

A STUDY TO DETERMINE THE QUALITY OF BUILDING STOCK AND EARTHQUAKE RISK IN KIRSEHIR

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Abstract

Technological developments, findings, and associated improvement of structural codes together with the change in the earthquake potentials and deficiencies of the old buildings necessitate the evaluation of the present building stocks. Both the Earthquake Regulations and the Seismic Zoning Map in Turkey have been going through a fast change in the recent years. Furthermore, the fact that the structural damage due to the recent earthquakes did not change according to the regions which is indicative of the building stock with low structural quality. Kirsehir is one of these regions with low quality buliding stock. Kirsehir is a developing region in relation to the increase in population and number of buildings in recent years. Accordingly, the heights of the buildings also increase in relation to the improving economical conditions. In contrary to the older masonry buildings of 1950s, the newer buildings are manufacturing using reinforced concrete. However, the lack of control mechanisms, designs according to lower eqarthquake risks without considering the the soil- structure relationship also make the more recent buildings prone to earthquake damage. In this study, the building stock in Kirsehir and its close surroundings (constructed before 1998) was considered and grouped in relation to their floor numbers, construction methods and some other properties. The performance analyses of the considered buildings were performed by taking into account the local soil conditions and construction material. Then, the earthquake risks of these buildings are calculated.

Keywords: Performance based analyse, Earthquake risk, Structrual damage length; topography.

1. Introduction

In Turkey, 92% of the land is located on the active seismic zones. Accordingly, earthquake risks may affect the 95% of the population. Furthermore, approximately 75% of the significant industrial centers are located on I. and II Degree Seismic Zones. Turkey is a country prone to frequent damaging earthquakes in relation to its geological location. 66 damaging earthquakes occurred in the recent period, between 1894 and 1999, also indicate this fact. Nonetheless, the study of Turkey’s tectonic structure and seismicity, and the reflection of the findings to the regulations, are not based on a long history of practice. Evaluation the level of damage observed in 1992 Erzincan, 1995 Dinar, 1999 Golcuk, 1999 Duzce, and 2003 Bingol earthquakes shows the low building qualiy in Turkey [1, 2, 3, 4, 5, 6, 7].

Especially Golcuk 1999 and 1999 Duzce Earthquakes, diplayed the significance of the earthquake concept one more time due to occurred vast damage and associated loss of lives. The damage occurred in these earthquakes were similar to the previous earhquakes shows that “earthquake resistant” structures are still not built in Turkey; and the necessary lessons are not taken from the previous earthquakes. As a matter of fact, reinforced conrete nd industrial buildings significantly damaged in these earthquakes similar to the masonry buildings that are known to be not earthquake resistant [8, 9, 10] (Figure 1). Nevertheless, regulations, seismic zoning maps, and the condition of the present building stock were discussed after each damaging earthquake. Numerous studies regarding the evaluation of the present building stock [11, 12, 13] and identification of the regional earthquake risks [14, 15, 16, 17] were conducted after the earthquake and some are still ongoing. The first Earthquake Regulations in Turkey were created immediately after the 1939 Erzincan Earthquake, and improved according to technological developments in 1947, 1953, 1968, 1975, and finally in 1997. The section on the evaluation and retrofitting of the buildings, however, was added to the Earthquake Regulations in 2007. The General Directorate of Disaster Affairs was founded within the Ministry of Public Works and Settlement in 1959; the Directorate was authorized for creating the Seismic Zoning Maps and Earthquake Regulation.

Figure 1. Buildings that were damaged in the earthquakes, a) 13 March 1992 Erzincan Earthquake, b) 1 October 1995 Dinar Earthquake, c) 17 August 1999 Golcuk Earthquake, d) 1 May 2003 Bingol Earthquakethe caption.

The first Earthquake Regions Map was created in 1945. The maps were revised in 1947, 1948, 1963, 1972, and 1996; and the map that is used now was created. Many regions were still displayed as having a low seismic risk in the 1972 Seismic Map; and, accordingly, the low seismic risk values were used in the building calculations. One of these provinces with low seismic risk is Kirsehir; Kirsehir and its close surroundings were displayed as being in the III. Degree Seismic Zone in the maps created before 1996 but the region was included in the I. Degree Seismic Zone in the new maps created in 1996. Many buildings built before the publication of 1996 Seismic Map and 1998 Earthquake Regulations exist in Kirsehir, a city with a high increase rate of population and building number; and these buildings need to be evaluated. In this study, the seismic risks of buildings in Kirsehir were determined by considering the effects of the local soil conditions, and the effects of previous earthquakes.

2. LOCATION OF KIRSEHIR PROVINCE AND ITS CLOSE SURROUNDINGS

Kirsehir is located in the Middle Kizilirmak in the Central Anatolia Region. Its acreage is 6665 km2. The land of the province, which is roughly shaped as a parallelogram, occupies 0.8% and 2.9% of the country and Central Anatolia Region, respectively; and the province is the 53th largest province in Turkey. The province is located between 38°50'-39°50' Northern Latitudes and 33°30'¬-34°50' Eastern Longitudes. The southern extreme point of the province is Central Ulupinar Town while the northern extreme point is the Konurkale Village in Cicekdagi. Likewise, the western extreme point is Kaman Boguz Village while the eastern extreme point is the Mucur Kilicli Village. The elevation from the sea level is 985 m.; and the air distances of the province from the sea are 362 km to the Anamur Cape in Mediterranean Sea towards south and 334 km to Sinop in Black Sea towards north. The population of Kirsehir is approximately 250,000. The districts of the province are Mucur, Kaman, Cicekdagi, Akpinar, Akcakent, and Boztepe (Figure 2).

3. THE GEOLOGY AND SEISMICITY OF THE KIRSEHIR REGION

Palaeozoic aged metamorphic rocks do shape the geological foundation of Kirsehir and its region. The structure termed as Kirsehir Massif is a part of "Cenral Anatolia Massif". Kırsehir Massif, the largest among the 9 massifs of Turkey, also extends along the Lake Tuz. The massif bulk is a groundmass that was twisted once, or a few times, as a result of the tectonic movements and then hardened by losing its twisting feature while most of it had been going through a metamorphism. The Massif of Kirşehir, formed in I., II., III., and IV. Times, is a structure with a thickness approximately 2000-2500 m. The layers encountered in this structure, from top to bottom, are lime schists, fillatas, green schists, marble belts, small grained crystal quartzites, mica schists, and marble layers. The geologic structure of the province, along with the whole Central Anatolia Region, was formed as a result of the non-deposition in the Neozoic Upper Eosen which is the III. Geological time. It gained its actual look during the Alpenese Folds. There exist formations from four different eras in the main plateau that the province is located on. The fault line that extends towards Northwest-Southeast and the Lake Seyfe rift zone is covered with alluvial deposits belonging to IV. time whereas the east of the fault line consists of crystalline schists.

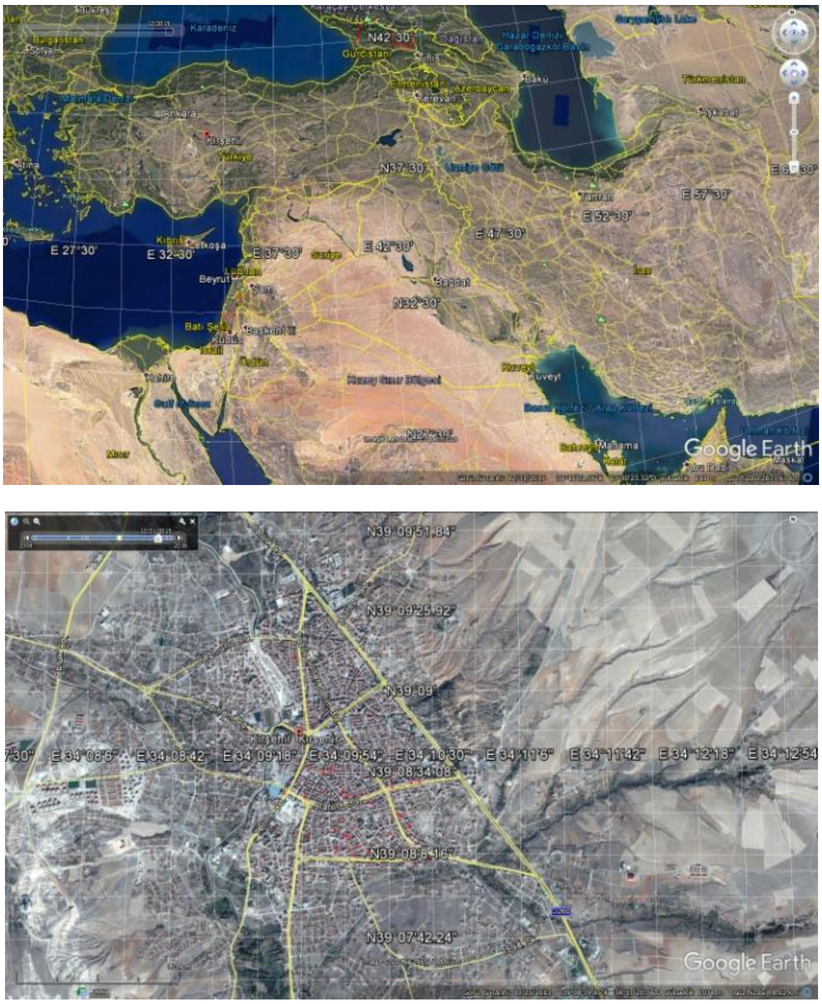

Figure 2. View of Kırşehir

The west of the province area is covered with marble lime stones and dolomites while the remaining areas are covered with Neogene lake deposits. The sequence direction of the metamorphosed crystalline masses is Northwest-Southeast near Kirsehir and Karaman whereas they are directioned towards South on the Kervansaray Mountains. The definite age of these metamorphosed crystalline masses could not be determined exactly. Nonetheless, it was determined exactly that metamorphic masses, located on Karalan Mountains in the west of Kaman, belonged to the eras before cretaceous. The formations under the metamorphic layers are regarded as belonging to Paleozoic Era [11, 12, 13]. Numerous active faults, with an earthquake potential, exist in the Kirsehir region. If the region is evaluated within a wide angle, it is enclosed with serial and active faults towards NE-SW, NW-SE, and WNW-ESE directions. The study area of this paper (Figure 3a) includes Lake Tuz Fault, Salanda Fault, Kesikkoru Fault, Bogazliyan Fault, Yerkoy Fault, and Akpinar Fault which triggered a damaging earthquake in 1938 [18, 19, 20].

In Kirsehir and its close surroundings generally earthquakes with strike-slip faults occurred. Since 1990, initiation of the instrumental recordings, 129 earthquakes with a magnitude of 2 or more were recorded in the area enclosed by (38-40) N latitudes and (33-35) E longitudes (Figure 3b) [19, 20]. 20 historical earthquakes were recoreded in the Central Anatolia. However, their details, exact location of the epicenters, and magnitudes are not definitely known [20].

These earthquakes occurred in Cankiri (1845-1888), northwest of Ankara (1168), Ilgin (1866), Konya (1871), Karaman (1190), Nigde (1104), Develi (1835), Kayseri (1205- 1704-1714-1717), Kayseri- Sivas (240), Eskisehir (1897), Beypazari (1168), Corum (1514), and Sivas and its close surroundings (1695-1754-1779).
The magnitudes of these earthquakes varied between 4.0 and 6.6. The most intense earthquake in the region near Kirsehir had occurred in 1938 with a magnitude of 6.6. The epicenter of this earthquake was determined near Akpinar between Kaman and Keskin. A 10-km long surface break formed in this earthquake; and the features that helped to determine the characteristic of the fault did appear as a result. The earthquake caused a great damage in the region; 3860 buildings were damaged and 146 people lost their lives. The most of the damage occurred in the area between Akpinar, Haciselimli, and Taskovan (Figure 3c). The residential buildings located in Kosker, Deveci, Alisar, Hanyeri, Tatarilyas, Homurlu, Curukler, Pala, Huyuk, Golhuyuk Villages either completely destroyed or became unusable [19, 20].
The return periods of considerable earthquake magnitudes for Kirsehir and its close surroundings were identified in the statistical study conducted by Temiz in 2004 [20] (Table 1).
From the table, it is observed that a damaging earthquake with a magnitude of 6 may occur in Kirsehir in near future.

Table 1. Return periods corresponding to considerable magnitudes calculated, for the area enclosed by (38.00-40.00) N-(33.00-35.00) E coordinates

Magnitude	Return Period (Years)
5	20
6	77
6.5	152
7	299

4. SOIL PROPERTIES OF STUDY AREA
The map of the study area is given in Figure 4 (Are Jeoteknik, 2008). The study area is divided in to regions according to its geological, hydrological and morphological properties. These regions are named as Precationary-I, Precationary II and Inappropriate for settlement areas (Figure 4a). On the other hand, change of the city in ten years is given in Figures 4b and 4c).

The study area is located on alluvium and Kızılırmak Formation. As a result of drilling and geophysical evaluations no considerable problems were observed in the soil profile.. Landslide, collapse and flow type mass movements haven't observed in the study area. However, study area is located in the first-degree seismic zone. For this reason, "The Regulations for The Structures to Be Built İn Disaster Areas" must be applied.

All alluviums area that quaternary aged have been identified as a "Precautionary I Area". These areas are shown in pink on the map (Figure 4). Underground water level in these areas is 2.0-4.0 m., but there isn't significant liquefaction risk because of the high grain content.

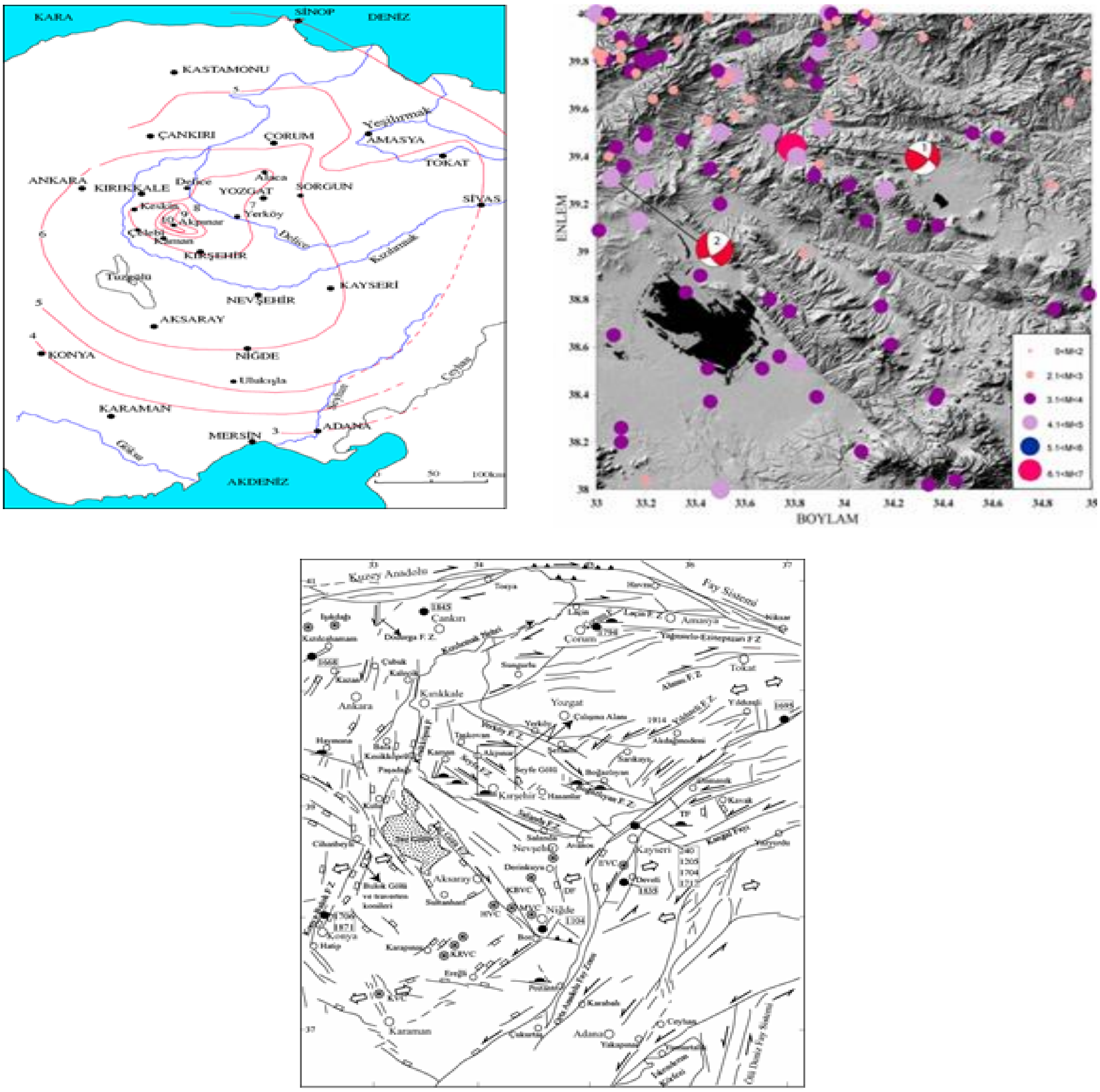

Figure 3.a. Neo-tectonic map of Central Anatolia and its close surroundings DF:Derinkuyu Fault, TF: Tuzla Fault ([21], [20]) **Figure 3. b**. The distrubition epicenters of the earthquakes, with magnitude values of 2 or more, that occurred in the area enclosed with (38.00-40.00)N -(33.00-35.00)E coordinates between 01.01.1900-10.03.2004 dates (1) 19.04.1938 Akpinar Earthquake and (2) 21.04.1983 Ankara Earthquake [20] **Figure 3. c**. 19.04.1938 Kırşehir earthquake isoseismal map [22]

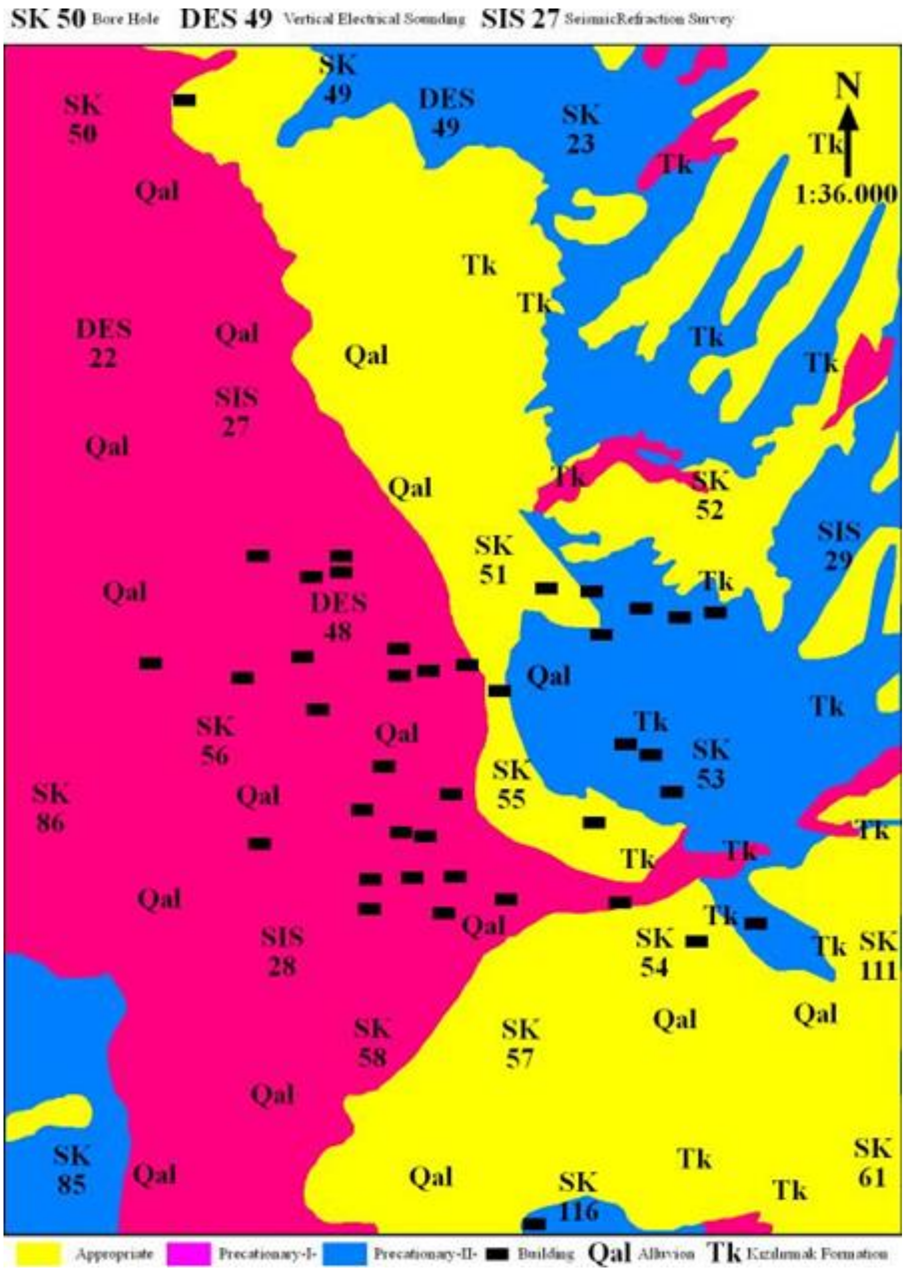

Figure 4. Soil map of study area

The study area is in the first-degree seismic zone. Therefore, water should be removed by drainage [31]. Kızılırmak Formation area have been identified as a "Precautionary II Area". These areas are shown in blue on the map (Figure 4). Formation consist of gravel, sand, silt and clay and rock. So, formation isn't homogeneous. The slope values in the study area range from 00-50. There are many dry lines in the study area.

5. THE EVALUATION OF THE BUILDINGS IN KIRSEHIR PROVINCE KIRŞEHIR

The evaluation of the present building stock has been an attractive subject area of the researchers for a long time [11, 12, 13, 23, 24, 25]. Determination of an earthquake risk and vulnerability of the building stock helps making accurate predictions of the earthquake effects. For this purpose, only regional investigations could be performed and the risks could be determined considering the seismic risk, quality of the building stock, and the effects of the previous earthquakes for the region.

Figure 5. Investigations performed in the buildings

Kirsehir and its close surroundings are one of the regions with a high seismic risk but it is not possible to say anything about the quality of the present building stock until today. In this study, the general structure of the buildings located in Kirsehir and its provinces were sampled and examined with rapid scanning method and 40 reinforced concrete buildings were subjected to a more detailed investigation (Figure 5).

The determination of the regional building quality was performed, as described in ATC-21 (26), by the investigation of short columns, disarrangement in architectural and structural systems, the condition of adjacent buildings, architectural consoles, weak-soft storey, observable inferiority, and structural damage; which all cause a building to be damaged in an earthquake. The findings related to this investigation are presented below.

The surveys of the buildings, included in the detailed investigation, were created; and their compressive concrete strengths, steel reinforcement type and amount, local soil conditions, and element dimensions were also determined. The free vibration periods of the buildings were determined by the method presented in Ersin (1997) and Ersin et all. (1998) [28, 29]. The free vibration periods of buildings with infill walls, determined by experiments, were compared with the equation presented by Güler et al. (2008)

[29] and the periods considering the frame only condition was determined by the equation given by Güler et al. (2008) [29], Tç=1.75Td, Numerical models of the all buildings are calibrated until obtaining the experimentally determined periods. The performance analyses of the models were performed as per Turkish Earthquake Regulations [30].

5.1 The Analysis of the Buildings

The considered buildings were analysed as per Turkish Earthquake Regulations [30]. The seismic safety of the buildings is related to the expected damage in the building under the earthquake effects in the Regulations and four different conditions were defined for the degree of the damage. Performance level of a building is determined by applying the method defined as "linear elastic" and "nonlinear inelastic" and deciding the damage regions for the elements. According to the linear elastic analysis method presented in the related regulation, the capacities of the structural elements are decided according to their load bearing capacity and ductility features. On the other hand, the demand for earthquake is calculated according to the linear theory under elastic earthquake effects. Elastic calculation methods are Equivalent Earthquake Load Method and Mode Superposition Method. Equivalent Earthquake Load Method was used in this study. Equivalent Earthquake Load Method is performed by exposing the building to the horizontal forces obtained by reducing the elastic response spectrum. In order to determine the damage limit values for the elements numerical values that represents the demand/capacity ratios (r) of the critical sections of the beams, columns, and shear walls are used. In the calculation of the bending demand/capacity ratios, bending moment demands due to earthquake loads of the system are calculated. Then, the bending moments due to vertical loads are calculated. Next, the moment capacity is calculated by substracting the bending moment due to vertical loads from the calculated moment capacity. Finally, the demand/capacity ratio is determined by dividing the bending moment demand to the bending moment capacity [30].

5.2 Section Damage Limits

Three different damage conditions at the section level are defined for ductile elements; Minimum Damage Limit (MN), Safety Damage Limit (SF), and Failure Damage Limit (FL). The MN is the limit value when the elastic behavior ends in the related section. SF defines the limit of the behavior, beyond the elastic limit, that the section can safely provide and the FL defines the limit for the behavior of the section before failure. This classification is not suitable for the elements that are fail with a brittle mode [30].

5.3 Section Damage Regions

The elements with critical section values not reaching MN would fall into the Minimum Damage Region; and the elements with values between MN and SF would fall into the Distinctive Damage Region whereas the elements, with values between SF and FL, would be accepted to be in the Advanced Damage Region. The elements with critical section values exceeding FL, however, would fall into the Failure Region (Figure 6).

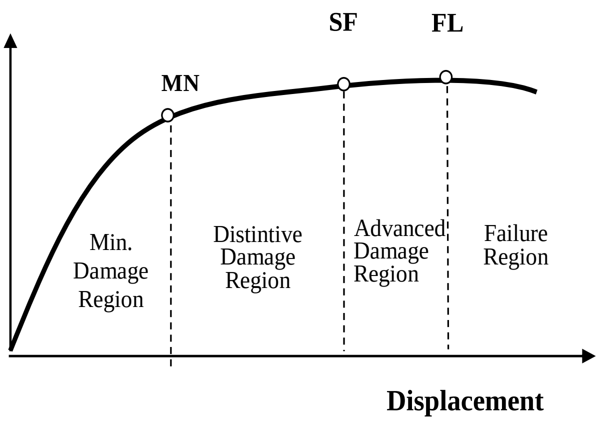

Figure 6. Graphical display of damage limits and regions

All the other elements should be in the Minimum Damage Region or Distinctive Damage Region. In this case, the building is accepted to be in the Life Safety Condition. For the acceptance of this life safety condition, in any storey, the shear force value carried by the columns that exceed the minimum damage limit in its both top and bottom sections should not exceed the shear force carried by all the columns in that storey. In the top floor, however, the maximum possible ratio for the total shear force value carried by the vertical elements in advanced damage region to the total shear force value carried by all the columns in that floor can be 40%."

5.4 Investigated Buildings, Analyses, and Calculation Results
The buildings investigated in Kirsehir Province falls into 6-8 intensity regions according to the isoseismal map presented in Figure 3 c. The total number of buildings located in the Province is shown in Table 2.

Table 2. The Number of Buildings in Kirsehir Provinc

Neighborhood	Residence	Privete Office	Public Office	Const.	Summer/ Seasonal	Other	Total
Ahıevran	4202	1462	37	26	23	23	5773
Asıkpasa	5885	330	35	76	24	17	6367
Bagbası	2510	43	17	14	21	220	2825
Bahcelıevler	1100	838	21	10		36	2005
Cukurcayır	634	12	11		6	7	670
Golhısar	331	8	3			8	350
Guldıken	1302	30	8	71	32	19	1462
Kayabası	895	33	20		2	3	953
Kervansaray	3239	53	33	106	32	15	3478
Kındam	583	45	50	7	3	11	699
Kusdıllı	1335	1028	24	7	13	48	2455
Medrese	5813	469	27	61	11	21	6402
Nasuhdede	1353	12	21	18	9	6	1419
Yenice	6613	458	23	61	30	14	7199
						Total	**42057**

Figure 7. Examples of weak storey, short column, and adjacent buildings

5.5 The Evaluation of the Structural Defects Observed in the Buildings

Defects were observed nearly for all buildings. The most common defects among the others are insufficient reinforcement, weak storey, short column effect, and hammering effect during the earthquake caused by different storey levels of the adjacent buildings (Figure 7). Interesting findings were also obtained from the concrete strength detection of the buildings. Minimum compressive concrete strength in the earthquake regions was required as C20 following the change in the Turkish Earthquake Regulations in 1998. The compressive concrete strength value of the sampled buildings constructed before 1998 was determined as 8-12 MPa while this value was determined as 16-22 MPa for the ones constructed after 1998. Corrosion and, accordingly, damage in the structural elements were detected in most of the buildings. The buildings were classified into 4 groups, according to their possible damage (Table 3).

Table 3. Classification of the damage in an earthquake situation as a result of the calculations

Building Class	Number
A	4
B	1
C	25
D	10
Total	40

A A well behavior is expected in a possible earthquake for the buildings falling into this class. The earthquake risk of the building is low.

B A not so bad behavior is expected in a possible earthquake for the buildings falling into this class. The earthquake risk of the building is acceptable.

C An inadequate behavior is expected in a possible earthquake for the buildings falling into this class. The earthquake risk of the building is high.

D Very inadequate behavior is expected in a possible earthquake for the buildings falling into this class. The earthquake risk of the building is very high.

5.6 Damage Ratio

In scope of the study the damage ratio (DR) of each building is calculated by taking the ratio of observed damage parameters to the number of all considered damage parameters. The variation of DR values in relation to the number of buildings is given in Table 4. The mean value of the DR of considered buildings was calculated as 37.5% for all of the buildings.

Table 4. Mean damage ratios of the considered buildings

DR	Number of Buildings	%
<25%	6	15
25%-40%	30	75
40%-70%	2	5
100%	2	5

6. Conclusion

Kirsehir province, like some other provinces, is among the regions where the earthquake region coefficient was changed and the quality of the building stock is rather unspecific. The damage ratio compared to the earthquake magnitude has been unfortunately very high observed from the recent earthquakes. Therefore, the need for the investigation of the Kirsehir building stock, having 42057 buildings in the city center, has emerged. A high ratio, 85%, of the investigated buildings is undert risk as observed from the results of the investigations. On the other side, it is possible to state that the masonry buildings, which were not investigated in this study, also fall into this risk group. Thus, retrofitting works should be initiated as soon as possible starting with the buildings at the high-risk group.

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