and then these data are subjected to evaluation.

Table 1. Inputs of the building examined.

District	Vertical irregularity
Neighbourhood	Irregularity in plan/torsion
Street	Building regulation/pounding
Door No.	Soft/weak storey
Block	Heavy overhangs
Parcel	Short column
Latitude	Hillside effect
Longitude	Structural system type
Seismicity of the region	Number of storey
Year of Construction	Soil type

The geometric location distribution of the buildings which is subject to this study is shown in Fig. 5.

When conducting building evaluations, the primary issues to determine are seismicity of the area and the seismic risk zone of the building according to its soil type. Earthquake area and the seismic risk zones according to soil types are given in Table 2.

The map of earthquake zones which were considered in this study is shown in Fig. 6. Soil types were determined for each city, and the references in the literature and the data obtained from relevant institutions and organizations were taken into consideration (Tabban, 2000).

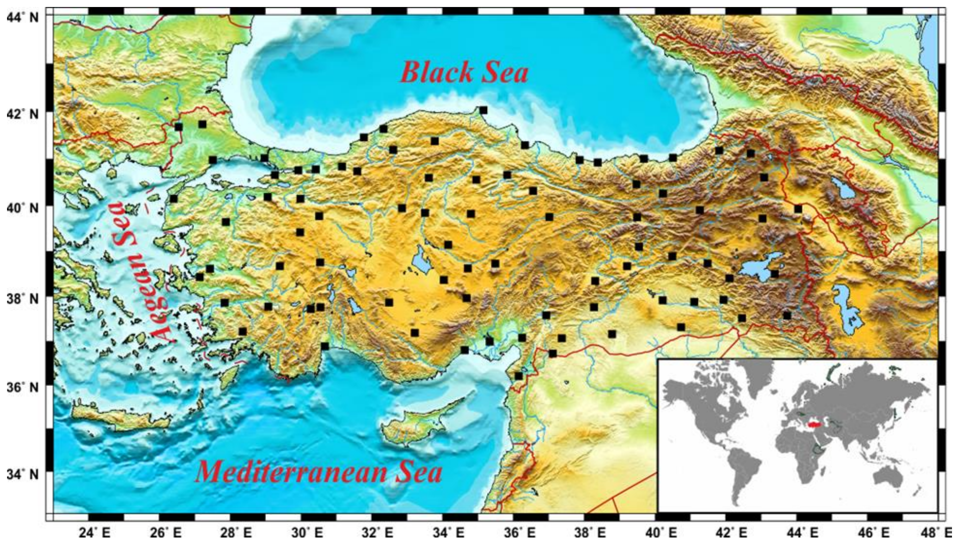

Fig. 5. Location distribution map of the buildings analyzed.

Table 2. Earthquake areas determined according to TEC-2007

Seismic risk zone	Earthquake area according to TEC-2007	Soil types according to TEC-2007
I	1	Z3/Z4
II	1	Z1/Z2
	2	Z3/Z4
III	2	Z1/Z2
	3	Z3/Z4
IV	3	Z1/Z2
	4	All soil types

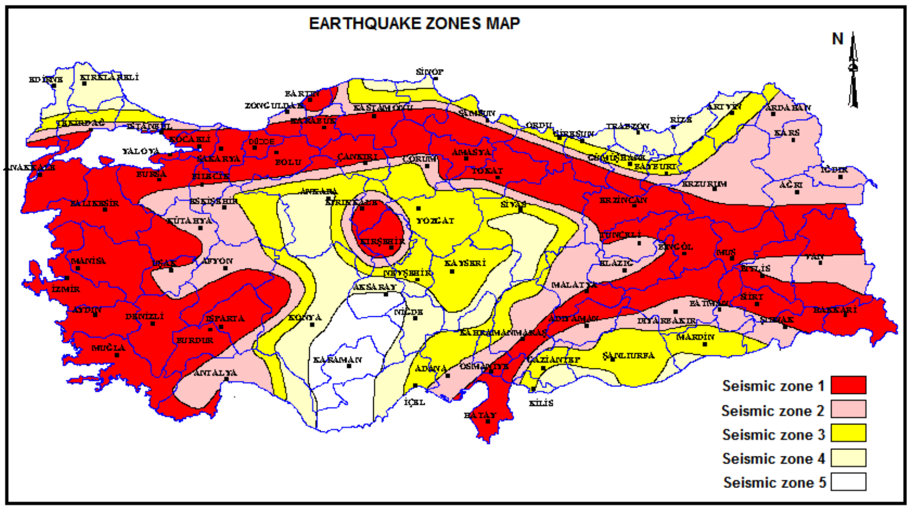

Fig. 6. The earthquake zones map for Turkey (arranged from http://deprem.gov.tr).

It is known fact that local soil conditions directly affect and change the characteristics of seismic movements and that these conditions can cause damage to existing buildings which are situated on these soils (Borcherd, 1990). Earthquake risk and soil type are one of the parameters to take into consideration. The local site classes and soil groups are determined by considering the ground criteria specified by TEC (2007). In the method, firstly, the hazard zone, in which the building is located, is determined taking into consideration seismic zones defined according to the soil class and the Turkish Earthquake Regulations. A base score (*TP*) is determined taking into account the number of building story according to the determined hazard zone. Structural system score (YSP) is determined according to type of the structural system. The obtained base score and structural system score are added. In the later stage, the negativity parameter values corresponding to each negativity parameter in the building are multiplied by the negativity parameter score. The sum of the values obtained as a result of this multiplication is subtracted from the sum of the base score and the structural system score, and thus the performance score for the building is calculated. After this procedure is performed for each building, the risk priority is determined between the buildings. The effect of structural system type will be considered as a positive score. This score is shown in short as YSP. No additional positive score (YSP) will be given for the buildings with RC frame system (RCF). The positive parameter score (YSP) will be added to the buildings which have RC frame system + RC walls (RCFW) structural systems in respect to Table 3. Table 4 describes how to get the base and structural system score.

All negativity parameters except visible quality will be determined as "Yes" or "No". The negativity parameter values corresponding to these determinations will be taken as 1 and 0 respectively for the cases of "Yes" and "No". If the visible quality evaluation is "good", "medium", and "bad", then the negativity parameter value will be taken as 0, 1, and 2, respectively. The negativity coefficients corresponding to each parameter are shown in Table 4.

After each negativity coefficient is multiplied by negativity parameter score according to total number of storey located in the building, the sum of these values determines the total score of the negativities in the building. The negativity parameter scores are presented in Table 5.

One of the negativity parameters regarding the buildings is the pounding effect. For determining the pounding effect, it is first checked whether the building is detached or attached. If it is detached, the negativity parameter score is assigned as zero. If it is attached, then it is first checked whether the building is located in the middle or on the edge. In the later stage, the position of floors of the attached buildings to each other is checked. Fig. 7 is used to decide the floors with the same or different level.

Table 3. Base and structural system score table (DRBB, 2013)

Total number of storeys	Base score				Structural system score (*YSP*)	
	Seismic risk zone				Structural system type	
	I	II	III	IV	RCF	RCFW
1 and 2	90	120	160	195	0	100
3	80	100	140	170	0	85
4	70	90	130	160	0	75
5	60	80	110	135	0	65
6 and 7	50	65	90	110	0	55

Table 4. Negativity parameter values (O_i) (DRBB, 2013)

Negativity parameter no	Negativity parameter	Condition 1		Condition 2	
		Parameter determination	Parameter value	Parameter determination	Parameter value
1	Soft storey	No	0	Yes	1
2	Heavy overhang	No	0	Yes	1
3	Visual quality	Good	0	Average (Bad)	1 (2)
4	Short column	No	0	Yes	1
5	Hill/slope effect	No	0	Yes	1
6	Irregularity in plan	No	0	Yes	1
7	Vertical Irregularity	No	0	Yes	1

Table5. Negativity parameter score (OP_i) table (DRBB, 2013)

Storey level/Detached building condition											
Total number of storeys	Soft storey	Visual quality	Heavy overhang	Same Middle	Same Side	Different Middle	Different Side	Vertical irregularity	Irregularity in plan	Short column	Hillside effect
1,2	-10	-10	-10	0	-10	-5	-15	-5	-5	-5	-3
3	-20	-10	-20	0	-10	-5	-15	-10	-10	-5	-3
4	-30	-15	-30	0	-10	-5	-15	-15	-10	-5	-3
5	-30	-25	-30	0	-10	-5	-15	-15	-10	-5	-3
6,7	-30	-30	-30	0	-10	-5	-15	-15	-10	-5	-3

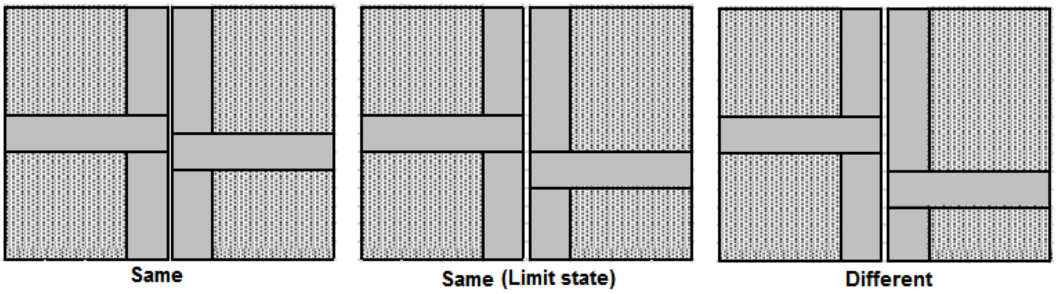

Fig. 7. Floors levels in adjacent buildings.

The performance score of a reinforced concrete building will be calculated with the data to be collected regarding the building. The building performance score for a reinforced concrete building will be calculated using the following formula;

$$PP = TP + \sum_{i=1}^{n} O_i \times OP_i + YSP \qquad (2)$$

The above formulation is described as; *PP*- Performance Score; *TP*- Base Score; *Oi*- Irregularity Score and *YSP*- Structural System Score. The final scores are compared to each other for risky buildings and provide priority for retrofit. The performance score (*PP*) for each building will be calculated applying the method on the buildings in the region studied. The calculated performance scores will be sorted descending from high to low values. The risk priority by region can be determined using the distribution of the scores calculated in this way. The performance score is calculated using the formula 2 and determined as 295 for a building that is located in the hazard zone IV and includes no negativity parameter. The performance score is calculated as -118 for a building that is located in the hazard zone I and includes all negativity parameters. The performance scores in this quick evaluation method range from -118 to 295. The method's application procedure is broadly shown in Fig. 8.

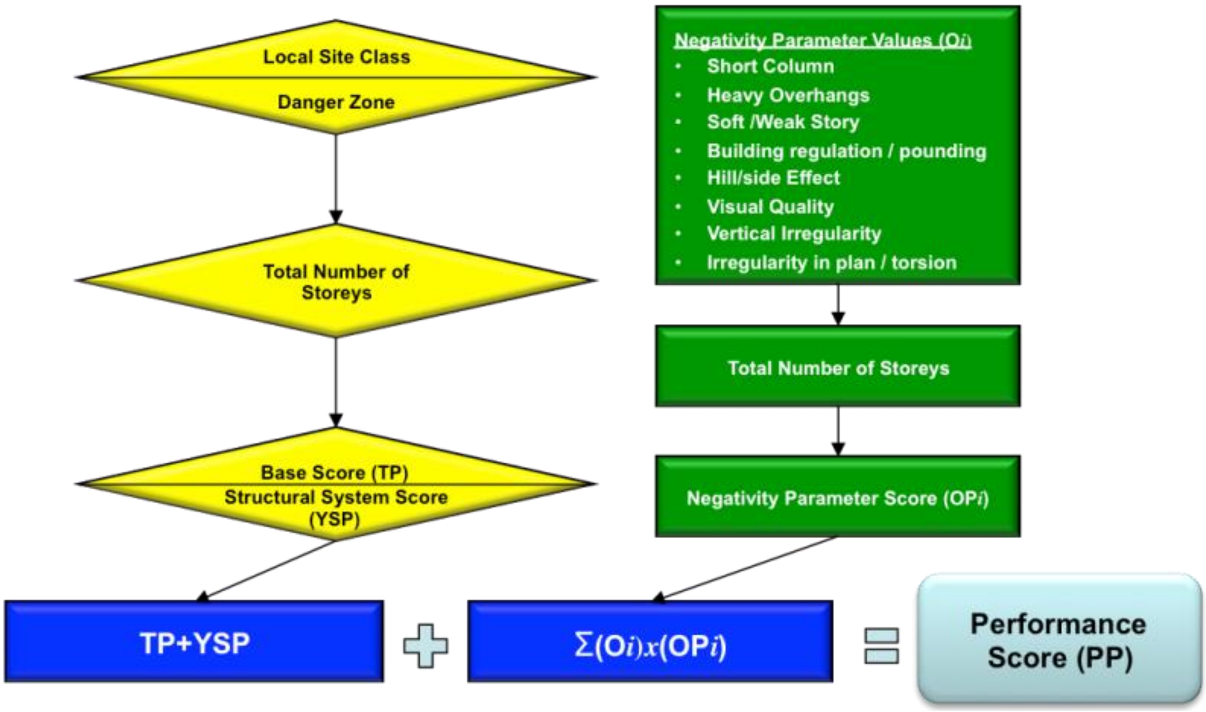

Fig. 8. Flowchart of the processes implemented in the study.

4. Analysis Results

Twenty RC buildings selected from each province which are 5-storey in Turkey were evaluated. Risk calculations were made for a total of 1620 reinforced concrete buildings from 81 provinces in Turkey. Following the creation of building credentials, the data on buildings' technical information was collected; it was seen that the data collection form prepared for the RC buildings consisted of the questions which can be filled out using observations from outside the building as suitable for visual screening method. In this context, the information such as the number of building stories, heavy overhangs, short columns, natural soil slope, building regulation, normal story function, which are located in the form, can be directly detected from outside the building, and there was no problem in determining these data in general. In this context, the data collection form given in Table 1 was filled out for each building. The completed data collection forms were then transferred to the computer in the office. Some information about the buildings was also obtained with the transfer of the data. The values of the negativity parameters obtained for mid-rise RC buildings are shown in Fig. 9.

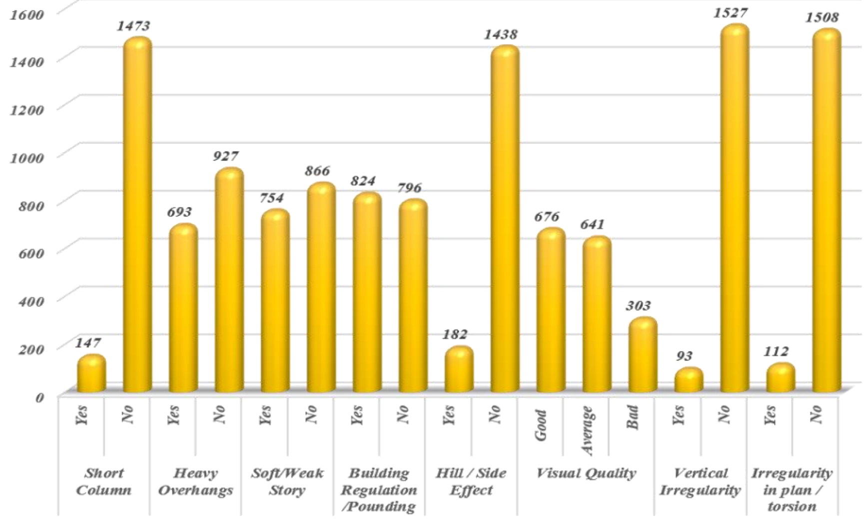

Fig. 9. Distribution of the negativity parameters of selected 5-storey buildings.

According to the results obtained, of the 1620 buildings examined, 9% had short columns, 43% had heavy overhangs, 47% had soft / weak story, 51% were attached buildings and could be subjected to pounding effect, 11% had hill/slope effect, 6% had vertical irregularity, and 7% had an irregularity in the plan. Also, it was determined that of the buildings examined, 42% had good quality, 40% had medium quality, and 18% had poor quality in terms of visual quality. The data collection form suitable for each building examined was filled out based on the observation made from outside the building, and the result performance scores of the buildings were calculated by deducting the penalty scores determined according to the structural defects observed in the building from the initial score defined for each building using the information in the form. The lower the resulting performance score, the higher the risk of building. Performance scores were calculated for each reinforced concrete building examined in the study, using the data collection form and equation 2. The distribution of these performance scores is shown in Fig. 10.

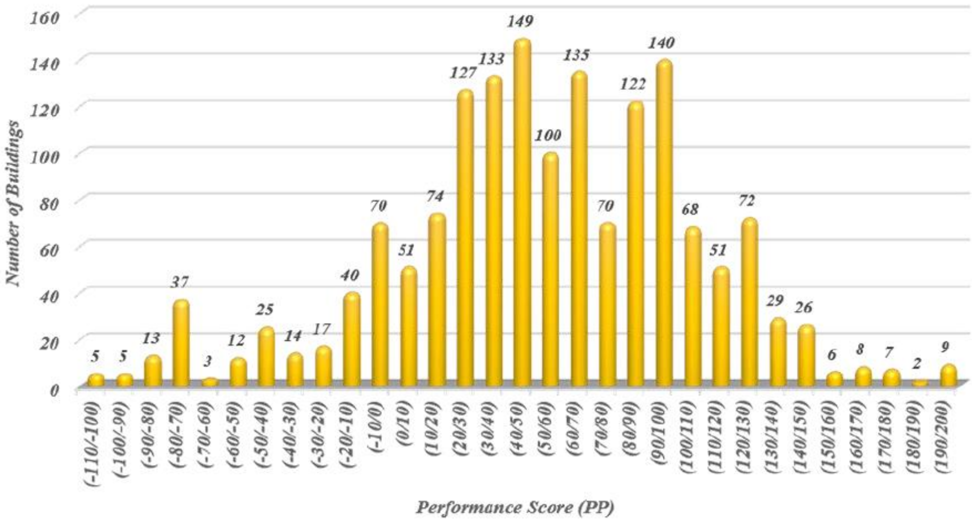

Fig. 10. The distribution of performance scores.

As it can be seen in the graphic, RC building performance scores range between -110 and 200. According to the distribution of performance scores of the reinforced concrete buildings examined in the study, the mean performance score of 1620 buildings was calculated as 53. This value is an average score, indicating that a significant percentage of the RC buildings in the region have high-performance scores. If the performance scores of all buildings with performance scores in the range of 50-200 are accepted to be higher than the mean score of 53, a total of 845 buildings have performance scores on average or higher. 52% of the buildings have a higher performance score than the mean performance score. The provincial risk priority map has been created by considering the total scores of 20 RC buildings selected from each province in Turkey. The performance scores of 20 reinforced concrete buildings from each province were calculated separately. These scores obtained for 20 reinforced concrete buildings from each province were added, and thus a total score was obtained for each province. A mapping procedure was applied according to the total scores obtained. Because a decrease in the result scores increases the risk priority according to the quick evaluation method used in this study, the mapping procedure has been applied accordingly. This map is shown in Fig. 11. According to this map, the provinces with risk priority are Bitlis, Tekirdağ, Sakarya, Niğde, Tokat, and Rize.

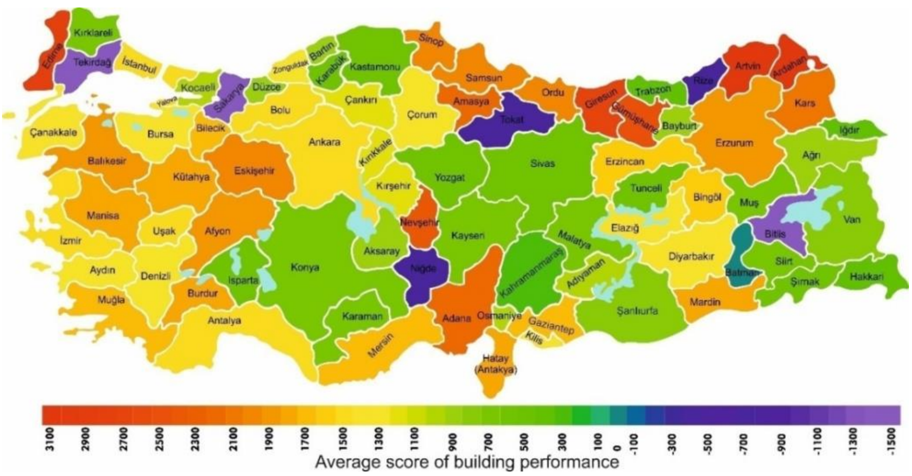

Fig. 11. The map for the risk priorities of cities according to the buildings included in this study.

5. Conclusions

Earthquake hazard is one of the main risks of human life in cities. *b*-value is an important parameter in terms of revealing the earthquake risk in settlements. In this study, changing of *a* and *b* values depending on Gutenberg-Richter (1942) relation in Turkey were examined, and the resulting value in the entire characteristic of earthquake occurrence was described. When these maps are examined, regional similarities are observed in the *a*-value distribution map in Fig. 2 and continuity can be defined in areas with near tectonic features. In contrast, the *b*-value distribution map in Fig. 3 shows no tectonic identification that can be associated with each other in the nearby settlements.

It cannot be said exactly whether buildings identified as low risk comply with existing earthquake regulations. As noted above, this is only the first stage assessment. Therefore, the final result can only be obtained as a result of certain analysis methods. This method aims only to determine the priorities of the buildings to be examined in the second stage evaluation method. However, selection of known earthquake behaviour buildings has made the results more valuable. The determination, analysis, detection and the management of all the information concerning the building stock of cities which gradually increase are important issues in terms of spatial planning and urban transformation. The priority of risky reinforced concrete buildings can be determined with this study.

The safe transfer of seismic loads to the soil through the structural system and the structural system's capability of reacting to the responses from the soil is directly related to the correct design and construction of the load-bearing mechanism. Therefore, avoiding all kinds of negativity will lead to adapt serious approaches to reduce the amount of damage that can occur in possible earthquakes. The calculation and design principles given in the building design rules must be strictly adhere in order to achieve this. Once this is achieved, then the construction of the properly designed buildings by their projects will contribute their project values.

A total of 1620 five-storey buildings from all provinces of Turkey were assessed. Twenty reinforced concrete buildings from each province were taken into consideration. These buildings were selected taking into consideration the population of the province they are located and the areas where the housing is intensive in the province. This number is a practically possible number. The first stage evaluation method specified in the principles regarding the identification of risky buildings promulgated in 2013 by the Republic of Turkey Ministry of Environment and Urbanization was used in this study. The performance scores for 1620 buildings were calculated using this method.

The buildings were examined in terms of effects such as heavy overhangs, soft story, short column, vertical irregularity and irregularity in the plan, which are included in the effects causing the building performance score to decrease in the RC buildings. These buildings were determined to be subjected to a pounding effect at most. In these structures, it was determined that the maximum number of collision effects was seen. Of the 1620 reinforced concrete buildings examined, 147 had short column effect, 693 had heavy overhangs, 745 had a soft story, 93 had vertical irregularity, and 112 had an irregularity in the plan. This result showed that the negative structure properties were more effective in 1st stage evaluation.

The study shows the ranking of the buildings in the area concerned in terms of their performance scores and thus determines the buildings concentrated in a certain range of scores in certain areas. It is not possible to classify the buildings as risky, medium risky or riskless within the scope of the method. Only a ranking and comparison of performance scores between buildings can be performed using the existing data. Accordingly, it can be said that the building with a higher performance score is better than the building with lower performance score. Again within this context, the same comparison can be made regarding the areas where the buildings within a specific score range are concentrated. Accordingly, the data obtained in the study reveals that the buildings with lower performance scores are concentrated. It can be concluded that it is appropriate to prioritize these regions in disaster risk assessment plans or urban transformation project plans to be carried out within this scope.

In this context, it is thought that the rapid screening method used in the study serves for area prioritization as it stands, however, does not contain a limit value to compare the building performance scores, or is missing in terms of being able to comment on the risk situation of buildings because there is no guidance regarding the risk range.

To obtain correct and healthy data in the process of filling the building data collection forms, the field inspection team must be selected from civil engineers or construction technicians who have adequate knowledge and experience in accurately determining and interpreting the data requested in the data collection form.

The multiplicity of negativity parameters is related to housing and inadequate engineering services. The ground floors of the majority of the buildings were generally designed as workplaces, which, in turn, have led to the formation of a soft story. This has also led to an increase in the buildings' risk priority scores. Weak-soft story formation should be avoided as much as possible. Structural systems that are free of irregularities and were designed in compliance with the regulations as well as of which quality control was effectively carried out in construction phase may be damaged only in acceptable limits by showing a ductile behaviour even in a very severe earthquake.

Additionally, the construction of attached buildings has become widespread to optimize land use. Constructing detached buildings instead of attached buildings will be a useful way to reduce earthquake damages. Moreover, ground floors are constructed to have a lower surface area than upper floors to be able to fully utilize from the building area, but this leads to the formation of heavy overhangs.

The prepared map only indicates the provinces with the buildings that were examined in the study and have risk priority. All buildings in these provinces should be examined in order to report that they are exactly risky.

Such work will lead to the system of earthquake prevention, which will be used to analyses an inventory of building stock against earthquake. While taking precautionary measures against reducing earthquake risk after producing a building inventory, the buildings, which are not safe and not economical to strengthen, need to be demolished. This study includes the previous earthquake code and rapid assessment method. This study will be a resource for similar studies based on new codes.

REFERENCES

Ahmed MM, Jahan I, Alam MJ (2014). Earthquake vulnerability assessment of existing buildings in cox's-bazar using field survey & GIS. *International Journal of Engineering*, 3(8), 1147-1156.

Aki K (1965). Maximum likelihood estimate of b in the formula log N=a-bM and its confidence limits. *Bulletin of the Earthquake Research Institute,* 43, 237-239.

Aksoylu C, Öztürk O, Erkan İH, Arslan MH (2016). Investigation of vertical column discontinuity in reinforced concrete buildings. *International Journal of Scientific & Engineering Research*, 7(6), 474-481.

Alam N, Alam MS, Tesfamariam S (2012). Buildings' seismic vulnerability assessment methods: a comparative study. *Natural Hazards*, 62(2), 405-424.

Alan E (2016). Deprem İstatistik Programı V1. Alan Mühendislik, Turkey.

Albayrak U, Canbaz M, Albayrak G (2015). A rapid seismic risk assessment method for existing building stock in urban areas. *Procedia Engineering*, 118, 1242-1249.

Anadolu NC, Kalyoncuoğlu ÜY (2010). Güneydoğu Anadolu Bölgesinin depremselliği ve deprem tehlike analizi. *Süleyman Demirel University Journal of Natural and Applied Science*, 14(1), 84-94.

Arslan MH, Ceylan M, Kayuncu TA (2010). New method for rapid assessment of performances of existing RC buildings under earthquake loading. *IV. European Conference on Computational Mechanics Palais des Congrès*, Paris, France

Arslan MH, Olgun M, Köroğlu MA, Erkan IH, Köken A, Tan O (2013). 19 May 2011 Kütahya--Simav earthquake and evaluation of existing sample RC buildings according to the TEC-2007 criteria. *Natural Hazards & Earth System Sciences*, 13(2).

Ates A, Kayıran T, Sincer I (2003). Structural interpretation of the Marmara region, NW Turkey, from aeromagnetic, seismic and gravity data. *Tectonophysics*, 367(1-2), 41-99.

Ateş A, Bilim F, Büyüksaraç A, Bektaş O (2008). A tectonic interpretation of the MarmaraSea, NW Turkey from geophysical data. *Earth Planets and Space*, 60(3), 169–177.

Ateş A, Büyüksaraç A, Bilim F, Bektaş Ö, Şendur Ç, Komanovalı G (2009). Spatial correlation of the aeromagnetic anomalies and seismogenic faults in the Marmara region, NW Turkey. *Tectonophysics*, 478(1-2), 135-142.

Ates A, Bilim F, Buyuksarac A, Aydemir A, Bektas O, Aslan Y (2012). Crustal structure of Turkey from aeromagnetic, gravity and deep seismic reflection data. *Surveys in Geophysics*, 33(5), 869-885.

Bal IE, Gulay FG, Tezcan SS (2008). A new approach for the preliminary seismic assessment of RC buildings: P25 scoring method. *Proceedings of 14th WCEE*, 12-17.

Bayrak Y, Çinar H, Bayrak E (2011). The North Anatolian Fault Zone: an evaluation of earthquake hazard parameters. *In: New Frontiers in Tectonic Research - At the Midst of Plate Convergence, Uri Schattner, Ed.,* Intech Open, Zagrep, 269-280.

Bayraktar A, Altunişik AC, Pehlivan M (2013). Performance and damages of reinforced concrete buildings during the October 23 and November 9, 2011 Van, Turkey, earthquakes. *Soil Dynamics and Earthquake Engineering*, 53, 49-72.

Benavent-Climent A (2011). A seismic index method for vulnerability assessment of existing frames: application to RC structures with wide beams in Spain. *Bulletin of Earthquake Engineering*, 9(2), 491-517.

Bender B (1983). Maximum likelihood estimation of b values for magnitude grouped data. *Bulletin of the Seismological Society of America*, 73(3), 831–851.

Bilgin H (2016). Generation of fragility curves for typical RC health care facilities: emphasis on hospitals in Turkey. *Journal of Performance of Constructed Facilities*, 30(3), 04015056.

Bilgin H, Frangu I (2017). Predicting the seismic performance of typical R/C healthcare facilities: emphasis on hospitals. *International Journal of Advanced Structural Engineering*, 9(3), 277-292.

Bilgin H, Uruçi R (2018). Effects of structural irregularities on low and mid-rise RC building response. *Challenge Journal of Structural Mechanics*, 4(2), 33-44.

Borcherdt RD (1990). Influence of local geology in the San Francisco bay region California on ground motions generated 1990, by the Loma Prieta earthquake of October 17, 1989. *Proceedings of International Symposium on Safety of Urban Life and Facilities,* Tokyo, Japan.

Bozkurt E (2001). Neotectonics of Turkey - a synthesis. *Geodinamica Acta*, 14, 3-30.

Cao A, Gao SS (2002). Temporal variation of seismic b-values beneath northeastern Japan island arc. *Geophysical Research Letters*, 29(9), 1–3.

Chever L (2012). Use of seismic assessment methods for planning vulnerability reduction of existing building stock. *Proceedings of the 15th World Conference on Earthquake Engineering—WCEE,* Lisbon, Portugal.

DRBB (Determination of Risk-Bearing Buildings) (2013). Afet riski altındaki alanların dönüştürülmesi hakkında kanunun uygulama yönetmeliğinde değişiklik yapılmasına dair yönetmelik*.* Türkiye Çevre ve Şehircilik Bakanlığı, Ankara, Turkey.

Eleftheriadou AK, Karabinis AI (2012). Seismic vulnerability assessment of buildings based on damage data after a near field earthquake (7 September 1999 Athens- Greece). *Earthquake and Structures,* 3(2)**,** 117-140.

Farrell J, Husen S, Smith RB (2009). Earthquake swarm and b-value characterization of the Yellowstone volcano–tectonic system. *Journal of Volcanology and Geothermal Research*, 188, 260–276.

FEMA-154 (2002*). Rapid Visual Screening of Buildings for Potential Seismic Hazards: a Handbook*, Federal Emergency Management Agency, Washington.

Foo S, Davenport A (2003). Seismic hazard mitigation for buildings. *Natural Hazards*, 28(2-3), 517-536.

Gülay FG, Bal İE, Gökçe T, Çelik N (2010). Field applications of P25 preliminary assessment method for identifying the collapse vulnerability of existing RC structures. *9th International Congress on Advances in Civil Engineering*, Karadeniz Technical University, Trabzon, Turkey, 10p.

Gutenberg B, Richter CF (1944). Frequency of earthquakes in California. *Bulletin of the Seismological Society of America*, 34(4), 185-188.

Hadzima-Nyarko, M., Nyarko, E. K., Morić, D. (2011). A neural network based modelling and sensitivity analysis of damage ratio coefficient. *Expert Systems with Applications*, 38(10), 13405-13413.

Hadzima-Nyarko M, Pavic G, Lesic M (2016). Seismic vulnerability of older confined masonry buildings in Osijek, Croatia. *Earthquakes and Structures*, 11(4), 629-648.

Hadzima-Nyarko M, Mišetić V, Morić D (2017). Seismic vulnerability assessment of an old historical masonry building in Osijek, Croatia, using Damage Index. *Journal of Cultural Heritage*, 28, 140-150.

Hadzima-Nyarko M, Morić D, Pavić G, Mišetić V (2018). Spectral functions of damage index (DI) for masonry buildings with flexible floors. *Tehnički Vjesnik*, 25(1), 181-187.

Harirchian E, Lahmer T, Buddhiraju S, Mohammad K, Mosavi A (2020). Earthquake safety assessment of buildings through rapid visual screening. *Buildings*, 10(3), 51.

Inel M, Meral E (2016). Seismic performance of RC buildings subjected to past earthquakes in Turkey. *Earthquakes and Structures,* 11(3), 483-503.

Inel M, Ozmen HB, Bilgin H (2008). Re-evaluation of building damage during recent earthquakes in Turkey. *Engineering Structures*, 30(2), 412-427.

Ishimoto M, Lida K (1939). Observations sur les seismes enregistres parle microsismographe construit dernierement (1). *Bulletin of the Earthquake Research Institute, The University of Tokyo*, 17, 443-478.

Işık E (2013). The evaluation of existing buildings in Bitlis province using a visual screening method. *Süleyman Demirel University Journal of Natural and Applied Science,* 17(1), 173-178.

Işık E (2015). Investigation of an existing RC building with different rapid assessment method. 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.

Işık E, Kutanis M (2015). Performance based assessment for existing residential buildings in Lake Van basin and seismicity of the region. *Earthquakes and Structures*, 9(4), 893-910.

Işık E, Işık MF, Bülbül MA (2017). Web based evaluation of earthquake damages for reinforced-concrete buildings. *Earthquakes and Structures*, 13(4), 423-432.

Işık E, Tozlu Z (2015). Calculation of building performance score by using different variables. *BEU Journal of Science,* 4(2), 161-172.

Işık MF, Işık E, Bülbül MA (2018). The application of IOS / android based assessment and monitoring system for building inventory under the impact of earthquake. *Gradevinar*, 70(12), 1095-1108.

Ilki A, Comert M, Demir C, Orakcal K, Ulugtekin D, Tapan M, Kumbasar, N (2014). Performance based rapid seismic assessment method (PERA) for reinforced concrete frame buildings. *Advances in Structural Engineering,* 17(3), 439-459.

Jain SK, Mitra K, Kumar M, Shah, M (2010). A proposed rapid visual screening procedure for seismic evaluation of RC-frame buildings in India. *Earthquake Spectra*, 26(3), 709-729.

Kalafat D, Güneş Y, Kekovalı K, Kara M, Deniz P, Yılmazer M (2011). A revised and extended earthquake catalogue for Turkey since 1900 (M≥4.0). İstanbul, Turkey: Boğaziçi University Kandilli Observatory and Earthquake Research Institute.

Kalyoncuoğlu UY (2007). Evaluation of seismicity and seismic hazard parameters in Turkey and surrounding area using a new approach to the Gutenberg–Richter relation. *Journal of Seismology*, 11, 131–148.

Kalyoncuoğlu UY, Elitok Ö, Dolmaz MN (2013).Tectonic implications of spatial variation of b-values and heat flow in the Aegean region. *Marine Geophysical Researches*, 34, 59–78.

Kaminosono T (1992). Evaluation method for seismic capacity of existing reinforced concrete buildings in Japan. In Memoria (pp. 44-53). México. Centro Nacional de Prevención de Desastes (CENAPRED); Japón. Agencia de Cooperación Internacional (JICA); NU. Centro para el Desarrollo Regional (UNCRD).

Kepekci D, Ozcep F (2011). Fast-track earthquake risk assessment for selected urban areas in Turkey. *Natural Hazards and Earth System Sciences*, 11(2), 571-585.

Mirshafiei F, Mirshafiei M, McClure G (2017). A new three-dimensional seismic assessment method (3D-SAM) for buildings based on experimental modal analysis. *Computers & Structures*, 180, 125-137.

Mogi K (1962). Magnitude-frequency relationship for elastic shocks accompanying fractures of various materials and some related problems in earthquakes. *Bulletin of the Earthquake Research Institute, The University of Tokyo*, 40, 831-883.

Monterroso D (2003). Seismic precursory potential of temporal variation of b-value: five case studies in Central America. *Comprehensive Summaries of Uppsala Dissertations from the Faculty of Science and Technology*, 897-914.

Monterroso D, Kulhanek O (2003). Spatial variations of b-values in the subduction zone of Central America. *Geofisica International*, 42, 1-13.

Murru M, Console R, Falcone G, Montuori C, Sgroi T (2007). Spatial mapping of the b value at Mount Etna, Italy, using earthquake data recorded from 1999 to 2005. *Journal of Geophysical Res*earch, 112, B12303.

NRRC (1993). Manual for Screening of Buildings for Seismic Investigation. Canadian Standard. National Research Council of Canada, Ottowa, Canada.

Nuannin P, Kulhanek O, Persson L (2005). Spatial and temporal b value anomalies preceding the devastating off coast of NW Sumatra Earthquake of December 26, 2004. *Geophysical Research Let*ters, 32, L11307

Ohkubo M (1991). Current Japanese system on seismic capacity and retrofit techniques for existing reinforced concrete buildings and post-earthquake damage inspection and restoration techniques, Report No. SSRP-91/02, Department of Applied Mechanics and Engineering Sciences, University of California, San Diego.

Okada T (1999). Needs to evaluate real seismic performance of buildings-lessons from the 1995 Hyogoken-nambu Earthquake. *INCEDE Report*, 15, 225-231.

Ozcebe G (2004). Seismic assessment and rehabilitation of existing buildings. *TÜBITAK Research Report,* no: ICTAG YMAU I, 574.

Ozmen HB, Inel M (2017). Effect of rapid screening parameters on seismic performance of RC buildings. *Structural Engıneerıng and Mechanics*, 62(4), 391-399.

Reilinger R, McClusky S, Vernant P, Lawrence S, Ergintav S, Cakmak R, Ozener H, Kadirov F, Guliev I, Stepanyan R (2006). GPS constraints on continental deformation in the Africa–Arabia–Eurasia continental collision zone and implications for the dynamics of plate interactions. *Journal of Geophysical Research,* 111.

Richter CF (1935). An instrumental earthquake magnitude scale. *Bulletin of the Seismological Society of America*, 25(1), 1-32.

Roberts NS, Bell AF, Main IG (2015). Are volcanic seismic b-values high, and if so when? *Journal of Volcanology and Geothermal Research*, 308, 127–141.

Scawthorn C (1986). Techniques for Rapid Assessment of Seismic Vulnerability. ASCE, USA.

Scholz CH (1968). The frequency-magnitude relation of microfracturing in rock and its relation to earthquakes. *Bulletin of Seismology Society of Am*erica, 58, 399-415.

Shehu R, Angjeliu G, Bilgin H (2019). A Simple approach for the design of ductile earthquake-resisting frame structures counting for P-Delta effect. *Buildings*, 9(10), 216.

Sinha R, Goyal A (2004). A national policy for seismic vulnerability assessment of buildings and procedure for rapid visual screening of buildings for potential seismic vulnerability. Report to Disaster Management Division, Ministry of Home Affairs, Government of India.

Srikanth T, Kumar RP, Singh AP, Rastogi BK, Kumar S (2014). Earthquake vulnerability assessment of existing buildings in Gandhidham and Adipur cities Kachchh, Gujarat (India). *European Journal of Scientific Research*, 41(3), 336-353.

Sucuoğlu H (2007). A screening procedure for seismic risk assessment in urban building stocks. *6th National Conference on Earthquake Engineering*, İstanbul, Turkey

Suyehiro S, Asada T, Ohtake M (1964). Foreshocks and aftershocks accompanying a perceptible earthquake in central Japan: On the peculiar nature of foreshocks. *Papers in Meteorology and Geophysics*, 19, 427-435.

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

Tabban A (2000). Kentlerin Jeolojisi ve Deprem Durumu. *Jeoloji Mühendisleri Odası Yayınları,* 56, 500 p.

Taymaz T, Eyidoğan H, Jackson J (1991). Source parameters of large earthquakes in the East Anatolian Fault Zone (Turkey). *Geophysical Journal International*, 106, 537-550.

Tesfamariam S, Liu Z (2010). Earthquake induced damage classification for reinforced concrete buildings. *Structural Safety*, 32(2), 154-164.

Tischer H, Mitchell D, McClure G (2011). Comparison of seismic screening methods for schools in a moderate seismic zone. *Proceedings of the COMPDYN*.

Tischer H, McClure G, Mitchell D (2012). Development of a seismic vulnerability assessment method for schools in Eastern Canada. *Proceedings of the 15th World Conference on Earthquake Engineering—WCEE*, Lisbon, Portugal.

Turkish Earthquake Code (2007), Turkish Earthquake Code-Specification for Structures to be built in Disaster Areas, Ankara, Turkey.

Utkucu M, Durmus H, Yalçin H, Budakoglu E, Isik E (2013). Coulomb static stress changes before and after the 23 October 2011 Van, eastern Turkey Earthquake (MW= 7.1): implications for the earthquake hazard mitigation. *Natural Hazards and Earth System Sciences*, 13(7), 1889.

Warren NW, Latham GV (1970). An experiment study of thermal induced microfracturing and its relation to volcanic seismicity. *Journal of Geophysical Reearch,* 75, 4455-4464.

Wessel P, Smith WHF (1991). Free software helps map and display data. *Eos, Transactions American Geophysical Union*, 72, 441.

Wiemer S, Benoit J (1996). Mapping the b-value anomaly at 100 km depth in the Alaska and New Zealand subduction zones. *Geophysical Research Letters,* 23, 1557-1560.

Wiemer S, McNutt SR, Wyss M (1998). Temporal and three-dimensional spatial analyses of the frequency-magnitude distribution near Long Valley Caldera, California. *Geophysical Journal International*, 134, 409-421.

Wyss M (1973). Towards a physical understanding of the earthquake frequency distribution. *Geophysical Journal of the Royal Astronomical Society,* 31, 341-359.

Villacís C, Cardona CN, Tucker B (2000). Implementation of fast earthquake scenarios for risk management in developing countries. *Proceedings of the 12th World Conference on Earthquake Engineering* (*12WCEE*), Auckland, New Zealand.

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

Yakut A, Erberik MA, Ilki A, Sucuoğlu H, Akkar S (2014). Rapid seismic assessment procedures for the Turkish Building Stock. In *Seismic Evaluation and Rehabilitation of Structures*, 15-35.

Zülfikar AC, Fercan NÖZ, Tunç S, Erdik M (2017). Real-time earthquake shake, damage, and loss mapping for Istanbul metropolitan area. *Earth, Planets and Space*, 69(1), 9.