Düzce University
Journal of Science & Technology

Research Article

Using AURAP Method in Determination of Building Earthquake Risk

Hüseyin BAYRAKTAR[a,*],

[a] *Department of Building Drafting, Kaynaşlı Vocational School , Düzce University, Düzce, TURKEY*
** Corresponding author's e-mail address: huseyinbayraktar@duzce.edu.tr*
DOI: 10.29130/dubited.1492696

ABSTRACT

Major earthquakes in our country cause heavy damages especially to buildings. Damage to buildings adversely affects people and their settlements. There are many factors that cause damage to buildings. The most important of these are the lack of engineering services and incorrect applications at the construction site. It is vital to identify any problems with buildings in advance. To do this, time is the most important concept. Rapid screening methods are advantageous in terms of time in determining the earthquake performance of buildings. Rapid screening methods are frequently used in highly urbanized areas. Rapid screening methods are of great benefit in classifying buildings according to their risk status. Düzce suffered heavy losses in the August 17, 1999 Marmara and November 12, 1999 Düzce Earthquakes. After the earthquake, there have been positive developments towards reconstruction in Düzce. However, there are still neighborhoods in the city where pre-earthquake constructions are dense. Among these neighbourhoods, Burhaniye District is connected to Düzce centre. Burhaniye neighborhood is a place where there are many buildings before 1999. In this study, the application and results of the AURAP Method, one of the rapid scanning methods, in a building built in 1979 in the Burhaniye District in the center of Düzce, will be explained.

Keywords: *Düzce, Earthquake, Rapid screening methods*

Bina Deprem Riskinin Belirlenmesinde AURAP Yönteminin Kullanılması

ÖZ

Ülkemizde yaşanan büyük depremler özellikle binalarda ağır hasarlara neden olmaktadır. Binaların hasar alması insanları ve bulunduğu yerleşim yerini olumsuz yönde etkilemektedir. Binaların hasar almasında birçok etken vardır. Bunlardan en önemlileri binanın mühendislik hizmeti almaması ve şantiyede yanlış uygulamaların yapılmasıdır. Binalar ile ilgili varsa olumsuzlukların önceden tespit edilmesi hayati öneme sahiptir. Bunun yapılması için de zaman en önemli kavramdır. Binalarda deprem performansının tespitinde hızlı tarama yöntemleri zaman bakımından avantajlıdır. Hızlı tarama yöntemleri kentleşmenin yoğun olduğu bölgelerde sıklıkla kullanılmaktadır. Binaların risk durumlarına göre sınıflandırmada hızlı tarama yöntemleri büyük fayda sağlamaktadır. 17 Ağustos 1999 Marmara Depremi ve 12 Kasım 1999 Düzce Depreminde ağır kayıplar veren Düzce'de deprem sonrası yeniden yapılaşma yolunda olumlu gelişmeler kaydedilmiştir. Fakat kentte hala deprem öncesi yapılaşmaların yoğun olarak bulunduğu mahalleler bulunmaktadır. Bu mahallelerden Burhaniye Mahallesi Düzce merkeze bağlı, 1999 yılı öncesi yapıların yoğun olarak yer aldığı bir mahalledir. Bu çalışmada hızlı tarama yöntemlerinden olan AURAP Yönteminin Düzce merkezde yer alan Burhaniye Mahallesinde 1979 yılında yapılan bir binada uygulanması ve sonuçları anlatılacaktır.

Anahtar Kelimeler: *Düzce, Deprem, Hızlı tarama yöntemleri*

Received: 30/05/2024, Revised: 17/07/2024, Accepted: 25/07/2024

I. INTRODUCTION

Turkey is frequently exposed to earthquakes due to the influence of African, Arabian and Eurasian plates in terms of seismic zone. Therefore, the North Anatolian Fault (NAF), East Anatolian Fault (EAF) and West Anatolian Fault (WAF) fractures, which can produce large earthquakes, have formed especially in the northern, eastern and western parts of our country. Major earthquakes have occurred on these fault lines, especially in recent years, such as the Marmara Earthquake of August 17, 1999 with moment magnitude (Mw) of 7.4 and the Düzce Earthquake of November 12, 1999 with moment magnitude (Mw) of 7.2 on the NAF line, the Izmir earthquake of October 30, 2020 with moment magnitude (Mw) of 6.6 on the EAF line, and the Pazarcık and Elbistan (Kahramanmaraş) Earthquakes of February 6, 2023 with moment magnitudes (Mw) of 7.7 and 7.6 on the EAF line, which are called major disasters. These earthquakes caused great loss of life and economic losses. Many factors such as mistakes made during the construction phase of the buildings, technically incorrect construction of the relationship between the ground and the building or not taking the ground into account at all, wrong material selection, and poor workmanship have been identified in the high losses in the earthquakes [1-7]. The fact that many buildings are damaged in earthquakes in our country is questioned in every aspect. Detailed examination of the damaged buildings in earthquake zones and detection of errors will ensure that the same mistakes are not repeated again.

After every major earthquake in Turkey, detailed studies are carried out by different institutions and organizations and reports are prepared. In these reports, administrative, regulatory or technical deficiencies experienced during the earthquake are identified and necessary steps are taken. For example, after the 1999 earthquakes, many positive works were carried out, such as the enhactment of the building control law, preparation of new earthquake regulations, urban transformation works, and the establishment of AFAD. However, there are still deficiencies to be made at the urban scale. For example, it is vital to review the building inventory, identify especially risky buildings and take the necessary steps. Because, in an earthquake, risky buildings and those inside those buildings are primarily negatively affected. Rapid construction has occurred in the cities of our country with the increase in population. The dense construction makes it difficult to detect risky buildings. It takes a lot of time to identify risky buildings in cities, analyze and verify their performance according to regulations. Therefore, it is important to use and develop fast building scanning methods. With rapid building scanning methods, the earthquake risk performance of many buildings can be determined quickly and with very realistic values. In this way, risk classification of buildings can be easily d one for decision makers. In our country, there are rapid evaluation methods with different names and contents. Some of these are Street Scan, Yakut, P25, DURTES, PERA and AURAP methods. In this study, the AURAP method developed by [8] will be used. 5-storey reinforced concrete building located in Burhaniye District of Düzce center was examined with the AURAP method and its earthquake risk performance was determined. However, it is recommended that the earthquake risk of the examined building be evaluated in accordance with the principles of the Turkish Building Earthquake Regulation (2018) by making more detailed examinations.

II. DUZCE AND SEISMICITY

The population growth of Düzce accelerated after the earthquakes of August 17, 1999 and November 12, 1999, as it became a province in 2000. The economic structure of Düzce also shapes the social structure. Düzce is a city that has been growing in recent years based on the industry and services sector and receiving migration due to its developing economy. There are currently 3 active organized industrial zones and it is planned to increase this number to 5. The fact that the city is the largest urban and commercial center in the Düzce plain and that it is located on a very important transportation axis on the Istanbul (205 km) - Ankara (241 km) highway are the most important factors that accelerate the development of the city. Established in 2006, Düzce University (around 30 thousand students in 2024) accelerated the mobility and population growth in the city. Today, the population is 405 thousand as of 2023.

The 17 August 1999 Gölcük earthquake, which occurred on the North Anatolian Fault Line, triggered the Düzce fault (Figure 1), and 3 months later, on 12 November 1999, the Düzce-Kaynaşlı earthquake with a magnitude of Mw 7.2 occurred. In both earthquakes, 1115 lives were lost and 3836 people were injured, 6444 buildings were recorded as heavy/destroyed, 5506 buildings were recorded as moderately damaged, and 9433 buildings were recorded as slightly damaged. The most recent earthquake, with a magnitude of Mw 5.9, occurred in Gölyaka district of Düzce province on November 23, 2022. Fortunately, there was no loss of life in this earthquake. In the earthquake, 816 buildings were found to be heavily damaged and 796 of them were demolished and their debris removed [9].

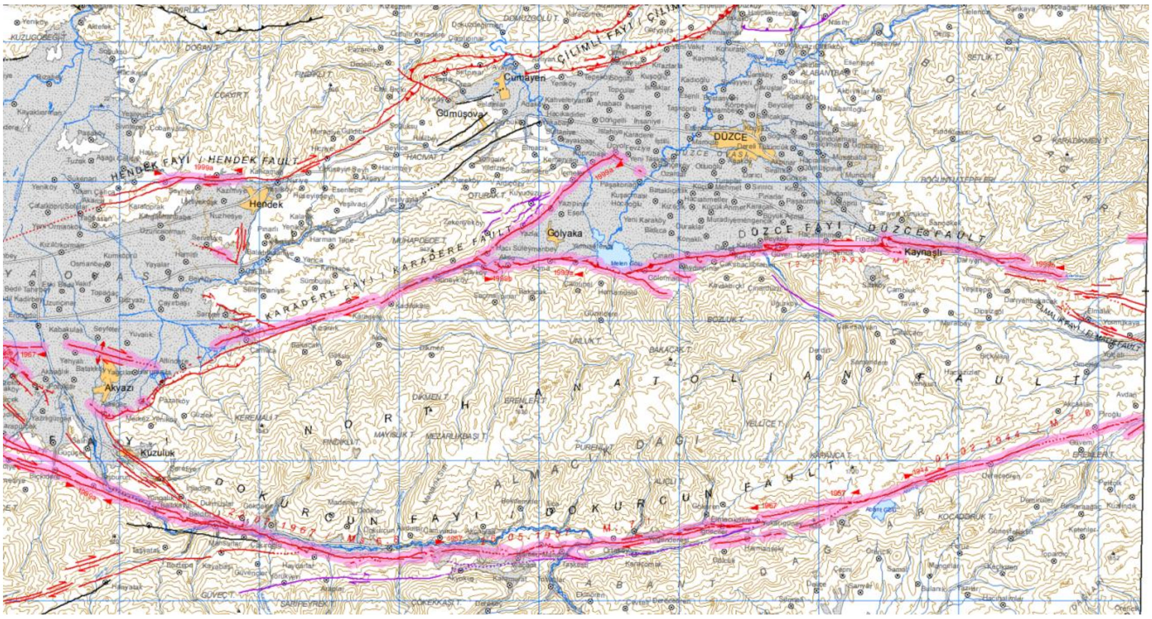

Figure 1. *North Anatolian Fault Line and Düzce Fault separated from this fault (MTA General Directorate Active Fault Map) [10]*

III. METHODOLOGY USED IN THE STUDY (AURAP METHOD)

Anatolian University Rapid Evaluation Method (AURAP) method [11] is a rapid screening method developed. The method can be used to estimate the earthquake risk status of a building with a reinforced concrete frame system by examining the critical floor using a non-destructive method. For this purpose, information was obtained about parameters such as the plan of the critical floor, the number of columns and walls with X and Y direction measurements taken, concrete compressive strength with a Schmidt hammer, the stirrup tightening rate in the column with an X-ray scanning device, floor heights, ground information, irregularities, etc. All information is used to decide the level of risk medium or high.

In this way, the earthquake performances of buildings can be determined in a short time with the AURAP rapid scanning method and the necessary steps can be taken by the relevant authorities before the earthquake.

In the AURAP method, risk levels are determined as low, medium and high risk. If the building result score (BSP) is equal to or below 50 points, it is considered high risk, if it is between 50 and 150 points, it is considered medium risk, and if it is equal to or above 150 points, it is considered low risk (Figure 2).

Figure 2. *Risk levels according to building result score*

Building Result Score (BRS) is estimated from Relative Building Score (RBS) which is multiplied by the Structural Safety Factor (SSS) and the Continuous Frame Score (CFS) (Equality 1).

$$BRS=RBS\times SSS\times CFS \quad (1)$$

In the relative building score (GBP) calculation, the building is first given a total of 100 points. This score is multiplied by the Penalty Coefficients (PC) greater than zero and less than In the Relative Building Score (RBS) calculation, the building is first given a total of 100 points. This score is multiplied by the Penalty Coefficients (PC) greater than zero and less than one defined for each of the irregularities and defects in the building such as short column, corner column problem, mezzanine floor, strong beam, weak column, etc. given in the Turkish Earthquake Code 1997 and the Relative Building Score is determined (Equation 2).

$$RBS = 100x \prod_{i=1}^{N} PCi \quad (2)$$

Structural Safety Factor (SSF) is found by the ratio of the shear force carrying capacity (Vc)of the critical floor to the base shear force calculated according to the equivalent earthquake load (Vb) method (Regulation on Buildings to be Built in Earthquake Zones, 2007) (Equality 3).

$$SSF=Vc/Vb \quad (3)$$

Continuous Frame Score (CFS) is calculated by dividing the number of continuous frames on the critical floor of the examined building by the number of Continuous Frames Rate (CFR) appropriate according to the plan of the floor where the floor should be located. According to the obtained (CFR), the coefficient of (CFS) is found (Table 1).

Table 1. *Coefficient values of Continuous Framework Score (CFS) according to Continuous Framework Rate (CFR)*

CFS = 0,25	(CFR ≤ 0,25)
CFS = CFR	(0,25 < CFR < 0,50)
CFS = 1	(CFR ≥ 0,50)

As a result, the Building Result Score (BRS) can be calculated as an estimate by substituting the data in the above-mentioned equations in the light of the information collected as a result of on-site inspection [8].

IV. THE RESEARCH FINDINGS AND DISCUSSION

5-storey (basement+4) reinforced concrete building (Figure 3) located in Burhaniye Neighborhood of the center of Düzce was examined by AURAP method and its earthquake risk performance was determined. The building was constructed in 1979 and it was determined on site that only the basement and ground floor were retrofitted in 2001 after November 12, 1999. However, the retrofitting project of the building could not be found. A detailed retrofitting project is recommended.

Figure 3. *View of the examined building from the road front*

When the basement of the building was examined, it was seen that some of the columns were shelled and corroded reinforcements were revealed. It was observed that there was no tightening in the column, and the stirrup hooks wrapped the longitudinal reinforcement by turning 90 degrees. Additionally, it is considered that aggregate gradation in concrete is not appropriate (Figure 4).

Figure 4. *Crust loss in the column and corrosion in the reinforcement*

The ground floor of the building has a seating area of 13.30 m x 19.00 m. The foundation type is continuous foundation according to the project examined, and the soil it has is Z4 soil class according to the 2007 Earthquake regulation. No heavy protrusions or irregularities were detected in the building. The ground floor is used as a workplace and its height is 3.40 m, the other floors are 2.90 m. In the readings made with the Schmidt hammer, the concrete compressive strength was found to be around 14 MPa. In the examination of the columns using hand scanning x-ray, it was observed that the stirrups were not tightened.

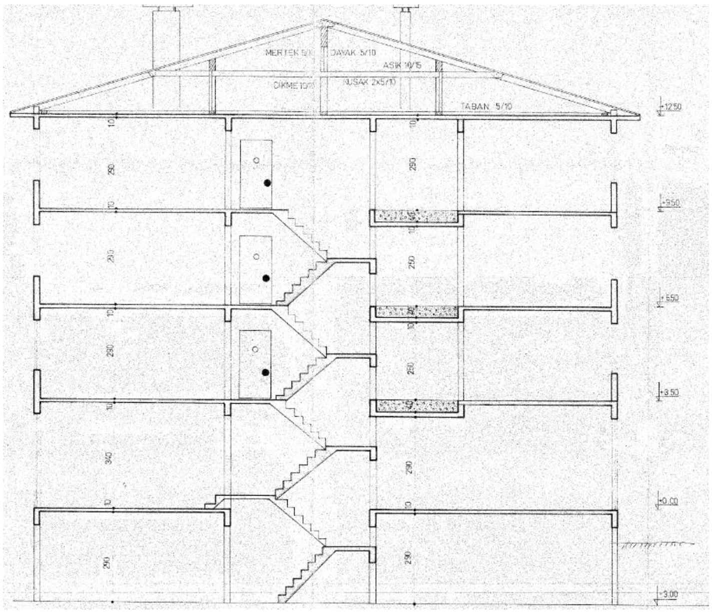

Figure 5. *5-storey building section*

The building section taken from the archive file of the examined building is given in Figure 5. When the building section is examined, the ground floor is 3.40 m high and the other floors, including the basement, are 2.90 m high. Leaving the ground floor higher is planned as a workplace. The floors are beamed floors and low floors are used in wet areas. Low flooring will have a negative impact on load transfer during an earthquake, thus creating a defect in the building. The roof was made as a wooden hipped roof.

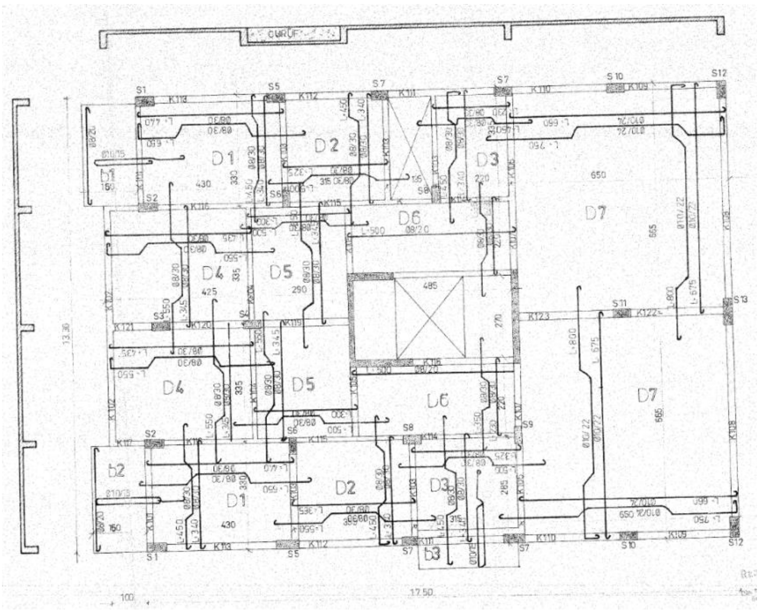

Figure 6. *Formwork plan of the building under review*

Figure 6 shows the formwork plan taken from the archive file of the building. When the formwork plan is examined, it is seen that flat and pleated irons are used in both directions in the slabs, and the tucked irons pass to the other slab. It is evaluated that the diameter and distribution of the reinforcement is done regularly.

The building inspection form used in the AURAP method was filled out by obtaining the necessary information from both the outside and the inside of the building. The ground floor, which was selected as the critical floor, was surveyed and compared with the projects in the archive. The possible risk score of the building was found by taking general information about the structure, carrier system features, material information, irregularities, defects and ground information. Building Result Score (BRS); As a result of the multiplication of Relative Building Score (RBS), Structural Safety Factor (SSF) and Continuous Frame Score (CFS), the Building Result Score (BRS) was found to be 68. 68 points correspond to the medium risk level on the risk level scale (Figure 7).

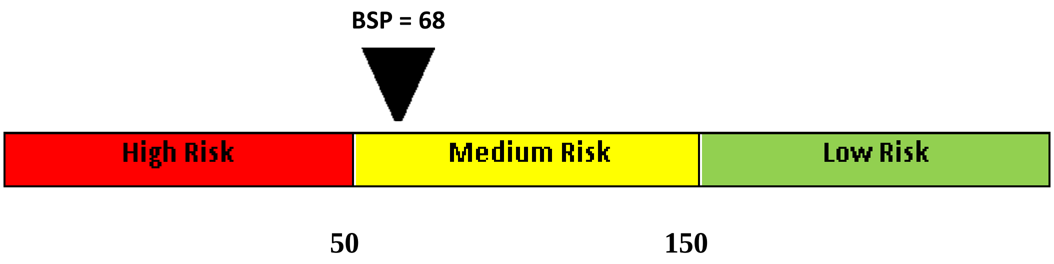

Figure 7. *Medium risk level determined according to Building Result Score (BSP)*

In the AURAP method, if a building is found to be at medium risk level, it is recommended that "medium risk level buildings should be examined with a more detailed seismic performance evaluation method, although not as urgently as high risk buildings."

IV. CONCLUSION

Düzce province experienced pass earthquake activities caused by the North Anatolian Fault line, may also be affected by earthquakes that may occur in nearby fault regions around the provinces such as Istanbul and Bolu. Therefore, it is important to determine the earthquake risk levels in the city as soon as possible, especially by examining the buildings built in 1999 and before. The fact that Duzce central settlements are located on alluvial ground may also increase the risk of damage to buildings in an earthquake. At the same time, the city's location in the middle between Ankara and Istanbul causes the population growth increasing every year. Increasing population density may also increase the level of vulnerability in possible disasters.

In this study, a 5-storey reinforced concrete building was chosen in the Burhaniye neighborhood, which is located in the center where buildings dating back to 1999 and before is concentrated. In the evaluation made with the AURAP method, the building was estimated to be at medium risk level. It is recommended that this building be examined in more detail and perform a performance analysis according to the Turkish Building Earthquake Regulation (TBDY 2018).

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